Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Cobalt-catalyzed Cascade Hydroalkenylation of 1,6-Enynes with Chalcones

Chunxiang Pan, [a†] Gaowei Wang,[a†] Hengyuan zhao,[a] Jianxiao Ni,[a] Ruifeng Fan,[a] Yongyun Zhou,*[a] Yuanbin Zhu,[b] Shiyuan Wu[b] and Baomin Fan*[a,b]

[a] Key Laboratory of Advanced Synthetic Chemistry (Yunnan Minzu University), State Ethnic Affairs Commission, Kunming 650500, China.

[b] Yunnan Tiefeng High Tech Mining Chemicals. Co. Ltd, Qingfeng industrial park, Lufeng, 651200, Yunnan Province, China.

[†] These authors contributed equally.

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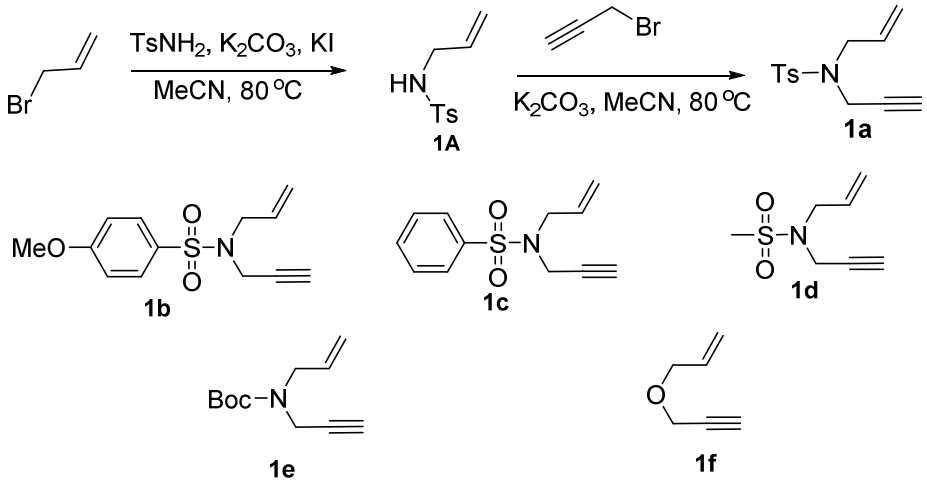
1. General Method

The reactions and manipulations were performed under an atmosphere of argon by using standard Schlenk techniques and Drybox (Mikrouna, Supper 1220/750). Anhydrous toluene, THF (Tetrahydrofuran) and 1,4-dioxane were distilled from sodium benzophenone ketyl prior to use. Anhydrous DCM and DMAC (*N*,*N*-Dimethylacetamide) were distilled from calcium hydride and stored under argon. ^{1}H NMR and ^{13}C NMR spectra were recorded on Bruker-Avance 400 MHz spectrometer. $CDCl_3$ was used as solvent. Chemical shifts (δ) were reported in ppm with tetramethylsilane as internal standard, and *J* values were given in Hz. The enantiomeric excesses were determined by Agilent 1260 Series HPLC using Daicel AS-H, AD-H or OD-H chiral columns eluted with a mixture of isopropyl alcohol and *n*-Heptane. Melting points were measured on X-4 melting point apparatus and uncorrected. High resolution mass spectra (HRMS) were performed on a VG Autospec-3000 spectrometer. Column chromatography was performed with silica gel (200-300 mesh).

1.1 General procedure for the preparation of substituted 1,6-enynes:



Literature reports were followed to prepare the following 1,6-enynes:**1b**[1], **1c**[1], **1d**[1], **1e**[2], **1f**[3]**.** And the **1a** were synthesized from the following procedure:

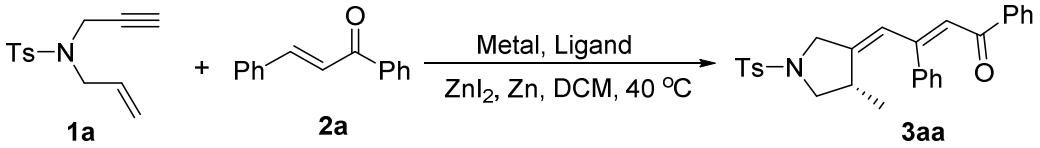
Preparation of allylamins 1A: To a solution of Allyl bromide (2.60 ml, 30.0 mmol, 1.0 equiv) in MeCN (90 mL) at 80 °C was added K_2CO_3 (8.29 g, 60.0 mmol, 2.0 equiv), KI (0.50 g, 3.0 mmol, 10 mol %) and $TsNH_2$ (10.27 g, 60.0 mmol, 2.0 equiv). The mixture was stirred with reflux at 80 °C for 8 h. After successive filtration and purification by column chromatography (PE:EA, 10:1), **S1** was given as colorless oil.

Preparation of propynylamine 1a: Dropwise adding 3-Bromopropyne (1.59 ml 18.4 mmol, 1.3 equiv) to the mixture of **S1**(3.00 g, 14.2 mmol, 1.0 equiv), K_2CO_3 (3.93 g, 28.4 mmol, 2.0 equiv) and MeCN (80 mL). The mixture was stirred with reflux at 80 °C for 5 h. The precipitate that had formed was filtered off and then organic layer was dried over Na_2SO_4 and evaporated. The crude product was purified by column chromatography (PE :EA, 15 :1) to give the **1a** as a white solid.

1.2 Typical procedure for the Asymmetric Cyclization of 1,6-enynes with Chalcones:

$CoBr_2$ (4.6 mg, 0.02 mmol), (*R*)-MeO-BIPHEP (14 mg, 0.024 mmol) and 1.0 mL DCM were added to a Schlenk tube under argon atmosphere. The resulting solution was stirred at room temperature for 30 min, then Zn,(1.3 mg, 0.02 mmol) and ZnI_2 (12.7 mg, 0.04 mmol) was added and stirred for additional 10 min. chalcones **2a** was added to the above mixture .Then the mixture was stirred at 40 °C under argon atmosphere .Then 1,6-enyne was dissolved in 1 ml DCM and then slowly added dropwise to the mixture with TLC monitoring until the complete consumption of **1a**. The residue was purified by chromatography on a silica gel column to afford the desired product **3aa** (56mg, 72% yield).

Table S1. Optimization of reaction conditions[a]



1a **2a** **3aa**

Entry	Metal	Ligand	Time	Yield (%)[b]	*ee* (%)[c]
1	CoI_2	(*R*)-MeO-BIPHEP	25min	41	89
2	$Co(OAc)_2$	(*R*)-MeO-BIPHEP	2h	26	91
3	$CoCl_2$	(*R*)-MeO-BIPHEP	4h	25	91
4	$NiBr_2$	(*R*)-MeO-BIPHEP	24 h	NR	-
5	$NiCl_2$	(*R*)-MeO-BIPHEP	24 h	NR	-
6	$CoBr_2$	(*R*)-Monophos	96h	NR	-
7	$CoBr_2$	(*R,R*)-BDPP	3h	31	12
8	$CoBr_2$	(*R,R*)-DIOP	3h	5	23
9	$CoBr_2$	(*R*)-SDP	72h	ND	-
10	$CoBr_2$	(*S,S*)-PyBox	72h	ND	-
11	$CoBr_2$	(*R*)-SYNPHOS	2h	40	89
12	$CoBr_2$	(*R*)-P-PHOS	2h	50	77
13	$CoBr_2$	(*R*)-Cl-MeO-BIPHEP	2h	31	91
14	$CoBr_2$	(*S*)-BIPHEP	1h	39	89
15	$CoBr_2$	(*R*)-DTB-MeO-BIPHEP	2h	15	80
16	$CoBr_2$	(*R*)-BINAP	2h	26	89
17[d]	$CoBr_2$	(*R*)-MeO-BIPHEP	25 min	65	93
18[e]	$CoBr_2$	(*R*)-MeO-BIPHEP	25 min	72	93
19[f]	$CoBr_2$	(*R*)-MeO-BIPHEP	25 min	70	93

[a] *Reaction Conditions:* All reactions were carried out using enyne 1a (0.2mmol), Chalcone 2a (0.4mmol), $CoBr_2$ (5 mol%), *(R)*-MeO-BIPHEP (6 mol%), Zn (10 mol%), ZnI_2 (20 mol %) for 25 min.

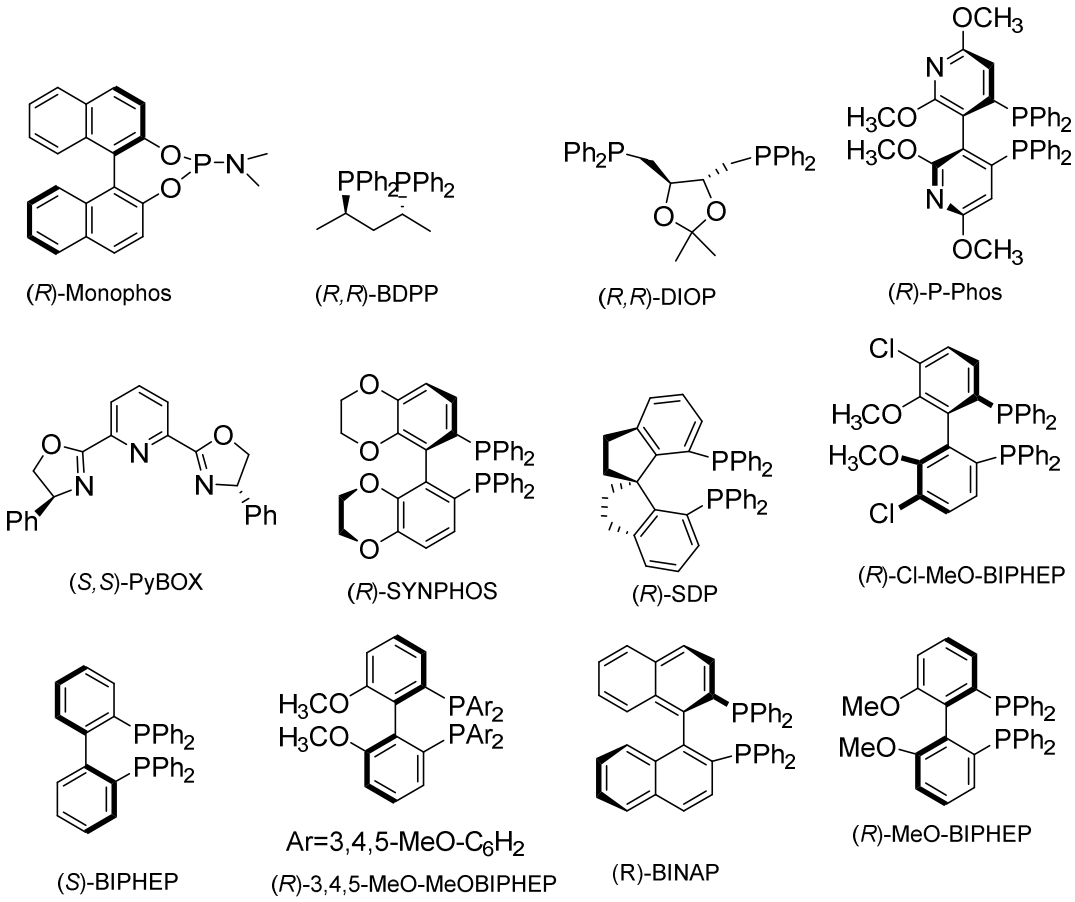
[b] Isolated yield after column chromatography.

[c] The *ee* values were determined by HPLC using a Chiralcel OD-H column.

[d] $CoBr_2$ (5 mol%), Ligand (6 mol%) were used.

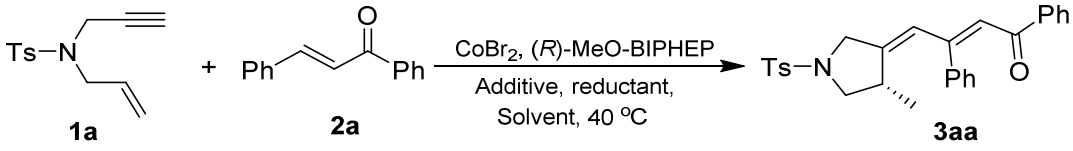
[e] $CoBr_2$ (10 mol%), Ligand (12 mol%) were used.

[f] $CoBr_2$ (10 mol%), Ligand (12 mol%), Chalcone (3 equiv) were used.



Scheme 1. Structures of the phosphine ligands for asymmetric cyclization of 1,6-enyne 1a with chalcone 2a.

Table S2. Screening of Additives, solvents and reductants[a]



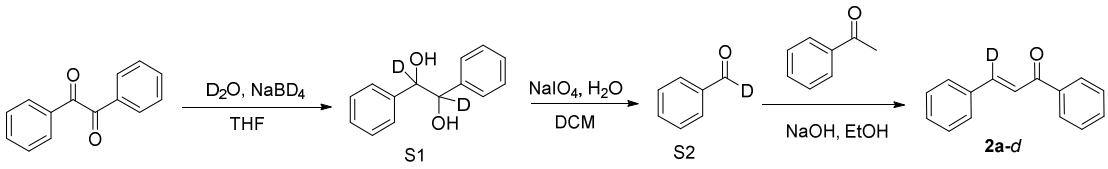
Entry	Solvent	Additive	Reductant	Time	Yield (%)[b]	*ee* (%)[c]
1	DCE	ZnI_2	Zn	2h	30	80
2	Toluene	ZnI_2	Zn	12h	15	91
3	CH_3CN	ZnI_2	Zn	24h	Trace	-
4	THF	ZnI_2	Zn	26h	ND	-
5	**DCM**	**ZnI_2**	**Zn**	**25 min**	**72**	**93**
6[d]	DCM	ZnI_2	Zn	25 min	40	93
7	DCM	ZnI_2	-	48h	NR	-
8	DCM	-	Zn	48h	NR	-
9	DCM	-	-	48h	NR	-
10	DCM	ZnI_2	Fe	20h	45	37
11	DCM	ZnI_2	Mn	2.2h	54	91

12	DCM	$ZnBr_2$	Zn	20 min	61	90
13	DCM	$ZnCl_2$	Zn	20 min	60	89
14	DCM	ZnF_2	Zn	12h	NR	-
15	DCM	$Zn(OAc)_2$	Zn	36h	Trace	-
16	DCM	$AgBF_4$	Zn	72h	NR	-

[a] *Reaction Conditions:*All reactions were carried out using enyne 1a (0.2mmol), Chalcone 2a (0.4mmol), $CoBr_2$ (10 mol%), *(R)*-MeO-BIPHEP (12 mol%), Zn (10 mol%), ZnI_2 (20 mol %) for 25 min.
[b] Isolated yield after column chromatography.
[c] The *ee* values were determined by HPLC using a Chiralcel OD-H column.
[d] Reaction was carried out at room temperature.

2. Isotopic Labelling Experiments

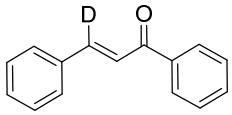
Preparation of deuterated substrate **2a**-*d*:



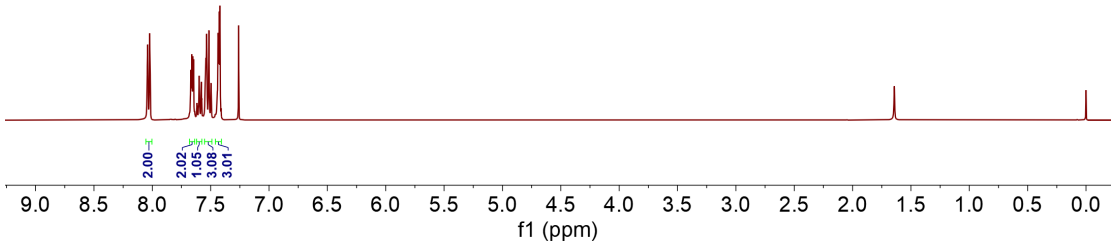
Benzil (420 mg, 2 mmol) was added to a mixture of tetrahydrofuran (4 ml) and D_2O (200 µL) and cooled to (0 ºC). Sodium borodeuteride (100 mg, 2.389 mmol) was added in small batches while stirring. The mixture was warmed to room temperature and stirred overnight where it was then quenched with water. Saturated aqueous ammonium chloride solution was added to the mixture to bring the pH to neutral. The aqueous components were then extracted three times with ethyl acetate. The organic extracts were dried over MgSO4, filtered, and the solvent was removed under reduced pressure to afford product a white solid (S1) which was used in the next step without further purification.[4]

The diol (S1) was oxidized overnight at room temperature in a mixture of DCM (2 mL) and water (2 mL) by adding sodium periodate (427 mg, 2 mmol). The aqueous layer was extracted three times with DCM. The organic extracts were washed with brine, dried over $MgSO_4$, and the solvent removed under reduced pressure to afford deuteriobenzaldehyde (S2)as a colourless oil.

Deuterated benzaldehyde was dissolved in ethanol (20 mL). Then aqueous NaOH (2.0 equiv) solution was added dropwise followed by slow addition of the corresponding acetophenone. The reaction mixture was stirred at room temperature until the complete consumption of the starting materials (TLC). After completion, the reaction mixture was diluted with water and the precipitate was collected by filtration and washed with water and EtOH, then *α,β*-unsaturated deuterated carbonyl compound was obtained.[5] ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.05 – 8.00 (m, 2H), 7.68 – 7.64 (m, 2H), 7.62 – 7.58 (m, 1H), 7.55 – 7.49 (m, 3H), 7.43 (dt, *J* = 4.5, 2.8 Hz, 3H).

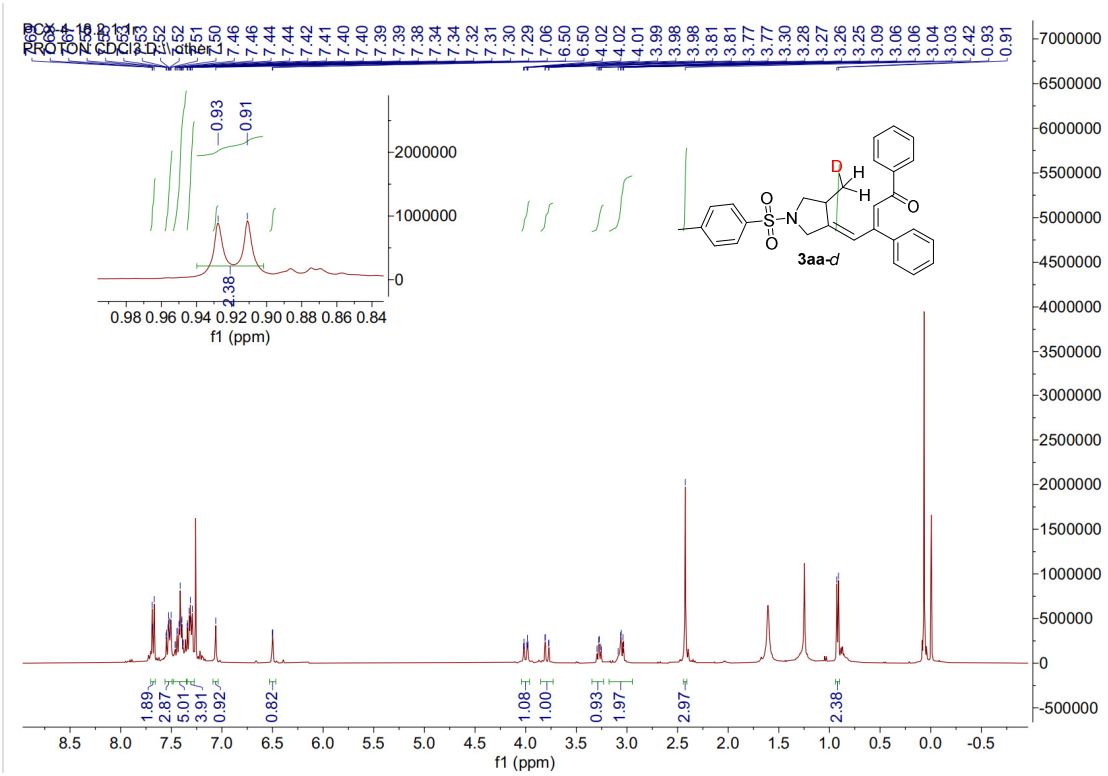


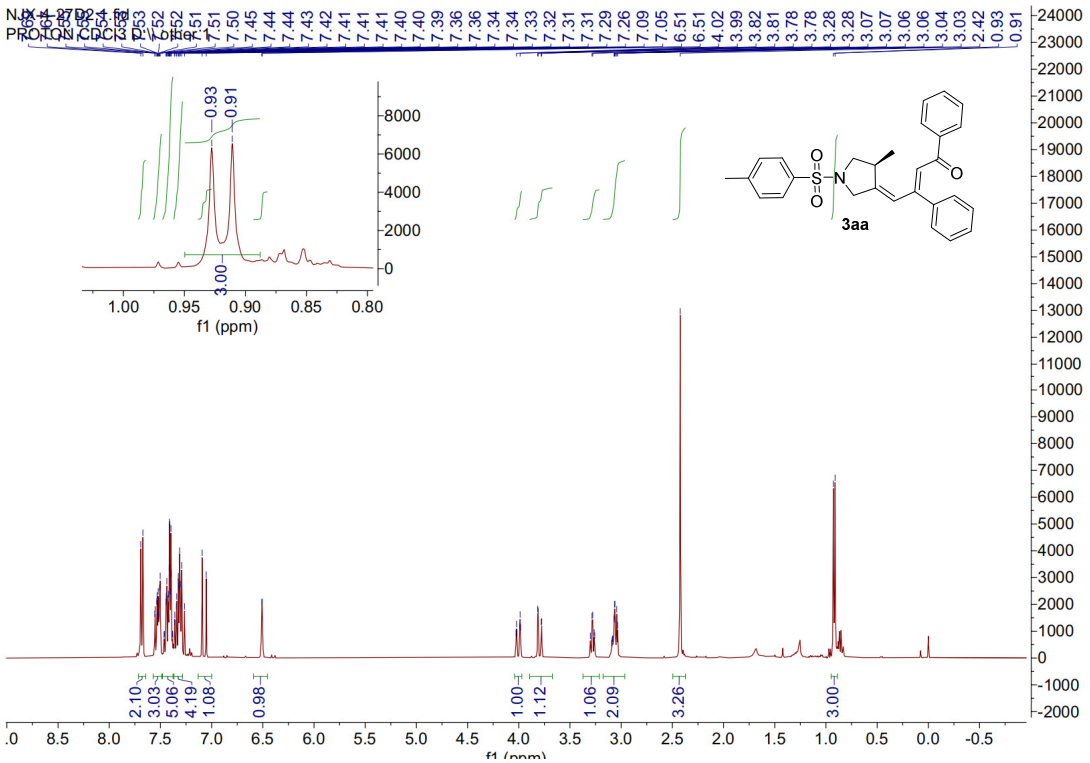
2a-*d*



Preparation of deuterated substrate **3aa**-*d*:

$CoBr_2$ (4.6 mg, 0.02 mmol), (*R*)-MeO-BIPHEP (14 mg, 0.024 mmol) and 1.0 mL DCM were added to a Schlenk tube under argon atmosphere. The resulting solution was stirred at room temperature for 30 min, then Zn,(1.3 mg, 0.02 mmol) and ZnI_2 (12.7 mg, 0.04 mmol) was added and stirred for additional 10 min. chalcones **2a**-*d* was added to the above mixture .Then the mixture was stirred at 40 °C under argon atmosphere .Then 1,6-enyne was dissolved in 1 ml DCM and then slowly added dropwise to the mixture with TLC monitoring until the complete consumption of **1a**. The residue was purified by chromatography on a silica gel column to afford the desired product **3aa**-*d* (62% D).^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.65 – 7.59 (m, 2H), 7.46 (ddd, *J* = 9.9, 6.9, 1.9 Hz, 3H), 7.41 – 7.31 (m, 4H), 7.31 – 7.20 (m, 5H), 6.99 (s, 1H), 6.43 (d, *J* = 2.0 Hz, 1H), 3.93 (dt, *J* = 14.0, 1.9 Hz, 1H), 3.72 (dd, *J* = 13.9, 1.9 Hz, 1H), 3.27 – 3.15 (m, 1H), 2.98 (dd, *J* = 9.5, 2.8 Hz, 2H), 2.36 (s, 3H), 0.85 (d, *J* = 6.7 Hz, 2H).

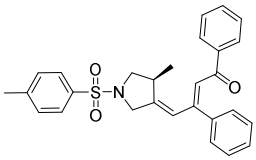




3. Characterization Data of the Products

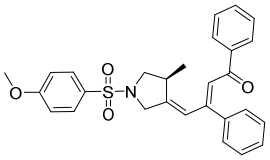
3aa:(*2Z,4E*)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1,3-diphenyl

but-2-en-1-one



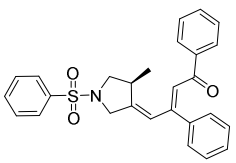
Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 56 mg, 72% yield, 93% *ee*. $[\alpha]_D^{20}$=52.9 (c =0.34 DCM). mp = 59-62 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.56-7.48 (m, 3H), 7.47-7.38 (m, 5H), 7.35-7.27 (m, 4H), 7.07 (d, *J* = 16 Hz, 1H), 6.50 (s, 1H), 4.01(dt, *J* = 13.9, 1.6 Hz, 1H), 3.79 (dd, *J* = 13.9, 1.6 Hz, 1H), 3.28 m, 1H), 3.08-3.03 (m, 2H), 2.42 (s, 3H), 0.91 (d, *J* = 6.7 Hz, 3H).^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.6, 145.7, 143.5, 138.7, 135.5, 134.4, 132.3, 130.8, 129.7, 129.0, 128.4, 127.8, 127.0, 126.2, 120.9, 55.6, 52.9, 35.9, 21.6, 18.2. HRMS calcd for $C_{27}H_{28}NO_3S$ [M+K]+: 480.1609, Found: 480.1610. The *ee* of **3aa** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 21.3 min, t_{major}= 27.4min.

3ba:(*2Z,4E*)-4-((*S*)-1-((4-methoxyphenyl)sulfonyl)-4-methylpyrrolidin -3-ylidene)-1,3-diphenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 60.5 mg, 64% yield, 89% *ee*. $[\alpha]_D^{20}$ = 7.3 (c = 0.41, DCM). mp = 76-79 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.74-7.27 (m, 2H), 7.55-7.50 (m, 2H), 7.47-7.29 (m, 7H), 7.07 (d, *J* = 16 Hz, 1H), 6.98-6.96 (m, 2H), 6.50 (s, 1H), 3.99(dt, *J* = 13.9, 1.6 Hz, 1H), 3.87 (s, 3H), 3.79 (dd, *J* = 13.9, 1.6 Hz, 1H), 3.28 (m, 1H), 3.09-3.02 (m, 2H), 0.91 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.6, 145.7, 143.5, 138.7, 135.5, 134.4, 130.8, 130.7, 129.8, 128.9, 128.4, 128.3, 127.0, 126.2, 121.0, 114.2, 55.5, 53.0, 35.0, 18.2. HRMS calcd for $C_{28}H_{27}NO_4S$ [M]+: 473.1661, Found: 473.1655. The *ee* of **3ab** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 33.8 min, t_{maior}= 42.6min.

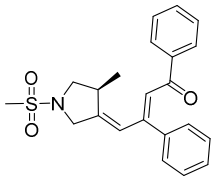
3ca:(*2Z,4E*)-4-((*S*)-4-methyl-1-(phenylsulfonyl)pyrrolidin-3-ylidene)- 1,3-diphenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20),

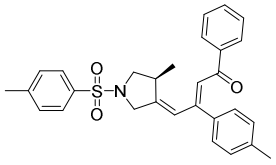
49.6 mg, 56% yield, 89% *ee*. $[\alpha]_D^{20}$ = 40.2 (c =0.15 DCM). mp = 80-84 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.80-7.78 (m, 2H), 7.57-7.49 (m, 7H), 7.44-7.38 (m, 4H), 7.33-7.29 (m, 2H), 7.05 (d, *J* = 16 Hz, 1H), 6.51 (s, 1H), 4.04 (dt, *J* = 13.9, 1.6 Hz, 1H), 3.81 (dd, *J* = 13.9, 1.6 Hz, 1H), 3.29 (m, 1H), 3.09-3.04 (m, 2H), 0.91 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.4, 145.5, 143.4, 138.8, 135.7, 135.5, 134.4, 132.8, 130.8, 130.6, 129.0, 128.3, 127.7, 127.0, 126.2, 121.1, 55.5, 52.8, 35.1, 18.2. HRMS calcd for $C_{27}H_{25}NO_3S$ [M]+: 443.1555, Found:443.1553. The *ee* of **3ca** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 22.8 min, t_{major}= 27.8min.

3da:(*2Z,4E*)-4-((*S*)-4-methyl-1-(methylsulfonyl)pyrrolidin-3-ylidene)-1,3-diphenylbut-2-en-1-one



Yellow oil, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 54 mg, 72% yield, 91% *ee*. $[\alpha]_D^{20}$ = 66.1 (c = 0.18, DCM),^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.60 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.56-7.53 (m, 2H), 7.50-7.44 (m, 2H), 7.44-7.37 (m, 5H), 7.12 (d, *J* =16.0, 1H), 6.59 (s, 1H), 4.18 (dt, *J* = 14.1, 1.6 Hz, 1H) , 3.92 (m, 1H), 3.37 (m, 1H), 2.7 (s, 3H), 0.91 (d, *J* = 6.7 Hz, 3H) . ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.6, 145.6, 143.3, 138.8, 135.5, 134.4, 130.9, 130.8, 129.1, 128.4, 127.2, 126.2, 121.5, 55.4, 52.5, 35.4, 34.3, 18.7. HRMS calcd for $C_{22}H_{23}NO_3S$ [M+Na]+: 404.1292, Found: 404.1296. The *ee* of **3da** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 31.7 min, t_{major}= 41.9min.

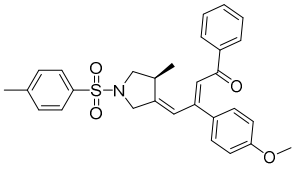
3ab:(*2Z,4E*)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenyl-3-(p-tolyl)but-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 64.9mg, 69% yield, 79% *ee*. $[\alpha]_D^{20}$= 35.1 (c = 0.17 DCM). mp = 79-82 °C, ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.53-7.51 (m, 2H), 7.41-7.39 (m, 3H), 7.36-7.29 (m, 5H), 7.21-7.19 (m, 2H), 7.01 (d, *J* = 16 Hz, 1H), 6.49 (s, 1H), 4.00(dt, *J* =

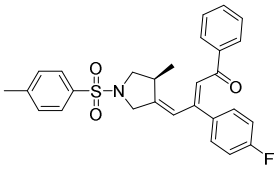
13.9, 1.6 Hz, 1H), 3.79 (m, 1H), 3.28-3.26 (m, 1H), 3.06-3.04 (m, 2H), 2.40 (d, *J* = 13.2 Hz, 6H), 0.91 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.6, 145.8, 143.6, 141.4, 139.0, 135.5, 132.7, 131.7, 130.4, 129.8, 128.1, 128.2, 127.8, 126.9, 125.4, 121.0, 55.6, 52.9, 35.0, 21.5, 18.2. HRMS calcd for $C_{29}H_{29}NO_3S$ [M]+: 471.1868, Found:471.1867. The *ee* of **3ab** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 17.3min, t_{major}= 22.2 min.

3ac:(*2Z,4E*)-3-(4-methoxyphenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 79.2 mg, 78% yield, 87% *ee*. $[\alpha]_D^{20}$= 175.0 (c = 0.20 DCM). mp = 66-70 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.66 (m, 2H), 7.52-7.50 (m, 1H), 7.47-7.44 (m, 2H), 7.42-7.38 (m, 1H), 7.34-7.29 (m, 5H), 6.95-6.89 (m, 3H), 6.49 (s, 1H), 4.00(dt, *J* = 13.9, 1.8 Hz, 1H), 3.84 (s, 3H), 3.81-3.77 (m, 1H), 3.30-3.25 (m, 1H), 3.06-3.03 (m, 2H), 2.41 (s, 3H), 0.92 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.6, 161.9, 145.6, 143.3, 139.2, 135.4, 132.6, 130.3, 130.1, 129.6, 128.8, 128.2, 127.8, 127.1, 126.9, 124.1, 121.0, 114.5, 55.4, 52.9, 35.0, 21.5, 18.2. HRMS calcd for $C_{29}H_{29}NO_4S$ [M]+: 487.1817, Found: 487.1818. The *ee* of **3ac** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 54.1 min, t_{maior}= 74.3min.

