

Supporting Information

Highly Enantioselective One-Pot Sequential Synthesis of Valerolactones and Pyrazolones Bearing All-Carbon Quaternary Stereocenters

Yan-Li Xu,[†] Zhou-Zhou Qin,[†] Yu-Xia Wang,[†] Peng-Fei Zhao,[†] Hong-Feng Li,[†] Zhi-Hong Du,[†]
Chao-Shan Da^{†,‡,*}

[†] Institute of Biochemistry and Molecular Biology, School of Life Sciences, Lanzhou University,
Lanzhou 730000, China

[‡] State Key Laboratory of Applied Organic Chemistry, and Key Lab of Preclinical Study for New
Drugs of Gansu Province, Lanzhou University, Lanzhou 730000, China

dachaoshan@lzu.edu.cn

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1. General Experimental Details

Instrumentations

All reactions were carried out in vials and stirred with a magnetic bar without inert atmosphere unless specified. The reactions were monitored by TLC (thin layer chromatography) method; column and preparative TLC purification were carried out using silica gel. All commercial reagents were purchased with the analysis purity grade. They were used without further purification unless specified. Melting points were uncorrected and recorded on XT- 5 melting point apparatus.

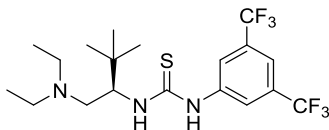
NMR spectra were acquired on a Bruker 400/600 spectrometer, running at 400/600 MHz and 100/151 MHz for ^1H and ^{13}C , respectively. NMR in CDCl_3 , DMSO-d_6 with TMS as an internal standard, chemical shifts (δ) are reported in ppm relative to residual solvent signals (CDCl_3 , 7.26 ppm for ^1H NMR and 77.00 ppm for ^{13}C NMR; DMSO-d_6 , 2.50 ppm for ^1H NMR, 40.00 ppm for ^{13}C NMR). The following abbreviations are used to describe peak patterns when appropriate: s (singlet), d (doublet), t (triplet), q (quartet), quint (quintet), sept (septuplet), m (multiplet), br (broad). High Resolution Mass Spectra (HR-MS) were measured with ESI-Orbitrap mass spectrometer. Enantiomeric excess (ee) were decided with chiral HPLC, Waters 1525 Binary HPLC Pump/Waters 2998 Photodiode Array Detector of Lanzhou University State Key Laboratory of Applied Organic Chemistry.

Crystal data was collected by SuperNova, Dual, Cu at zero, Eos diffractometer, the structure was solved with the ShelXS structure solution program using Direct Methods and refined with the ShelXL refinement package using Least Squares minimisation. All products in this text, if not stated otherwise, are oily liquids.

The α -acyl δ -valerolactone was prepared according to the disclosed method in literature.¹ The vinyl ketone was prepared according to the reported procedure.²

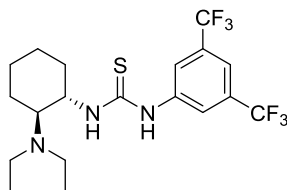
2. Preparation and characterization of catalysis L

Thiourea L1 was prepared by the literature procedure.³



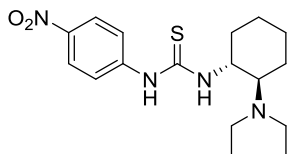
L1: White solid, mp 114.5 – 114.8 °C, $[\alpha]_D^{24} = -13.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, CDCl₃) δ 13.14 (s, 1 H), 8.00 (s, 2 H), 7.58 (s, 1 H), 6.24 (d, *J* = 6.0 Hz, 1 H), 3.44 – 3.42 (m, 1 H), 2.85 – 2.79 (m, 2 H), 2.76 (d, *J* = 13.8 Hz, 1 H), 2.65 – 2.57 (m, 3 H), 1.10 (t, *J* = 7.2 Hz, 6 H), 1.06 (s, 9 H). ¹⁹F NMR (CDCl₃, 376 MHz) δ - 62.05 (s, 6 F).

Thiourea L2 was prepared by the literature procedure.⁴



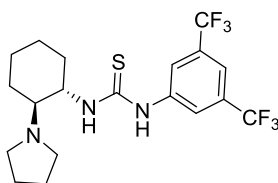
L2: White solid, mp 143.7 – 144.3 °C, $[\alpha]_D^{26} = -25.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 10.04 (s, 1H), 8.21 (s, 2H), 7.84 (s, 1H), 7.64 (s, 1H), 4.07 (s, 1H), 2.61 – 2.60 (m, 3H), 2.27 (s, 3H), 1.78 – 1.59 (m, 3H), 1.20 – 1.11 (m, 4H), 0.93 (t, *J* = 6.6 Hz, 6H).

Thiourea L3 was prepared by the literature procedure.⁵



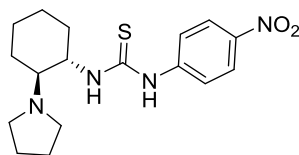
L3: Yellow solid, mp 109.9 - 111.7 °C, $[\alpha]_D^{26} = -41.0$ (c 1.0, CHCl₃); ¹H NMR (CDCl₃, 400 MHz) δ 8.19 (d, *J* = 8.0 Hz, 2 H), 7.47 (d, *J* = 8.0 Hz, 2 H), 3.84 (t, *J* = 12.0 Hz, 1 H), 2.53 - 2.75 (m, 4 H), 2.32 - 2.39 (m, 2 H), 1.70 - 1.89 (m, 3 H), 1.06 - 1.23 (m, 4 H), 0.93 - 0.96 (m, 6 H).

Thiourea L4 was prepared by the literature procedure.⁶



L4: White solid, mp 115.9 - 117.6 °C, $[\alpha]_D^{26} = +3.6$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, CDCl₃) δ 7.88 (s, 2H), 7.61 (s, 1H), 2.03 (s, 1H), 1.96 (d, *J* = 10.8 Hz, 1H), 1.86 – 1.65 (m, 9H), 1.41 – 1.14 (m, 8H).

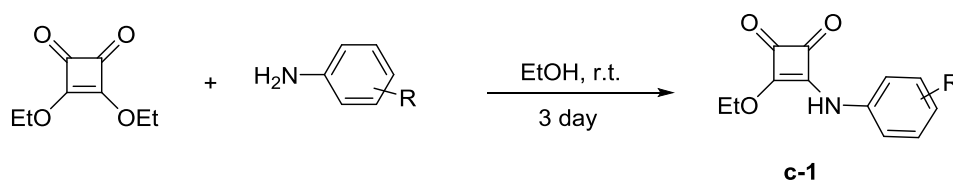
Thiourea L5 was prepared by the literature procedure.⁷



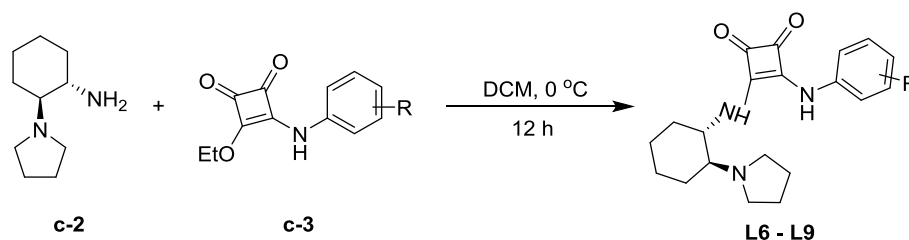
L5: Yellow solid, mp 133.5 - 134.1 °C, $[\alpha]_D^{24} = +11.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 10.04 (s, 1 H), 8.34 (s, 1 H), 8.11 (d, *J* = 9.0 Hz, 2 H), 7.78 (d, *J* = 9.6 Hz, 2 H), 4.14 (s, 1 H), 2.70 –

2.47 (m, 5 H), 2.11 (d, $J = 9.0$ Hz, 1 H), 1.77 (d, $J = 12.0$ Hz, 1 H), 1.71 – 1.58 (m, 6 H), 1.37 – 1.14 (m, 4 H).

3. Preparation of catalyst L6 - L9.⁵

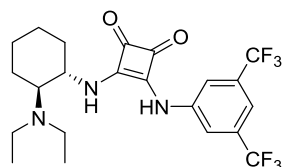


Dissolved substituted aniline (5.0 mmol) in dry ethanol, slowly added dropwise anhydrous ethanol solution of diethyl squarate (5.5 mmol, 935 mg) in the ethanol mixture, stirred at room temperature for three days. The mixture was directly filtered to obtain product after the reaction finished with the TLC check. The filtered product was directly used in the following steps without further purification.



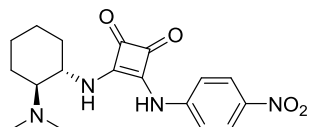
Added a solution of **c-2** (3.3 mmol, 554 mg) in DCM (2.0 mL) to **c-3** (3.3 mmol) in anhydrous DCM (5.0 mL) at 0 °C, slowly warmed up the reaction mixture to room temperature and stirred for 12 h to complete checked by TLC. The mixture was concentrated under reduced pressure, and the resulted residue was purified by preparative silica gel column chromatography (DCM : MeOH = 20:1) to obtain the squaramides **L6 - L9**.

Squaramide L6.⁵



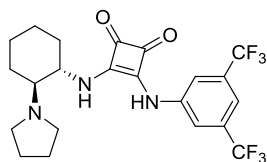
L6: White solid, mp 232.5 – 233.1 °C, $[\alpha]_D^{26} = -16.2$ (c 0.50, EtOH); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.95 (s, 2H), 7.40 (s, 1H), 4.12 (s, 1H), 2.66 (s, 2H), 2.43 (s, 2H), 2.16 – 1.73 (m, 5H), 1.50 – 1.19 (m, 5H), 0.96 (s, 6H).

Squaramide L7.⁸



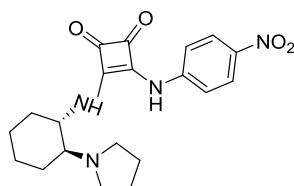
L7: Yellow solid, mp 191.8 - 192.3 °C, $[\alpha]_D^{24} = -15.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, DMSO-d_6) δ 10.70 (s, 1 H), 8.19 (d, $J = 8.4$ Hz, 2 H), 7.64 (d, $J = 8.4$ Hz, 2 H), 3.92 (s, 1 H), 2.28 (s, 6 H), 2.06 (d, $J = 12.0$ Hz, 1 H), 1.88 (s, 1H), 1.74 (s, 1 H), 1.65 (s, 1 H), . 1.43 – 1.19 (m, 6H).

Squaramide L8.⁹



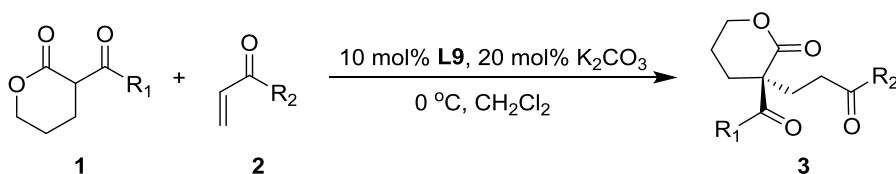
L8: Yellow solid, mp 238.0 - 238.9 °C, $[\alpha]_D^{24} = +2.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 10.15 (s, 1 H), 8.03 (s, 2 H), 7.74 (s, 1 H), 7.61 (s, 1 H), 3.94 (s, 1 H), 2.60 (d, *J* = 7.2 Hz, 2 H), 2.51 – 2.47 (m, 2 H), 2.02 (s, 1 H), 1.80 – 1.78 (m, 1 H), 1.71 – 1.69 (m, 1 H), 1.60 – 1.56 (m, 5 H), 1.39 – 1.23 (m, 4 H).

Squaramide L9



L9: A red-brown solid (775 mg, 61% yield), mp 179.5 - 180.2 °C, $[\alpha]_D^{24} = -33.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 10.47 (s, 1 H), 8.21 (d, *J* = 7.8 Hz, 2 H), 7.66 (d, *J* = 8.4 Hz, 2 H), 4.03 (q, *J* = 14.4, 7.2 Hz, 1 H), 2.72 (s, 4 H), 2.04 (d, *J* = 10.2 Hz, 1 H), 1.91 (s, 1 H), 1.73 – 1.67 (m, 7 H), 1.47 – 1.43 (m, 3 H), 1.36 – 1.27 (m, 3 H). ¹³C NMR (150 MHz, DMSO-d₆) δ 185.5, 180.3, 170.3, 162.3, 145.8, 141.8, 126.1, 118.1, 62.8, 55.9, 48.0, 33.0, 23.8, 23.2. HRMS (ESI-Orbitrap) *m/z*: $[M+H]^+$ Calcd for C₂₀H₂₅N₄O₄ 385.1880, found 385.1870.

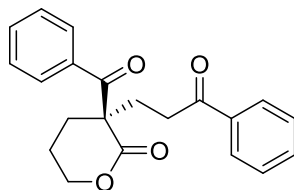
4. General procedure for the catalytic asymmetric synthesis of enantioenriched α -acyl- α -alkyl δ -valerolactones



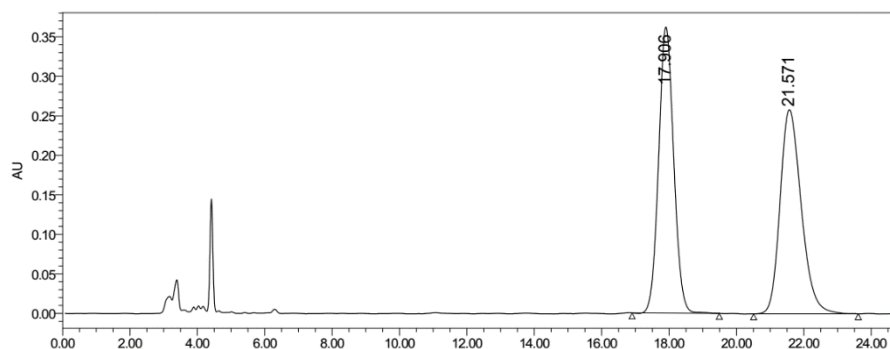
To the mixture of the lactone **1** (0.1 mmol), the catalyst **L9** (3.8 mg, 0.01 mmol), and K₂CO₃ (2.76 mg, 0.02 mmol) in analytical purity grade dichloromethane (0.5 mL) was added the vinyl ketone **2** (0.12 mmol). The reaction was stirred for 3 to 6 days at 0 °C to complete checked by TLC. The mixture was directly submitted to preparative silica gel column chromatography (petroleum ether : ethyl acetate = 8:1 to 3:1) to furnish the α -acyl- α -alkyl δ -valerolactones **3**.

5. Characterization of compounds 3a – 3y, 3 α , 3 β .

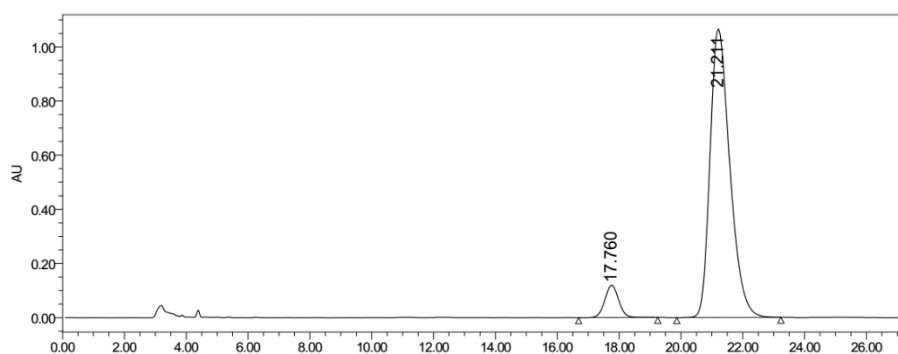
(S)-3-Benzoyl-3-(3-oxo-3-phenylpropyl)tetrahydro-2H-pyran-2-one (3a)



The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 30.2 mg, 90% yield, colorless oil, $[\alpha]_D^{24} = +3.0$ (c 1.0, CHCl₃); ¹H NMR (300 MHz, CDCl₃) δ 7.88 – 7.81 (m, 4 H), 7.50 – 7.30 (m, 6 H), 4.40 – 4.33 (m, 1 H), 4.18 – 4.09 (m, 1 H), 3.13 – 2.88 (m, 2 H), 2.69 – 2.59 (m, 1 H), 2.49 (t, *J* = 7.8 Hz, 2 H), 2.10 – 1.85 (m, 2 H), 1.77 – 1.68 (m, 1 H). ¹³C NMR (100 MHz, CDCl₃) δ 199.0, 196.2, 172.5, 136.6, 134.7, 133.4, 133.1, 129.0, 128.8, 128.5, 128.0, 68.1, 57.3, 33.8, 30.6, 28.9, 19.8. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₁H₂₁O₄ 377.1434; found 377.1438. The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 242.8 nm; retention time: 17.8 min (minor) and 21.2 min (major)

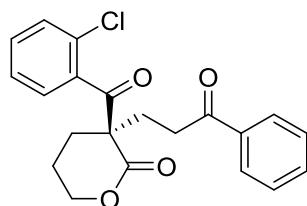


	Name	retention time (min)	Area (μ V*s)	Height (μ V)	% Area
1		17.906	11241832	362001	49.93
2		21.571	11274395	258261	50.07



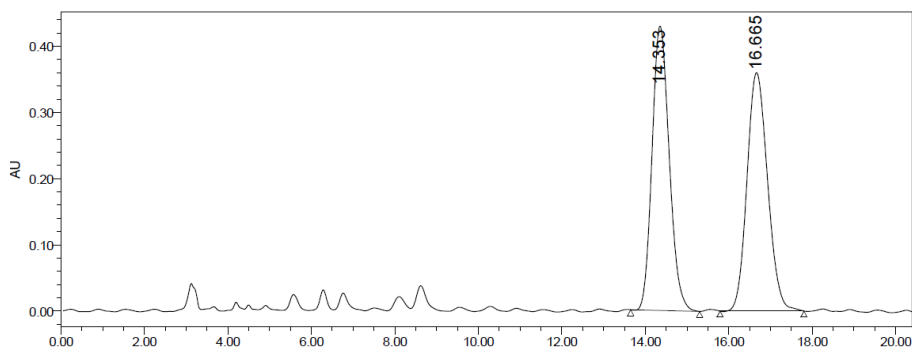
	Name	Retention time (min)	Area (μ V*s)	Height (μ V)	% Area
1		17.760	3691208	119209	7.23
2		21.211	47370728	1064628	92.77

(S)-3-(2-Chlorobenzoyl)-3-(3-oxo-3-phenylpropyl)tetrahydro-2H-pyran-2-one (3b)

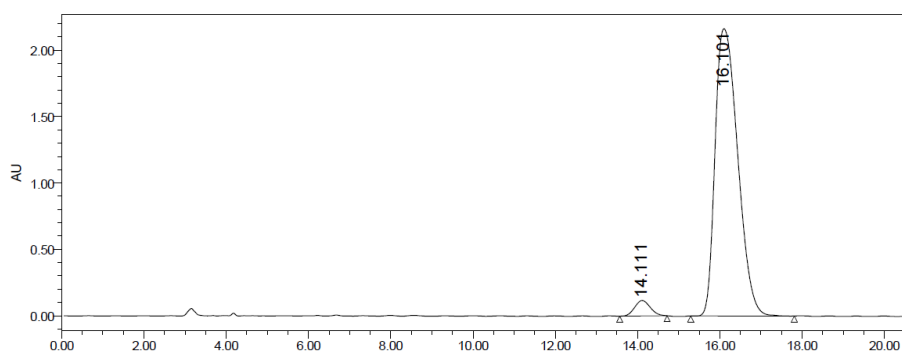


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 36.3 mg, 98% yield, colorless oil, $[\alpha]_D^{23} = +41.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.96 – 7.94 (m, 2 H), 7.57 – 7.55 (m, 1 H), 7.46 (t, $J = 7.8$ Hz, 2 H), 7.43 – 7.40 (m, 2 H), 7.39 – 7.36 (m, 1 H), 7.32 – 7.29 (m, 1 H), 4.46 – 4.42 (m, 1 H), 4.41 – 4.37 (m, 1 H), 3.17 – 3.07 (m, 2 H), 2.64 – 2.55 (m, 2 H), 2.50 – 2.45 (m, 1 H), 2.06 – 1.94 (m, 3 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 200.4, 198.6, 170.3, 138.0, 136.5, 133.2, 131.2, 130.5, 130.3, 128.6, 128.1, 127.5, 126.7, 69.9, 60.3, 33.8, 30.7, 28.1, 20.5. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{21}\text{H}_{20}\text{ClO}_4$ 371.1045, found 371.1053.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 240.4 nm; retention time: 14.1 min (minor) and 16.1 min (major)

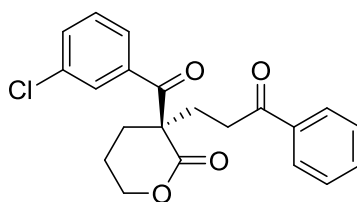


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		14.353	12283881	429427	49.86
2		16.665	12355188	360151	50.14



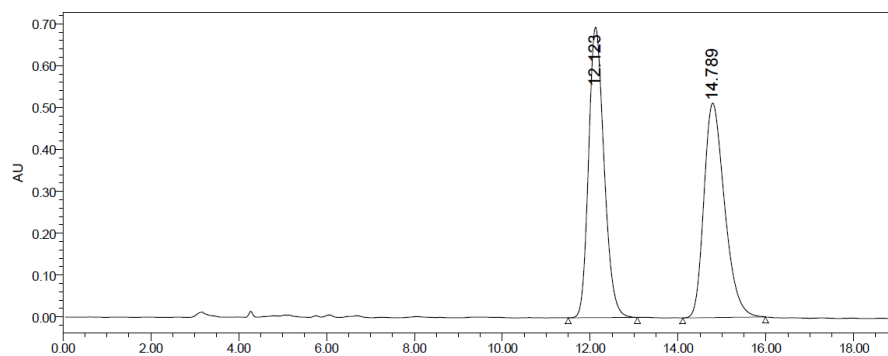
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		14.111	3059447	116380	3.57
2		16.101	82722098	2164615	96.43

(S)-3-(3-Chlorobenzoyl)-3-(3-oxo-3-phenylpropyl)tetrahydro-2H-pyran-2-one (3c)

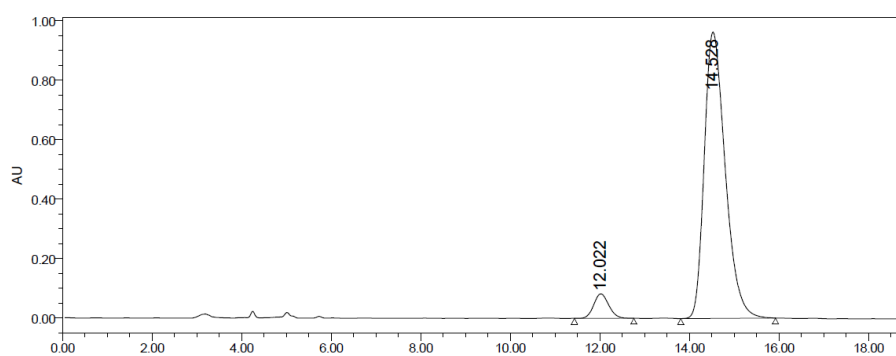


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 36.6 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +18.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.94 – 7.92 (m, 2 H), 7.83 – 7.81 (m, 1 H), 7.56 – 7.53 (m, 2 H), 7.48 – 7.42 (m, 2 H), 7.40 (t, $J = 7.8$ Hz, 1 H), 4.51 – 4.47 (m, 1 H), 4.27 – 4.23 (m, 1 H), 3.19 – 3.14 (m, 1 H), 3.06 – 3.00 (m, 1 H), 2.70 – 2.66 (m, 1 H), 2.60 – 2.57 (m, 2 H), 2.23 – 2.12 (m, 1 H), 2.03 – 1.97 (m, 1 H), 1.87 – 1.82 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 198.9, 195.2, 172.0, 136.6, 136.4, 135.2, 133.3, 133.2, 130.0, 129.2, 128.6, 128.0, 126.8, 68.4, 57.3, 33.7, 30.6, 29.0, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{21}\text{H}_{20}\text{ClO}_4$ 371.1042, found 371.1045.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 242.8 nm; retention time: 12.0 min (minor) and 14.5 min (major)

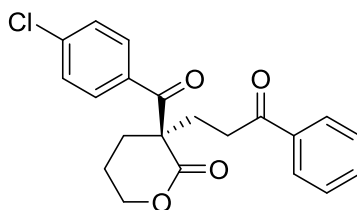


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	12.123	16899493	693231	50.19
2	14.789	16772410	512078	49.81



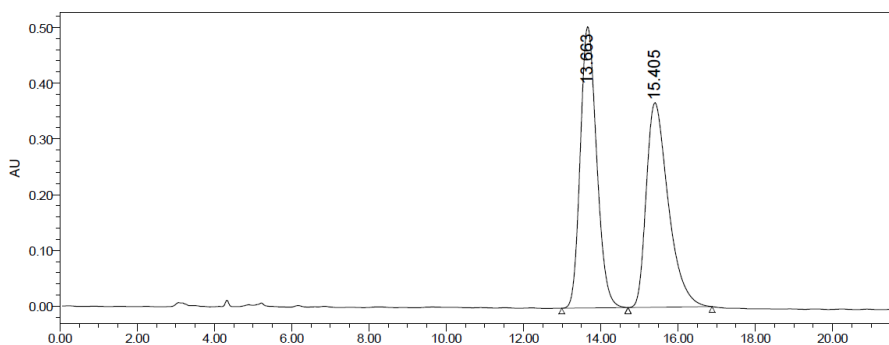
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	12.022	1918255	82695	5.78
2	14.528	31288316	963520	94.22

(S)-3-(4-Chlorobenzoyl)-3-(3-oxo-3-phenylpropyl)tetrahydro-2H-pyran-2-one (3d)

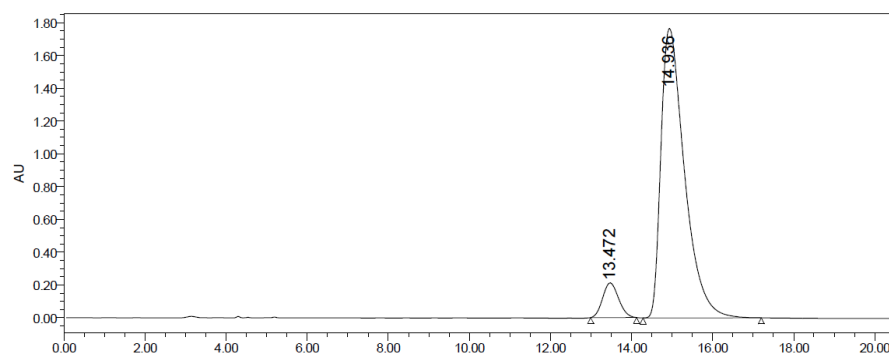


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 36.6 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +27.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.92 – 7.91 (m, 4 H), 7.55 – 7.53 (m, 1 H), 7.44 – 7.42 (m, 4 H), 4.48 – 4.44 (m, 1 H), 4.22 – 4.18 (m, 1 H), 3.18 – 3.12 (m, 1 H), 3.04 – 2.98 (m, 1 H), 2.73 – 2.68 (m, 1 H), 2.58 (t, $J = 7.2$ Hz, 2 H), 2.18 – 2.10 (m, 1 H), 2.02 – 1.96 (m, 1 H), 1.84 – 1.80 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 198.8, 195.0, 172.3, 140.0, 136.6, 133.1, 133.0, 130.4, 129.1, 128.5, 128.0, 68.2, 57.3, 33.7, 30.6, 28.7, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{21}\text{H}_{20}\text{ClO}_4$ 371.1042, found 371.1045.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 247.5 nm; retention time: 13.5 min (minor) and 14.9 min (major)

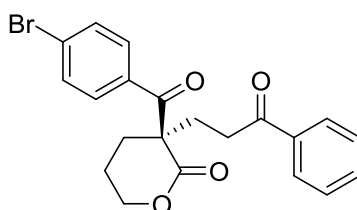


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	13.663	14853131	504310	50.52
2	15.405	14548808	366722	49.48



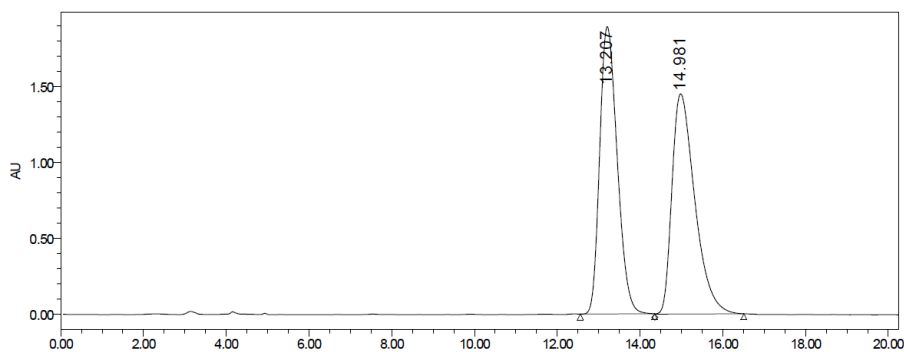
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	13.472	5753712	210905	7.48
2	14.936	71182206	1765022	92.52

(S)-3-(4-Bromobenzoyl)-3-(3-oxo-3-phenylpropyl)tetrahydro-2H-pyran-2-one (3e)

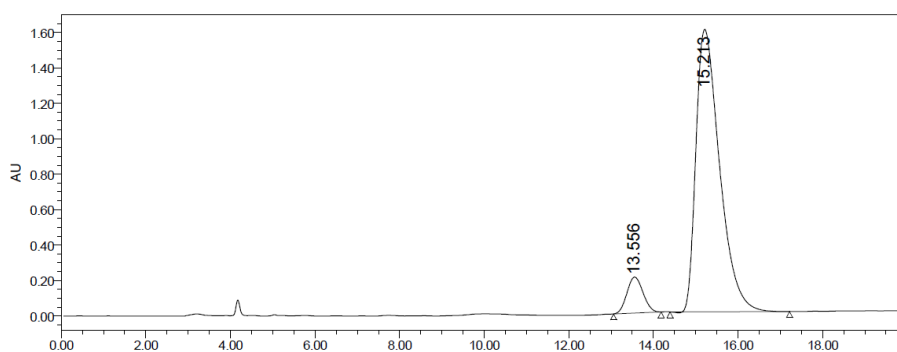


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 39.6 mg, 96% yield, colorless oil, $[\alpha]_D^{23} = +52.0$ (c 1.0, CHCl_3); ^1H NMR (600 MHz, CDCl_3) δ 7.88 – 7.86 (m, 2 H), 7.72 – 7.70 (m, 2 H), 7.51 – 7.48 (m, 3 H), 7.39 (t, $J = 7.8$ Hz, 2 H), 4.41 – 4.38 (m, 1 H), 4.20 – 4.16 (m, 1 H), 3.08 – 3.02 (m, 1 H), 2.97 – 2.91 (m, 1 H), 2.66 – 2.61 (m, 1 H), 2.53 – 2.45 (m, 2 H), 2.11 – 2.03 (m, 1 H), 1.95 – 1.89 (m, 1 H), 1.77 – 1.73 (m, 1 H). ^{13}C NMR (150 MHz, CDCl_3) δ 198.0, 196.2, 172.3, 135.3, 134.7, 133.4, 131.8, 129.6, 129.0, 128.8, 128.2, 68.3, 57.1, 33.8, 30.5, 29.1, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{21}\text{H}_{20}\text{BrO}_4$ 415.0537, found 415.0539.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 247.5 nm; retention time: 13.6 min (minor) and 15.2 min (major)

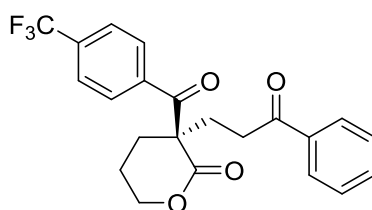


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		13.207	55596224	1894236	49.96
2		14.981	55688384	1452224	50.04



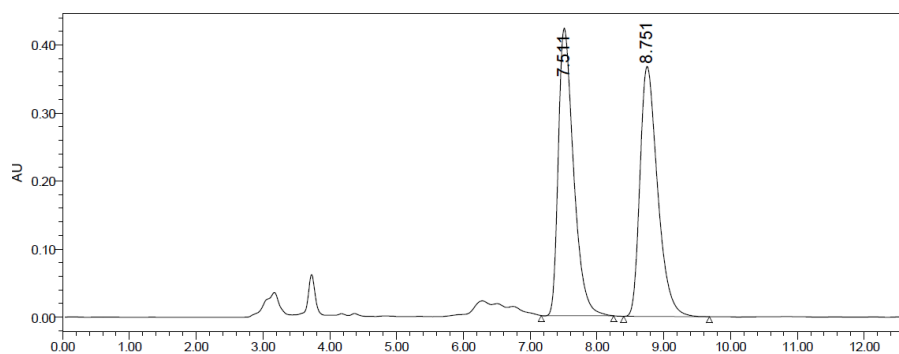
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		13.556	5349285	202728	7.95
2		15.213	61915332	1593212	92.05

(S)-3-(3-Oxo-3-phenylpropyl)-3-(4-(trifluoromethyl)benzoyl)tetrahydro-2H-pyran-2-one (3f)

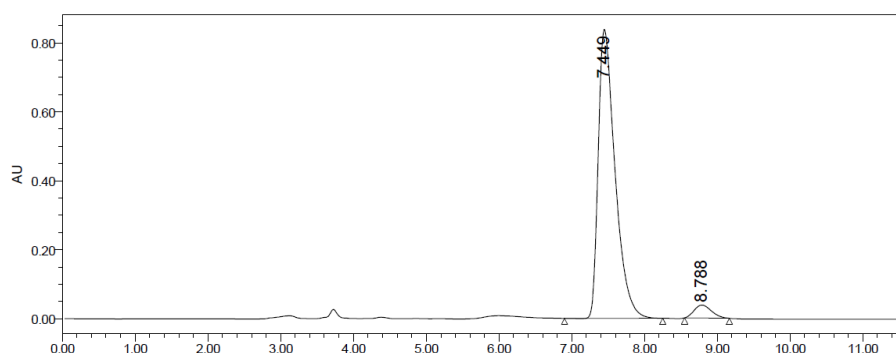


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 40.0 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +6.0$ (c 1.0, CHCl_3); ^1H NMR (600 MHz, CDCl_3) δ 8.04 (d, $J = 8.4$ Hz, 2 H), 7.92 (d, $J = 7.2$ Hz, 2 H), 7.72 (d, $J = 8.4$ Hz, 2 H), 7.54 (t, $J = 7.2$ Hz, 1 H), 7.43 (t, $J = 7.8$ Hz, 2 H), 4.52 – 4.49 (m, 1 H), 4.32 – 4.24 (m, 1 H), 3.20 – 3.15 (m, 1 H), 3.07 – 3.01 (m, 1 H), 2.69 – 2.63 (m, 1 H), 2.62 – 2.56 (m, 2 H), 2.22 – 2.13 (m, 1 H), 2.04 – 1.99 (m, 1 H), 1.90 – 1.85 (m, 1 H). ^{13}C NMR (150 MHz, CDCl_3) δ 198.8, 195.8, 171.8, 142.9, 137.8, 136.6, 134.6, 134.4, 133.2, 129.3, 128.8, 128.6, 128.0, 125.8, 124.3, 122.5, 68.5, 57.5, 33.7, 30.5, 28.9, 19.9. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{20}\text{F}_3\text{O}_4$ 405.1309, found 405.1308.

