

Supplementary Information:

**Chiral diene-promoted room temperature conjugate arylation:
highly enantioselective synthesis of substituted chiral phenylalanine
derivatives and α,α -di(arylmethyl)acetates**

Jian-Ping Chen[†] and Ming-Hua Xu^{*,†,‡}

[†]State Key Laboratory of Drug Research, Shanghai Institute of Materia Medica, Chinese Academy of Sciences, 555
Zuchongzhi Road, Shanghai 201203, China.

[‡]Shenzhen Key Laboratory of Discovery and Synthesis of Small Molecule Drugs, Department of Chemistry,
Southern University of Science and Technology, 1088 Xueyuan Blvd., Shenzhen 518055, China.

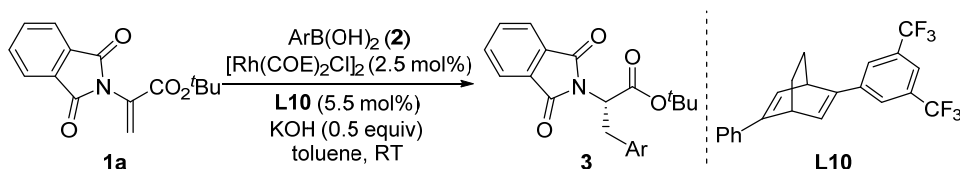
E-mail: xumh@simm.ac.cn; xumh@sustech.edu.cn

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1. General

All anaerobic and moisture-sensitive manipulations were carried out with standard Schlenk techniques under predried nitrogen or argon. Solvents were dried and distilled by standard procedures. NMR spectra were recorded on a Mercury 300 spectrometer (300 MHz for ^1H), and Varian spectrometer (400 MHz or 600 MHz for ^1H , 125 MHz or 150 MHz for ^{13}C). Chemical shifts are reported in δ (ppm) referenced to an internal SiMe_4 standard or the residual peak of methanol- d_4 (δ 3.31), dimethyl sulfoxide- d_6 (δ 2.50) for ^1H NMR, and chloroform- d (δ 77.16), methanol- d_4 (δ 49.00) for ^{13}C NMR. Optical rotations were measured on a Perkin-Elmer 241 MC polarimeter. HPLC was performed on a JASCO 2000 instrument by using Daicel columns with 2-propanol/hexane as the eluent.

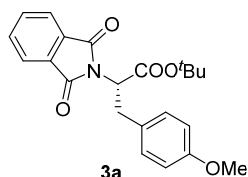
2. General procedure for Rh-catalyzed 1,4-addition/asymmetric protonation of α -phthalylimide *tert*-butyl acrylate **1a**



Under Ar atmosphere, a solution of α -phthalylimide *tert*-butyl acrylate **1a** (0.1 mmol), arylboronic acid **2** (0.3 mmol), $[\text{Rh}(\text{COE})_2\text{Cl}]_2$ (1.8 mg, 0.005 mmol of Rh), **L10** (2.2 mg, 0.0055 mmol) in 1.0 mL of anhydrous toluene was stirred at room temperature for 30 min. To this mixture was added KOH (0.05 mL, 1.0 M, 0.05 mmol). After reaction for another 12 hours, a saturated aq. NH_4Cl was added and the mixture was extracted with EtOAc (10 mL \times 3). The combined organic phase was dried over Na_2SO_4 , filtered, and concentrated. The residue was purified by silica gel flash chromatography, eluting with petroleum ether/EtOAc (20%-30% EtOAc), to afford the corresponding products **3**.

3. Characterization data and HPLC of products 3

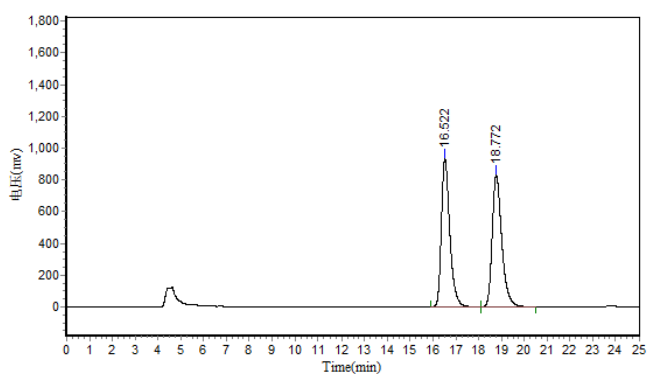
tert-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(4-methoxyphenyl)propanoate (**3a**)



99% yield, colorless oil, 94% ee.

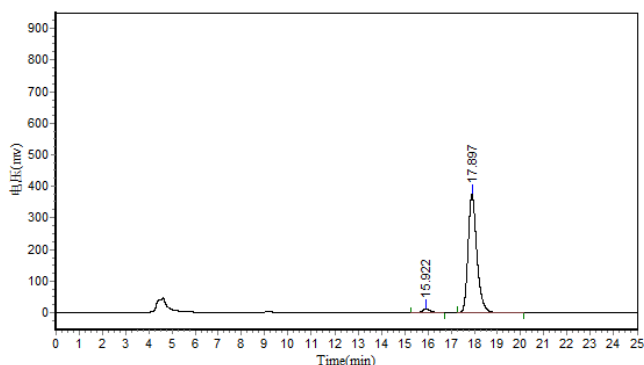
^1H NMR (300 MHz, CDCl_3): δ 7.75 (dd, $J = 5.1, 3.2$ Hz, 2H), 7.67-7.54 (m, 2H), 7.05 (d, $J = 8.4$ Hz, 2H), 6.78-6.57 (m, 2H), 5.00 (dd, $J = 9.6, 7.0$ Hz, 1H), 3.70 (s, 3H), 3.56-3.37 (m, 2H), 1.43 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 167.9, 167.7, 158.3, 134.0, 131.7, 129.8, 129.1, 123.4, 113.9, 82.7, 55.1, 54.3, 33.8, 27.9. HRMS (ESI) for $\text{C}_{22}\text{H}_{23}\text{NNaO}_5$ $[\text{M}+\text{Na}]^+$: calcd 404.1474, found 404.1468.

HPLC: Chiralpak IC column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 15.9 min, 17.9 min (major).



Results

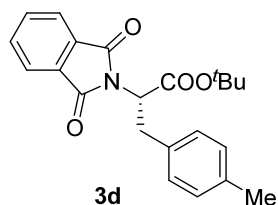
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		16.522	932769.375	23978046.000	49.6586
2		18.772	829777.188	24307766.000	50.3414
Total			1762546.563	48285812.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		15.922	13112.486	308711.688	2.9974
2		17.897	375600.188	9990632.000	97.0026
Total			388712.674	10299343.688	100.0000

***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(*p*-tolyl)propanoate (**3d**)**



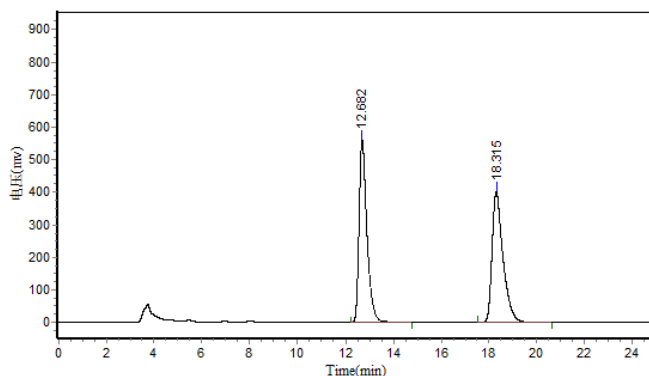
99% yield, colorless oil, 95% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.78 (dt, $J = 7.1, 2.7$ Hz, 2H), 7.68 (dt, $J = 5.6, 3.5$ Hz, 2H), 7.04 (t, $J = 8.2$ Hz, 2H), 6.99 (d, $J = 8.0$ Hz, 2H), 5.06 (dd, $J = 9.8, 6.8$ Hz, 1H),

3.51 (dd, $J = 12.0, 5.4$ Hz, 2H), 2.22 (s, 3H), 1.46 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 167.9, 167.7, 136.2, 134.0, 131.7, 129.2, 128.7, 123.4, 82.8, 54.3, 34.2, 27.9, 21.0.

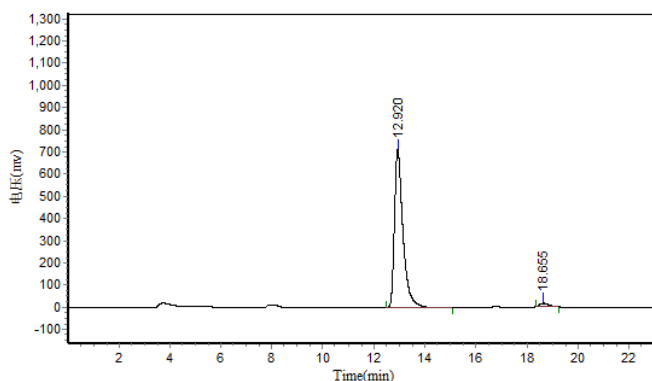
HRMS (ESI) for $\text{C}_{22}\text{H}_{23}\text{NNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 388.1525, found 388.1517.

HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 12.9 min (major), 18.6 min.



Results

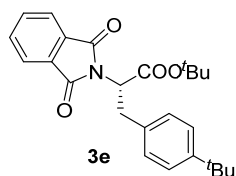
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		12.682	556372.875	12857949.000	50.1231
2		18.315	401100.781	12794789.000	49.8769
Total			957473.656	25652738.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		12.920	711555.188	16445455.000	97.4612
2		18.655	16265.929	428398.094	2.5388
Total			727821.116	16873853.094	100.0000

***tert*-butyl (*S*)-3-(4-(*tert*-butyl)phenyl)-2-(1,3-dioxisoindolin-2-yl)propanoate (**3e**)**



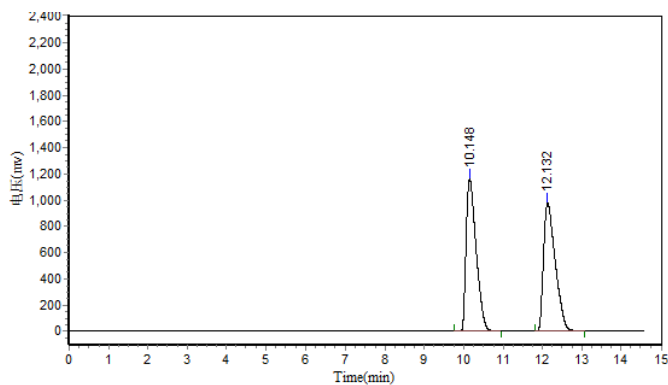
97% yield, colorless oil, 97% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.78 (dt, $J = 7.5, 3.8$ Hz, 2H), 7.74-7.59 (m, 2H), 7.21 (d, $J = 8.2$ Hz, 2H), 7.10 (d, $J = 8.2$ Hz, 2H), 5.09 (dd, $J = 9.5, 6.8$ Hz, 1H), 3.51 (dd, $J = 13.8,$

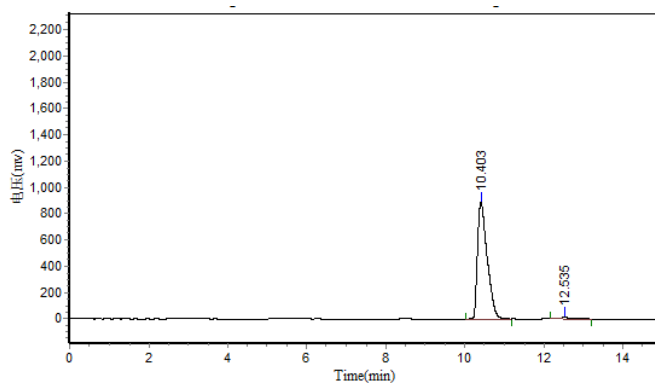
10.7 Hz, 2H), 1.45 (s, 9H), 1.20 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 168.0, 167.8, 149.4, 134.0, 133.9, 131.8, 128.4, 125.4, 123.3, 82.7, 54.1, 34.4, 34.1, 31.3, 27.9.

HRMS (ESI) for $\text{C}_{25}\text{H}_{29}\text{NNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 430.1994, found 430.1990.

HPLC: Chiralpak AD-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 1.0 mL/min; Retention time: 10.4 min (major), 12.5 min.

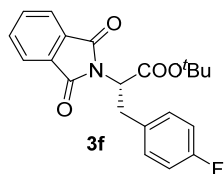


Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.148	1161167.625	20597112.000	50.2671
2		12.132	977401.125	20378242.000	49.7329
Total			2138568.750	40975354.000	100.0000



Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.403	890699.813	15209188.000	98.5707
2		12.535	10509.735	220530.109	1.4293
Total			901209.548	15429718.109	100.0000

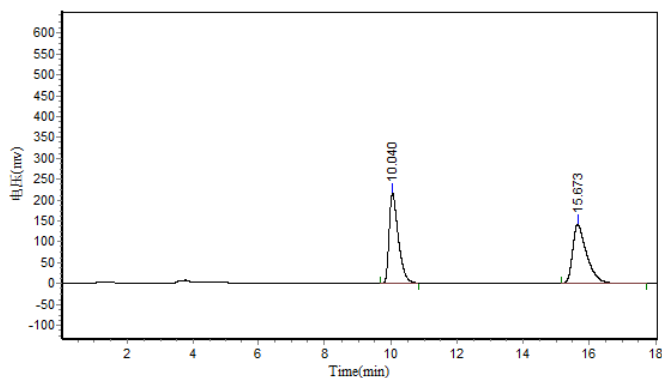
***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(4-fluorophenyl)propanoate (**3f**)**



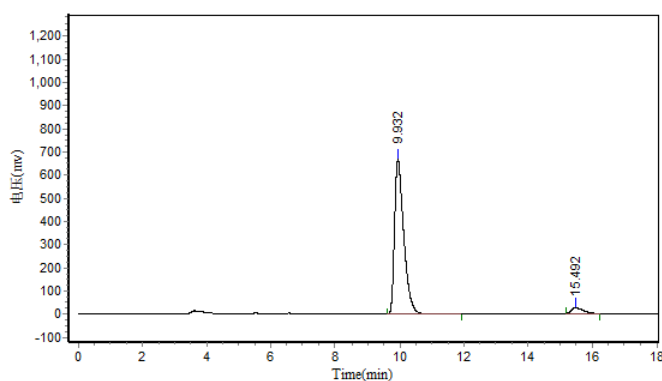
99% yield, colorless oil, 90% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.89-7.73 (m, 2H), 7.69 (dd, $J = 6.2, 2.2$ Hz, 2H), 7.18-6.99 (m, 2H), 6.86 (t, $J = 8.1$ Hz, 2H), 5.03 (dd, $J = 8.8, 6.7$ Hz, 1H), 3.48 (dd, $J = 14.1, 10.6$ Hz, 2H), 1.43 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 167.7, 167.6, 161.3 (d, $J_{\text{CF}} = 291$ Hz), 134.1, 132.8, 131.6, 130.3 (d, $J_{\text{CF}} = 11$ Hz), 123.5, 115.4 (d, $J_{\text{CF}} = 24$ Hz), 82.9, 54.1, 33.9, 27.9. HRMS (ESI) for $\text{C}_{21}\text{H}_{20}\text{FNNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 392.1274, found 392.1268.

HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 9.9 min (major), 15.5 min.