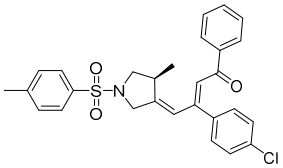
3ad:(*2Z,4E*)-3-(4-fluorophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 68.4 mg, 72% yield, 83% *ee*. $[\alpha]_D^{20}$ = 21.3 (c = 0.28 DCM). mp = 72-76 °C, ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.55-7.49 (m, 3H), 7.44-7.30 (m, 6H), 7.11-7.06 (m, 2H), 7.00 (d, *J* = 16 Hz, 1H), 6.50 (s, 1H), 4.00(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.79 (m, 1H), 3.31-3.27 (m, 1H), 3.07-3.03 (m, 2H), 2.43 (s, 3H), 0.91 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.1, 165.4, 162.9, 144.0, 143.6, 138.7, 135.6, 132.6, 130.7, 130.3, 130.2, 129.6, 129.0, 128.3, 127.8, 127.0, 126.0, 121.0, 116.3, 116.1, 55.5, 52.9, 35.0, 29.7, 21.5, 18.2. HRMS calcd for $C_{28}H_{26}FNO_3S$ [M+Na]+: 498.1507, Found: 498.1515. The *ee* of **3ad** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm;

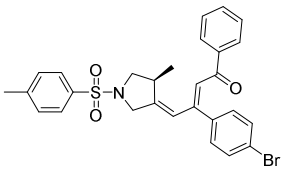
t_{minor}= 21.1 min, t_{major}= 27.2min.

3ae:(*2Z,4E*)-3-(4-chlorophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenylbut-2-en-1-one



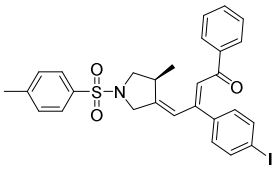
Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 66.7 mg, 68% yield, 93% *ee*. $[\alpha]_D^{20}$ = 31.9 (c = 0.19 DCM). mp = 81-83 °C, ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.56-7.54 (m, 1H), 7.45-7.40 (m, 3H), 7.37-7.30 (m, 7H), 7.00 (dd, *J* = 16, 1.9 Hz, 1H), 6.51 (s, 1H), 4.00(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.82-3.78 (m, 1H), 3.31-3.27 (m, 1H), 3.06-3.04 (m, 2H), 2.43 (s, 3H), 0.91 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 194.9, 143.7, 143.7, 138.6, 136.7, 135.6, 132.9, 132.6, 130.8, 129.6, 129.4, 129.3, 129.0, 128.4, 127.8, 127.0, 126.6, 121.0, 55.5, 52.9, 35.0, 21.5, 18.2. HRMS calcd for $C_{28}H_{26}ClNO_3S$ [M+Na]+: 514.1214, Found:514.1220. The *ee* of **3ae** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 22.7 min, t_{major}= 29.6min.

3af:(*2Z,4E*)-3-(4-bromophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenylbut-2-en-1-one



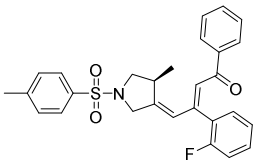
Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 64.2 mg, 60% yield, 93% *ee*. $[\alpha]_D^{20}$ = 30 (c = 0.20 DCM). mp = 73-77 °C, ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.55-7.51 (m, 3H), 7.44-7.42 (m, 1H), 7.38-7.30 (m, 7H), 7.00 (d, *J* = 16 Hz, 1H), 6.50 (s, 1H), 4.00(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.82 (m, 1H), 3.31-3.26 (m, 1H), 3.07-3.03 (m, 2H), 2.43 (s, 3H), 0.90 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 194.9, 143.7, 143.7, 138.6, 136.7, 135.6, 132.9, 132.6, 130.8, 129.6, 129.4, 129.3, 129.0, 128.4, 127.8, 127.0, 126.6, 121.0, 55.5, 52.9, 35.0, 21.5, 18.2. HRMS calcd for $C_{28}H_{26}BrNO_3S$ [M+H]+: 536.0886, Found: 536.0895. The *ee* of **3af** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 24.5 min, t_{major}= 32.4min.

3ag:(*2Z,4E*)-3-(4-iodophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenylbut-2-en-1-one



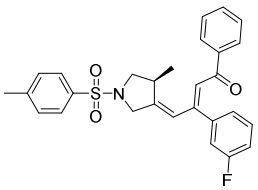
Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 23.3 mg, 20% yield, 75% *ee*. $[\alpha]_D^{20}$ = 25 (c = 0.16 DCM). mp = 68-71 °C, ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.75-7.72 (m, 2H), 7.69-7.67 (m, 2H), 7.56-7.53 (m, 1H), 7.45-7.43 (m, 1H), 7.36-7.30 (m, 5H), 7.24-7.22 (m, 2H), 7.07 (d, *J* = 16 Hz, 1H), 6.50 (s, 1H), 4.00(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.79 (m, 1H), 3.30-3.26 (m, 1H), 3.08-3.02 (m, 2H), 2.43 (s, 3H), 0.90 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.1, 144.1, 143.6, 138.5, 138.2, 135.6, 133.9, 132.3, 131.0, 130.8, 129.7, 129.0, 128.4, 127.9, 127.1, 126.6, 120.9, 97.2, 55.5, 52.9, 35.0, 21.5, 18.2. HRMS calcd for $C_{28}H_{26}INO_3S$ [M+H]+: 584.0756, Found: 584.0763. The *ee* of **3ag** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 47.7 min, t_{maior}= 61.5min.

3ah:(*2Z,4E*)-3-(2-fluorophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 57.0 mg, 60% yield, 91% *ee*. $[\alpha]_D^{20}$ = 34 (c = 0.26 DCM). mp = 67-70 °C, ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.58-7.51 (m, 3H), 7.46-7.28 (m, 6H), 7.20-7.16 (m, 2H), 7.11-7.06 (m, 1H), 6.52 (s, 1H), 4.00(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.81 (m, 1H), 3.31-3.27 (m, 1H), 3.06-3.03 (m, 2H), 2.41 (s, 3H), 0.90 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.1,162.8, 162.2, 143.7, 143.6, 138.6, 137.7, 132.7, 132.1, 130.8, 129.6, 129.4, 129.0, 128.5, 127.8, 127.1, 124.6, 122.6, 122.5, 121.1, 116.4, 116.1,55.5, 52.9, 35.0, 29.7, 21.5, 18.2. HRMS calcd for $C_{28}H_{26}FNO_3S$ [M+Na]+: 498.1509, Found: 498.1515. The *ee* of **3ah** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 19.5 min, t_{maior}= 23.7min.

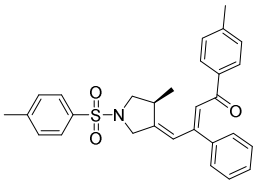
3ai:(*2Z,4E*)-3-(3-fluorophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20),

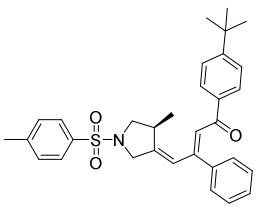
62.7 mg, 66% yield, 93% *ee*. $[\alpha]_D^{20}$ = 42 (c = 0.38 DCM). mp = 76-79 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.57-7.53 (m, 3H), 7.46-7.42 (m, 1H), 7.38-7.29 (m, 5H), 7.20-7.16 (m, 2H), 7.16-7.06(m, 1H), 6.50 (s, 1H), 4.01(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.80 (m, 1H), 3.30-3.26 (m, 1H), 3.05-3.02 (m, 2H), 2.4 (s, 3H), 0.90 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 194.2, 142.6, 137.5, 136.8, 134.6, 131.3, 131.1, 131.0, 129.8, 128.6, 128.4, 127.9, 127.4, 126.8, 126.0, 123.6, 123.5, 120.0, 115.3, 115.1, 54.5, 51.9, 34.0, 20.5. HRMS calcd for $C_{28}H_{26}FNO_3S$ [M+Na]+: 498.1508, Found: 498.1515. The *ee* of **3ai** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 21.7 min, t_{major}= 27.8 min.

3aj:(*2Z,4E*)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-3-phenyl-1-(p-tolyl)but-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 47.1mg, 50% yield, 79% *ee*. $[\alpha]_D^{20}$ = 35.1 (c = 0.17 DCM). mp = 51-53 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.52-7.47 (m, 3H), 7.43-7.38 (m, 4H), 7.30-7.28 (m, 3H), 7.15-7.12 (m, H), 7.09-7.08 (M, 1H), 6.53 (s, 1H), 4.02-3.98 (m, 1H), 3.82-3.79 (m, 1H), 3.32-3.27 (m, 1H), 3.06-3.00 (m, 2H), 2.42 (s, 3H), 2.38 (s, 3H), 0.91 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 193.7, 143.8, 142.5, 141.9, 140.2, 135.0, 134.9, 133.5, 131.6, 129.6, 128.7, 128.6, 127.9, 127.7, 127.2, 126.8, 126.6, 125.0, 120.5, 54.5, 51.9, 34.0, 20.5, 17.1. HRMS calcd for $C_{29}H_{29}NO_3S$ [M]+: 471.1868, Found:471.1868. The *ee* of **3ab** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 17.1min, t_{major}= 21.0 min.

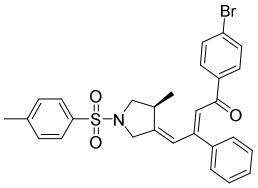
3ak:(*2Z,4E*)-1-(4-(tert-butyl)phenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-3-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 62.5 mg, 61% yield, 36% *ee*. $[\alpha]_D^{20}$ = 21.0 (c = 0.14 DCM). mp = 67-70 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.70-7.68 (m, 2H), 7.55-7.49 (m, 3H), 7.45-7.39 (m, 3H), 7.36-7.33 (m, 5H), 7.31-7.29 (m, 2H), 7.10 (d, *J* = 16 Hz, 1H), 6.58 (s, 1H), 4.02(d, *J* = 13.8 Hz, 1H), 3.83 (d, *J* = 13.9 Hz, 1H), 3.32-3.28 (m, 1H), 3.07-3.04 (m, 2H), 2.42 (s,

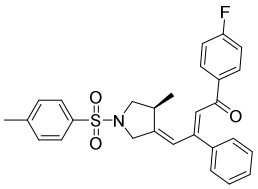
3H), 1.64 (s, 1H), 1.33 (s, 9H), 0.95 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.6, 145.8, 143.6, 141.4, 139.0, 135.5, 132.7, 131.7, 130.4, 129.8, 128.1, 128.2, 127.8, 126.9, 125.4, 121.0, 55.6, 52.9, 35.0, 21.5, 18.2. HRMS calcd for $C_{32}H_{35}NO_5S$ [M+H]+: 514.2408, Found:514.2416 *ee* of **3ak** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 14.9 min, t_{major}= 19.7 min.

3al:(*2Z,4E*)-1-(4-bromophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-yl idene)-3-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 69.5 mg, 65% yield, 93% *ee*. $[\alpha]_D^{20}$ = 21 (c = 0.28 DCM). mp = 57-60 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.52-7.46 (m, 3H), 7.44-7.40 (m, 6H), 7.32-7.30 (m, 2H), 7.04 (dd, *J* = 16, 1.9 Hz, 1H), 6.44 (s, 1H), 4.01(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.79 (m, 1H), 3.32-3.28 (m, 1H), 3.08-3.03 (m, 2H), 2.43 (s, 3H), 0.92 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 194.3, 146.0, 144.9, 143.8, 137.6, 137.4, 134.2, 132.2, 131.9, 131.0, 130.0, 129.9, 129.7, 129.1, 128.4, 127.9, 125.1, 125.0, 119.8, 55.5, 5.0, 35.0, 21.6, 18.2. HRMS calcd for $C_{28}H_{26}BrNO_3S$ [M+H]+:536.0881, Found:536.0895. The *ee* of **3al** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 25.1 min, t_{major}= 33.1 min.

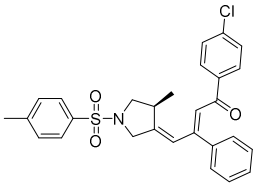
3am:(*2Z,4E*)-1-(4-fluorophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-y lidene)-3-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 47.5 mg, 50% yield, 89% *ee*. $[\alpha]_D^{20}$= 2.1 (c = 0.42 DCM). mp = 73-75 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.61-7.57 (m, 1H), 7.53-7.51 (m, 2H), 7.47-7.40 (m, 4H),7.32-7.30 (m, 2H), 7.10-7.03(m, 2H), 7.01-6.96 (m, 1H), 6.50 (s, 1H), 4.01(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.80 m, 1H), 3.32-3.28 (m, 1H), 3.08-3.05 (m, 2H), 2.42 (s, 3H), 0.93 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 193.8, 164.9, 162.4, 145.6, 144.6, 143.8, 138.7, 138.6, 134.9, 134.3, 132.3, 130.9, 129.7, 129.1, 128.4, 127.8, 125.8, 120.3, 116.0, 115.8, 114.1, 113.9, 55.5, 53.0, 35.0, 21.6, 18.2. HRMS calcd for $C_{28}H_{26}FNO_3S$ [M+Na]+: 498.1511, Found:498.1515. The *ee* of **3am** was determined by

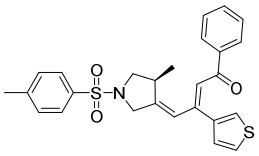
HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 22.9 min, t_{major}= 29.2 min.

3an:(*2Z,4E*)-1-(4-chlorophenyl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-3-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 45.1 mg, 46% yield, 75% *ee*. $[\alpha]_D^{20}$= 3.8 (c = 0.26 DCM). mp = 68-71 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69-7.67 (m, 2H), 7.53-7.49 (m, 3H), 7.44-7.40 (m, 4H), 7.33-7.30 (m, 3H), 7.25(m, 1H), 7.05 (dd, *J* = 16, 1.9 Hz, 1H), 6.45 (s, 1H), 4.01(dt, *J* = 13.8 Hz, 1.8 Hz, 1H), 3.80 (m, 1H), 3.33-3.28 (m, 1H), 3.08-3.03 (m, 2H), 2.43 (s, 3H), 0.92 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 194.1, 146.0, 144.8, 143.8, 137.5, 136.9, 136.7, 134.2, 132.4, 131.0, 129.8, 129.7, 129.1, 129.0, 128.4, 127.8, 127.1, 125.7, 120.0, 55.5, 53.0, 35.0, 21.6, 18.2. HRMS calcd for $C_{28}H_{26}ClNO_3S$ [M+Na]+: 514.1211, Found: 514.1220. The *ee* of **3an** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 80/20, 0.5 mL/min, 254nm; t_{minor}=54.2 min, t_{major}=71.5 min.

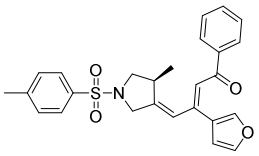
3ao:(*2Z,4E*)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-1-phenyl-3-(thiophen-3-yl)but-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 46.3 mg, 50% yield, 92% *ee*. $[\alpha]_D^{20}$= 11.7 (c = 0.17 DCM). mp = 84-87 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.70-7.68 (m, 2H), 7.52-7.50 (m, 2H), 7.43-7.29 (m, 8H), 6.87 (d, *J* = 16, Hz 1H), 6.47 (s, 1H), 4.02-3.98 (m, 1H), 3.78 (m, 1H), 3.29-3.25 (m, 1H), 3.09-3.04 (m, 2H), 2.43 (s, 3H), 0.92 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 194.1, 146.0, 144.8, 143.8, 137.5, 136.9, 136.7, 134.2, 132.4, 131.0, 129.8, 129.7, 129.1, 129.0, 128.4, 127.8, 127.1, 125.7, 120.0, 55.5, 53.0, 35.0, 21.6, 18.2. HRMS calcd for $C_{26}H_{25}NO_3S_2$ [M]+:463.1276, Found: 463.1279. The *ee* of **3ao** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 28.2 min, t_{major}= 35.5 min.

3ap:(*2Z,4E*)-3-(furan-3-yl)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-yliden

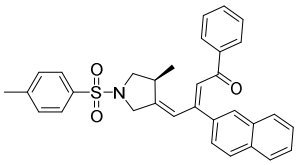
e)-1-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 67.9 mg, 76% yield, 80% *ee*. $[\alpha]_D^{20}$= 14.2 (c = 0.42 DCM). mp = 110-113 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.70-7.68 (m, 2H), 7.63 (s, 1H), 7.51-7.49 (m, 1H), 7.45-7.40 (m, 1H), 7.34-7.29 (m, 5H), 6.77 (d, *J* = 16 Hz, 1H), 6.59 (m, 1H), 6.47 (s, 1H), 4.00 (dt, *J*=14, 1.4 Hz,1H), 3.77 m, 1H), 3.29-3.24 (m,1H), 3.08-3.04 (m,2H), 2.43 (s, 3H), 0.91 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.5, 145.5, 144.7, 143.7, 143.4, 138.7, 135.7, 135.4, 132.3, 130.5, 129.7, 128.8, 128.2, 127.8, 127.0, 126.3, 122.9, 120.9, 107.2, 55.6, 52.9, 35.0, 21.5, 18.2. HRMS calcd for $C_{26}H_{25}NO_4S$ [M+Na]+: 470.1394, Found: 470.1402. The *ee* of **3ap** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 21.8 min, t_{major}= 27.5 min.

3aq:(*2Z,4E*)-4-((*S*)-4-methyl-1-tosylpyrrolidin-3-ylidene)-3-(naphthal

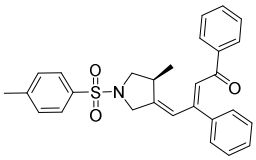
en-2-yl)-1-phenylbut-2-en-1-one



Yellow solid, purified by silica gel column chromatography (ethyl acetate/hexane, 1/20), 56.7 mg, 56% yield, 75% *ee*. $[\alpha]_D^{20}$ = 17.6 (c = 0.17 DCM). mp = 85-88 °C,^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.90-7.83 (m, 4H), 7.67-7.65 (m, 3H), 7.60-7.51 (m, 4H), 7.46-7.43 (m, 1H), 7.37-7.32 (m, 2H), 7.24 (s, 1H), 7.18 (d, *J* = 16 Hz, 1H), 6.53 (m, 1H), 4.01 (dt, *J*=14, 1.4 Hz,1H), 3.80 (m, 1H), 3.30-3.26 (m,1H), 3.10-3.04 (m,2H), 2.37 (s, 3H), 0.94 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.6, 145.8, 143.6, 138.8, 135.6, 134.4, 133.2, 132.3, 131.9, 130.8, 130.7, 129.6, 128.9, 128.6, 128.4, 127.8, 127.6, 127.0, 126.9, 126.3, 123.3, 121.0, 55.6, 52.3, 35.1, 21.5, 18.2. HRMS calcd for $C_{32}H_{29}NO_3S$ [M+H]+:508.1935, Found: 508.1946. The *ee* of **3aq** was determined by HPLC analysis using Daicel Chiralcel OD-H column (25 cm × 0.46 cm ID), conditions: *n*-heptane/EtOH = 90/10, 1mL/min, 254nm; t_{minor}= 31.6 min, t_{major}= 41.1 min.

4. NMR spectra

3aa：

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7.508
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7.461
7.445
7.442
7.438
7.426
7.423
7.412
7.410
7.397
7.387
7.381
7.360
7.341
7.324
7.312
7.292
7.092
7.052
6.509
6.506
4.026
4.022
3.987
3.815
3.811
3.780
3.776
3.301
3.284
3.278
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3.065
3.061
3.043
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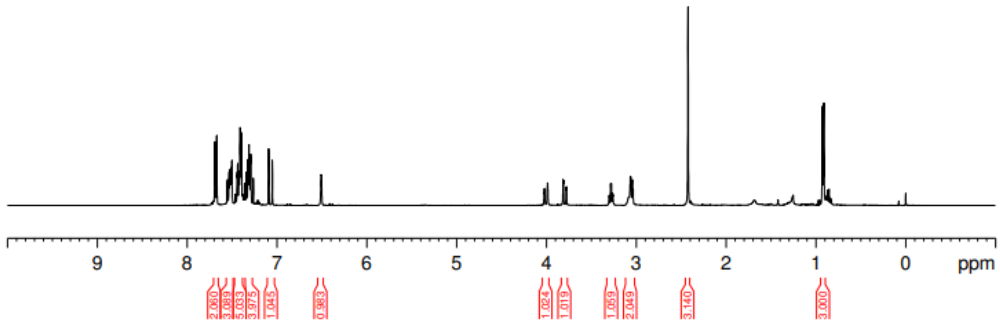
0.911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ppm
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3.975
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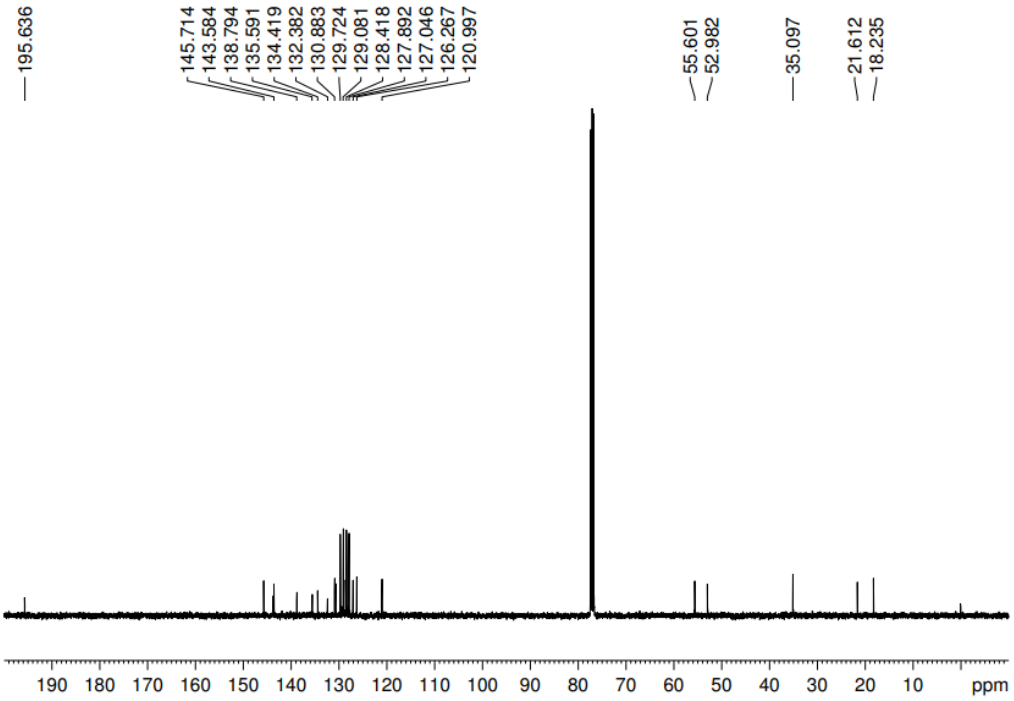
0.983
1.024
1.019
1.059
2.049
3.140
3.000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134.419
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127.892
127.046
126.267
120.997
55.601
52.982
35.097
21.612
18.235
190
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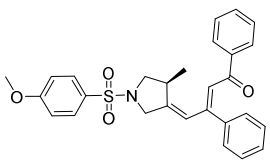
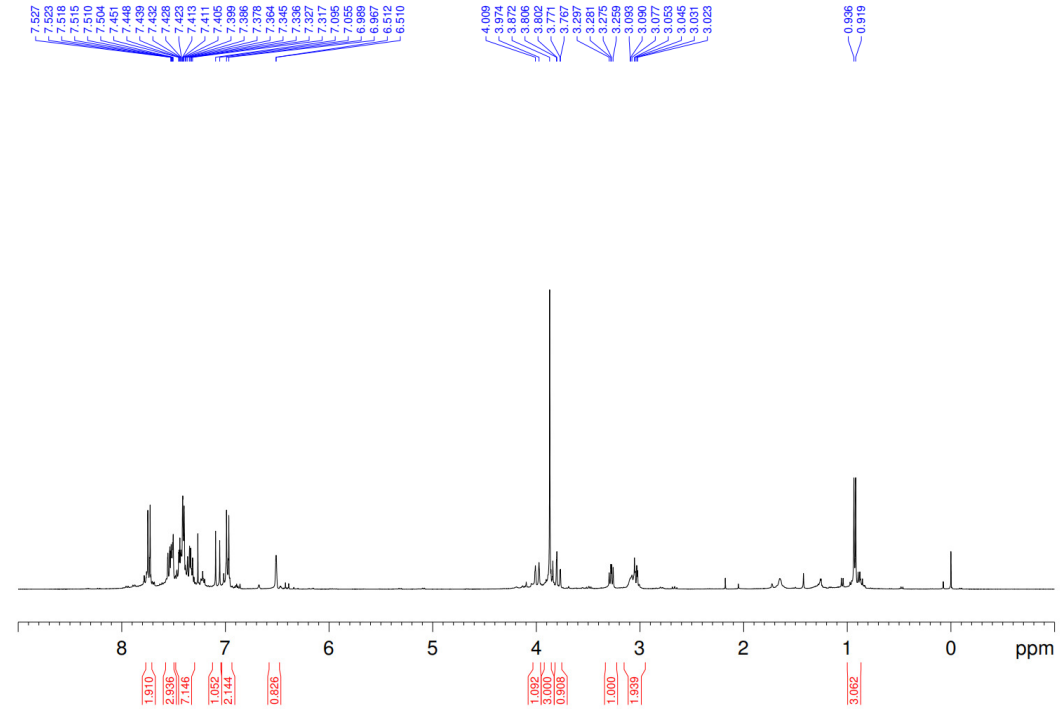
60
50
40
30
20
10
ppm

3ba


O
S
O
O
N
O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7.411
7.405
7.399
7.386
7.378
7.364
7.345
7.336
7.327
7.317
7.095
7.035
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6.957
6.512
6.510
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3.806
3.802
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3.297
3.281
3.275
3.259
3.093
3.090
3.077
3.053
3.045
3.031
3.023
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0.919
8
7
6
5
4
3
2
1
0
ppm
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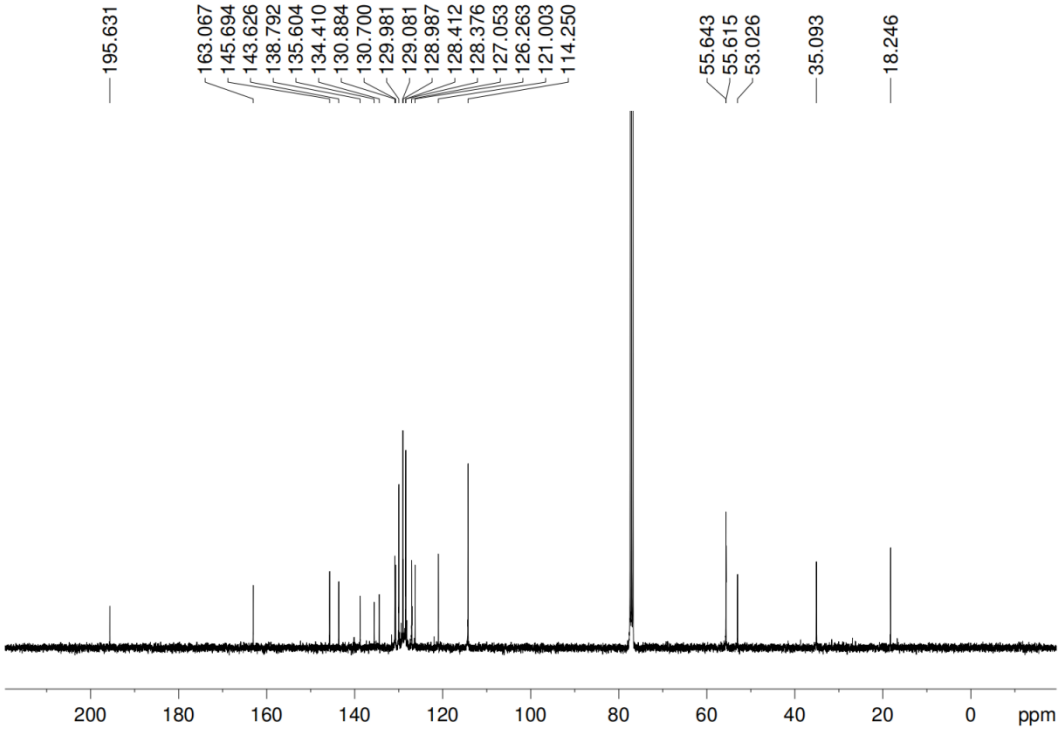
3.062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128.987
128.412
128.376
127.053
126.263
121.003
114.250
55.643
55.615
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18.246
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140
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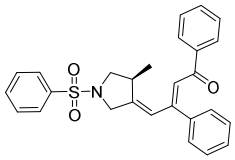
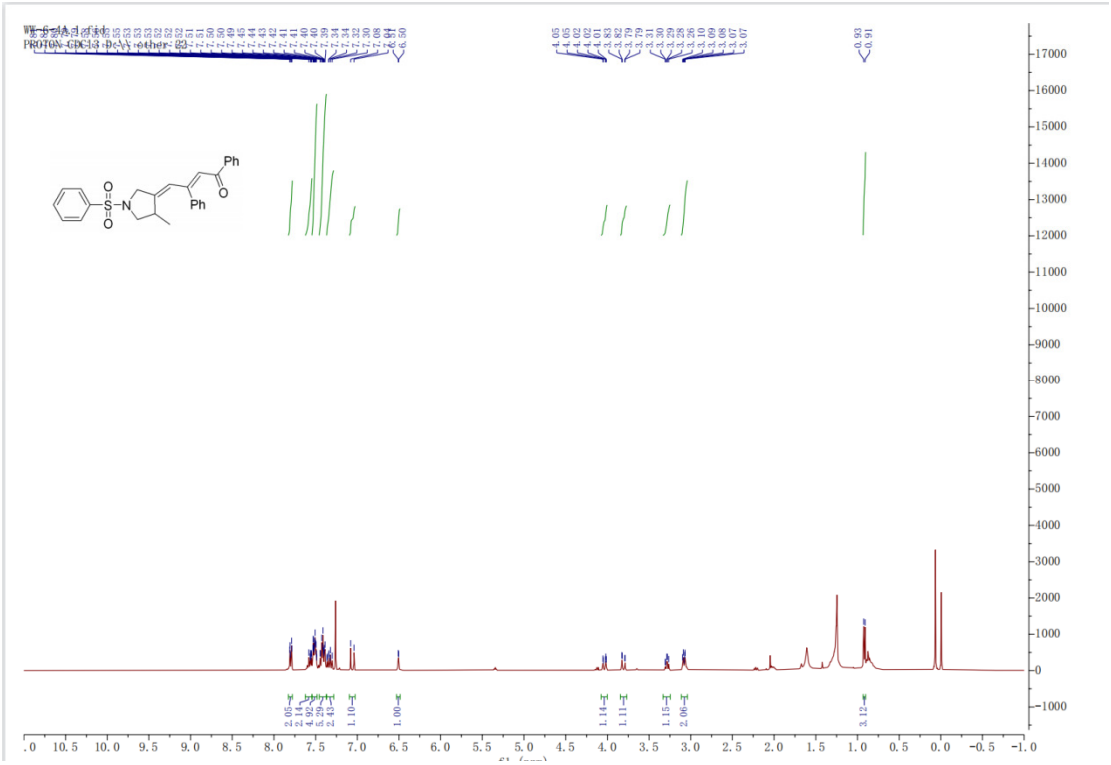
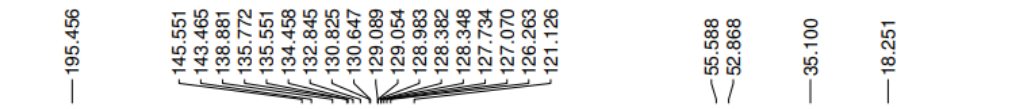
100
80
60
40
20
0
ppm

