Organocatalytic inverse-electron-demand Diels–Alder reaction between 5-alkenyl thiazolones and β,γ-unsaturated carbonyl compounds

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1 General Information

Chemicals and solvents were either purchased from commercial suppliers or purified by standard techniques. Analytical thin-layer chromatography (TLC) was performed on silica gel plates with F-254 indicator and compounds were visualized by irradiation with UV light. Flash chromatography was carried out utilizing silica gel 200-300 mesh. $^1$H NMR, $^{13}$C NMR spectra were recorded on a 400 spectrometer (400 MHz $^1$H, 100 MHz $^{13}$C) or a 600 spectrometer (600 MHz $^1$H, 150 MHz $^{13}$C). The spectra were recorded in CDCl$_3$ as the solvent at room temperature, $^1$H and $^{13}$C NMR chemical shifts are reported in ppm relative to either the residual solvent peak ($^{13}$C) ($\delta = 77.00$ ppm) or TMS ($^1$H) ($\delta = 0$ ppm) as an internal standard. Data for $^1$H NMR are reported as follows: chemical shift (\hbox{$\delta$} ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet , br = broad), integration, coupling constant (Hz) and assignment. Data for $^{13}$C NMR are reported as chemical shift. HRMS were performed on mass instrument (ESI). Enantiomeric excess values were determined by HPLC with Chirapak column on Agilent 1260 series with $i$-PrOH, $n$-hexane, NEt$_3$ and DCM. Optical rotation was measured on the Perkin Elmer 341 polarimeter with $[\alpha]_D$ values reported in degrees. Concentration (c) is in 10 g/mL.

2 Procedure of Experiments

2.1 General Procedure for the Synthesis of Substrates.

2.1.1 General procedure for the synthesis of $\beta,\gamma$-Unsaturated Carbonyl Compounds

Method A

\[
\begin{align*}
\text{R} & \quad \text{+} \quad \text{R'} \\
\text{KO}^\text{Bu}/\text{DMSO} \quad 100^\circ\text{C}, 30\text{ min} \\
\text{KO}^\text{Bu}/\text{DMSO} \quad 100^\circ\text{C}, 30\text{ min} \\
\text{R} & \quad \text{R'} \\
\end{align*}
\]

Method A: A mixture of the corresponding methyl ketone (5.0 mmol, 1 equiv.), alkyne (5.0 mmol, 1 equiv.) and KOBu (561 mg, 5.0 mmol, 1 equiv.) in DMSO (12 mL) was heated to 100 $^\circ$C and stirred for 30 min. The reaction mixture was cooled to room temperature and was diluted with H$_2$O (12 mL), neutralized with a saturated aqueous solution of NH$_4$Cl, and extracted with Et$_2$O (12 mL $\times$ 4). The organic extract was washed with H$_2$O (6 mL $\times$ 3) and dried with MgSO$_4$. After filtration
the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography (eluent hexane/ethyl acetate 97/3).

**Method B**: A mixture of the corresponding aldehyde (5.0 mmol, 1 equiv.), In powder (1.15 g, 10 mmol, 2 equiv.), InCl₃ (553 mg, 2.5 mmol, 0.5 equiv.) and the corresponding vinyl ketone (15 mmol, 3 equiv.) in a mixture of THF and H₂O (1: 1, 30 mL) was stirred at room temperature for 8 h. After the addition of 1 M HCl (15 mL), the reaction mixture was stirred for 30 min and extracted with ethyl acetate (50 mL × 4). The combined organic phases were washed with brine (100 mL) and dried with MgSO₄. After filtration, the solvent was evaporated under reduced pressure and the crude product was purified by flash column chromatography (eluent hexane/ethyl acetate 97/3).

### 2.1.2 General procedure for the synthesis of 5-alkenyl thiazolone 1

![Chemical structure](image)

3The solution of NaHCO₃ (20 mmol in 20 mL water) was added to a CH₂Cl₂ (40 mL) solution of thiobenzamide S1 (10 mmol). After cooling to 0 °C with ice-water bath, chloroacetyl chloride (S2 10 mmol) was added drop-wise to the stirred solution. Then reaction mixture was then stirred overnight at room temperature. The organic phase of the reaction mixture was separated, aqueous phase was extracted with CH₂Cl₂ (50 mL × 2). The combined organic phase was washed with H₂O (40 mL × 2), dried with anhydrous Na₂SO₄, and evaporated to dryness. The solid residue was washed with EtOH and filtered to give S3 (yield 70%). Compound S3 (1 mmol), benzaldehyde (1.1 mmol), and Et₃N (2 mmol) were dissolved in 20 mL of MeOH, and heated to reflux at 65°C for 3h, during which some precipitate appear gradually. After cooling to room temperature, the precipitate was filtered, and washed with another 20 mL of cold MeOH. The 5-alkenyl thiazolone 1 was obtained as a solid.

### References

2.2 General Procedure of the oxa-Diels-Alder Reaction.

To a test tube (flame dried) with a stirrer were successively added 5-alkenyl thiazolone 1 (0.1 mmol, 26.5 mg), \(\beta,\gamma\)-unsaturated carbonyl compounds 2 (0.15 mmol, 33.3 mg), catalyst a (0.01 mmol, 6.3 mg) and dried toluene (precooled to 0 °C) (0.5 mL) at 0 °C. When TLC analysis showed that 1 was completely consumed, the solvent was evaporated under reduced pressure and the residue was purified by silica gel flash column chromatography (Petroleumether/EtOAc/DCM=10:1:2) to give the corresponding compound 3a. Chiral 3b-4l were synthesized using the same method.