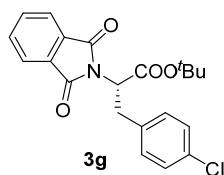


Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.040	215721.984	4212422.000	49.9140
2		15.673	141787.453	4226931.000	50.0860
Total			357509.438	8439353.000	100.0000



Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		9.932	667817.125	13328599.000	95.0847
2		15.492	25326.398	688999.875	4.9152
Total			693143.523	14017598.875	100.0000

***tert*-butyl (*S*)-3-(4-chlorophenyl)-2-(1,3-dioxisoindolin-2-yl)propanoate (**3g**)**



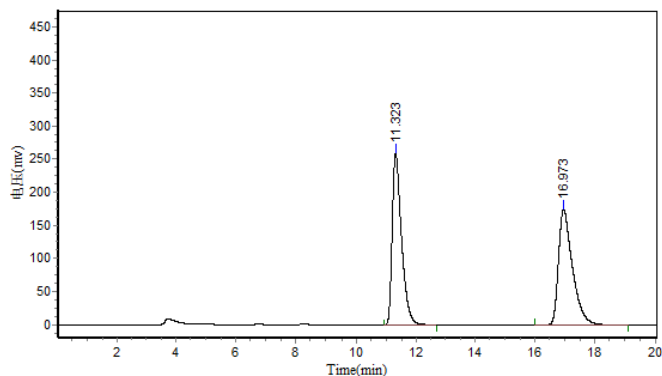
93% yield, colorless oil, 91% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.75 (s, 2H), 7.68 (s, 2H), 7.10

(dd, $J = 17.5, 8.3$ Hz, 4H), 5.08-4.92 (m, 1H), 3.48 (d, $J = 8.1$

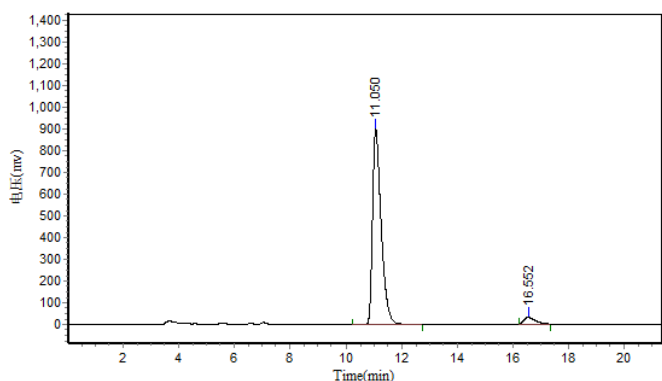
Hz, 2H), 1.42 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 167.7, 167.6, 135.7, 134.2, 132.6, 131.6, 130.2, 128.7, 123.5, 83.0, 53.9, 34.1, 27.9. HRMS (ESI) for $\text{C}_{21}\text{H}_{20}\text{ClNNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 408.0979, found 408.0968.

HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 11.0 min (major), 16.5 min.



Results

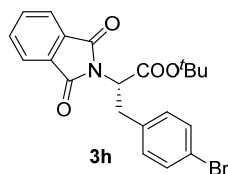
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		11.323	258438.391	5607319.500	49.7523
2		16.973	174505.219	5663161.500	50.2477
Total			432943.609	11270481.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		11.050	896427.438	19367386.000	95.6812
2		16.552	30098.697	874204.813	4.3189
Total			926526.135	20241590.813	100.0000

***tert*-butyl (S)-3-(4-bromophenyl)-2-(1,3-dioxisoindolin-2-yl)propanoate (3h)**

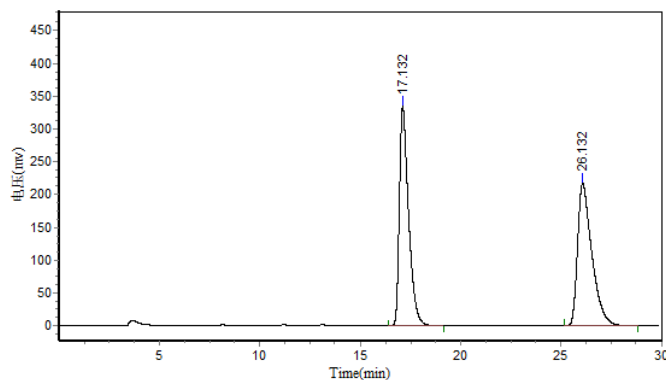


93% yield, colorless oil, 95% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.79 (dd, $J = 5.2, 3.2$ Hz, 2H), 7.70 (dd, $J = 5.6, 3.0$ Hz, 2H), 7.31 (d, $J = 7.4$ Hz, 2H), 7.05 (d, $J = 8.2$ Hz, 2H), 5.04 (m, 1H), 3.50 (d, $J = 8.1$ Hz, 2H),

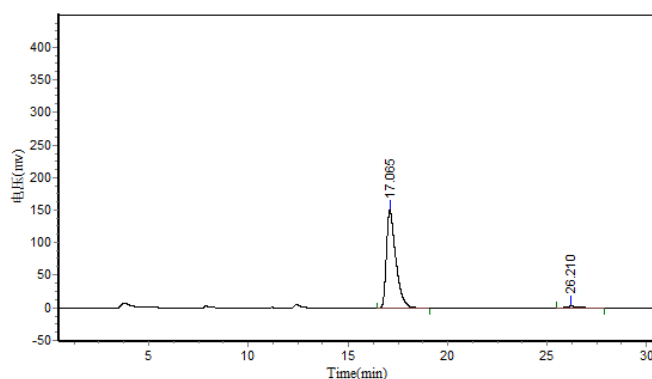
1.45 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 167.7, 167.6, 136.2, 134.2, 131.7, 131.6, 130.6, 123.5, 120.7, 83.0, 53.8, 34.2, 27.9. HRMS (ESI) for $\text{C}_{21}\text{H}_{20}\text{BrNNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 452.0473, found 452.0476.

HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 17.0 min (major), 26.2 min.



Results

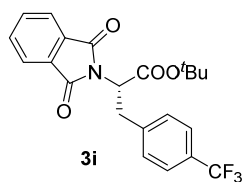
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		17.132	334852.688	10691557.000	49.7633
2		26.132	217304.188	10793266.000	50.2367
Total			552156.875	21484823.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		17.065	151024.797	4926689.500	97.4707
2		26.210	2631.797	127844.102	2.5293
Total			153656.594	5054533.602	100.0000

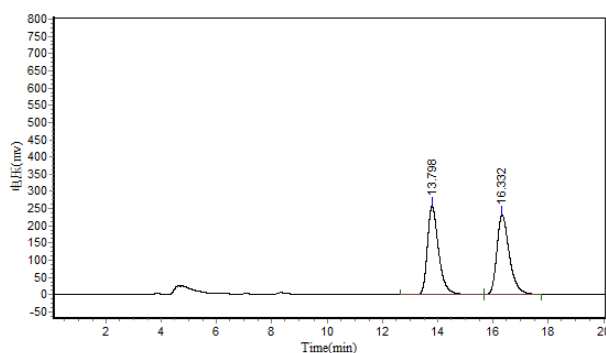
***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(4-(trifluoromethyl)phenyl)propanoate (**3i**)**



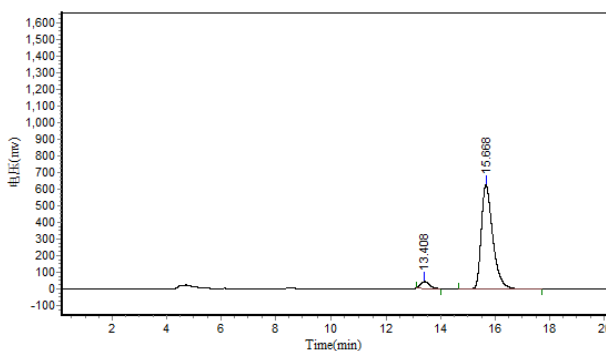
99% yield, colorless oil, 90% ee.

$^1\text{H NMR}$ (300 MHz, CDCl_3): δ 7.79 (dt, $J = 7.1, 3.5$ Hz, 2H), 7.74-7.68 (m, 2H), 7.44 (t, $J = 8.0$ Hz, 2H), 7.30 (d, $J = 8.1$ Hz, 2H), 5.10 (dd, $J = 9.4, 7.2$ Hz, 1H), 3.65-3.49 (m, 2H), 1.45 (s, 9H). $^{13}\text{C NMR}$ (125 MHz, CDCl_3): δ 167.7, 167.5, 141.4, 134.2, 131.5, 129.2, 129.0 (q, $J_{\text{CF}} = 32.5$ Hz), 125.5 (q, $J_{\text{CF}} = 4.2$ Hz), 124.5 (q, $J_{\text{CF}} = 270$ Hz), 123.5, 83.2, 53.7, 34.6, 27.9. HRMS (ESI) for $\text{C}_{22}\text{H}_{20}\text{F}_3\text{NNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 442.1242, found 442.1240.

HPLC: Chiralpak IC column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 13.4 min, 15.6 min (major).

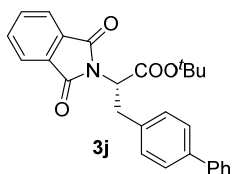


Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		13.798	257018.875	7253085.000	49.7479
2		16.332	230986.000	7326583.000	50.2521
Total			488004.875	14579668.000	100.0000



Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		13.408	40447.207	942301.438	4.8922
2		15.668	624965.438	18319196.000	95.1078
Total			665412.645	19261497.438	100.0000

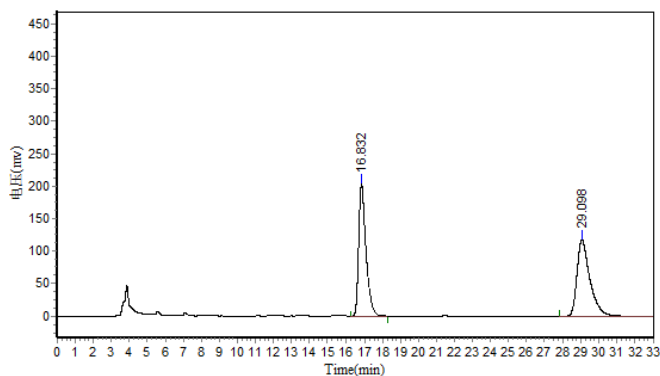
***tert*-butyl (*S*)-3-([1,1'-biphenyl]-4-yl)-2-(1,3-dioxisoindolin-2-yl)propanoate (**3j**)**



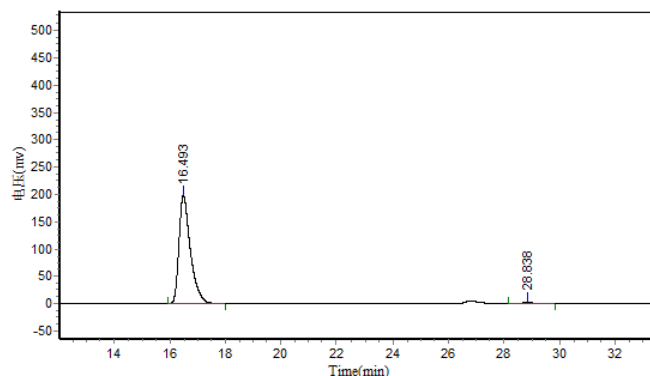
93% yield, colorless oil, 97% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.79 (dt, $J = 7.5, 3.7$ Hz, 2H), 7.68 (dd, $J = 5.3, 2.1$ Hz, 2H), 7.58-7.35 (m, 6H), 7.27 (t, $J = 7.6$ Hz, 3H), 5.15 (t, $J = 8.3$ Hz, 1H), 3.61 (d, $J = 8.8$ Hz, 2H), 1.48 (s, 9H). ^{13}C NMR (125MHz, CDCl_3): δ 167.9, 167.8, 140.7, 139.5, 136.2, 134.1, 131.7, 129.3, 128.7, 127.2, 126.9, 123.9, 123.4, 82.9, 54.1, 34.4, 27.9. HRMS (ESI) for $\text{C}_{27}\text{H}_{25}\text{NNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 450.1681, found 442.1674.

HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 16.4 min (major), 28.8 min.

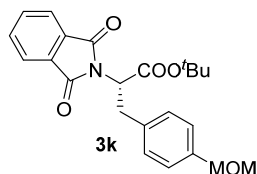


Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		16.832	202801.094	5771444.500	49.5610
2		29.098	117585.430	5873678.500	50.4390
Total			320386.523	11645123.000	100.0000



Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		16.493	198489.250	5685311.000	98.3933
2		28.838	2179.165	92835.102	1.6067
Total			200668.415	5778146.102	100.0000

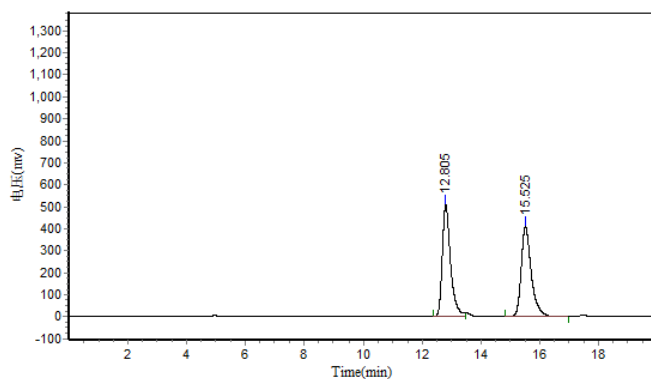
***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(4-(methoxymethyl)phenyl)propanoate (**3k**)**



95% yield, colorless oil, 95% ee.

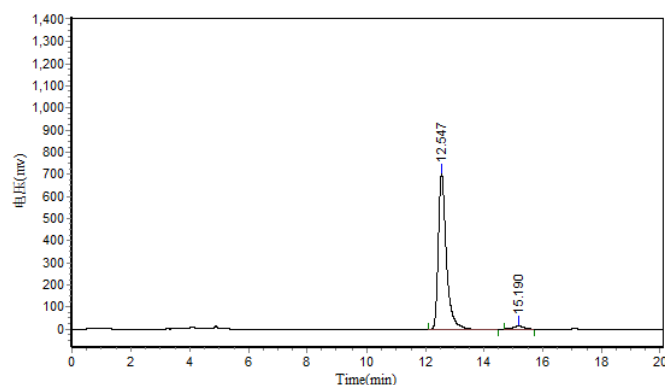
$^1\text{H NMR}$ (300 MHz, CDCl_3): δ 7.78 (dt, $J = 7.1, 3.5$ Hz, 2H), 7.72-7.66 (m, 2H), 7.08 (d, $J = 8.6$ Hz, 2H), 6.85 (d, $J = 8.6$ Hz, 2H), 5.09-4.98 (m, 3H), 3.49 (d, $J = 6.7$ Hz, 2H), 3.41 (s, 3H), 1.45 (s, 9H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3): δ 168.0, 167.8, 156.0, 134.1, 131.8, 130.6, 129.9, 123.5, 116.4, 94.6, 82.8, 56.0, 54.4, 33.9, 28.0. HRMS (ESI) for $\text{C}_{23}\text{H}_{25}\text{NNaO}_5$ $[\text{M}+\text{Na}]^+$: calcd 418.1630, found 418.1629.

HPLC: Chiralpak AD-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 90/10; flow = 0.7 mL/min; Retention time: 12.5 min (major), 15.2 min.