The ee was determined by HPLC analysis. CHIRALPAK OD-H; Hexane/2-propanol = 65/35; flow rate 1.0 mL/min; 279.5 nm; retention time: 7.4 min (minor) and 8.8 min (major)

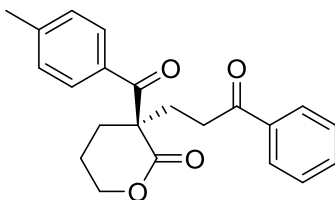


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		7.511	6698140	422577	49.88
2		8.751	6730381	367656	50.12



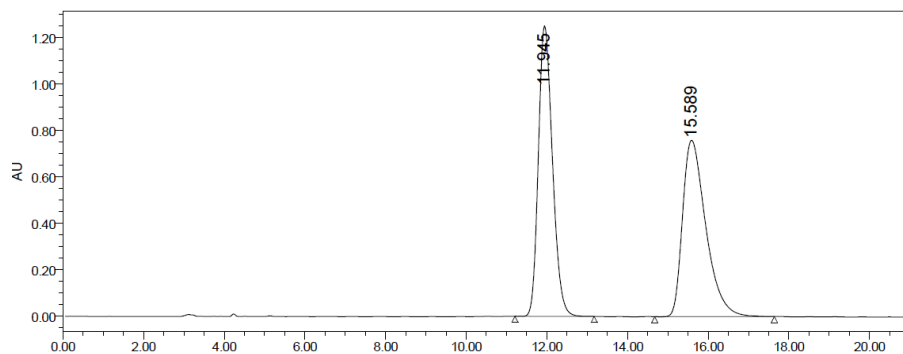
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		7.449	13430563	837477	95.56
2		8.788	623759	37786	4.44

(S)-3-(4-Methylbenzoyl)-3-(3-oxo-3-phenylpropyl)tetrahydro-2H-pyran-2-one (3g)

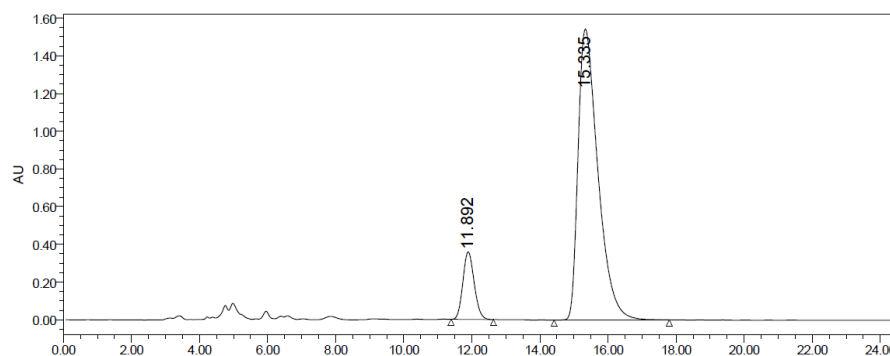


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 31.9 mg, 91% yield, white solid, mp 209.6 - 201.7 °C, $[\alpha]_D^{23} = +60.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, CDCl₃) δ 7.93 – 7.91 (m, 2 H), 7.88 (d, *J* = 8.4 Hz, 2 H), 7.54 – 7.52 (m, 1 H), 7.42 (t, *J* = 7.8 Hz, 2 H), 7.25 (d, *J* = 8.4 Hz, 2 H), 4.44 – 4.40 (m, 1 H), 4.21 – 4.16 (m, 1 H), 3.17 – 3.11 (m, 1 H), 3.05 – 2.99 (m, 1 H), 2.79 – 2.74 (m, 1 H), 2.59 – 2.56 (m, 2 H), 2.40 (s, 3 H), 2.15 – 2.08 (m, 1 H), 2.00 – 1.95 (m, 1 H), 1.81 – 1.77 (m, 1 H). ¹³C NMR (150 MHz, CDCl₃) δ 199.0, 195.7, 172.8, 144.5, 136.7, 133.1, 132.2, 129.5, 129.2, 128.5, 128.0, 67.9, 57.3, 33.8, 30.7, 28.7, 21.6, 19.8. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₂H₂₃O₄ 351.1588, found 351.1591.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 247.5 nm; retention time: 11.9 min (minor) and 15.3 min (major)

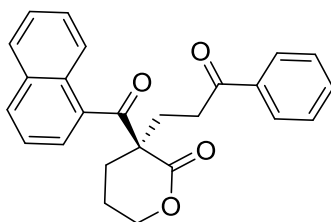


Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	11.945	30347962	1249458	49.96
2	15.589	30401806	759290	50.04



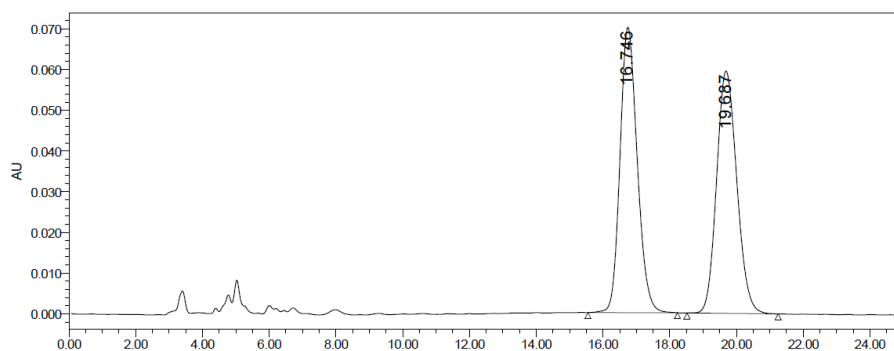
Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	11.892	8275867	358046	11.72
2	15.335	62349539	1542356	88.28

(S)-3-(1-Naphthoyl)-3-(3-oxo-3-phenylpropyl)tetrahydro-2H-pyran-2-one (3h)

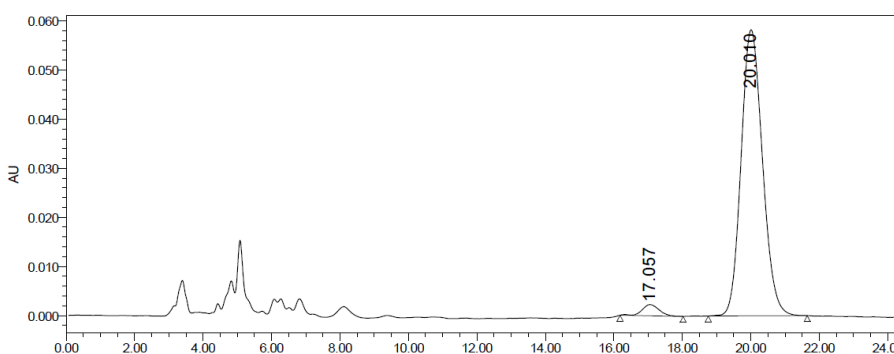


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 38.2 mg, 99% yield, white solid, mp 117.6 - 118.0 °C, $[\alpha]_D^{23} = +1.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, CDCl₃) δ 8.08 (d, *J* = 8.4 Hz, 1 H), 7.96 (d, *J* = 7.8 Hz, 1 H), 7.92 – 7.90 (m, 2 H), 7.88 (d, *J* = 7.8 Hz, 1 H), 7.80 (d, *J* = 7.2 Hz, 1 H), 7.59 – 7.52 (m, 3 H), 7.47 (t, *J* = 7.8 Hz, 1 H), 7.42 (t, *J* = 7.8 Hz, 2 H), 4.39 – 4.36 (m, 1 H), 4.27 – 4.23 (m, 1 H), 3.24 – 3.19 (m, 1 H), 3.17 – 3.11 (m, 1 H), 2.75 – 2.70 (m, 1 H), 2.66 – 2.61 (m, 1 H), 2.56 – 2.51 (m, 1 H), 2.07 – 1.92 (m, 3 H). ¹³C NMR (150 MHz, CDCl₃) δ 201.1, 198.9, 171.6, 136.6, 134.9, 133.9, 133.1, 132.1, 130.4, 128.8, 128.6, 128.1, 128.0, 126.6, 125.4, 124.8, 124.2, 68.8, 60.3, 34.0, 31.2, 28.8, 20.3. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₅H₂₃O₄ 387.1589, found 387.1591.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 314.7 nm; retention time: 17.1 min (minor) and 20.0 min (major)

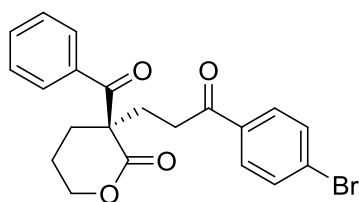


Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	16.746	2513298	70144	50.13
2	19.687	2500261	59560	49.87



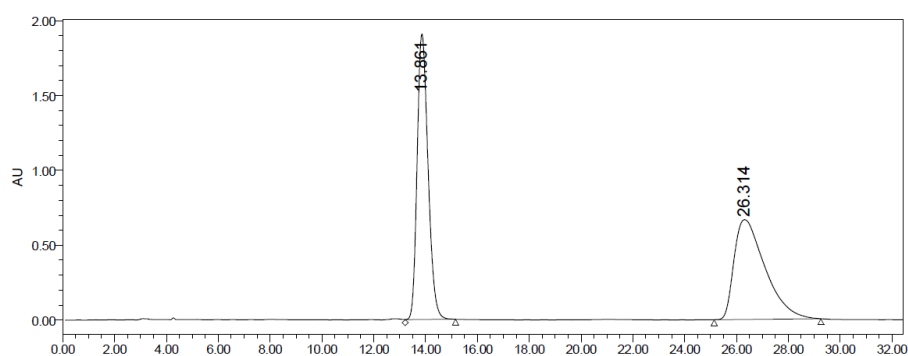
Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	17.057	77748	2277	2.99
2	20.010	2526781	58249	97.01

(S)-3-Benzoyl-3-(3-(4-bromophenyl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3i)

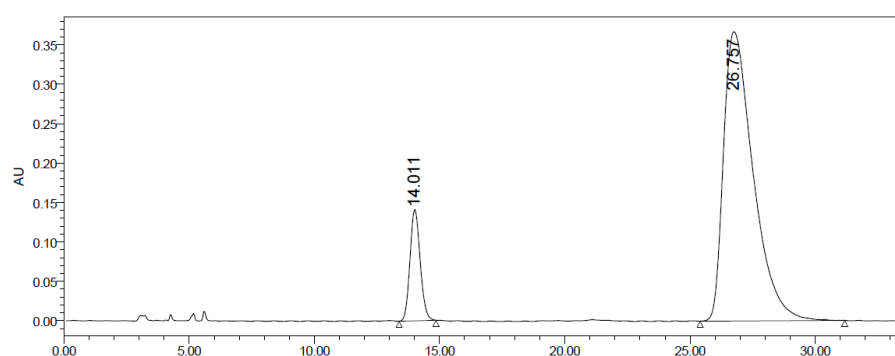


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 41.0 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +25.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.95 – 7.94 (m, 2 H), 7.80 – 7.78 (m, 2 H), 7.59 – 7.55 (m, 2 H), 7.47 – 7.45 (m, 2 H), 4.49 – 4.46 (m, 1 H), 4.28 – 4.23 (m, 1 H), 3.15 – 3.10 (m, 1 H), 3.04 – 2.99 (m, 1 H), 2.74 – 2.69 (m, 1 H), 2.61 – 2.53 (m, 2 H), 2.19 – 2.11 (m, 1 H), 2.03 – 1.97 (m, 1 H), 1.85 – 1.80 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 198.0, 196.2, 172.4, 135.4, 134.7, 133.5, 131.8, 129.6, 129.0, 128.8, 128.3, 68.3, 57.2, 33.9, 30.6, 29.1, 19.8. HRMS (ESI - Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{21}\text{H}_{20}\text{BrO}_4$ 415.0547, found 415.0539.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 252.2 nm; retention time: 14.0 min (minor) and 26.8 min (major)

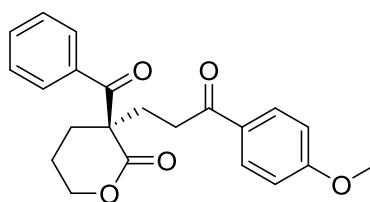


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		13.861	55712945	1906143	50.16
2		26.314	55361823	666436	49.84



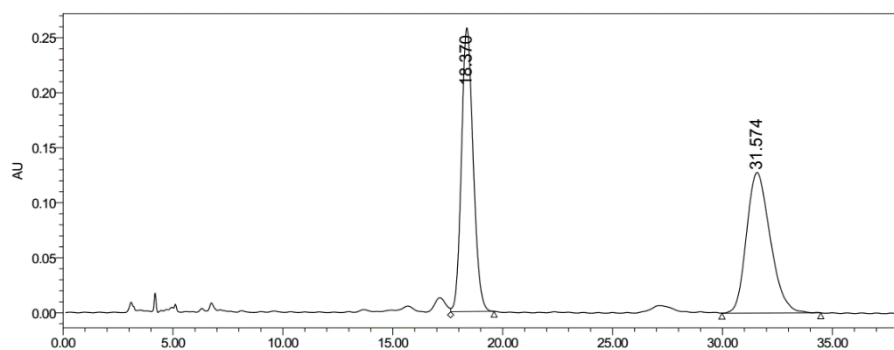
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		14.011	3987854	140835	11.65
2		26.757	30236625	366875	88.35

(S)-3-Benzoyl-3-(3-(4-methoxyphenyl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3j)

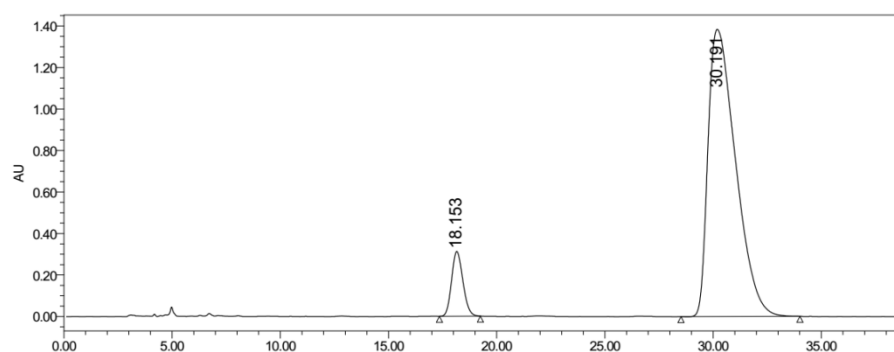


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 35.8 mg, 98% yield, colorless oil, $[\alpha]_D^{23} = +51.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.97 – 7.95 (m, 2 H), 7.92 – 7.90 (m, 2 H), 7.58 – 7.55 (m, 1 H), 7.47 – 7.44 (m, 2 H), 6.91 – 6.88 (m, 2 H), 4.46 – 4.42 (m, 1 H), 4.24 – 4.19 (m, 1 H), 3.85 (s, 3 H), 3.13 – 3.07 (m, 1 H), 3.00 – 2.95 (m, 1 H), 2.76 – 2.71 (m, 1 H), 2.60 – 2.55 (m, 2 H), 2.16 – 2.09 (m, 1 H), 2.02 - 1.96 (m, 1 H), 1.84 – 1.80 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 197.5, 196.3, 172.5, 163.5, 134.9, 133.4, 130.3, 129.7, 129.0, 128.8, 113.7, 68.1, 57.5, 55.4, 33.4, 30.9, 28.8, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{23}\text{O}_5$ 367.1540, found 367.1548.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 255.8 nm; retention time: 18.2 min (minor) and 30.2 min (major)

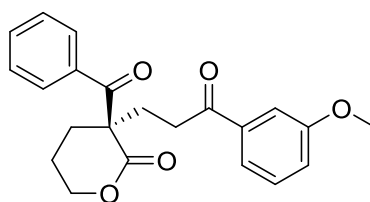


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	18.370	9566778	257976	49.94
2	31.574	9589112	127811	50.06



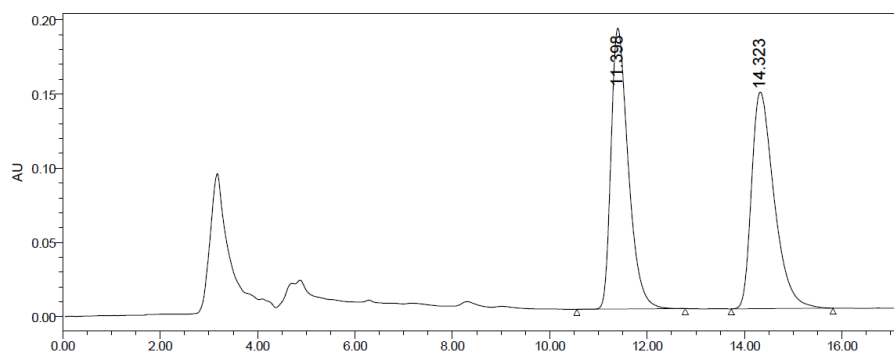
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	18.153	11347811	311915	8.49
2	30.191	122330038	1383601	91.51

(S)-3-Benzoyl-3-(3-(3-methoxyphenyl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3k)

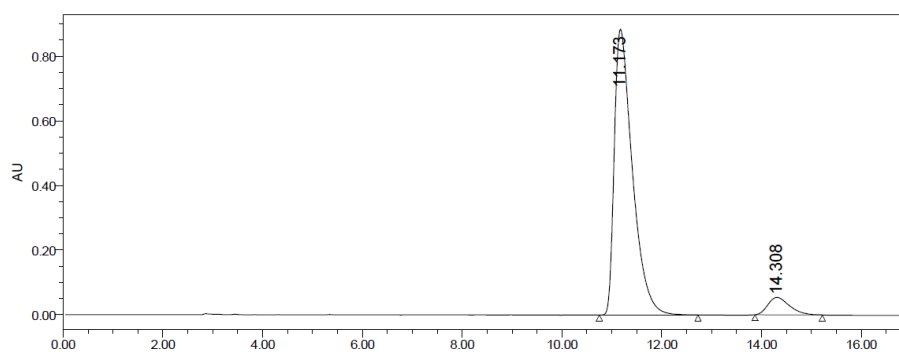


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 35.5 mg, 97% yield, colorless oil, $[\alpha]_D^{23} = +32.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.97 – 7.95 (m, 2 H), 7.57 (t, $J = 7.2$ Hz, 1 H), 7.50 (d, $J = 7.8$ Hz, 1 H), 7.47 – 7.44 (m, 3 H), 7.33 (t, $J = 7.8$ Hz, 1 H), 7.09 – 7.07 (m, 1 H), 4.46 – 4.43 (m, 1 H), 4.24 – 4.20 (m, 1 H), 3.83 (s, 3 H), 3.17 – 3.11 (m, 1 H), 3.05 – 2.99 (m, 1 H), 2.76 – 2.72 (m, 1 H), 2.61 – 2.55 (m, 2 H), 2.17 – 2.09 (m, 1 H), 2.02 – 1.96 (m, 1 H), 1.84 – 1.79 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 198.8, 196.2, 172.5, 159.8, 138.0, 134.8, 133.4, 129.5, 129.0, 128.8, 120.7, 119.7, 112.2, 68.1, 57.4, 55.4, 33.9, 30.8, 28.8, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{23}\text{O}_5$ 367.1540, found 367.1544.

The ee was determined by HPLC analysis. CHIRALPAK OD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 303.2 nm; retention time: 11.2 min (minor) and 14.3 min (major)

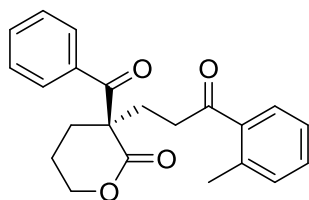


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	11.398	4661314	189169	49.79
2	14.323	4700570	145995	50.21



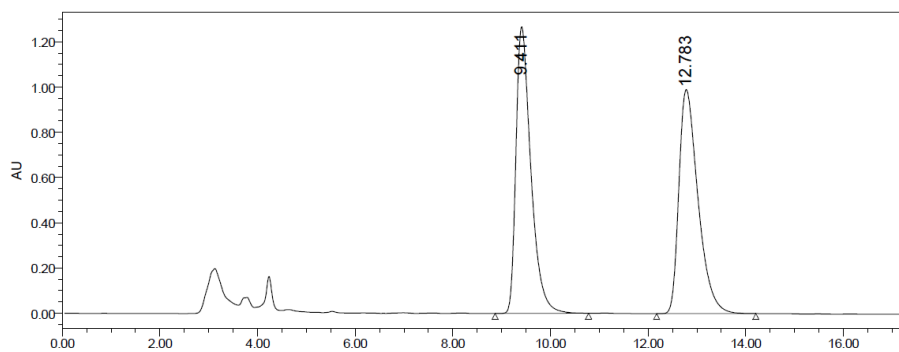
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	11.173	22312873	884577	93.20
2	14.308	1629096	53861	6.80

(S)-3-Benzoyl-3-(3-oxo-3-(o-tolyl)propyl)tetrahydro-2H-pyran-2-one (3l)

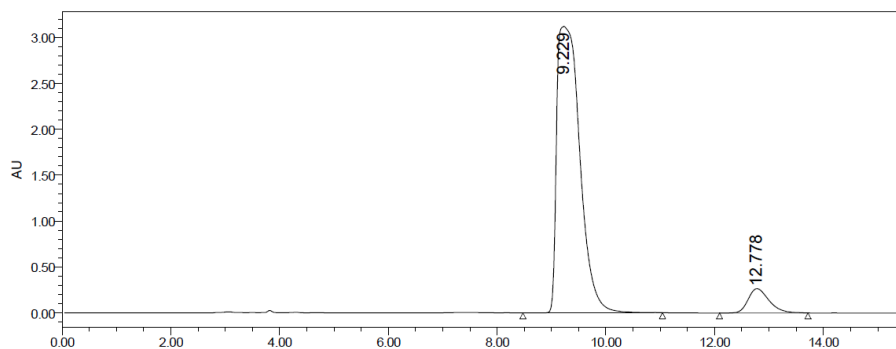


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 34.7 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +36.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.95 – 7.94 (m, 2 H), 7.61 – 7.60 (m, 1 H), 7.57 – 7.55 (m, 1 H), 7.46 – 7.44 (m, 2 H), 7.35 – 7.32 (m, 1 H), 7.22 – 7.19 (m, 2 H), 4.47 – 4.44 (m, 1 H), 4.24 – 4.20 (m, 1 H), 3.09 – 3.04 (m, 1 H), 3.00 – 2.94 (m, 1 H), 2.75 – 2.70 (m, 1 H), 2.62 – 2.53 (m, 2 H), 2.46 (s, 3 H), 2.18 – 2.10 (m, 1 H), 2.02 – 1.96 (m, 1 H), 1.83 – 1.78 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 202.8, 196.2, 172.5, 138.0, 137.5, 134.8, 133.4, 131.8, 131.3, 129.0, 128.8, 128.5, 125.6, 68.1, 57.3, 36.5, 30.7, 28.9, 21.2, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{23}\text{O}_4$ 351.1591, found 351.1598.

The ee was determined by HPLC analysis. CHIRALPAK OD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 243.9 nm; retention time: 9.2 min (minor) and 12.8 min (major)

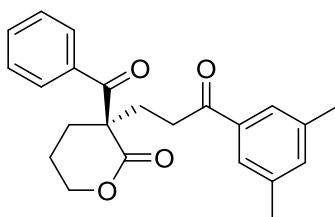


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	9.411	26896488	1266005	49.97
2	12.783	26930010	989852	50.03



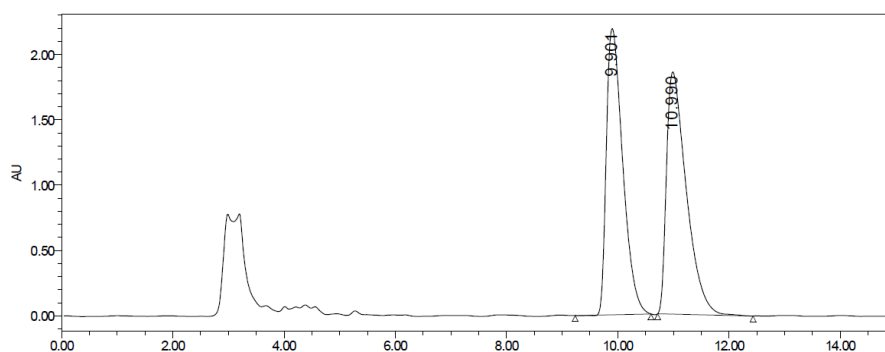
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	9.229	91947222	3120816	92.93
2	12.778	6994347	264142	7.07

(S)-3-benzoyl-3-(3-(3,5-dimethylphenyl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3m)

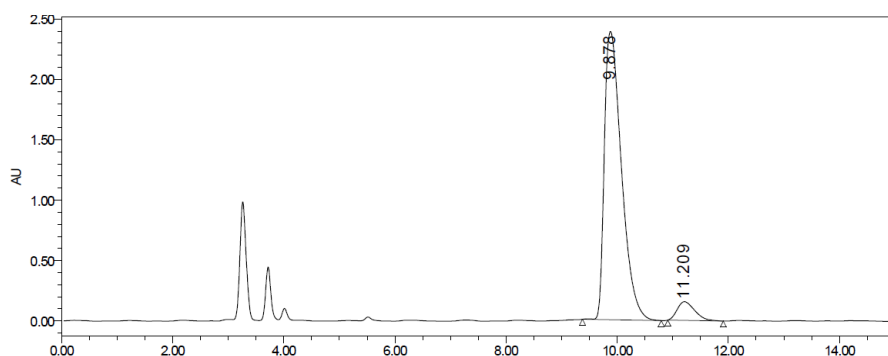


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 36.0 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +45.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.98 – 7.96 (m, 2 H), 7.58 – 7.55 (m, 1 H), 7.52 (s, 2 H), 7.46 (t, $J = 7.8$ Hz, 2 H), 7.16 (s, 1 H), 4.46 – 4.43 (m, 1 H), 4.24 – 4.20 (m, 1 H), 3.15 – 3.09 (m, 1 H), 3.03 – 2.98 (m, 1 H), 2.77 – 2.72 (m, 1 H), 2.58 (t, $J = 7.2$ Hz, 2 H), 2.33 (s, 6 H), 2.17 – 2.09 (m, 1 H), 2.02 – 1.96 (m, 1 H), 1.84 – 1.79 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 199.4, 196.3, 172.5, 138.1, 136.7, 134.8, 134.7, 133.4, 129.0, 128.8, 125.8, 68.1, 57.4, 33.9, 30.7, 28.8, 21.2, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{25}\text{O}_4$ 365.1747, found 365.1747.

The ee was determined by HPLC analysis. CHIRALPAK OD-H; Hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 229.9 nm; retention time: 9.9 min (minor) and 11.2 min (major)

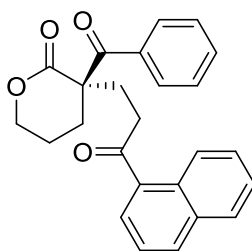


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	9.901	44847026	2191159	49.42
2	10.990	45906495	1853295	50.58



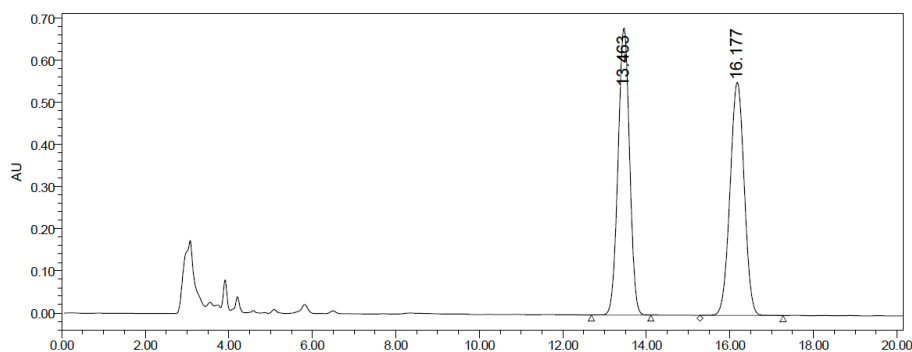
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	9.878	51049574	2388027	93.80
2	11.209	3371544	154049	6.20

(S)-3-Benzoyl-3-(3-(naphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3n)

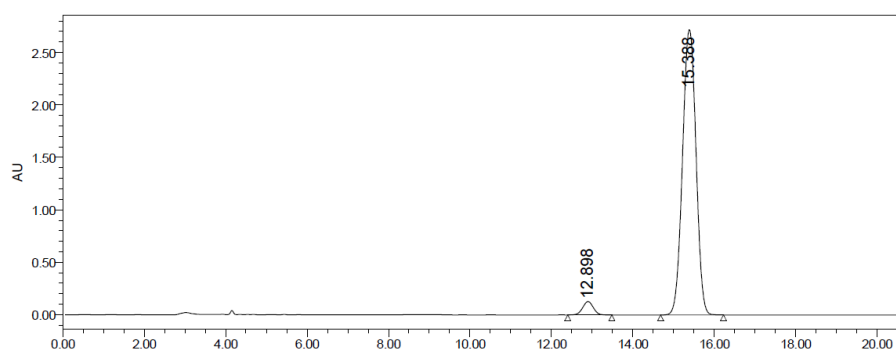


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 34.7 mg, 90% yield, colorless oil, $[\alpha]_D^{24} = +11.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.54 (d, $J = 8.4$ Hz, 1 H), 7.97 – 7.94 (m, 3 H), 7.86 – 7.84 (m, 2 H), 7.58 – 7.43 (m, 6 H), 4.50 – 4.45 (m, 1 H), 4.27 – 4.20 (m, 1 H), 3.28 – 3.10 (m, 2 H), 2.79 – 2.61 (m, 3 H), 2.22 – 2.10 (m, 1 H), 2.04 – 1.95 (m, 1 H), 1.87 – 1.80 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 203.1, 201.4, 196.4, 172.7, 135.7, 134.9, 134.0, 133.5, 132.8, 130.2, 129.1, 128.9, 128.5, 128.0, 127.8, 126.5, 125.8, 124.5, 68.3, 57.4, 37.3, 31.0, 29.1, 19.9. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{23}\text{O}_4$ 387.1589, found 387.1591.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 240.4 nm; retention time: 12.9 min (minor) and 15.4 min (major)

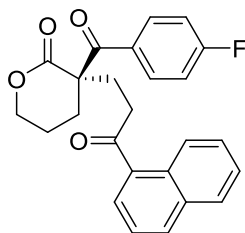


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		13.463	13025252	681041	49.97
2		16.177	13038701	553358	50.03



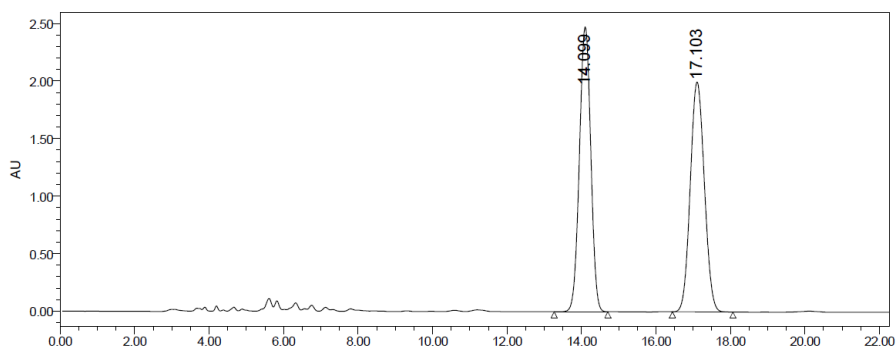
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		12.898	2286473	126735	3.54
2		15.388	62329088	2718234	96.46

(S)-3-(4-Fluorobenzoyl)-3-(3-(naphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3o)

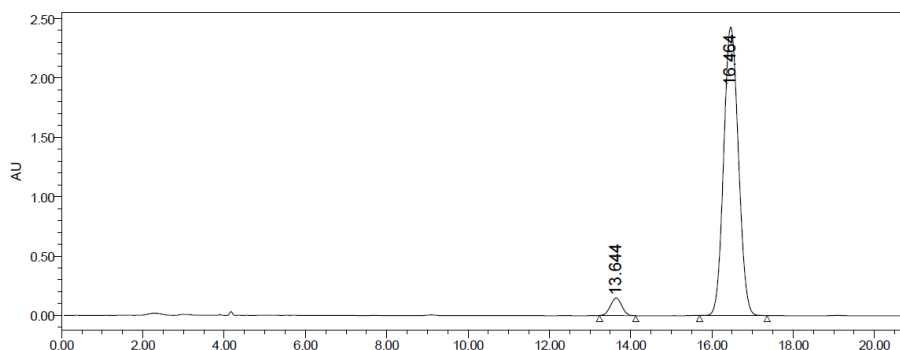


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 36.8 mg, 91% yield, colorless oil, $[\alpha]_D^{23} = +15.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.53 (d, $J = 9.0$ Hz, 1 H), 8.04 – 8.01 (m, 2 H), 7.96 (d, $J = 8.4$ Hz, 1 H), 7.86 – 7.84 (m, 2 H), 7.58 – 7.55 (m, 1 H), 7.53 – 7.50 (m, 1 H), 7.46 (t, $J = 7.8$ Hz, 1 H), 7.14 – 7.11 (m, 2 H), 4.49 – 4.45 (m, 1 H), 4.21 – 4.17 (m, 1 H), 3.25 – 3.19 (m, 1 H), 3.13 – 3.08 (m, 1 H), 2.77 – 2.62 (m, 3 H), 2.20 – 2.12 (m, 1 H), 2.03 – 1.97 (m, 1 H), 1.85 – 1.80 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 202.8, 194.5, 172.6, 166.6, 164.9, 135.5, 133.9, 132.7, 131.9, 131.8, 130.0, 128.4, 127.9, 127.7, 126.4, 125.7, 124.3, 116.1, 115.9, 68.0, 57.3, 37.0, 30.9, 28.7, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{22}\text{FO}_4$ 405.1495, found 405.1497.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 240.4 nm; retention time: 13.6 min (minor) and 16.5 min (major)

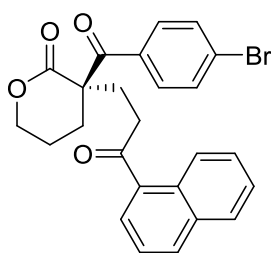


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	14.099	52470741	2473856	49.93
2	17.103	52621162	1997693	50.07



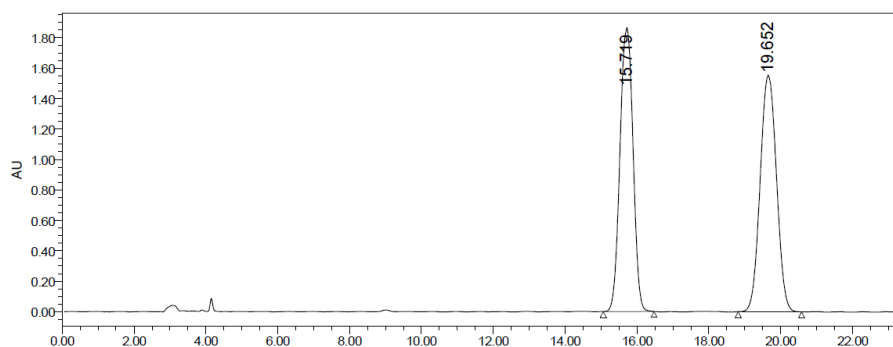
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	13.644	2867745	147902	4.48
2	16.464	61191078	2428204	95.52

(S)-3-(4-Bromobenzoyl)-3-(3-(naphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3p)

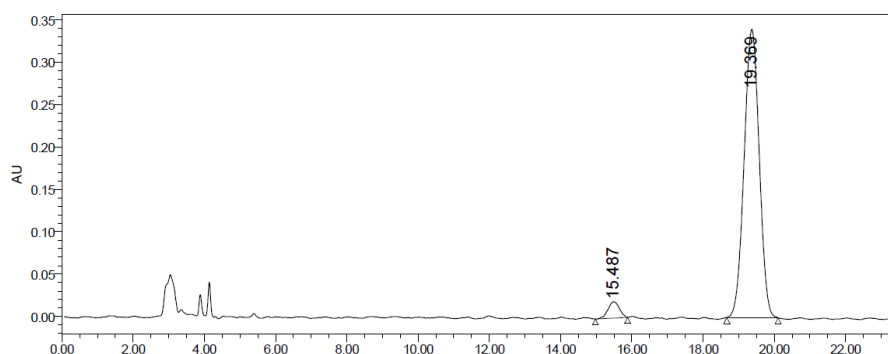


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 44.5 mg, 96% yield, white solid, mp 112.4 – 113.7 °C, $[\alpha]_D^{23} = +36.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, CDCl₃) δ 8.43 (d, *J* = 8.4 Hz, 1 H), 7.85 (d, *J* = 8.4 Hz, 1 H), 7.75 – 7.71 (m, 3 H), 7.49 – 7.44 (m, 2 H), 7.42 – 7.39 (m, 1 H), 7.34 (t, *J* = 7.2 Hz, 1 H), 4.37 – 4.34 (m, 1 H), 4.11 – 4.07 (m, 1 H), 3.14 – 3.09 (m, 1 H), 3.04 – 2.99 (m, 1 H), 2.60 – 2.50 (m, 3 H), 2.06 – 1.98 (m, 1 H), 1.89 – 1.83 (m, 1 H), 1.73 – 1.68 (m, 1 H). ¹³C NMR (150 MHz, CDCl₃) δ 202.7, 195.2, 172.2, 135.4, 133.8, 133.4, 132.6, 132.0, 130.4, 129.9, 128.6, 128.3, 127.8, 127.6, 126.3, 125.6, 124.3, 68.2, 57.2, 37.0, 30.7, 28.7, 19.7. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₅H₂₂BrO₄ 465.0695, found 465.0696.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 213.3 nm; retention time: 15.5 min (minor) and 19.4 min (major)

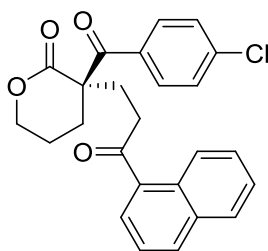


	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		15.719	47062714	1863653	48.94
2		19.652	49093298	1553437	51.06



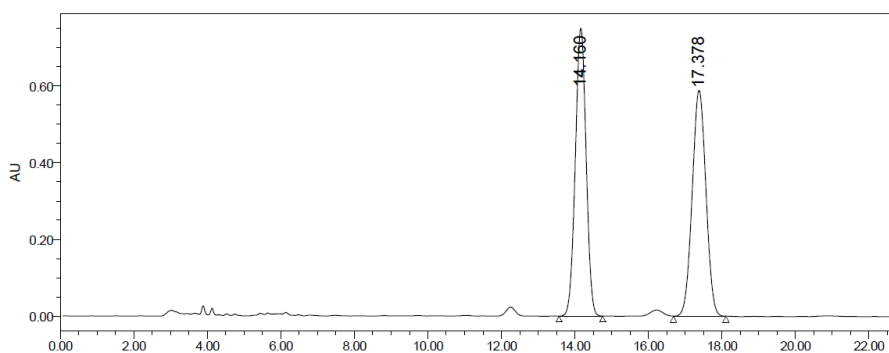
	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		15.487	425228	19256	4.08
2		19.369	10007907	340149	95.92

(S)-3-(4-Chlorobenzoyl)-3-(3-(naphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3q)

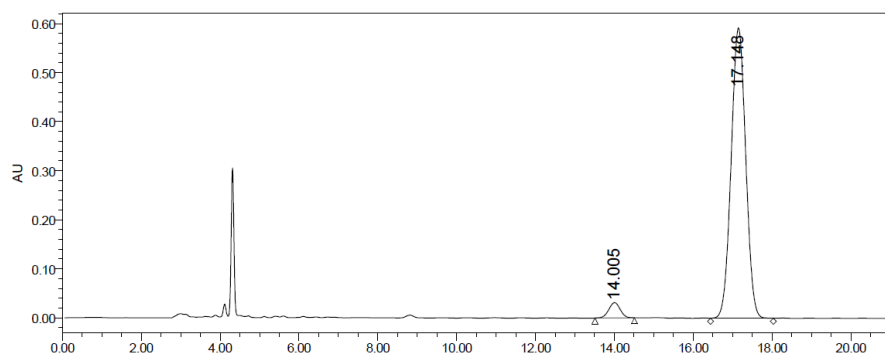


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 41.6 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +1.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.52 (d, $J = 8.4$ Hz, 1 H), 7.94 (d, $J = 8.4$ Hz, 1 H), 7.91 – 7.89 (m, 2 H), 7.84 (d, $J = 7.2$ Hz, 2 H), 7.57 – 7.54 (m, 1 H), 7.52 – 7.49 (m, 1 H), 7.45 – 7.40 (m, 3 H), 4.48 – 4.44 (m, 1 H), 4.21 – 4.17 (m, 1 H), 3.24 – 3.18 (m, 1 H), 3.13 – 3.08 (m, 1 H), 2.71 – 2.60 (m, 3 H), 2.17 – 2.09 (m, 1 H), 2.03 – 1.94 (m, 1 H), 1.84 – 1.79 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 202.8, 195.1, 172.3, 140.0, 135.5, 133.9, 133.1, 132.7, 130.5, 130.0, 129.1, 128.4, 127.9, 127.7, 126.4, 125.7, 124.3, 68.2, 57.3, 37.0, 30.8, 28.8, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{22}\text{ClO}_4$ 421.1201, found 421.1212.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 246.3 nm; retention time: 14.0 min (minor) and 17.1 min (major)