3ca



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135.551
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132.845
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129.089
129.054
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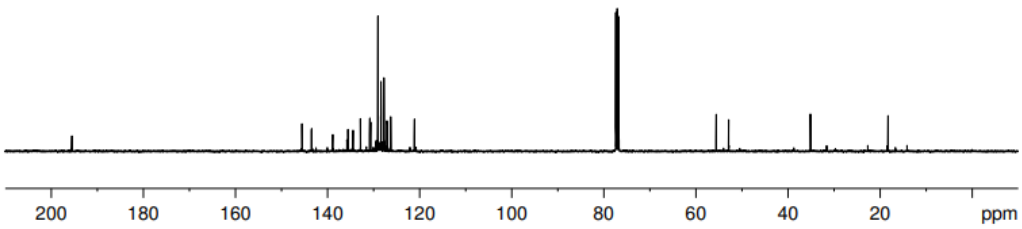
128.348
127.734
127.070
126.263
121.126
55.588
52.868
35.100
18.251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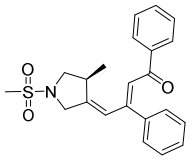
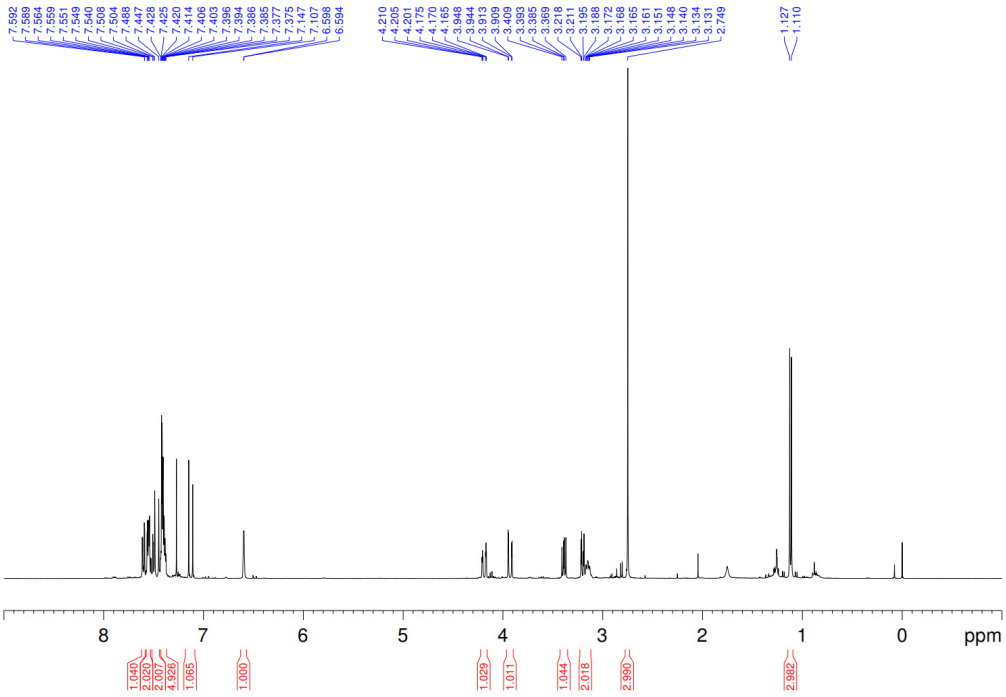
100
80
60
40
20
ppm

3da

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7.425
7.420
7.414
7.406
7.403
7.396
7.394
7.386
7.385
7.377
7.375
7.147
7.107
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6.594
4.210
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4.201
4.175
4.170
4.165
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3.161
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7
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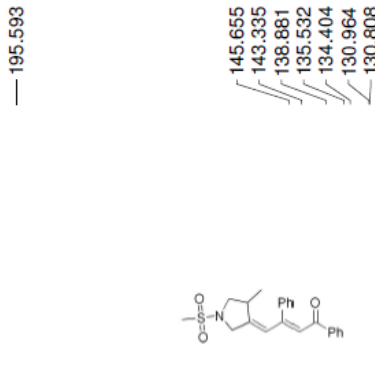
2.982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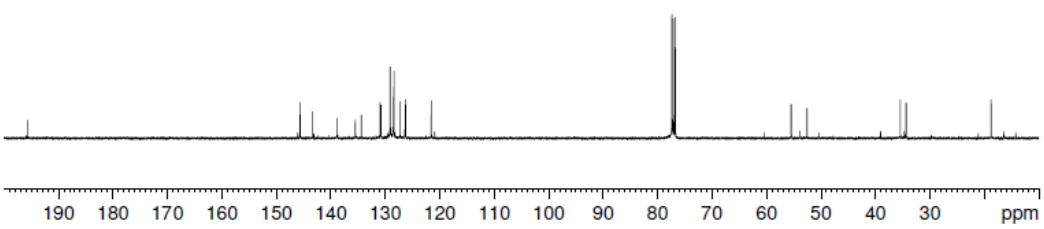
35.417
34.354
18.741

Ph
Ph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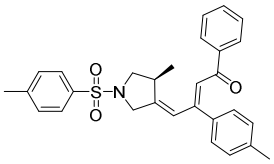
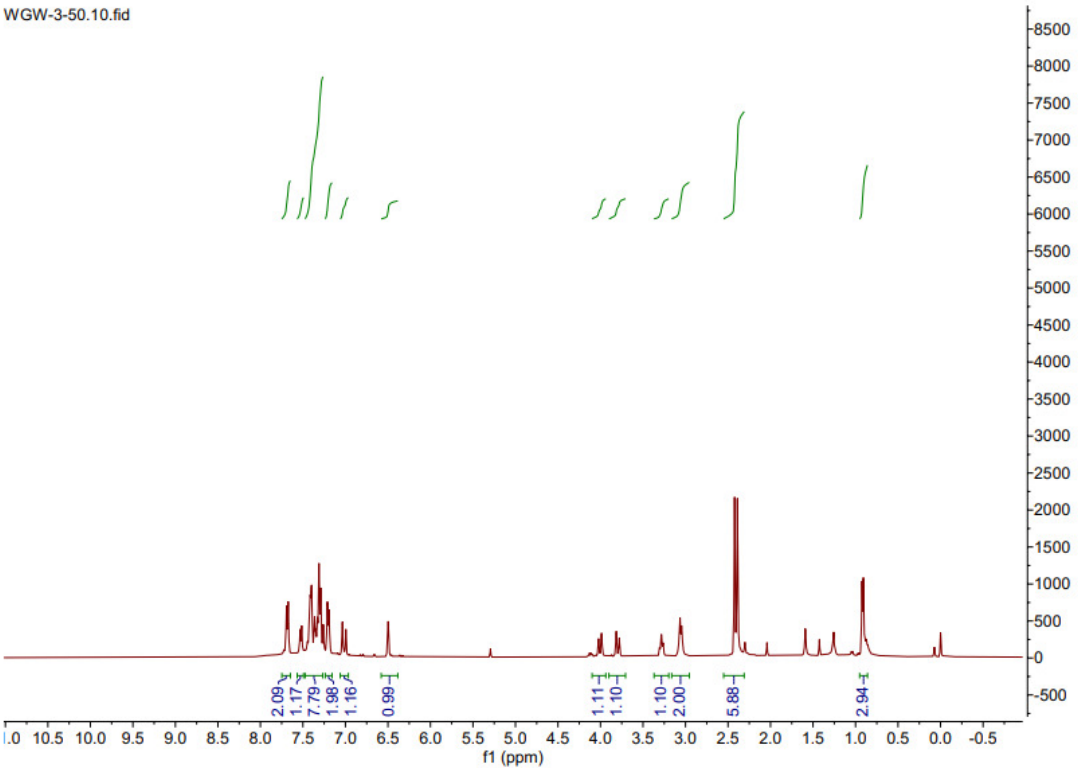
90
80
70
60
50
40
30
ppm

3ab

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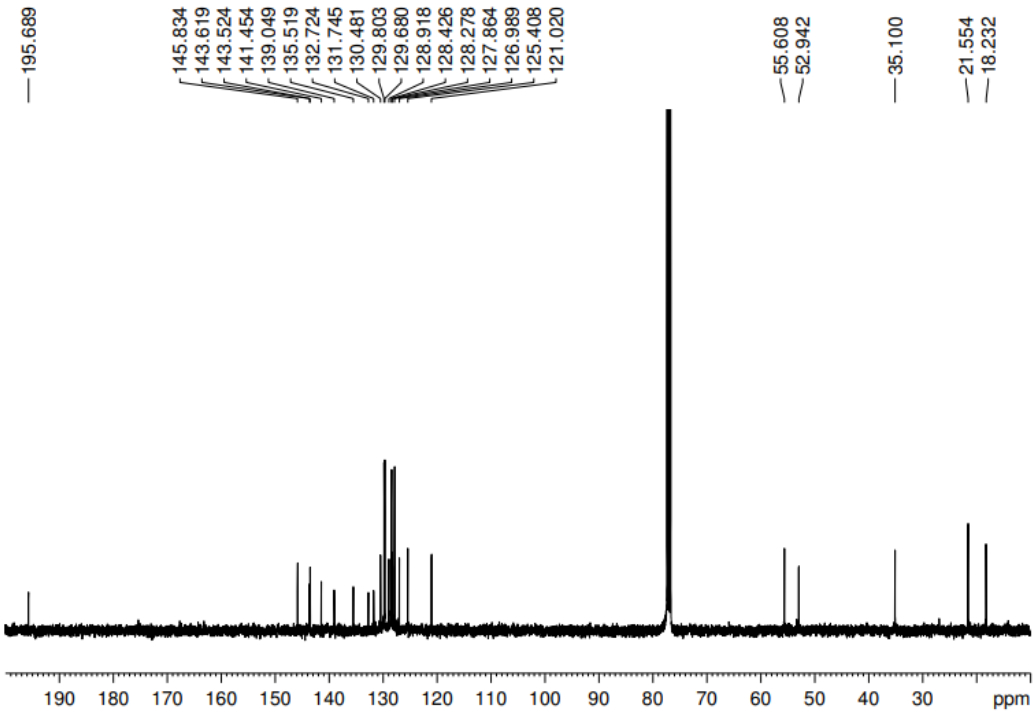
f1 (ppm)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ppm

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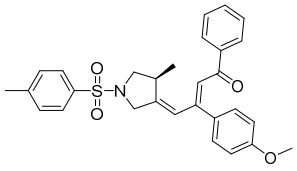

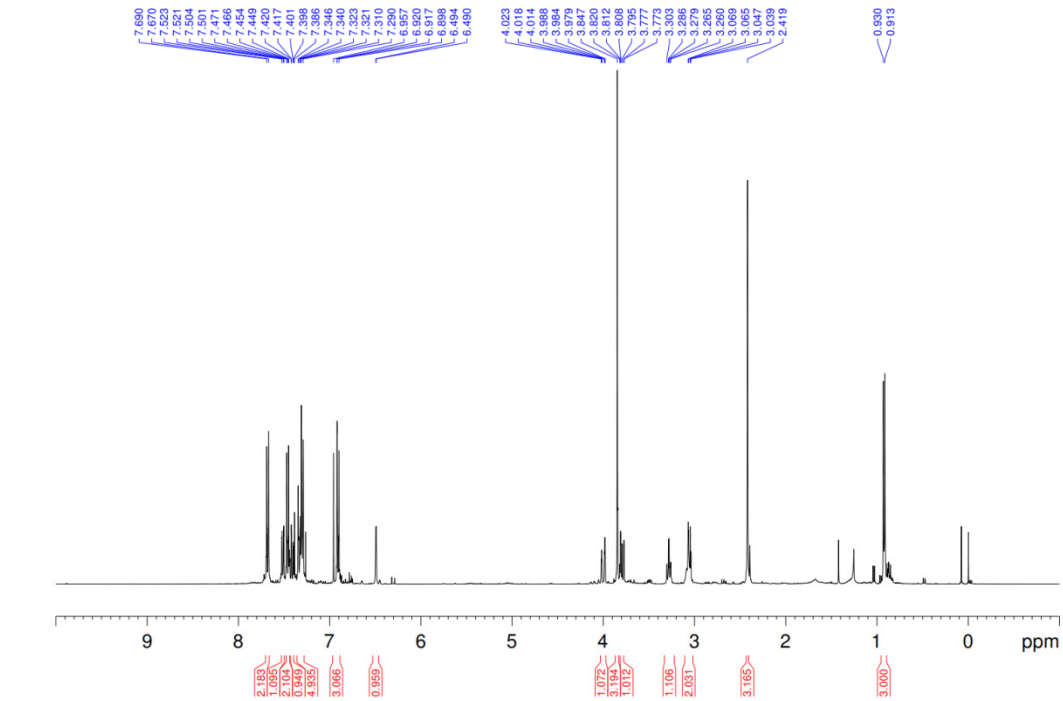
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7.417
7.401
7.398
7.386
7.346
7.340
7.323
7.321
7.310
7.269
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6.917
6.898
6.494
6.490
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3.279
3.265
3.260
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8
7
6
5
4
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1
0
ppm
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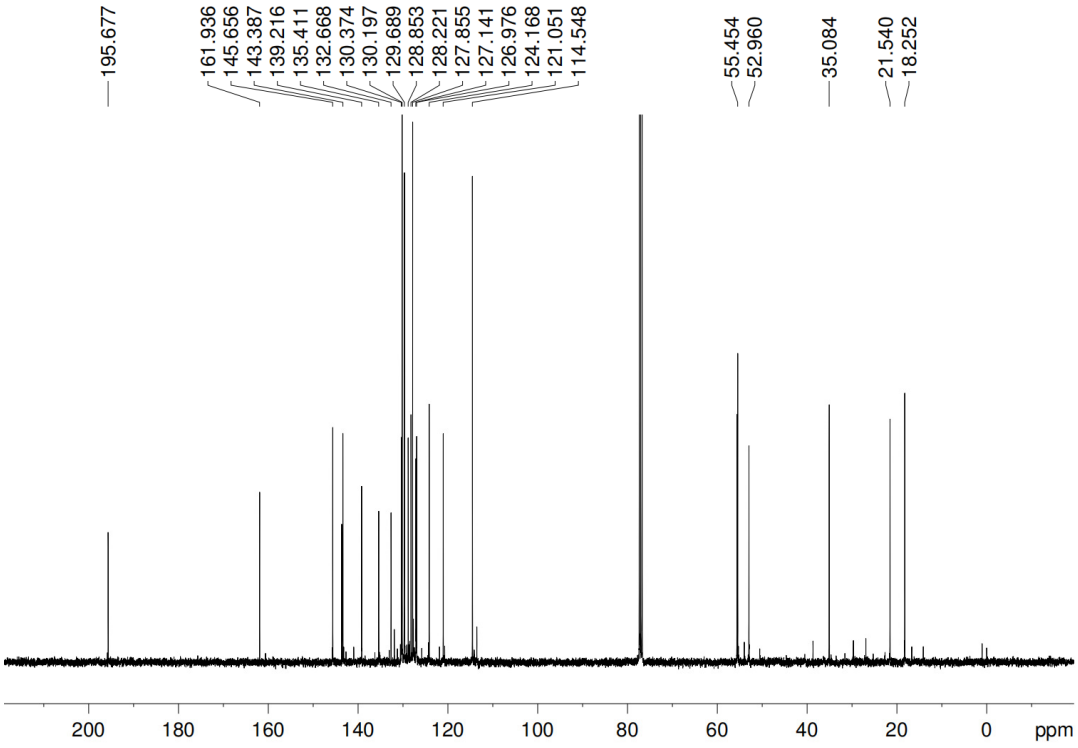
3.000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127.141
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114.548
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20
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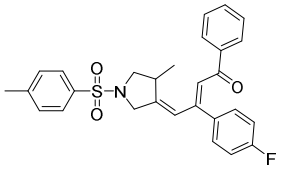
ppm

3ad


O
O
S
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N
O
F


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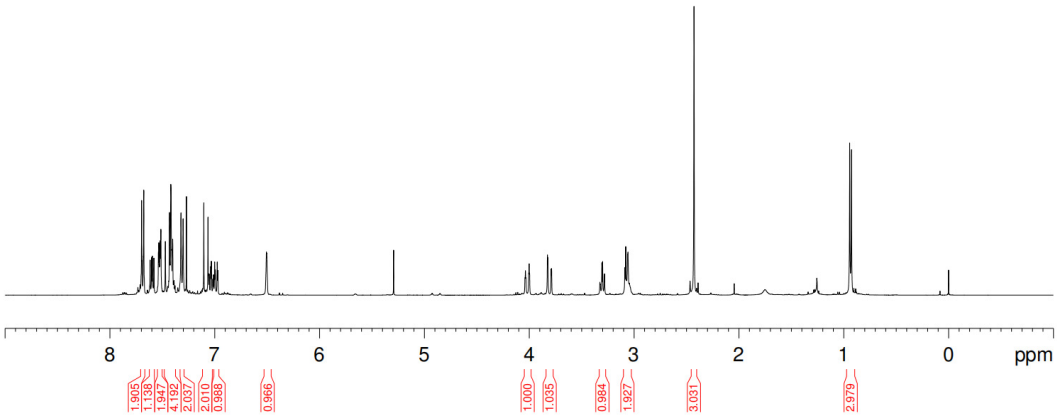
0.926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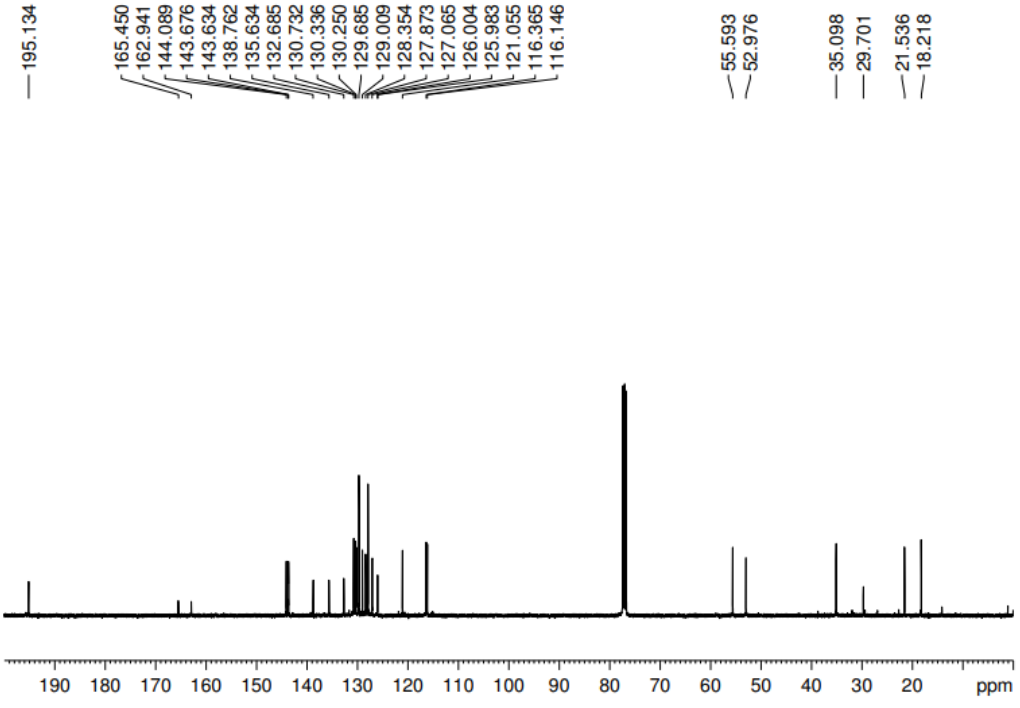
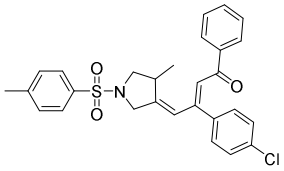
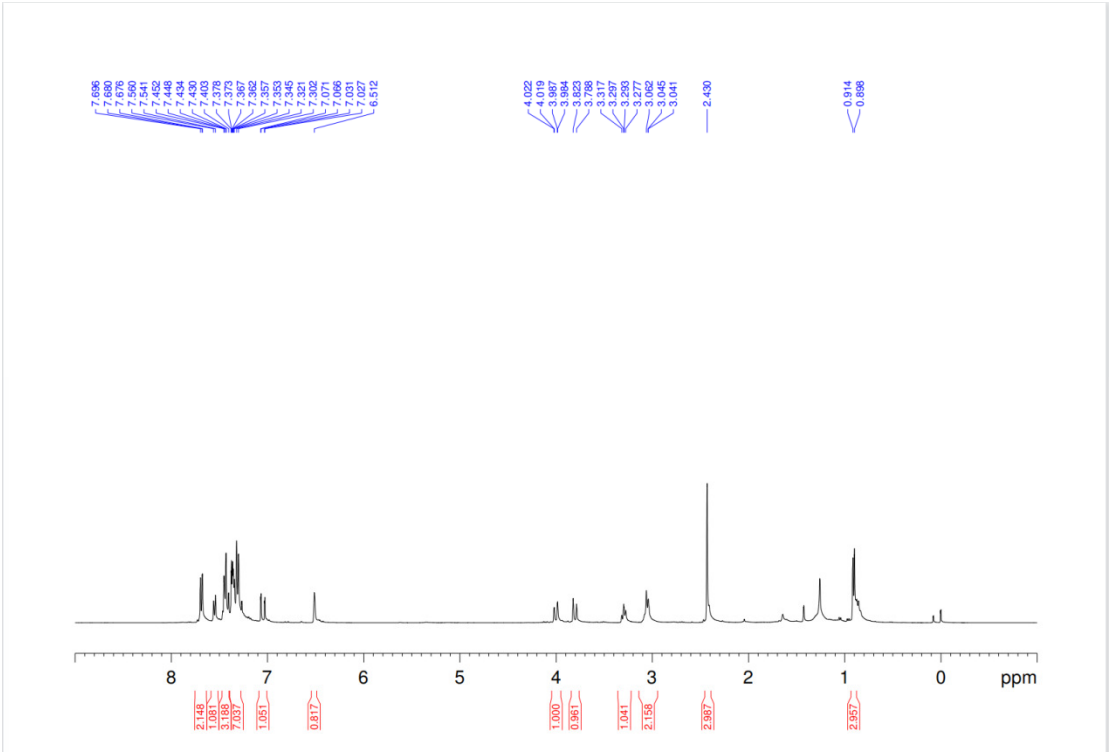
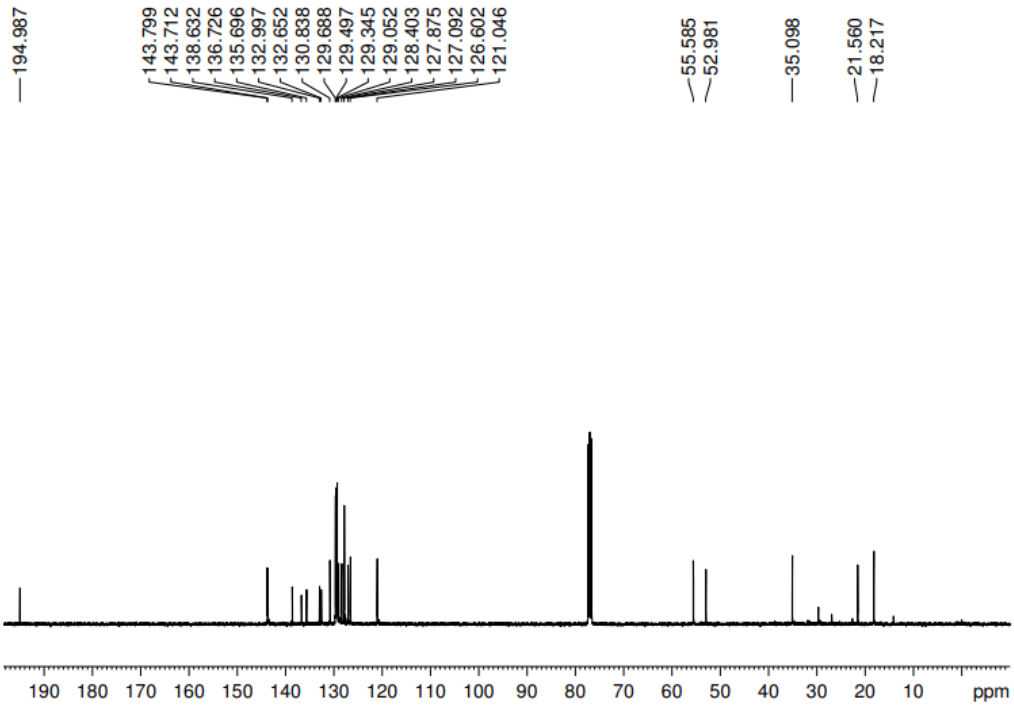
1.927
3.031
2.979


195.134
165.450
162.941
144.089
143.676
143.634
138.762
135.634
132.685
130.732
130.336
130.250
129.685
129.009
128.354
127.873
127.065
126.004
125.983
121.055
116.365
116.146
55.593
52.976
35.098
29.701
21.536
18.218
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

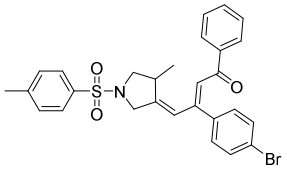
3ae

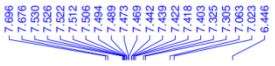

O
O
S
N
O
Cl

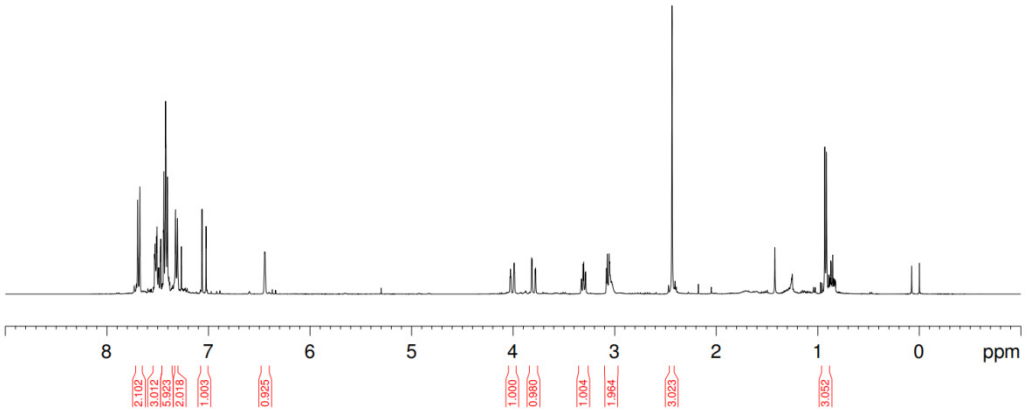

7.696
7.680
7.676
7.560
7.541
7.452
7.444
7.434
7.430
7.403
7.378
7.373
7.367
7.362
7.357
7.353
7.345
7.321
7.302
7.071
7.066
7.031
7.027
6.512
4.022
4.019
3.987
3.994
3.823
3.798
3.317
3.297
3.293
3.277
3.062
3.045
3.041
2.430
0.914
0.898
8
7
6
5
4
3
2
1
0
ppm
2.148
1.081
1.189
7.037
1.051
0.817
1.000
0.961
1.041
2.158
2.987
2.957

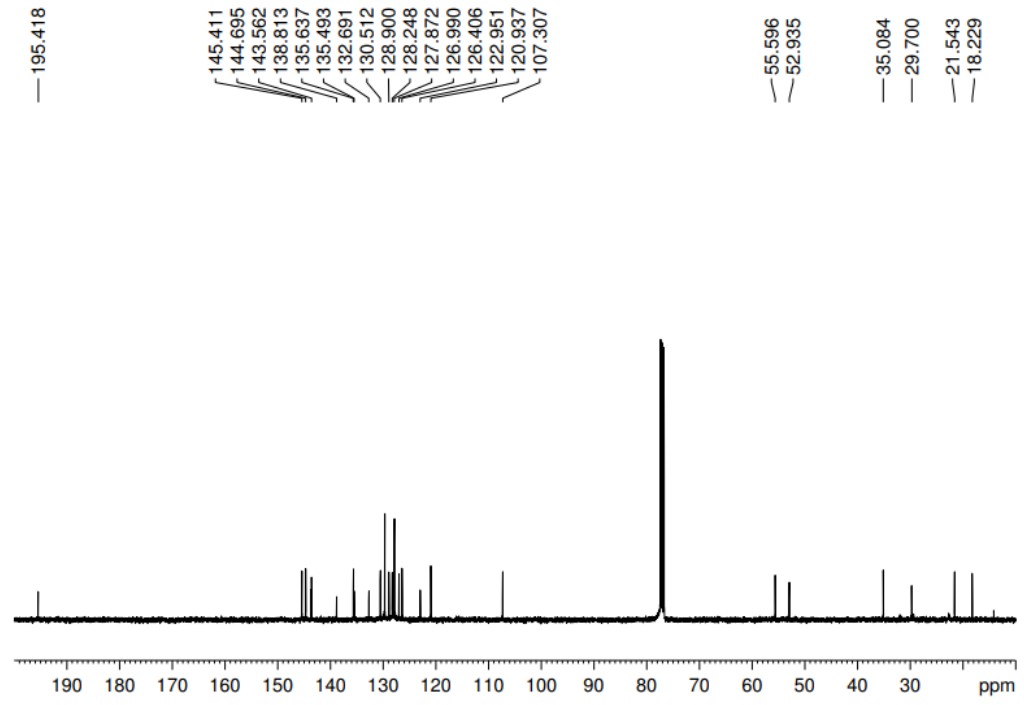

194.987
143.799
143.712
138.632
136.726
135.696
132.997
132.652
130.838
129.688
129.497
129.345
129.052
128.403
127.875
127.092
126.602
121.046
55.585
52.981
35.098
21.560
18.217
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

3af

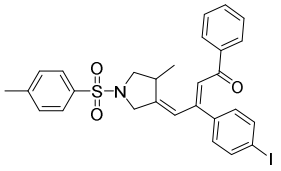

O
S
O
N
O
Br

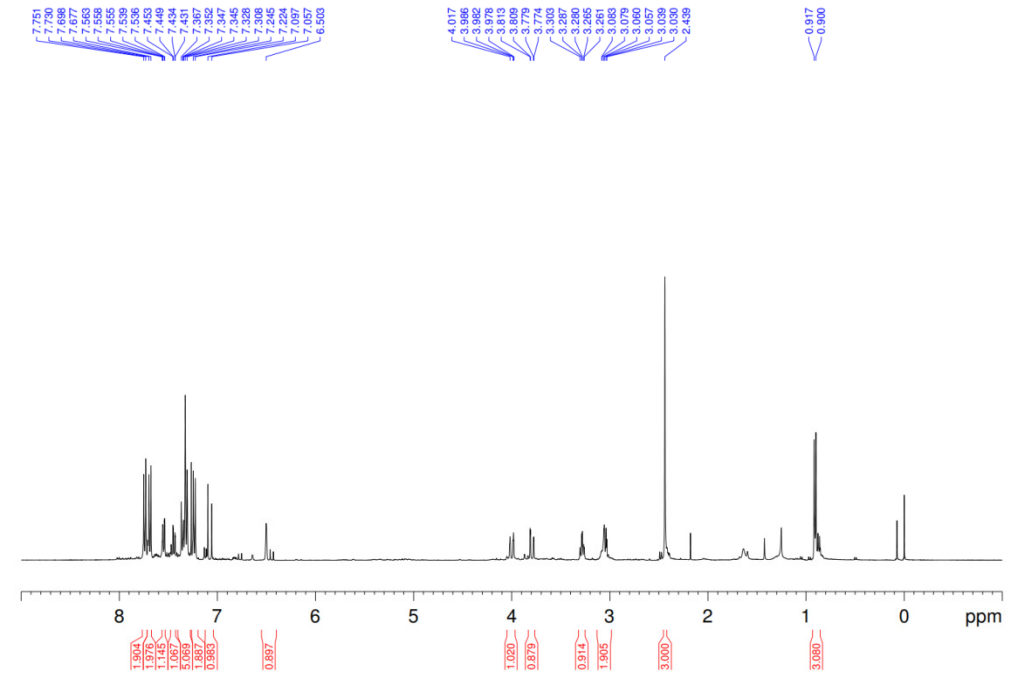

7.696
7.676
7.530
7.526
7.522
7.512
7.506
7.494
7.489
7.473
7.469
7.442
7.439
7.422
7.418
7.403
7.325
7.305
7.063
7.023
6.446
4.030
4.026
4.021
3.994
3.990
3.985
3.817
3.813
3.782
3.777
3.327
3.311
3.304
3.287
3.081
3.072
3.064
3.049
3.043
3.031
2.435
0.931
0.914