Results

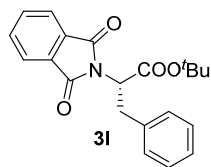
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		12.805	506825.906	9999668.000	49.7893
2		15.525	409489.219	9885955.000	49.2231
Total			923561.003	20083975.375	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		12.547	702695.813	13368232.000	97.5608
2		15.190	13034.164	334230.250	2.4392
Total			715729.977	13702462.250	100.0000

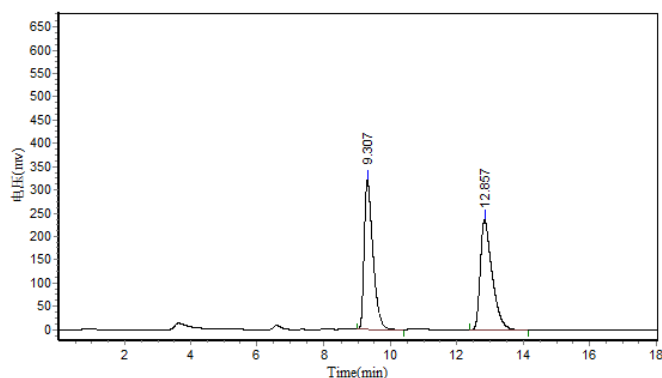
tert-butyl (S)-2-(1,3-dioxisoindolin-2-yl)-3-phenylpropanoate (3I)



99% yield, colorless oil, 90% ee.

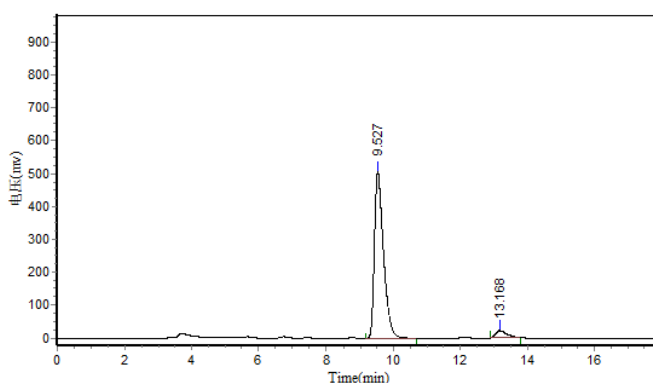
^1H NMR (300 MHz, CDCl_3): δ 7.77 (td, $J = 5.3, 2.0$ Hz, 2H), 7.71-7.63 (m, 2H), 7.34-7.05 (m, 5H), 5.08 (dd, $J = 10.5, 6.1$ Hz, 1H), 3.65-3.42 (m, 2H), 1.45 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 167.9, 167.7, 137.2, 134.0, 131.7, 128.8, 128.5, 126.7, 123.4, 82.8, 54.2, 34.7, 27.9. HRMS (ESI) for $\text{C}_{21}\text{H}_{21}\text{NNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 374.1368, found 374.1363.

HPLC: Chiralpak AD-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 9.3 min (major), 12.9 min.



Results

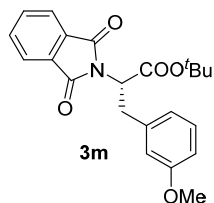
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		9.307	319899.688	5950452.000	50.1580
2		12.857	236853.063	5912961.000	49.8420
Total			556752.750	11863413.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		9.527	506074.031	9557676.000	94.9159
2		13.168	21810.477	511951.719	5.0841
Total			527884.508	10069627.719	100.0000

***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(3-methoxyphenyl)propanoate (**3m**)**

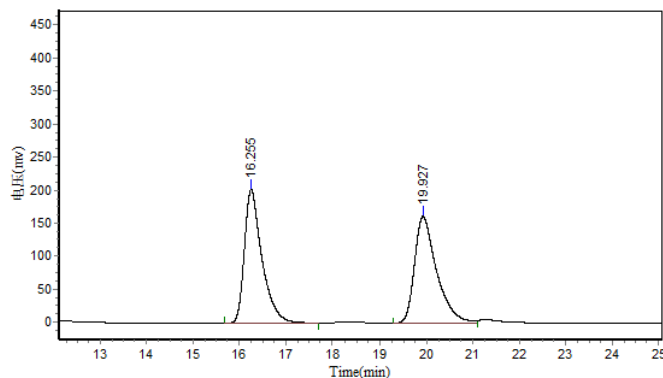


99% yield, colorless oil, 95% ee.

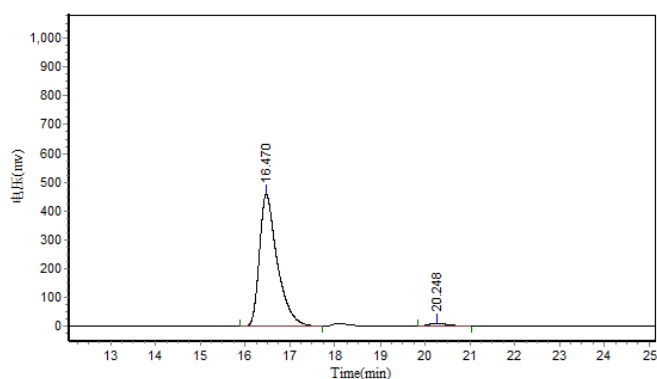
¹H NMR (300 MHz, CDCl₃): δ 7.82-7.75 (m, 2H), 7.74-7.64 (m, 2H), 7.10 (td, *J* = 8.2, 3.9 Hz, 1H), 6.76 (d, *J* = 7.7 Hz, 1H), 6.71-6.60 (m, 2H), 5.09 (dd, *J* = 10.1, 6.4 Hz, 1H), 3.68 (s, 3H),

3.53 (dd, *J* = 12.5, 6.6 Hz, 2H), 1.46 (s, 9H). ¹³C NMR (125 MHz, CDCl₃): δ 167.8, 167.7, 159.6, 138.7, 134.0, 131.7, 129.5, 123.4, 121.2, 114.1, 112.6, 82.8, 55.1, 54.1, 34.7, 27.9. HRMS (ESI) for C₂₂H₂₃NNaO₅ [M+Na]⁺: calcd 404.1474, found 404.1471.

HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 16.4 min (major), 20.2 min.

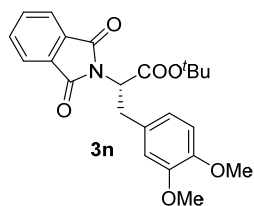


Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		16.255	201975.063	5270053.500	49.7797
2		19.927	161116.641	5316699.500	50.2203
Total			363091.703	10586753.000	100.0000



Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		16.470	459042.000	12752050.000	97.5364
2		20.248	10552.647	322097.688	2.4636
Total			469594.647	13074147.688	100.0000

***tert*-butyl (*S*)-3-(3,4-dimethoxyphenyl)-2-(1,3-dioxisoindolin-2-yl)propanoate (3n)**

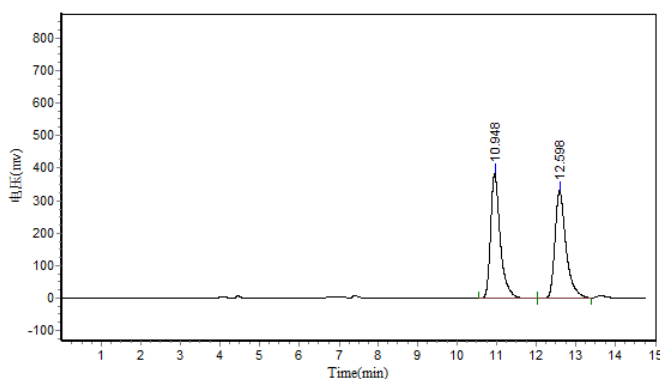


94% yield, colorless oil, 93% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.77 (dd, $J = 5.6, 3.0$ Hz, 2H), 7.69-7.65 (m, 2H), 6.70 (dd, $J = 6.4, 4.7$ Hz, 2H), 6.64 (t, $J = 2.1$ Hz, 1H), 5.06 (dd, $J = 9.7, 7.1$ Hz, 1H), 3.77 (s, 3H),

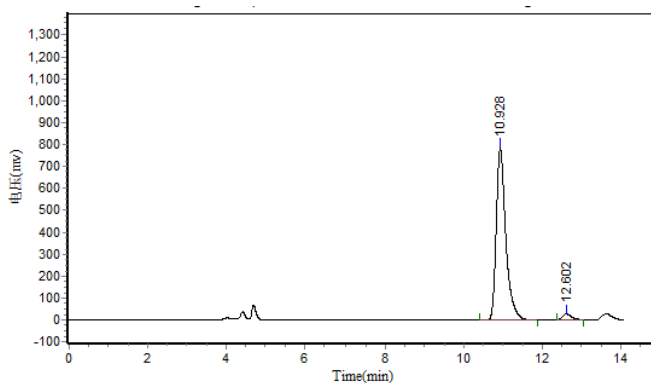
3.70 (s, 3H), 3.50-3.42 (m, 2H), 1.46 (s, 9H). ^{13}C NMR (150 MHz, CDCl_3): δ 167.9, 167.7, 148.7, 147.6, 134.0, 131.7, 129.5, 123.4, 120.9, 111.7, 111.1, 82.8, 55.7, 55.7, 54.1, 34.2, 27.9. HRMS (ESI) for $\text{C}_{23}\text{H}_{25}\text{NNaO}_6$ $[\text{M}+\text{Na}]^+$: calcd 434.1580, found 434.1575.

HPLC: Chiralpak AD-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 80/20; flow = 0.7 mL/min; Retention time: 10.9 min (major), 12.6 min.



Results

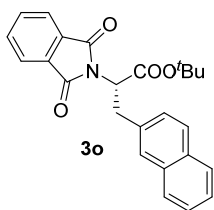
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.948	382261.438	6480073.500	50.0868
2		12.598	329213.688	6457619.500	49.9132
Total			711475.125	12937693.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.928	782781.250	13288629.000	96.7633
2		12.602	26060.676	444499.906	3.2367
Total			808841.926	13733128.906	100.0000

***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(naphthalen-2-yl)propanoate (**3o**)**

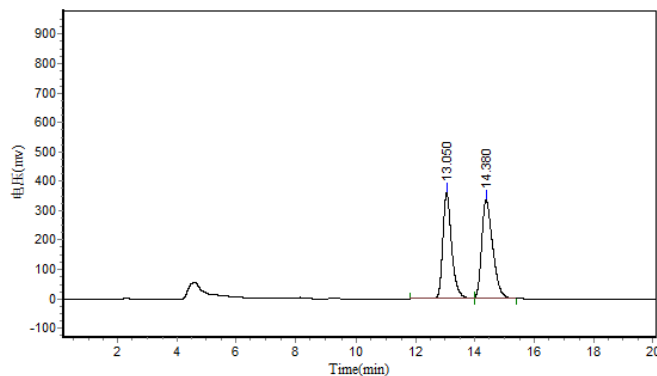


91% yield, colorless oil, 94% ee.

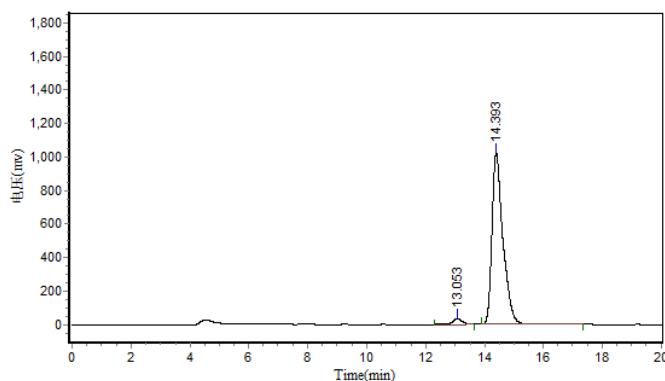
¹H NMR (300 MHz, CDCl₃): δ 7.78-7.66 (m, 6H), 7.61 (dt, *J* = 5.2, 3.0 Hz, 2H), 7.43-7.31 (m, 3H), 5.34-5.19 (m, 1H), 3.76 (d, *J* = 8.4 Hz, 2H), 1.49 (s, 9H). ¹³C NMR (125 MHz, CDCl₃): δ

167.9, 167.8, 134.7, 134.0, 133.5, 132.4, 131.7, 128.3, 127.7, 127.6, 127.5, 126.9, 126.0, 125.5, 123.4, 82.9, 54.1, 34.9, 28.0. HRMS (ESI) for C₂₅H₂₃NNaO₄ [M+Na]⁺: calcd 424.1525, found 424.1517.

HPLC: Chiralpak IC column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 13.0 min, 14.4 min (major).

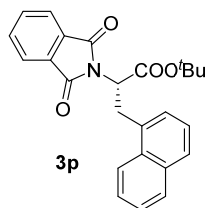


Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		13.050	358881.063	7499789.000	46.4397
2		14.380	336450.719	8649728.000	53.5603
Total			695331.781	16149517.000	100.0000



Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		13.053	35270.023	786484.250	2.8950
2		14.393	1021479.000	26380060.000	97.1050
Total			1056749.023	27166544.250	100.0000

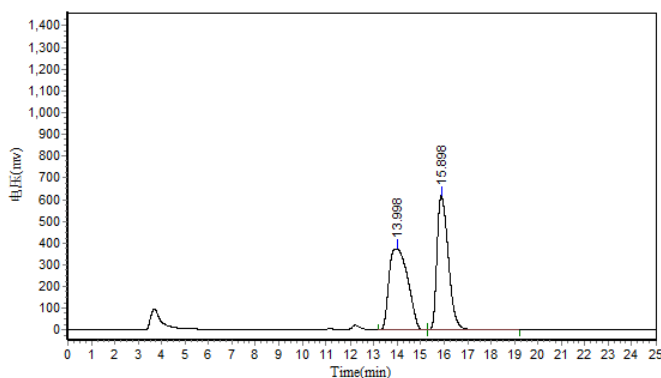
***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(naphthalen-1-yl)propanoate (**3p**)**



99% yield, colorless oil, 91% ee.

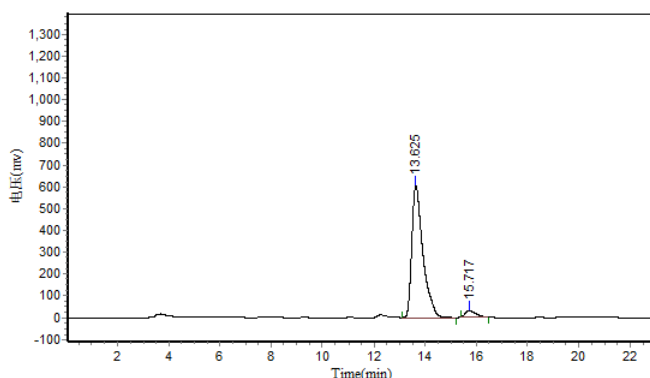
^1H NMR (300 MHz, CDCl_3): δ 8.11 (d, $J = 8.8$ Hz, 1H), 7.81 (d, $J = 8.4$ Hz, 1H), 7.75 (dd, $J = 5.3, 3.3$ Hz, 2H), 7.70-7.62 (m, 3H), 7.50 (dt, $J = 22.7, 7.4$ Hz, 2H), 7.30-7.19 (m, 2H), 5.25 (dd, $J = 11.2, 4.4$ Hz, 1H), 4.19-4.05 (m, 1H), 3.97-3.80 (m, 1H), 1.49 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.9, 167.6, 134.0, 133.8, 133.3, 131.8, 131.7, 128.9, 127.7, 127.1, 126.3, 125.7, 125.2, 123.3, 123.2, 82.9, 53.6, 31.8, 28.0. HRMS (ESI) for $\text{C}_{25}\text{H}_{23}\text{NNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 424.1525, found 424.1517.

HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 13.8 min (major), 15.7 min.