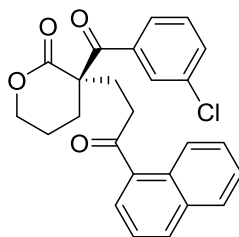


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	14.160	15337183	749844	50.08
2	17.378	15289365	589051	49.92



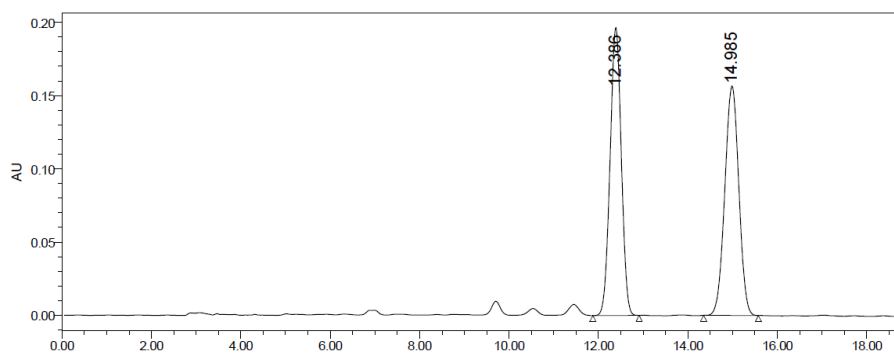
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	14.005	628311	31157	3.98
2	17.148	15175182	591772	96.02

(S)-3-(3-Chlorobenzoyl)-3-(3-(naphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3r)

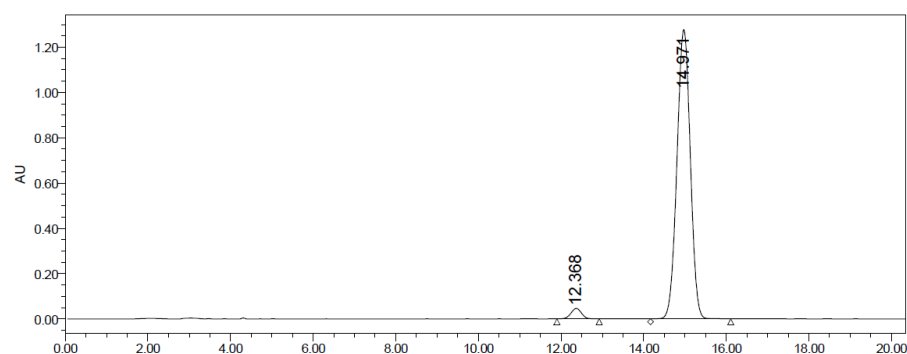


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 41.6 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +15.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.54 (d, $J = 8.4$ Hz, 1 H), 7.96 (d, $J = 8.4$ Hz, 1 H), 7.92 (t, $J = 2.4$ Hz, 1 H), 7.87 – 7.81 (m, 3 H), 7.58 – 7.56 (m, 1 H), 7.54 – 7.50 (m, 2 H), 7.47 (t, $J = 7.8$ Hz, 1 H), 7.39 (t, $J = 7.8$ Hz, 1 H), 4.53 – 4.50 (m, 1 H), 4.28 – 4.24 (m, 1 H), 3.26 – 3.21 (m, 1 H), 3.16 – 3.10 (m, 1 H), 2.72 – 2.62 (m, 3 H), 2.22 – 2.14 (m, 1 H), 2.04 – 1.98 (m, 1 H), 1.88 – 1.84 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 202.8, 195.2, 172.0, 136.3, 135.5, 135.2, 133.9, 133.3, 132.7, 130.0, 129.2, 128.4, 127.9, 127.7, 126.8, 126.4, 125.7, 124.4, 68.4, 57.3, 37.1, 30.8, 29.0, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{22}\text{ClO}_4$ 421.1201, found 421.1211.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 298.5 nm; retention time: 12.4 min (minor) and 14.9 min (major)

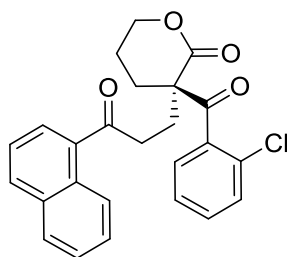


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	12.386	3418881	196414	50.04
2	14.985	3413850	156474	49.96



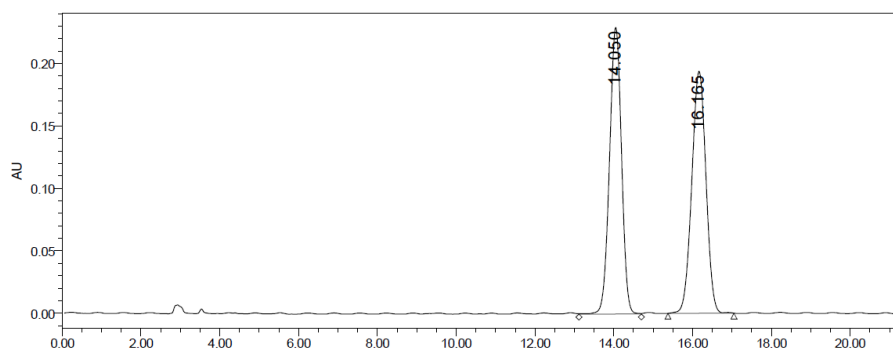
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	12.368	801979	45712	2.73
2	14.971	28618881	1276703	97.27

(S)-3-(2-Chlorobenzoyl)-3-(3-(naphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3s)

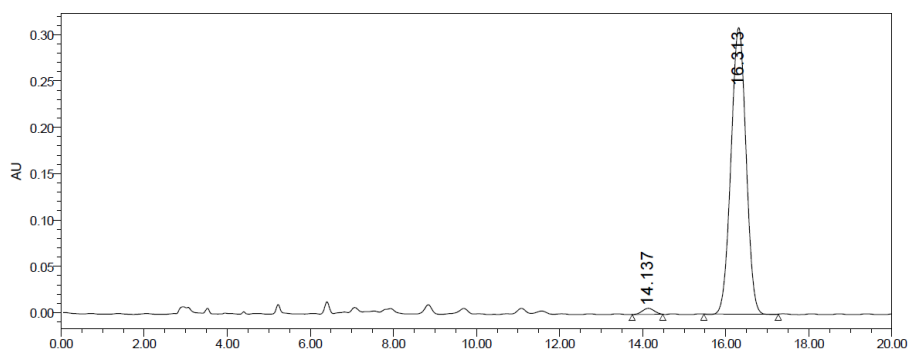


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 41.6 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +65.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.55 (d, $J = 8.4$ Hz, 1 H), 7.98 (d, $J = 8.4$ Hz, 1 H), 7.89 – 7.86 (m, 2 H), 7.59 – 7.56 (m, 1 H), 7.54 – 7.48 (m, 2 H), 7.42 – 7.40 (m, 2 H), 7.38 – 7.35 (m, 1 H), 7.31 – 7.29 (m, 1 H), 4.46 – 4.36 (m, 2 H), 3.22 – 3.19 (m, 2 H), 2.67 – 2.54 (m, 3 H), 2.06 – 1.96 (m, 3 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 202.6, 200.4, 170.3, 138.0, 135.4, 133.9, 132.8, 131.2, 130.4, 130.3, 130.1, 128.4, 128.0, 127.7, 127.6, 126.7, 126.4, 125.7, 124.4, 69.9, 60.3, 37.1, 31.0, 28.1, 20.5. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{22}\text{ClO}_4$ 421.1201, found 421.1211.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 300.9 nm; retention time: 14.1 min (minor) and 16.3 min (major)

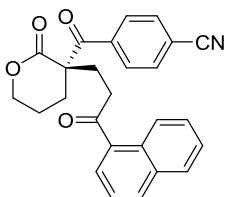


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	14.050	4843728	229582	49.98
2	16.165	4847617	193800	50.02



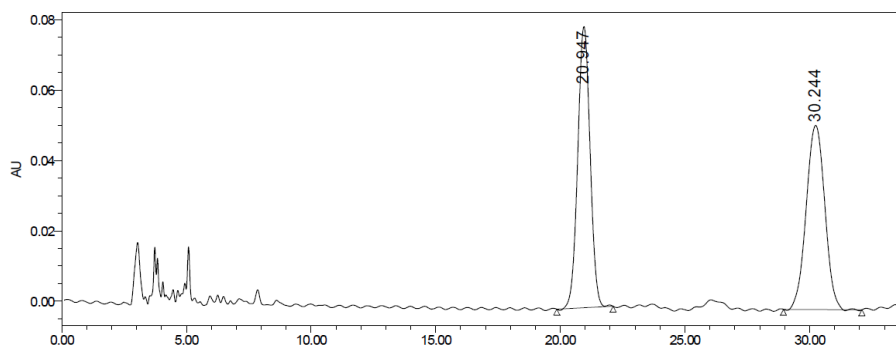
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	14.137	129845	6565	1.64
2	16.313	7783829	309091	98.36

**(S)-4-(3-(3-(Naphthalen-1-yl)-3-oxopropyl)-2-oxotetrahydro-2H-pyran-3-carbonyl)benzoni-
trile (3t)**

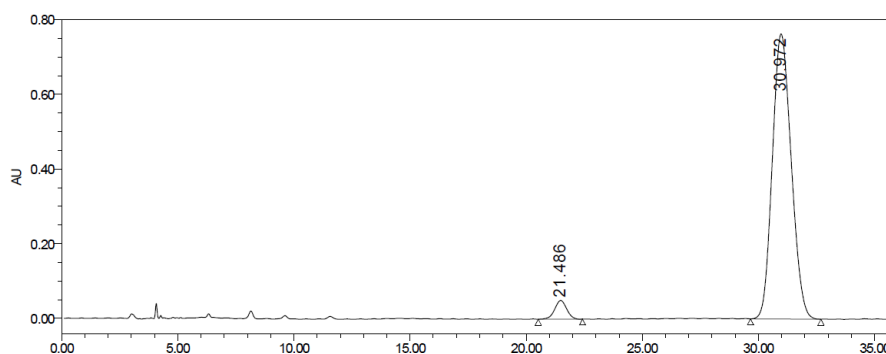


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 38.6 mg, 94% yield, colorless oil, $[\alpha]_D^{23} = +25.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.52 (d, $J = 9.0$ Hz, 1 H), 7.99 (d, $J = 8.4$ Hz, 2 H), 7.97 (d, $J = 8.4$ Hz, 1 H), 7.86 – 7.85 (m, 2 H), 7.74 (d, $J = 8.4$ Hz, 2 H), 7.58 – 7.56 (m, 1 H), 7.53 – 7.51 (m, 1 H), 7.48 – 7.45 (d, $J = 7.8$ Hz, 1 H), 4.57 – 4.53 (m, 1 H), 4.32 – 4.26 (m, 1 H), 3.26 – 3.21 (m, 1 H), 3.15 – 3.10 (m, 1 H), 2.72 – 2.63 (m, 3 H), 2.24 – 2.16 (m, 1 H), 2.05 – 1.99 (m, 1 H), 1.92 – 1.87 (m, 1 H). $^{13}\text{C NMR}$ (100 MHz,) δ 202.7, 195.6, 171.8, 138.3, 135.5, 134.0, 132.9, 132.6, 130.1, 129.4, 128.5, 128.1, 127.8, 126.6, 125.7, 124.4, 117.7, 116.6, 68.8, 57.5, 37.1, 30.8, 29.1, 19.9. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{26}\text{H}_{22}\text{NO}_4$ 412.1540, found 412.1543.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 65/35; flow rate 1.0 mL/min; 242.8 nm; retention time: 21.5 min (minor) and 30.9 min (major)

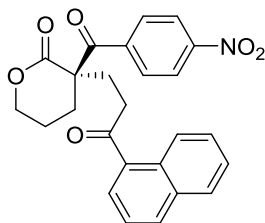


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		20.947	2761317	79991	50.28
2		30.244	2730153	52398	49.72



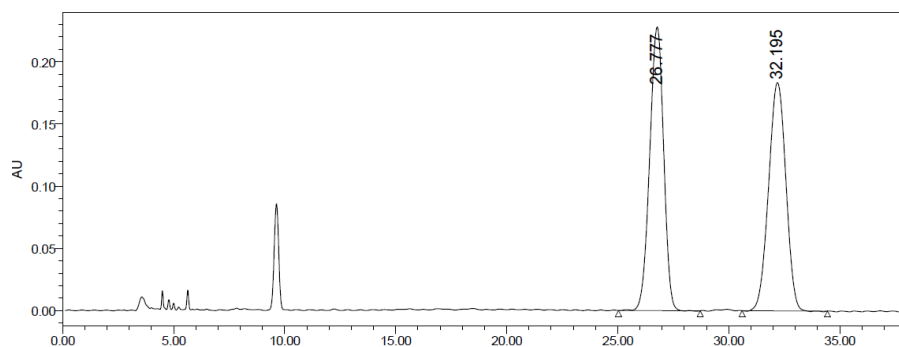
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		21.486	1785297	49795	3.98
2		30.972	43104242	763150	96.02

(S)-3-(3-(Naphthalen-1-yl)-3-oxopropyl)-3-(4-nitrobenzoyl)tetrahydro-2H-pyran-2-one (3u)

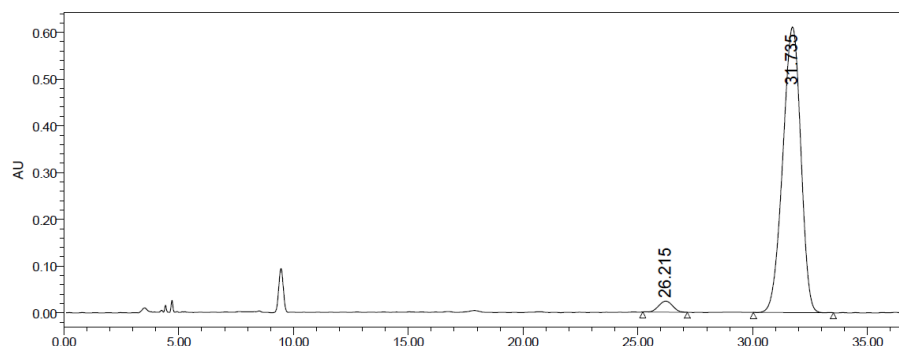


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 42.2 mg, 98% yield, colorless oil, $[\alpha]_D^{23} = +21.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.52 (d, $J = 9.0$ Hz, 1 H), 8.27 (d, $J = 9.0$ Hz, 2 H), 8.06 (d, $J = 8.4$ Hz, 2 H), 7.97 (d, $J = 7.8$ Hz, 1 H), 7.87 – 7.85 (m, 2 H), 7.58 – 7.55 (m, 1 H), 7.53 – 7.50 (m, 1 H), 7.46 (t, $J = 7.8$ Hz, 1 H), 4.57 – 4.54 (m, 1 H), 4.32 – 4.28 (m, 1 H), 3.27 – 3.22 (m, 1 H), 3.17 – 3.11 (m, 1 H), 2.74 – 2.62 (m, 3 H), 2.24 – 2.16 (m, 1 H), 2.06 – 1.99 (m, 1 H), 1.94 – 1.89 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 202.6, 195.5, 171.6, 150.1, 139.9, 135.4, 133.9, 132.8, 130.0, 129.9, 128.4, 127.9, 127.7, 126.4, 125.6, 124.3, 123.8, 68.7, 57.5, 37.0, 30.7, 29.0, 19.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{22}\text{NO}_6$ 432.1439, found 432.1442.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 65/35; flow rate 1.0 mL/min; 254.0 nm; retention time: 26.2 min (minor) and 31.7 min (major)

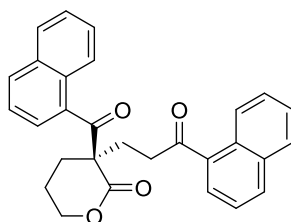


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	26.777	9983860	228029	50.09
2	32.195	9949350	183507	49.91



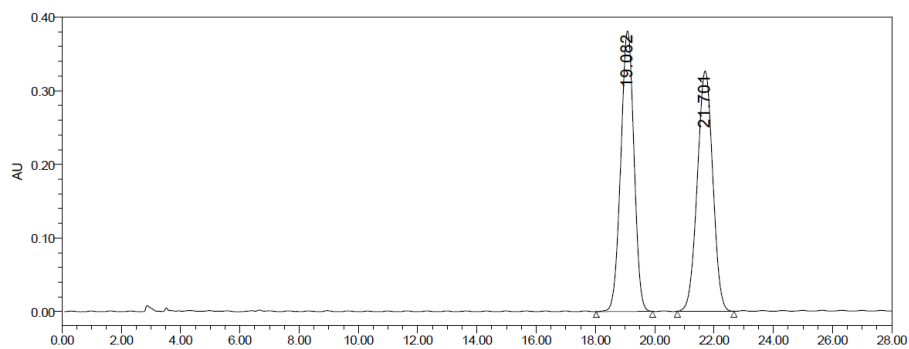
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	26.215	997419	23514	2.91
2	31.735	33295599	610474	97.09

(S)-3-(1-Naphthoyl)-3-(3-(naphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3v)

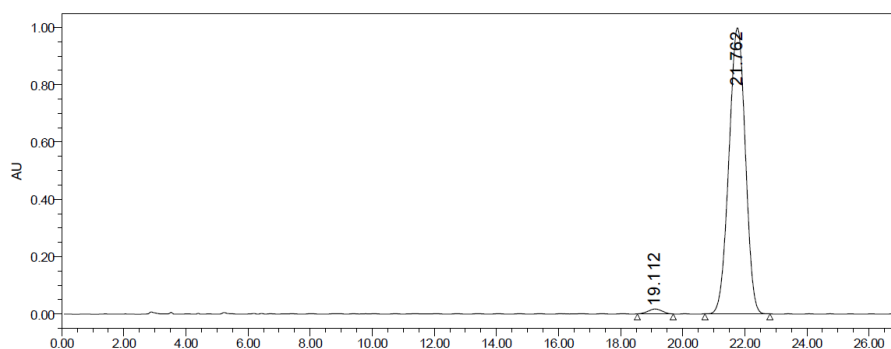


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 43.2 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +15.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 8.53 (d, $J = 8.8$ Hz, 1 H), 8.07 (d, $J = 8.4$ Hz, 1 H), 7.93 (d, $J = 8.0$ Hz, 2 H), 7.86 – 7.79 (m, 2 H), 7.56 – 7.39 (m, 6 H), 4.37 – 4.31 (m, 1 H), 4.24 – 4.18 (m, 1 H), 3.27 – 3.22 (m, 2 H), 2.73 – 2.58 (m, 3 H), 2.04 – 1.89 (m, 3 H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 202.8, 201.0, 171.5, 135.4, 134.8, 133.8, 132.7, 132.0, 130.4, 130.0, 128.7, 128.3, 128.0, 127.8, 127.7, 126.5, 126.3, 125.6, 125.3, 124.7, 124.3, 124.1, 68.8, 60.2, 37.3, 31.4, 28.8, 20.2. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{29}\text{H}_{25}\text{O}_4$ 437.1747, found 437.1755.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 300.9 nm; retention time: 19.1 min (minor) and 21.8 min (major)

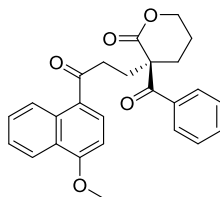


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		19.082	11771433	380878	49.88
2		21.701	11827469	326069	50.12



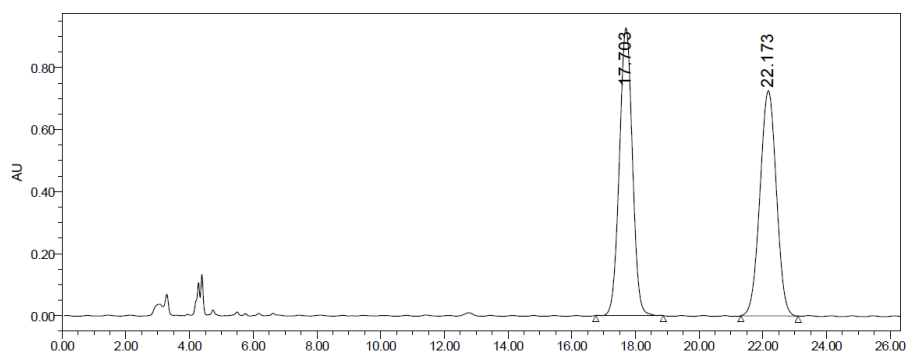
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		19.112	541898	17305	1.46
2		21.762	36548311	997242	98.54

(S)-3-Benzoyl-3-(3-(4-methoxynaphthalen-1-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one
(3w)

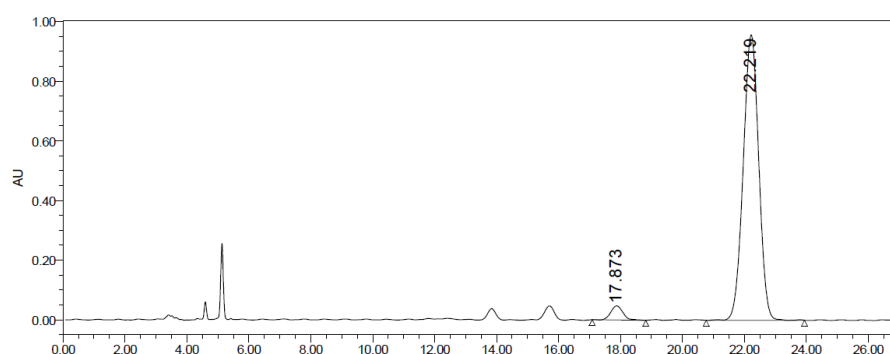


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 41.2 mg, 99% yield, colorless oil, $[\alpha]_D^{23} = +31.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.85 (d, $J = 8.4$ Hz, 1 H), 8.9 (d, $J = 8.4$ Hz, 1 H), 7.98 – 7.96 (m, 3 H), 7.60 – 7.55 (m, 2 H), 7.51 – 7.44 (m, 3 H), 6.75 (d, $J = 8.4$ Hz, 1 H), 4.47 – 4.44 (m, 1 H), 4.24 – 4.20 (m, 1 H), 4.04 (s, 3 H), 3.23 – 3.18 (m, 1 H), 3.12 – 3.07 (m, 1 H), 2.78 – 2.73 (m, 1 H), 2.68 – 2.62 (m, 2 H), 2.17 – 2.10 (m, 1 H), 2.02 – 1.96 (m, 1 H), 1.87 – 1.82 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 201.0, 196.4, 172.6, 159.0, 134.9, 133.3, 131.9, 130.9, 129.0, 128.8, 128.6, 127.1, 125.9, 125.7, 125.7, 122.0, 102.0, 68.1, 57.5, 55.8, 36.1, 31.4, 28.8, 19.9. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{26}\text{H}_{25}\text{O}_5$ 417.1697, found 417.1707.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 236.9 nm; retention time: 17.9 min (minor) and 22.2 min (major)

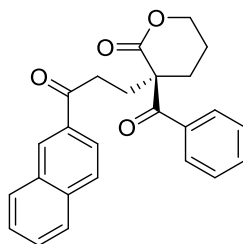


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		17.703	26258159	927189	50.30
2		22.173	25944830	725151	49.70



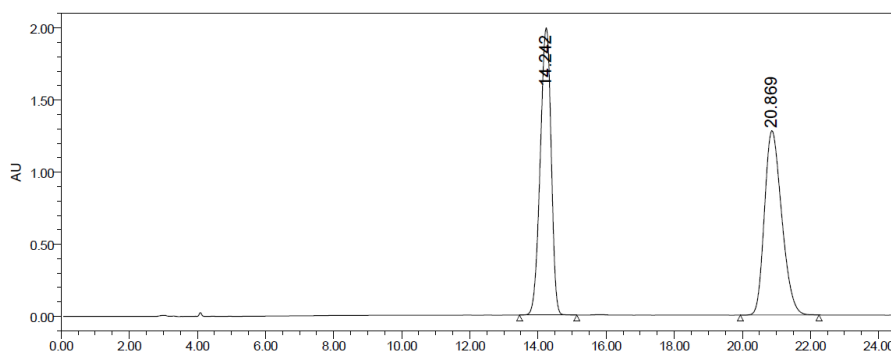
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		17.873	1290971	47275	3.73
2		22.219	33278983	956755	96.27

(S)-3-Benzoyl-3-(3-(naphthalen-2-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3x)

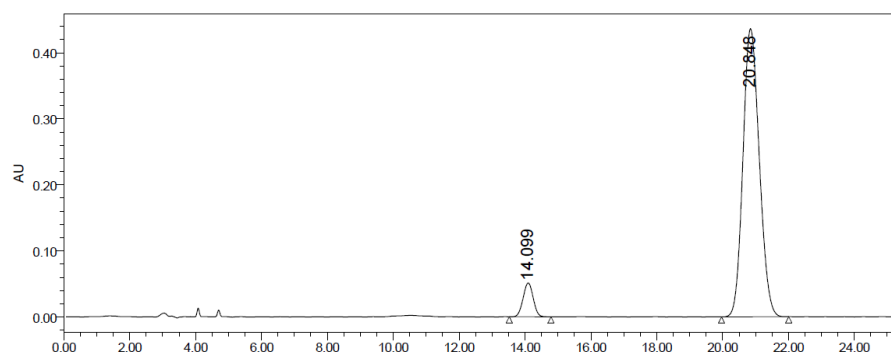


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 35.5 mg, 92% yield, colorless oil, $[\alpha]_D^{23} = +37.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 8.45 (s, 1 H), 8.00 – 7.98 (m, 3 H), 7.93 (d, $J = 7.8$ Hz, 1 H), 7.86 – 7.84 (m, 2 H), 7.59 – 7.56 (m, 2 H), 7.54 – 7.52 (m, 1 H), 7.48 – 7.45 (m, 2 H), 4.49 – 4.45 (m, 1 H), 4.27 – 4.23 (m, 1 H), 3.33 – 3.28 (m, 1 H), 3.20 – 3.15 (m, 1 H), 2.79 – 2.74 (m, 1 H), 2.68 – 2.62 (m, 2 H), 2.19 – 2.12 (m, 1 H), 2.04 – 1.98 (m, 1 H), 1.88 – 1.84 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 198.9, 196.3, 172.5, 135.6, 134.8, 133.9, 133.4, 132.5, 129.8, 129.6, 129.0, 128.8, 128.4 (d, $J = 4.5$ Hz), 127.7, 126.7, 123.8, 68.2, 57.4, 33.9, 30.8, 28.9, 19.9. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{23}\text{O}_4$ 387.1588, found 387.1591.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 65/35; flow rate 1.0 mL/min; 281.8 nm; retention time: 14.1 min (minor) and 20.8 min (major)

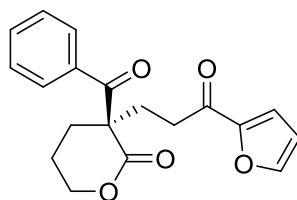


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		14.242	44262057	1991021	49.59
2		20.869	44986243	1277964	50.41



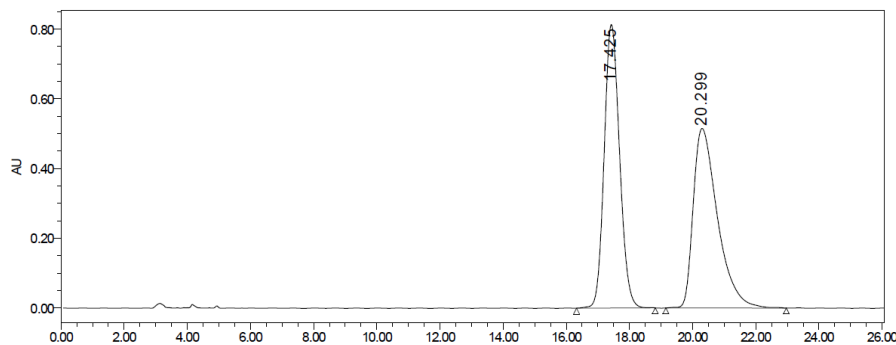
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		14.099	1092267	51263	6.78
2		20.848	15008056	436145	93.22

(S)-3-Benzoyl-3-(3-(furan-2-yl)-3-oxopropyl)tetrahydro-2H-pyran-2-one (3y)

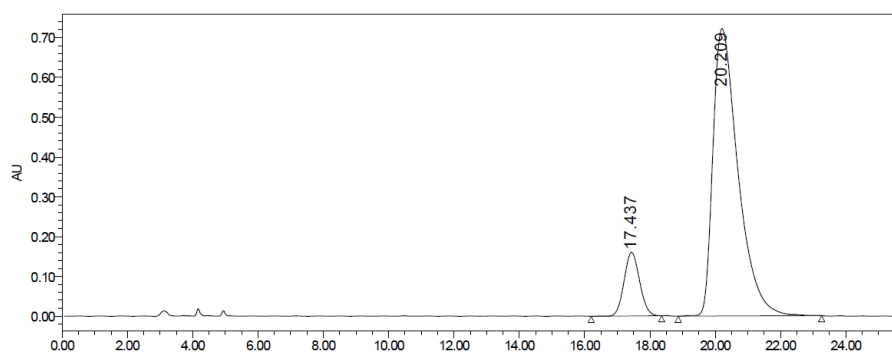


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 31.9 mg, 98% yield, colorless oil, $[\alpha]_D^{23} = +35.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.96 – 7.94 (m, 2 H), 7.57 – 7.54 (m, 2 H), 7.46 – 7.44 (m, 2 H), 7.18 – 7.17 (m, 1 H), 6.49 (q, $J = 3.6, 1.8$ Hz, 1 H), 4.45 – 4.41 (m, 1 H), 4.23 – 4.18 (m, 1 H), 3.03 – 2.98 (m, 1 H), 2.91 – 2.86 (m, 1 H), 2.76 – 2.71 (m, 1 H), 2.57 – 2.54 (m, 2 H), 2.15 – 2.07 (m, 1 H), 2.01 – 1.95 (m, 1 H), 1.82 – 1.78 (m, 1 H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 196.1, 187.9, 172.3, 152.2, 146.3, 134.8, 133.3, 128.9, 128.7, 117.2, 112.1, 68.0, 57.3, 33.5, 30.2, 28.5, 19.7. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{19}\text{H}_{19}\text{O}_5$ 327.1223, found 327.1227.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 253.4 nm; retention time: 17.4 min (minor) and 20.2 min (major)

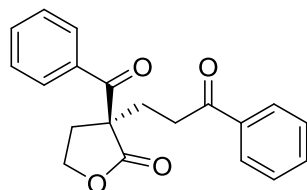


Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	17.425	27506874	813436	50.01
2	20.299	27494015	515264	49.99



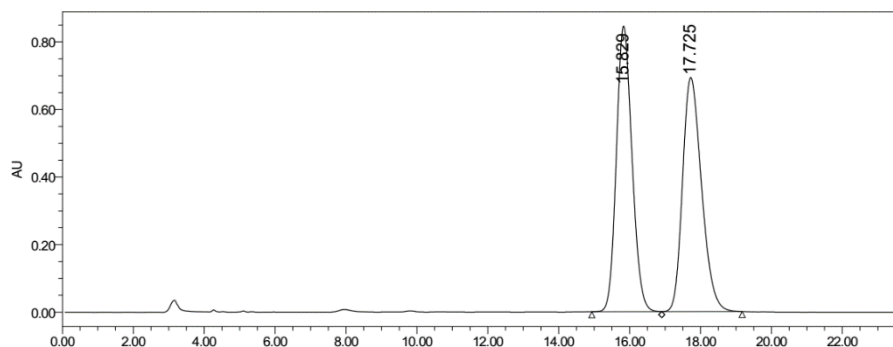
Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1	17.437	5298632	159882	12.06
2	20.209	38620811	722352	87.94

(S)-3-Benzoyl-3-(3-oxo-3-phenylpropyl)dihydrofuran-2(3H)-one (3a)

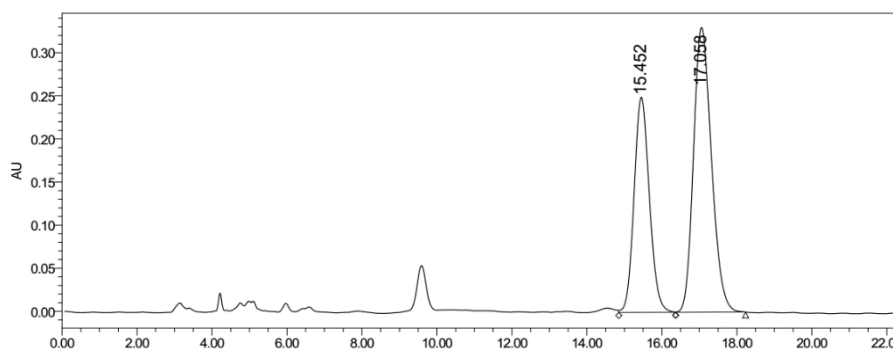


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 30.2 mg, 94% yield, white solid, mp 95.7 - 96.4 °C, $[\alpha]_D^{23} = +2.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, CDCl₃) δ 8.07 – 8.06 (m, 2 H), 7.87 – 7.86 (m, 2 H), 7.59 – 7.57 (m, 1 H), 7.55 – 7.52 (m, 1 H), 7.47 (t, *J* = 7.8 Hz, 2 H), 7.42 (t, *J* = 7.8 Hz, 2 H), 4.49 – 4.40 (m, 2 H), 3.15 – 3.00 (m, 3 H), 2.69 – 2.64 (m, 1 H), 2.60 – 2.55 (m, 1 H), 2.34 – 2.30 (m, 1 H). ¹³C NMR (150 MHz, CDCl₃) δ 198.6, 195.6, 175.9, 136.4, 134.8, 133.4, 133.2, 129.2, 128.7, 128.6, 128.0, 66.2, 58.6, 33.8, 29.2. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₀H₁₉O₄ 323.1276, found 323.1278.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 243.9 nm; retention time: 15.5 min (minor) and 17.1 min (major)

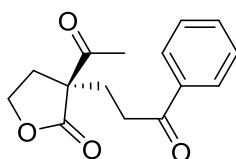


Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	15.829	25913677	845345	50.06
2	17.725	25852049	692904	49.94



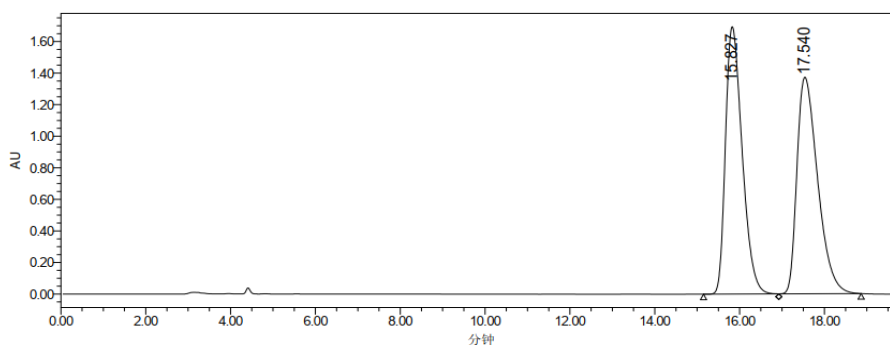
Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	15.452	7081457	249609	39.14
2	17.058	11013116	330239	60.86

(S)-3-Acetyl-3-(3-oxo-3-phenylpropyl)dihydrofuran-2(3H)-one (3 β)

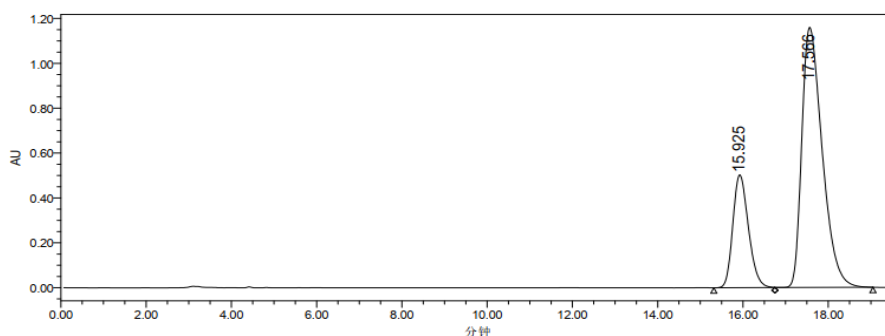


The title compound was purified by column chromatography on silica gel (PE : EA = 8:1 to 3:1), 25.5 mg, 98% yield, white solid, mp 67.8 - 69.1 °C, $[\alpha]_D^{26} = +0.1$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, CDCl₃) δ 7.85 (d, $J = 7.2$ Hz, 2H), 7.52 – 7.49 (m, 1H), 7.39 (t, $J = 7.8$ Hz, 2H), 4.30 – 4.26 (m, 1H), 4.15 – 4.11 (m, 1H), 2.93 – 2.79 (m, 3H), 2.45 – 2.40 (m, 1H), 2.31 – 2.26 (m, 1H), 2.30 (s, 3H), 2.05 – 2.00 (m, 1H). ¹³C NMR (150 MHz, CDCl₃) δ 202.6, 197.9, 175.4, 136.3, 133.4, 128.7, 128.0, 66.1, 60.5, 33.6, 29.9, 28.1, 25.8. HRMS (ESI-Orbitrap) m/z : $[M+Na]^+$ Calcd for C₁₅H₁₆O₄Na 283.0946, found 283.0948.