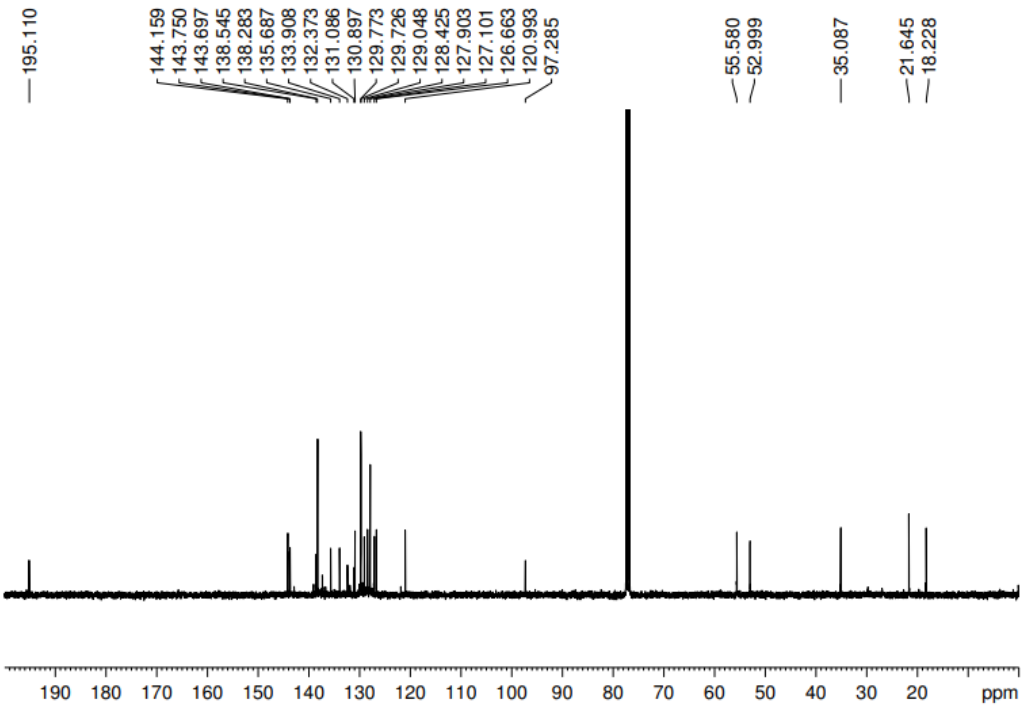

8
7
6
5
4
3
2
1
0
ppm
2.102
3.012
3.023
2.019
1.003
0.925
1.000
0.980
1.004
1.964
3.023
3.052


195.418
145.411
144.695
143.562
138.813
135.637
135.493
132.691
130.512
128.900
128.248
127.872
126.990
126.406
122.951
120.937
107.307
55.596
52.935
35.084
29.700
21.543
18.229
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
ppm

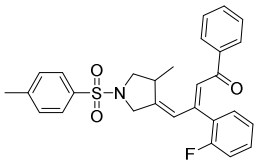
3ag



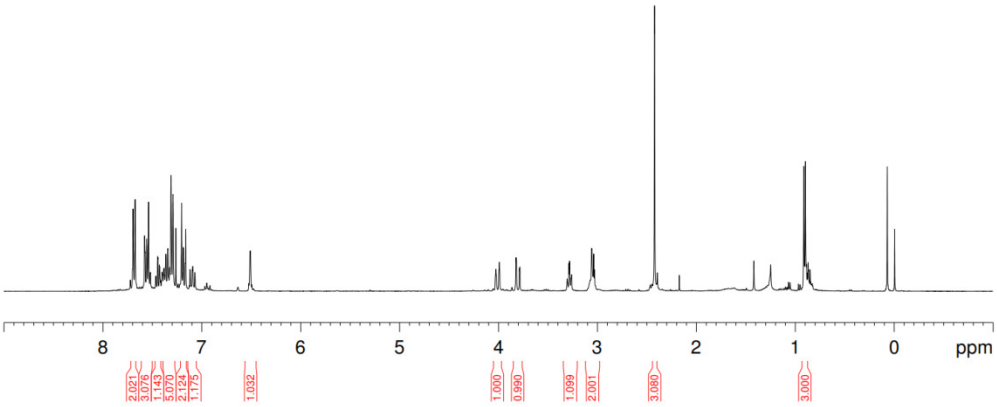


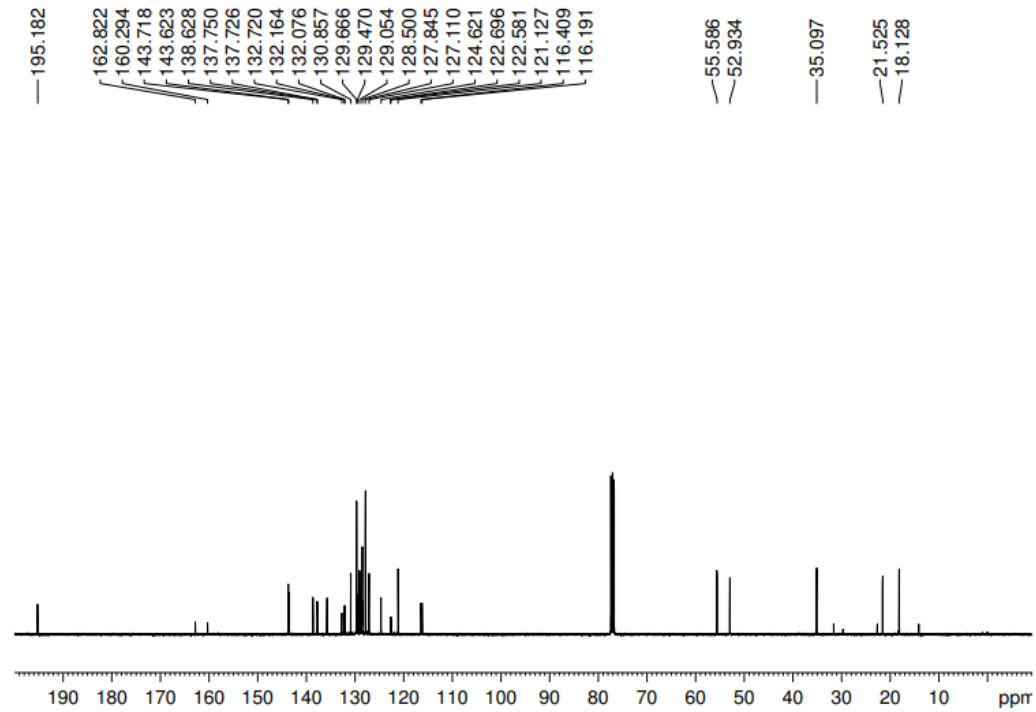


3ah

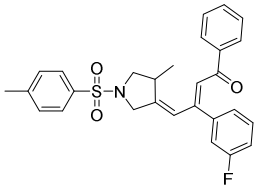

O
S
O
N
O
F


7.674
7.579
7.573
7.557
7.539
7.466
7.463
7.447
7.444
7.428
7.425
7.421
7.382
7.364
7.343
7.325
7.291
7.204
7.188
7.167
7.163
7.119
7.096
7.092
7.071
7.069
6.509
4.028
3.993
3.824
3.820
3.789
3.785
3.306
3.288
3.282
3.257
3.252
3.058
3.038
3.029
2.423
0.914
0.897

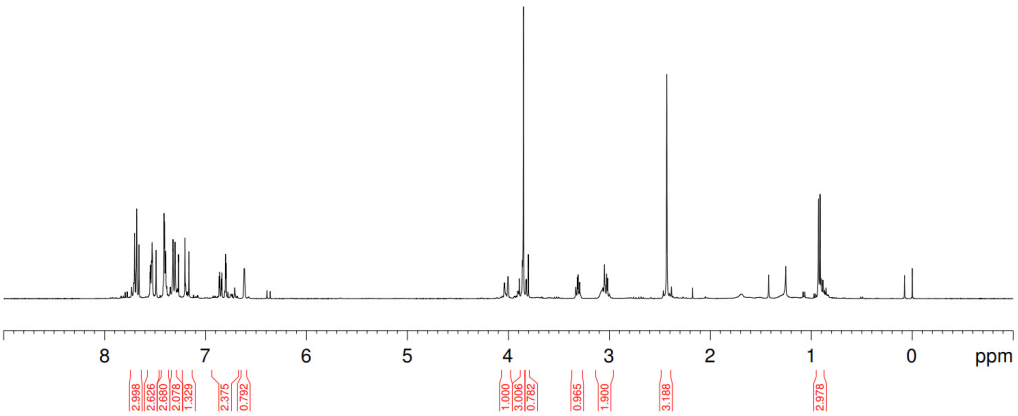

8
7
6
5
4
3
2
1
0
ppm
2.021
3.076
1.143
5.070
2.124
1.175
1.032
1.000
0.990
1.099
2.001
3.080
3.000

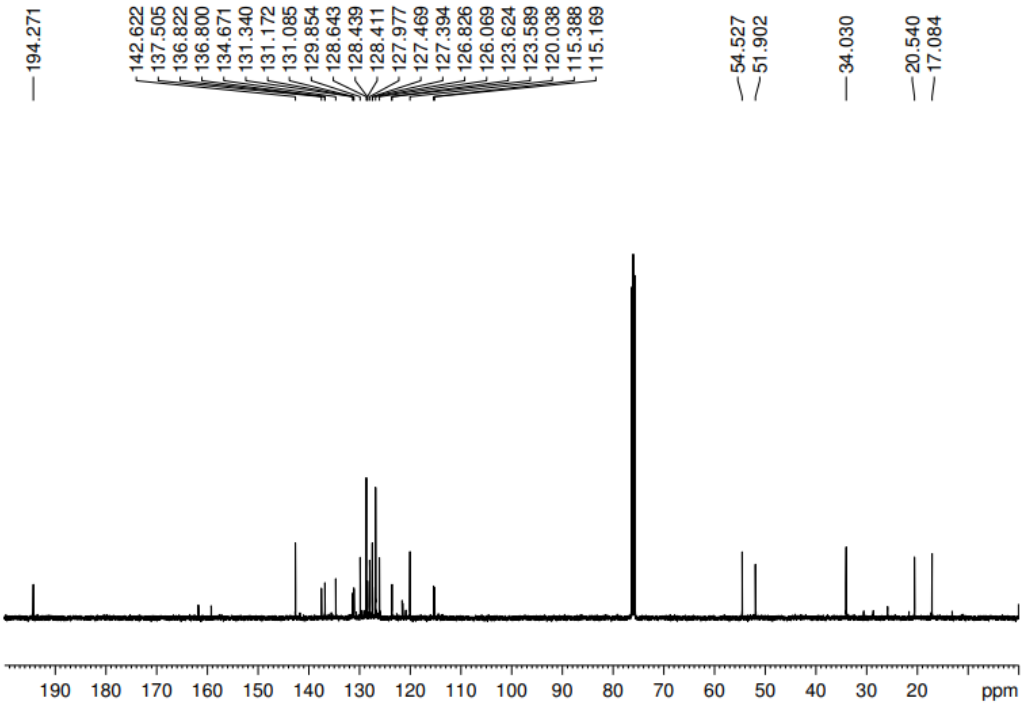

195.182
162.822
160.294
143.718
143.623
138.628
137.750
137.726
132.720
132.164
132.076
130.857
129.666
129.470
129.054
128.500
127.845
127.110
124.621
122.696
122.581
121.127
116.409
116.191
55.586
52.934
35.097
21.525
18.128
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

3ai

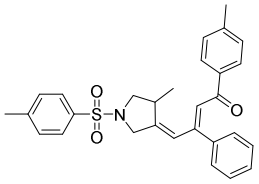

O
S
N
O
O
F

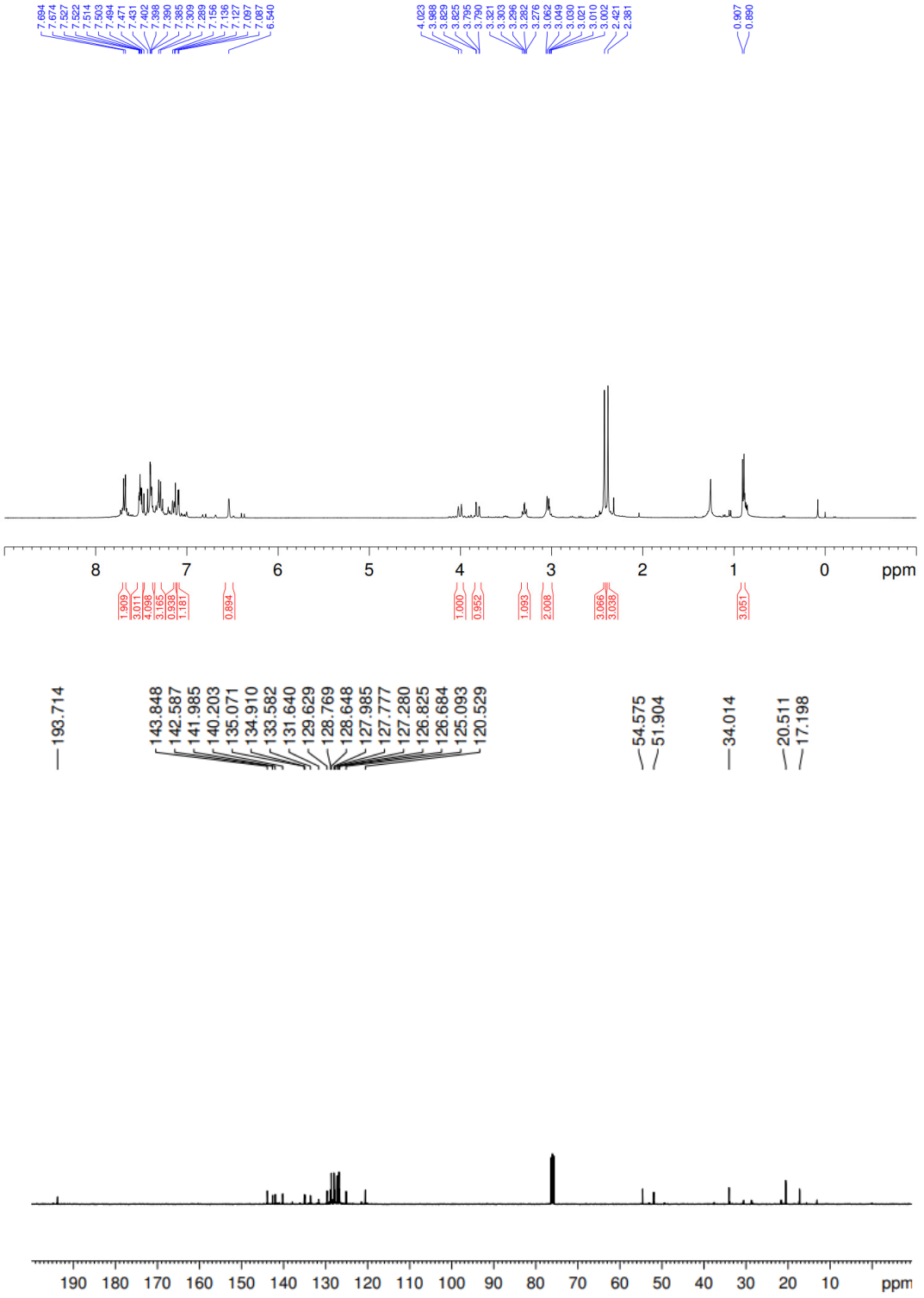

7.703
7.682
7.668
7.549
7.544
7.534
7.529
7.489
7.410
7.405
7.397
7.393
7.321
7.301
7.203
7.164
6.865
6.859
6.844
6.837
6.801
6.795
6.617
6.613
4.043
4.038
4.035
4.029
4.008
4.003
3.851
3.825
3.821
3.802
3.332
3.316
3.309
3.301
3.293
3.282
3.075
3.072
3.063
3.048
3.040
3.026
3.017
2.430
0.929
0.913


8
7
6
5
4
3
2
1
0
ppm
2.998
2.626
2.680
2.078
1.000
1.349
2.375
0.792
1.000
3.006
0.782
0.965
1.900
3.188
2.978

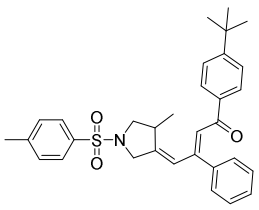

194.271
142.622
137.505
136.822
136.800
134.671
131.340
131.172
131.085
129.854
128.643
128.439
128.411
127.977
127.469
127.394
126.826
126.069
123.624
123.589
120.038
115.388
115.169
54.527
51.902
34.030
20.540
17.084
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

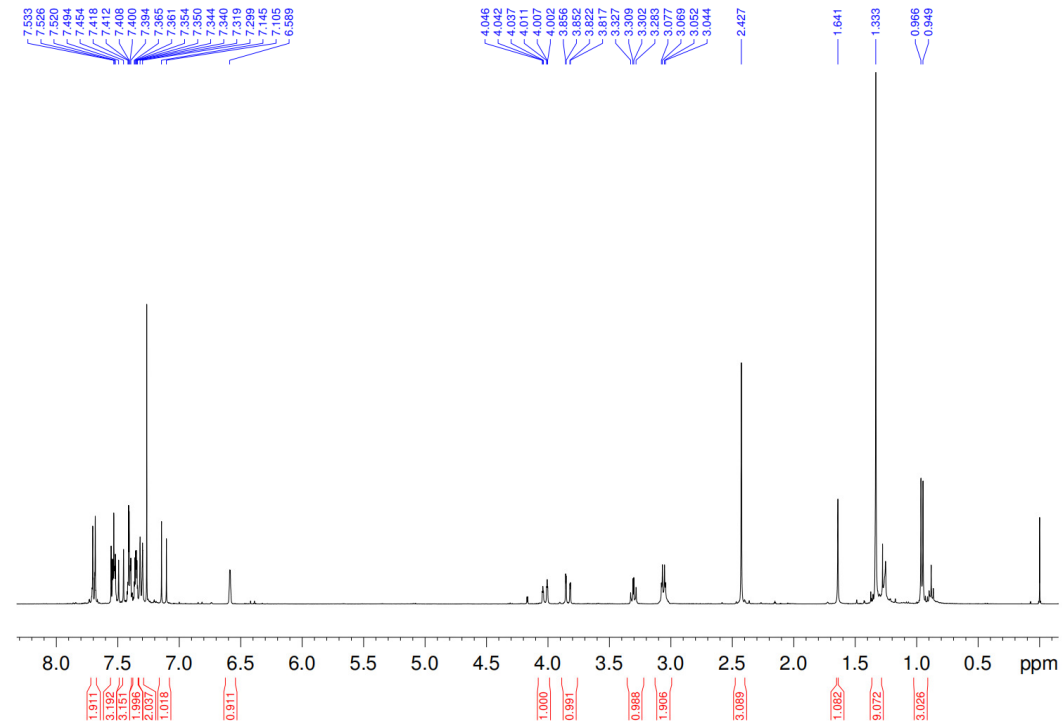
3aj


O
S
O
N
O


7.694
7.674
7.527
7.522
7.514
7.503
7.494
7.471
7.431
7.402
7.398
7.390
7.385
7.309
7.289
7.156
7.136
7.127
7.097
7.087
6.540
4.023
3.988
3.829
3.825
3.795
3.790
3.321
3.303
3.296
3.282
3.276
3.062
3.049
3.030
3.021
3.010
3.002
2.421
2.381
0.907
0.890
8
7
6
5
4
3
2
1
0
ppm
1.909
3.011
4.098
3.165
0.938
1.181
0.894
1.000
0.952
1.093
2.008
3.066
3.038
3.051
193.714
143.848
142.587
141.985
140.203
135.071
134.910
133.582
131.640
129.629
128.769
128.648
127.985
127.777
127.280
126.825
126.684
125.093
120.529
54.575
51.904
34.014
20.511
17.198
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

3ak

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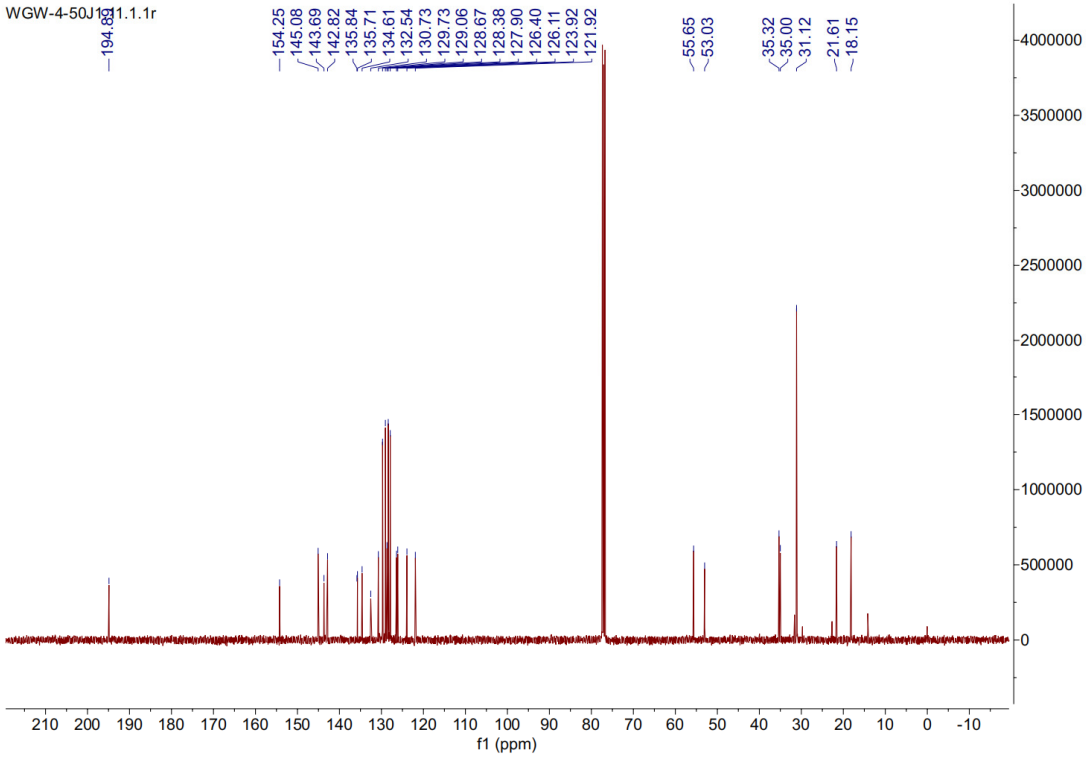
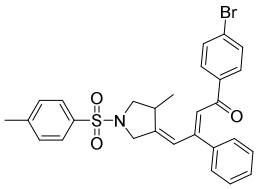
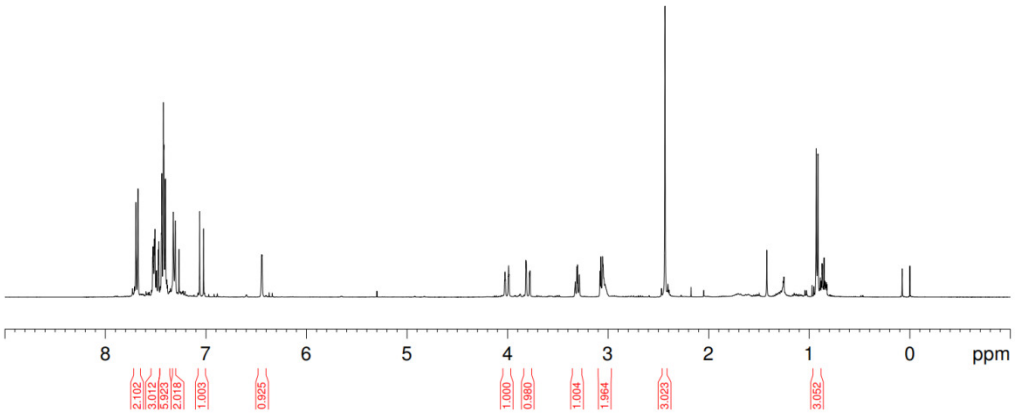
7.526
7.520
7.494
7.454
7.418
7.412
7.408
7.400
7.394
7.365
7.361
7.354
7.350
7.344
7.340
7.319
7.299
7.145
7.105
6.589
4.046
4.042
4.037
4.011
4.007
4.002
3.856
3.852
3.822
3.817
3.327
3.309
3.302
3.283
3.077
3.069
3.052
3.044
2.427
1.641
1.333
0.966
0.949
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.911
3.192
3.151
1.996
2.037
1.018
0.911
1.000
0.991
0.988
1.906
3.089
1.082
9.072
3.026

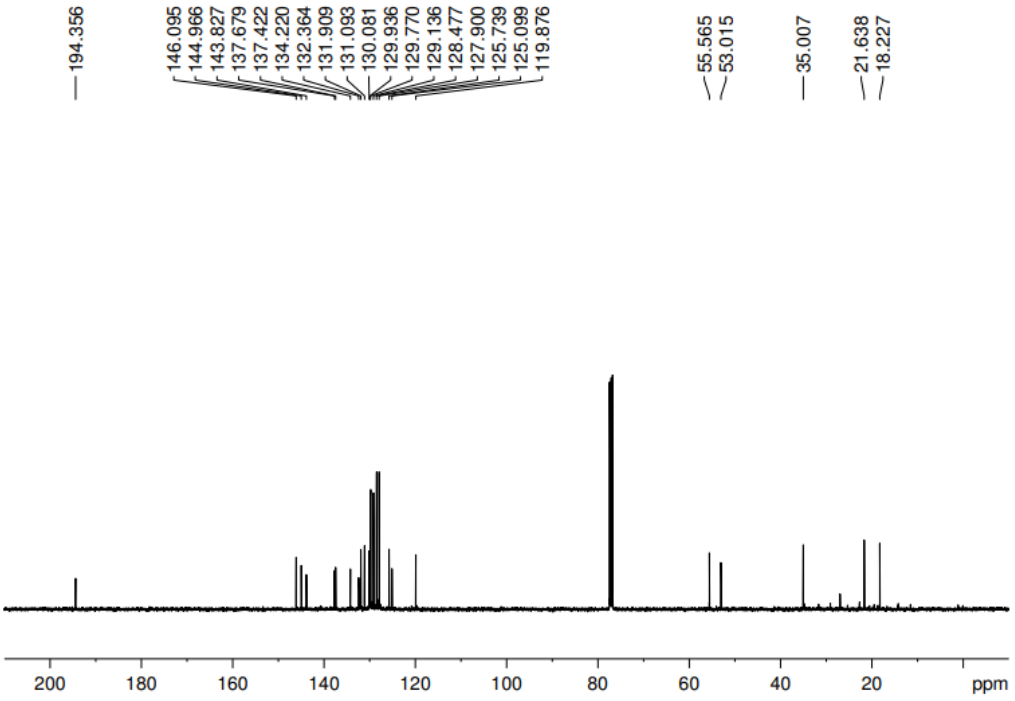

WGW-4-50J1
194.83
154.25
145.08
143.69
142.82
135.84
135.71
134.61
132.54
130.73
129.73
129.06
128.67
128.38
127.90
126.40
126.11
123.92
121.92
55.65
53.03
35.32
35.00
31.12
21.61
18.15
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

3al

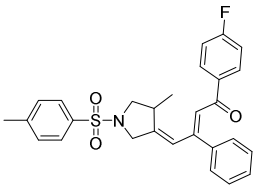

Br
O
S
O
N
O


7.696
7.676
7.530
7.526
7.522
7.512
7.506
7.494
7.489
7.473
7.469
7.442
7.439
7.422
7.418
7.403
7.325
7.305
7.063
7.023
6.446
4.030
4.026
4.021
3.994
3.990
3.986
3.817
3.813
3.782
3.777
3.327
3.311
3.304
3.287
3.281
3.072
3.054
3.049
3.043
3.031
2.435
0.931
0.914


8
7
6
5
4
3
2
1
0
ppm
2.102
3.012
5.923
2.018
1.003
0.925
1.000
0.980
1.004
1.964
3.023
3.052


194.356
146.095
144.966
143.827
137.679
137.422
134.220
132.364
131.909
131.093
130.081
129.936
129.770
129.136
128.477
127.900
125.739
125.099
119.876
55.565
53.015
35.007
21.638
18.227
200
180
160
140
120
100
80
60
40
20
ppm

3am


F
O
S
N
O
O
O


7.601
7.594
7.580
7.537
7.533
7.527
7.524
7.519
7.513
7.471
7.431
7.426
7.419
7.416
7.410
7.401
7.322
7.301
7.104
7.064
7.038
7.032
7.018
7.011
7.009
6.994
6.976
6.970
6.507
4.040
4.036
4.032
4.005
4.001
3.996
3.826
3.822
3.791
3.786
3.326
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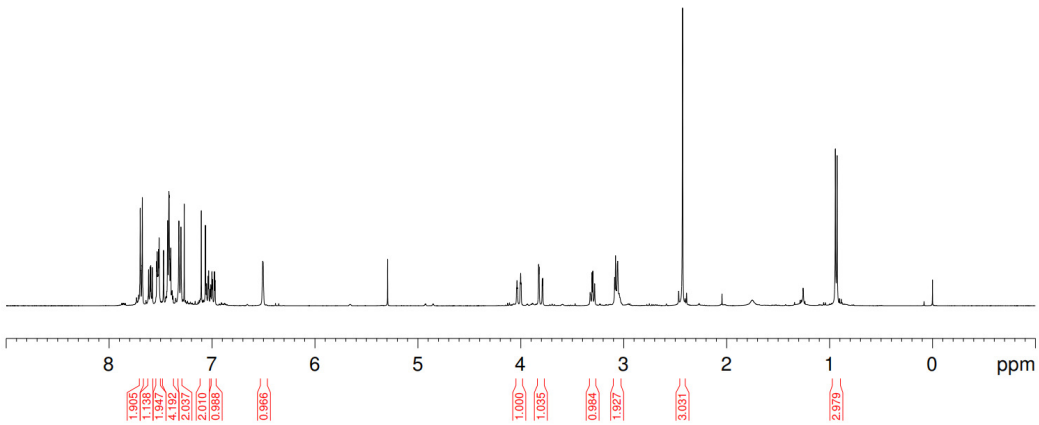
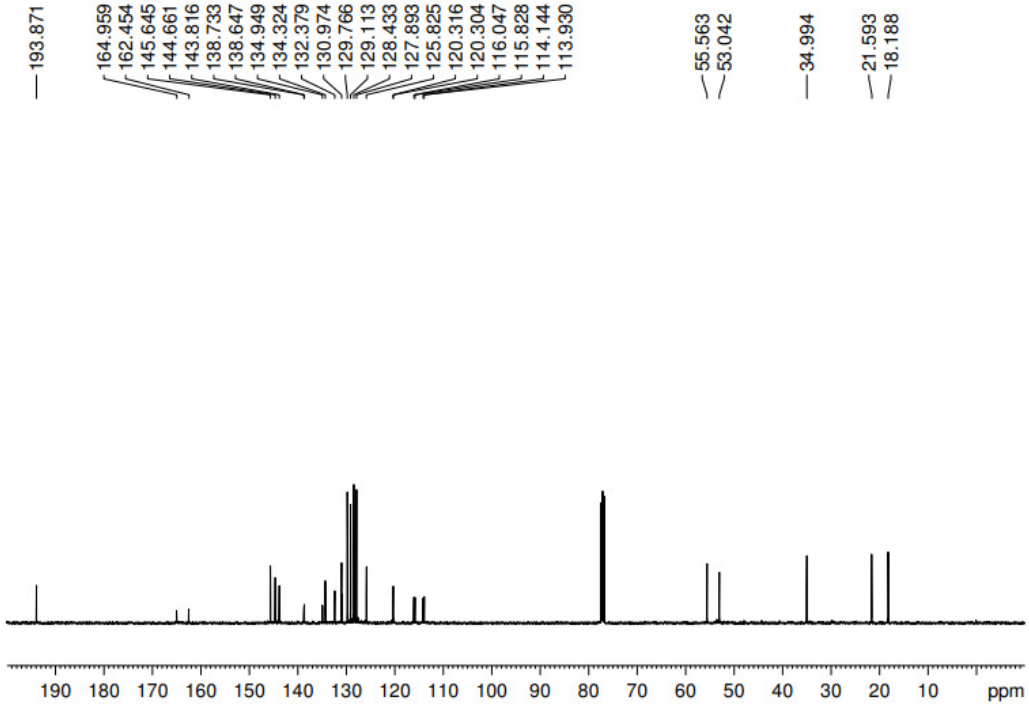
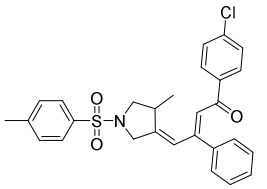
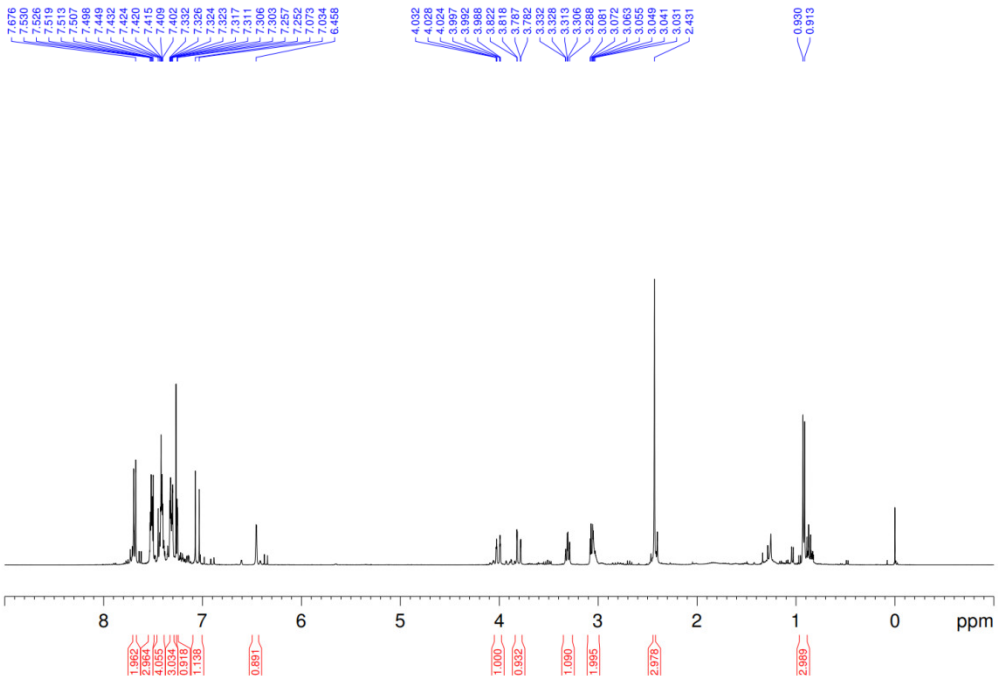
3.282
3.088
3.079
3.071
3.061
3.058
2.428
0.943
0.926