To a test tube (flame dried) with a stirrer were successively added 5-alkenyl thiazolone 1 (0.1 mmol, 26.5 mg), \(\beta,\gamma\)-unsaturated carbonyl compounds (0.15 mmol, 36.0 mg), catalyst a (0.0025 mmol, 1.5 mg) and dried mesitylene (0.5 mL) at room temperature. When TLC analysis showed that 1 was completely consumed, the solvent was evaporated under reduced pressure and the residue was purified by silica gel flash column chromatography (Petroleumether/EtOAc=10:1 to 5:1) to give a pair of corresponding enantiomers, 5a was separated by cyclic preparative HPLC. Chiral 5b-5j were synthesized using the same method.
2.3 Procedure for the Derivatization.

2.3.1 Synthesis of ester 6c

Compound 5c (52.0 mg, 0.1 mmol) and DBU (3.5 mg, 0.024 mmol) in 1 mL MeOH were stirred for 3 hours at room temperature. After removal of the solvent under reduced pressure, the reaction mixture was purified by silica gel column chromatography (hexane/EtOAc = 8/1) to give product 6c (96% yield, 43.7 mg, 98% ee).

2.3.2 Synthesis of alcohol 7a

Compound 3a (195.0 mg, 0.4 mmol, 1.0 equiv.) in THF (3.08 mL) were cooled to 0 °C, then NaBH₄ (22.6 mg, 0.6 mmol, 1.5 equiv.) was added. The reaction mixture was warstirred for additional 0.5 hours. After that, the reaction was quenched by 1 N HCl (0.5 mL) and extracted with CH₂Cl₂ (15 mL×3). The combined organic layers were dried over Na₂SO₄. After removal of the solvent under reduced pressure, the crude was purified by silica gel column chromatography (hexane/EtOAc = 1/1) to give product 7a (67% yield, 131.2 mg, 99% ee).

2.4 The Procedure of the Gram-scale Asymmetric Synthesis of 3a

In a 25 mL round-bottomed flame dried flask, 1a (5 mmol, 1.325g), β,γ-unsaturated ketones 2a (7.5 mmol, 1.665g) and cat. A (0.1 mmol, 0.12g) were successively added, 25 mL toluene (precooled to 0 °C) was added by syringe, and the mixture was stirred for 10 hours at
0 °C. Then the solvent was evaporated under reduced pressure and the residue was purified by silica gel flash column chromatography (Petroleum ether/EtOAc/DCM=10:1:2) to give the corresponding compound 3a (2.41g, 99% yield, 6:1 dr, 99% ee).
3 Reaction conditions optimization of $\beta,\gamma$-unsaturated amides

3.1 Screening data of $\beta,\gamma$-unsaturated ketone

Table S1. Catalyst screening of $\beta,\gamma$-unsaturated ketone

<table>
<thead>
<tr>
<th>Entry</th>
<th>Catalyst</th>
<th>Dr (%)</th>
<th>Yield (%)</th>
<th>ee (%)</th>
<th>Time (h)</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>a</td>
<td>6:1</td>
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<td>89</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>b</td>
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<td>96</td>
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</tr>
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<td>3</td>
<td>c</td>
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<td>d</td>
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<td>12</td>
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<tr>
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<td>e</td>
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<td>-89</td>
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<tr>
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</table>

Conditions: *Reactions performed with 0.1 mmol 1a, 0.1 mmol 2a, catalyst (10% mmol) in solvent (1 mL) at rt.*

* Determined by crude $^1$H NMR analysis. *Isolated yield given. *Determined by chiral-phase HPLC analysis.

Table S2. Solvent screening of $\beta,\gamma$-unsaturated ketone

<table>
<thead>
<tr>
<th>Entry</th>
<th>Solvent</th>
<th>Dr (%)</th>
<th>Yield (%)</th>
<th>ee (%)</th>
<th>Time (h)</th>
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<td>5:1</td>
<td>96</td>
<td>89</td>
<td>8</td>
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<tr>
<td>14</td>
<td>CHCl₃</td>
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<td>90</td>
<td>8</td>
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<tr>
<td>16</td>
<td>1,4-dioxane</td>
<td>3:1</td>
<td>85</td>
<td>94</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>Xylene</td>
<td>4:1</td>
<td>98</td>
<td>90</td>
<td>8</td>
</tr>
<tr>
<td>18</td>
<td>Mesitylene</td>
<td>3:1</td>
<td>83</td>
<td>89</td>
<td>8</td>
</tr>
</tbody>
</table>

Conditions: *Reactions performed with 0.1 mmol 1a, 0.1 mmol 2a, catalyst (10% mmol) in solvent (1 mL) at rt.*

* Determined by crude $^1$H NMR analysis. *Isolated yield given. *Determined by chiral-phase HPLC analysis.
Table S3. Optimization of other reaction conditions for β,γ-unsaturated ketone