The ee was determined by HPLC analysis. CHIRALPAK AS-H; Hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 240.4 nm; retention time: 15.9 min (minor) and 17.6 min (major)

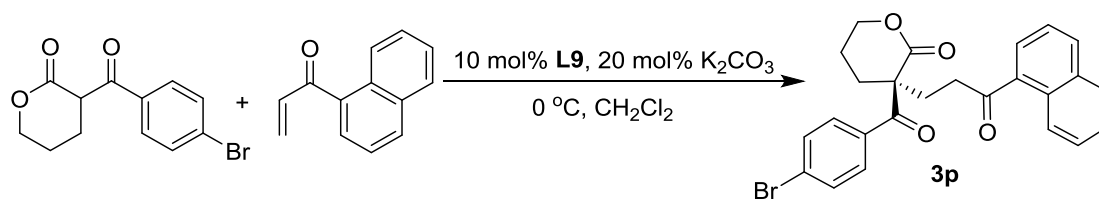


	Name	Retention time (min)	Area ($\mu V*s$)	Height (μV)	% Area
1		15.827	46283336	1693800	49.89
2		17.540	46482488	1371739	50.11



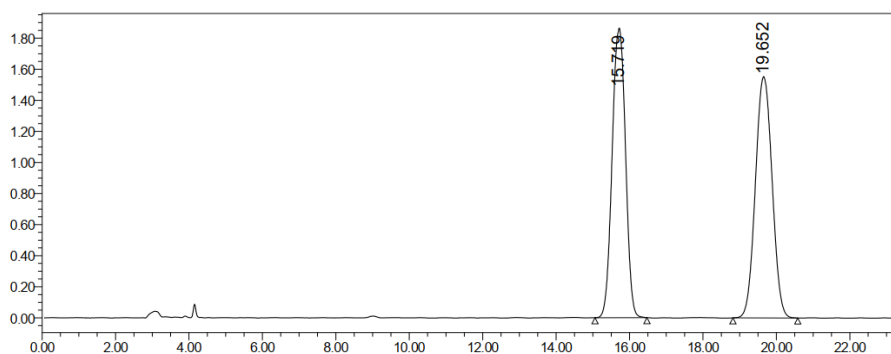
	Name	Retention time (min)	Area ($\mu V*s$)	Height (μV)	% Area
1		15.925	12789854	502835	24.91
2		17.566	38557039	1158795	75.09

6. Gram-scale procedure for the preparation of (S) – 3p

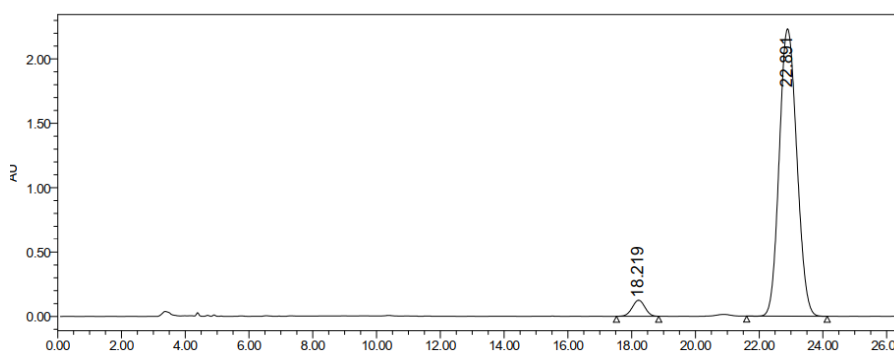


To the mixture of 2-(4-bromo)benzoyl- δ -valerolactone (0.843 mg, 3.0 mmol), catalyst **L9** (115.2 mg, 0.3 mmol), and K_2CO_3 (82.8 mg, 0.02 mmol) in analytical purity grade dichloromethane (3 mL) was added α -naphthyl vinyl ketone (655.2 mg, 3.6 mmol) at $0^\circ C$. The reaction was stirred for 6 days at $0^\circ C$ to complete checked by thin layer chromatography. The mixture was directly submitted to preparative silica gel column chromatography (petroleum ether : ethyl acetate = 8:1 to 3:1) to furnish the product (S)-**3p** (1.32 g, 95% yield, 92% ee).

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 298.5 nm; retention time: 18.2 min (minor) and 22.9 min (major)

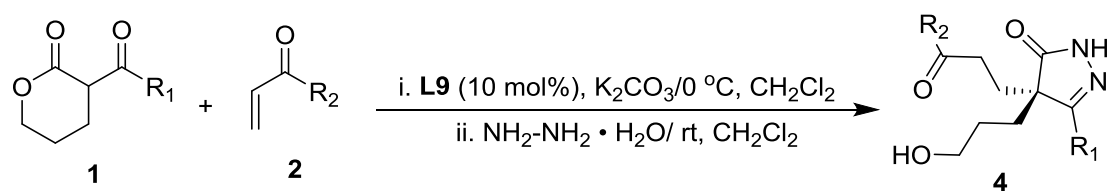


Name	Retention time (min)	Area ($\mu V*s$)	Height (μV)	% Area
1	15.719	47062714	1863653	48.94
2	19.652	49093298	1553437	51.06



Name	Retention time (min)	Area ($\mu V*s$)	Height (μV)	% Area
1	18.219	3417732	124133	3.86
2	22.891	85230188	2230930	96.14

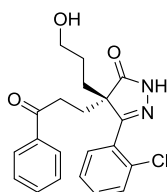
7. General procedure for the catalytic one-pot asymmetric synthesis of 4,4-dialkyl pyrazolones **4**



To the mixture of the lactone **1** (0.1 mmol), catalyst **L9** (3.8 mg, 0.01 mmol), and K₂CO₃ (2.76 mg, 0.02 mmol) in analytical purity grade dichloromethane (0.5 mL) was added the vinyl ketone **2** (0.12 mmol). The reaction was stirred for 3 to 6 days at 0 °C to complete checked by thin layer chromatography. NH₂NH₂·H₂O (0.5 mmol, 25.0 mg) was then added, and the mixture was stirred at room temperature for 3-4 h to complete checked by thin layer chromatography. The mixture was directly submitted to preparative silica gel column chromatography (PE : EA = 3:1 to DCM : MeOH = 50:1) to furnish the product **4**.

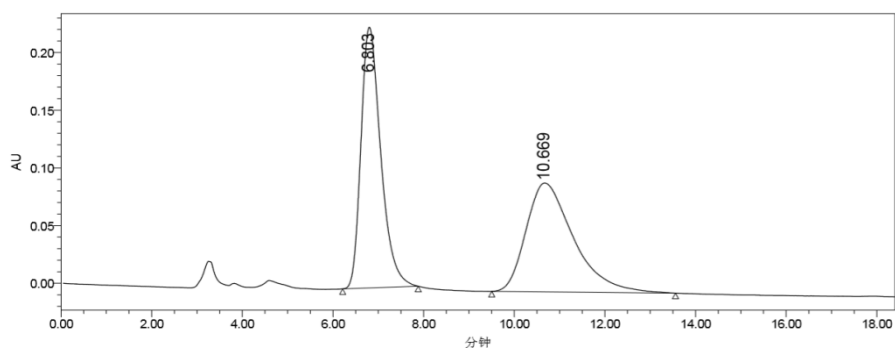
8. Characterization of compounds 4

(S)-5-(2-Chlorophenyl)-4-(3-hydroxypropyl)-4-(3-oxo-3-phenylpropyl)-2,4-dihydro-3H-pyrazol-3-one (4a)

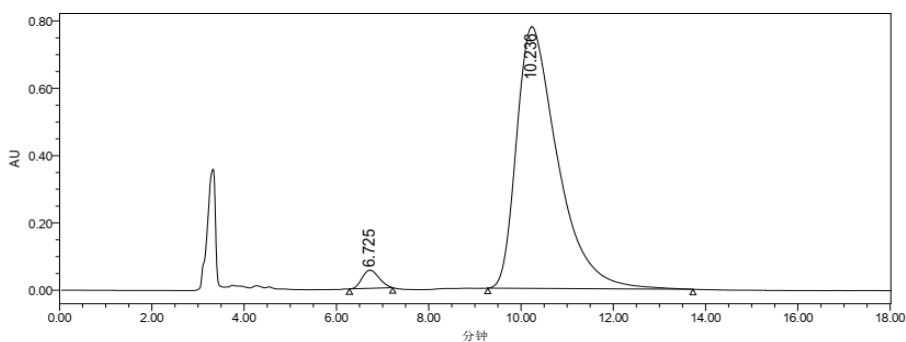


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 33.8 mg, 88% yield, white solid, mp: 171.5 – 172.1 °C, $[\alpha]_D^{23} = -4.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 11.80 (s, 1H), 7.82 – 7.80 (m, 2H), 7.63 – 7.61 (m, 2H), 7.54 – 7.45 (m, 4H), 4.53 (s, 1H), 3.40 – 3.33 (m, 3H), 2.98 – 2.93 (m, 1H), 2.83 – 2.77 (m, 1H), 2.06 – 1.88 (m, 3H), 1.79 – 1.73 (m, 1H), 1.37 – 1.28 (m, 1H). ¹³C NMR (150 MHz, DMSO-d₆) δ 198.6, 178.7, 158.2, 136.6, 133.7, 132.8, 131.4, 131.4, 130.6, 130.2, 129.2, 128.1, 128.0, 60.7, 56.7, 32.8, 31.2, 28.7, 27.7. HRMS (ESI-Orbitrap) m/z: Calcd for C₂₁H₂₂ClN₂O₃ 385.1311, found 385.1313.

The ee was determined by HPLC analysis. CHIRALPAK OJ-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 240.4 nm; retention time: 6.8 min (minor) and 10.2 min (major)

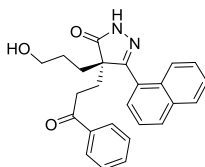


Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	6.803	6858574	225989	50.00
2	10.669	6857732	94360	50.00



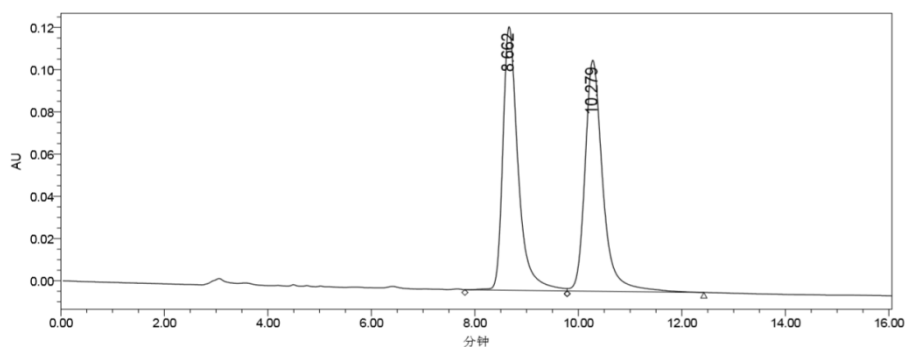
Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1	6.725	1363806	53750	2.76
2	10.236	48046176	777388	97.24

(S)-4-(3-Hydroxypropyl)-5-(naphthalen-1-yl)-4-(3-oxo-3-phenylpropyl)-2,4-dihydro-3H-pyrazol-3-one (4b)

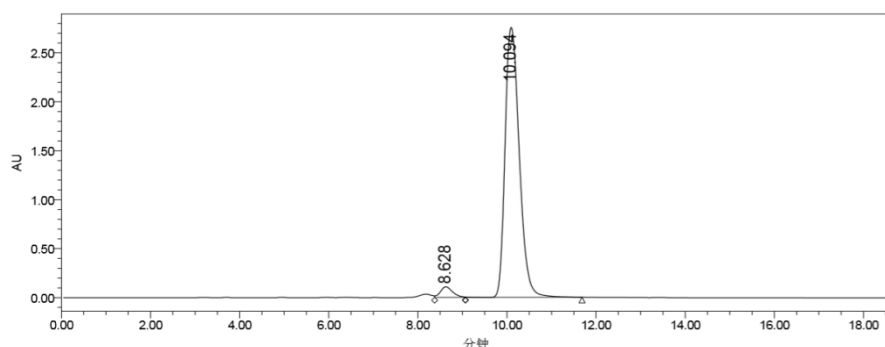


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 34.4 mg, 86% yield, colorless oil, $[\alpha]_D^{23} = +17.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, DMSO-d_6) δ 11.90 (s, 1H), 8.77 (d, $J = 8.4$ Hz, 1H), 8.05 (d, $J = 8.4$ Hz, 1H), 8.00 (d, $J = 7.8$ Hz, 1H), 7.74 (d, $J = 6.6$ Hz, 1H), 7.68 (d, $J = 7.2$ Hz, 2H), 7.63 – 7.56 (m, 4H), 7.41 (t, $J = 7.8$ Hz, 2H), 4.48 (t, $J = 5.4$ Hz, 1H), 3.36 – 3.33 (m, 1H), 3.31 – 3.27 (m, 1H), 2.84 – 2.72 (m, 1H), 2.78 – 2.71 (m, 1H), 2.20 – 2.15 (m, 1H), 2.10 – 2.04 (m, 2H), 1.86 – 1.81 (m, 1H), 1.30 – 1.24 (m, 1H). $^{13}\text{C NMR}$ (150 MHz, DMSO-d_6) δ 198.6, 178.9, 159.9, 136.5, 134.4, 133.7, 131.1, 130.6, 129.2, 129.1, 128.5, 128.1, 127.7, 126.7, 126.6, 126.2, 125.7, 60.7, 57.2, 33.2, 32.6, 30.3, 28.1. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{25}\text{N}_2\text{O}_3$ 401.1864, found 401.1860.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 312.8 nm; retention time: 8.6 min (minor) and 10.1 min (major)

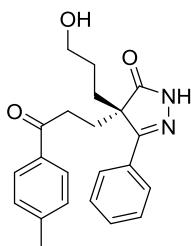


	Name	Retention time(min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		8.662	2559415	124842	49.45
2		10.279	2616771	109380	50.55



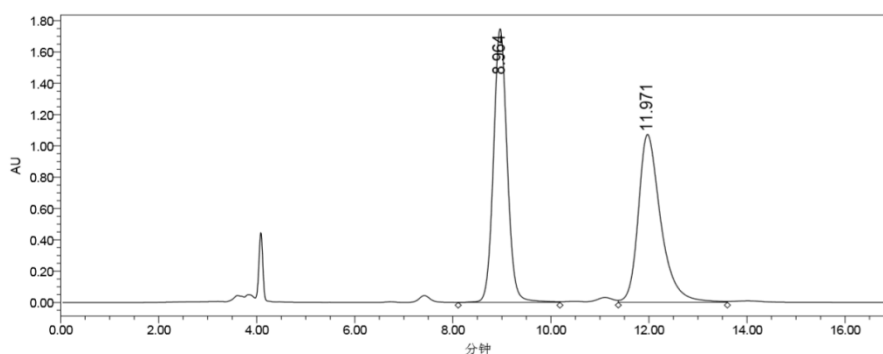
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		8.628	2038283	108315	3.23
2		10.094	61110991	2756388	96.77

(S)-4-(3-Hydroxypropyl)-4-(3-oxo-3-(p-tolyl)propyl)-5-phenyl-2,4-dihydro-3H-pyrazol-3-one (4c)

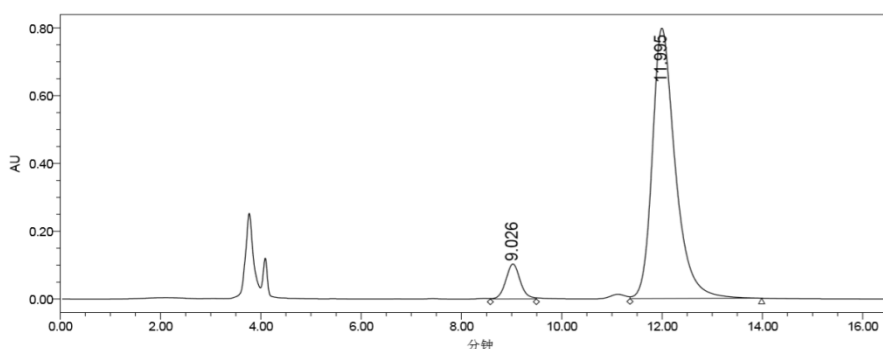


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 32.4 mg, 89% yield, colorless oil, $[\alpha]_D^{23} = -4.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 11.71 (s, 1H), 7.84 – 7.82 (m, 2H), 7.63 (d, *J* = 8.4 Hz, 2H), 7.49 – 7.45 (m, 3H), 7.25 (d, *J* = 7.8 Hz, 2H), 3.28 – 3.22 (m, 2H), 2.69 – 2.56 (m, 2H), 2.34 (s, 3H), 2.31 – 2.26 (m, 1H), 2.14 – 2.08 (m, 2H), 1.86 – 1.81 (m, 1H), 1.12 – 1.03 (m, 2H). ¹³C NMR (150 MHz, DMSO-d₆) δ 198.1, 179.6, 159.4, 144.1, 134.0, 131.7, 130.3, 129.7, 129.5, 128.3, 126.0, 60.7, 55.6, 33.2, 32.8, 28.1, 21.5. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₂H₂₅N₂O₃ 365.1866, found 365.1860.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 252.2 nm; retention time: 9.0 min (minor) and 12.0 min (major)

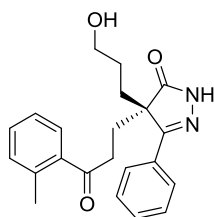


	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		8.964	33945792	1748073	49.91
2		11.971	34075021	1072607	50.09



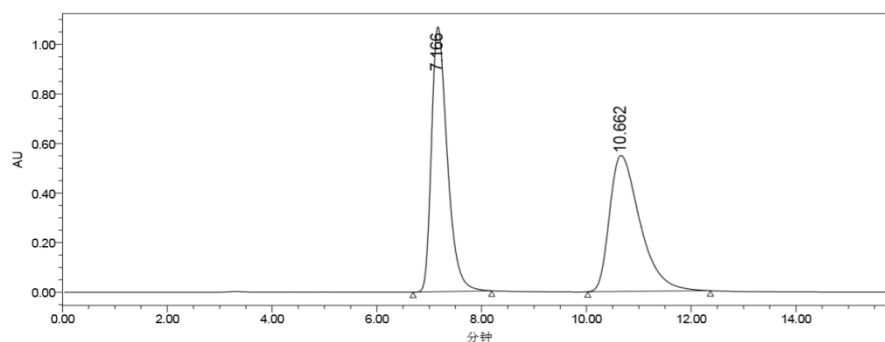
	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		9.026	2051418	103198	7.47
2		11.995	25419997	797667	92.53

(S)-4-(3-Hydroxypropyl)-4-(3-oxo-3-(p-tolyl)propyl)-5-phenyl-2,4-dihydro-3H-pyrazol-3-one (4d)

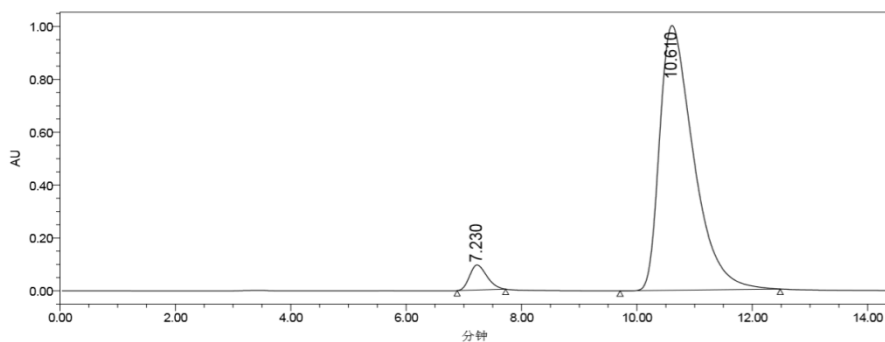


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 33.8 mg, 93% yield, colorless oil, $[\alpha]_D^{23} = -3.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, DMSO-d_6) δ 11.68 (s, 1H), 7.83 – 7.81 (m, 2H), 7.49 – 7.45 (m, 4H), 7.38 (t, $J = 7.2$ Hz, 1H), 7.24 – 7.20 (m, 2H), 4.39 (s, 1H), 3.28 – 3.22 (m, 2H), 2.65 – 2.60 (m, 1H), 2.57 – 2.52 (m, 1H), 2.31 – 2.27 (m, 1H), 2.26 (s, 3H), 2.14 – 2.07 (m, 2H), 1.86 – 1.81 (m, 1H), 1.12 – 1.01 (m, 2H). $^{13}\text{C NMR}$ (150 MHz, DMSO-d_6) δ 202.6, 179.5, 159.4, 137.8, 137.2, 132.0, 131.7, 130.3, 129.5, 128.6, 126.3, 126.0, 60.7, 55.6, 36.3, 32.8, 30.5, 28.1, 20.9. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{25}\text{N}_2\text{O}_3$ 365.1862, found 365.1860.

The ee was determined by HPLC analysis. CHIRALPAK OJ-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 289.0 nm; retention time: 7.2 min (minor) and 10.6 min (major)

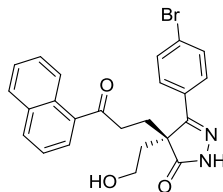


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		7.166	22407271	1068152	50.22
2		10.662	22208666	548660	49.78



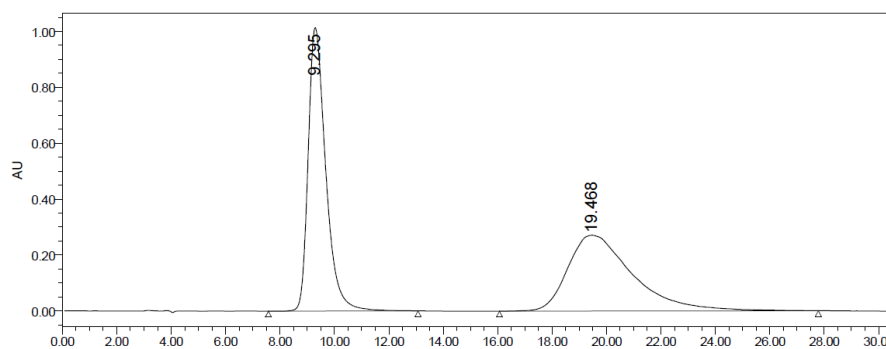
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		7.230	1970769	94620	4.61
2		10.610	40788244	1001491	95.39

(S)-5-(4-Bromophenyl)-4-(2-hydroxyethyl)-4-(3-(naphthalen-1-yl)-3-oxopropyl)-2,4-dihydro-3H-pyrazol-3-one (4e)

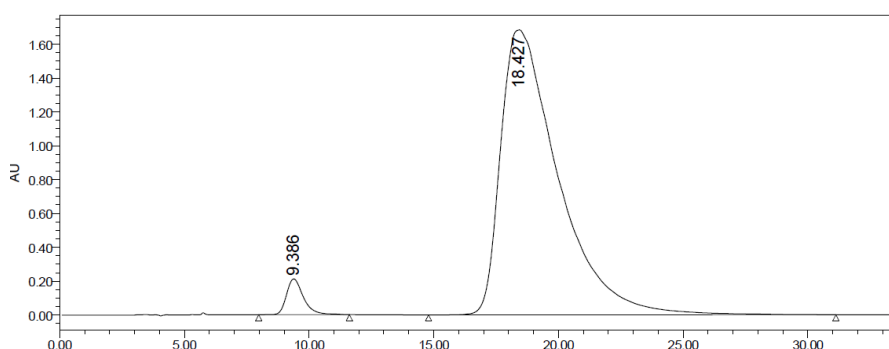


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 42.2 mg, 91% yield, colorless oil, $[\alpha]_D^{23} = -4.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, CDCl_3) δ 9.31 (s, 1H), 8.44 (d, $J = 8.4$ Hz, 1H), 7.93 (d, $J = 8.4$ Hz, 1H), 7.83 – 7.82 (m, 1H), 7.71 – 7.66 (m, 3H), 7.57 – 7.48 (m, 3H), 7.39 – 7.37 (m, 1H), 3.56 – 3.49 (m, 2H), 3.00 – 2.95 (m, 1H), 2.76 – 2.70 (m, 1H), 2.54 – 2.44 (m, 2H), 2.17 – 2.14 (m, 2H), 1.69 (s, 2H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3) δ 201.7, 179.2, 170.9, 159.3, 134.9, 133.8, 133.0, 132.4, 130.0, 129.8, 128.4, 128.0, 127.7, 127.3, 126.5, 125.5, 125.0, 124.2, 63.4, 55.6, 36.2, 32.8, 30.8, 23.8, 20.8. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{24}\text{H}_{22}\text{BrN}_2\text{O}_3$ 479.0965, found 479.0964.

The ee was determined by HPLC analysis. CHIRALPAK OJ-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 298.5 nm; retention time: 9.4 min (minor) and 18.4 min (major)

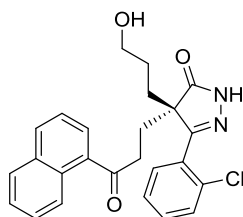


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		9.295	45513152	1013369	50.40
2		19.468	44781997	271301	49.60



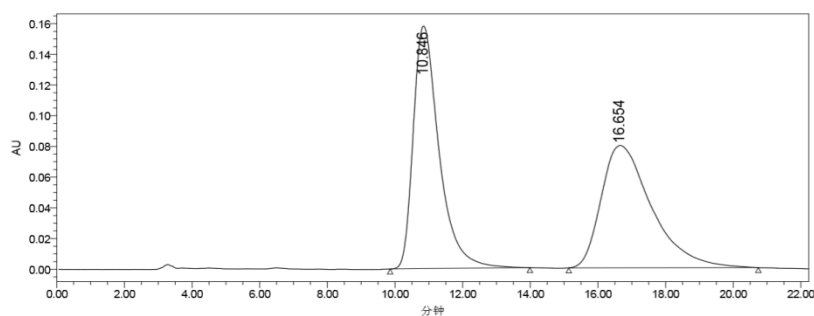
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		9.386	9944674	211009	3.55
2		18.427	270452307	1683511	96.45

(S)-5-(2-Chlorophenyl)-4-(3-hydroxypropyl)-4-(3-(naphthalen-1-yl)-3-oxopropyl)-2,4-dihydro-3H-pyrazol-3-one (4f)

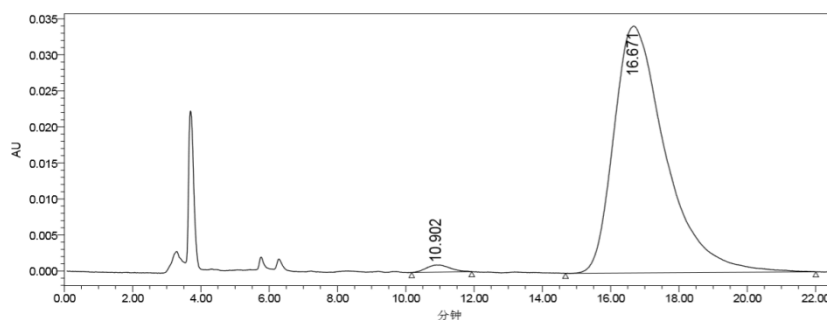


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 40.3 mg, 93% yield, white solid, mp 121.0 – 123.5 °C, $[\alpha]_D^{23} = -18.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 11.79 (s, 1H), 8.35 – 8.34 (m, 1H), 8.12 (d, *J* = 8.4 Hz, 1H), 8.00 – 7.98 (m, 1H), 7.86 (d, *J* = 7.2 Hz, 1H), 7.63 – 7.54 (m, 4H), 7.51 – 7.46 (m, 2H), 4.53 (t, *J* = 5.4 Hz, 1H), 3.41 – 3.34 (m, 2H), 3.07 – 3.01 (m, 1H), 2.92 – 2.86 (m, 1H), 2.15 – 2.10 (m, 1H), 2.06 – 2.01 (m, 1H), 1.93 – 1.88 (m, 1H), 1.79 – 1.74 (m, 1H), 1.36 – 1.28 (m, 1H), 0.89 – 0.84 (m, 1H). ¹³C NMR (150 MHz, DMSO-d₆) δ 202.8, 178.7, 158.2, 135.7, 133.9, 132.9, 132.8, 131.4 (d, *J* = 4.5 Hz), 130.6, 130.2, 129.7, 128.9, 128.2, 128.0 (d, *J* = 4.5 Hz), 126.9, 125.7, 125.2, 60.7, 56.6, 36.4, 31.1, 28.9, 27.7. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₅H₂₄ClN₂O₃ 435.1468, found 435.1470.

The ee was determined by HPLC analysis. CHIRALPAK OJ-H; Hexane/2-propanol = 65/35; flow rate 1.0 mL/min; 286.6 nm; retention time: 10.9 min (minor) and 16.7 min (major)

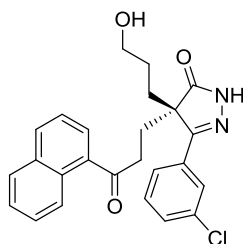


	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		10.846	8374067	158013	50.40
2		16.654	8241141	79709	49.60



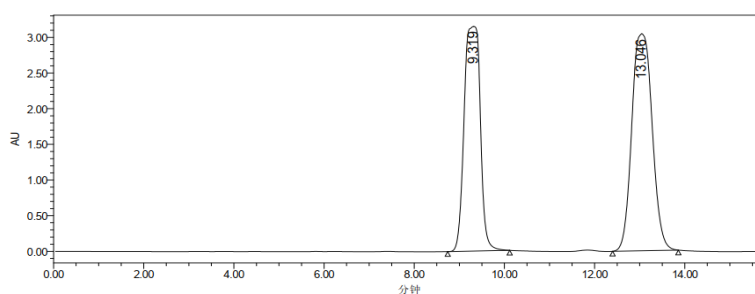
	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		10.902	48783	1009	1.34
2		16.671	3602658	34256	98.66

(S)-5-(3-Chlorophenyl)-4-(3-hydroxypropyl)-4-(3-(naphthalen-1-yl)-3-oxopropyl)-2,4-dihydro-3H-pyrazol-3-one (4g)

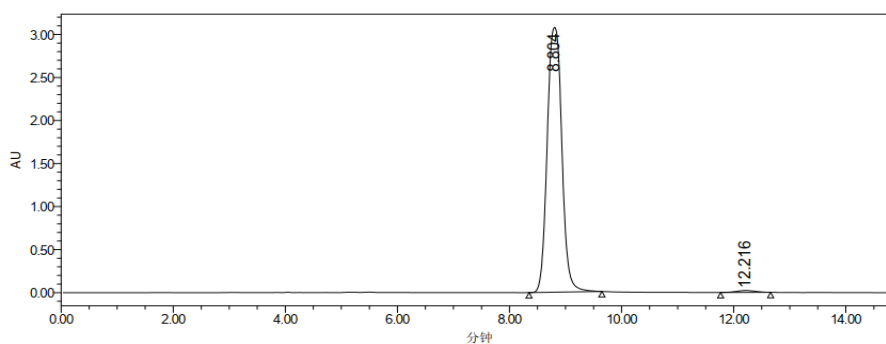


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 40.8 mg, 94% yield, colorless oil, $[\alpha]_D^{23} = +9.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, DMSO-d_6) δ 11.84 (s, 1H), 8.26 – 8.24 (m, 1H), 8.09 (d, $J = 8.4$ Hz, 1H), 7.98 – 7.97 (m, 1H), 7.82 – 7.81 (m, 2H), 7.79 – 7.77 (m, 1H), 7.58 – 7.50 (m, 4H), 4.42 (t, $J = 4.8$ Hz, 1H), 3.29 – 3.24 (m, 2H), 2.87 – 2.82 (m, 1H), 2.79 – 2.74 (m, 1H), 2.47 – 2.42 (m, 1H), 2.25 – 2.20 (m, 1H), 2.16 – 2.11 (m, 1H), 1.89 – 1.84 (m, 1H), 1.12 – 1.00 (m, 2H). $^{13}\text{C NMR}$ (150 MHz, DMSO-d_6) δ 202.6, 179.5, 158.0, 135.4, 134.3, 133.8, 133.6, 132.9, 131.5, 130.1, 129.6, 128.9, 128.2, 128.1, 126.8, 125.6, 125.3, 125.2, 124.7, 60.7, 55.6, 40.4, 36.7, 32.7, 30.5, 28.1. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{25}\text{H}_{24}\text{ClN}_2\text{O}_3$ 435.1469, found 435.1470.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 294.9 nm; retention time: 8.8 min (minor) and 12.2 min (major)

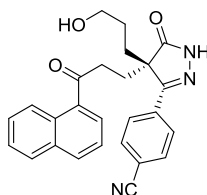


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		9.319	78606397	3148542	45.16
2		13.046	95436725	3042109	54.84



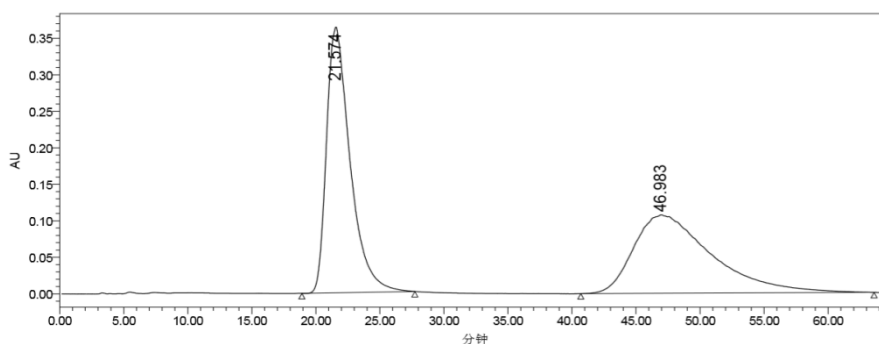
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		8.804	55650311	3076191	99.11
2		12.216	497950	21533	0.89

(S)-4-(4-(3-Hydroxypropyl)-4-(3-(naphthalen-1-yl)-3-oxopropyl)-5-oxo-4,5-dihydro-1H-pyrazol-3-yl)benzotrile (4h)

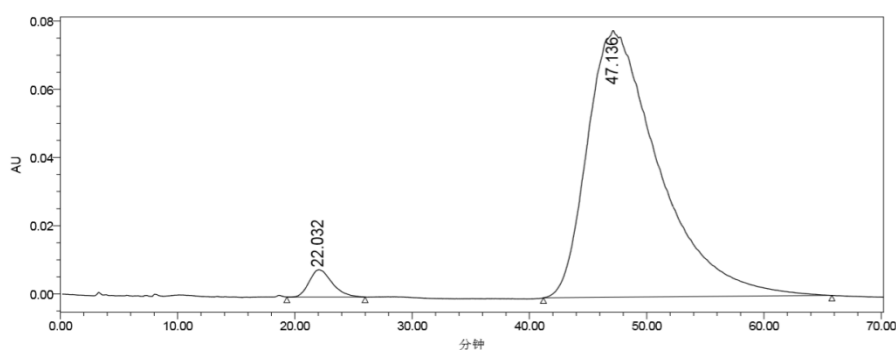


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 38.2 mg, 90% yield, colorless oil, $[\alpha]_D^{23} = -9.0$ (c 1.0, CHCl_3); $^1\text{H NMR}$ (600 MHz, DMSO-d_6) δ 11.99 (s, 1H), 8.24 (d, $J = 8.4$ Hz, 1H), 8.09 (d, $J = 8.4$ Hz, 1H), 8.01 (d, $J = 7.8$ Hz, 2H), 7.97 (d, $J = 7.2$ Hz, 1H), 7.91 (d, $J = 9.0$ Hz, 2H), 7.82 (d, $J = 7.2$ Hz, 1H), 7.57 – 7.51 (m, 3H), 4.41 (t, $J = 5.4$ Hz, 1H), 3.28 – 3.23 (m, 2H), 2.88 – 2.82 (m, 1H), 2.77 – 2.72 (m, 1H), 2.49 – 2.45 (m, 1H), 2.26 – 2.21 (m, 1H), 2.19 – 2.14 (m, 1H), 1.90 – 1.85 (m, 1H), 1.11 – 0.96 (m, 2H). $^{13}\text{C NMR}$ (150 MHz, DMSO-d_6) δ 202.5, 179.6, 157.8, 135.6, 135.3, 133.8, 133.3, 132.9, 129.6, 128.9, 128.2, 128.1, 126.8, 126.6, 125.6, 125.2, 118.9, 112.4, 60.6, 55.6, 36.7, 32.7, 30.4, 28.1. HRMS (ESI-Orbitrap) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{26}\text{H}_{24}\text{N}_3\text{O}_3$ 426.1810, found 426.12.