Results

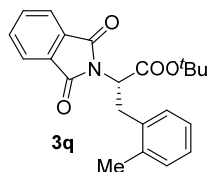
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		13.998	369473.781	20723822.000	50.0604
2		15.898	615535.188	20673784.000	49.9396
Total			985008.969	41397606.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		13.625	605989.250	18266516.000	95.5858
2		15.717	30078.732	843564.313	4.4142
Total			636067.982	19110080.313	100.0000

***tert*-butyl (*S*)-2-(1,3-dioxisoindolin-2-yl)-3-(*o*-tolyl)propanoate (3q)**



99% yield, colorless oil, 94% ee.

$^1\text{H NMR}$ (300 MHz, CDCl_3): δ 7.88-7.75 (m, 2H), 7.69 (m, 2H),

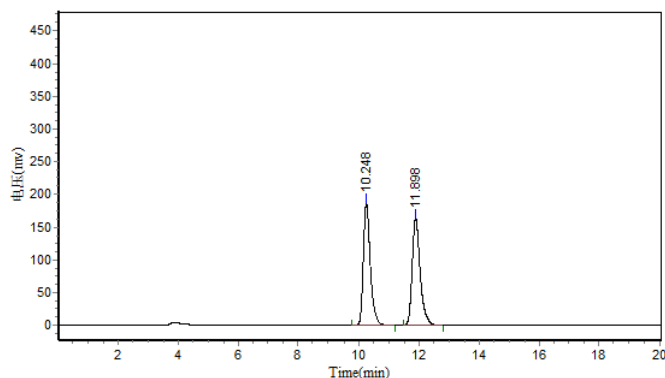
7.19-6.84 (m, 4H), 5.09 (dd, $J = 11.0, 5.1$ Hz, 1H), 3.68-3.34 (m,

2H), 2.39 (s, 3H), 1.47 (s, 9H). $^{13}\text{C NMR}$ (150 MHz, CDCl_3): δ 168.0, 167.7, 136.6,

135.2, 134.0, 131.7, 130.5, 129.6, 126.9, 125.9, 123.4, 82.8, 52.5, 32.3, 27.9, 19.3.

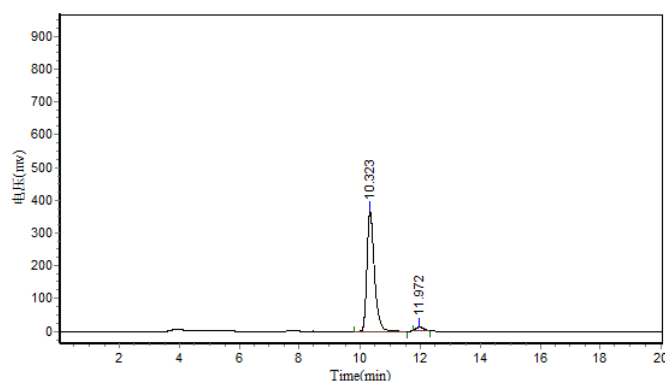
HRMS (ESI) for $\text{C}_{22}\text{H}_{23}\text{NNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 388.1525, found 388.1520.

HPLC: Chiralpak AD-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 0.7 mL/min; Retention time: 10.3 min (major), 11.9 min.



Results

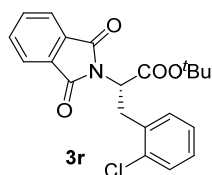
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.248	187121.766	3075198.750	50.1664
2		11.898	163839.594	3054798.500	49.8336
Total			350961.359	6129997.250	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.323	366041.750	6380191.500	96.9115
2		11.972	12642.690	203330.703	3.0885
Total			378684.440	6583522.203	100.0000

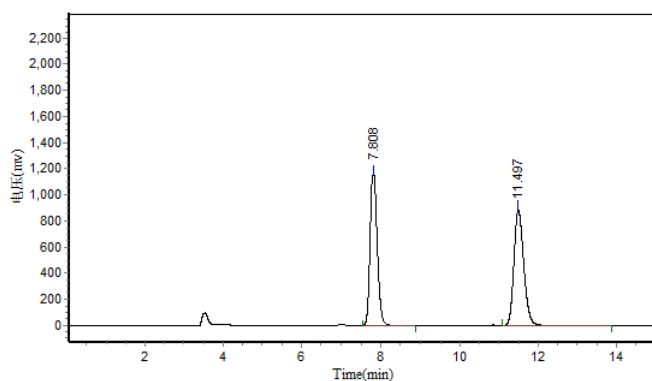
***tert*-butyl (*S*)-3-(2-chlorophenyl)-2-(1,3-dioxisoindolin-2-yl)propanoate (**3r**)**



63% yield, colorless oil, 79% ee.

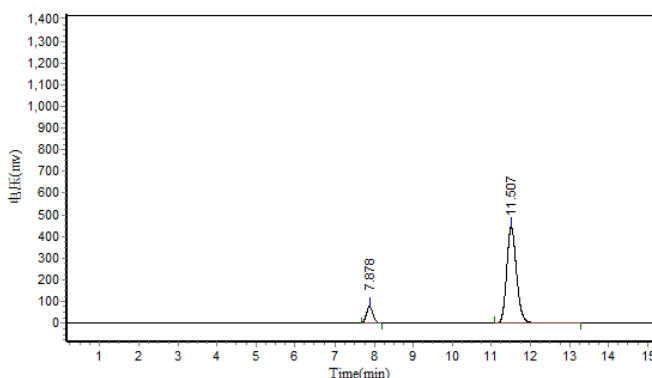
^1H NMR (300 MHz, CDCl_3): δ 7.78 (dt, $J = 6.9, 3.5$ Hz, 2H), 7.73-7.55 (m, 2H), 7.29 (dd, $J = 7.6, 6.2$ Hz, 1H), 7.05 (dt, $J = 14.6, 7.6$ Hz, 3H), 5.23 (dd, $J = 11.3, 4.7$ Hz, 1H), 3.75 (dd, $J = 14.2, 4.7$ Hz, 1H), 3.55 (dd, $J = 14.1, 11.4$ Hz, 1H), 1.46 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.6, 167.5, 135.0, 134.4, 134.0, 131.7, 131.3, 129.6, 128.4, 126.8, 123.4, 82.9, 52.2, 33.0, 27.9. HRMS (ESI) for $\text{C}_{21}\text{H}_{20}\text{ClNNaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 408.0979, found 408.0974.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 90/10; flow = 0.7 mL/min; Retention time: 7.8 min, 11.5 min (major).



Results

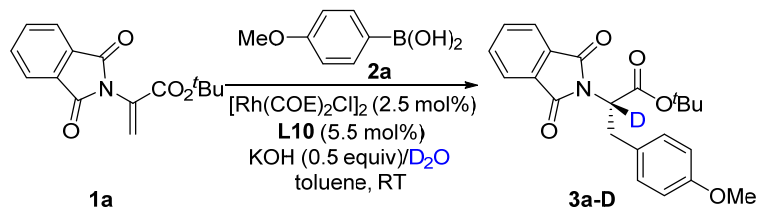
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		7.808	1153082.875	14955612.000	49.1913
2		11.497	885966.125	15447328.000	50.8087
Total			2039049.000	30402940.000	100.0000



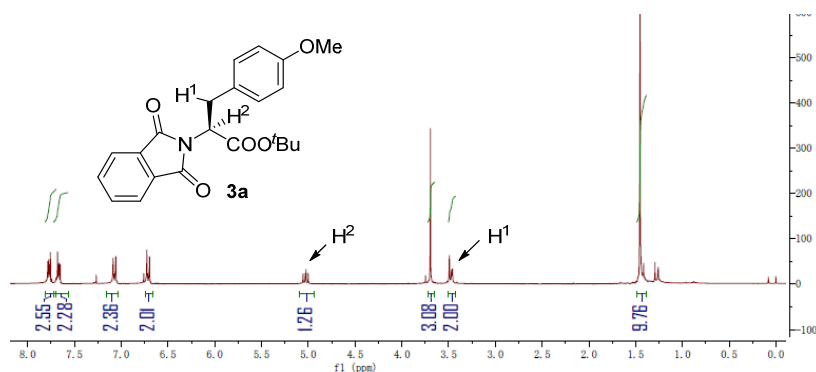
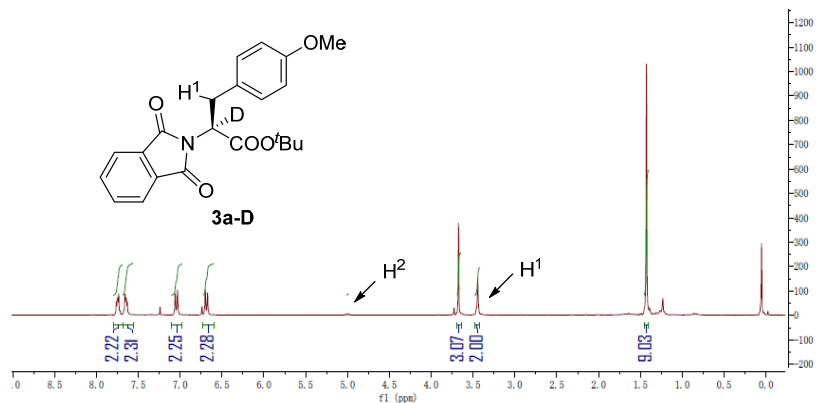
Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		7.878	76719.398	910756.313	10.5258
2		11.507	443128.281	7741860.000	89.4742
Total			519847.680	8652616.313	100.0000

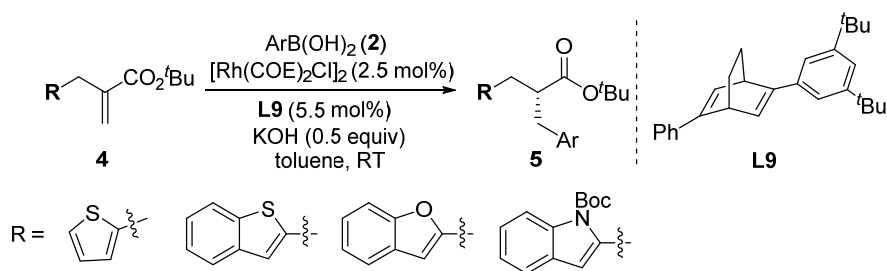
4. Deuterium labeling experiment of phenylalanine product 3



Under Ar atmosphere, a solution of α -phthalylimide *tert*-butyl acrylate **1a** (0.1 mmol), 4-methoxy arylboronic acid **2a** (0.3 mmol), $[\text{Rh}(\text{COE})_2\text{Cl}]_2$ (1.8 mg, 0.005 mmol of Rh), **L10** (2.2 mg, 0.0055 mmol) in 1.0 mL of anhydrous toluene was stirred at room temperature for 30 min. To this mixture was added aqueous KOH in D_2O (0.05 mL, 1.0 M, 0.05 mmol). After reaction for another 12 hours, a saturated aq. NH_4Cl was added and the mixture was extracted with EtOAc (10 mL \times 3). The combined organic phase was dried over Na_2SO_4 , filtered, and concentrated. The residue was purified by silica gel flash chromatography, eluting with petroleum ether/EtOAc (20%-30% EtOAc), to afford the corresponding products **3a-D**.



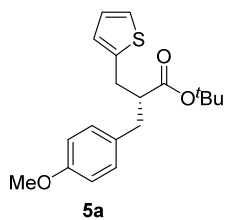
5. General procedure for Rh-catalyzed asymmetric 1,4-addition/asymmetric protonation of acrylate substrates **4**



Under Ar atmosphere, a solution of acrylate **4** (0.1 mmol), arylboronic acid **2** (0.3 mmol), $[\text{Rh}(\text{COE})_2\text{Cl}]_2$ (1.8 mg, 0.005 mmol of Rh), **L9** (2.2 mg, 0.0055 mmol) in 1.0 mL of anhydrous toluene was stirred at room temperature for 30 min. To this mixture was added KOH (0.05 mL, 1.0 M, 0.05 mmol). After reaction for another 12 hours, a saturated aq. NH_4Cl was added and the mixture was extracted with EtOAc (10 mL \times 3). The combined organic phase was dried over Na_2SO_4 , filtered, and concentrated. The residue was purified by silica gel flash chromatography, eluting with petroleum ether/EtOAc (1%-5% EtOAc), to afford the corresponding products **5**.

6. Characterization data and HPLC of products 5

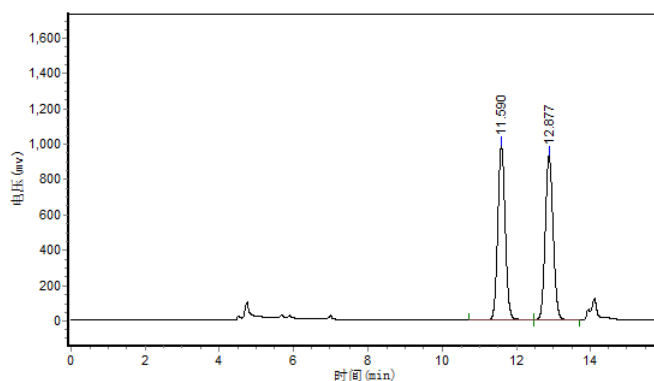
tert-butyl (*R*)-2-(4-methoxybenzyl)-3-(thiophen-2-yl)propanoate (**5a**)



98% yield, light yellow oil, 98% ee.

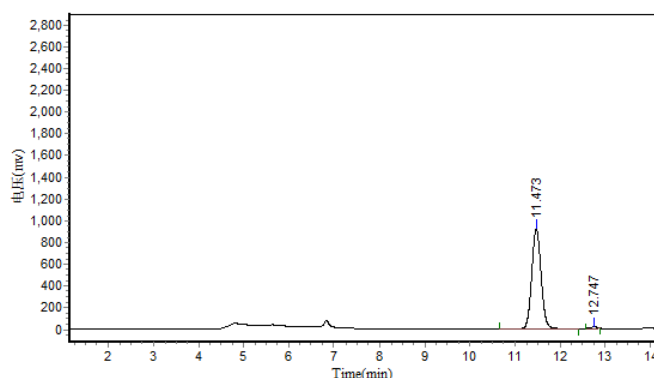
$^1\text{H NMR}$ (300 MHz, CDCl_3): δ 7.09 (t, $J = 6.5$ Hz, 3H), 6.95-6.84 (m, 1H), 6.80 (d, $J = 8.5$ Hz, 3H), 3.77 (s, 3H), 3.11 (dd, $J = 14.7, 8.0$ Hz, 1H), 2.92 (dd, $J = 20.1, 5.2$ Hz, 1H), 2.83 (t, $J = 12.5$ Hz, 2H), 2.79-2.64 (m, 1H), 1.26 (s, 9H). $^{13}\text{C NMR}$ (125 MHz, CDCl_3): δ 173.4, 157.7, 141.3, 130.6, 129.6, 126.1, 125.1, 123.2, 113.3, 80.1, 54.8, 50.1, 37.0, 31.7, 27.5. HRMS (ESI) for $\text{C}_{19}\text{H}_{24}\text{NaO}_3\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 355.1344, found 355.1337.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99/1; flow = 1.0 mL/min; Retention time: 11.5 min (major), 12.7 min.