8
7
6
5
4
3
2
1
0
ppm
1.905
1.138
1.047
1.047
4.139
2.037
2.010
0.988
0.966
1.000
1.035
0.984
1.927
3.031
2.979


193.871
164.959
162.454
145.645
144.661
143.816
138.733
138.647
134.949
134.324
132.379
130.974
129.766
129.113
128.433
127.893
125.825
120.316
120.304
116.047
115.828
114.144
113.930
55.563
53.042
34.994
21.593
18.188
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

3an


Cl
O
S
N
O
O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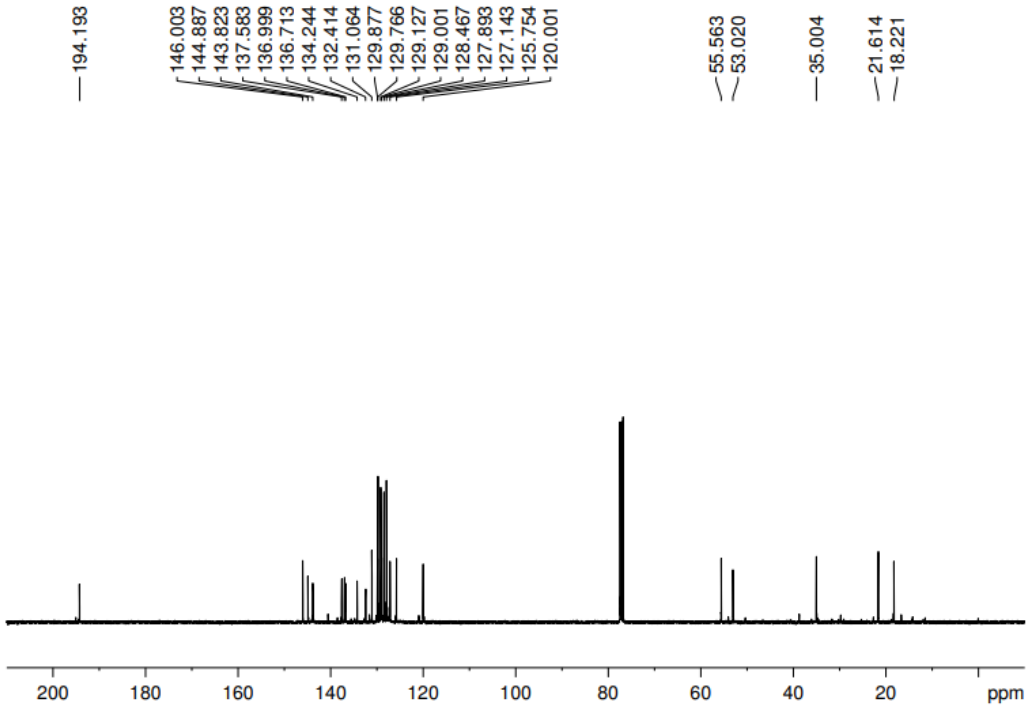
7.530
7.526
7.519
7.513
7.507
7.498
7.449
7.432
7.424
7.420
7.415
7.409
7.402
7.332
7.326
7.324
7.323
7.317
7.311
7.306
7.300
7.257
7.252
7.073
7.034
6.458
4.032
4.028
4.024
3.997
3.992
3.988
3.822
3.818
3.787
3.782
3.332
3.328
3.313
3.306
3.288
3.081
3.072
3.063
3.055
3.049
3.041
3.031
2.431
0.930
0.913
8 7 6 5 4 3 2 1 0 ppm
1.962
2.964
4.065
3.034
0.918
1.138
0.891
1.000
0.932
1.090
1.995
2.978
2.969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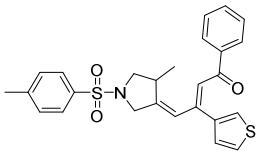
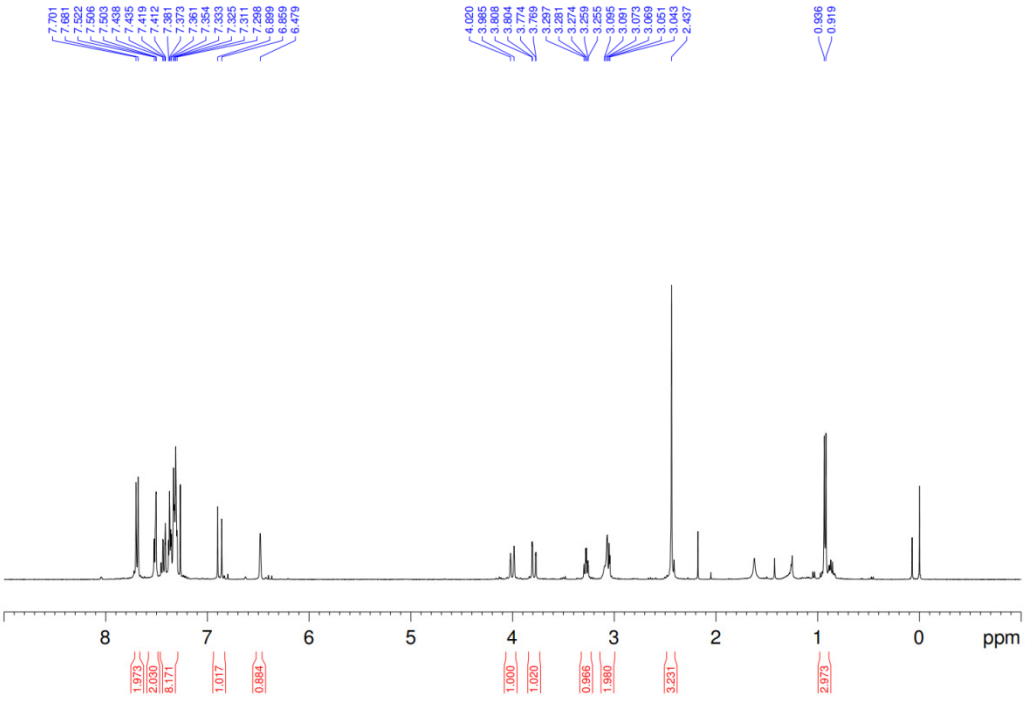
146.003
144.887
143.823
137.583
136.999
136.713
134.244
132.414
131.064
129.877
129.766
129.127
129.001
128.467
127.893
127.143
125.754
120.001
55.563
53.020
35.004
21.614
18.221
200
180
160
140
120
100
80
60
40
20
ppm

3ao

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7.681
7.522
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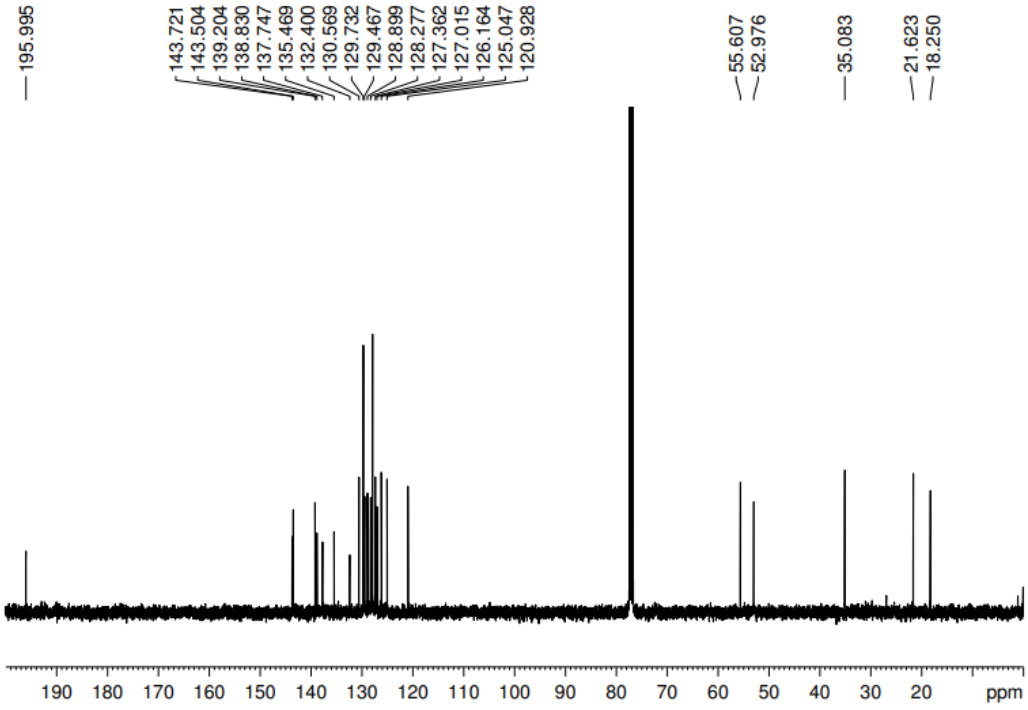
7.503
7.438
7.435
7.419
7.412
7.381
7.373
7.361
7.354
7.333
7.325
7.311
7.298
6.899
6.859
6.479
4.020
3.985
3.808
3.804
3.774
3.769
3.297
3.281
3.274
3.259
3.255
3.095
3.091
3.073
3.069
3.051
3.043
2.437
0.936
0.919
8
7
6
5
4
3
2
1
0
ppm
1.973
2.030
8.171
1.017
0.884
1.000
1.020
0.966
1.980
3.231
2.973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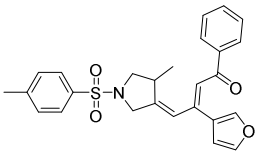
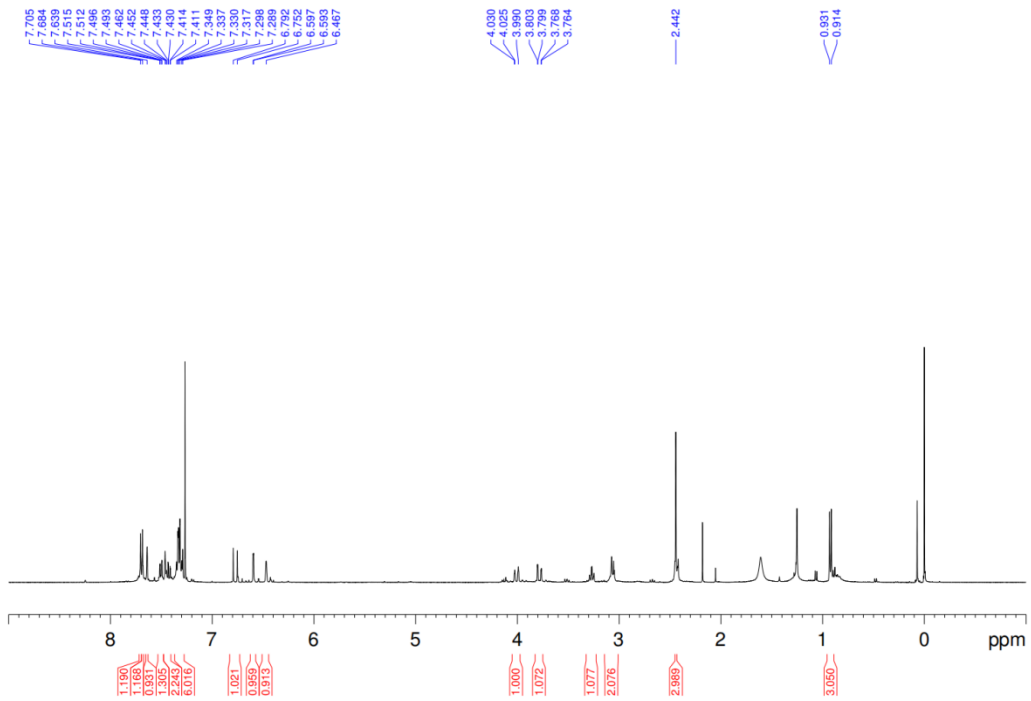
143.721
143.504
139.204
138.830
137.747
135.469
132.400
130.569
129.732
129.467
128.899
128.277
127.362
127.015
126.164
125.047
120.928
55.607
52.976
35.083
21.623
18.250
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

3ap

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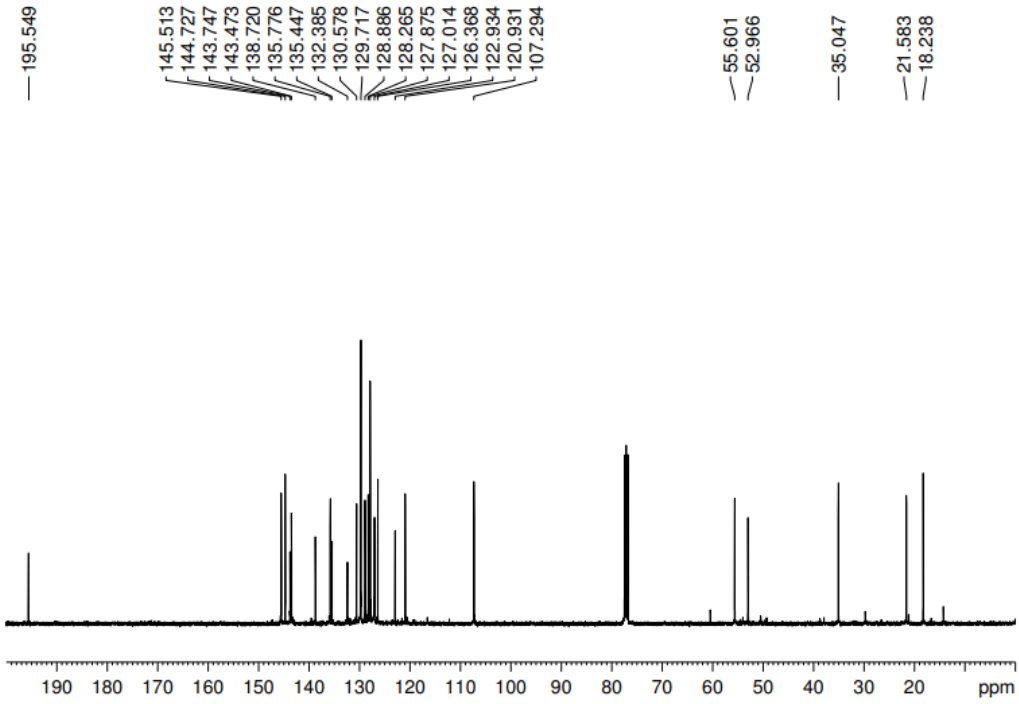
7.684
7.639
7.515
7.512
7.496
7.495
7.462
7.452
7.448
7.433
7.430
7.414
7.411
7.349
7.337
7.330
7.317
7.298
7.289
6.792
6.752
6.597
6.593
6.467
4.030
4.025
3.990
3.803
3.799
3.768
3.764
2.442
0.931
0.914
8 7 6 5 4 3 2 1 0 ppm
1.190
1.168
0.987
1.145
2.245
6.016
1.021
0.959
0.913
1.000
1.072
1.077
2.076
2.989
3.050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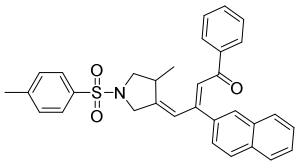
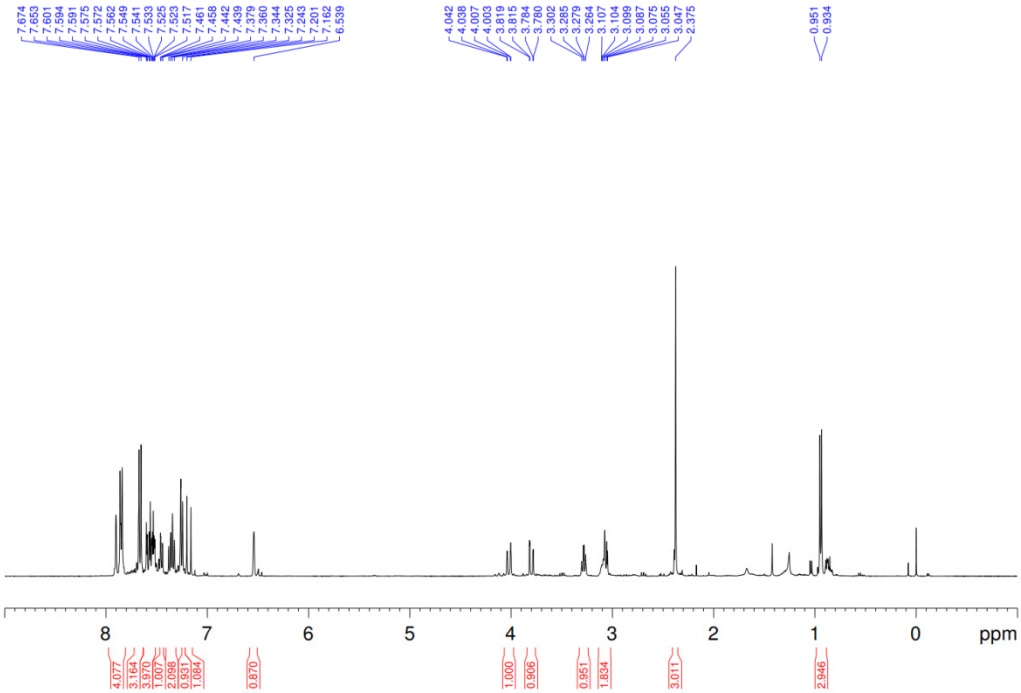
145.513
144.727
143.747
143.473
138.720
135.776
135.447
132.385
130.578
129.717
128.886
128.265
127.875
127.014
126.368
122.934
120.931
107.294
55.601
52.966
35.047
21.583
18.238
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

3aq

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7.653
7.601
7.594
7.591
7.575
7.572
7.562
7.549
7.541
7.533
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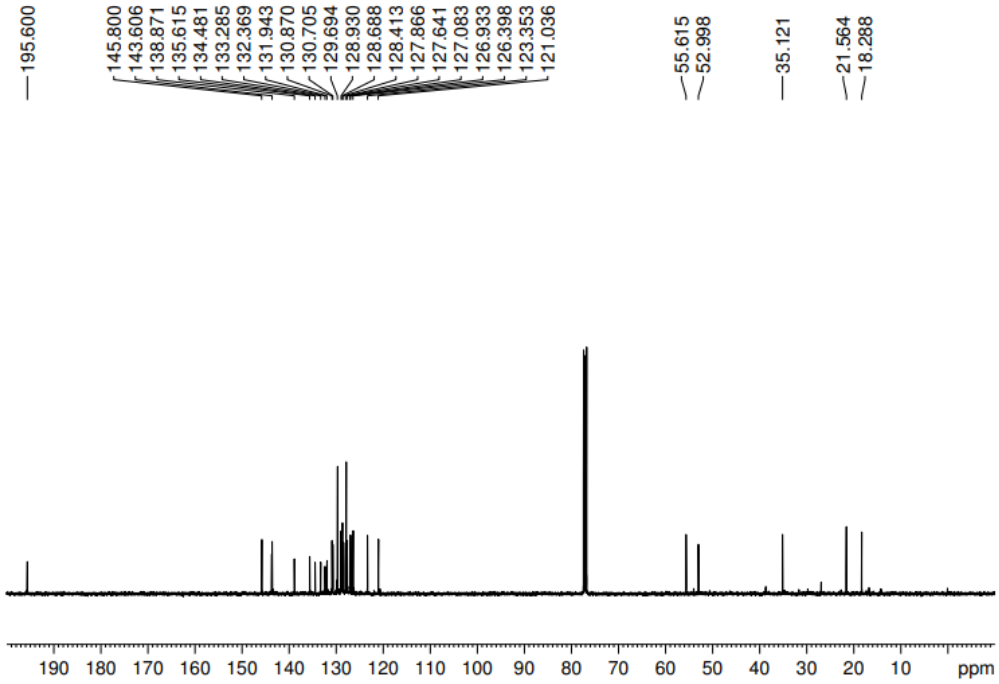
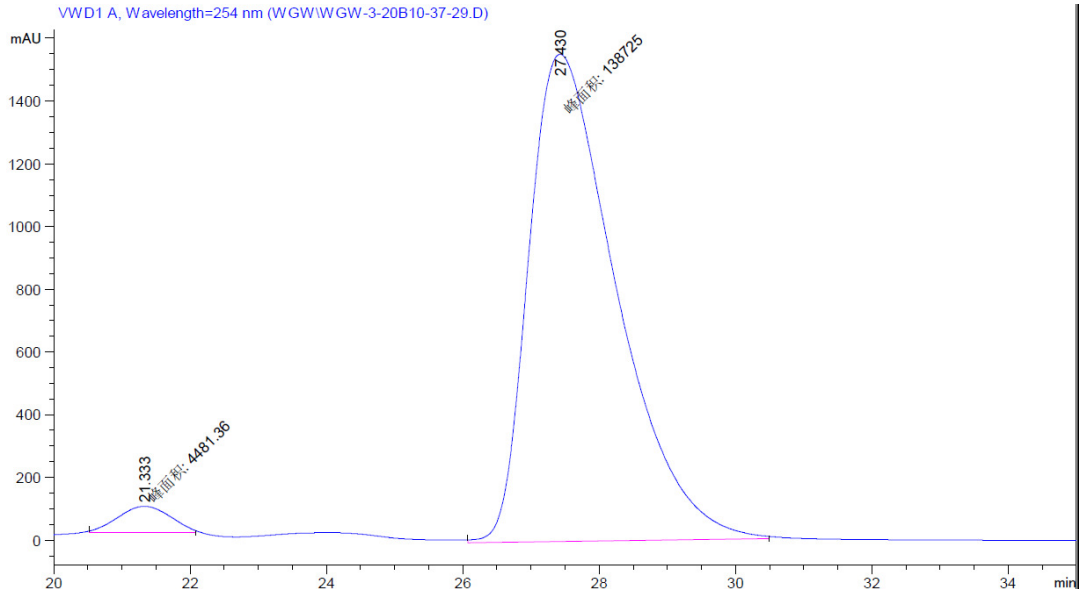
7.523
7.517
7.461
7.458
7.442
7.439
7.379
7.360
7.344
7.335
7.243
7.201
7.162
6.539
4.042
4.038
4.007
4.003
3.819
3.815
3.784
3.780
3.302
3.285
3.279
3.264
3.107
3.104
3.099
3.087
3.075
3.055
3.047
2.375
0.951
0.934
8 7 6 5 4 3 2 1 0 ppm
4.077
3.164
3.970
1.007
2.098
0.931
1.084
0.870
1.000
0.906
0.951
1.834
3.011
2.946

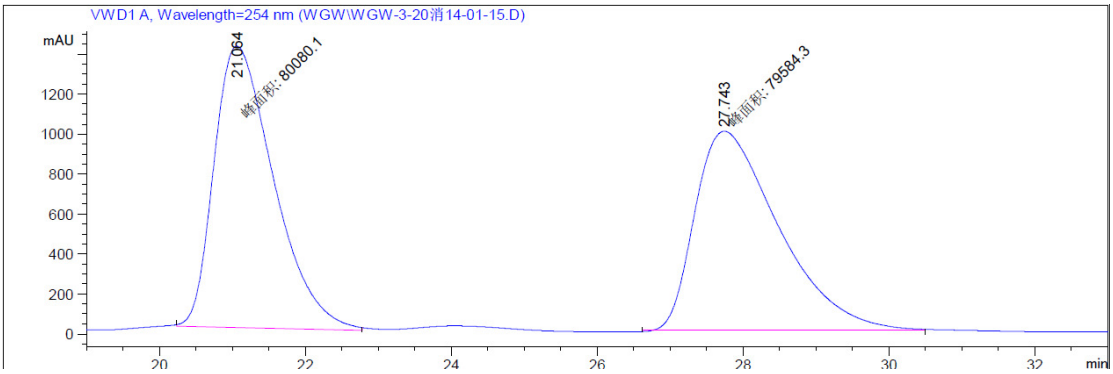


5. HPLC Spectra

3aa

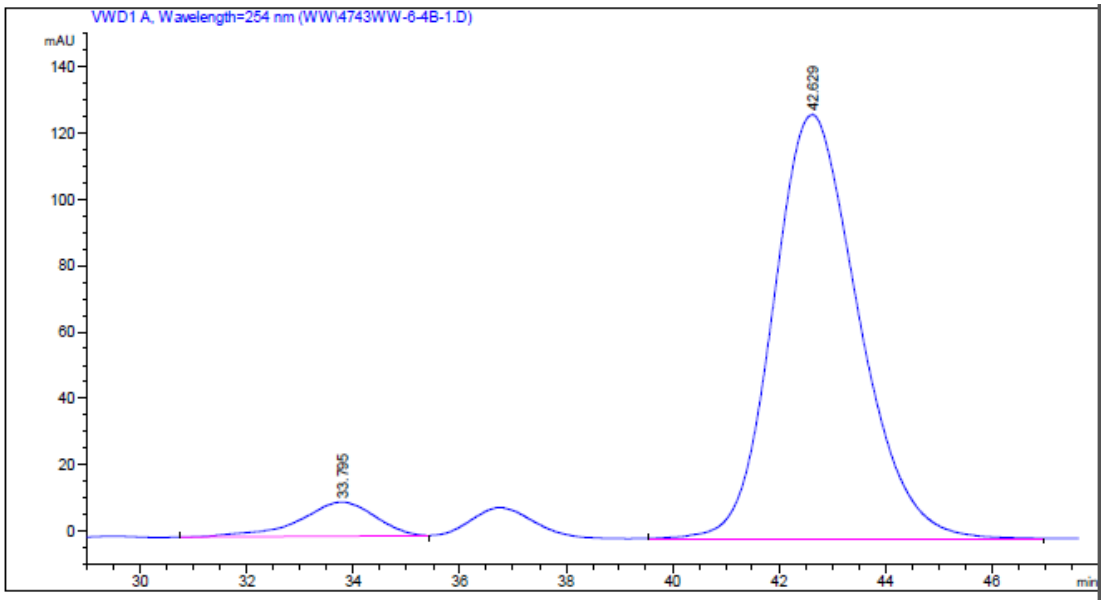


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.333	MM	0.8896	4481.35742	83.95590	3.1293
2	27.430	MM	1.4893	1.38725e5	1552.42236	96.8707

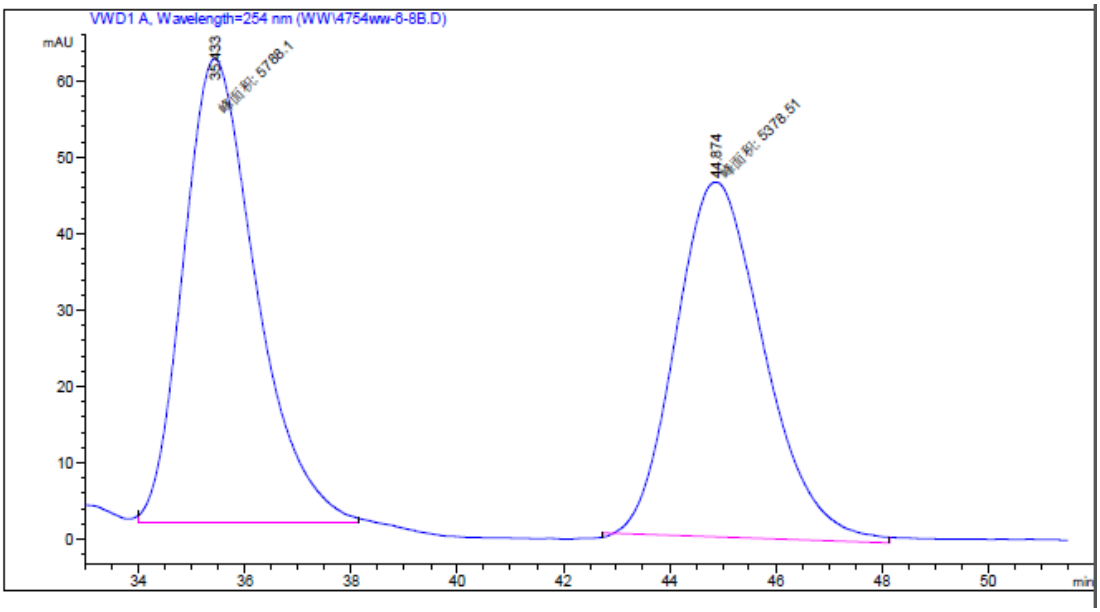


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.064	MM	0.9484	8.00801e4	1407.27478	50.1553
2	27.743	MM	1.3304	7.95843e4	996.96503	49.8447

3ba

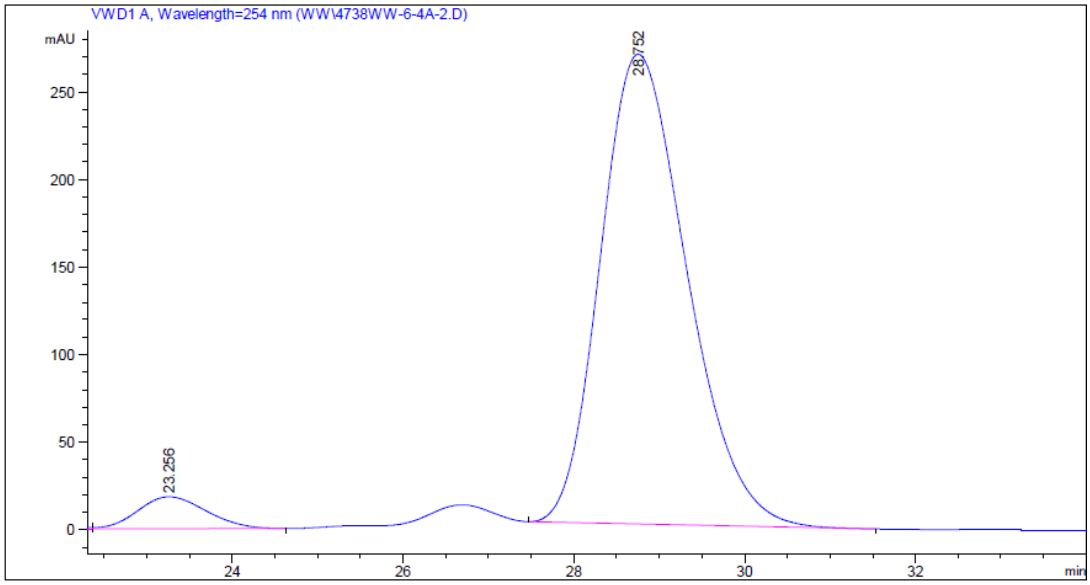


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	33.795	BB	1.2989	1015.85559	10.23532	6.6887
2	42.629	BB	1.7112	1.41717e4	127.65553	93.3113