The ee was determined by HPLC analysis. CHIRALPAK OJ-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 305.6 nm; retention time: 22.0 min (minor) and 47.1 min (major)

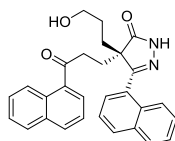


	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		21.574	46599022	363949	50.66
2		46.983	45383813	107592	49.34



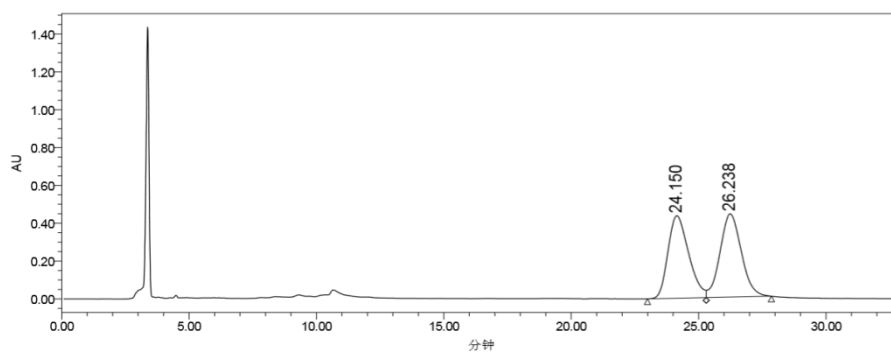
	Name	Retention time (min)	Area ($\mu\text{V}\cdot\text{s}$)	Height (μV)	% Area
1		22.032	109257	8006	3.19
2		47.136	33199286	78231	96.81

(S)-4-(3-Hydroxypropyl)-5-(naphthalen-1-yl)-4-(3-(naphthalen-1-yl)-3-oxopropyl)-2,4-dihydro-3H-pyrazol-3-one (4i)

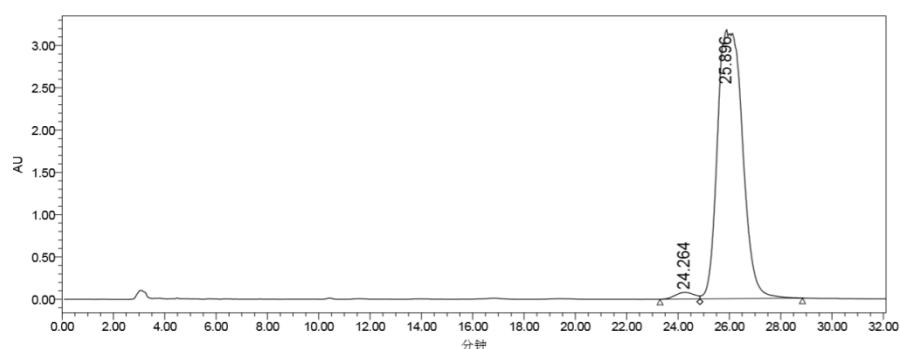


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 41.4 mg, 92% yield, white solid, mp 186.3 - 189.0 °C, $[\alpha]_D^{23} = +29.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 11.90 (s, 1H), 8.75 (d, *J* = 8.4 Hz, 1H), 8.24 (d, *J* = 8.4 Hz, 1H), 8.07 – 8.01 (m, 3H), 7.95 (d, *J* = 7.8 Hz, 1H), 7.77 (d, *J* = 7.2 Hz, 1H), 7.66 (d, *J* = 7.2 Hz, 1H), 7.63 – 7.50 (m, 5H), 7.45 – 7.42 (m, 1H), 4.44 (s, 1H), 2.95 – 2.90 (m, 1H), 2.87 – 2.81 (m, 1H), 2.30 – 2.25 (m, 1H), 2.17 – 2.06 (m, 2H), 1.87 – 1.82 (m, 1H), 1.30 – 1.17 (m, 3H), 0.89 – 0.85 (m, 1H). ¹³C NMR (150 MHz, DMSO-d₆) δ 202.7, 178.9, 159.9, 135.4, 134.4, 133.8, 132.8, 131.1, 130.6, 129.6, 129.2, 128.8, 128.5, 128.1, 128.0, 127.7, 126.8, 126.7, 126.6, 126.2, 125.7, 125.6, 125.1, 60.7, 57.2, 36.7, 32.5, 30.4, 28.1. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₉H₂₇N₂O₃ 451.2017, found 451.2016.

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 220.3 nm; retention time: 24.3 min (minor) and 25.9 min (major)

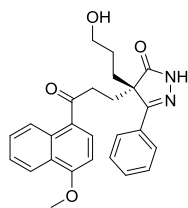


	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		24.150	24583462	435866	49.04
2		26.238	25542193	440348	50.96



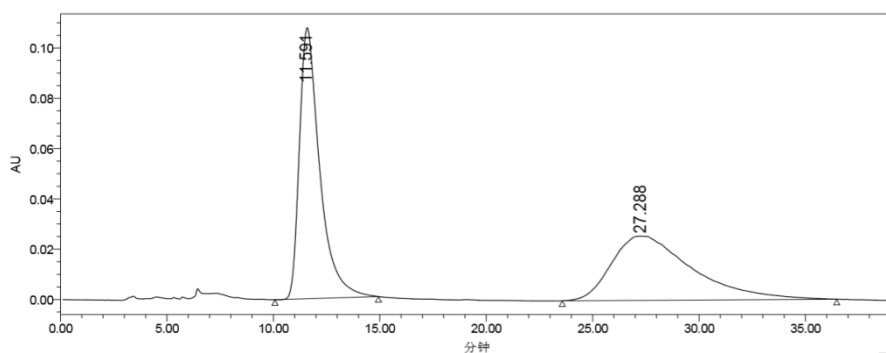
	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		24.264	4013611	79233	1.82
2		25.896	216126722	3181522	98.18

(S)-4-(3-Hydroxypropyl)-4-(3-(4-methoxynaphthalen-1-yl)-3-oxopropyl)-5-phenyl-2,4-dihydro-3H-pyrazol-3-one (4j)

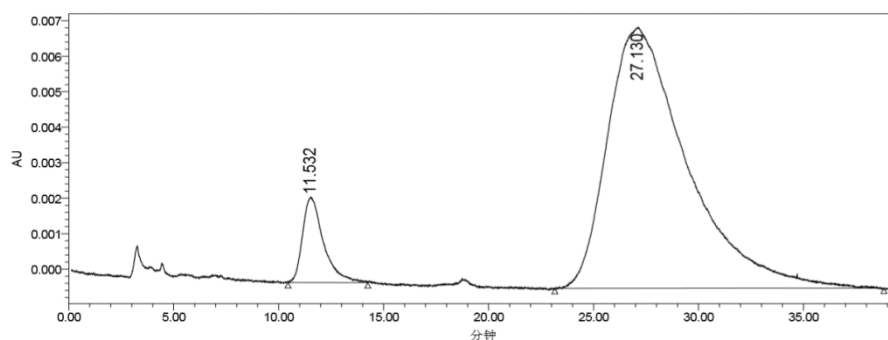


The title compound was purified by column chromatography on silica gel (PE : EA = 3:1 to DCM : MeOH = 50:1), 36.5 mg, 85% yield, white solid, mp 209.0 - 211.2 °C, $[\alpha]_D^{23} = +5.0$ (c 1.0, CHCl₃); ¹H NMR (600 MHz, DMSO-d₆) δ 11.70 (s, 1H), 8.60 (d, *J* = 8.4 Hz, 1H), 8.20 (d, *J* = 8.4 Hz, 1H), 7.87 – 7.84 (m, 3H), 7.59 – 7.52 (m, 2H), 7.49 – 7.46 (m, 3H), 6.94 (d, *J* = 8.4 Hz, 1H), 4.39 (s, 1H), 4.03 (s, 3H), 3.26 – 3.25 (m, 2H), 2.81 – 2.76 (m, 1H), 2.71 – 2.66 (m, 1H), 2.41 – 2.36 (m, 1H), 2.22 – 2.09 (m, 1H), 1.90 – 1.83 (m, 2H), 1.12 – 1.04 (m, 2H). ¹³C NMR (150 MHz, DMSO-d₆) δ 200.6, 179.6, 159.4, 158.7, 131.8, 131.6 (d, *J* = 9.0 Hz), 130.3, 129.7, 128.8, 126.7, 126.3, 126.0, 125.4, 122.1, 103.5, 60.8, 56.5, 55.7, 35.8, 31.2, 28.1. HRMS (ESI-Orbitrap) *m/z*: [M+H]⁺ Calcd for C₂₆H₂₇N₂O₃ 431.1963 found 431.1965.

The ee was determined by HPLC analysis. CHIRALPAK OJ-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 298.5 nm; retention time: 11.5 min (minor) and 27.1 min (major)

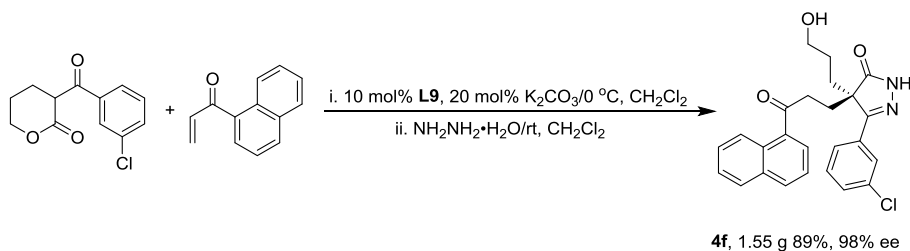


	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		11.591	7150202	107809	51.61
2		27.288	6703869	25498	48.39



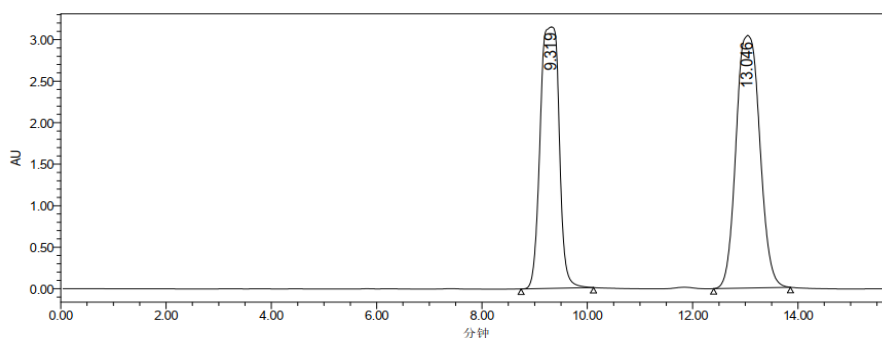
	Name	Retention time (min)	Area (μV*s)	Height (μV)	% Area
1		11.532	166970	2414	7.93
2		27.130	1937454	7365	92.07

9. Gram-scale procedure for the preparation of (S) - 4f

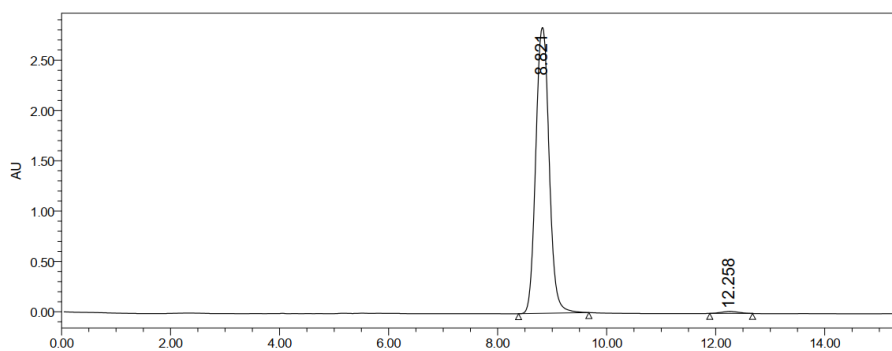


To the mixture of 2-(3-chloro)benzoyl- δ -valerolactone (952 mg, 4.0 mmol), catalyst **L9** (154.0 mg, 0.4 mmol), and K_2CO_3 (110 mg, 0.8 mmol) in analytical purity grade dichloromethane (3.0 mL) was added α -naphthyl vinyl ketone (873 mg, 4.8 mmol) at 0 °C. The reaction was stirred for 6 days at 0 °C to completion checked by TLC. $NH_2NH_2 \cdot H_2O$ (100 mg, 20.0 mmol) was then added, and the mixture was stirred at room temperature for another 5 h to completion checked by TLC. The mixture was directly submitted to preparative silica gel column chromatography (PE : EA = 3:1 to DCM : MeOH = 50:1) to furnish the product (S)- **4f** (1.55 g, 89% yield, 98% ee).

The ee was determined by HPLC analysis. CHIRALPAK AD-H; Hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 294.9 nm; retention time: 8.8 min (minor) and 12.3 min (major)



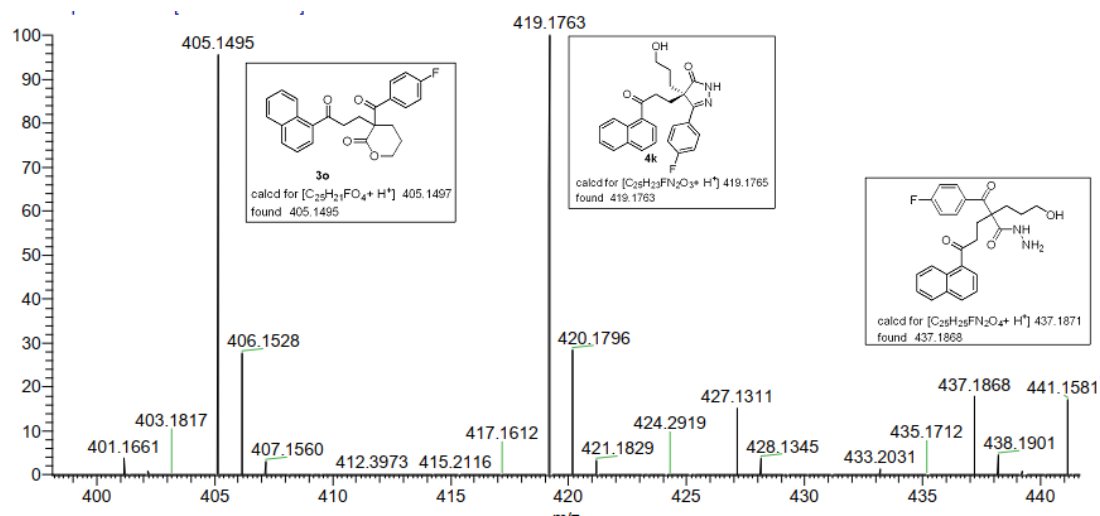
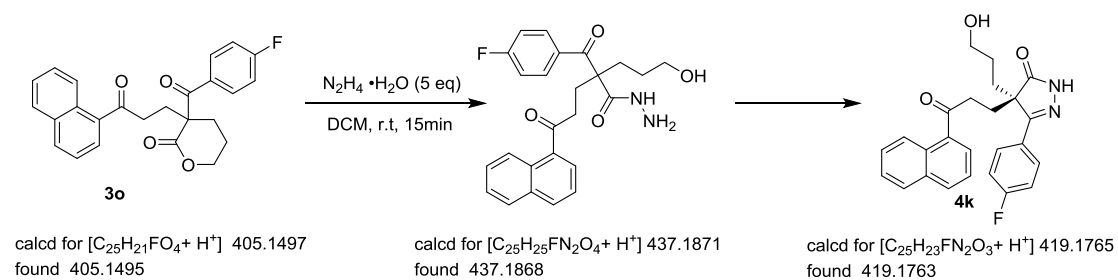
	Name	Retention time (min)	Area ($\mu V \cdot s$)	Height (μV)	% Area
1		9.319	78606397	3148542	45.16
2		13.046	95436725	3042109	54.84



	Name	Retention time (min)	Area ($\mu V \cdot s$)	Height (μV)	% Area
1		8.821	48320675	2839802	99.12
2		12.258	431196	19168	0.88

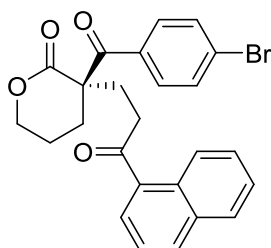
10. Exploration of the process of pyrazolone formation

To the solution of **3o** (0.05 mmol, 20 mg) in 0.5 mL CH₂Cl₂ was added hydrazine hydrate (0.25 mmol, 12.5 mg) and the reaction was stirred at room temperature for 15 min, a small sample was taken out to directly perform the HRMS detection of the reaction mixture.



11. Single crystal data, structural refinement and measurement of 3p

3p (CCDC Number: 2011405)



(S)-3p

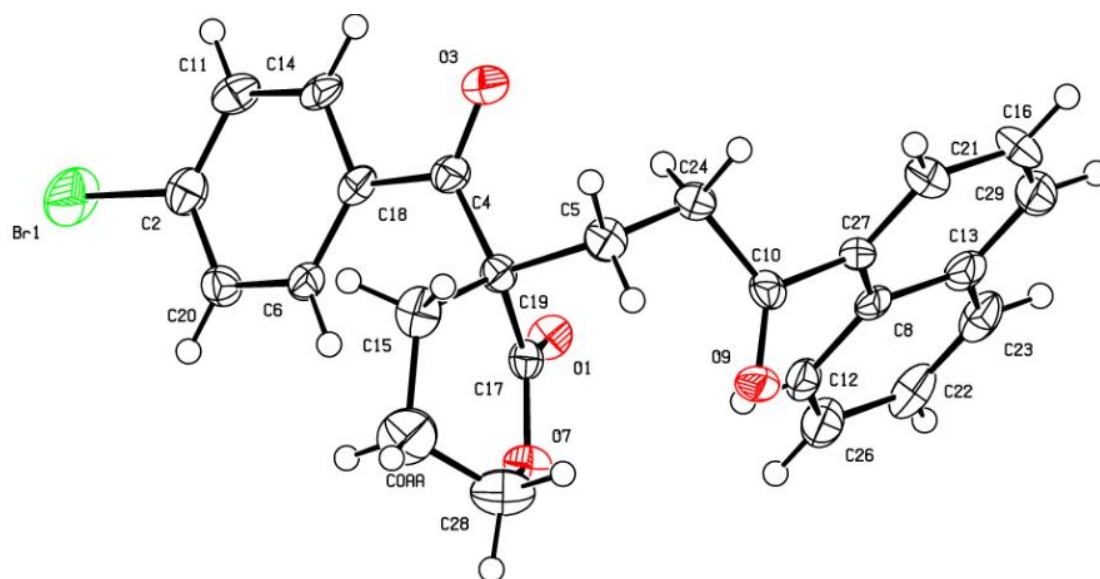


Table 1 Crystal data and structure refinement for zhaopf_0415.

Identification code	zhaopf_0415
Empirical formula	C ₂₅ H ₂₁ BrO ₄
Formula weight	465.33
Temperature/K	292.90(10)
Crystal system	orthorhombic
Space group	P2 ₁ 2 ₁ 2 ₁
a/Å	10.0294(4)
b/Å	10.8154(6)
c/Å	19.2909(9)
α/°	90
β/°	90
γ/°	90
Volume/Å ³	2092.51(17)
Z	4
ρ _{calc} /cm ³	1.477
μ/mm ⁻¹	1.994
F(000)	952.0

Crystal size/mm ³	0.18 × 0.15 × 0.12
Radiation	MoK α ($\lambda = 0.71073$)
2 Θ range for data collection/ $^{\circ}$	6.968 to 52.042
Index ranges	$-12 \leq h \leq 7, -13 \leq k \leq 7, -23 \leq l \leq 23$
Reflections collected	6822
Independent reflections	4113 [$R_{\text{int}} = 0.0355, R_{\text{sigma}} = 0.0754$]
Data/restraints/parameters	4113/0/271
Goodness-of-fit on F^2	1.038
Final R indexes [$I \geq 2\sigma(I)$]	$R_1 = 0.0486, wR_2 = 0.0865$
Final R indexes [all data]	$R_1 = 0.0740, wR_2 = 0.0975$
Largest diff. peak/hole / e \AA^{-3}	0.39/-0.49
Flack parameter	-0.004(8)

12. Single crystal data, structural refinement and measurement of 4f

4f (CCDC Number: 2011408)

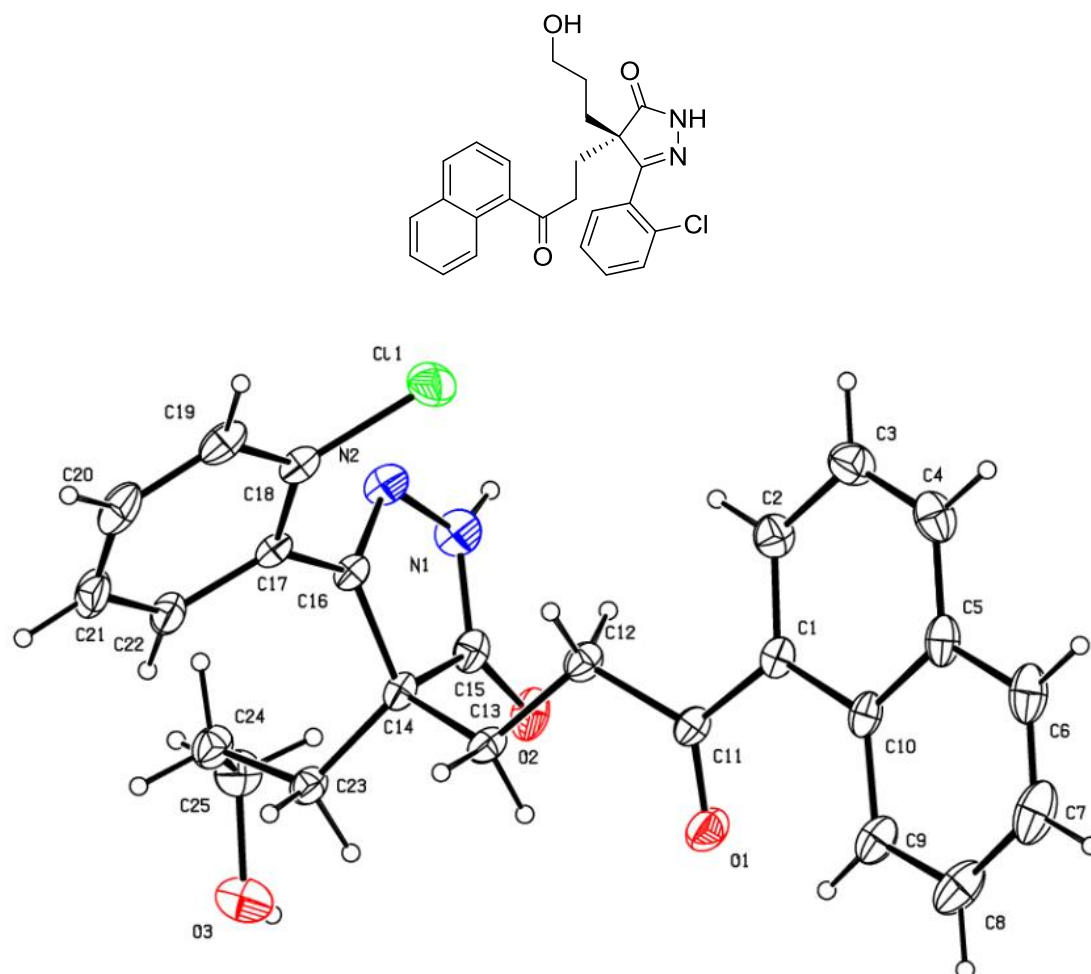
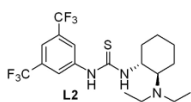
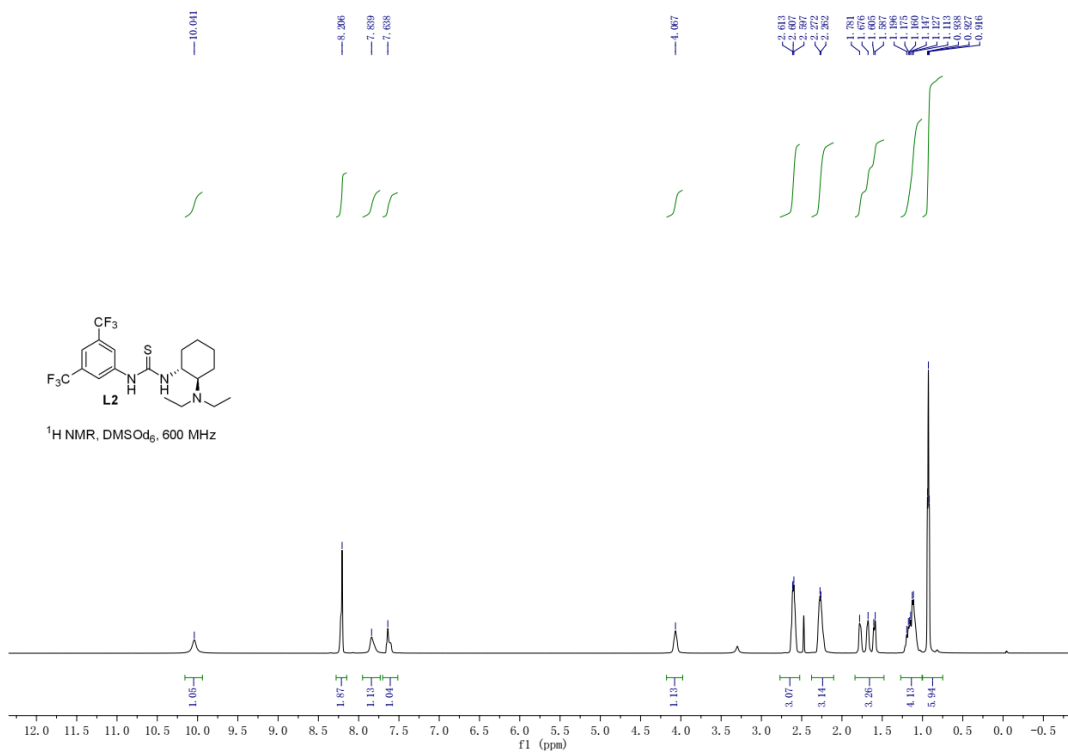


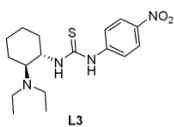
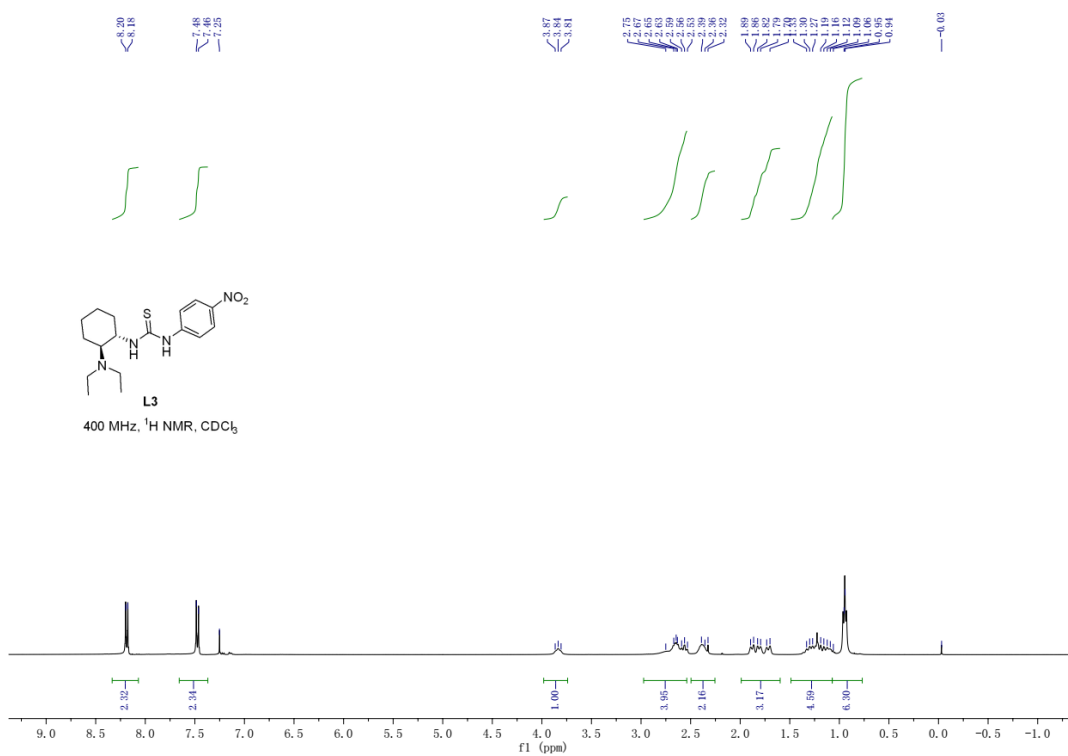
Table 1 Crystal data and structure refinement for xuy1_0218.

Identification code	xuy1_0218
Empirical formula	C ₂₅ H ₂₃ ClN ₂ O ₃
Formula weight	434.90
Temperature/K	293.44(10)
Crystal system	orthorhombic
Space group	P2 ₁ 2 ₁ 2 ₁
a/Å	7.04410(19)
b/Å	16.2447(4)
c/Å	18.7200(5)
α /°	90.00
β /°	90.00
γ /°	90.00
Volume/Å ³	2142.11(9)
Z	4
$\rho_{\text{calc}}/\text{cm}^3$	1.349

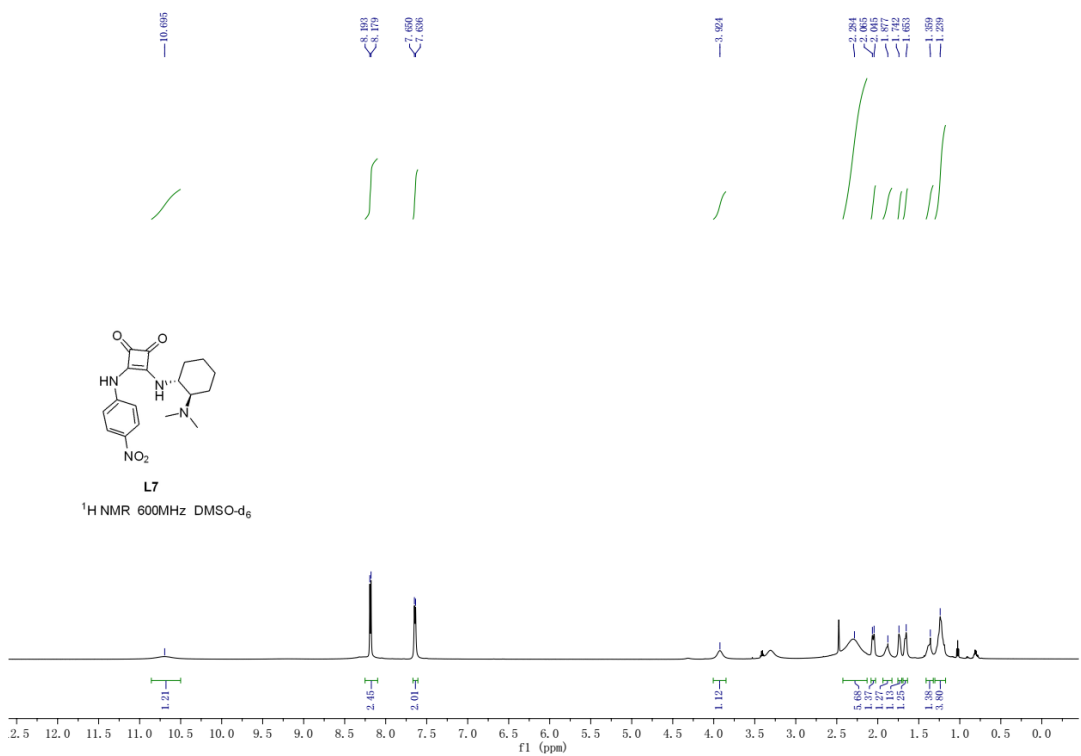
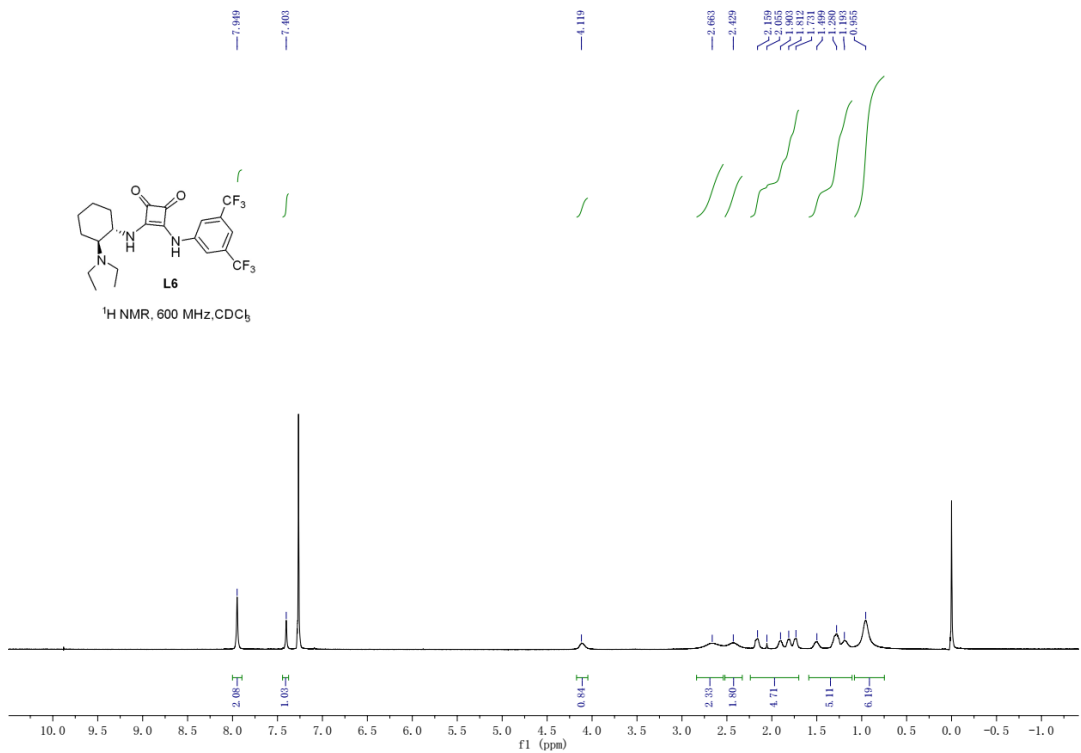
μ/mm^{-1}	1.823
F(000)	912.0
Crystal size/ mm^3	$0.12 \times 0.07 \times 0.06$
Radiation	$\text{CuK}\alpha$ ($\lambda = 1.54184$)
2θ range for data collection/ $^\circ$	7.2 to 133.12
Index ranges	$-8 \leq h \leq 8, -10 \leq k \leq 19, -22 \leq l \leq 19$
Reflections collected	5081
Independent reflections	3222 [$R_{\text{int}} = 0.0228, R_{\text{sigma}} = 0.0436$]
Data/restraints/parameters	3222/0/281
Goodness-of-fit on F^2	1.038
Final R indexes [$I \geq 2\sigma(I)$]	$R_1 = 0.0416, wR_2 = 0.0957$
Final R indexes [all data]	$R_1 = 0.0496, wR_2 = 0.1031$
Largest diff. peak/hole / $e \text{ \AA}^{-3}$	0.18/-0.17
Flack parameter	-0.02(2)

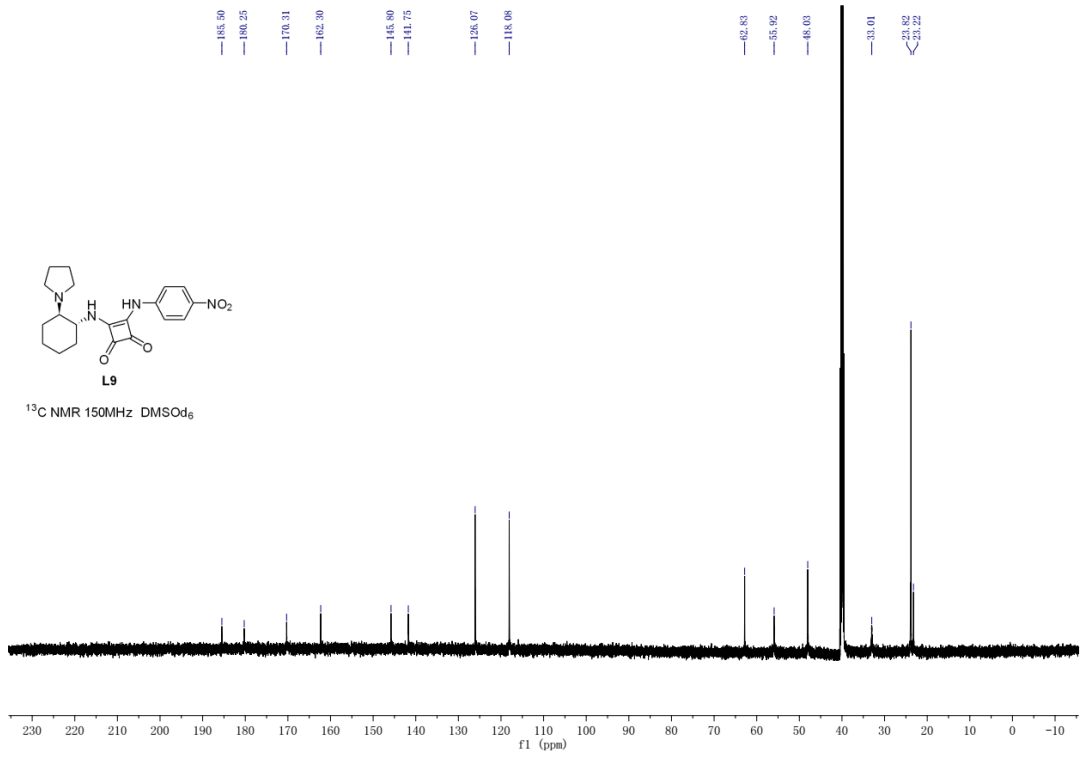


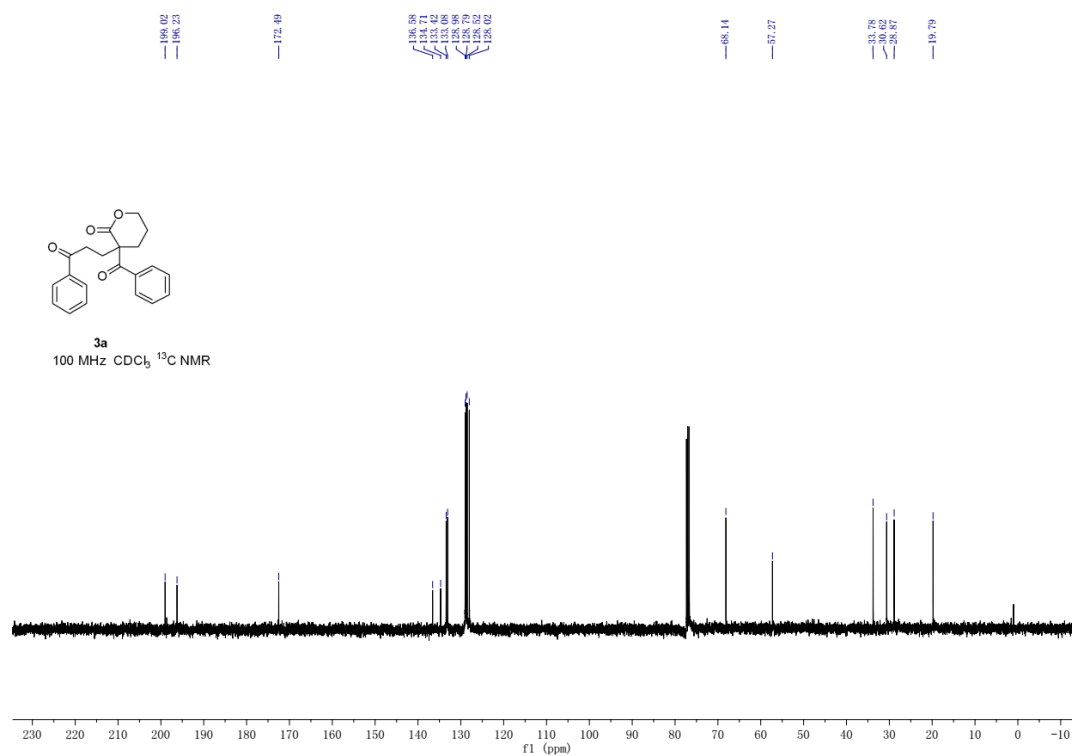
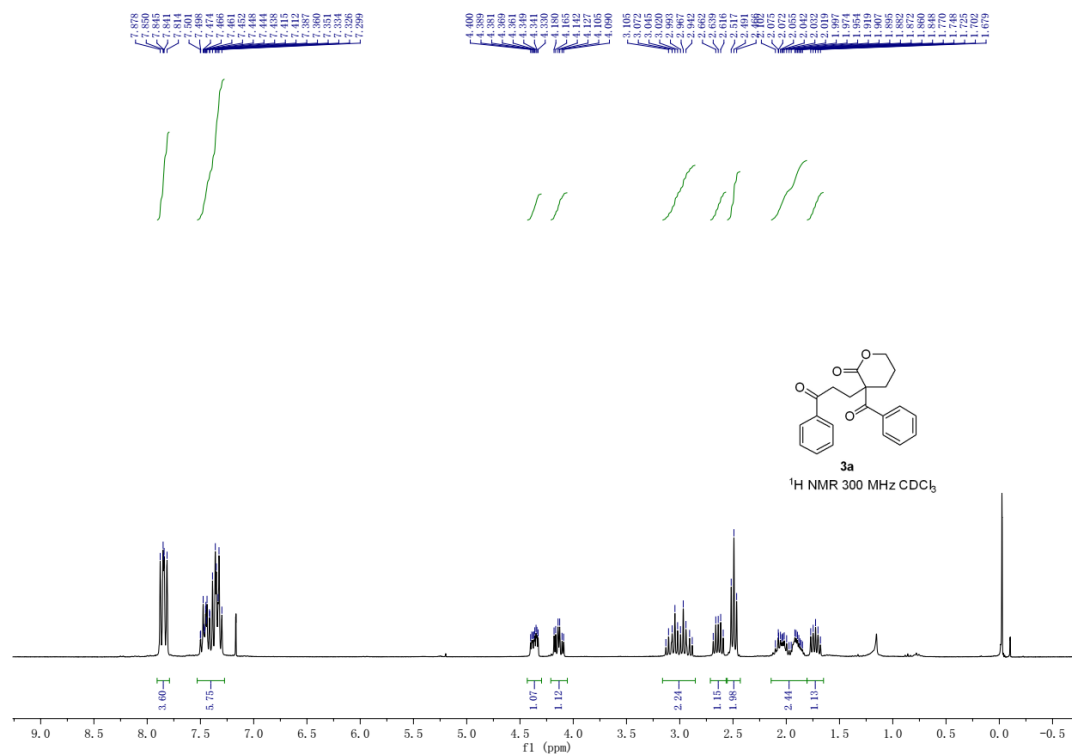
$^1\text{H NMR}$, DMSO-d_6 , 600 MHz