<table>
<thead>
<tr>
<th>Entry</th>
<th>1a (mmol)</th>
<th>2a (mmol)</th>
<th>Solvent</th>
<th>Cat (mol%)</th>
<th>Dr (%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Yield (%)&lt;sup&gt;c&lt;/sup&gt;</th>
<th>ee (%)&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Time (h)</th>
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<td>87</td>
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<td>5:1</td>
<td>94</td>
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<td>4</td>
</tr>
<tr>
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<td>0.125</td>
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<td>93</td>
<td>90</td>
<td>6</td>
</tr>
<tr>
<td>22</td>
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<td>0.15</td>
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<td>6:1</td>
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<td>90</td>
<td>6</td>
</tr>
<tr>
<td>23</td>
<td>0.125</td>
<td>0.1</td>
<td>1</td>
<td>10</td>
<td>5:1</td>
<td>96</td>
<td>90</td>
<td>6</td>
</tr>
<tr>
<td>24</td>
<td>0.15</td>
<td>0.1</td>
<td>1</td>
<td>10</td>
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<td>98</td>
<td>92</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
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<td>0.15</td>
<td>0.5</td>
<td>10</td>
<td>6:1</td>
<td>97</td>
<td>92</td>
<td>5</td>
</tr>
<tr>
<td>26</td>
<td>0.1</td>
<td>0.15</td>
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<td>10</td>
<td>5:1</td>
<td>94</td>
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<td>7</td>
</tr>
<tr>
<td>27&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>0.15</td>
<td>2</td>
<td>10</td>
<td>5:1</td>
<td>95</td>
<td>83</td>
<td>8</td>
</tr>
<tr>
<td>28&lt;sup&gt;e&lt;/sup&gt;</td>
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<td>0.15</td>
<td>0.5</td>
<td>10</td>
<td>6:1</td>
<td>98</td>
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<td>24</td>
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<tr>
<td>29&lt;sup&gt;h&lt;/sup&gt;</td>
<td>0.1</td>
<td>0.15</td>
<td>0.5</td>
<td>10</td>
<td>6:1</td>
<td>94</td>
<td>99</td>
<td>36</td>
</tr>
</tbody>
</table>

Conditions: <sup>a</sup>Reactions performed with catalyst (2.5% mmol) in solvent at rt. <sup>b</sup>Determined by crude <sup>1</sup>H NMR analysis. <sup>c</sup>Isolated yield given. <sup>d</sup>Determined by chiral-phase HPLC analysis. <sup>e</sup>4A MS molecular sieve was added. <sup>f</sup>Reactions performed at 0 °C. <sup>h</sup>Reaction performed at -10 °C.
Table S4. Catalyst screening of β,γ-unsaturated amides

<table>
<thead>
<tr>
<th>Entry</th>
<th>Catalyst</th>
<th>Dr (%)</th>
<th>Yield (%)</th>
<th>Ee (%)</th>
<th>Time (h)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>a</td>
<td>6:1</td>
<td>95</td>
<td>&gt;99</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>b</td>
<td>2.5:1</td>
<td>36</td>
<td>87</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>c</td>
<td>2.5:1</td>
<td>15</td>
<td>&gt;99</td>
<td>48</td>
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<tr>
<td>4</td>
<td>d</td>
<td>3:1</td>
<td>82</td>
<td>&gt;99</td>
<td>12</td>
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<tr>
<td>5</td>
<td>e</td>
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<td>&gt;99</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>f</td>
<td>5:2:1</td>
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Conditions: *Reactions performed with 0.1 mmol 1a, 0.1 mmol 2a, catalyst (10% mmol) in solvent (1 mL) at rt.*

Table S5. Solvent screening of β,γ-unsaturated amides

<table>
<thead>
<tr>
<th>Entry</th>
<th>Solvent</th>
<th>Dr (%)</th>
<th>Yield (%)</th>
<th>Ee (%)</th>
<th>Time (h)</th>
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Conditions: *Reactions performed with 0.1 mmol 1a, 0.1 mmol 2a, catalyst (10% mmol) in solvent (1 mL) at rt.*

*H NMR analysis. Isolated yield given. Determined by chiral-phase HPLC analysis.
### Table S6. Catalyst dosage screening of $\beta,\gamma$-unsaturated amides

<table>
<thead>
<tr>
<th>Entry</th>
<th>Cat (mol%)</th>
<th>Dr (%)</th>
<th>Yield (%)</th>
<th>Ee (%)</th>
<th>Time (h)</th>
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<td>24</td>
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Conditions: oReactions performed with 0.1 mmol 1a, 0.1 mmol 2a, catalyst (10% mmol) in solvent (1 mL) at rt.  
* Determined by crude $^1$H NMR analysis.  
† Isolated yield given.  
‡ Determined by chiral-phase HPLC analysis.

### Table S7. Screening of substrate ratio and solvent amount of $\beta,\gamma$-unsaturated amides

<table>
<thead>
<tr>
<th>Entry</th>
<th>1a (mmol)</th>
<th>2a (mmol)</th>
<th>Dr (%)</th>
<th>Solvent (ml)</th>
<th>Yield (%)</th>
<th>Ee (%)</th>
<th>Time (h)</th>
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<tr>
<td>31</td>
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<td>0.15</td>
<td>8:1</td>
<td>1</td>
<td>96</td>
<td>&gt;99</td>
<td>14</td>
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<td>0.2</td>
<td>8:1</td>
<td>1</td>
<td>97</td>
<td>&gt;99</td>
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<tr>
<td>33</td>
<td>0.125</td>
<td>0.1</td>
<td>7:1</td>
<td>1</td>
<td>98</td>
<td>&gt;99</td>
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<td>34</td>
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<td>0.1</td>
<td>7:1</td>
<td>1</td>
<td>92</td>
<td>&gt;99</td>
<td>14</td>
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<tr>
<td>35</td>
<td>0.1</td>
<td>0.15</td>
<td>7:1</td>
<td>0.25</td>
<td>91</td>
<td>&gt;99</td>
<td>14</td>
</tr>
<tr>
<td>36</td>
<td>0.1</td>
<td>0.15</td>
<td>8:1</td>
<td>0.5</td>
<td>96</td>
<td>&gt;99</td>
<td>14</td>
</tr>
<tr>
<td>37</td>
<td>0.1</td>
<td>0.15</td>
<td>7:1</td>
<td>2</td>
<td>95</td>
<td>&gt;99</td>
<td>14</td>
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<tr>
<td>38</td>
<td>0.1</td>
<td>0.15</td>
<td>7:1</td>
<td>0.5</td>
<td>94</td>
<td>&gt;99</td>
<td>14</td>
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<tr>
<td>39</td>
<td>0.1</td>
<td>0.15</td>
<td>7:1</td>
<td>0.5</td>
<td>96</td>
<td>&gt;99</td>
<td>10</td>
</tr>
</tbody>
</table>