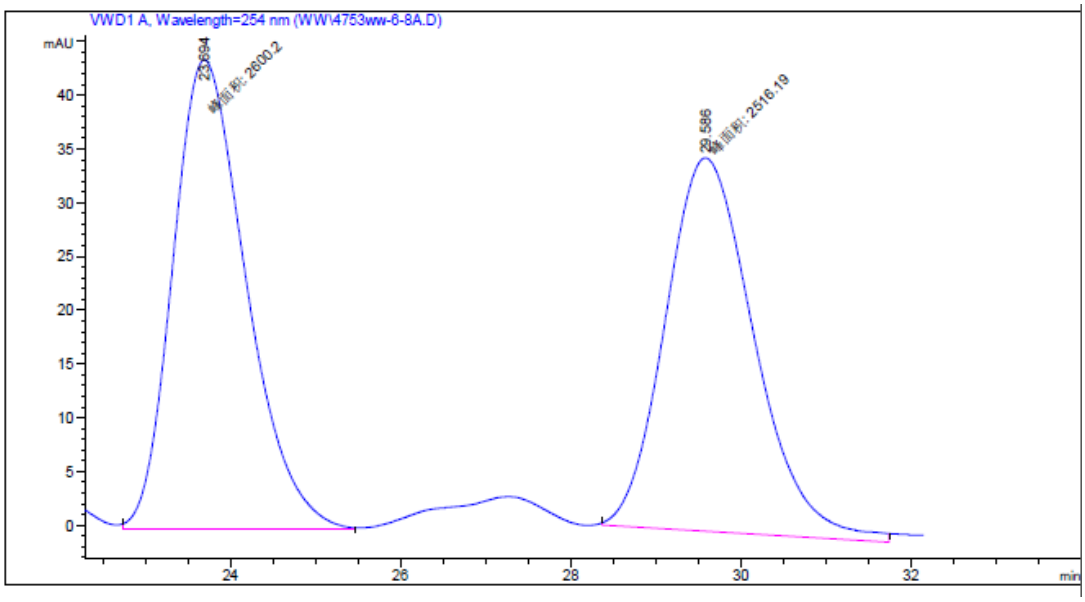


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	35.433	MM	1.5885	5788.10254	60.73086	51.8340
2	44.874	MM	1.9303	5378.51367	46.43922	48.1660

3ca

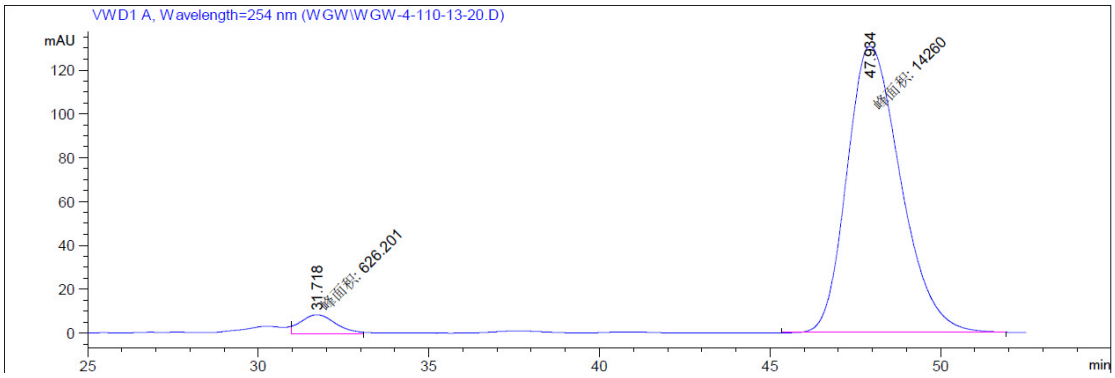


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.256	VB	0.8594	1020.51324	18.27843	5.1248
2	28.752	BB	1.0920	1.88926e4	268.15826	94.8752

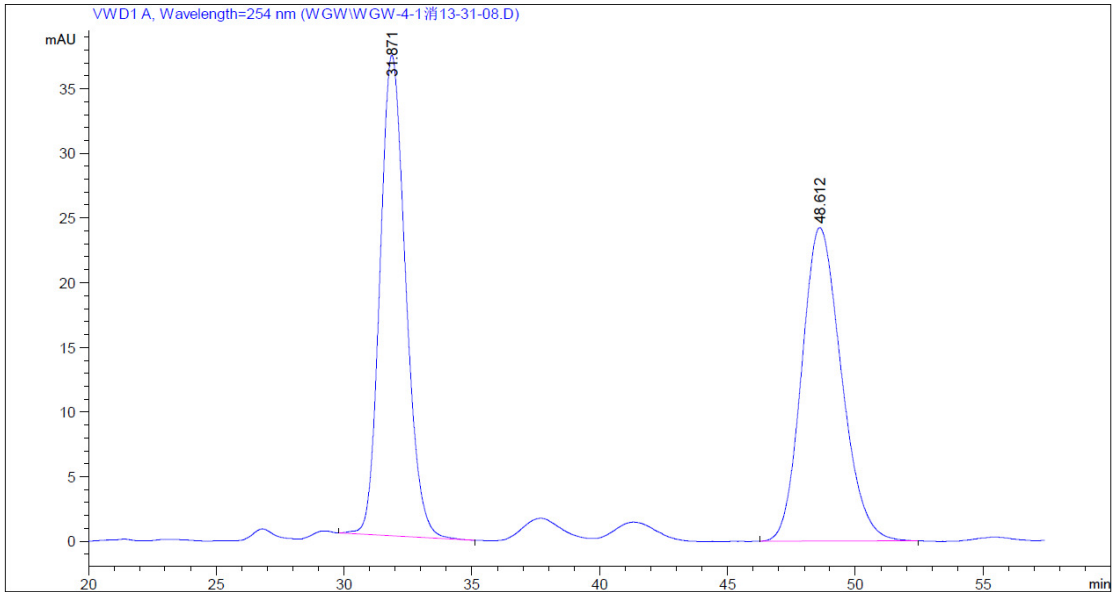


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.694	MM	0.9943	2600.19531	43.58659	50.8209
2	29.586	MM	1.2081	2516.19263	34.71363	49.1791

3da

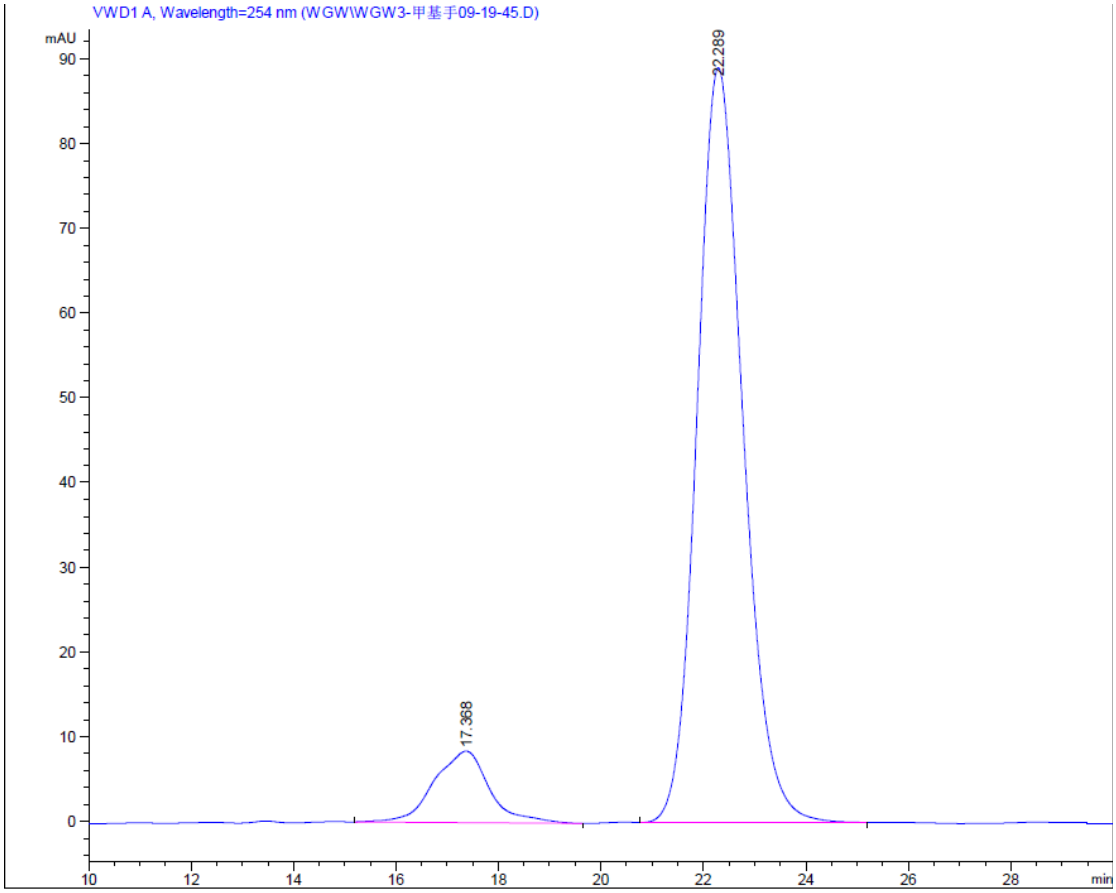


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	31.718	FM	1.1902	626.20099	8.76913	4.2066
2	47.934	MM	1.8211	1.42600e4	130.50803	95.7934

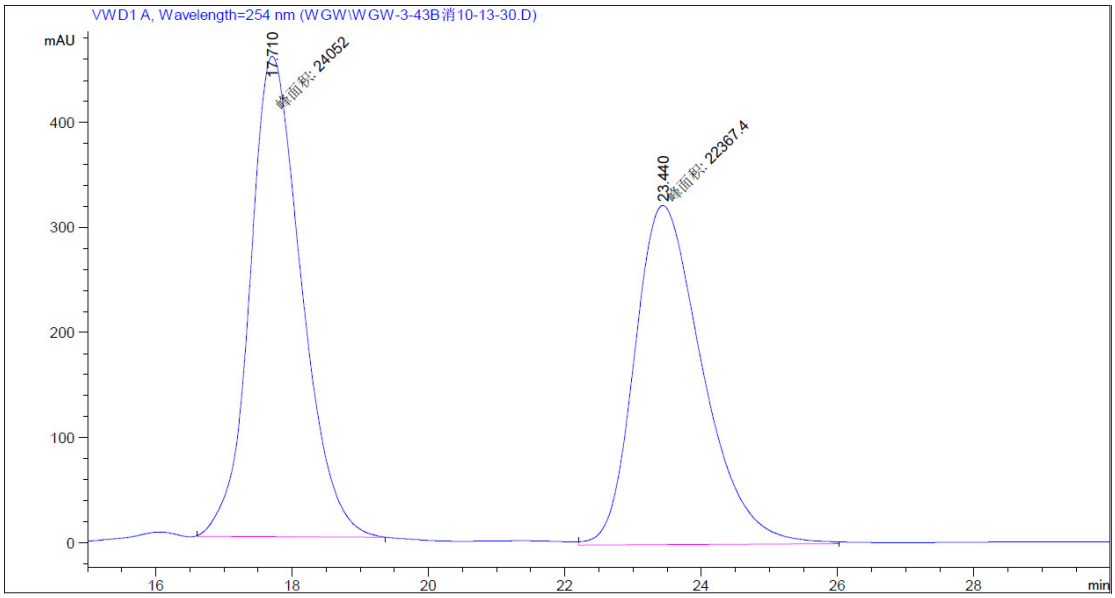


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	31.871	BB	1.0656	2590.71240	37.19677	49.7648
2	48.612	BB	1.6085	2615.20190	24.26334	50.2352

3ab

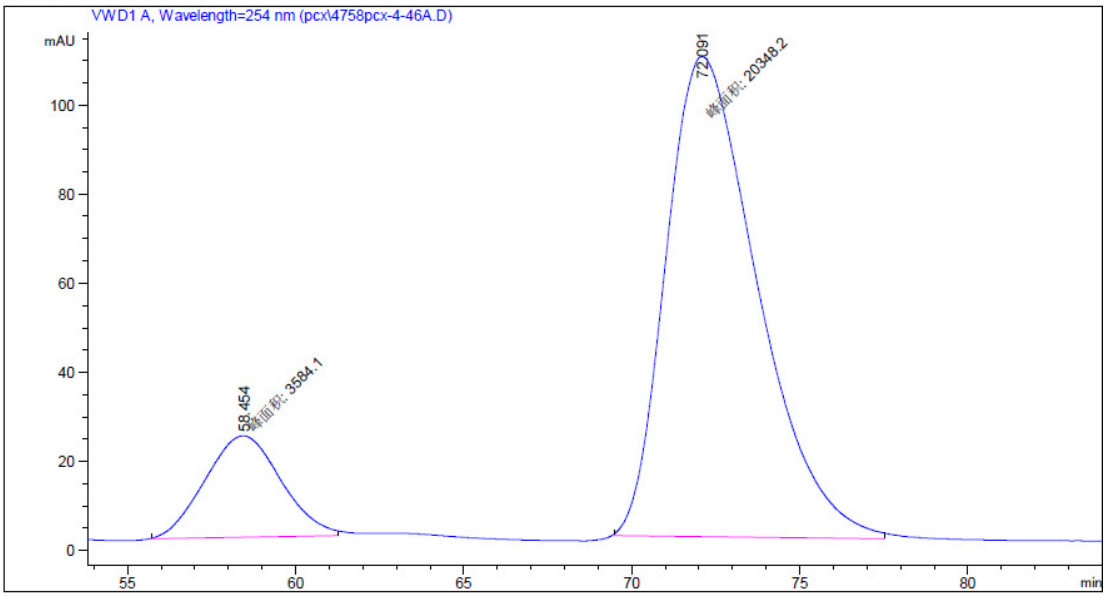


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.368	BB	1.0196	633.02557	8.44401	10.2625
2	22.289	BB	0.9532	5535.29297	89.04948	89.7375

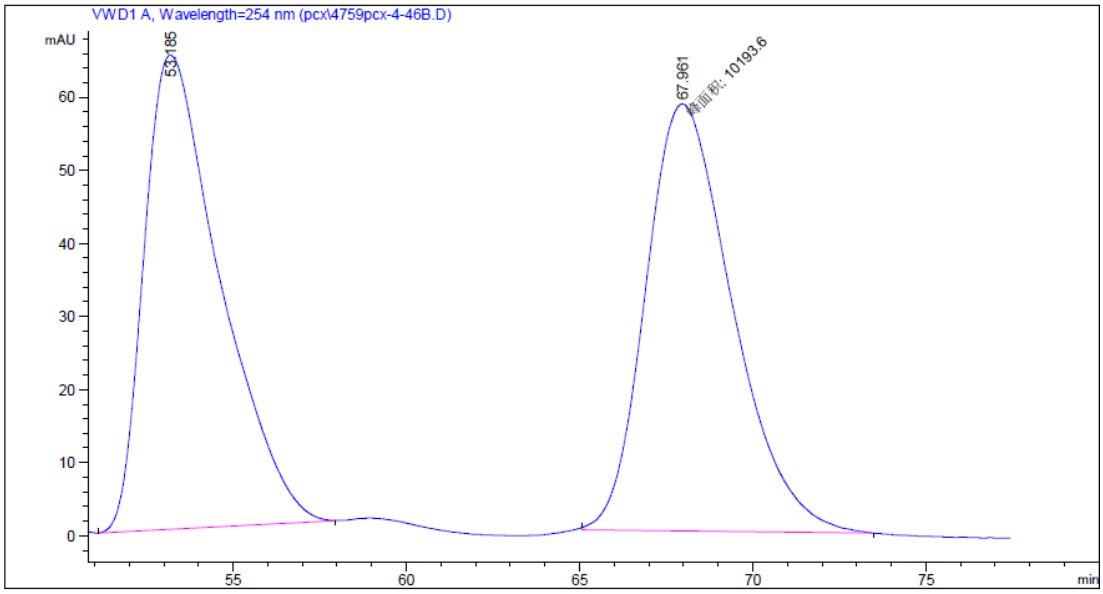


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.710	MM	0.8763	2.40520e4	457.46915	51.8146
2	23.440	MM	1.1546	2.23674e4	322.87314	48.1854

3ac

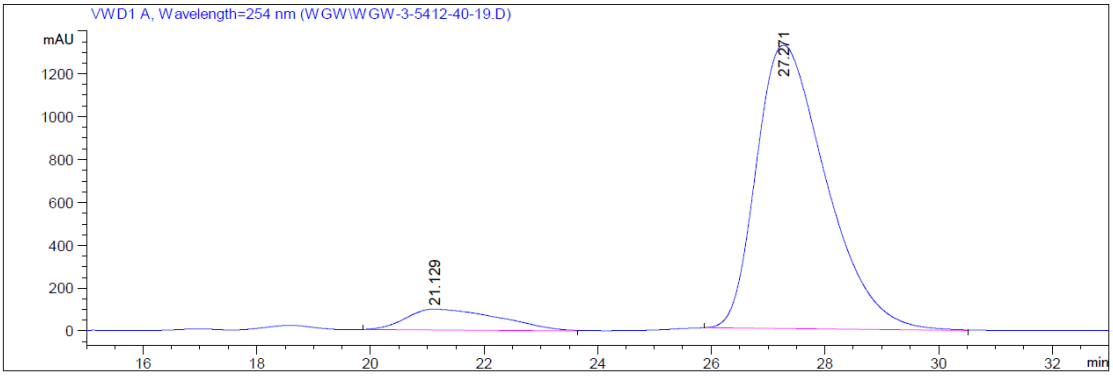


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	58.454	MM	2.6232	3584.09814	22.77181	14.9760
2	72.091	MM	3.1456	2.03482e4	107.81476	85.0240

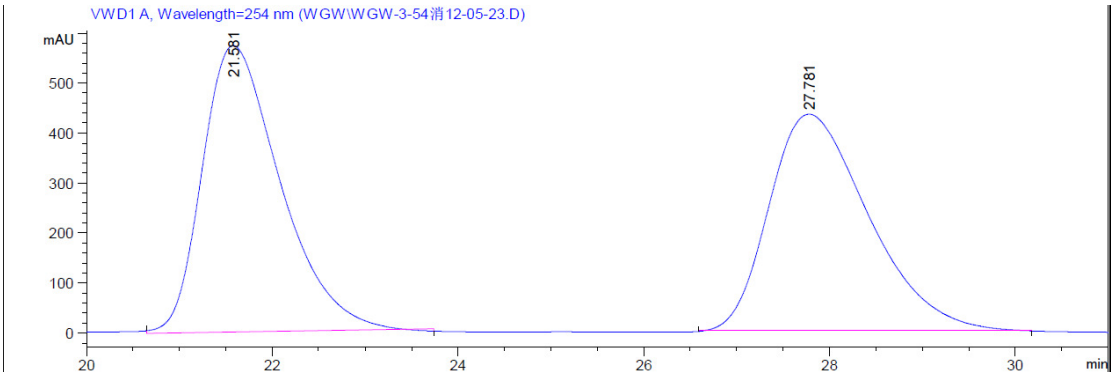


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	53.185	BB	2.1857	9917.52344	64.86801	49.3136
2	67.961	MM	2.9065	1.01936e4	58.45379	50.6864

3ad

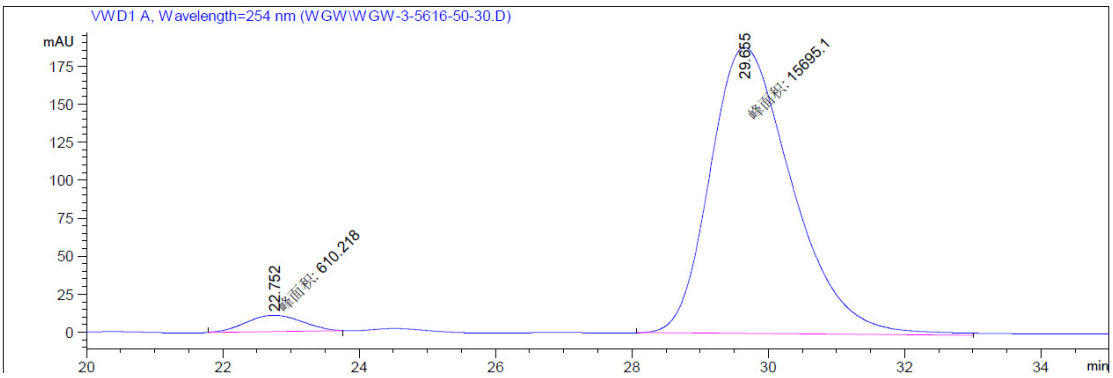


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.129	MM R	1.8930	1.10006e4	96.85483	8.9096
2	27.271	MM R	1.4183	1.12468e5	1321.67261	91.0904

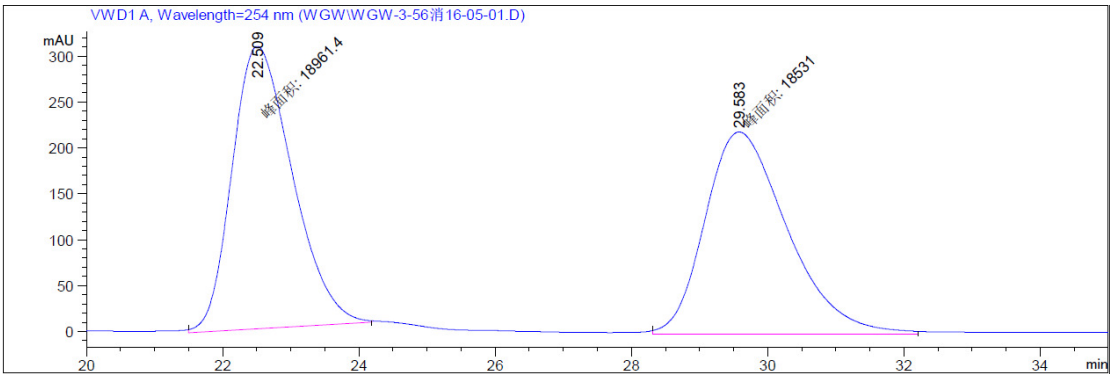


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.581	MM R	0.9717	3.34357e4	573.48846	50.9856
2	27.781	MM R	1.2381	3.21430e4	432.68198	49.0144

3ae

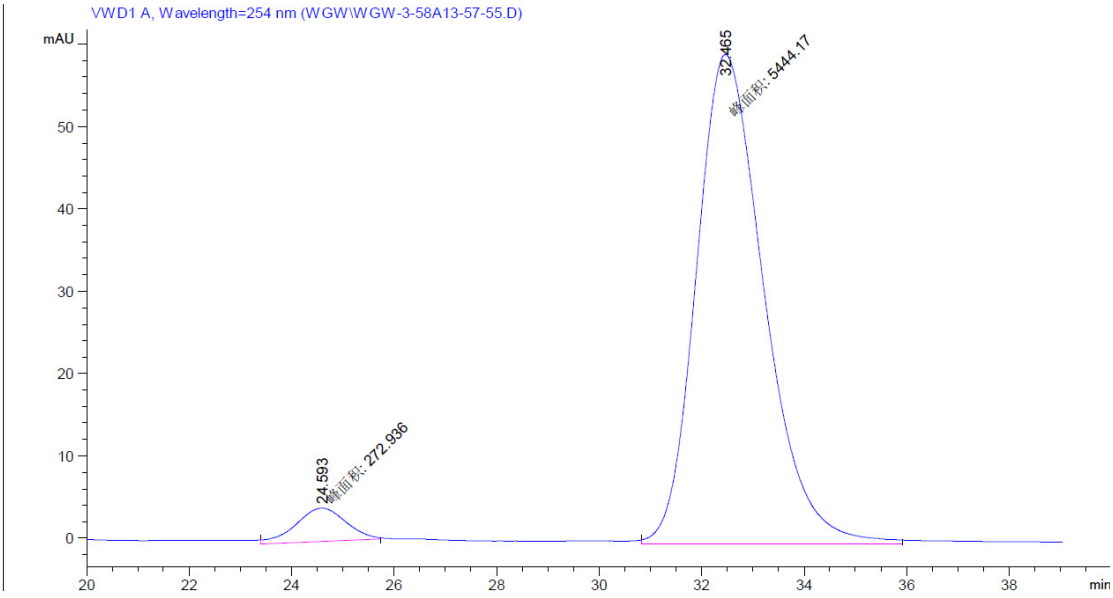


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	22.752	MM	0.9490	610.21790	10.71716	3.7425
2	29.655	MM	1.3924	1.56951e4	187.86708	96.2575

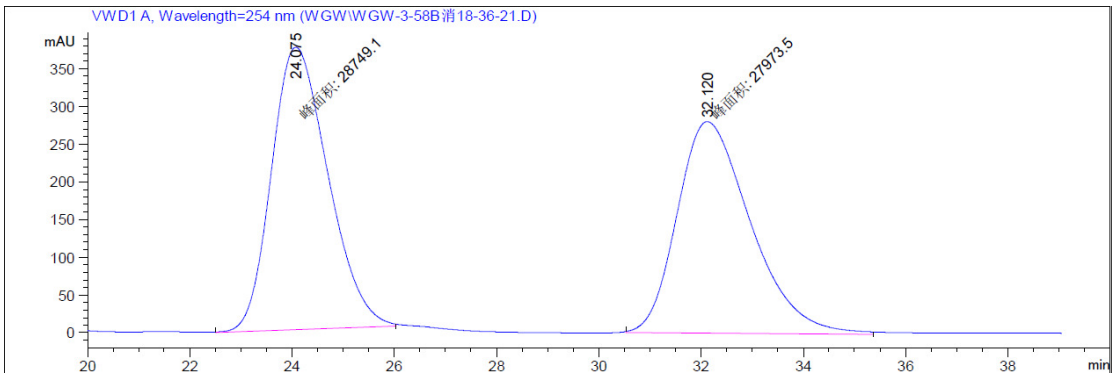


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	22.509	MM	1.0270	1.89614e4	307.71790	50.5740
2	29.583	MM	1.4020	1.85310e4	220.29982	49.4260

3af

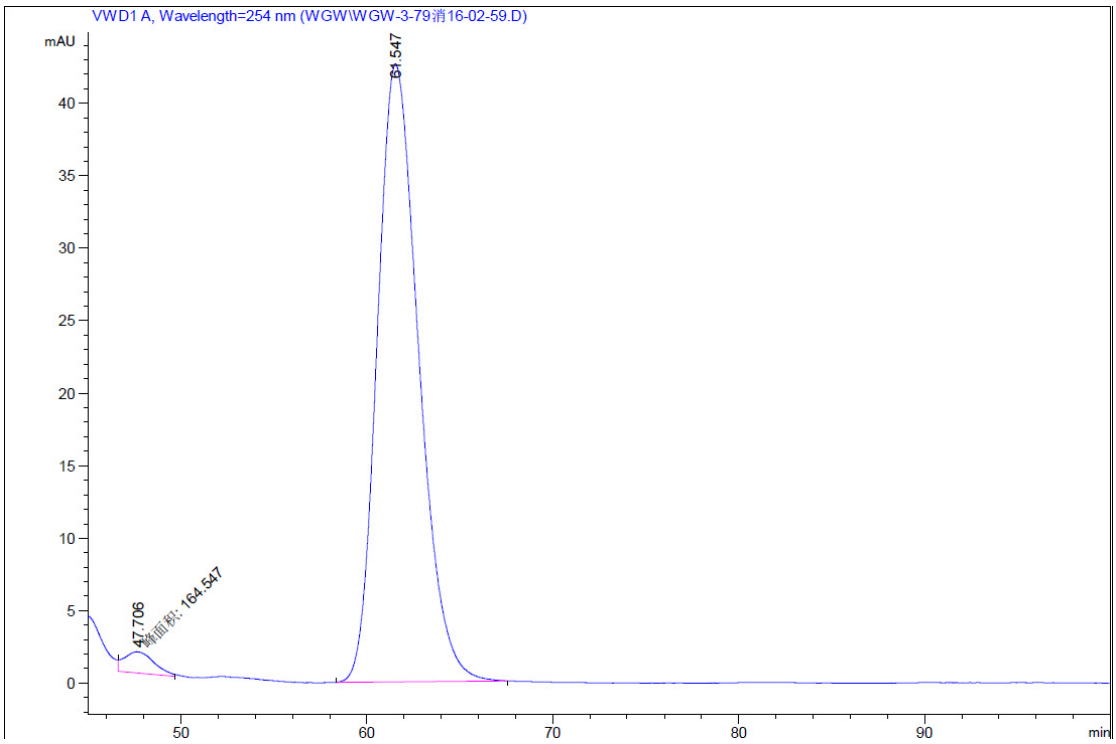


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.593	MM	1.1277	272.93640	4.03372	4.7740
2	32.465	MM	1.5266	5444.16992	59.43698	95.2260

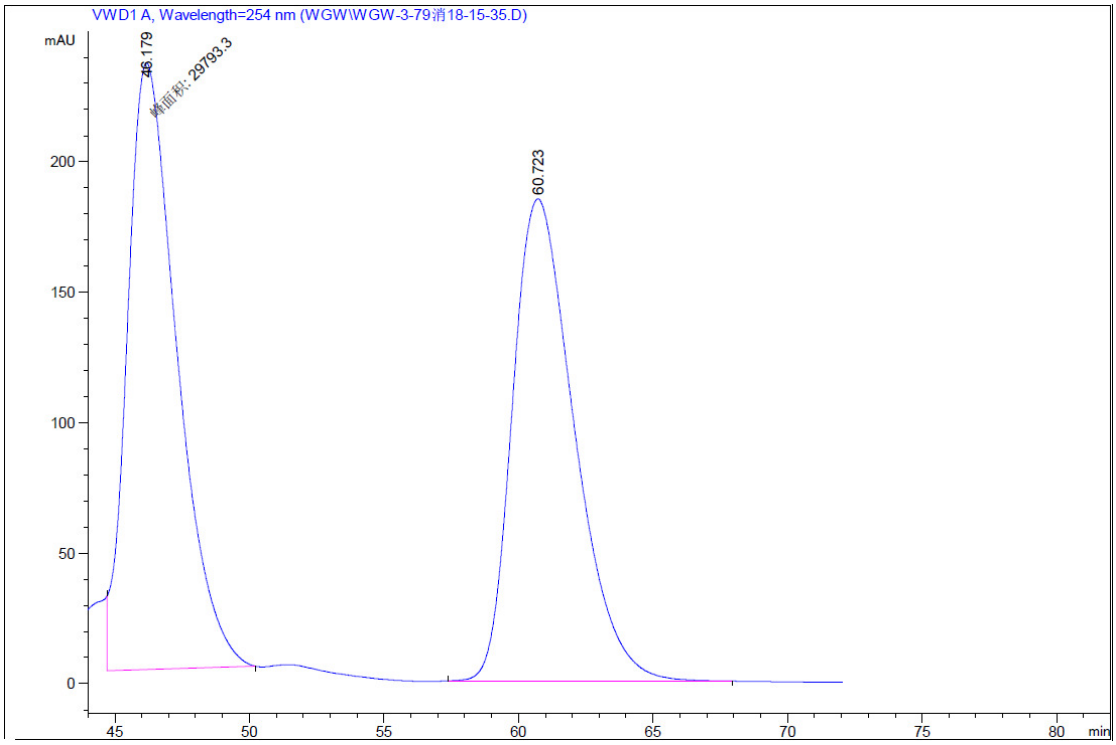


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.075	MM	1.2805	2.87491e4	374.20029	50.6837
2	32.120	MM	1.6631	2.79735e4	280.33194	49.3163

3ag

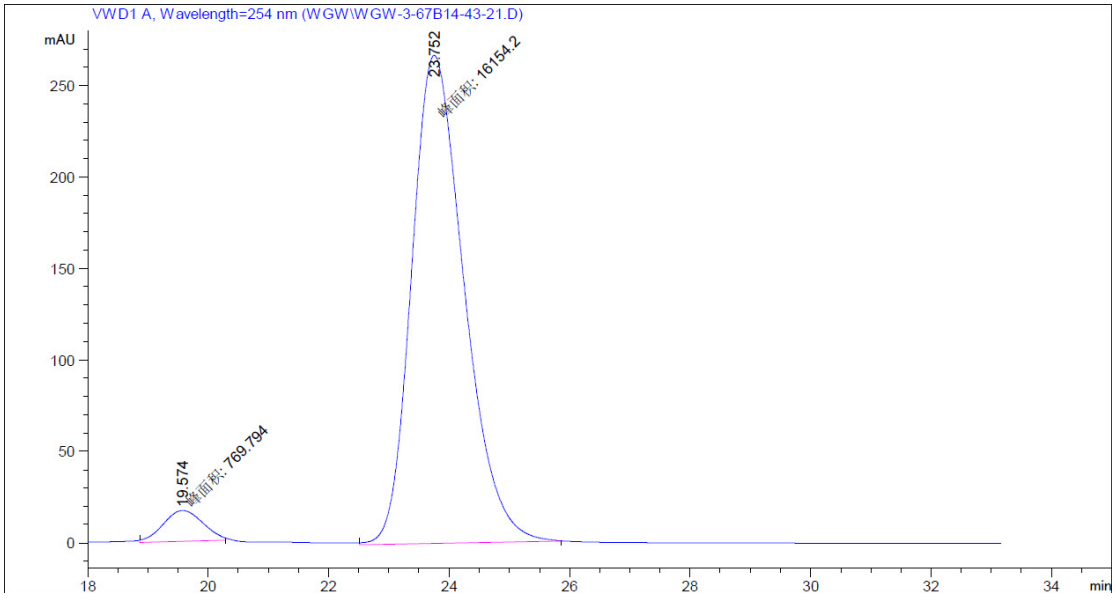


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	47.706	FM	1.8599	164.54704	1.47454	2.4358
2	61.547	BB	2.2479	6590.81592	42.62515	97.5642