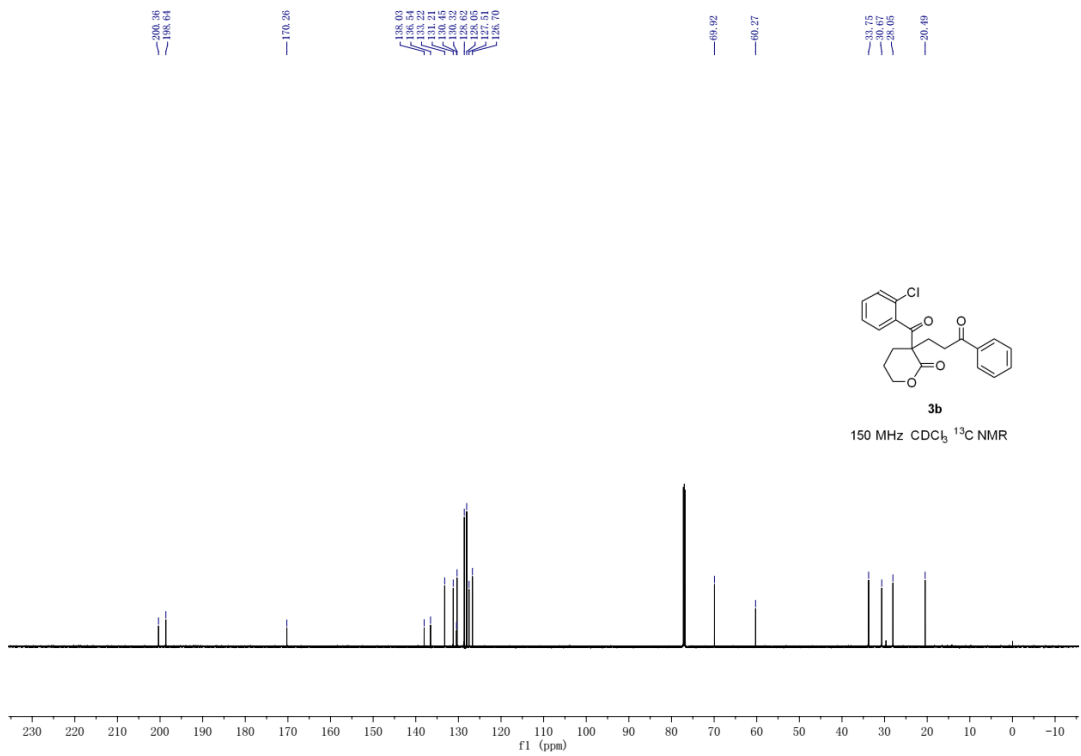
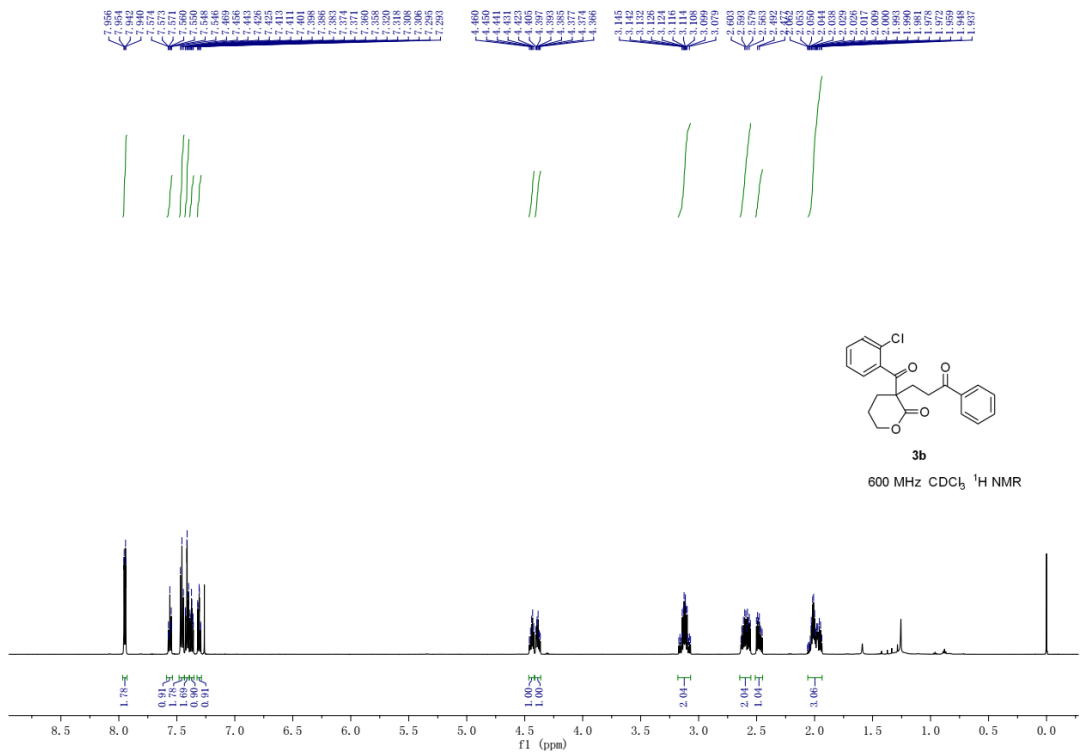


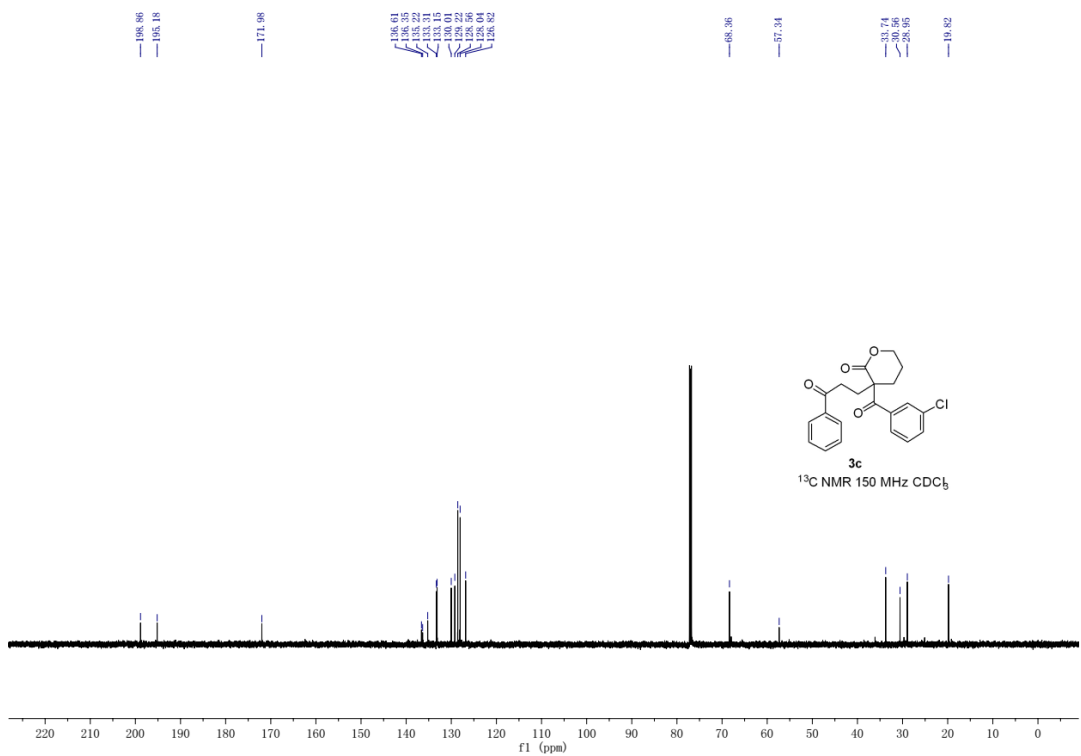
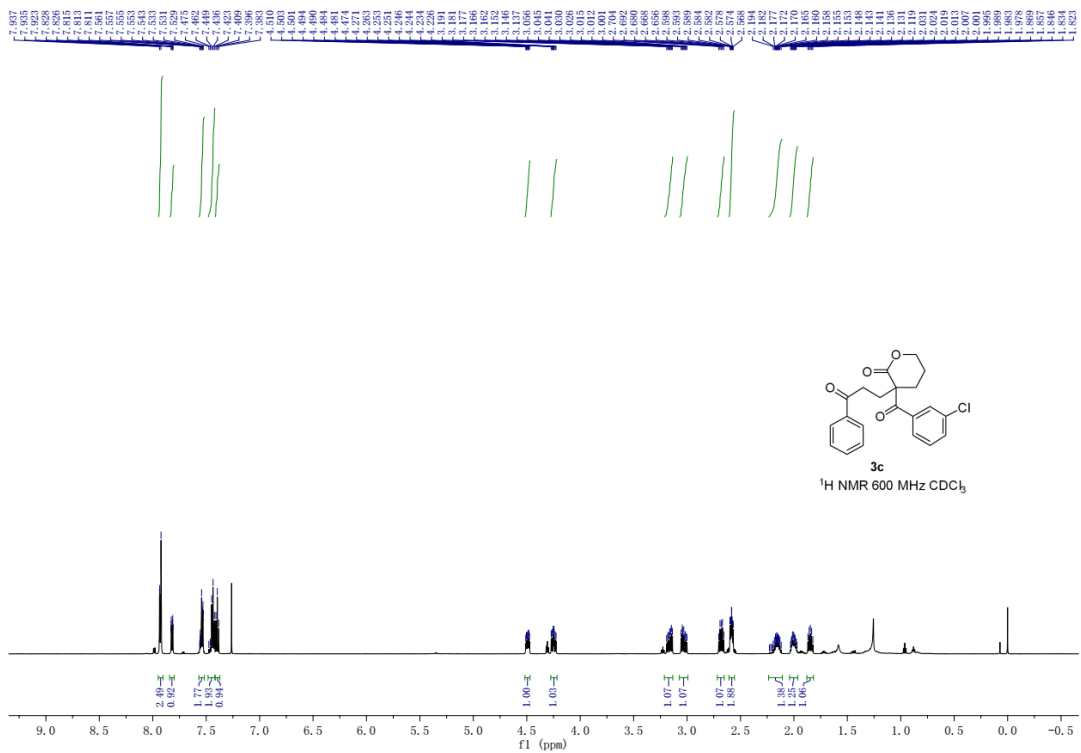
400 MHz, $^1\text{H NMR}$, CDCl_3

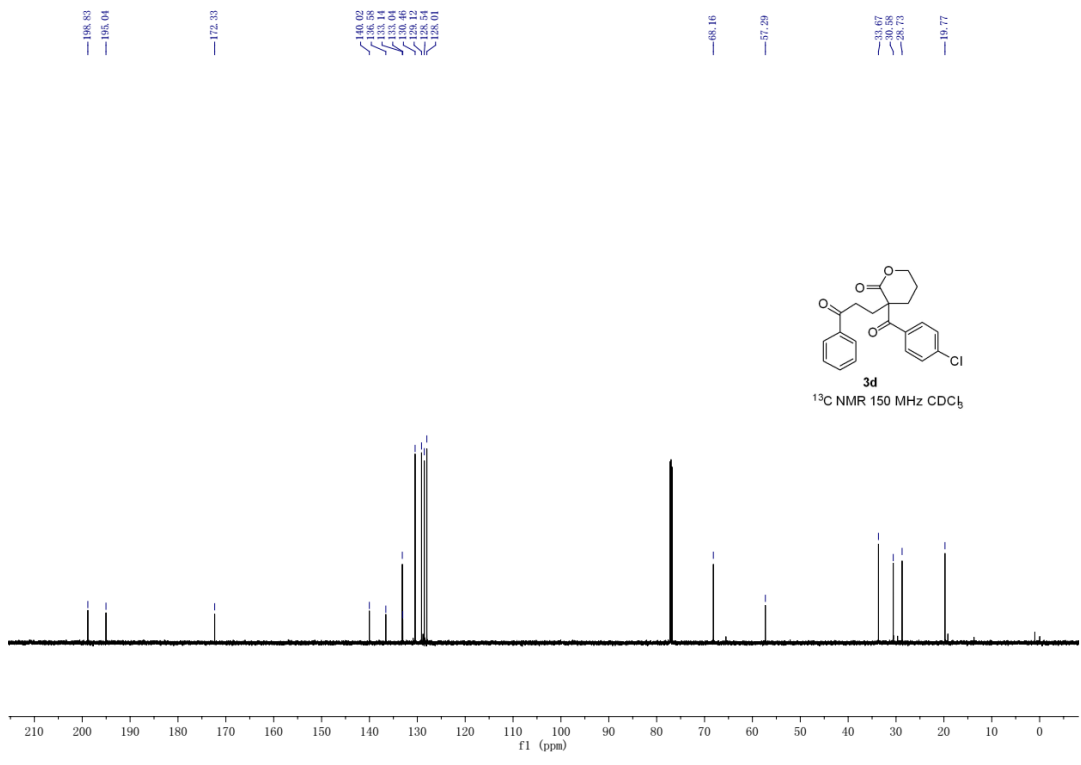
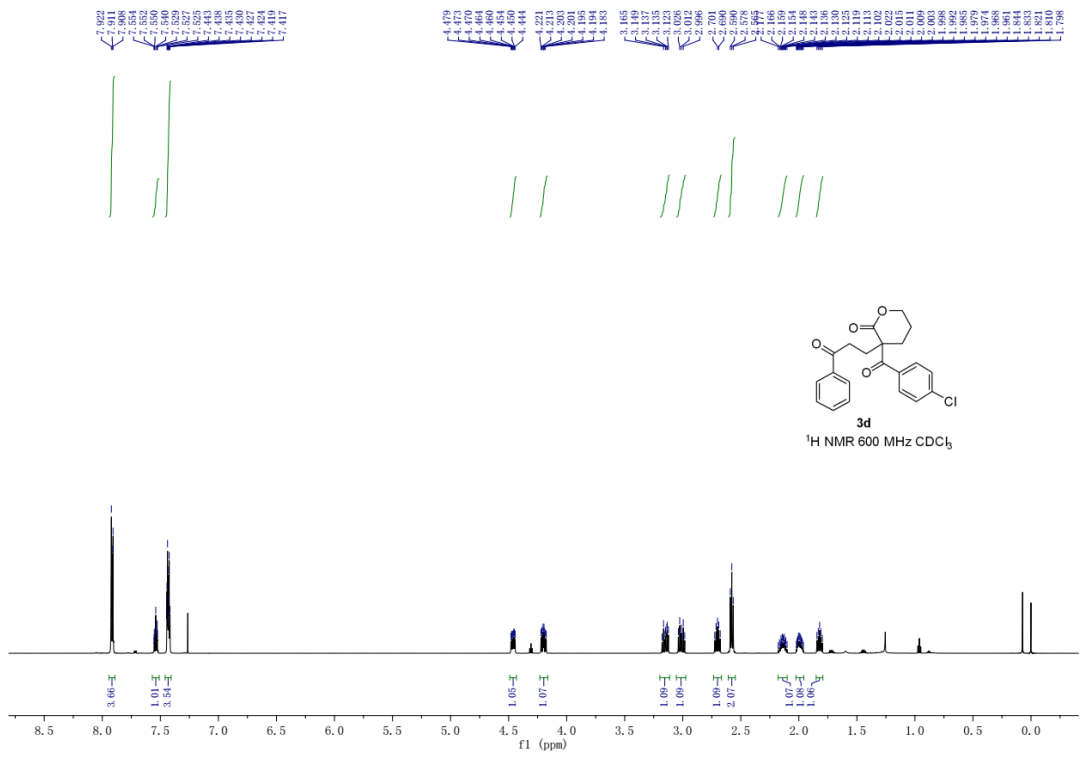


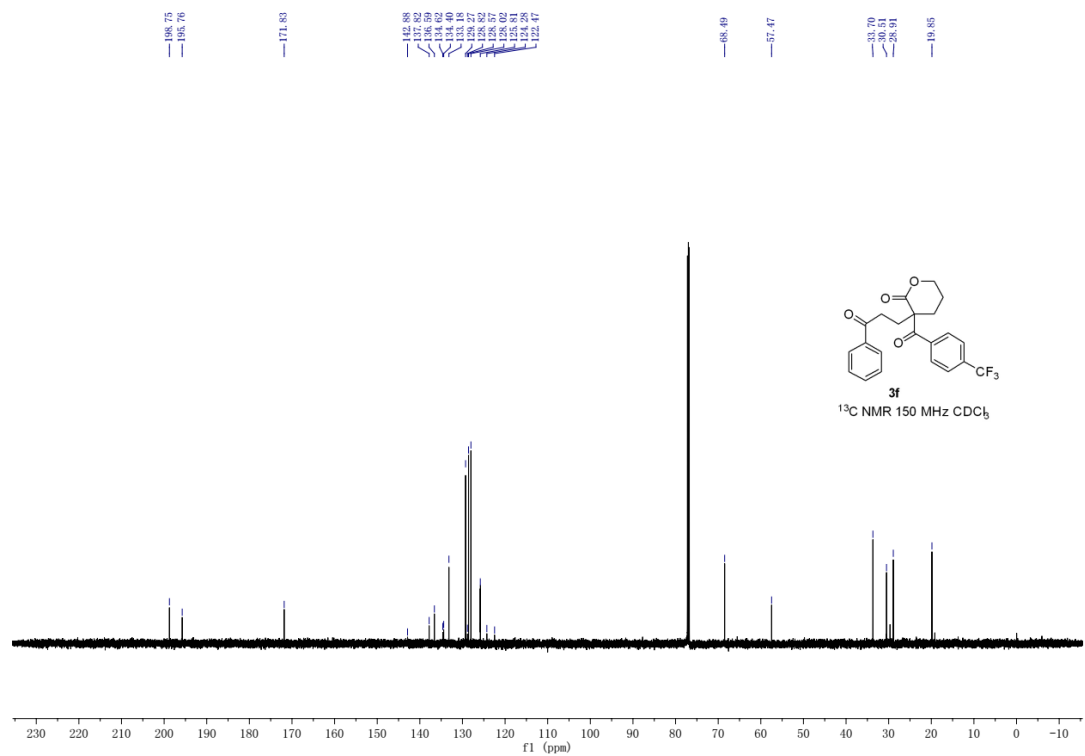
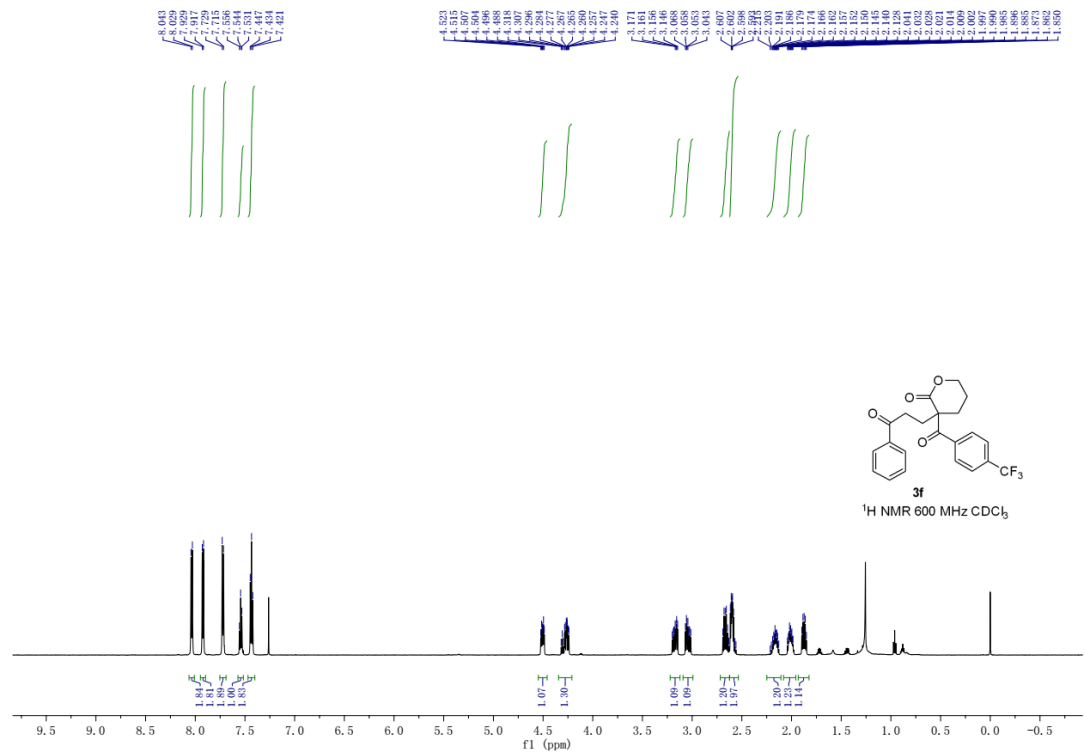


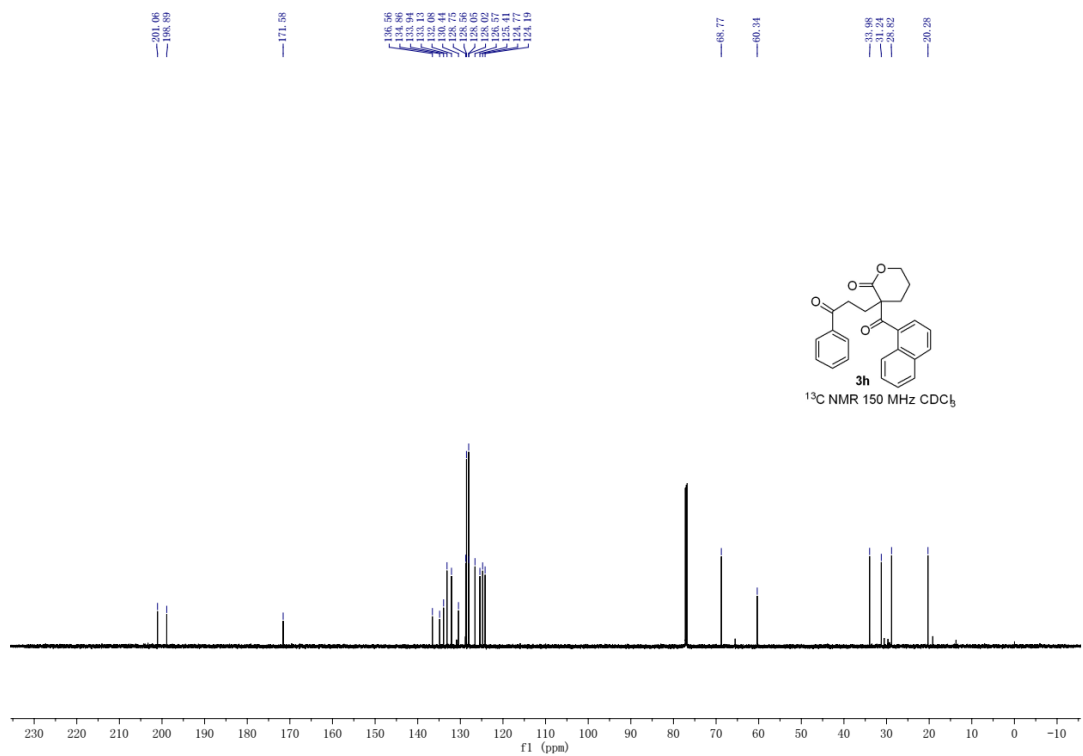
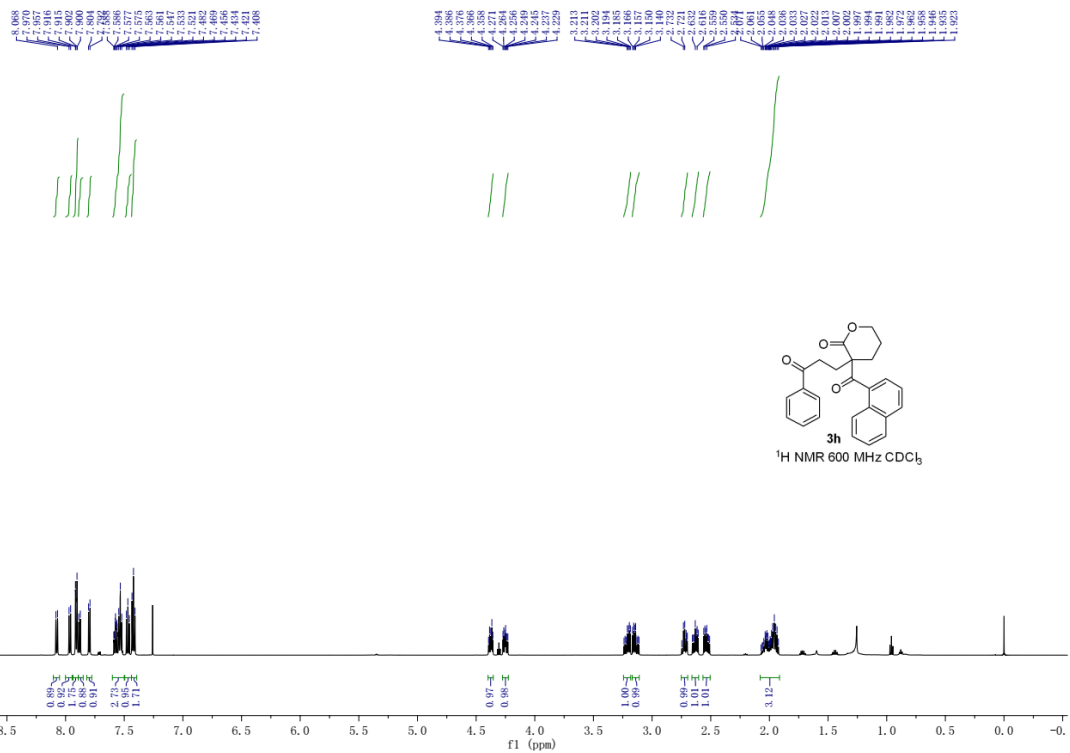


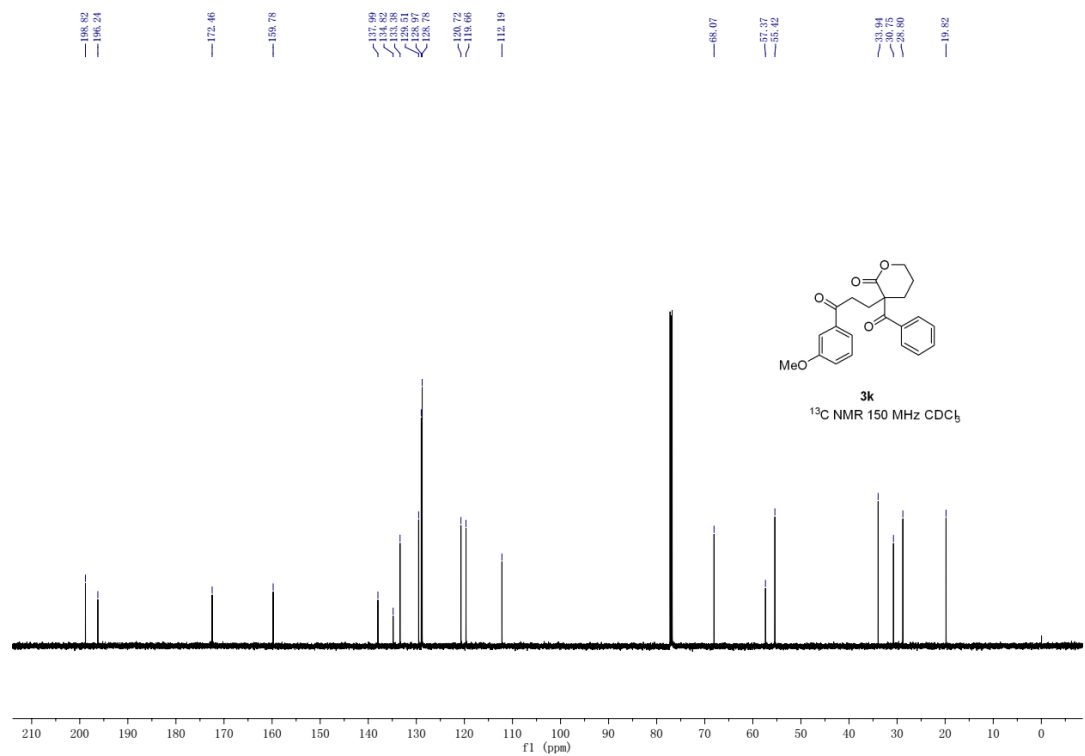
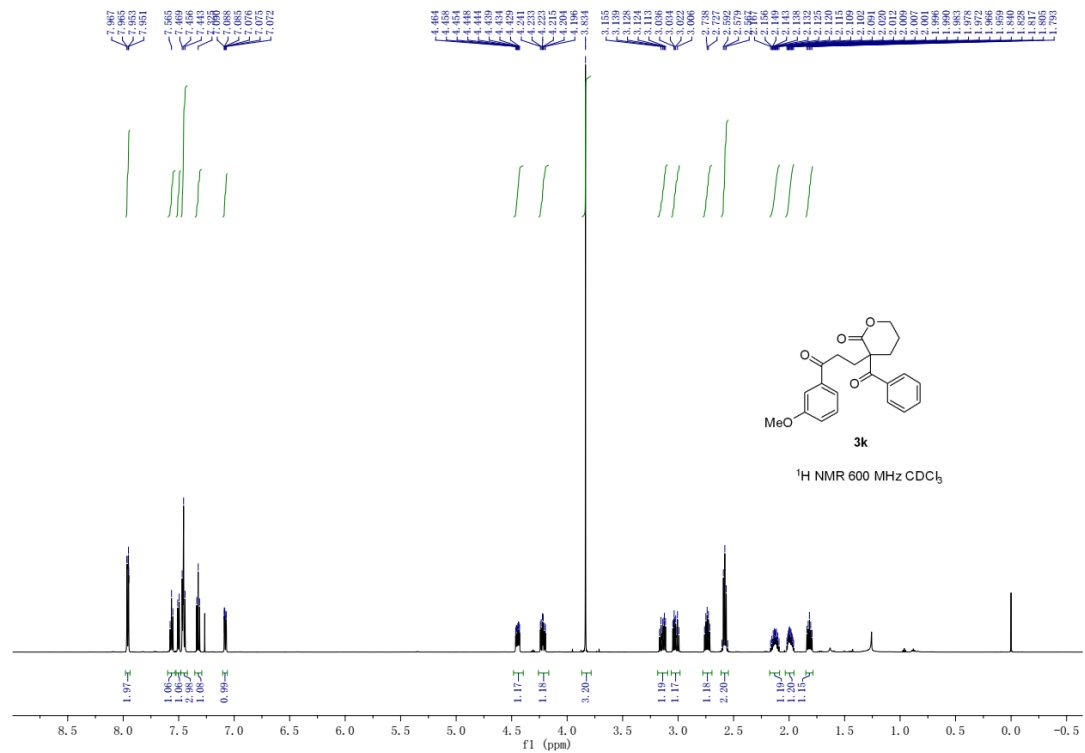


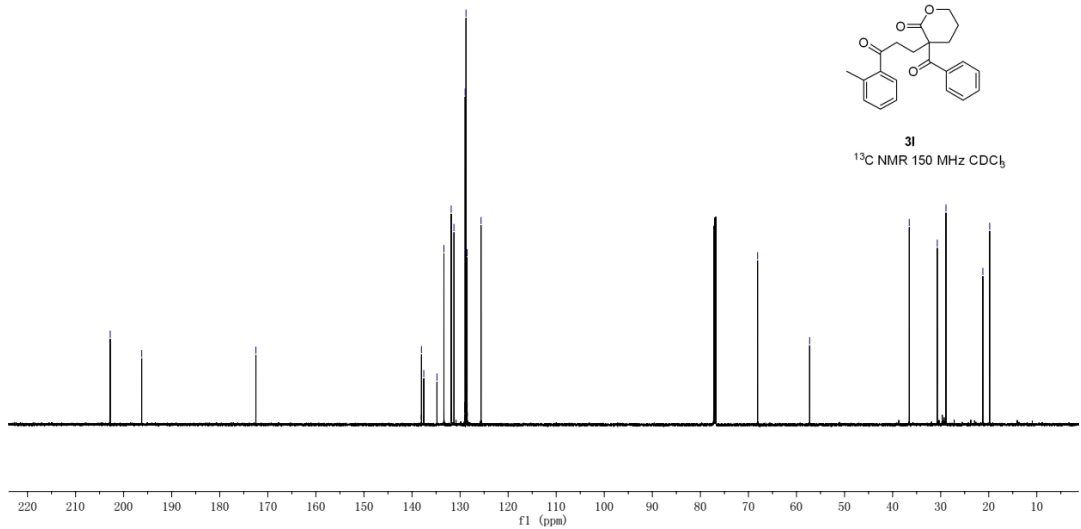
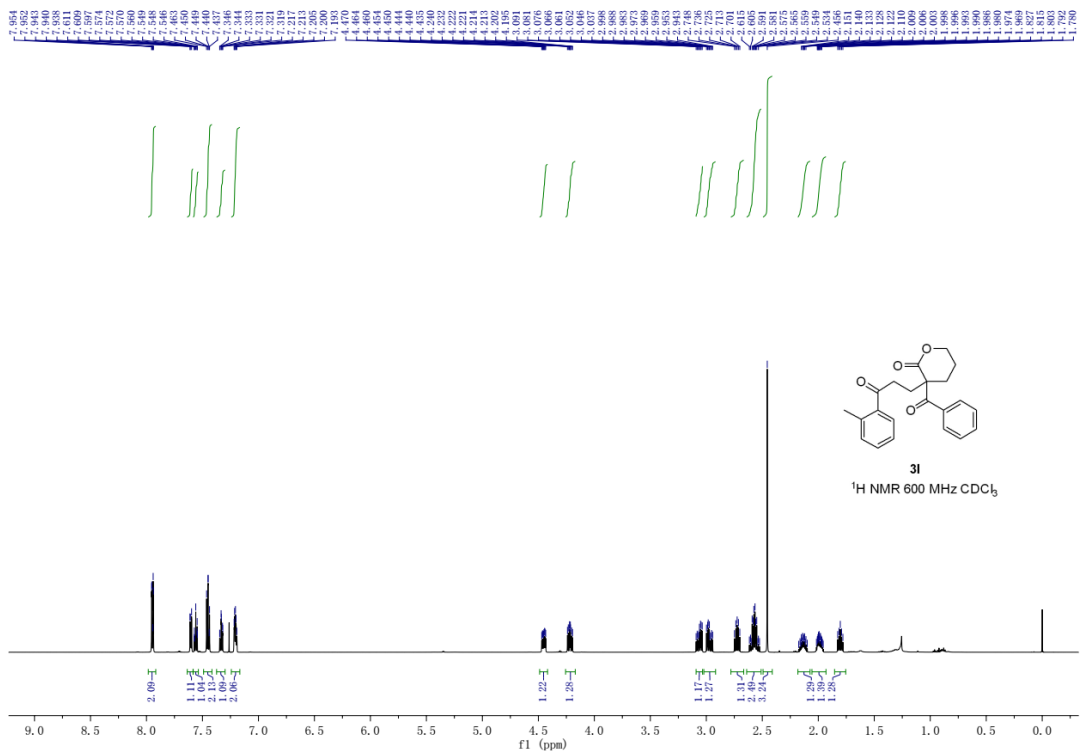