Conditions: oReactions performed with catalyst (2.5% mmol) in solvent at rt.  
* Determined by crude $^1$H NMR analysis.  
† Isolated yield given.  
‡ Determined by chiral-phase HPLC analysis.  
§ 4A molecular sieve was added.  
¶ Reactions performed at 0 °C.
4. Characterization Data of Compounds

1-phenyl-2-((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyran-2,3-d-thiazol-5-yl)ethan-1-one (3a)

White solid (PE/EtOAc/DCM = 10:1:1, 98% isolated yield, 6.1 dr, 47.8 mg);

m. p.: 148-151 °C;

[α]D = -14.0 (c=1.0, CH2Cl2, 99% ee);

1H NMR (400 MHz, CDCl3) δ 7.92 – 7.78 (m, 4H), 7.50 (t, J = 7.6 Hz, 1H), 7.36 (dd, J = 11.2, 8.0, 6.0 Hz, 5H), 7.22 – 7.12 (m, 6H), 7.08 – 6.84 (m, 4H), 5.37 (dd, J = 10.8, 8.0, 2.8 Hz, 1H), 4.36 (d, J = 10.8 Hz, 1H), 3.45 (dd, J = 16.8, 8.0 Hz, 1H), 3.20 (t, J = 10.8 Hz, 1H), 2.87 (dd, J = 16.8, 2.8 Hz, 1H);

13C NMR (101 MHz, CDCl3) δ 196.4, 163.9, 159.8, 142.1, 138.7, 137.0, 133.4, 133.0, 129.9, 128.8, 128.7, 128.4, 128.2, 128.1, 128.0, 127.4, 127.2, 125.6, 109.4, 77.5, 53.7, 47.7, 41.7.

HPLC (IH, i-PrOH/n-hexane = 93/7), flow rate = 1.0 mL/min, tR = 26.50 min (major);


2-((5R,6R,7R)-7-(4-chlorophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-2,3-d-thiazol-5-yl)-1-phenylethan-1-one (3b)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 7.1 dr, 48.6 mg);

m. p.: 66-68 °C.

[α]D = -8.0 (c=1.0, CH2Cl2, 99% ee);

1H NMR (400 MHz, CDCl3) δ 7.84 (m, J = 11.6, 6.8, 1.2 Hz, 4H), 7.55 – 7.47 (m, 1H), 7.38 (m, J = 6.4, 5.2 Hz, 5H), 7.28 – 7.08 (m, 5H), 7.00 (d, J = 6.8 Hz, 2H), 6.91 – 6.81 (m, 2H), 5.36 (ddd, J = 10.8, 8.8, 2.4 Hz, 1H), 4.35 (d, J = 10.8 Hz, 1H), 3.44 (dd, J = 17.2, 8.8 Hz, 1H), 3.15 (t, J = 10.8 Hz, 1H), 2.87 (dd, J = 17.2, 2.4 Hz, 1H);

13C NMR (101 MHz, CDCl3) δ 196.3, 164.2, 157.0, 140.7, 138.4, 137.0, 133.4, 133.1, 133.0, 130.0, 129.3, 129.0, 128.8, 128.5, 128.4, 128.1, 127.6, 125.7, 108.7, 77.5, 53.8, 47.2, 41.7.

HPLC (IF, i-PrOH/n-hexane = 85/15), flow rate = 1.0 mL/min, tR = 46.509 min (major);

2-((5R,6R,7R)-7-(4-bromophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-2,3-d-thiazol-5-yl)-1-phenylethan-1-one (3c)

Brown solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 7:1 dr, 52.6 mg);

m. p.: 68-70 °C;

\([\alpha]_D^{20} = -16.0 (c = 1.0, \text{CH}_2\text{Cl}_2, 99\% \text{ ee});

^{1}H \text{ NMR (400 MHz, CDCl}_3\) δ 7.91 – 7.79 (m, 4H), 7.51 (t, \(J = 7.2 \text{ Hz, 1H}\)), 7.46 – 7.33 (m, 5H), 7.28 (d, \(J = 8.0 \text{ Hz, 2H}\)), 7.25 – 7.13 (m, 3H), 7.00 (d, \(J = 6.8 \text{ Hz, 2H}\)), 6.80 (d, \(J = 8.4 \text{ Hz, 2H}\)), 5.36 (ddd, \(J = 10.5, 8.4, 2.4 \text{ Hz, 1H}\)), 4.34 (d, \(J = 10.5 \text{ Hz, 1H}\)), 3.44 (dd, \(J = 17.2, 8.4 \text{ Hz, 1H}\)), 3.14 (t, \(J = 10.5 \text{ Hz, 1H}\)), 2.87 (dd, \(J = 17.2, 2.4 \text{ Hz, 1H}\));