分析结果表

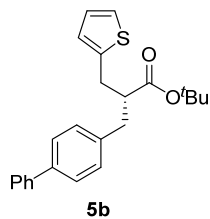
峰号	峰名	保留时间	峰高	峰面积	含量
1		11.590	982080.438	13716245.000	50.0199
2		12.877	924450.875	13705355.000	49.9801
总计			1906531.313	27421600.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		11.473	918679.250	13294426.000	99.0423
2		12.747	12062.463	128549.570	0.9577
Total			930741.713	13422975.570	100.0000

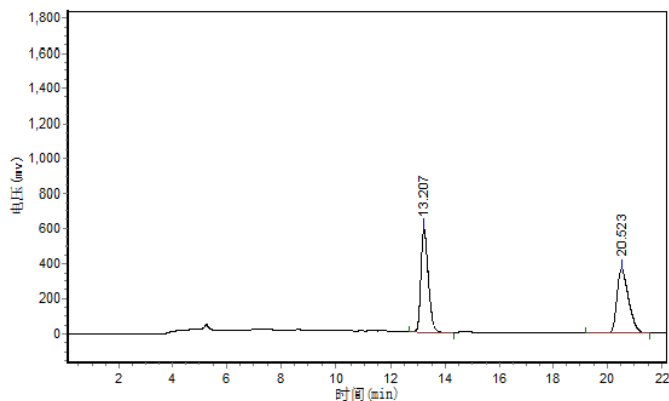
***tert*-butyl (*R*)-3-([1,1'-biphenyl]-4-yl)-2-(thiophen-2-ylmethyl)propanoate (**5b**)**



95% yield, light yellow oil, 97% ee.

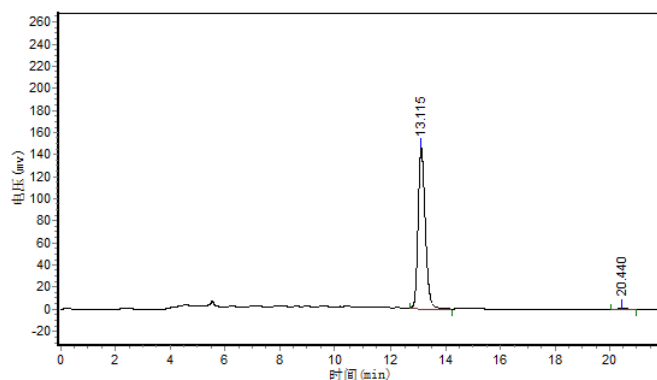
$^1\text{H NMR}$ (300 MHz, CDCl_3): δ 7.59 (d, $J = 8.3$ Hz, 2H), 7.52 (d, $J = 8.2$ Hz, 2H), 7.44 (t, $J = 7.1$ Hz, 2H), 7.35 (d, $J = 7.3$ Hz, 1H), 7.27 (d, $J = 5.6$ Hz, 2H), 7.15 (d, $J = 5.0$ Hz, 1H), 6.92 (m, 1H), 6.84 (m, 1H), 3.28-3.11 (m, 1H), 2.96 (m, 4H), 1.28 (s, 9H). $^{13}\text{C NMR}$ (125 MHz, CDCl_3): δ 173.3, 141.2, 140.5, 138.8, 137.6, 129.0, 128.3, 126.7, 126.6, 126.5, 126.2, 125.2, 123.3, 80.2, 49.8, 37.4, 31.8, 27.4. HRMS (ESI) for $\text{C}_{24}\text{H}_{26}\text{NaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 401.1551, found 401.1547.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 13.1 min (major), 20.4 min.



分析结果表

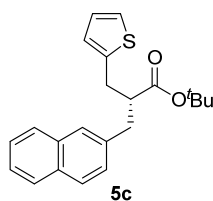
峰号	峰名	保留时间	峰高	峰面积	含量
1		13.207	584342.875	11334915.000	60.0465
2		20.523	370854.719	11313871.000	49.9535
总计			955197.594	22848786.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		13.115	144669.875	2628346.750	98.4602
2		20.440	1585.299	41104.602	1.5398
总计			146255.174	2669451.352	100.0000

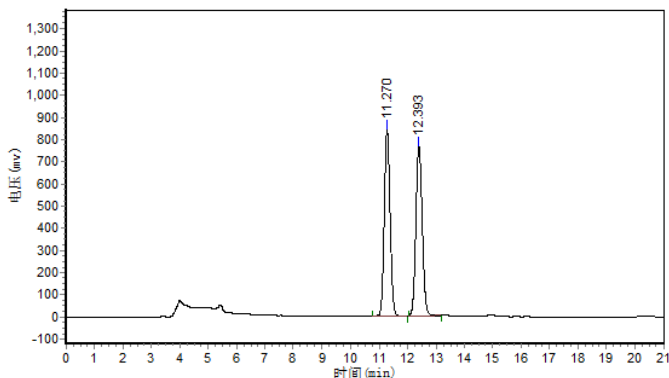
***tert*-butyl (*R*)-3-(naphthalen-2-yl)-2-(thiophen-2-ylmethyl)propanoate (**5c**)**



98% yield, light yellow oil, 98% ee.

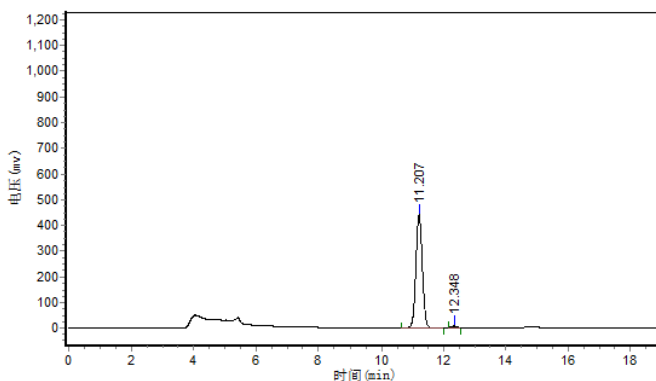
$^1\text{H NMR}$ (300 MHz, CDCl_3): δ 7.77 (t, $J = 9.4$ Hz, 3H), 7.62 (s, 1H), 7.46-7.37 (m, 2H), 7.32 (d, $J = 8.4$ Hz, 1H), 7.13 (d, $J = 5.1$ Hz, 1H), 6.93-6.86 (m, 1H), 6.82 (s, 1H), 3.25-3.08 (m, 2H), 3.07-2.90 (m, 3H), 1.23 (s, 9H). $^{13}\text{C NMR}$ (125 MHz, CDCl_3): δ 173.3, 141.2, 136.1, 133.0, 131.8, 127.5, 127.2, 127.0, 126.2, 125.5, 125.2, 124.9, 123.3, 80.2, 49.8, 37.9, 31.8, 27.4. HRMS (ESI) for $\text{C}_{22}\text{H}_{24}\text{NaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 375.1395, found 375.1392.

HPLC: Chiralcel OD-3 column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 11.2 min (major), 12.3 min.



分析结果表

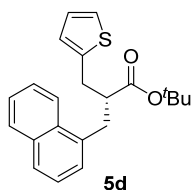
峰号	峰名	保留时间	峰高	峰面积	含量
1		11.270	840562.000	12010578.000	50.2155
2		12.393	763877.625	11907513.000	49.7845
总计			1604439.625	23918091.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		11.207	439217.188	6348518.500	98.8011
2		12.348	5977.667	77035.203	1.1989
总计			445194.854	6425553.703	100.0000

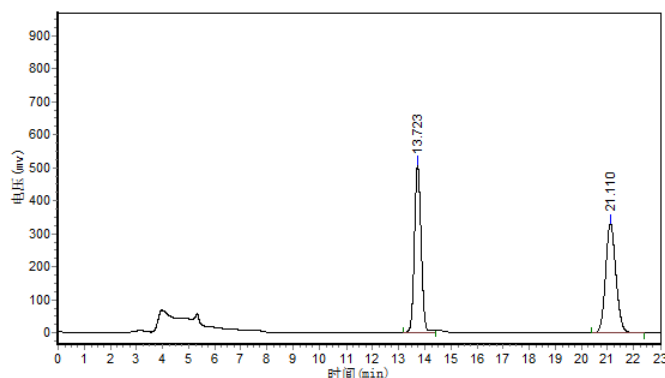
***tert*-butyl (*R*)-3-(naphthalen-1-yl)-2-(thiophen-2-ylmethyl)propanoate (5d)**



98% yield, light yellow oil, 97% ee.

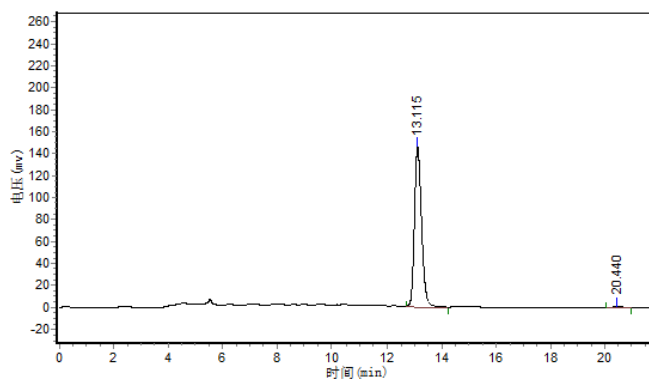
^1H NMR (300 MHz, CDCl_3): δ 7.95 (d, $J = 7.4$ Hz, 1H), 7.86 (d, $J = 8.6$ Hz, 1H), 7.74 (d, $J = 7.5$ Hz, 1H), 7.51 (dd, $J = 9.1, 6.1$ Hz, 2H), 7.44-7.32 (m, 2H), 7.15 (d, $J = 4.0$ Hz, 1H), 6.97-6.89 (m, 1H), 6.85 (s, 1H), 3.41 (dd, $J = 13.9, 8.3$ Hz, 1H), 3.29 (dd, $J = 14.1, 5.4$ Hz, 2H), 3.18-3.00 (m, 2H), 1.23 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 173.4, 141.2, 134.6, 133.4, 131.4, 128.3, 126.8, 126.7, 126.2, 125.5, 125.3, 125.0, 124.8, 123.3, 123.2, 80.1, 49.0, 34.9, 32.1, 27.4. HRMS (ESI) for $\text{C}_{22}\text{H}_{24}\text{NaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 375.1395, found 375.1392.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 13.1 min (major), 20.4 min.



分析结果表

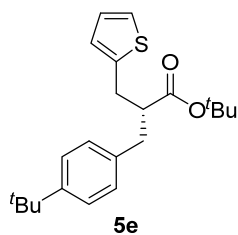
峰号	峰名	保留时间	峰高	峰面积	含量
1		13.723	506419.750	9074102.000	49.7063
2		21.110	332515.563	9181336.000	50.2937
总计			838935.313	18255438.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		13.115	144669.875	2628346.750	98.4602
2		20.440	1585.299	41104.602	1.5398
总计			146255.174	2669451.352	100.0000

***tert*-butyl (*R*)-2-(4-(*tert*-butyl)benzyl)-3-(thiophen-2-yl)propanoate (**5e**)**



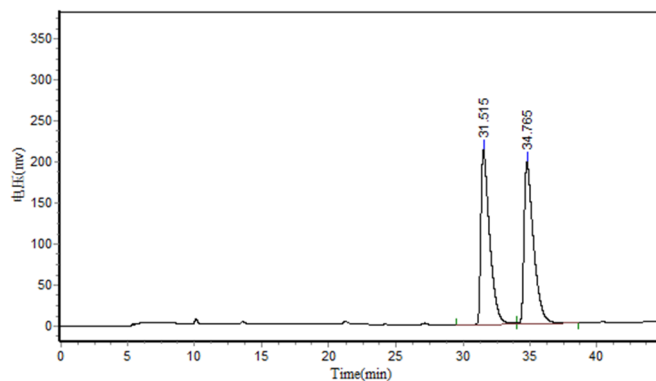
95% yield, light yellow oil, 96% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.27 (t, $J = 8.5$ Hz, 2H), 7.16-7.06 (m, 3H), 6.91-6.84 (m, 1H), 6.80 (d, $J = 2.3$ Hz, 1H), 3.21-3.05 (m, 1H), 3.00-2.83 (m, 3H), 2.83-2.69 (m, 1H), 1.29 (s, 9H), 1.24 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 173.4, 148.7,

141.4, 135.4, 128.3, 126.1, 125.1, 124.7, 123.1, 80.0, 49.8, 37.4, 33.9, 31.7, 30.9, 27.4.

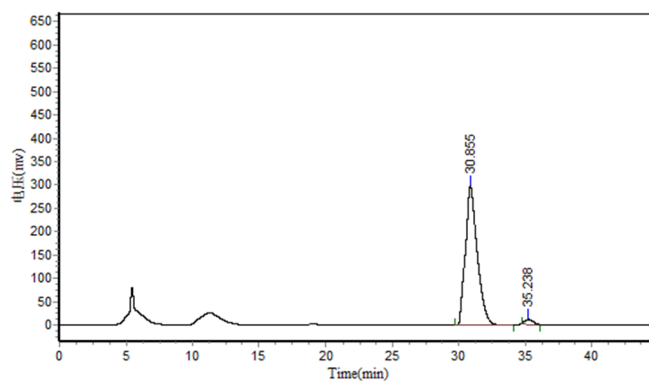
HRMS (ESI) for $\text{C}_{22}\text{H}_{30}\text{NaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 381.1864, found 381.1857.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99.5/0.5; flow = 0.5 mL/min; Retention time: 30.85 min (major), 35.24 min.



Results

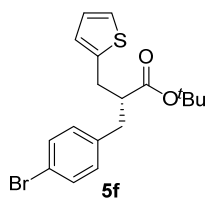
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		31.515	212916.344	9800965.000	49.7370
2		34.765	197463.734	9904624.000	50.2630
Total			410380.078	19705589.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		30.855	299362.094	18664564.000	97.7667
2		35.238	9566.298	426365.875	2.2333
Total			308928.392	19090929.875	100.0000

tert-butyl (R)-2-(4-bromobenzyl)-3-(thiophen-2-yl)propanoate (5f)

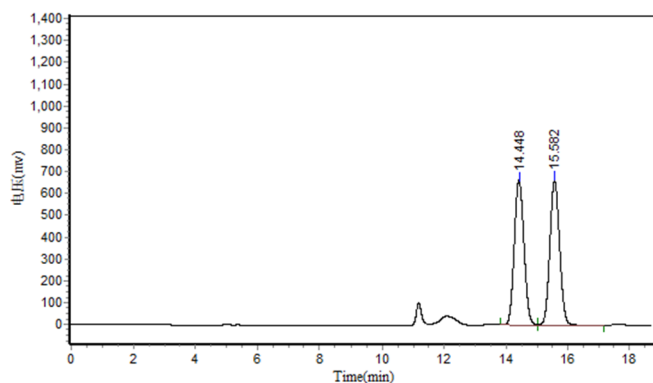


95% yield, light yellow oil, 96% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.39 (t, $J = 8.3$ Hz, 2H), 7.15 (d, $J = 4.6$ Hz, 1H), 7.06 (d, $J = 8.2$ Hz, 2H), 6.98-6.86 (m, 1H), 6.82 (s, 1H), 3.16 (dd, $J = 14.5, 7.3$ Hz, 1H), 3.04-2.91 (m, 1H),

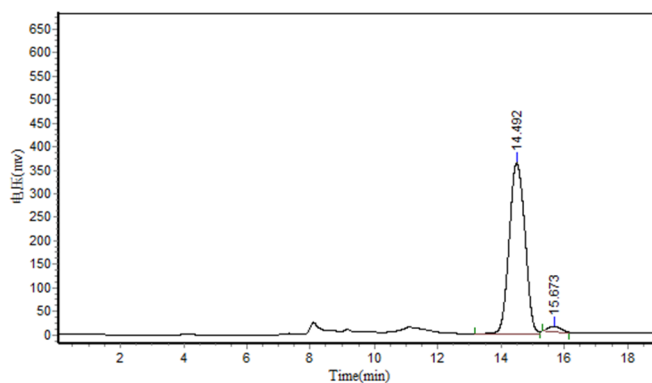
2.85 (dd, $J = 15.6, 8.1$ Hz, 2H), 2.80-2.70 (m, 1H), 1.28 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 173.0, 140.9, 137.6, 130.9, 130.3, 126.2, 125.3, 123.4, 119.7, 80.3, 49.7, 37.0, 31.9, 27.5. HRMS (ESI) for $\text{C}_{18}\text{H}_{21}\text{BrNaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 403.0343, found 403.0334.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99.5/0.5; flow = 0.5 mL/min; Retention time: 14.49 min (major), 15.69 min.