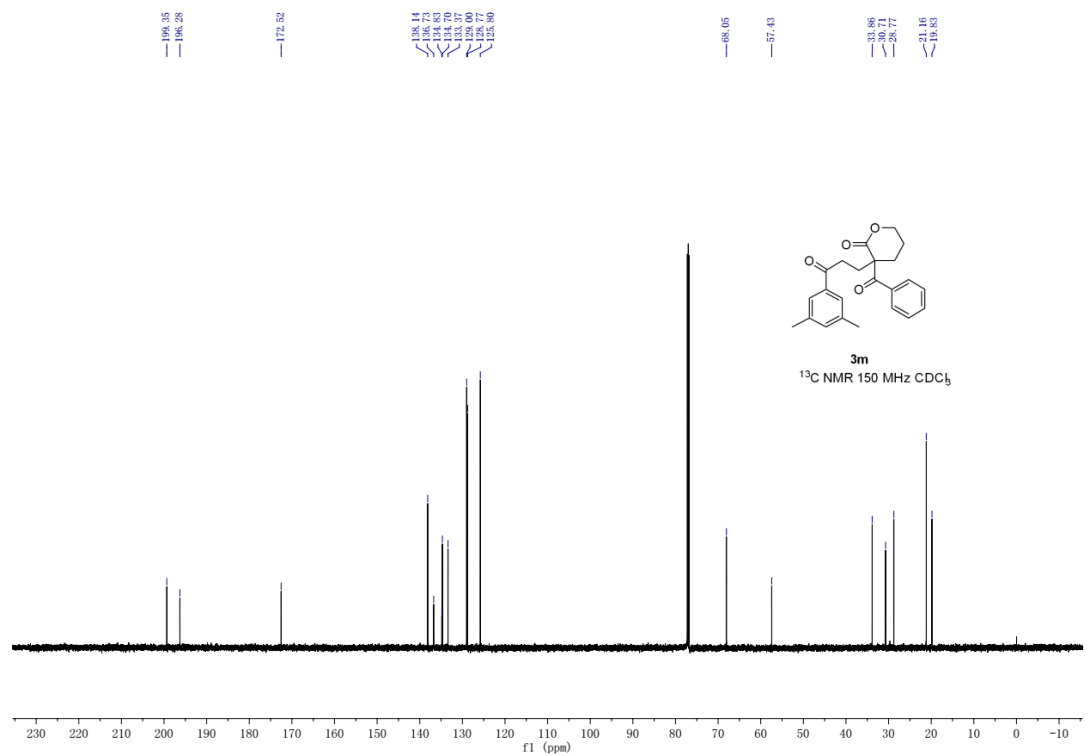
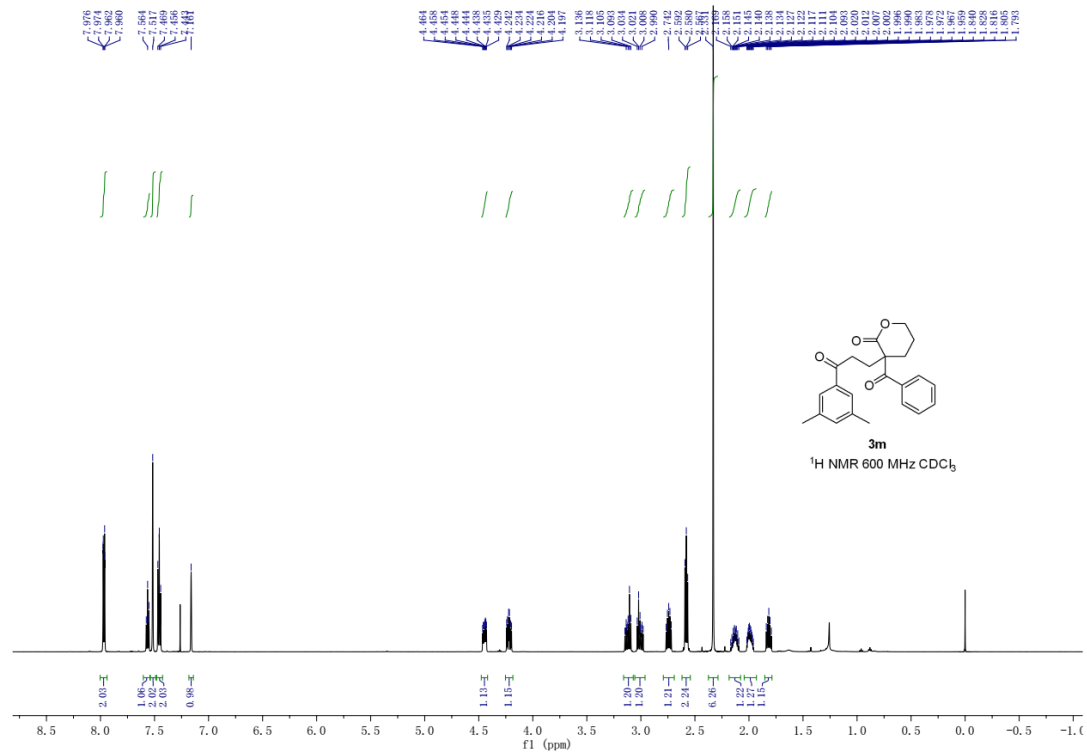


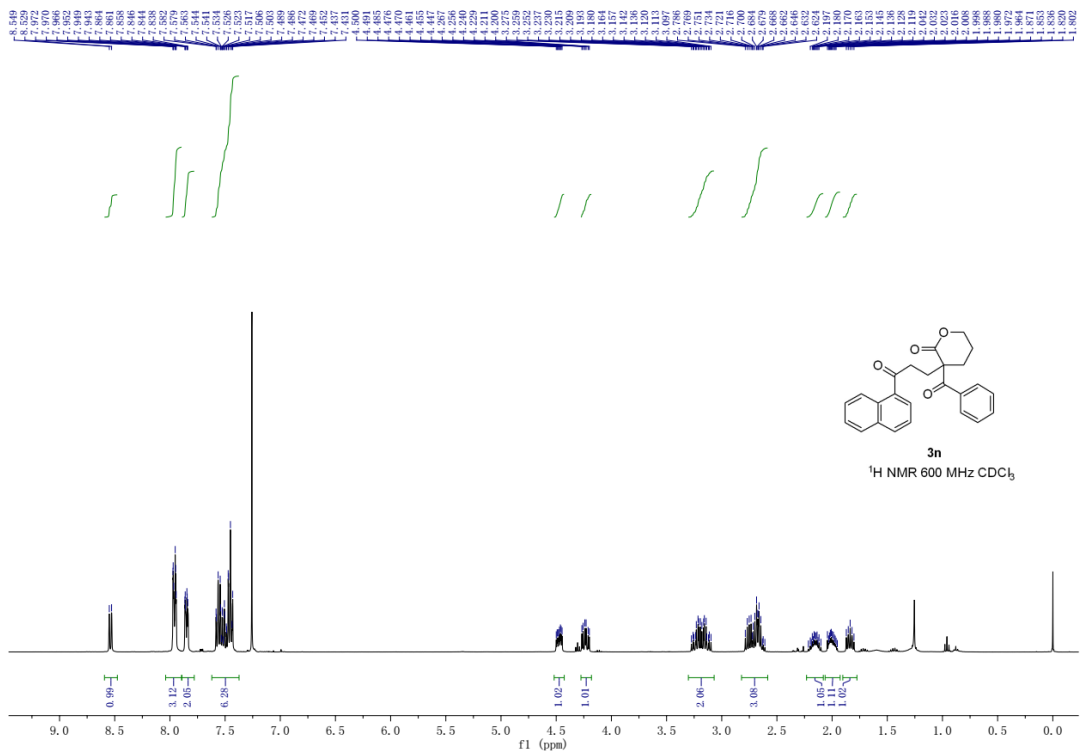






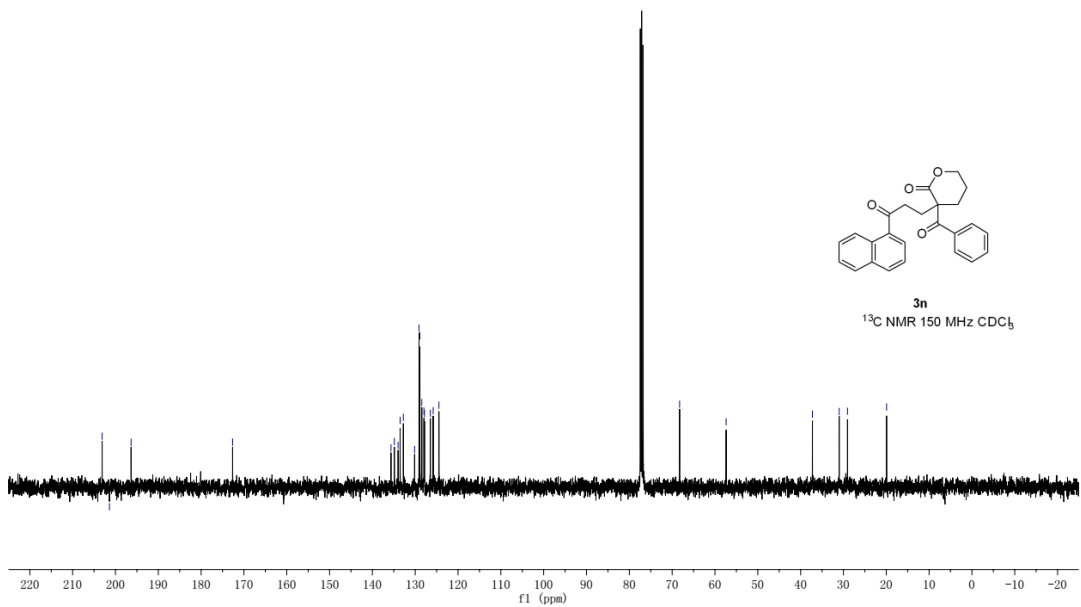


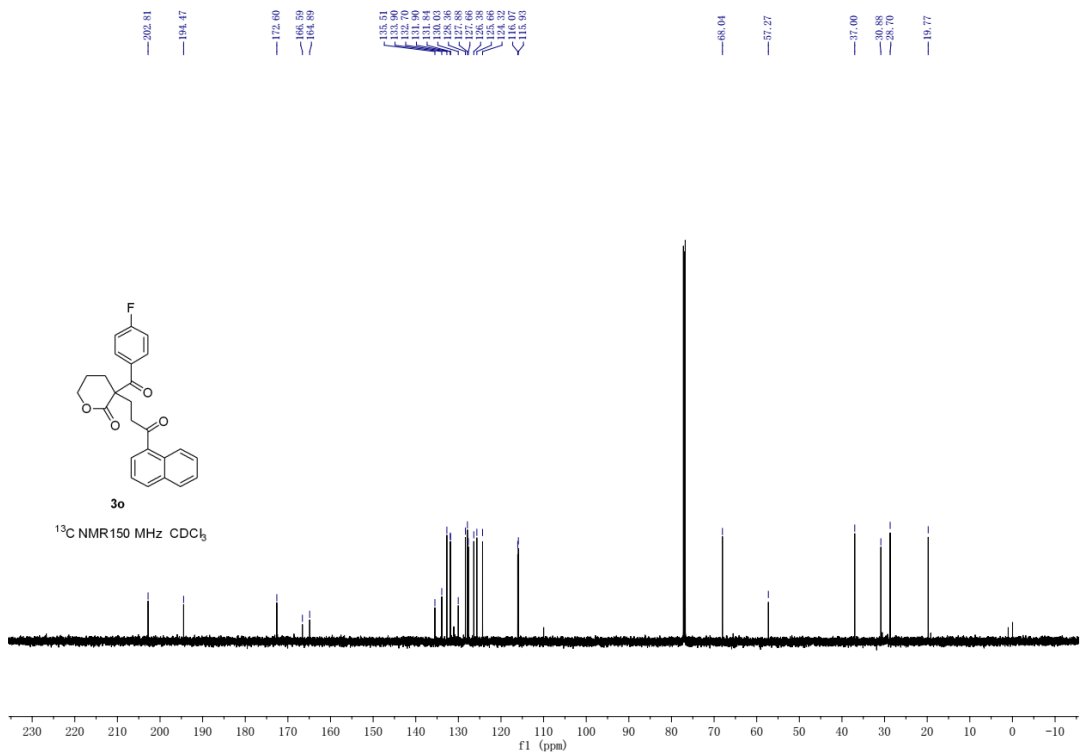
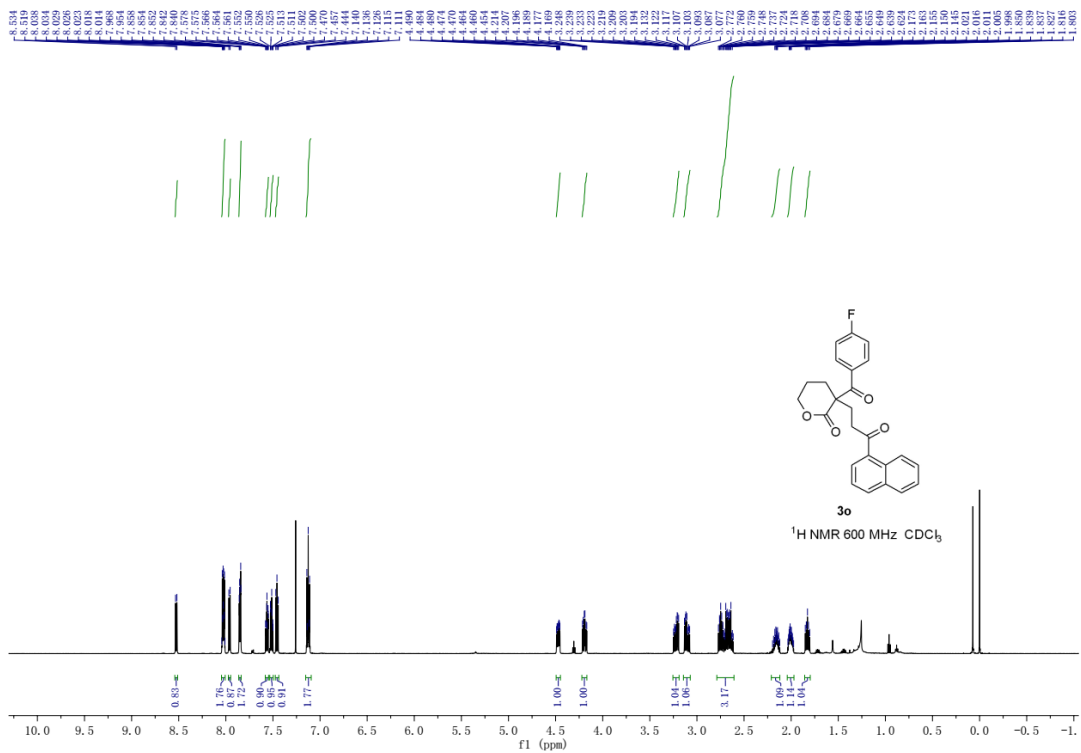


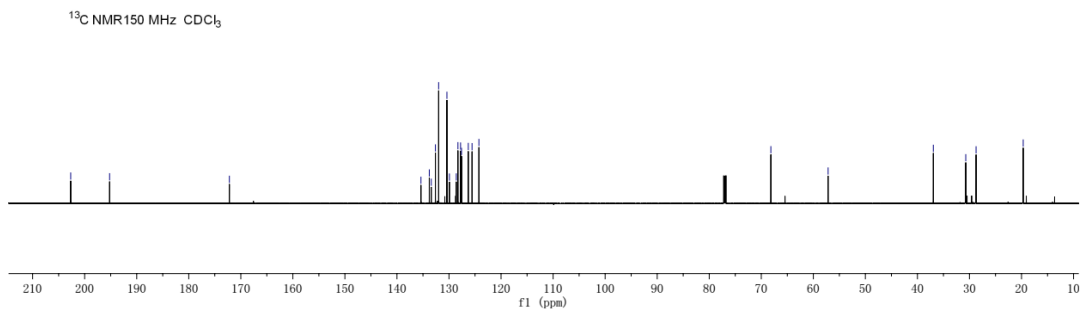
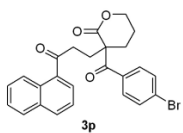
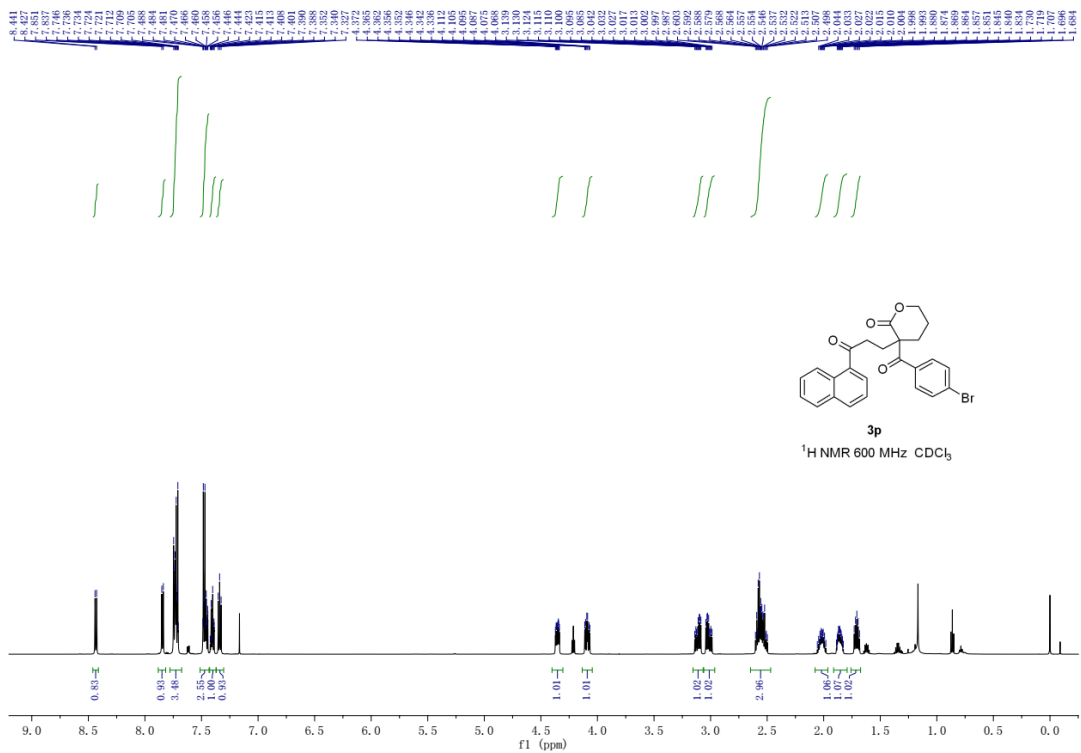


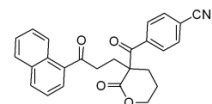
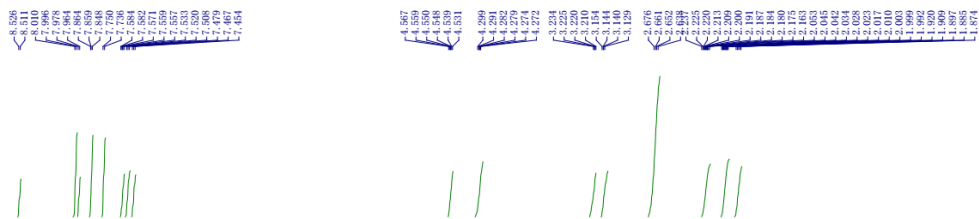
201.11
 201.41
 196.35
 172.05
 133.66
 133.06
 133.53
 133.17
 129.11
 128.46
 127.97
 127.53
 125.61
 124.46

68.26
 57.40
 37.25
 30.99
 29.05
 19.93

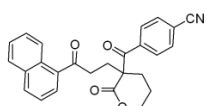
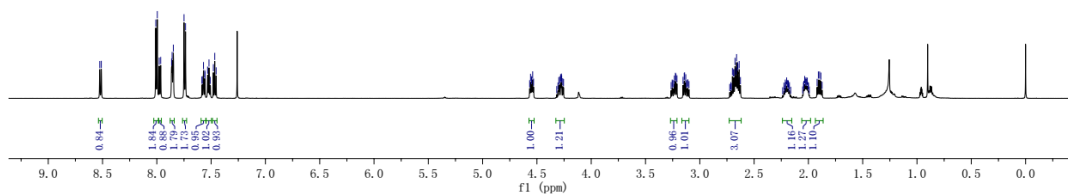




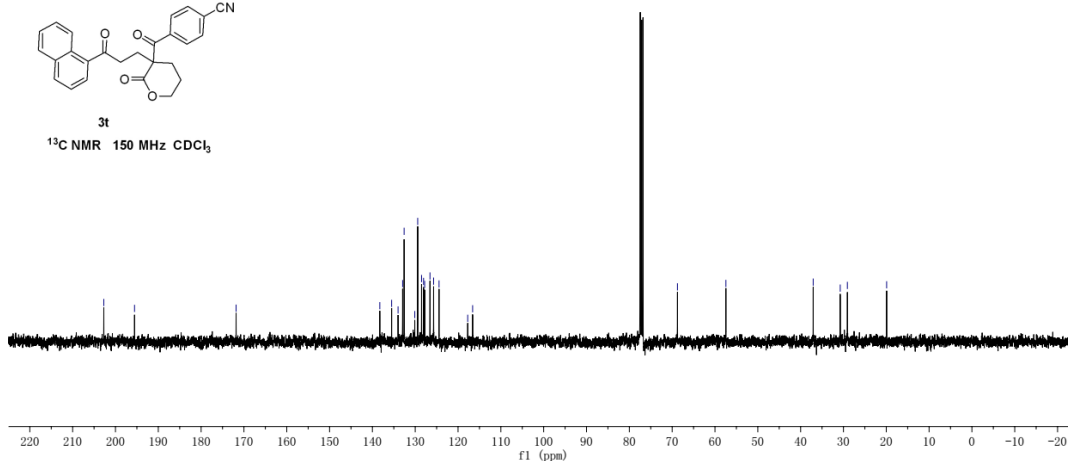


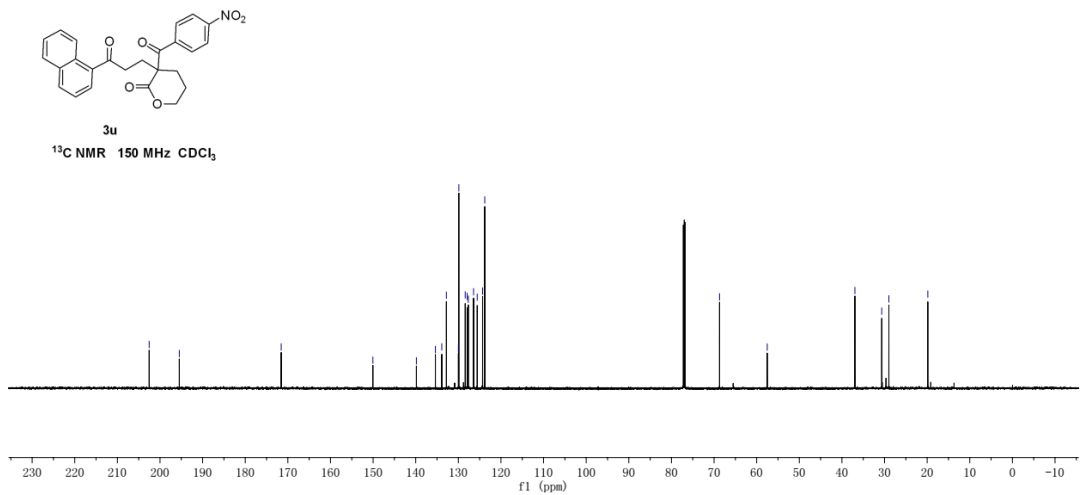
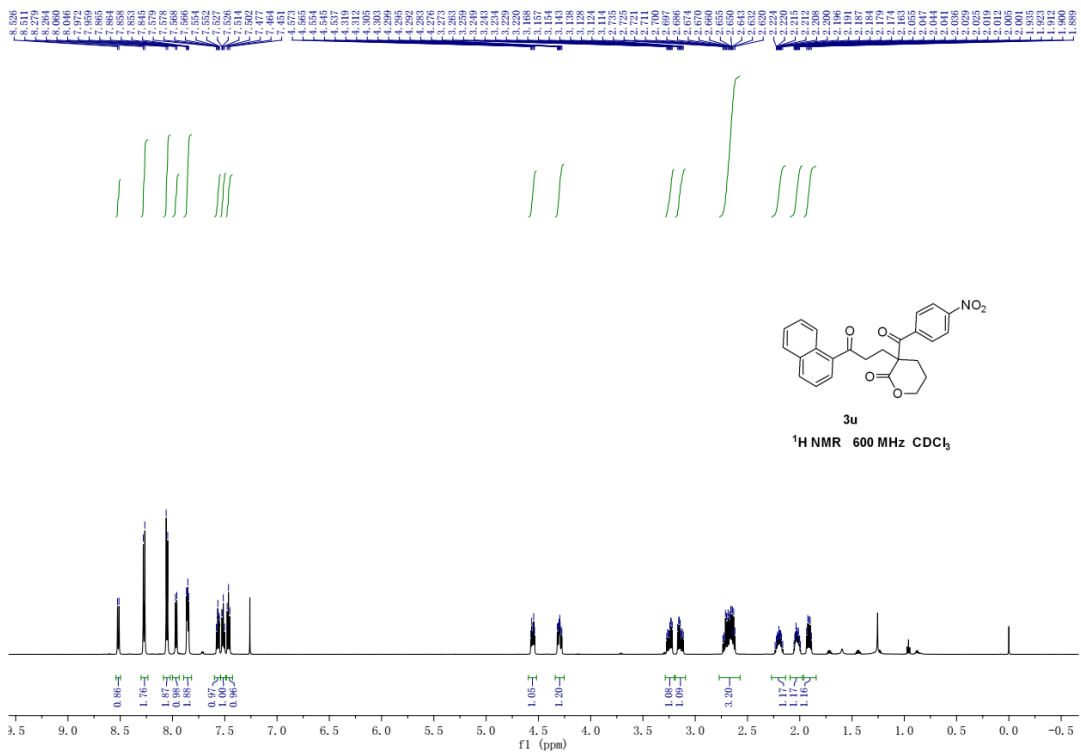


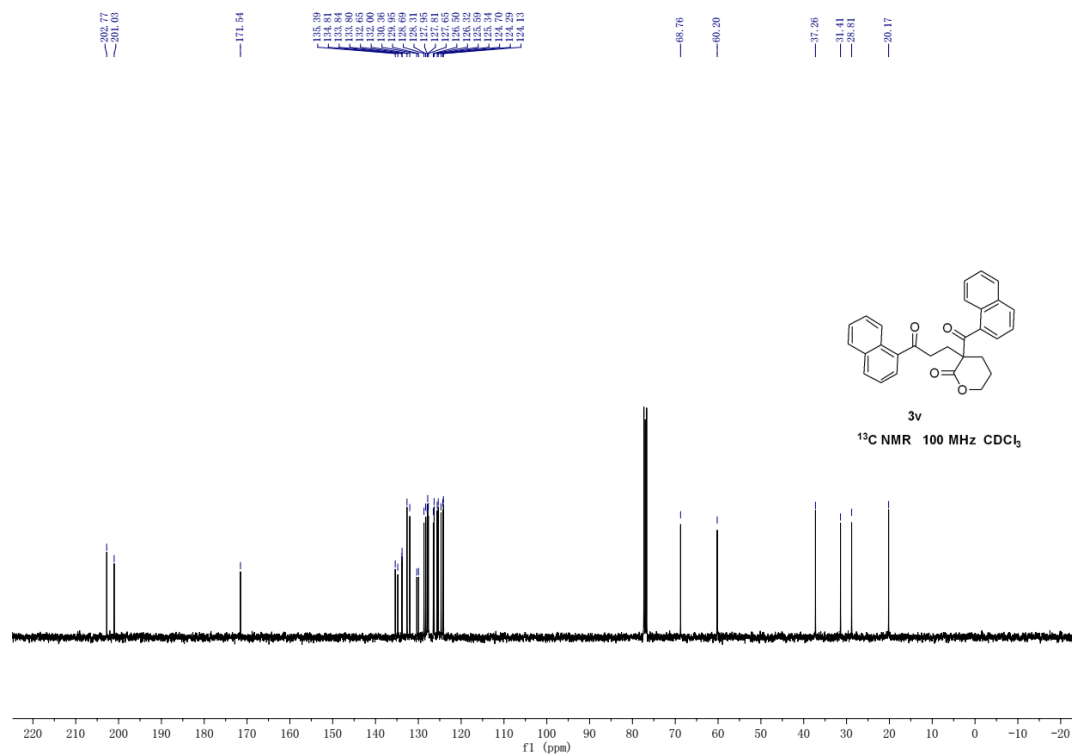
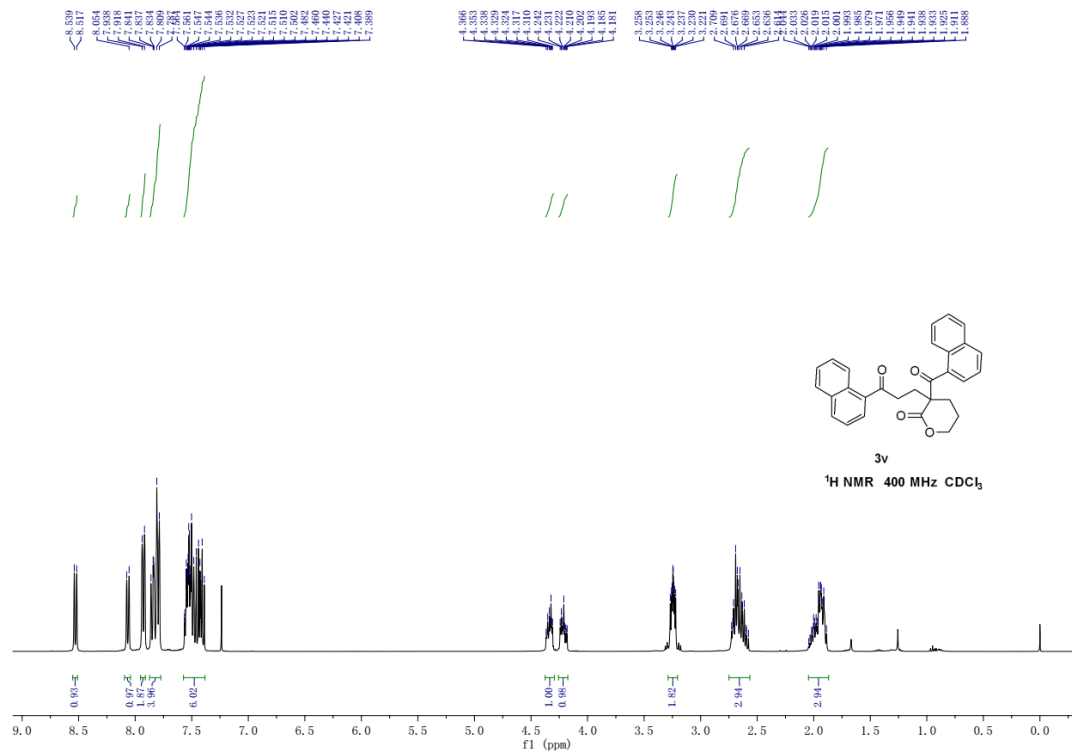
3t
¹H NMR 600 MHz CDCl₃

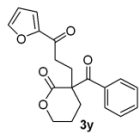
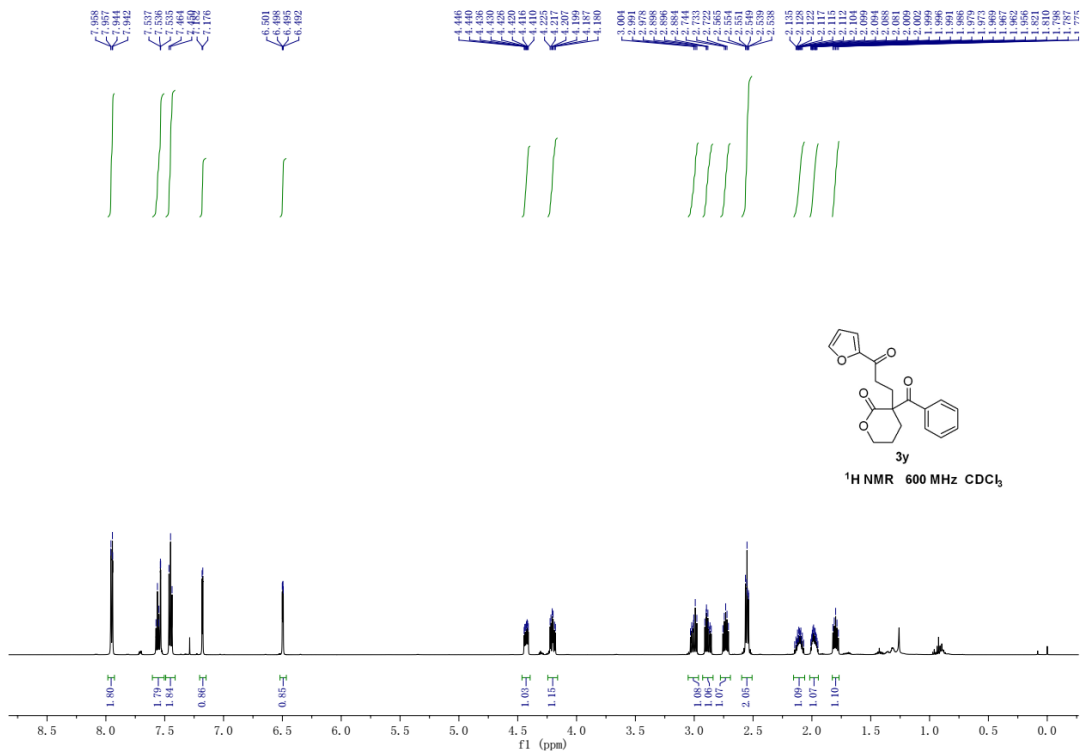


3t
¹³C NMR 150 MHz CDCl₃

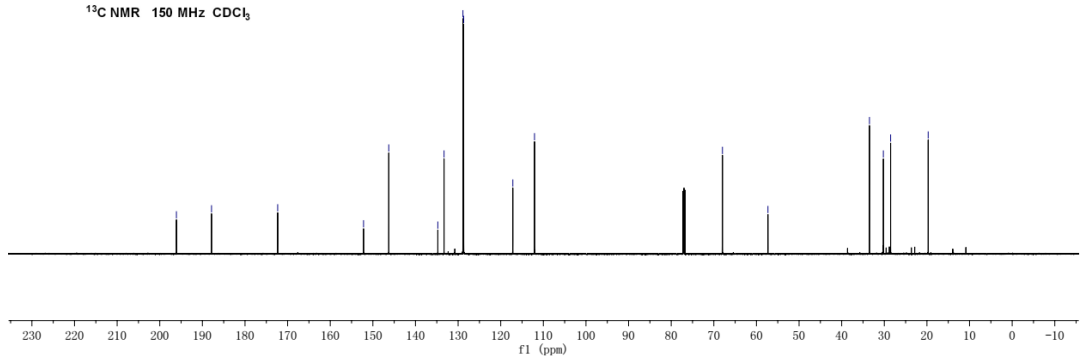


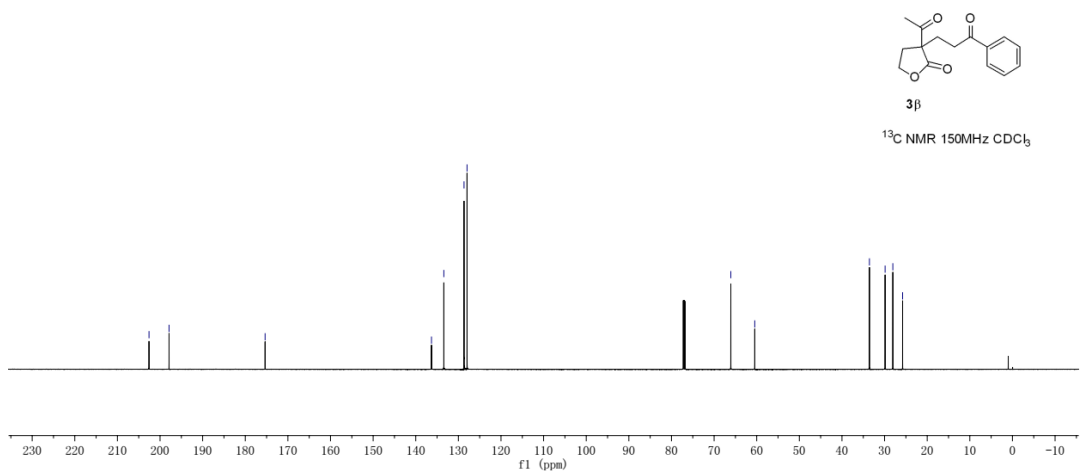
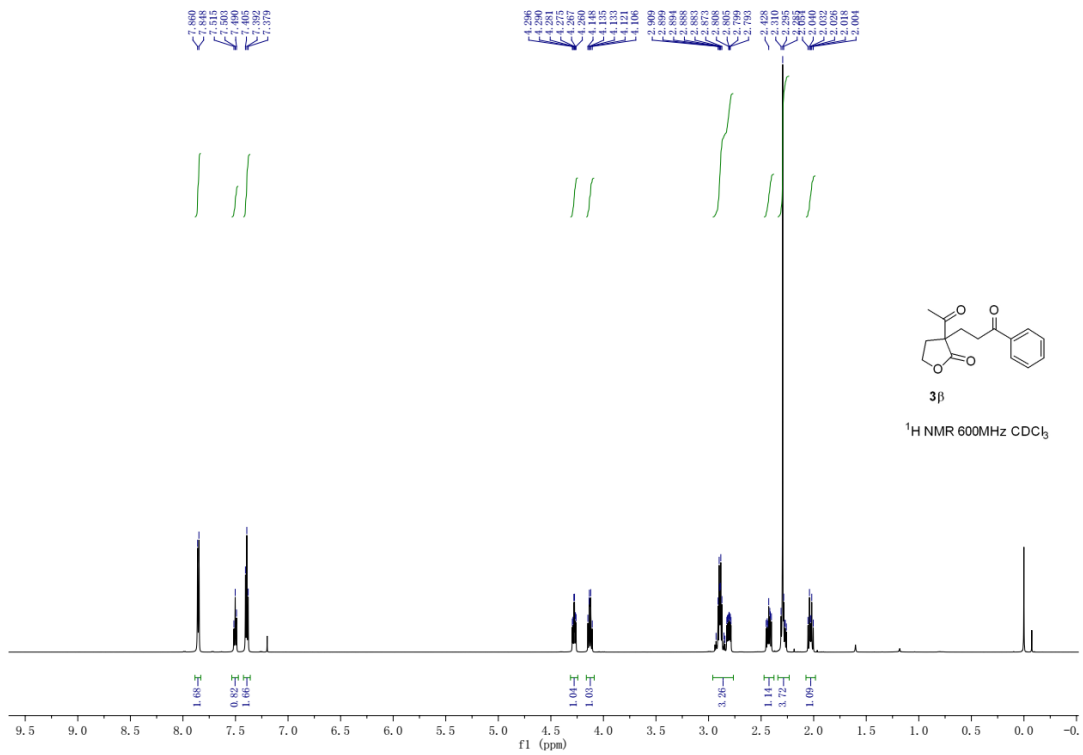