^{13}C \text{ NMR (101 MHz, CDCl}_3\) δ 196.2, 164.2, 159.9, 144.4, 138.1, 136.8, 133.3, 133.0, 130.8, 130.4, 130.0, 129.8, 128.9, 128.7, 128.4, 128.0, 127.6, 126.7, 125.6, 122.3, 108.3, 77.4, 53.5, 47.3, 41.5;

HPLC (IH, i-PrOH/ n-hexane = 93/7), flow rate = 1.0 mL/min, \(t_R = 22.8 \text{ min (major)}\);

HRMS (ESI): [M+H]⁺ calcd for \([\text{C}_{21}\text{H}_{23}\text{BrNO}_2\text{S}]\): 566.0784, 568.0763, found: 566.0786, 568.0766.

2-((5R,6R,7R)-7-(4-(tert-butyl)phenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-2,3-d-thiazol-5-yl)-1-phenylethan-1-one (3d)

White solid (PE/EtOAc/DCM = 10:1:1, 89% isolated yield, 11:1 dr, 48.5 mg);

m. p.: 74-78 °C;

\([\alpha]_D^{20} = -28.0 (c = 1.0, \text{CH}_2\text{Cl}_2, 99\% \text{ ee});

^{1}H \text{ NMR (400 MHz, CDCl}_3\) δ 7.92 – 7.78 (m, 4H), 7.55 – 7.45 (m, 1H), 7.46 – 7.31 (m, 5H), 7.24 – 7.10 (m, 5H), 7.02 (d, \(J = 6.8 \text{ Hz, 2H}\)), 6.84 (d, \(J = 8.4 \text{ Hz, 2H}\)), 5.35 (ddd, \(J = 10.4, 8.0, 2.8 \text{ Hz, 1H}\)), 4.35 (d, \(J = 10.4 \text{ Hz, 1H}\)), 3.44 (dd, \(J = 17.2, 8.0 \text{ Hz, 1H}\)), 3.19 (t, \(J = 10.4 \text{ Hz, 1H}\)), 2.85 (dd, \(J = 17.2, 2.8 \text{ Hz, 1H}\)), 1.25 (s, 9H);

^{13}C \text{ NMR (101 MHz, CDCl}_3\) δ 196.5, 163.8, 159.7, 139.0, 139.0, 137.0, 133.6, 133.0, 129.8, 128.8, 128.7, 128.5, 128.4, 128.1, 127.5, 127.4, 125.7, 125.1, 109.8, 77.6, 53.6, 47.1, 41.8, 34.4, 31.3;

HPLC (IH, i-PrOH/ n-hexane/ NEt\(_2)/ \text{DCM} = 80/10/5/5\), flow rate = 1.0 mL/min, \(t_R = 7.965 \text{ min (major)}\);

HRMS (ESI): [M+H]⁺ calcd for \([\text{C}_{29}\text{H}_{27}\text{NO}_2\text{S}]\): 544.2305, found: 544.2305.
2-((5R,6R,7R)-7-(4-nitrophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-2,3-d|thiazol-5-yl)-1-phenylethan-1-one (3e)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 97% isolated yield, 6:1 dr, 48.6 mg);

**m. p.:** 195-198 °C.

\[ \alpha \] = -13.0 (c =1.0, CH₂Cl₂, 92% ee);

\[^1\text{H} \] NMR (400 MHz, CDCl₃) \( \delta \) 8.02 (m, 2H), 7.89 – 7.75 (m, 4H), 7.52 (t, J = 7.4 Hz, 1H), 7.46 – 7.30 (m, 5H), 7.26 – 7.14 (m, 3H), 7.04 (m, 4H), 5.39 (ddd, J = 10.8, 8.0, 2.8 Hz, 1H), 4.50 (d, J = 10.4 Hz, 1H), 3.45 (dd, J = 17.2, 8.4 Hz, 1H), 2.90 (dd, J = 17.2, 2.8 Hz, 1H);

\[^{13}\text{C} \] NMR (101 MHz, CDCl₃) \( \delta \) 196.1, 164.6, 160.2, 149.7, 147.1, 137.7, 136.8, 133.2, 133.1, 130.3, 129.2, 128.9, 128.8, 128.2, 128.0, 127.9, 125.7, 123.6, 107.2, 77.4, 53.6, 47.6, 41.4.

HPLC (IC, i-PrOH/n-hexane = 83/17), flow rate = 1.0 mL/min), \( t_\text{R} \) = 8.444 min (major)\( t_\text{R} \) = 12.404 min (major);


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4-((5R,6R,7R)-5-(2-oxo-2-phenylethyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-2,3-d|thiazol-7-yl)benzonitrile (3f)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 98% isolated yield, 9:1 dr, 50.3 mg);

**m. p.:** 204-206 °C.

\[ \alpha \] = -20.0 (c =1.0, CH₂Cl₂, 98% ee);

\[^1\text{H} \] NMR (400 MHz, CDCl₃) \( \delta \) 7.89 – 7.79 (m, 4H), 7.52 (m, 1H), 7.48 – 7.33 (m, 7H), 7.25 – 7.13 (m, 3H), 7.01 (m, 4H), 5.37 (ddd, J = 10.8, 8.0, 2.7 Hz, 1H), 4.48 – 4.41 (m, 1H), 3.43 (dd, J = 17.2, 8.0 Hz, 1H), 3.17 (t, J = 10.8 Hz, 1H), 2.88 (dd, J = 17.2, 2.8 Hz, 1H);

\[^{13}\text{C} \] NMR (101 MHz, CDCl₃) \( \delta \) 196.1, 164.7, 160.3, 149.7, 147.2, 137.7, 136.8, 133.2, 133.1, 130.3, 129.2, 129.0, 128.9, 128.5, 128.1, 128.0, 125.8, 123.6, 107.2, 77.4, 53.8, 47.7, 41.4, 29.7.