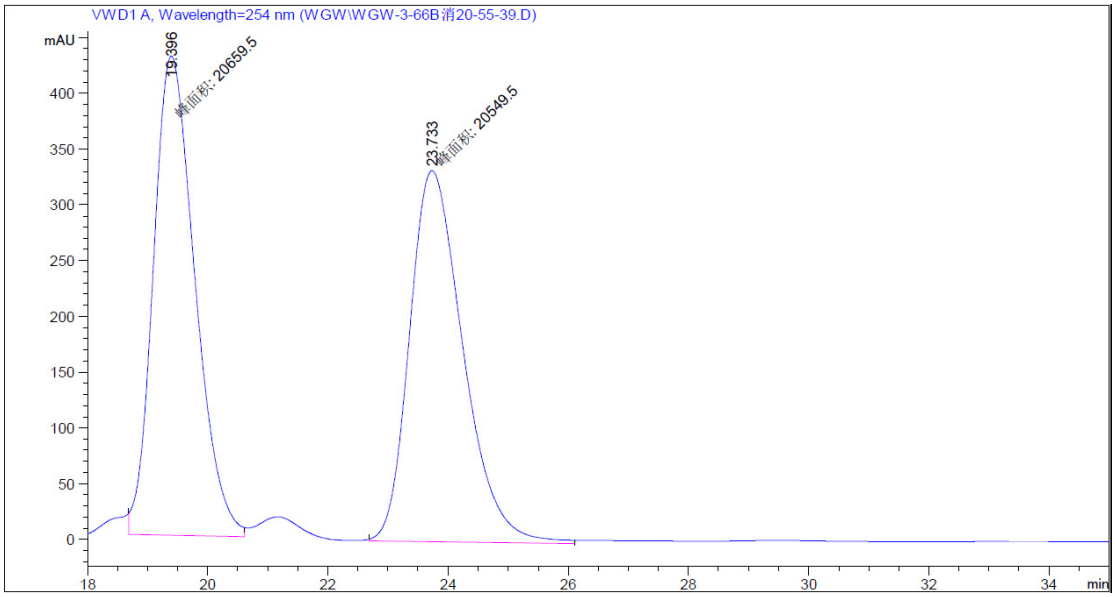


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	46.179	FM	2.1354	2.97933e4	232.53822	50.2880
2	60.723	BB	2.3250	2.94521e4	184.73206	49.7120

3ah

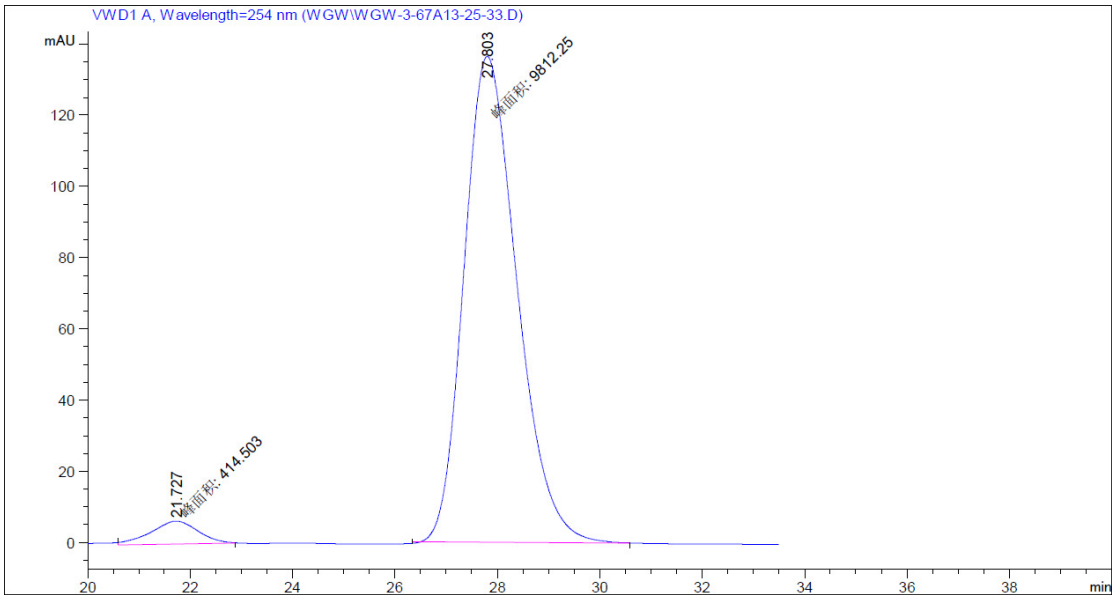


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.574	MM	0.7644	769.79449	16.78438	4.5485
2	23.752	MM	1.0085	1.61542e4	266.96399	95.4515

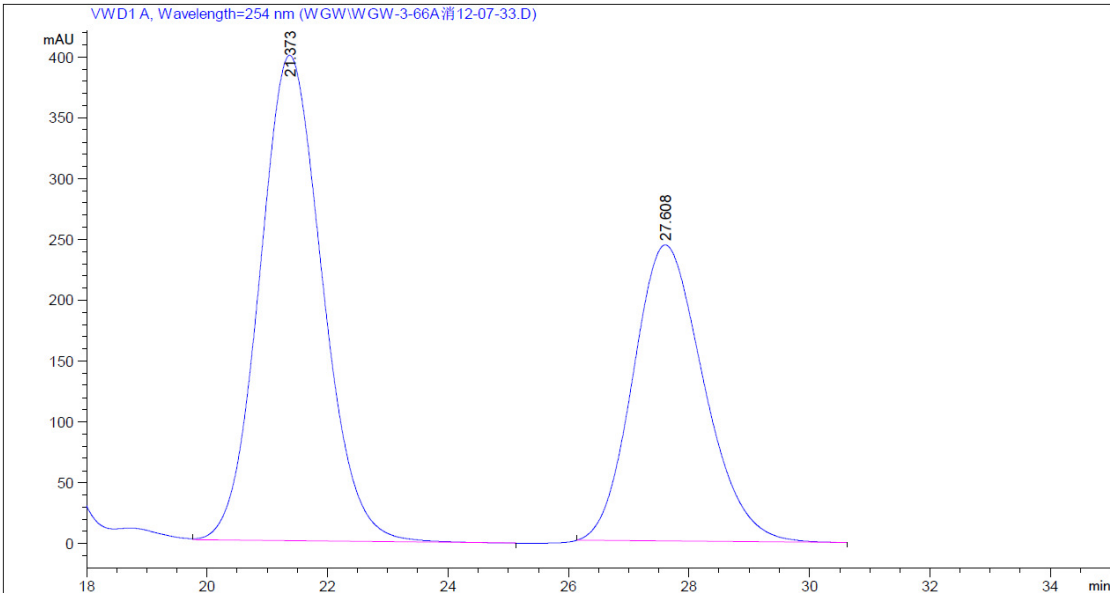


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.396	MF	0.8013	2.06595e4	429.71484	50.1335
2	23.733	MM	1.0296	2.05495e4	332.63745	49.8665

3ai

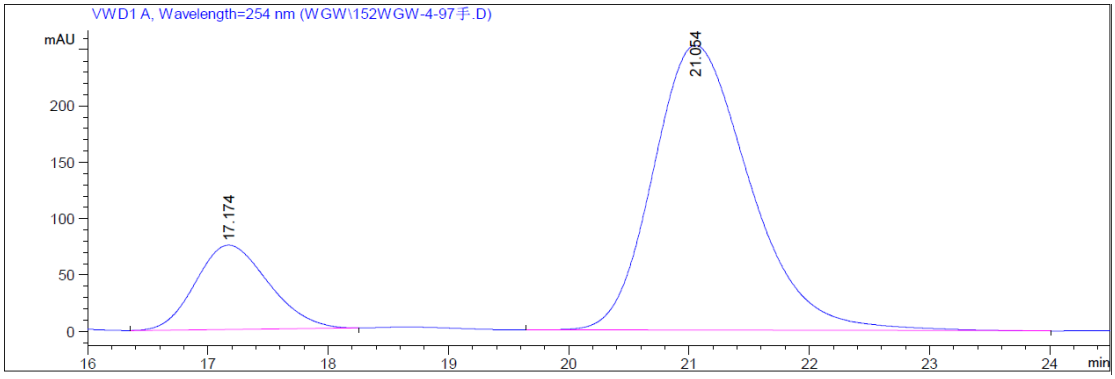


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.727	MM	1.0778	414.50348	6.40990	4.0531
2	27.803	MM	1.1986	9812.24805	136.44405	95.9469

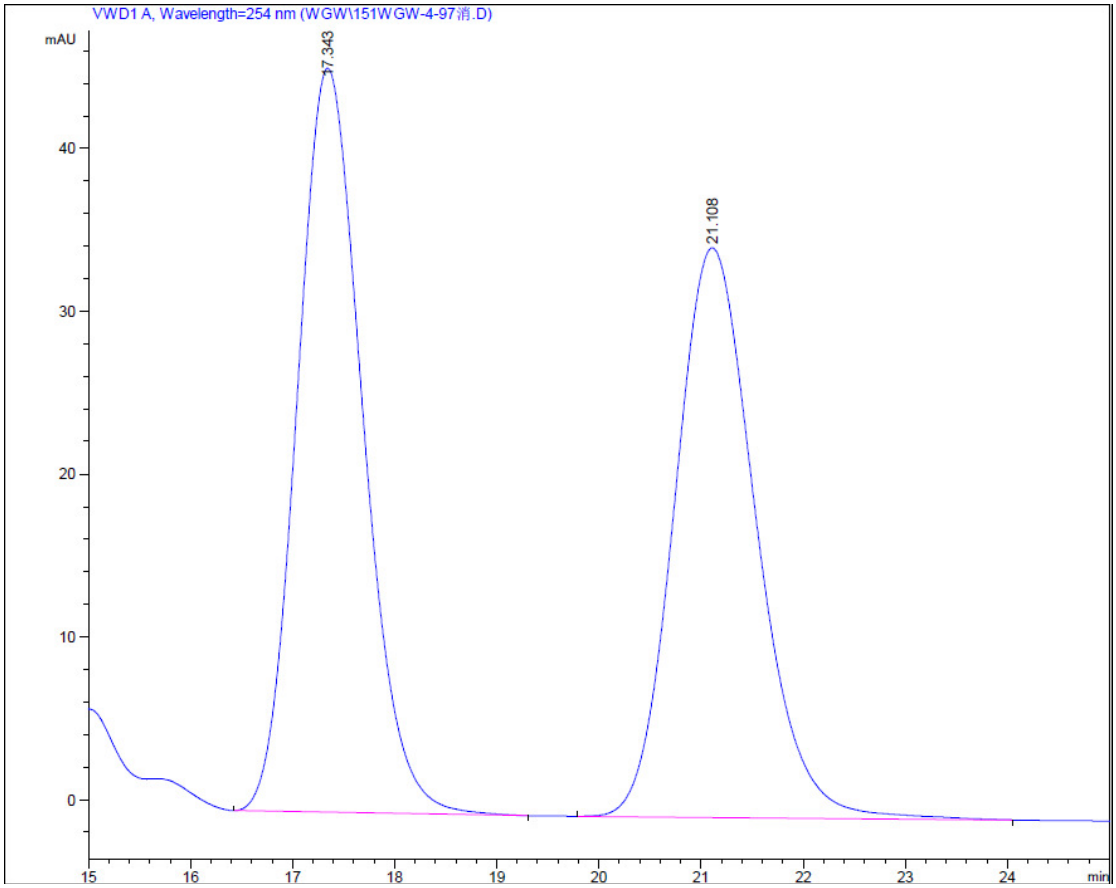


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.373	VB	1.1142	2.88503e4	399.17487	59.2450
2	27.608	BBA	1.1990	1.98463e4	243.47554	40.7550

3aj

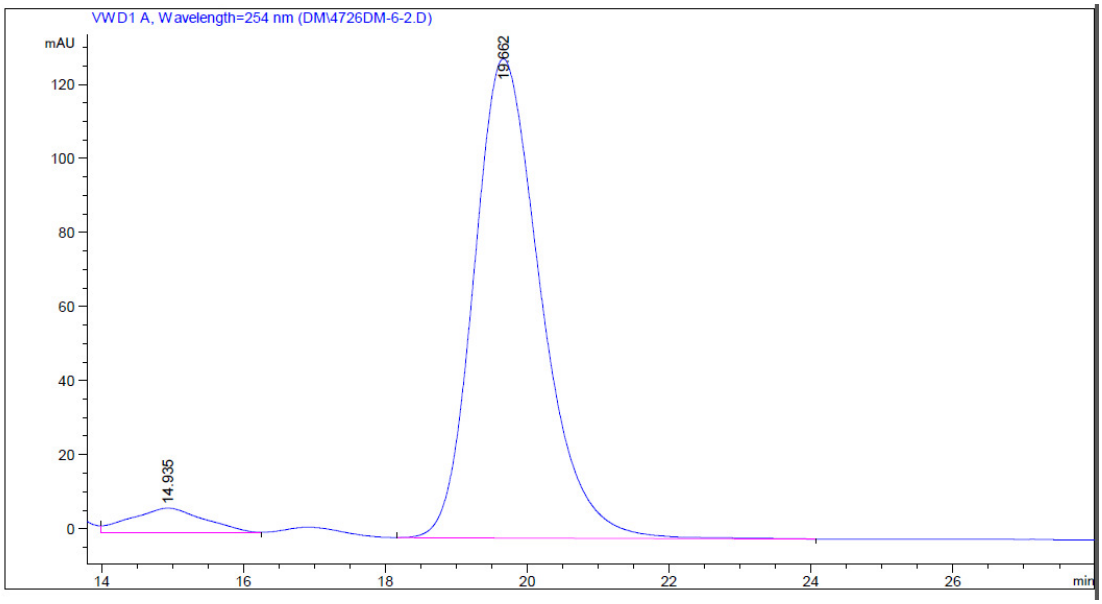


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.174	BB	0.6551	3139.60498	74.74445	18.2109
2	21.054	BB	0.8596	1.41007e4	252.85097	81.7891

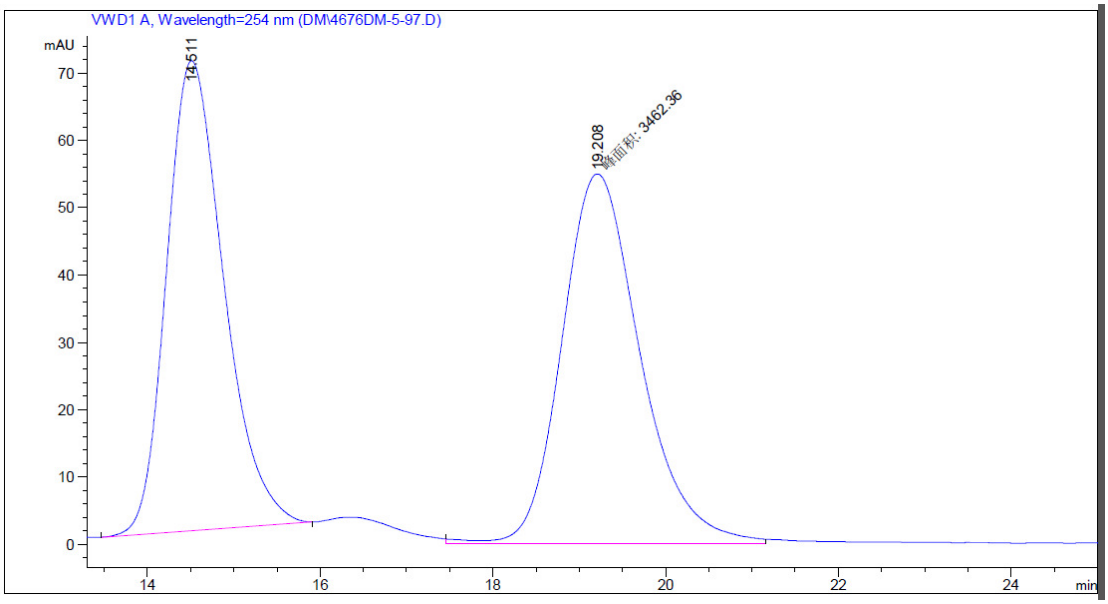


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.343	BB	0.6934	2042.76514	45.70736	51.3706
2	21.108	BB	0.8508	1933.75952	34.98757	48.6294

3ak

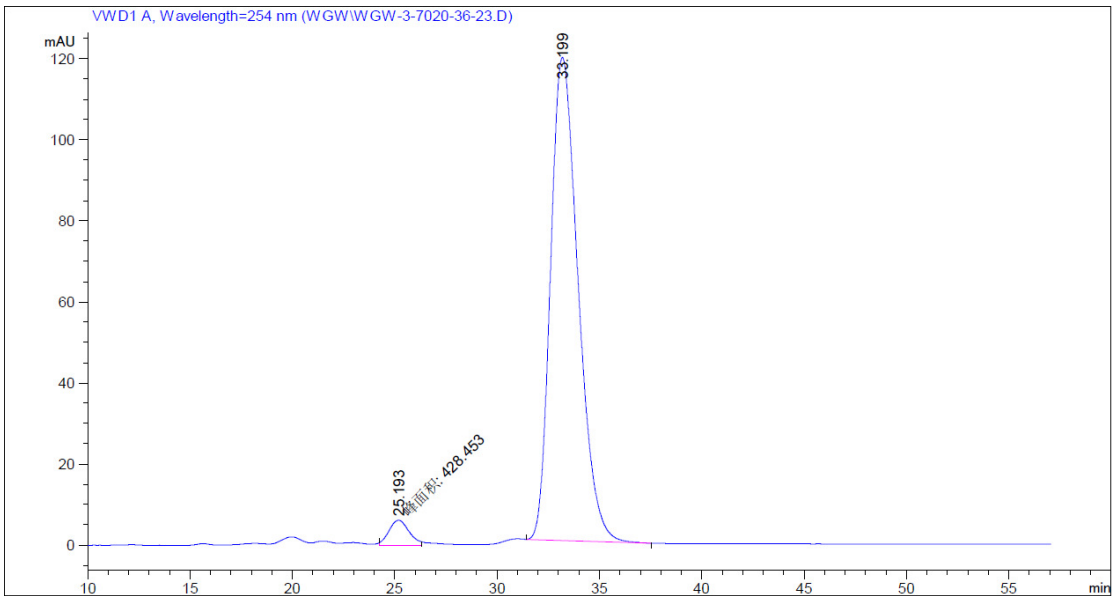


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.935	VB	0.9714	465.10300	6.52667	5.2352
2	19.662	MM	1.0820	8419.11621	129.68997	94.7648

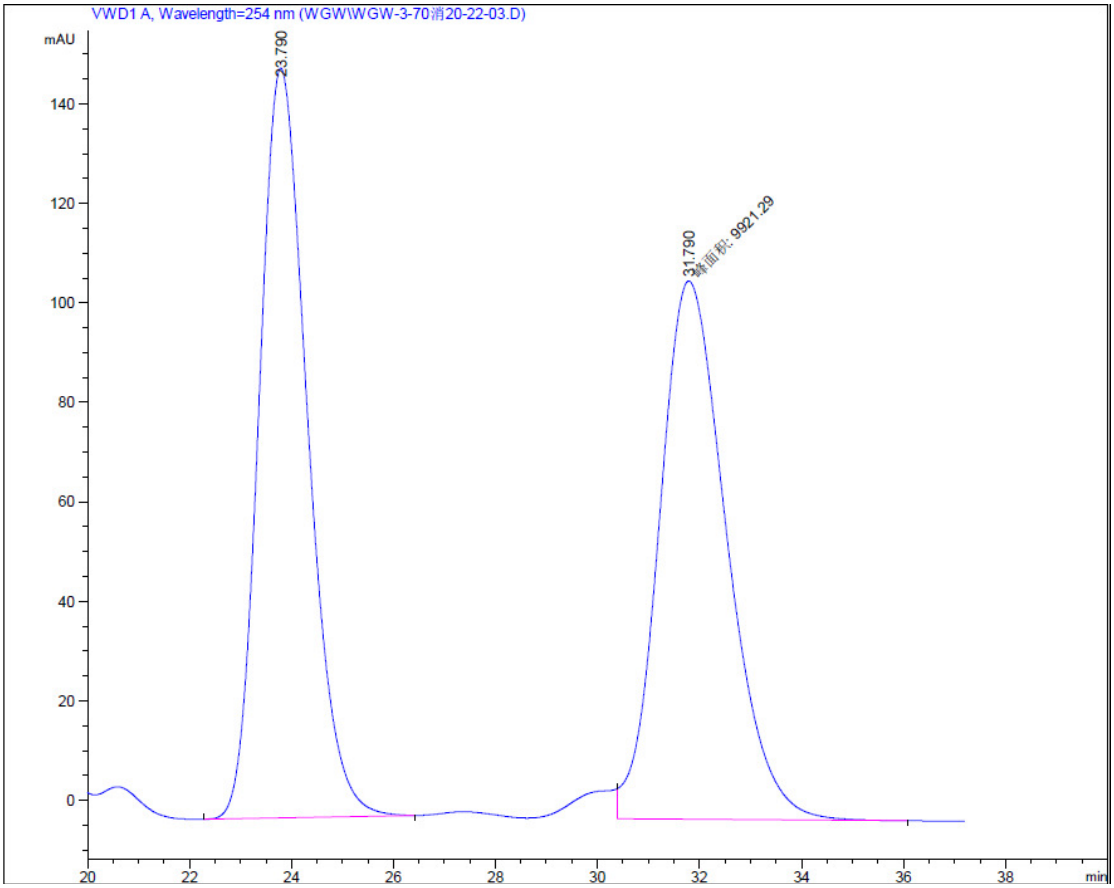


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.511	BB	0.7135	3213.19092	69.87316	48.1337
2	19.208	MM	1.0502	3462.36450	54.94539	51.8663

3al

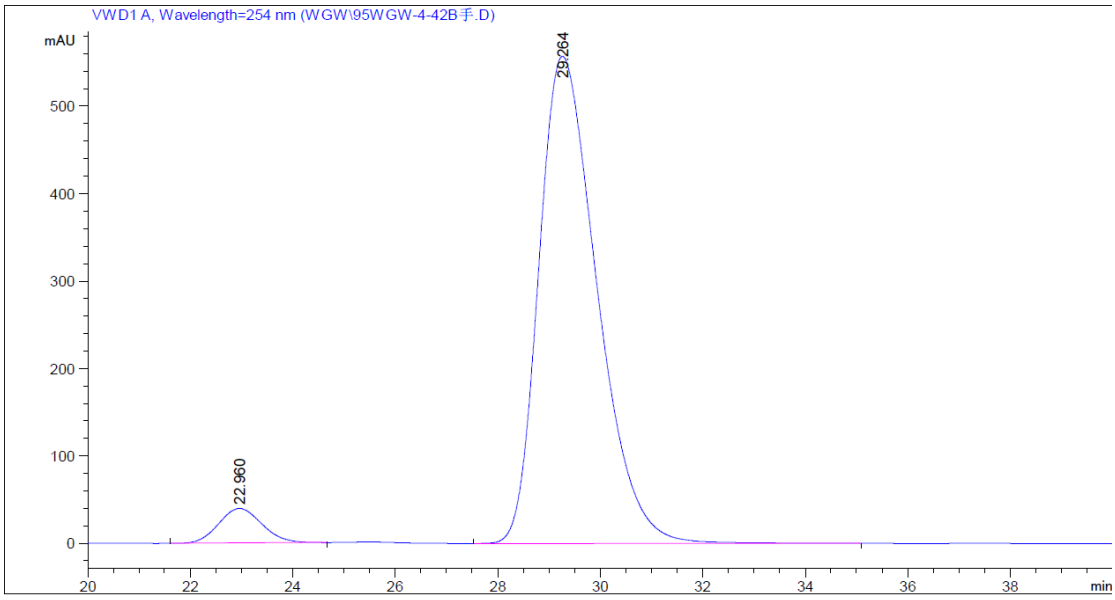


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.193	MM	1.1441	428.45319	6.24174	3.7021
2	33.199	BB	1.4488	1.11447e4	119.19968	96.2979

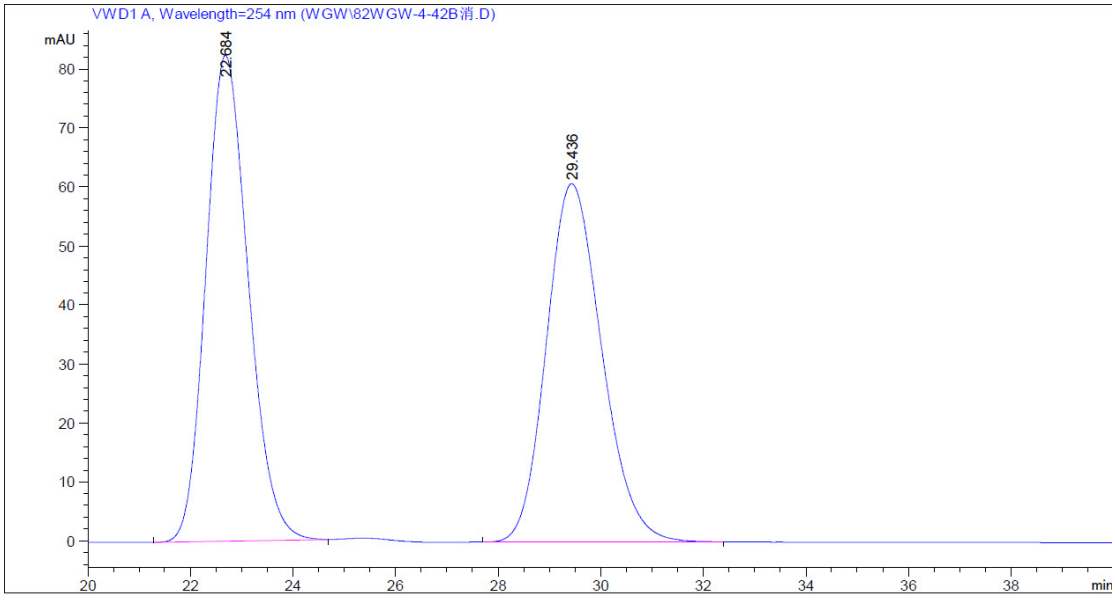


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.790	BB	1.0205	9925.97363	150.68684	50.0118
2	31.790	FM	1.5285	9921.29297	108.18142	49.9882

3am

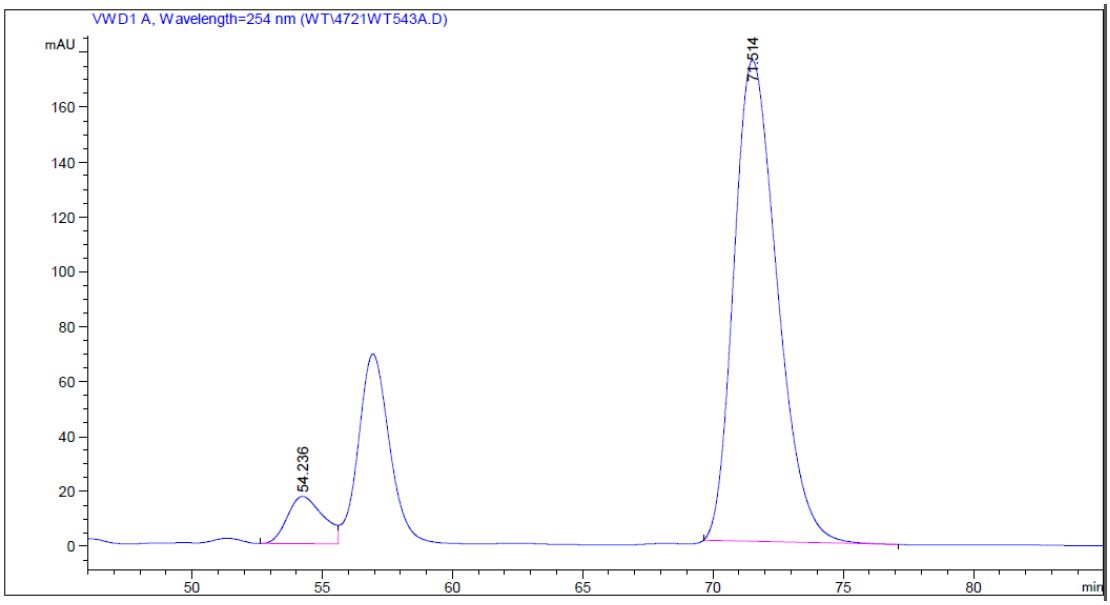


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	22.960	BB	0.9185	2324.76050	39.50683	5.0352
2	29.264	BB	1.2204	4.38458e4	556.97528	94.9648

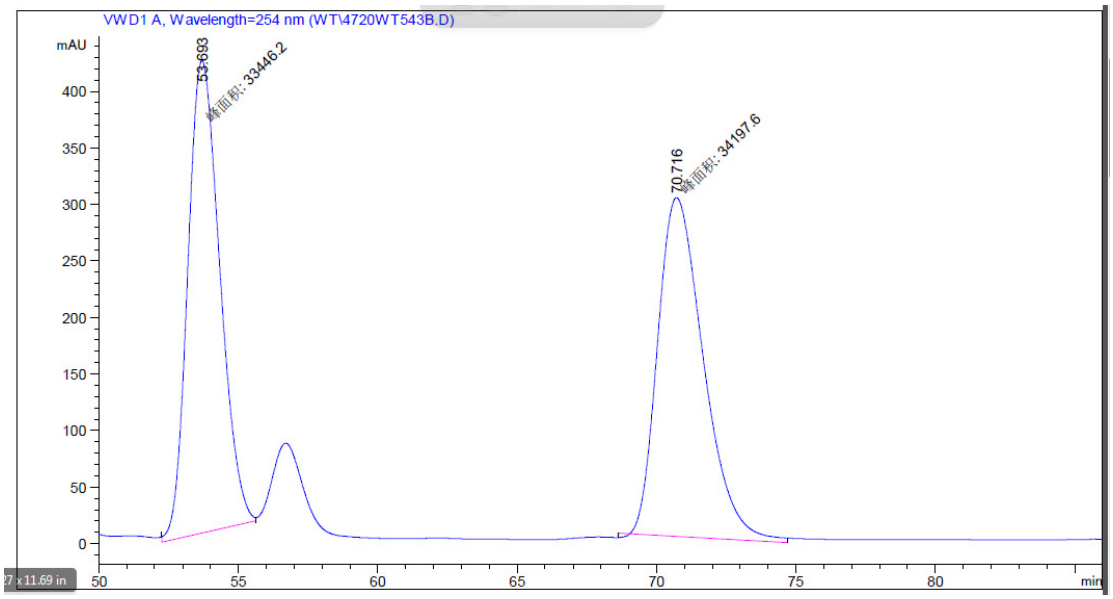


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	22.684	BB	0.8919	4728.84912	82.35050	50.9499
2	29.436	BB	1.1629	4552.51660	60.70897	49.0501

3an

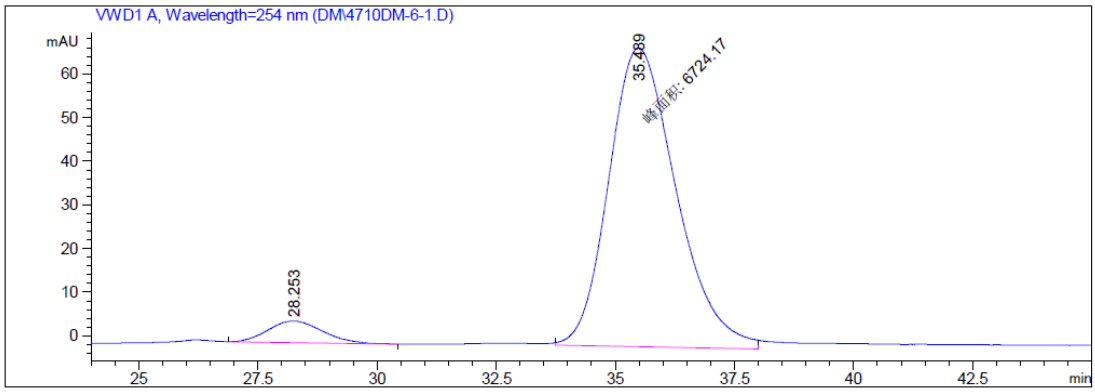


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	54.236	BV	1.3586	1640.49255	17.23368	7.4754
2	71.514	BB	1.6845	2.03049e4	175.14999	92.5246