Results

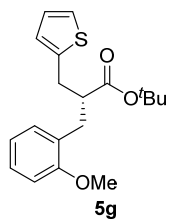
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		14.448	662783.000	14553785.000	49.9536
2		15.582	661657.875	14580839.000	50.0464
Total			1324440.875	29134624.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		14.492	364179.188	12592760.000	97.8505
2		15.673	10377.890	276626.188	2.1495
Total			374557.077	12869386.188	100.0000

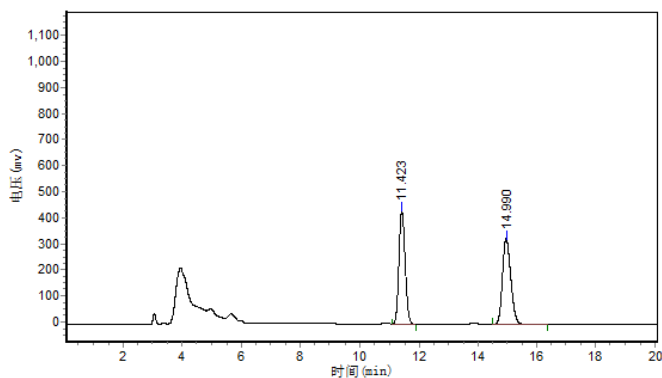
***tert*-butyl (*R*)-2-(2-methoxybenzyl)-3-(thiophen-2-yl)propanoate (**5g**)**



98% yield, light yellow oil, 96% ee.

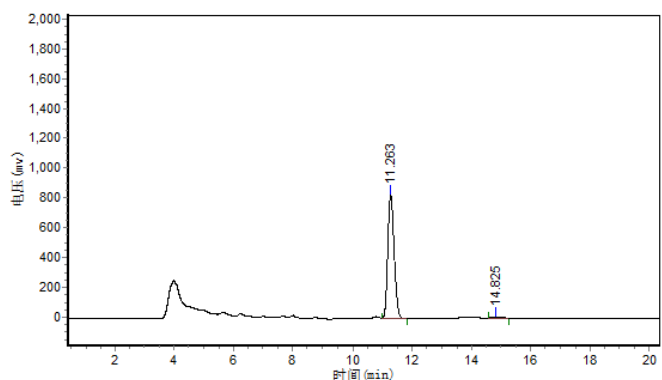
¹H NMR (300 MHz, CDCl₃): δ 7.19 (t, *J* = 7.0 Hz, 1H), 7.15-7.09 (m, 2H), 6.94-6.76 (m, 4H), 3.82 (s, 3H), 3.17 (dd, *J* = 13.2, 8.1 Hz, 1H), 3.09-2.95 (m, 2H), 2.94-2.78 (m, 2H), 1.24 (s, 9H). ¹³C NMR (125 MHz, CDCl₃): δ 173.7, 157.2, 141.7, 130.4, 127.2, 126.9, 126.0, 124.9, 123.0, 119.6, 109.7, 79.7, 54.7, 47.7, 33.0, 32.0, 27.4. HRMS (ESI) for C₁₉H₂₄NaO₃S [M+Na]⁺: calcd 355.1344, found 355.1337.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 93/7; flow = 0.6 mL/min; Retention time: 11.2 min (major), 14.8 min.



分析结果表

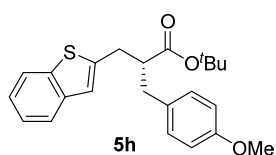
峰号	峰名	保留时间	峰高	峰面积	含量
1		11.423	433707.813	6433252.500	49.5985
2		14.990	327818.969	6537402.500	50.4015
总计			761526.781	12970655.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		11.263	822617.500	12328463.000	98.3760
2		14.825	8711.854	203518.188	1.6240
总计			831329.354	12531981.188	100.0000

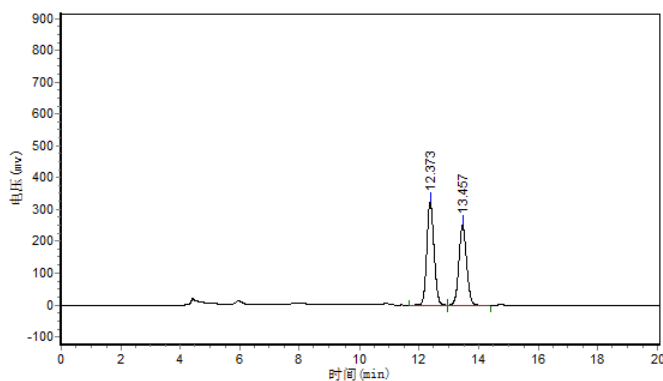
tert-butyl (R)-3-(benzo[b]thiophen-2-yl)-2-(4-methoxybenzyl)propanoate (5h)



99% yield, light yellow oil, 98% ee.

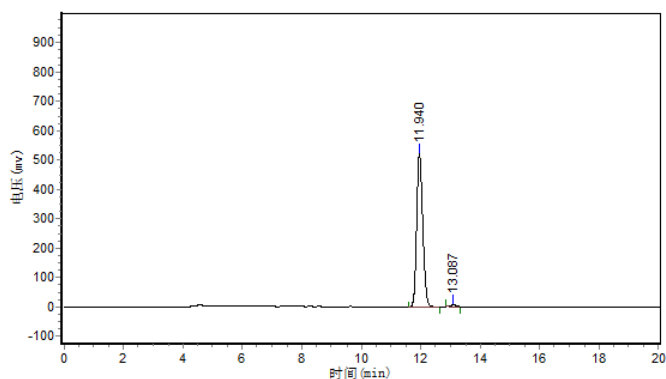
¹H NMR (300 MHz, CDCl₃): δ 7.77 (d, *J* = 7.6 Hz, 1H), 7.67 (d, *J* = 7.6 Hz, 1H), 7.39-7.21 (m, 2H), 7.13 (d, *J* = 8.3 Hz, 2H), 7.04 (s, 1H), 6.84 (d, *J* = 8.4 Hz, 2H), 3.80 (s, 3H), 3.23 (dd, *J* = 14.4, 7.3 Hz, 1H), 3.10-2.87 (m, 3H), 2.82 (t, *J* = 8.7 Hz, 1H), 1.29 (s, 9H). ¹³C NMR (125 MHz, CDCl₃): δ 173.3, 157.8, 142.6, 139.6, 139.2, 130.5, 129.7, 123.7, 123.2, 122.4, 121.8, 121.7, 113.3, 80.3, 54.8, 49.5, 37.0, 32.5, 27.5. HRMS (ESI) for C₂₃H₂₆NaO₃S [M+Na]⁺: calcd 405.1500, found 405.1506.

HPLC: Chiralcel OD-3 column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 11.9 min (major), 13.0 min.



分析结果表

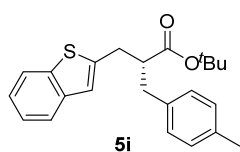
峰号	峰名	保留时间	峰高	峰面积	含量
1		12.373	324833.250	5475811.500	54.4085
2		13.457	250194.719	4588441.500	45.5915
总计			575027.969	10064253.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		11.940	520447.563	7442627.000	99.0260
2		13.087	5289.159	73201.000	0.9740
总计			525736.721	7515828.000	100.0000

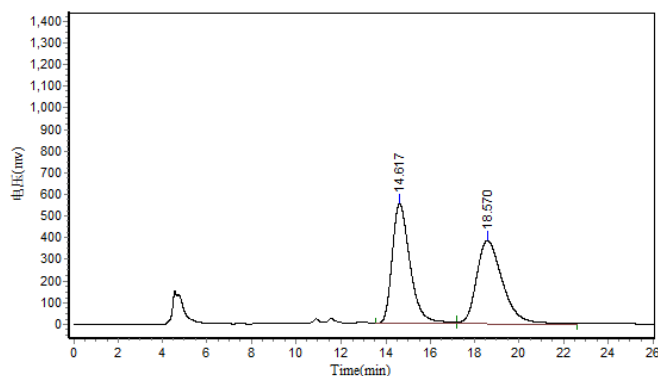
***tert*-butyl (*R*)-3-(benzo[*b*]thiophen-2-yl)-2-(4-methylbenzyl)propanoate (**5i**)**



98% yield, light yellow oil, 97% ee.

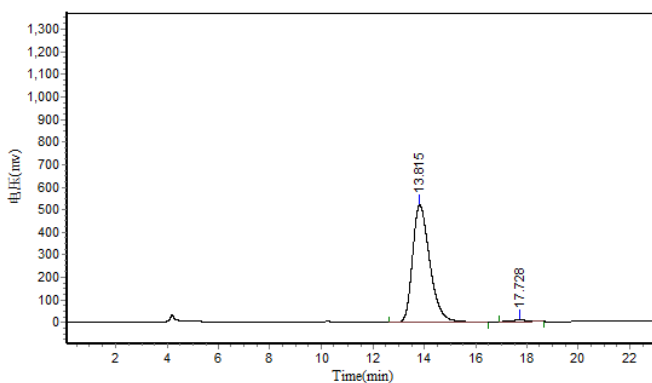
^1H NMR (300 MHz, CDCl_3): δ 7.77 (d, $J = 7.9$ Hz, 1H), 7.71-7.60 (m, 1H), 7.37-7.27 (m, 2H), 7.10 (m, 4H), 7.04 (s, 1H), 3.22 (dd, $J = 14.2, 6.9$ Hz, 1H), 3.07-2.87 (m, 3H), 2.83 (t, $J = 8.2$ Hz, 1H), 2.33 (s, 3H), 1.29 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 173.7, 143.0, 139.9, 139.5, 135.9, 135.6, 129.0, 128.9, 124.0, 123.6, 122.8, 122.1, 122.0, 80.7, 49.7, 37.8, 32.8, 27.9, 21.0. HRMS (ESI) for $\text{C}_{23}\text{H}_{26}\text{NaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 389.1551, found 389.1549.

HPLC: Chiralcel OJ-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 13.8 min (major), 17.7 min.



Results

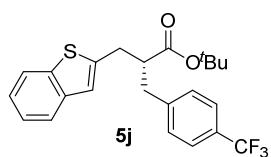
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		14.617	555852.313	31276084.000	50.0357
2		18.570	385747.781	31231466.000	49.9643
Total			941600.094	62507550.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		13.815	520208.563	24421908.000	98.5015
2		17.728	6697.141	371524.000	1.4985
Total			526905.704	24793432.000	100.0000

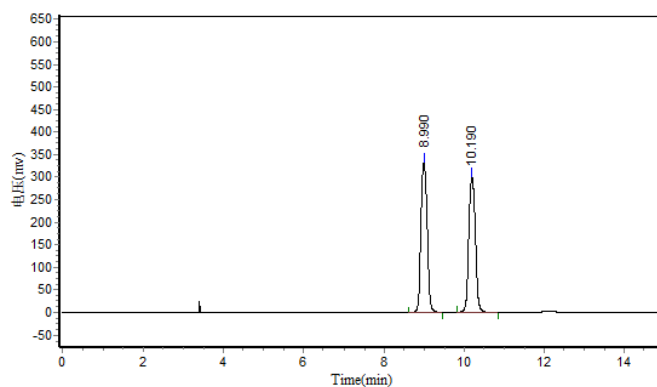
***tert*-butyl (*R*)-3-(benzo[*b*]thiophen-2-yl)-2-(4-(trifluoromethyl)benzyl)propanoate (5j)**



96% yield, light yellow oil, 90% ee.

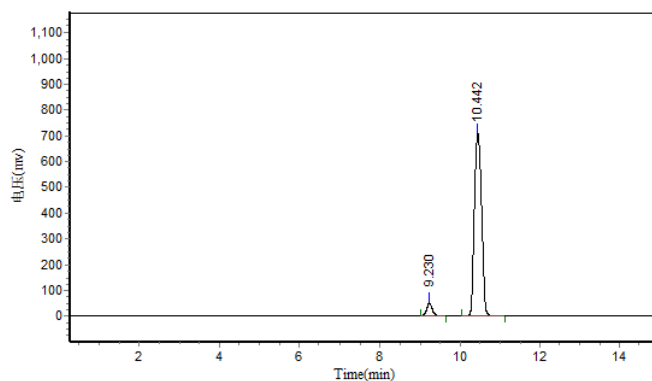
¹H NMR (300 MHz, CDCl₃): δ 7.79 (d, *J* = 7.2 Hz, 1H), 7.71-7.63 (m, 1H), 7.55 (d, *J* = 8.3 Hz, 2H), 7.41-7.24 (m, 4H), 7.06 (s, 1H), 3.34-3.17 (m, 1H), 3.12-2.88 (m, 4H), 1.26 (s, 9H). ¹³C NMR (125 MHz, CDCl₃): δ 173.1, 143.0, 142.3, 139.9, 139.5, 129.4, 128.9 (q, *J*_{CF} = 32.5 Hz), 125.2 (q, *J*_{CF} = 3.8 Hz), 124.2, 123.8, 123.2 (q, *J*_{CF} = 292 Hz), 122.9, 122.5, 122.2, 81.1, 49.4, 37.8, 33.2, 27.8. HRMS (ESI) for C₂₃H₂₃F₃NaO₂S [M+Na]⁺: calcd 443.1269, found 443.1265.

HPLC: Chiralpak AD-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 95/5; flow = 1.0 mL/min; Retention time: 12.6 min (major), 14.3 min.



Results

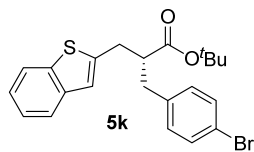
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		8.990	331297.438	3609549.500	51.2075
2		10.190	298622.219	3439316.250	48.7925
Total			629919.656	7048865.750	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		9.230	50512.469	510753.188	5.4094
2		10.442	707657.625	8931227.000	94.5906
Total			758170.094	9441980.188	100.0000

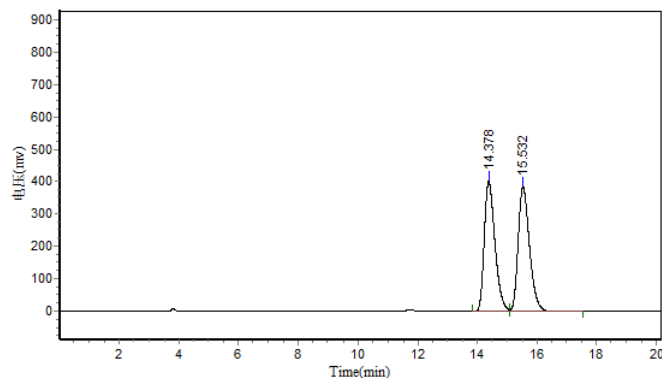
***tert*-butyl (*R*)-3-(benzo[*b*]thiophen-2-yl)-2-(4-bromobenzyl)propanoate (**5k**)**



93% yield, light yellow oil, 95% ee.