HPLC (IC, i-ProOH/n-hexane = 83/17), flow rate = 1.0 mL/min), \( t_\text{R} \) = 35.414 min (major)\( t_\text{R} \) = 100.343 min (major);

HRMS (ESI): [M+H]⁺ calcd for \([C_{35}H_{31}N_{2}O_{2}S]⁺\): 513.1631, found: 513.1632.
2-((5R,6R,7R)-2,6-diphenyl-7-(p-tolyl)-6,7-dihydro-5H-pyrimido[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (3g)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 94% isolated yield, 11:1 dr, 45.6 mg);

m. p.: 148-170 °C.

$[\alpha]_D^{23} = -12.0$ (c = 1.0, CH$_2$Cl$_2$, 99% ee);

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.99 – 7.71 (m, 4H), 7.63 – 7.28 (m, 7H), 7.18 (m, J = 14.4, 6.8 Hz, 3H), 6.99 (dd, J = 22.0, 7.6 Hz, 4H), 6.82 (d, J = 8.0 Hz, 2H), 5.36 (dd, J = 10.8, 8.0, 2.8 Hz, 1H), 4.34 (d, J = 10.4 Hz, 1H), 3.45 (dd, J = 17.2, 8.8 Hz, 1H), 1.38 (t, J = 10.4 Hz, 1H), 2.85 (dd, J = 17.2, 2.8 Hz, 1H), 2.26 (s, 3H);

$^1$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.5, 163.9, 159.7, 139.1, 138.9, 137.0, 136.8, 133.5, 133.0, 129.9, 129.0, 128.8, 128.7, 128.4, 128.1, 127.9, 127.4, 125.7, 109.8, 77.6, 53.7, 47.2, 41.8, 21.1;

HPLC (OD. i-PrOH/ n-hexane = 80/20), flow rate = 1.0 mL/min, $t_R = 12.786$ min (major);


2-((5R,6R,7R)-2,6-diphenyl-7-(m-tolyl)-6,7-dihydro-5H-pyrimido[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (3h)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 91% isolated yield, 6:1 dr, 45.8 mg);

m. p.: 104-106 °C;

$[\alpha]_D^{23} = -15.0$ (c = 1.0, CH$_2$Cl$_2$, 99% ee);

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.90 – 7.79 (m, 4H), 7.49 (m, 1H), 7.41 – 7.30 (m, 5H), 7.23 – 7.11 (m, 3H), 7.08 – 6.93 (m, 4H), 6.77 – 6.67 (m, 2H), 5.36 (dd, J = 10.8, 8.0, 2.8 Hz, 1H), 4.32 (d, J = 10.4 Hz, 1H), 3.45 (dd, J = 17.2, 8.4 Hz, 1H), 3.21 (t, J = 10.4 Hz, 1H), 2.87 (dd, J = 16.8, 2.8 Hz 1H), 2.19 (s, 3H);

$^1$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.5, 163.9, 159.7, 142.1, 138.9, 137.9, 137.0, 133.5, 133.1, 129.9, 128.8, 128.7, 128.4, 128.1, 128.0, 127.4, 125.7, 125.2, 109.7, 77.6, 53.6, 47.6, 41.8, 21.4;

HPLC (OD, i-PrOH/ n-hexane/DCM = 91/4/5), flow rate = 1.0 mL/min, $t_R = 65.157$ min (major);

2-((5R,6R,7R)-7-(3-chlorophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)-1-phenylethano-1-one (3i)

White solid (PE/EtOAc/DCM = 10:1:1, 94% isolated yield, 8.1 dr, 47.8 mg);

m. p.: 84-88 °C.

\[ \alpha \] D = -14.0 (c = 1.0, CHCl₃, 99% ee);  

\(^1\)H NMR (400 MHz, Chloroform-d) \( \delta \) 7.98 – 7.75 (m, 4H), 7.55 – 7.46 (m, 1H), 7.46 – 7.31 (m, 5H), 7.26 – 6.88 (m, 8H), 6.78 (d, \( J = 7.6 \) Hz, 1H), 5.36 (ddd, \( J = 10.8, 8.0, 2.8 \) Hz, 1H), 4.34 (d, \( J = 10.0 \) Hz, 1H), 3.45 (dd, \( J = 17.2, 8.4 \) Hz, 1H), 3.18 (t, \( J = 10.4 \) Hz, 1H), 2.87 (dd, \( J = 17.2, 2.8 \) Hz, 1H);  

\(^1\)C NMR (101 MHz, CDCl₃) \( \delta \) 196.3, 164.3, 159.9, 144.2, 138.2, 136.9, 134.1, 133.3, 133.1, 130.1, 129.5, 129.0, 128.8, 128.5, 128.1, 128.0, 127.1, 127.5, 126.3, 125.7, 108.4, 77.5, 53.6, 47.4, 41.6;  

HPLC (IH, i-PrOH/ \( n \)-hexane/DCM = 91/4/5), flow rate = 1.0 mL/min, \( t_R = 21.7 \) min (major), \( t_R = 35.566 \) min (major);  

HRMS (ESI): [M+H]+ calcd for \([\text{C}_{22}\text{H}_{22}\text{ClN} \text{O}_2\text{S}]^+\): 522.1289, found: 522.1288.