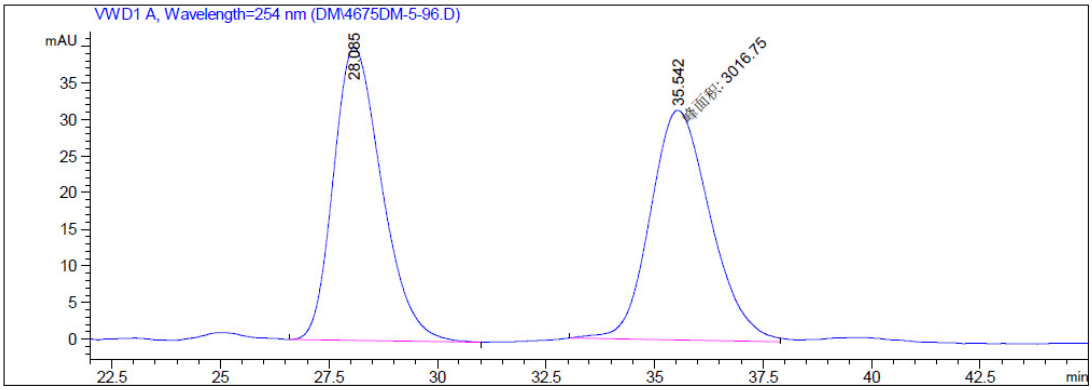


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	53.693	MM	1.3334	3.34462e4	418.06464	49.4446
2	70.716	MM	1.9009	3.41976e4	299.82993	50.5554

3ao

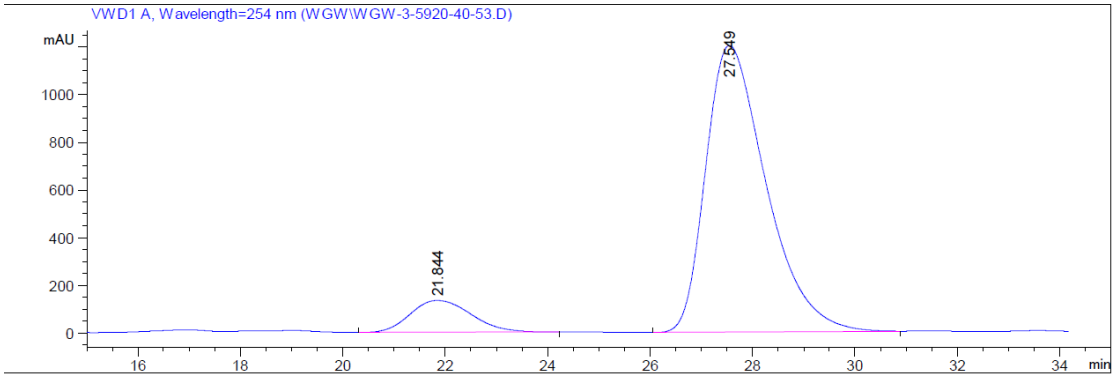


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	28.253	BB	1.0061	393.24075	4.94314	5.5251
2	35.489	MM	1.6388	6724.17432	68.38329	94.4749

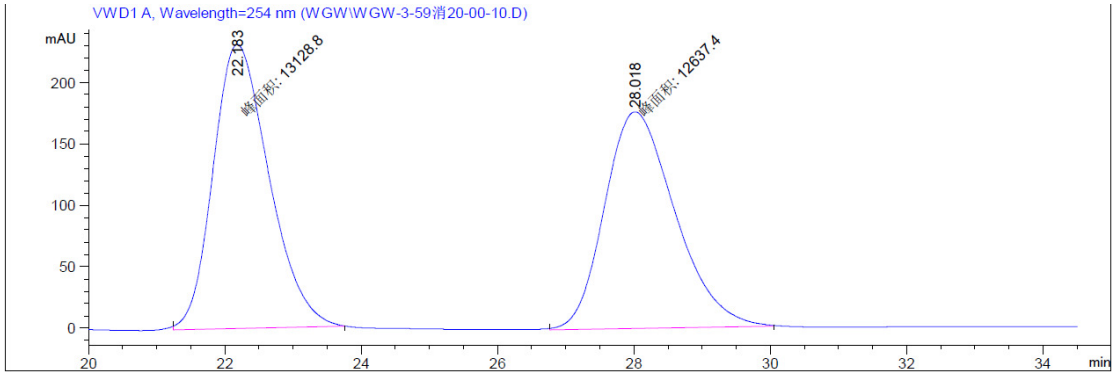


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	28.085	BB	1.1597	3091.31958	40.04329	50.6105
2	35.542	MM	1.6038	3016.74536	31.34954	49.3895

3ap



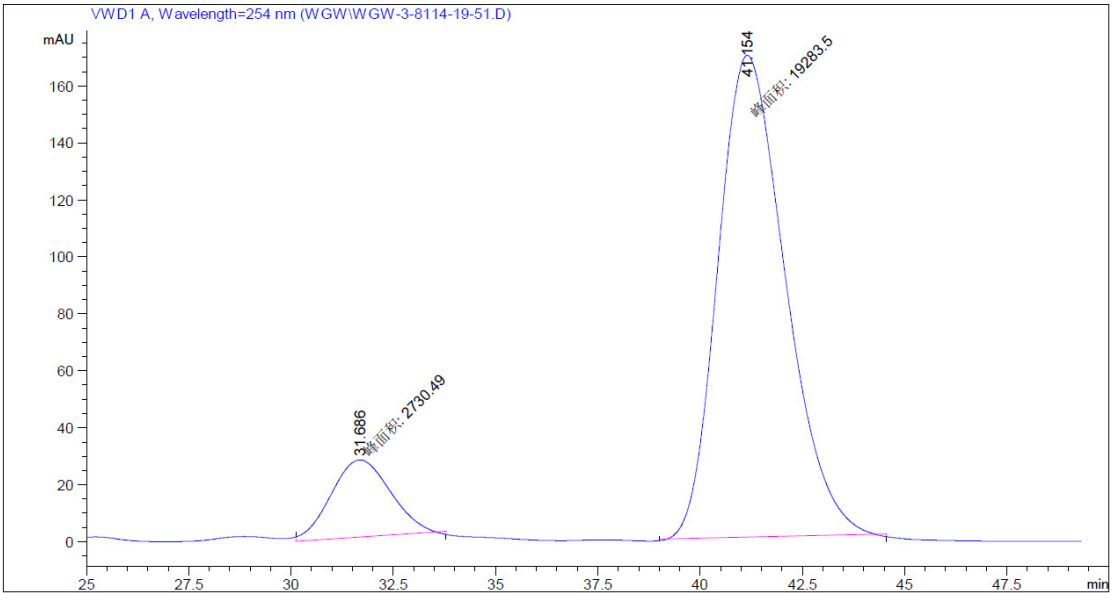
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.844	BB	1.3126	1.09857e4	133.28845	10.0426
2	27.549	BB	1.2548	9.84061e4	1202.41980	89.9574



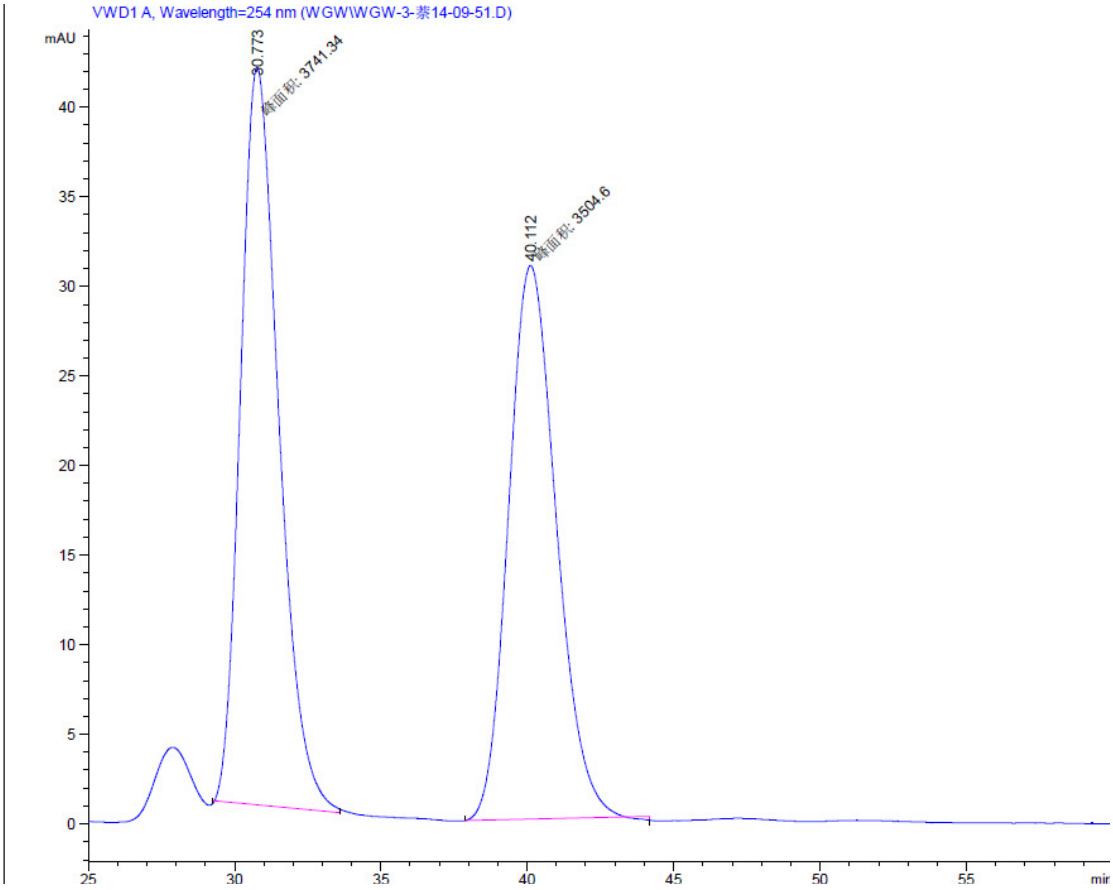
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	22.183	MM	0.9474	1.31288e4	230.97047	50.9536
2	28.018	MM	1.1960	1.26374e4	176.10226	49.0464

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.884	MM	1.7186	513.36371	4.97838	7.9861
2	31.982	MM	1.6461	5914.87354	59.88941	92.0139

3aq



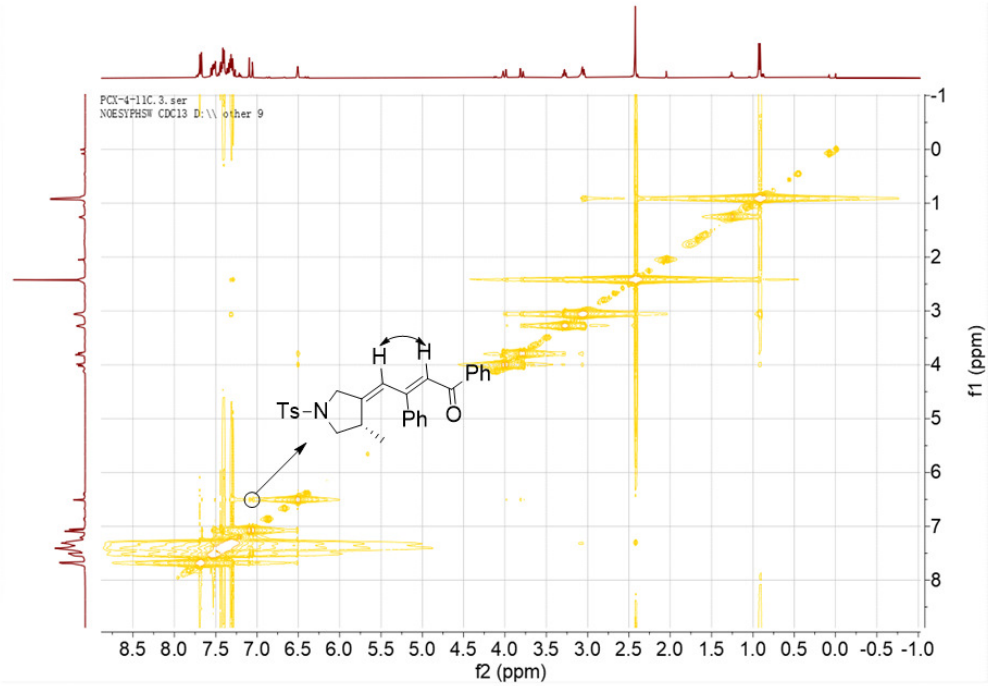
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	31.686	MM	1.6796	2730.48682	27.09403	12.4034
2	41.154	MM	1.9006	1.92835e4	169.10123	87.5966

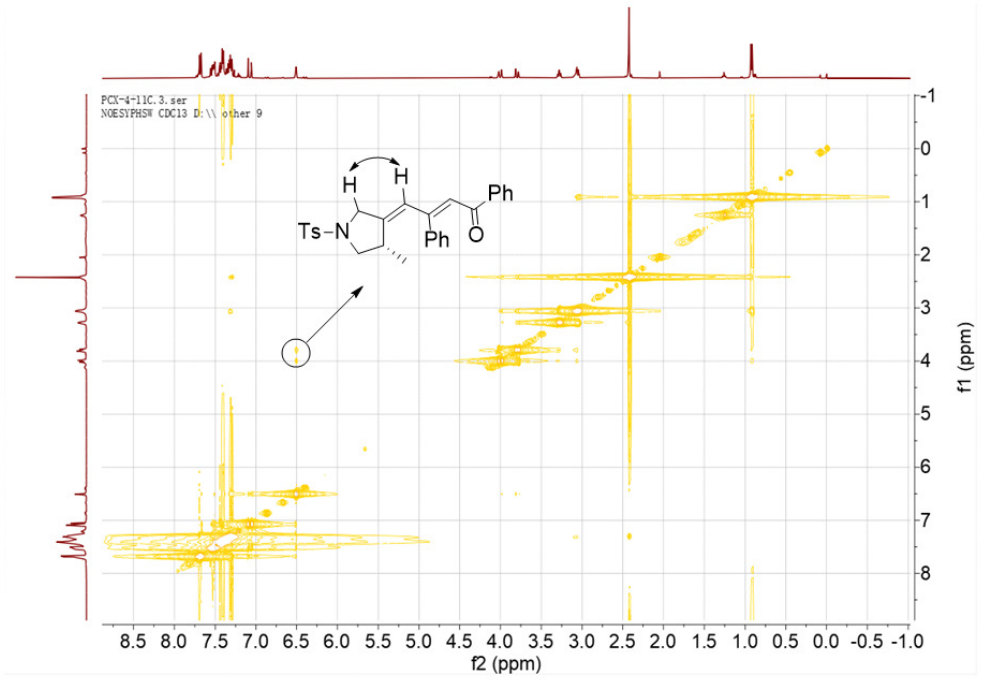


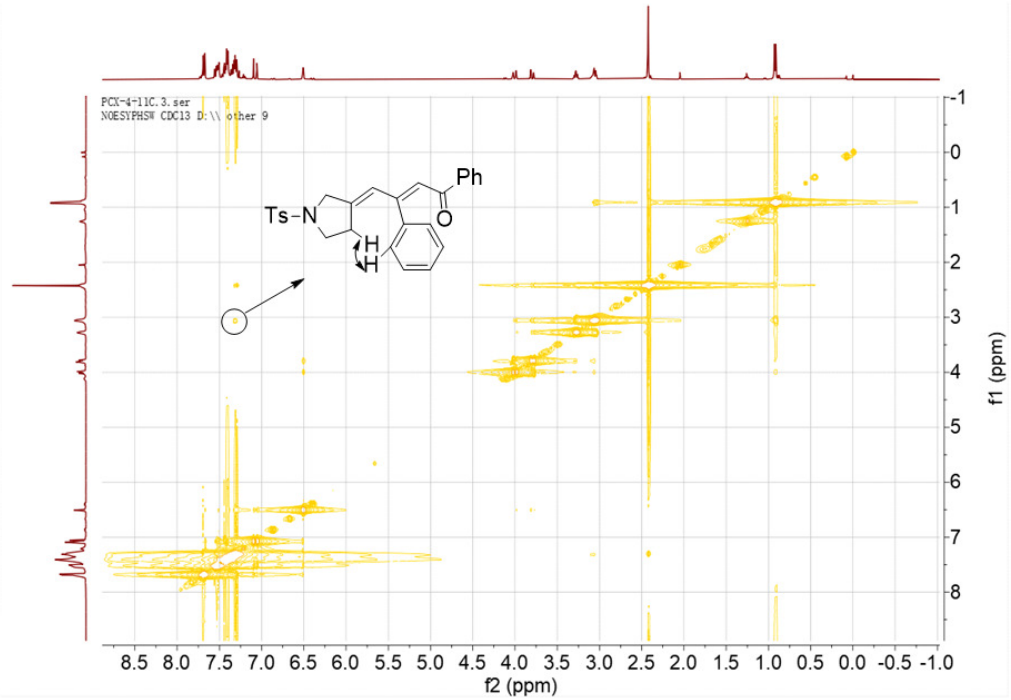
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.773	MM	1.5145	3741.33765	41.17240	51.6336
2	40.112	MM	1.8901	3504.60083	30.90250	48.3664

6. Selected NOESY Spectra

（1）H,H-NOSEY NMR spectrum (400 MHz, $CDCl_3$) of **3aa**.


PCX-4-11C.3.ser
NOESYPHSW CDCl3 D:\\ other 9
H
H
Ph
Ts-N
Ph
O
f1 (ppm)
f2 (ppm)


PCX-4-11C.3.ser
NOESYPHSW CDCl3 D:\\ other 9
H
H
Ph
Ts-N
Ph
O
f1 (ppm)
f2 (ppm)


PCX-4-11C.3.ser
NOESYPHSW CDCl3 D:\\ other 9
Ts-N
Ph
O
H
H
f1 (ppm)
f2 (ppm)
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
-1 0 1 2 3 4 5 6 7 8

7. ECD Specture and Calculation

Therefore, only two configurations were generated for theoretical calculations to identify the most probable candidate for 3aa. A conformational search was then performed using ABCluster3.0 software[6] with a NWPEsSe method and the xtb force field.The 3 corresponding(Figure S1) minimum geometries were fully optimizedusing DFT at the B3LYP(D3BJ)/def2svp level for geometry optimization and revDSD-PBEP86-D3(BJ) /defTZVP for energy calculation[7], as implementedin the Gaussian 16 program package[8].All of them displayedno imaginary frequencies.Initially, the global minimumenergy-minimized structures of probable configurations of 1 were submitted to ECD calculations using the TDDFT method at the PBE1/defTZVP level. The calculated ECD spectrum of 3aa wascompared with the experimental ECD spectrum todetermine the most probable configuration (Figure S1).Finally, with the aid of Multiwfn 3.7 software[9], theBoltzmann-averaged ECD spectrum of **3aa**(Figure S2) was obtainedto provide a clear comparison with the experimentaldata (Figure S3).

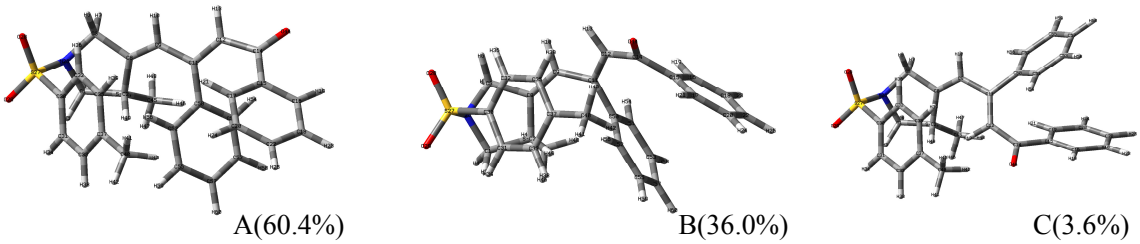


Figure S1. Boltzmann distribution of 3 corresponding minimum geometries

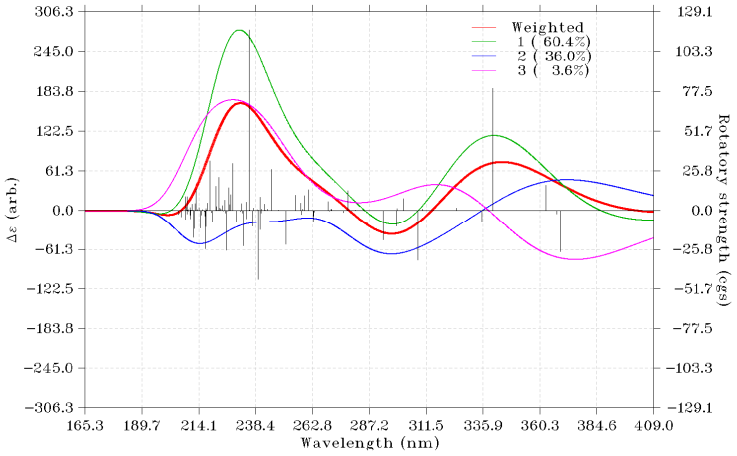


Figure S2. Boltzmann-averaged theoretical ECD spectrum of **3aa**

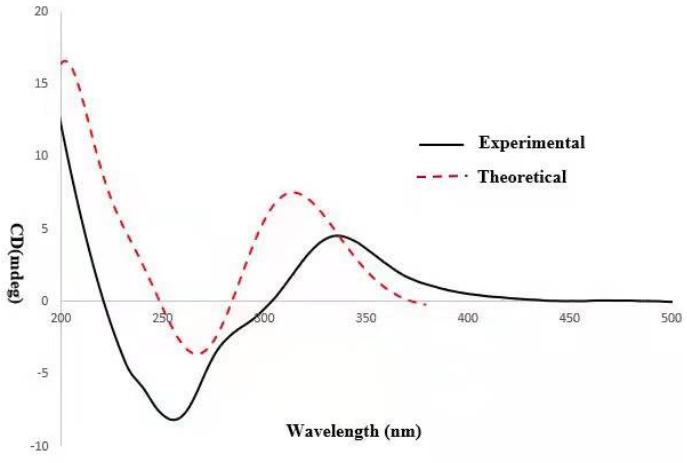
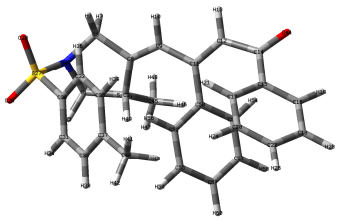


Figure S3. Boltzmann-averaged theoretical ECD spectrum of **3aa** comparison with the experimentaldata

The Cartesian coordinates (Å) and energies at 273 K for the optimized structures



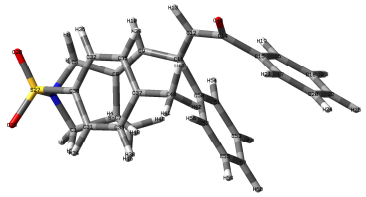
A

SCF energy[revDSD-PBEP86-D3(BJ)/defTZVP/SMD(methanol)]:-1758.9926373

Charge = 0 Multiplicity = 1

C	-3.30625900	-1.67581700	1.24318600
C	-1.75939700	-1.69438800	1.12324200
C	-2.86081500	-2.02169300	-1.03521600
H	-3.68101600	-2.66256000	1.55873000
H	-3.68257400	-0.93504400	1.95879800
H	-2.94392700	-1.60221900	-2.04493400
H	-3.09589900	-3.09915100	-1.10398400
C	-1.51291100	-1.81917100	-0.37282700
C	-0.38170200	-1.77572100	-1.10852400
H	-0.51158800	-1.94195300	-2.18411800
C	1.01260900	-1.53655900	-0.72669200
C	1.98062700	-1.84899300	-1.63550200
H	1.68838300	-2.38551100	-2.54477100
C	3.44103800	-1.65068500	-1.51743600
C	4.00079300	-0.36084400	-1.00561900
C	5.29819600	-0.35894900	-0.46716100
C	3.29256100	0.84787900	-1.10018100

C	5.86559300	0.82523200	0.00097200
H	5.84677400	-1.30111200	-0.40757100
C	3.86854900	2.03617700	-0.64780000
H	2.29327900	0.86079900	-1.53721700
C	5.15027000	2.02563100	-0.08786100
H	6.86789900	0.81574300	0.43644000
H	3.31338200	2.97323900	-0.73140400
H	5.59479700	2.95525100	0.27667100
N	-3.83165800	-1.41867200	-0.10859700
S	-4.36124100	0.13293800	-0.45963800
O	-4.80635700	0.09114200	-1.86152200
O	-5.31500800	0.47789200	0.60571600
C	-2.99756100	1.28153800	-0.35960400
C	-2.75714100	1.95941400	0.83978400
C	-2.19131000	1.49192000	-1.48323800
C	-1.68876600	2.85241000	0.90957800
H	-3.40818200	1.80389300	1.70090100
C	-1.12444000	2.38444500	-1.39150900
H	-2.40097500	0.97497400	-2.42046300
C	-0.85156700	3.07361800	-0.19714300
H	-1.50053700	3.38871100	1.84280900
H	-0.48872900	2.54921200	-2.26502000
C	0.34339000	3.97711700	-0.08630900
H	0.61968500	4.40711300	-1.06047500
H	0.16796700	4.79554600	0.62782400
H	1.21325800	3.40432700	0.27954100
O	4.20082000	-2.53991700	-1.90505500
C	-1.13667300	-2.81700300	1.95638300
H	-0.04000900	-2.79526200	1.90767700
H	-1.43174400	-2.71423600	3.01350600
H	-1.47909600	-3.80234100	1.60069500
H	-1.36903900	-0.73085600	1.47674600
C	1.36403900	-0.94348800	0.58938100
C	2.33066600	-1.54034200	1.41415400
C	0.77842300	0.26458500	0.99395900
C	2.71117300	-0.93258500	2.61297900
H	2.78176100	-2.48938400	1.11626200
C	1.16138100	0.87594500	2.18694400
H	0.03927200	0.73657000	0.35043200
C	2.13098000	0.27879400	3.00094100
H	3.46552800	-1.40701300	3.24555000
H	0.70422000	1.82428100	2.47901600
H	2.43246900	0.75693500	3.93634600



B

SCF energy[revDSD-PBEP86-D3(BJ)/defTZVP/SMD(methanol)]:-1758.9904687

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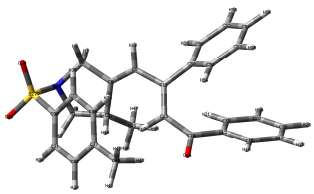
C	-3.10124500	-1.41256500	-1.59833900
H	-3.70971100	-2.91047700	0.82634300
H	-3.25864200	-1.42294800	1.66744000
H	-3.30662000	-0.64280800	-2.35060500
H	-3.41759800	-2.38671200	-2.01054500
C	-1.67488100	-1.45180600	-1.10207200
C	-0.69708100	-0.75891700	-1.72314800
H	-0.98487000	-0.25724500	-2.65290700
C	0.64067000	-0.39754400	-1.25306100
C	1.19937900	0.71011200	-1.82375200
H	0.61157400	1.23047000	-2.58573000
C	2.38675700	1.48438800	-1.42073000
C	3.60806500	0.84500000	-0.84897500
C	4.04414800	-0.42190400	-1.26339200
C	4.35687200	1.55853400	0.10124600
C	5.19967500	-0.97926600	-0.71417800
H	3.48042500	-0.96777000	-2.02079400
C	5.50127400	0.99313700	0.66250700
H	4.01821600	2.55001900	0.40833800
C	5.92260300	-0.27884200	0.25721600
H	5.53456500	-1.96654300	-1.04131900
H	6.06713700	1.54268400	1.41888400
H	6.81886300	-0.72369600	0.69712100
N	-3.87300100	-1.18478900	-0.35975700
S	-4.28603600	0.40280200	0.00415200
O	-4.86182300	0.96157900	-1.22944700
O	-5.10322000	0.32190500	1.22492800
C	-2.81597800	1.33484400	0.40158200
C	-2.33261400	1.32691700	1.71552700
C	-2.14843200	2.03378900	-0.60772400
C	-1.15997200	2.01986800	2.00762500
H	-2.87482800	0.80153100	2.50249900
C	-0.97858600	2.72590300	-0.29359600

H	-2.54046600	2.04216400	-1.62526000
C	-0.46419600	2.72941100	1.01277000
H	-0.77923600	2.01708800	3.03220400
H	-0.44735900	3.26759200	-1.07842000
C	0.81040800	3.45347200	1.34869700
H	0.68026400	4.08991400	2.23864300
H	1.61363100	2.73492100	1.58514200
H	1.15513900	4.07856400	0.51423500
O	2.35514500	2.71019900	-1.56903300
C	-1.40918000	-3.66345200	0.11623400
H	-1.52993800	-4.15401300	1.09571500
H	-2.10002200	-4.14832800	-0.59239700
H	-0.38354100	-3.84019900	-0.22864100
H	-1.02088200	-1.70218500	0.94586600
C	1.28091300	-1.13572400	-0.13150200
C	1.70473900	-2.45978400	-0.31406000
C	1.52105600	-0.50417000	1.09739000
C	2.37628500	-3.13391600	0.70719700
H	1.53323400	-2.95109900	-1.27413300
C	2.18432000	-1.18131700	2.12240700
H	1.18535100	0.52184900	1.24430400
C	2.61817400	-2.49661200	1.92841900
H	2.71610300	-4.16027800	0.54754900
H	2.36813700	-0.67665000	3.07418300
H	3.14525500	-3.02402800	2.72745200



C

SCF energy[revDSD-PBEP86-D3(BJ)/defTZVP/SMD(methanol)]:-1758.9899801

Charge = 0 Multiplicity = 1

C	2.95145900	-1.32494700	-1.97530800
C	1.54027600	-0.81156200	-1.58992900
C	2.45306600	-2.38764100	0.04987600
H	2.87572600	-2.17879300	-2.66723900
H	3.58250100	-0.56538700	-2.45249800
H	2.70122000	-2.46755900	1.11483200
H	2.27383300	-3.41029600	-0.32670500
C	1.26570800	-1.49838800	-0.26018700
C	0.20890000	-1.40529100	0.57085200
H	0.22526900	-2.04958900	1.45711200

C	-0.98987800	-0.56523800	0.44914600
C	-0.94907700	0.67003600	-0.12675600
H	0.02310000	1.09282500	-0.38888100
C	-2.06167400	1.60219300	-0.38416800
C	-3.39932700	1.11112600	-0.84085900
C	-4.52527500	1.91317700	-0.59183300
C	-3.55595100	-0.09784500	-1.53719000
C	-5.79183600	1.49671300	-0.99923500
H	-4.39462000	2.85684800	-0.05860100
C	-4.82218700	-0.50689700	-1.95764400
H	-2.68578300	-0.71715900	-1.75510200
C	-5.94275500	0.28332500	-1.68104900
H	-6.66581800	2.11648400	-0.78386600
H	-4.93552300	-1.44813900	-2.50090400
H	-6.93527600	-0.04469400	-2.00051000
N	3.56735500	-1.82369100	-0.73139000
S	4.59281000	-0.75922600	0.07676800
O	4.94382000	-1.42314300	1.34168200
O	5.64777400	-0.41157900	-0.88659300
C	3.67483000	0.72074800	0.45103000
C	3.73829900	1.80693900	-0.42562900
C	2.82223200	0.73386300	1.56115100
C	2.92227300	2.91363100	-0.19071700
H	4.41869700	1.78625800	-1.27787600
C	2.01121200	1.84524900	1.77459800
H	2.79332500	-0.11184000	2.24906600
C	2.03986200	2.94789500	0.90148900
H	2.96951600	3.76715500	-0.87155600
H	1.33858000	1.85879900	2.63579300
C	1.11862100	4.11430500	1.11944000
H	1.45835300	5.00680100	0.57379600
H	0.10685700	3.86155400	0.75885100
H	1.03253400	4.36362000	2.18850000
O	-1.86986400	2.81771100	-0.27714700
C	0.50156700	-1.08270700	-2.67882400
H	0.82508900	-0.63411700	-3.63190200
H	0.37447200	-2.16581500	-2.83586700
H	-0.47685100	-0.65399200	-2.42266800
H	1.60628600	0.27355100	-1.42211100
C	-2.22213100	-1.11838500	1.06711300
C	-3.04921900	-0.32375000	1.87900300
C	-2.58648100	-2.45573500	0.83150800
C	-4.23405000	-0.83974000	2.40600200
H	-2.75596300	0.70339100	2.10476300

C	-3.77525200	-2.96904300	1.35165500
H	-1.94835100	-3.08458300	0.20612200
C	-4.60560400	-2.16054300	2.13604400
H	-4.86890400	-0.20810200	3.03233600
H	-4.05789900	-4.00367800	1.14155100
H	-5.53628300	-2.56293500	2.54398800

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