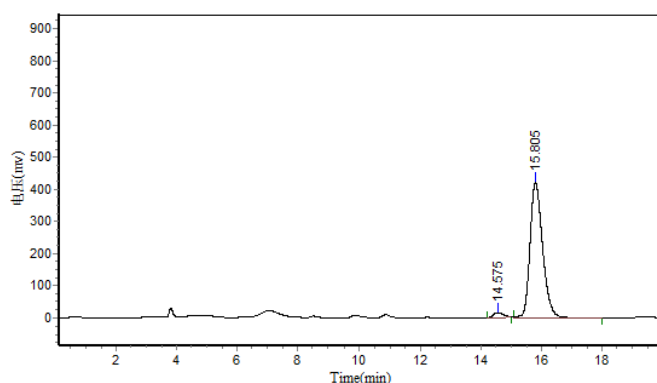
^1H NMR (300 MHz, CDCl_3): δ 7.77 (d, $J = 7.2$ Hz, 1H), 7.67 (d, $J = 7.1$ Hz, 1H), 7.41 (d, $J = 8.1$ Hz, 2H), 7.31 (dd, $J = 14.6, 7.8$ Hz, 2H), 7.17-6.97 (m, 3H), 3.31-3.16 (m, 1H), 3.09-2.70 (m, 4H), 1.28 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 172.9, 142.1, 139.5, 139.1, 137.5, 131.0, 130.4, 123.8, 123.3, 122.5, 121.9, 121.7, 119.9, 80.6, 49.1, 37.04 32.6, 27.5. HRMS (ESI) for $\text{C}_{22}\text{H}_{23}\text{BrNaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 453.0500, found 453.0496.

HPLC: Chiralpak AD-3 column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 99/1; flow = 1.0 mL/min; Retention time: 14.5 min, 15.8 min (major).



Results

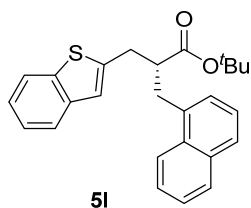
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		14.378	401877.719	10052480.000	49.6082
2		15.532	385048.063	10211261.000	50.3918
Total			786925.781	20263741.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		14.575	14770.711	331948.250	2.6441
2		15.805	422202.625	12222138.000	97.3559
Total			436973.336	12554086.250	100.0000

***tert*-butyl (*R*)-3-(benzo[*b*]thiophen-2-yl)-2-(naphthalen-1-ylmethyl)propanoate (5I)**

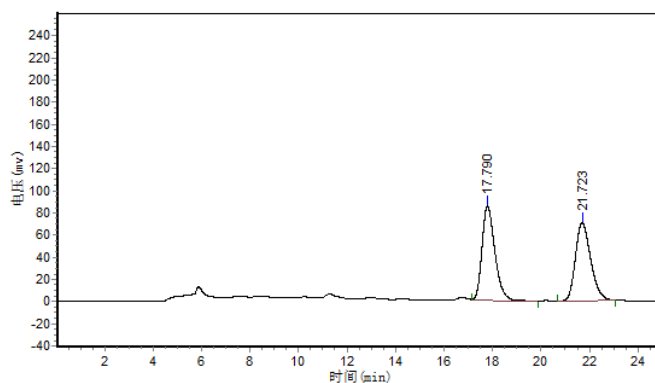


91% yield, light yellow oil, 96% ee.

$^1\text{H NMR}$ (300 MHz, CDCl_3): δ 7.99 (d, $J = 5.8$ Hz, 1H), 7.86 (d, $J = 8.0$ Hz, 1H), 7.77 (d, $J = 7.3$ Hz, 2H), 7.67 (d, $J = 7.2$ Hz, 1H), 7.57-7.43 (m, 2H), 7.39 (d, $J = 6.8$ Hz, 2H), 7.30

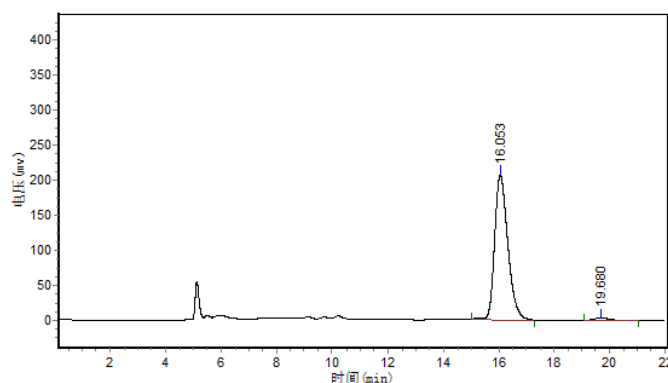
(dd, $J = 14.6, 7.2$ Hz, 2H), 7.06 (s, 1H), 3.44 (dt, $J = 17.0, 8.6$ Hz, 1H), 3.38-3.25 (m, 2H), 3.25-3.01 (m, 2H), 1.23 (s, 9H). $^{13}\text{C NMR}$ (125 MHz, CDCl_3): δ 173.4, 142.4, 139.5, 139.2, 134.5, 133.5, 131.5, 128.4, 127.0, 126.9, 125.6, 125.1, 124.9, 123.7, 123.3, 123.2, 122.5, 121.9, 121.7, 80.4, 48.5, 35.1, 33.0, 27.4. HRMS (ESI) for $\text{C}_{26}\text{H}_{26}\text{NaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 425.1551, found 425.1546.

HPLC: Chiralcel OD-H column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.6 mL/min; Retention time: 16.0 min (major), 19.7 min.



分析结果表

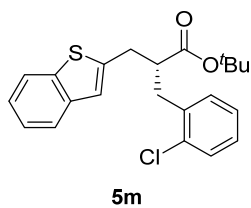
峰号	峰名	保留时间	峰高	峰面积	含量
1		17.790	85311.906	3170736.750	50.0871
2		21.723	70653.586	3159713.750	49.9129
总计			155965.492	6330450.500	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		16.053	205568.563	6829581.000	98.0486
2		19.680	3326.109	135923.453	1.9514
总计			208894.672	6965504.453	100.0000

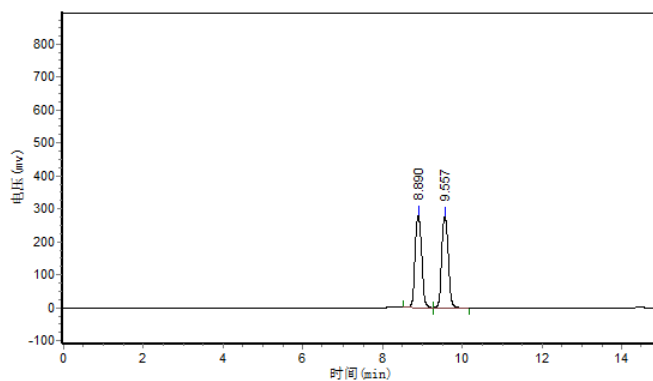
tert-butyl (R)-3-(benzo[b]thiophen-2-yl)-2-(2-chlorobenzyl)propanoate (5m)



92% yield, light yellow oil, 90% ee.

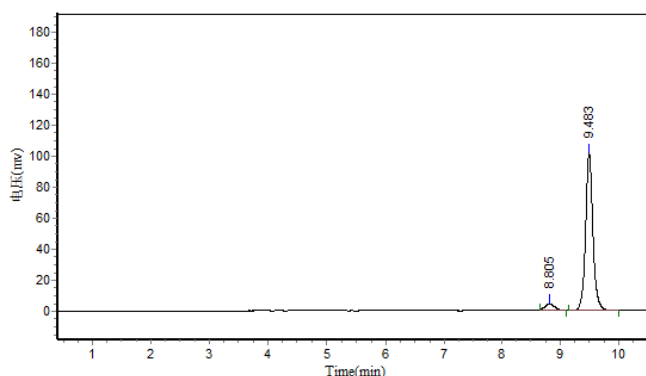
^1H NMR (300 MHz, CDCl_3): δ 7.77 (d, $J = 7.6$ Hz, 1H), 7.67 (d, $J = 7.6$ Hz, 1H), 7.41-7.35 (m, 1H), 7.29 (dd, $J = 8.5, 6.8$ Hz, 3H), 7.21-7.15 (m, 2H), 7.07 (s, 1H), 3.31 (dd, $J = 14.0, 8.2$ Hz, 1H), 3.25-3.12 (m, 1H), 3.08 (dd, $J = 13.0, 6.3$ Hz, 3H), 1.26 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 173.4, 142.6, 139.9, 139.6, 136.5, 134.3, 131.4, 129.5, 128.0, 126.6, 124.1, 123.6, 122.8, 122.2, 122.1, 80.8, 47.6, 36.2, 33.3, 27.8. HRMS (ESI) for $\text{C}_{22}\text{H}_{23}\text{ClNaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 409.1005, found 409.1006.

HPLC: Chiralcel OD-3 column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 8.8 min, 9.4 min (major).



分析结果表

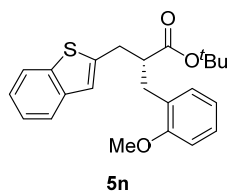
峰号	峰名	保留时间	峰高	峰面积	含量
1		8.890	277439.625	3218330.500	50.2171
2		9.557	276824.563	3190508.000	49.7829
总计			554264.188	6408838.500	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		8.805	3799.218	43714.500	4.6697
2		9.483	101726.898	892422.375	95.3303
Total			105526.116	936136.875	100.0000

tert-butyl (R)-3-(benzo[b]thiophen-2-yl)-2-(2-methoxybenzyl)propanoate (5n)

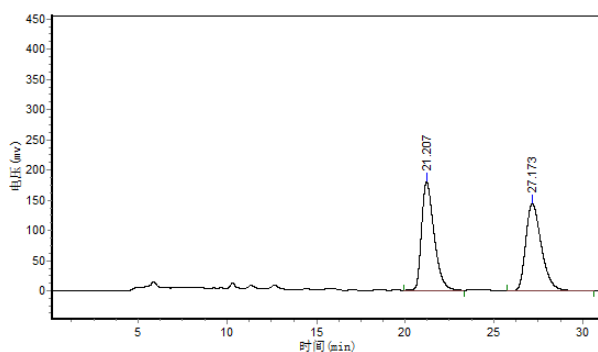


98% yield, light yellow oil, 99% ee.

¹H NMR (300 MHz, CDCl₃): δ 7.76 (d, *J* = 7.4 Hz, 1H), 7.66 (d, *J* = 7.7 Hz, 1H), 7.35-7.19 (m, 2H), 7.19-7.10 (m, 2H), 7.05 (s, 1H), 6.87 (t, *J* = 9.1 Hz, 2H), 3.83 (s, 3H), 3.26 (dd, *J* =

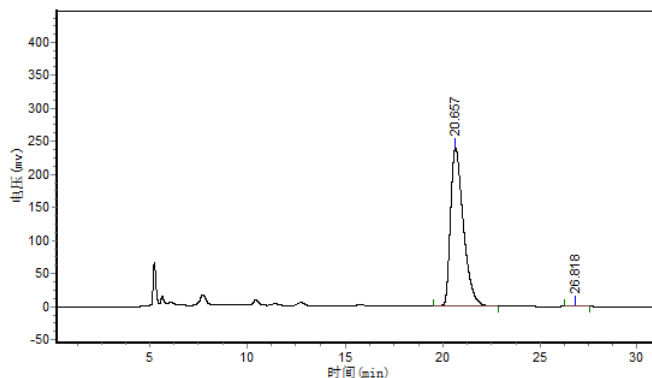
14.3, 8.9 Hz, 1H), 3.20-3.08 (m, 1H), 3.02 (dd, *J* = 14.2, 4.8 Hz, 1H), 2.97-2.81 (m, 2H), 1.25 (s, 9H). ¹³C NMR (125 MHz, CDCl₃): δ 173.7, 157.3, 143.0, 139.6, 139.2, 130.5, 127.4, 126.8, 123.6, 123.1, 122.4, 121.6, 121.5, 119.8, 109.8, 80.0, 54.8, 47.2, 45.2, 33.3, 32.8, 27.5. HRMS (ESI) for C₂₃H₂₆NaO₃S [M+Na]⁺: calcd 405.1500, found 405.1496.

HPLC: Chiralpak AD-H column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.6 mL/min; Retention time: 20.6 min (major), 26.8 min.



分析结果表

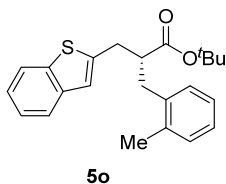
峰号	峰名	保留时间	峰高	峰面积	含量
1		21.207	179384.891	8858161.000	50.3787
2		27.173	143776.578	8724971.000	49.6213
总计			323161.469	17583132.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		20.657	239357.656	10986769.000	99.4639
2		26.818	1428.370	59215.703	0.5361
总计			240786.026	11045984.703	100.0000

***tert*-butyl (*R*)-3-(benzo[*b*]thiophen-2-yl)-2-(2-methylbenzyl)propanoate (**5o**)**

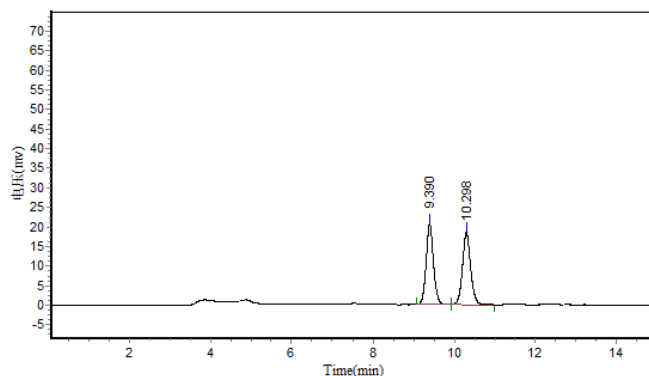


91% yield, light yellow oil, 97% ee.

¹H NMR (300 MHz, CDCl₃): δ 7.77 (d, *J* = 7.5 Hz, 1H), 7.67 (d, *J* = 7.6 Hz, 1H), 7.37-7.23 (m, 3H), 7.21-7.14 (m, 3H), 7.05 (s, 1H), 3.36-3.22 (m, 1H), 3.11-2.93 (m, 3H), 2.92-2.80 (m,

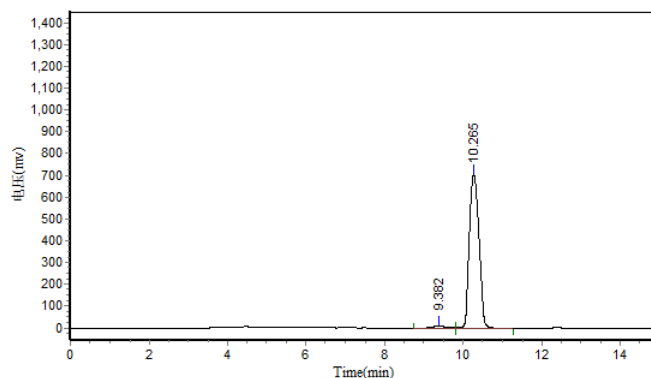
1H), 2.52(s, 3H), 1.28 (s, 9H). ¹³C NMR (125 MHz, CDCl₃): δ 173.8, 142.9, 139.9, 139.5, 137.0, 136.3, 130.3, 129.7, 126.5, 125.8, 124.1, 123.6, 122.8, 122.2, 122.1, 80.7, 48.3, 35.8, 33.2, 27.8, 19.5. HRMS (ESI) for C₂₃H₂₆NaO₂S [M+Na]⁺: calcd 389.1551, found 389.1550.

HPLC: Chiralcel OD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 9.3 min, 10.2 min (major).