2-((5R,6R,7R)-7-(3-bromophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)-1-phenylethano-1-one (3j)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 7:1 dr, 54.4 mg);

m. p.: 94-96 °C.

\[ \alpha \] D = -7.0 (c = 1.0, CHCl₃, 99% ee);  

\(^1\)H NMR (400 MHz, CDCl₃) \( \delta \) 7.84 (m, 4H), 7.33 – 7.14 (m, 4H), 7.12 – 6.94 (m, 4H), 6.82 (d, \( J = 7.7 \) Hz, 1H), 5.36 (ddd, \( J = 10.8, 8.0, 2.8 \) Hz, 1H), 4.33 (d, \( J = 10.4 \) Hz, 1H), 3.45 (dd, \( J = 17.2, 8.0 \) Hz, 1H), 3.17 (t, \( J = 10.4 \) Hz, 1H), 2.87 (dd, \( J = 17.2, 2.8 \) Hz, 1H);  

\(^1\)C NMR (101 MHz, CDCl₃) \( \delta \) 196.3, 164.3, 159.9, 144.2, 138.2, 136.9, 134.1, 133.3, 133.1, 130.1, 129.5, 129.0, 128.8, 128.4, 128.1, 128.0, 127.7, 127.5, 126.3, 125.7, 108.4, 77.5, 53.6, 47.4, 41.6;  

HPLC (IH, i-PrOH/ \( n \)-hexane/DCM = 91/4/5), flow rate = 1.0 mL/min, \( t_R = 45.797 \) min (major);  

HRMS (ESI): [M+H]+ calcd for \([\text{C}_{22}\text{H}_{22}\text{BrN} \text{O}_2\text{S}]^+\): 566.0784, 568.0763, found: 566.0782, 568.0764.
2-((5R,6R,7R)-7-(2-fluorophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-3(2H)-yl)-1-phenylethan-1-one (3k)

White solid (PE/EtOAc/DCM = 10:1:1, 89% isolated yield, 4.1 g, 45.1 mg).

m. p.: 163-166 °C.

$[\alpha]_D^{20} = -8.0 (c = 1.0, \text{CH}_2\text{Cl}_2$, 99% ee);

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.84 (m, $J = 6.5, 3.5, 2.1$ Hz, 4H), 7.55 – 7.48 (m, 1H), 7.45 – 7.31 (m, 5H), 7.24 – 6.97 (m, 8H), 6.86 (dd, $J = 14.0, 4.8$ Hz, 1H), 5.40 (ddd, $J = 10.8, 8.4, 2.8$ Hz, 1H), 4.78 (d, $J = 10.4$ Hz, 1H), 3.46 (dd, $J = 17.2, 8.4$ Hz, 1H), 3.33 (t, $J = 10.4$ Hz, 1H); 2.88 (dd, $J = 17.2, 2.8$ Hz, 1H);

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.4, 163.8, 161.8, 159.7, 159.3, 138.3, 137.0, 133.0, 133.1, 129.5, 129.0, 128.90, 128.8 ($J = 230.0$ Hz), 128.80, 128.8, 128.4, 128.3, 128.1, 127.6, 124.3 ($J = 4$ Hz), 115.5 ($J = 22$ Hz), 108.5, 77.7, 52.1, 41.7;

HPLC (IH, i-PrOH/ n-hexane/DCM = 91/4/5), flow rate = 1.0 mL/min, $t_R = 10.956$ min (major), $t_R = 13.332$ min (major);


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2-((5R,6R,7R)-7-(2-bromophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-3(2H)-yl)-1-phenylethan-1-one (3l)

White solid (PE/EtOAc/DCM = 10:1:1, 95% isolated yield, 6.1 g, 53.9 mg).

m. p.: 86-87 °C.

$[\alpha]_D^{20} = -22.0 (c = 1.0, \text{CH}_2\text{Cl}_2$, 99% ee).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.87 – 7.79 (m, 5H), 7.50 (t, $J = 7.4$ Hz, 1H), 7.36 (M, 7H), 7.29 – 7.23 (m, 2H), 7.17 (t, $J = 7.6$ Hz, 3H), 7.08 (d, $J = 6.8$ Hz, 2H), 7.04 – 6.98 (m, 1H), 5.44 (ddd, $J = 10.4, 8.0, 2.8$ Hz, 1H), 5.14 (d, $J = 10.4$ Hz, 1H), 3.49 – 3.30 (m, 2H), 2.92 (dd, $J = 17.2, 2.8$ Hz, 1H);

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.3, 164.1, 159.4, 141.4, 137.6, 137.0, 133.4, 133.1, 132.7, 129.9, 129.2, 128.7, 128.4, 128.1, 127.9, 127.6, 125.6, 124.7, 109.1, 77.7, 52.7, 45.0, 41.6;

HPLC (IH, i-PrOH/ n-hexane/DCM = 91/4/5), flow rate = 1.0 mL/min, $t_R = 27.693$ min (major).