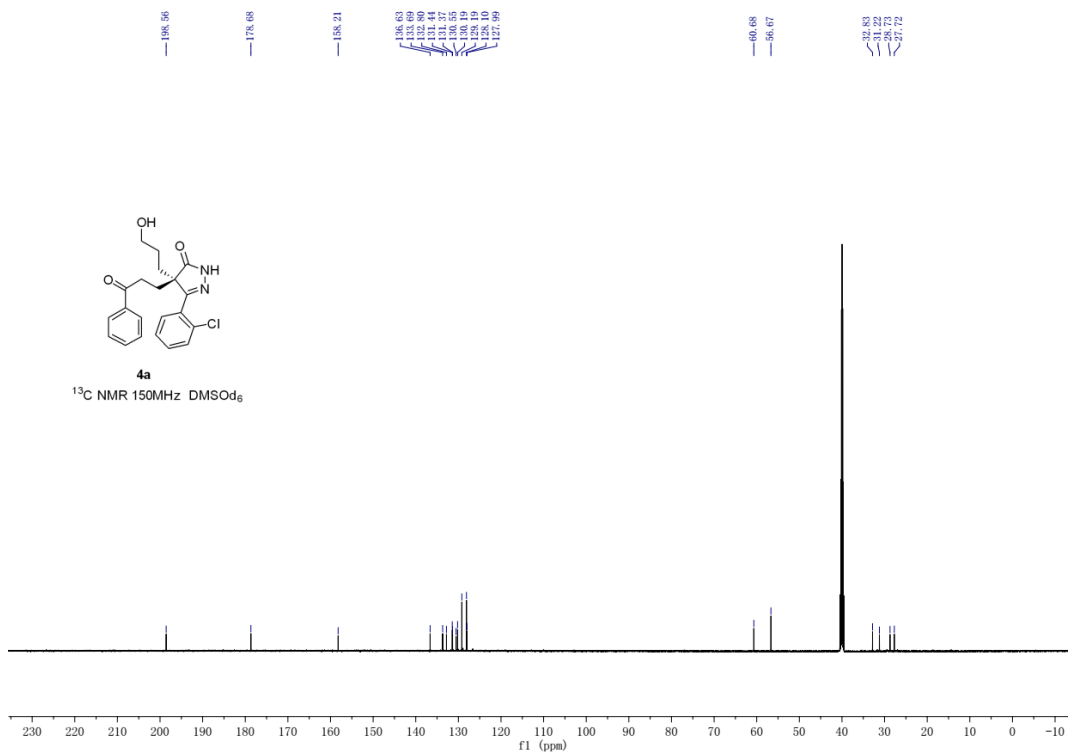
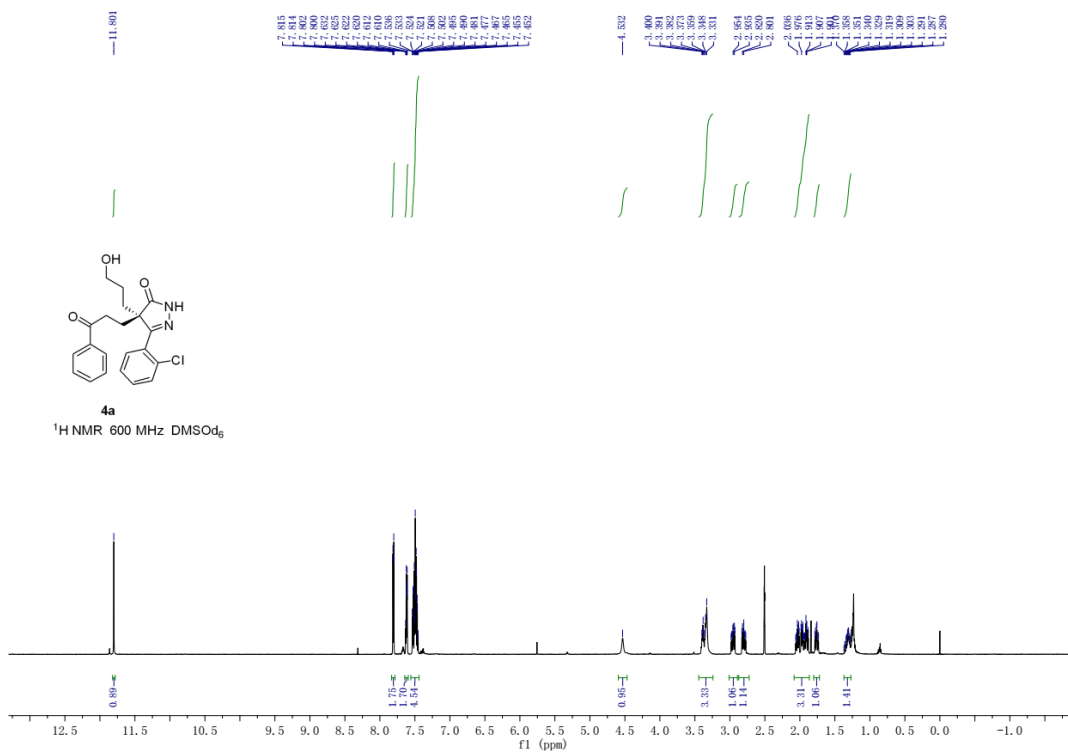


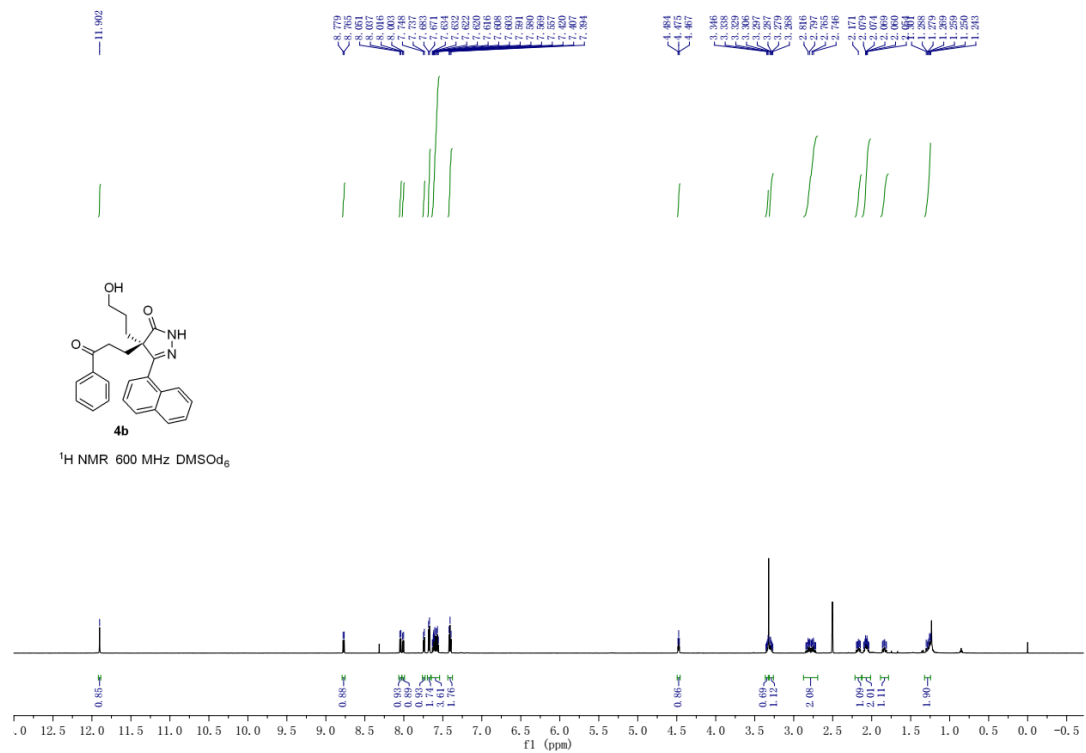


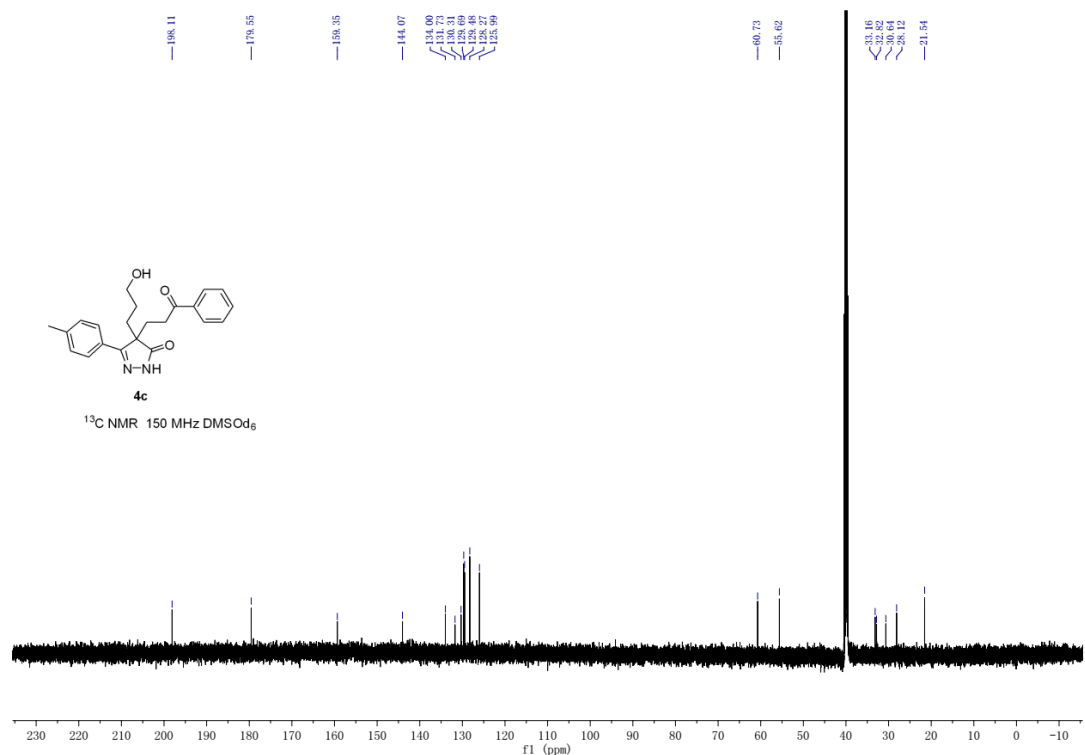
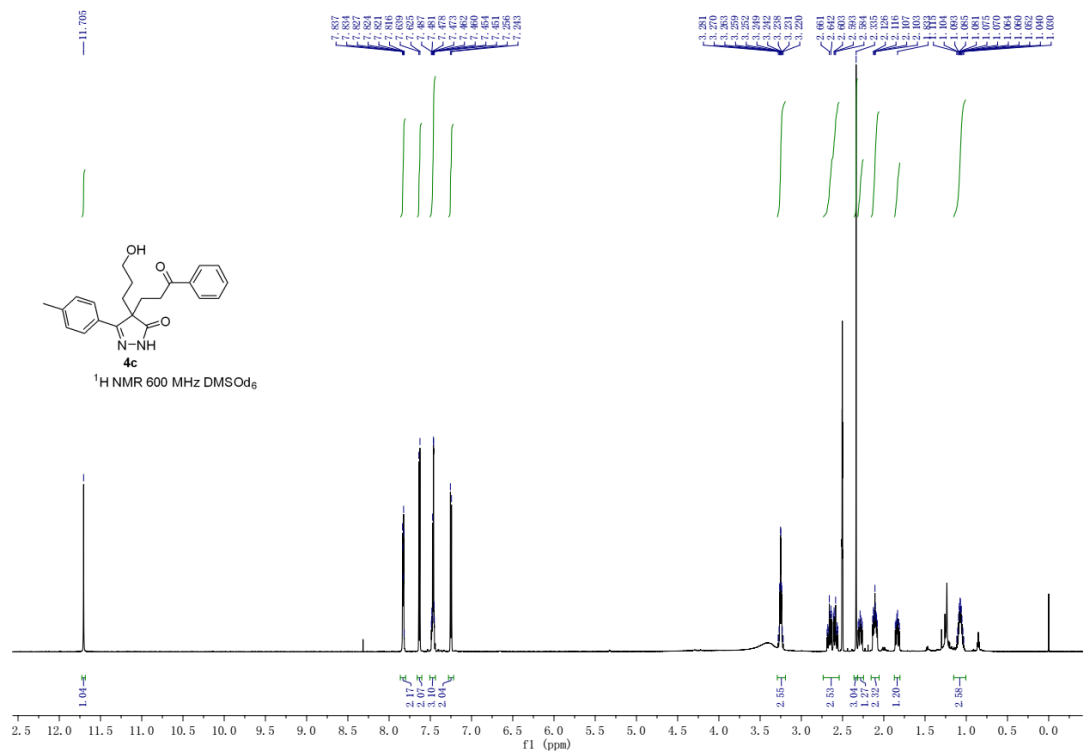
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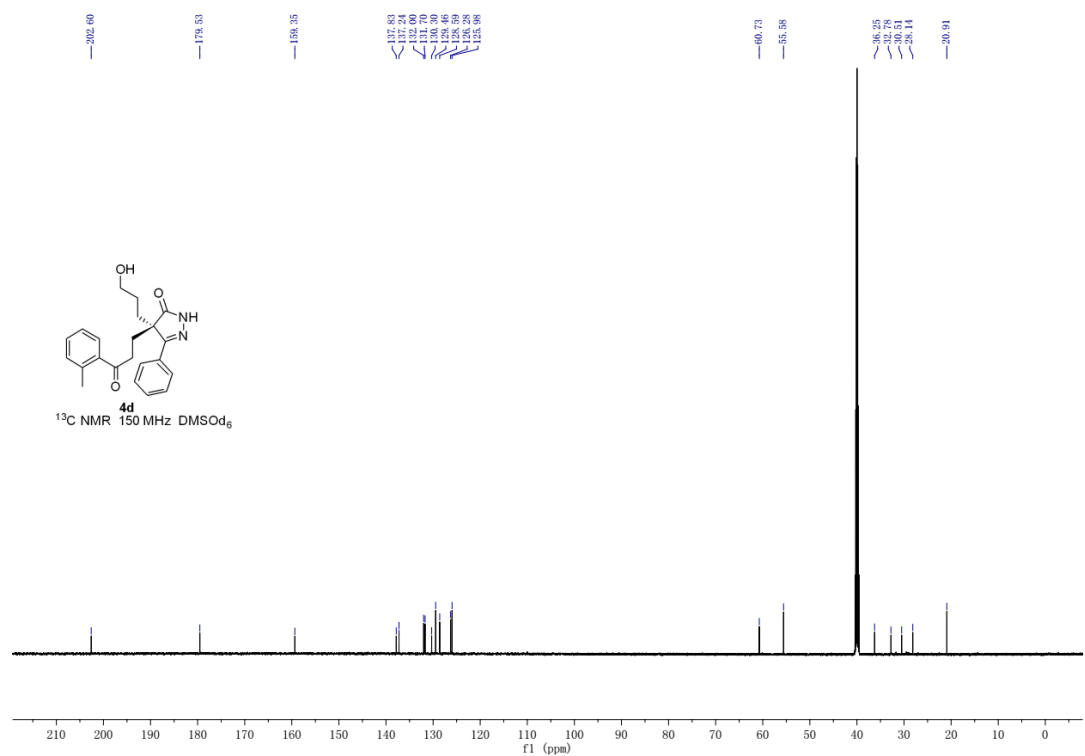
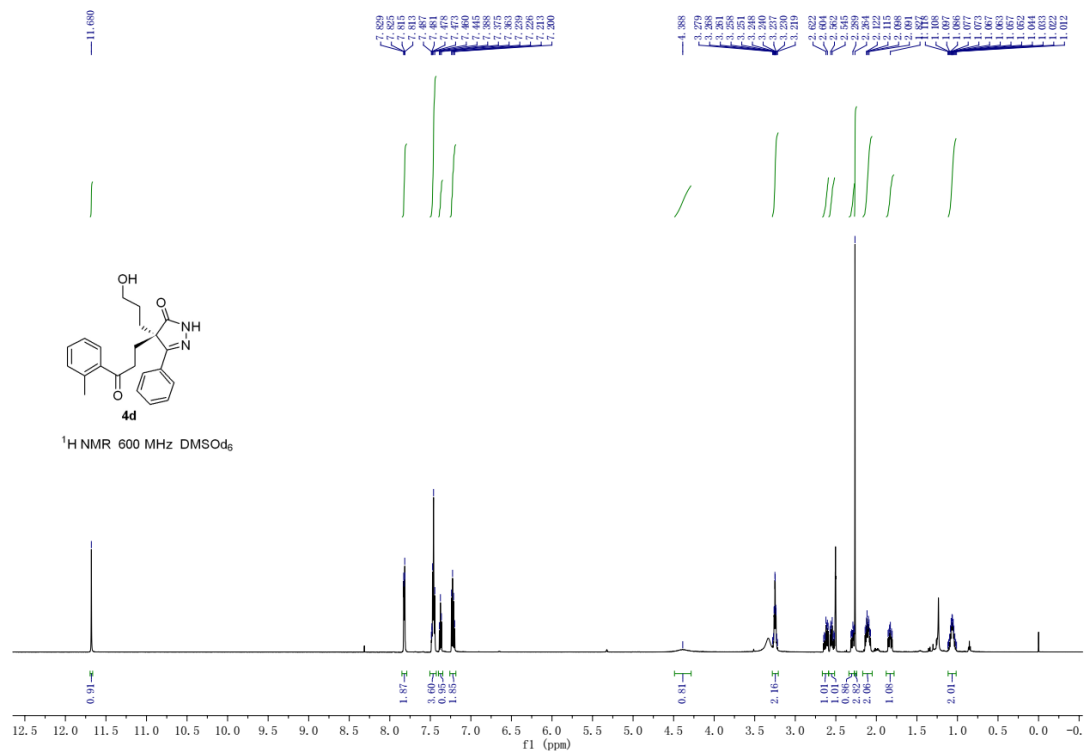


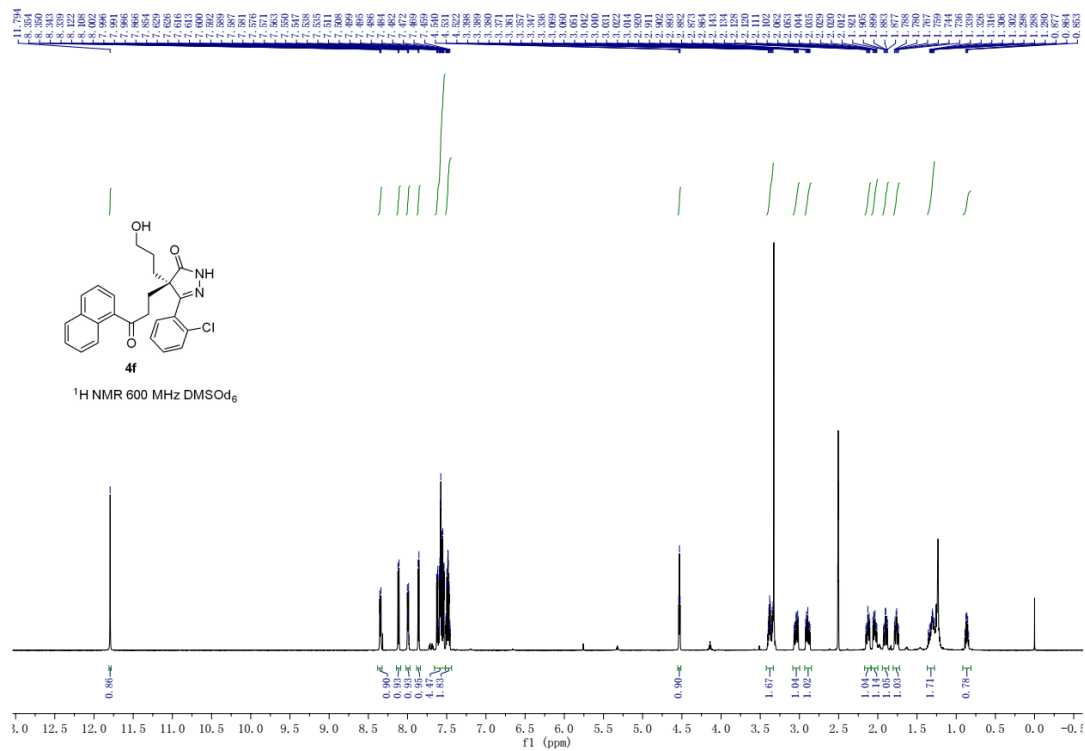


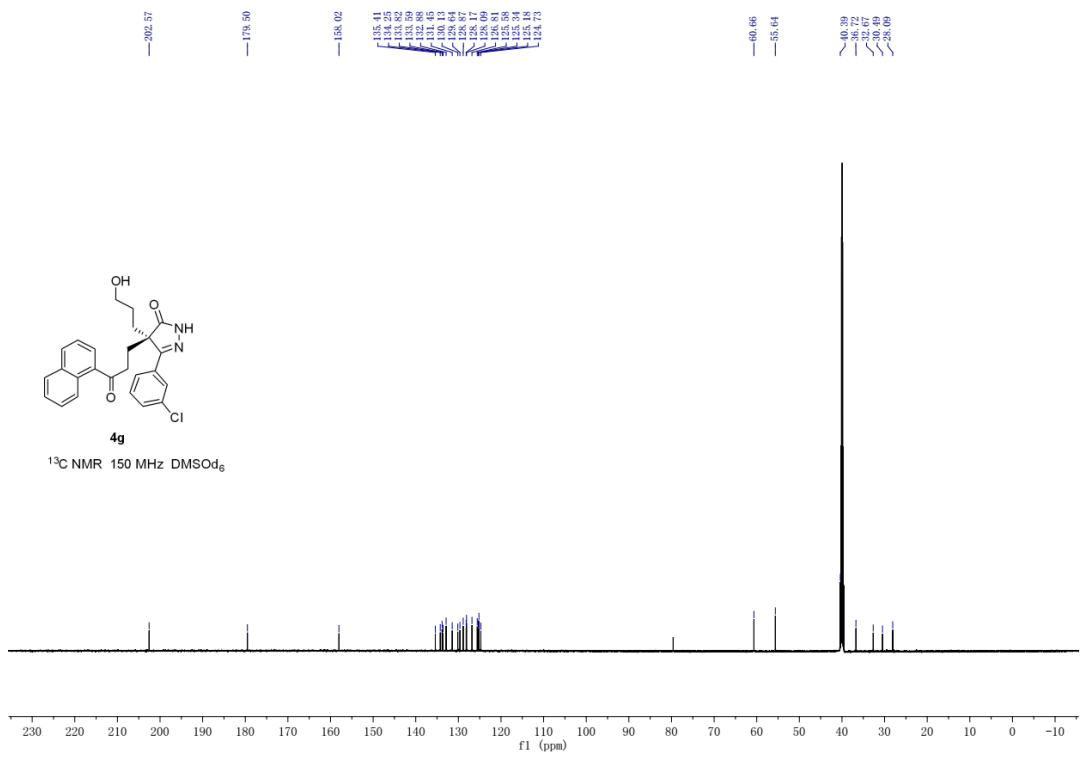
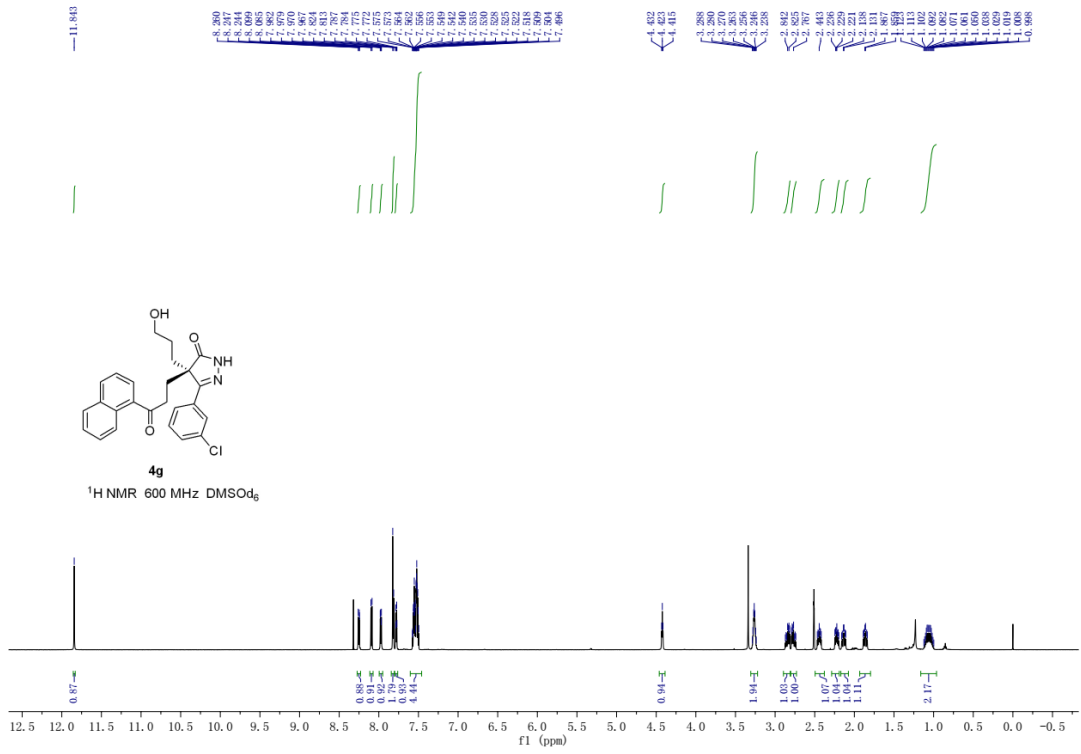


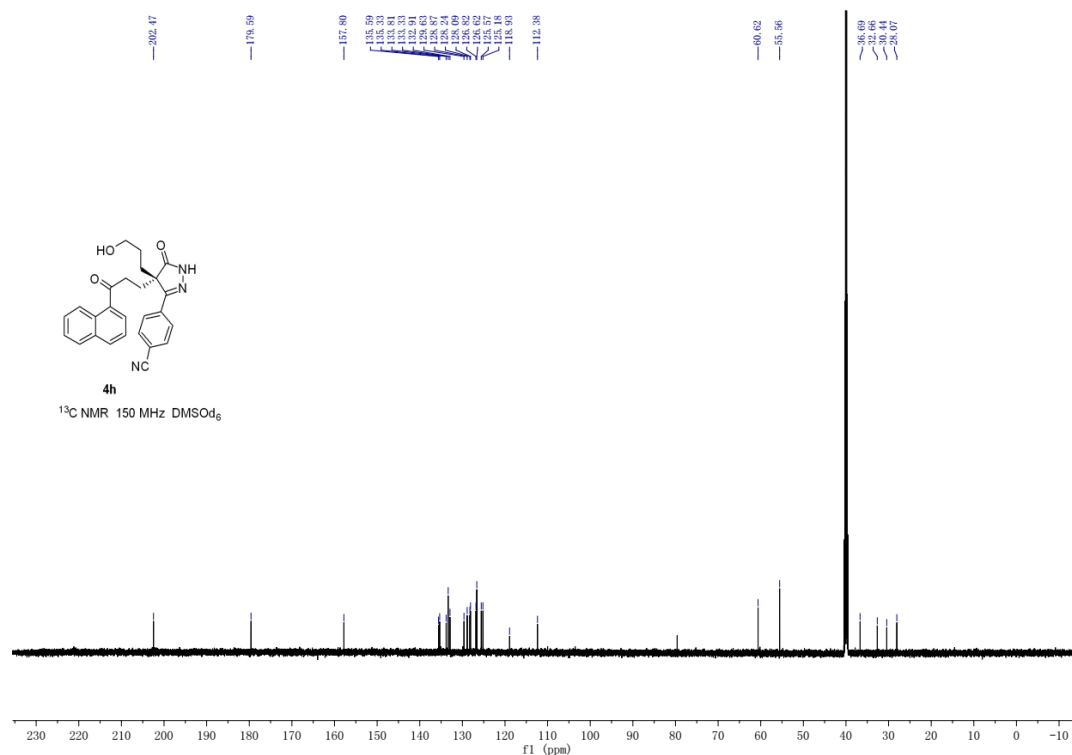
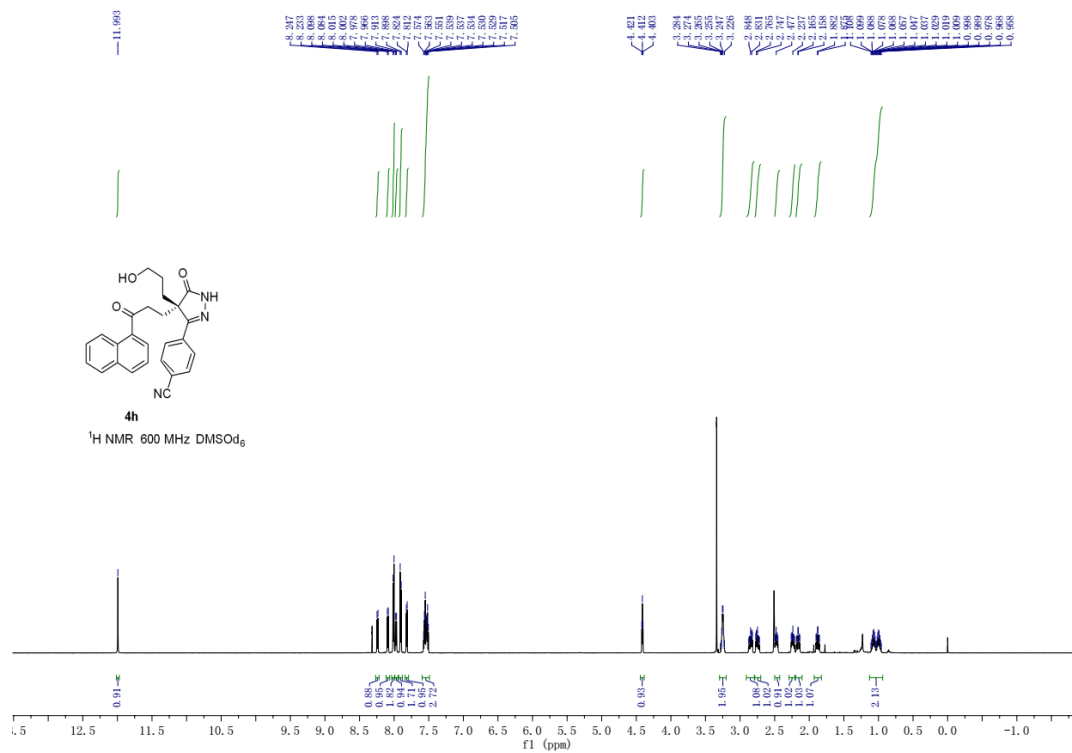


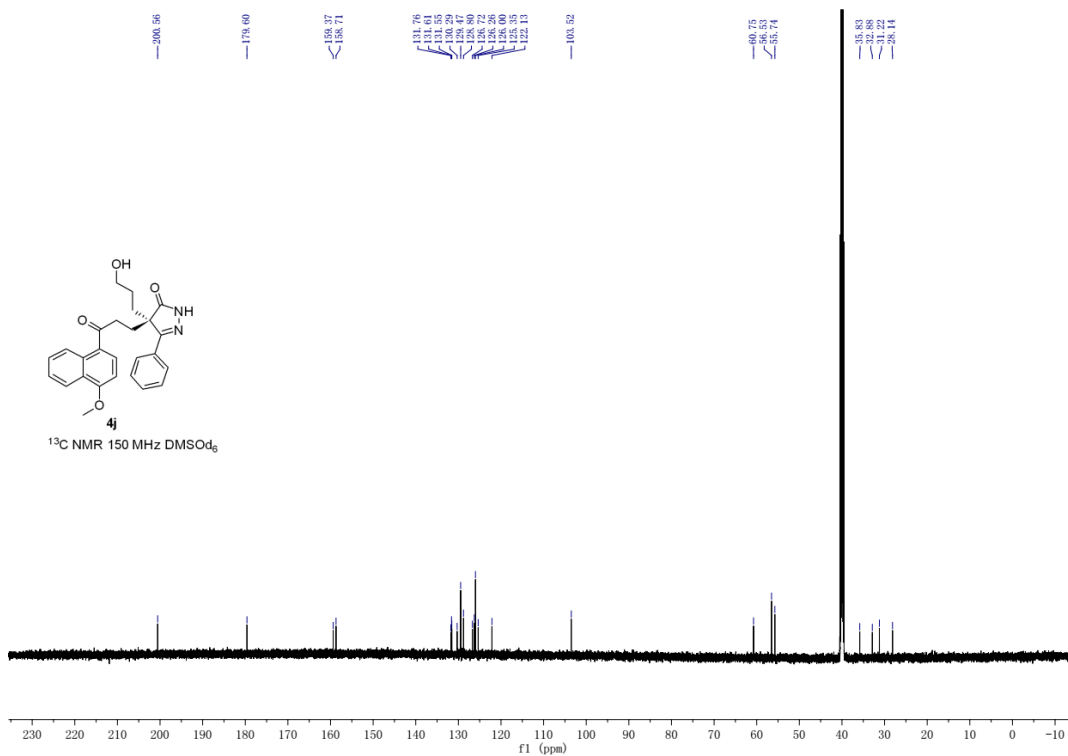
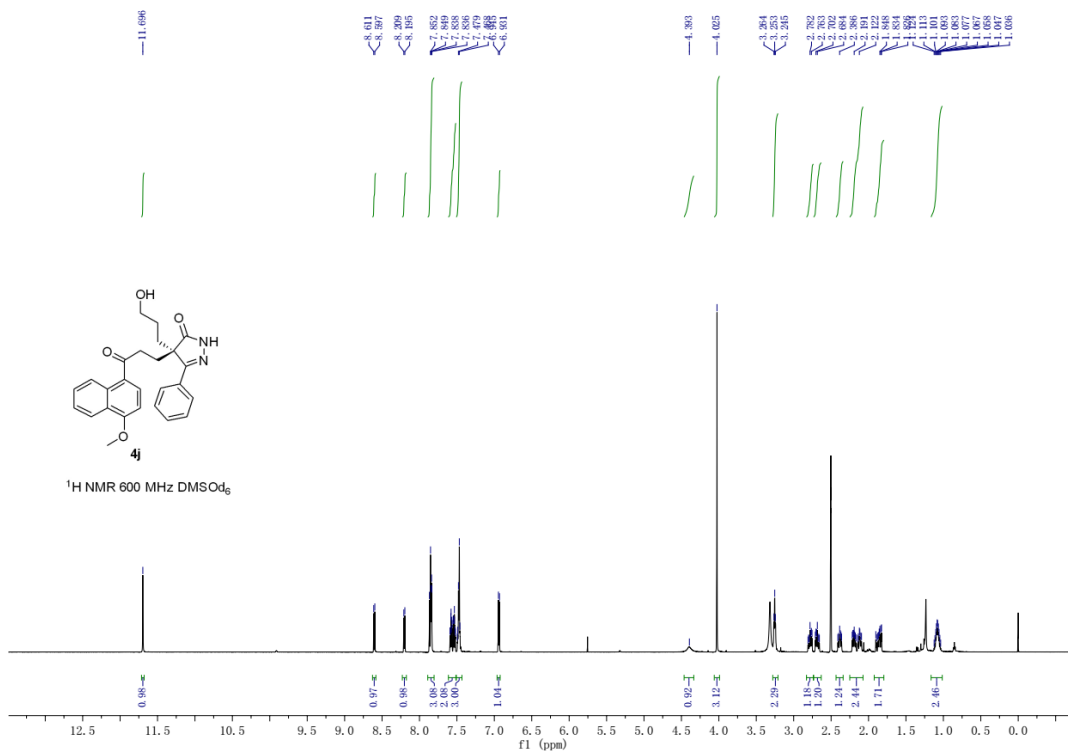












14 References

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