Results

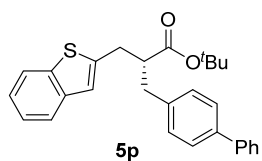
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		9.390	20706.047	260903.656	50.3254
2		10.298	18426.400	257529.953	49.6746
Total			39132.447	518433.609	100.0000



Results

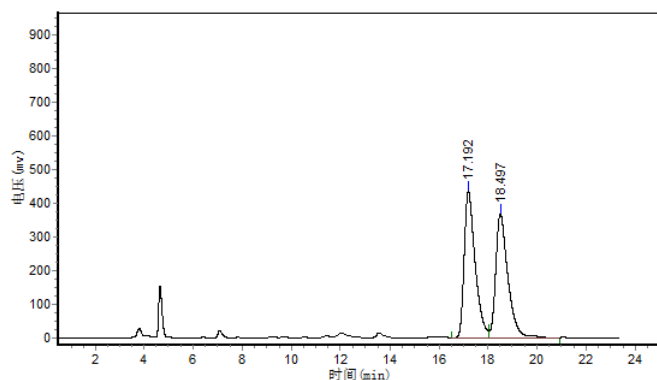
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		9.382	9923.603	188384.203	1.5364
2		10.265	701285.563	12072746.000	98.4636
Total			711209.165	12261130.203	100.0000

***tert*-butyl (*R*)-3-([1,1'-biphenyl]-4-yl)-2-(benzo[*b*]thiophen-2-ylmethyl)propanoate (5p)**



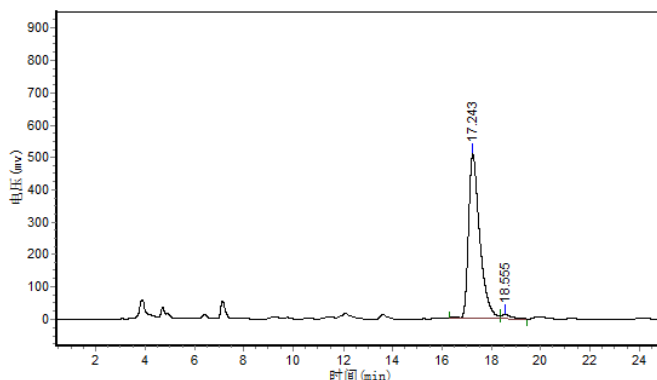
99% yield, light yellow oil, 96% ee.

^1H NMR (300 MHz, CDCl_3): δ 7.79 (d, $J = 7.5$ Hz, 1H), 7.68 (d, $J = 7.2$ Hz, 1H), 7.60 (d, $J = 7.5$ Hz, 2H), 7.54 (d, $J = 6.7$ Hz, 2H), 7.45 (t, $J = 7.4$ Hz, 2H), 7.40-7.23 (m, 5H), 7.07 (s, 1H), 3.37-3.17 (m, 1H), 3.04 (dd, $J = 22.0, 10.5$ Hz, 3H), 2.92 (dd, $J = 17.0, 10.4$ Hz, 1H), 1.30 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 173.2, 142.5, 140.6, 139.6, 139.2, 138.9, 137.5, 129.1, 128.3, 126.7, 126.6, 126.5, 123.7, 123.3, 122.5, 121.8, 121.7, 80.4, 49.3, 37.5, 32.6, 27.5. HRMS (ESI) for $\text{C}_{28}\text{H}_{28}\text{NaO}_2\text{S}$ $[\text{M}+\text{Na}]^+$: calcd 451.1708, found 451.1706. HPLC: Chiralpak AD-3 column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 90/10; flow = 0.5 mL/min; Retention time: 17.2 min (major), 18.5 min.



分析结果表

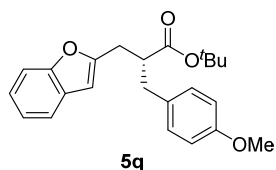
峰号	峰名	保留时间	峰高	峰面积	含量
1		17.192	434398.469	13437980.000	51.5285
2		18.497	368400.063	12640748.000	48.4715
总计			802798.531	26078728.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		17.243	508001.000	16061972.000	97.7840
2		18.555	11757.348	363994.094	2.2160
总计			519758.348	16425966.094	100.0000

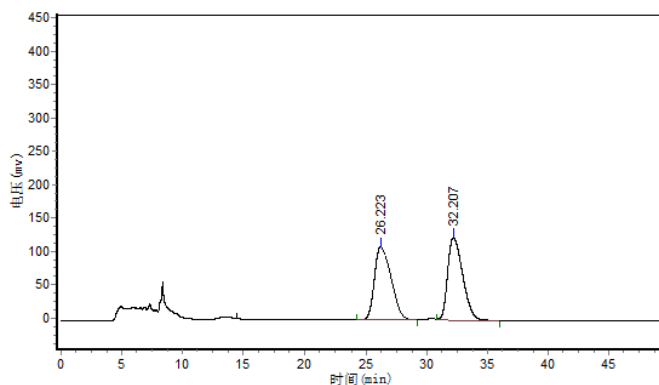
***tert*-butyl (*R*)-3-(benzofuran-2-yl)-2-(4-methoxybenzyl)propanoate (5q)**



93% yield, light yellow oil, 90% ee.

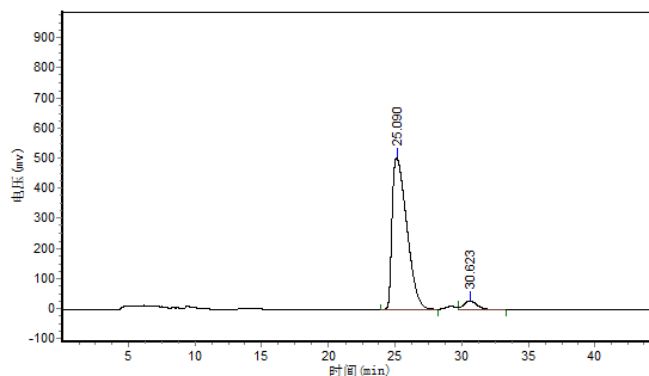
^1H NMR (300 MHz, CDCl_3): δ 7.46 (d, $J = 7.3$ Hz, 1H), 7.38 (d, $J = 7.5$ Hz, 1H), 7.21-7.13 (m, 2H), 7.10 (d, $J = 8.5$ Hz, 2H), 6.80 (d, $J = 8.6$ Hz, 2H), 6.41 (s, 1H), 3.76 (s, 3H), 2.97 (dt, $J = 25.6, 12.5$ Hz, 4H), 2.82-2.69 (m, 1H), 1.27 (s, 9H). ^{13}C NMR (125 MHz, CDCl_3): δ 173.3, 157.8, 156.1, 154.3, 130.4, 129.7, 128.3, 122.9, 122.0, 119.9, 113.3, 110.3, 103.0, 80.2, 54.8, 46.7, 36.9, 30.3, 27.5. HRMS (ESI) for $\text{C}_{23}\text{H}_{26}\text{NaO}_4$ $[\text{M}+\text{Na}]^+$: calcd 389.1729, found 389.1724.

HPLC: Chiralpak IC column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 25.0 min (major), 30.6 min.



分析结果表

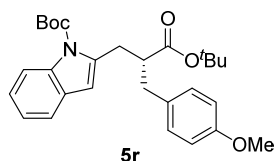
峰号	峰名	保留时间	峰高	峰面积	含量
1		26.223	109645.859	10523389.000	50.2935
2		32.207	122211.547	10400568.000	49.7065
总计			231857.406	20923957.000	100.0000



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		25.090	504321.938	38741300.000	95.0576
2		30.623	28637.494	2014292.625	4.9424
总计			532959.432	40755592.625	100.0000

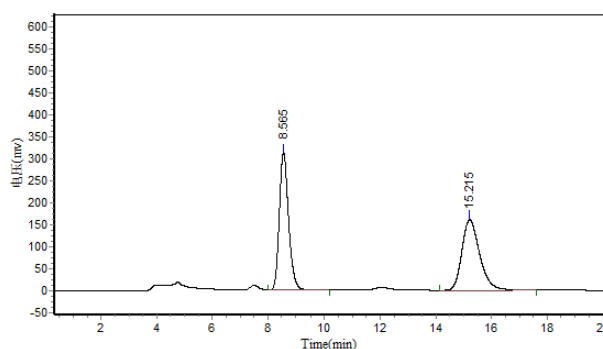
***tert*-butyl (*R*)-2-(3-(*tert*-butoxy)-2-(4-methoxybenzyl)-3-oxopropyl)-1*H*-indole-1-carboxylate (**5r**)**



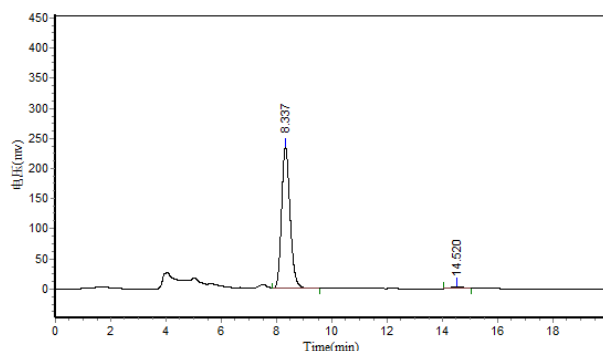
92% yield, light yellow oil, 97% ee.

^1H NMR (300 MHz, CDCl_3): δ 8.08 (d, $J = 8.2$ Hz, 1H), 7.44 (d, $J = 7.2$ Hz, 1H), 7.25-7.16 (m, 2H), 7.12 (d, $J = 8.4$ Hz, 2H), 6.81 (d, $J = 8.6$ Hz, 2H), 6.41 (s, 1H), 3.78 (s, 3H), 3.29 (dd, $J = 20.3, 10.7$ Hz, 2H), 3.05 (m, 1H), 2.87 (dt, $J = 13.7, 10.7$ Hz, 2H), 1.70 (s, 9H), 1.19 (s, 9H). ^{13}C NMR (126 MHz, CDCl_3): δ 174.3, 158.2, 150.5, 139.0, 136.7, 131.2, 130.0, 129.1, 123.5, 122.6, 119.8, 115.5, 113.6, 108.6, 83.8, 80.4, 55.3, 47.7, 38.2, 33.0, 28.3, 27.8. HRMS (ESI) for $\text{C}_{28}\text{H}_{35}\text{NNaO}_5$ $[\text{M}+\text{Na}]^+$: calcd 488.2413, found 488.2409.

HPLC: Chiralcel OD-H column (250 mm); detected at 224 nm; *n*-hexane/*i*-propanol = 99/1; flow = 0.7 mL/min; Retention time: 8.3 min (major), 14.5 min.

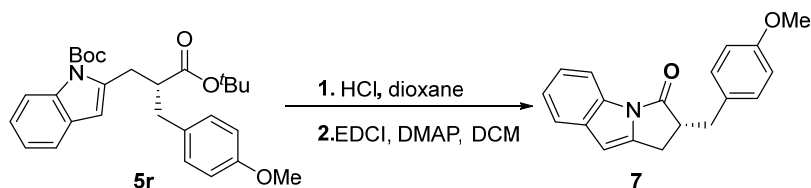


Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		8.565	311206.375	7229826.500	50.1628
2		15.215	160345.781	7182886.500	49.8372
Total			471552.156	14412713.000	100.0000



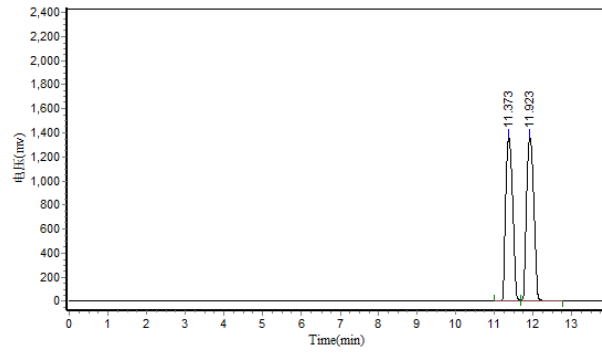
Results					
Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		8.337	233647.516	5038195.500	98.5283
2		14.520	2420.783	75256.453	1.4717
Total			236068.299	5113451.953	100.0000

7. Construction of compound 7



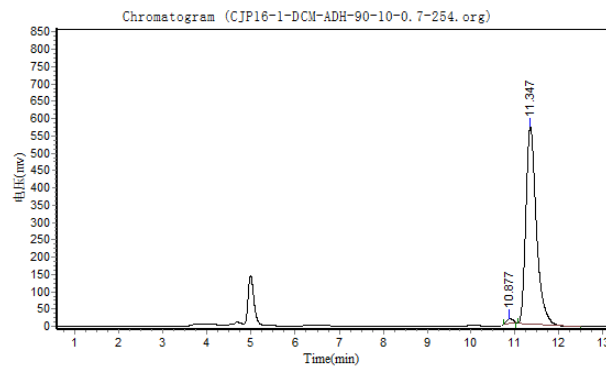
A 10 mL vessel was charged with the product **5r** (46.5 mg, 0.10 mmol, 97% ee) in 4 mL HCl/dioxane and the mixture was stirred at room temperature for 3 hours. After the reaction was completed, saturated Na₂CO₃ was added to the system and was extracted with EtOAc (2x10 mL). The combined organic layers were dried on anhydrous Na₂SO₄, filtered, and removed under vacuum and the residue was used for next step directly. To the above residue was added dichloromethane (5 mL), EDCI (29 mg, 0.15 mmol), 4-dimethylaminopyridine (25 mg, 0.20 mmol) and the solution was stirred for 12 h at room temperature. After solvent evaporation, the crude compound was purified by column chromatography over silica gel to furnish the desired cyclic product (**R**)-2-(4-methoxybenzyl)-1,2-dihydro-3H-pyrrolo[1,2-a]indol-3-one (**7**): 88% yield, light yellow oil, 97% ee. ¹H NMR (300 MHz, CDCl₃) δ 8.10 (d, *J* = 8.8 Hz, 1H), 7.49 (d, *J* = 8.6 Hz, 1H), 7.31-7.26 (m, 2H), 7.18 (d, *J* = 8.6 Hz, 2H), 6.85 (d, *J* = 8.6 Hz, 2H), 6.22 (s, 1H), 3.79 (s, 3H), 3.47 (dd, *J* = 9.0, 4.6 Hz, 1H), 3.34 (dd, *J* = 14.1, 4.3 Hz, 1H), 3.17 (dd, *J* = 17.7, 9.1 Hz, 1H), 2.90 (dd, *J* = 14.2, 9.1 Hz, 2H). ¹³C NMR (125 MHz, CDCl₃) δ 172.9, 158.0, 141.6, 134.8, 130.0, 129.7, 129.5, 123.6, 122.8, 120.0, 113.7, 113.3, 100.0, 54.8, 48.0, 35.8, 24.9. HRMS (ESI) for C₁₉H₁₇NNaO₂ [M+Na]⁺: calcd 314.1157, found 314.1154.

HPLC: Chiralcel AD-H column (250 mm); detected at 254 nm; *n*-hexane/*i*-propanol = 90/10; flow = 0.7 mL/min; Retention time: 10.9 min (major), 11.3 min.



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		11.373	1356207.125	17177762.000	48.8248
2		11.923	1359109.500	18004666.000	51.1752
Total			2715316.625	35182428.000	100.0000



Results

Peak No.	Peak ID	Ret Time	Height	Area	Conc.
1		10.877	13934.208	136140.484	1.4324
2		11.347	567769.625	9368122.000	98.5676
Total			581703.833	9504262.484	100.0000

8. Copies of ^1H NMR and ^{13}C NMR spectra of products 3-7