2-((5R,6R,7R)-2,6-diphenyl-7-(o-tolyl)-6,7-dihydro-5H-pyran-2,3-d-thiazol-5-yl)-1-phenylethan-1-one (3m)

White solid (PE/EtOAc/DCM = 10:1:1, 92% isolated yield, 5:1 dr, 46.1 mg).

m. p.: 146-149 °C.

$[\alpha]_D^{21} = -36.0$ (c $=1.0,$ CH$_2$Cl$_2$), 99% ee.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.93 – 7.79 (m, 4H), 7.50 (dd, $J$ = 10.4, 4.2 Hz, 1H), 7.38 (t, $J$ = 7.6 Hz, 2H), 7.35 – 7.30 (m, 3H), 7.22 – 7.10 (m, 5H), 7.09 – 6.96 (m, 3H), 6.92 (d, $J$ = 7.6 Hz, 1H), 5.56 – 5.41 (m, 1H), 4.67 (d, $J$ = 10.4 Hz, 1H), 3.49 (dd, $J$ = 17.2, 8.0 Hz, 1H), 3.27 (t, $J$ = 10.4 Hz, 1H), 2.89 (dd, $J$ = 17.2, 2.4 Hz, 1H), 1.81 (s, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 196.5, 163.7, 159.6, 140.7, 138.8, 136.9, 136.0, 133.4, 133.0, 129.9, 129.8, 128.7, 128.4, 128.1, 127.6, 127.4, 126.8, 126.4, 125.5, 110.3, 77.3, 53.4, 42.2, 41.7, 19.1.

HPLC (iH, i-PrOH/ n-hexane = 95/5), flow rate = 1.0 mL/min, $t_{R}$ = 32.404 min (major).

HRMS (ESI): [M+H]$^+$ calcd for [C$_{3}H$_{2}N$_{2}$O$_{2}$S]: 502.1835, found: 502.1835.

2-((5R,6R,7R)-7-(2-methoxyphenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-2,3-d-thiazol-5-yl)-1-phenylethan-1-one (3n)

White solid (PE/EtOAc/DCM = 10:1:1, 97% isolated yield, 8:1 dr, 50.2 mg).

m. p.: 68-70 °C.

$[\alpha]_D^{21} = -18.0$ (c $=1.0,$ CH$_2$Cl$_2$), 99% ee.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.55 – 7.48 (m, 1H), 7.44 – 7.31 (m, 5H), 7.20 – 7.11 (m, 4H), 7.06 (m, 2H), 6.85 (t, $J$ = 7.2 Hz, 1H), 6.68 (d, $J$ = 8.2 Hz, 1H), 5.39 (ddd, $J$ = 10.8, 8.4, 2.7 Hz, 1H), 3.52 – 3.38 (m, 4H), 3.32 (s, 1H), 2.87 (dd, $J$ = 17.2, 2.4 Hz, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 196.6, 157.1, 139.1, 137.1, 133.7, 130.0, 129.7, 128.7, 128.6, 128.4, 128.3, 128.1, 127.2, 125.6, 120.7, 110.8, 109.9, 77.7, 55.2, 42.0.

HPLC (AD, i-PrOH/ n-hexane = 80/20), flow rate = 1.0 mL/min, $t_{R}$ = 38.57 min (major).

HRMS (ESI): [M+H]$^+$ calcd for [C$_{3}H$_{2}N$_{2}$O$_{2}$S]: 518.1784, found: 518.1785.
(3o)  

White solid (PE/EtOAc/DCM = 10:1:1, 90% isolated yield, 15.1 dr, 43.2 mg).  

m. p.: 97-101 °C.  

[α]D = -3.0 (c =1.0, CH₂Cl₂, 98% ee).  

1H NMR (400 MHz, CDCl₃) δ 7.91 – 7.78 (m, 4H), 7.52 (m, 1H), 7.44 – 7.33 (m, 5H), 7.24 – 7.09 (m, 6H), 6.19 (dd, J = 3.2, 1.9 Hz, 1H), 5.97 (d, J = 1.9 Hz, 1H), 5.34 (ddd, J = 10.8, 8.0, 2.8 Hz, 1H), 4.56 (d, J = 10.4 Hz, 1H), 3.53 – 3.43 (m, 2H), 2.87 (dd, J = 16.8, 2.8 Hz, 1H).

13C NMR (101 MHz, CDCl₃) δ 196.3, 164.0, 159.1, 153.7, 141.9, 138.9, 136.9, 133.5, 133.1, 129.9, 129.0, 128.7, 128.4, 128.2, 128.1, 127.6, 125.7, 110.1, 107.2, 106.5, 77.4, 49.6, 41.7, 41.0.

HPLC (iPrOH/ n-hexane = 93/7), flow rate = 1.0 mL/min, tₘ = 27.002 min (major), tₖ = 32.938 min (major);


(3p)  

White solid (PE/EtOAc/DCM = 10:1:1, 89% isolated yield, 6:1 dr, 46.6 mg).  

m. p.: 106-108 °C.  

[α]D = -10.0 (c =0.1, CH₂Cl₂, 99% ee).  

1H NMR (400 MHz, CDCl₃) δ 7.87 – 7.74 (m, 4H), 7.52 (m, J = 10.4, 4.4 Hz, 1H), 7.41 (t, J = 7.6 Hz, 2H), 7.37 – 7.29 (m, 2H), 7.23 – 7.13 (m, 6H), 7.08 – 6.88 (m, 4H), 5.37 (ddd, J = 10.8, 8.0, 2.4 Hz, 1H), 4.37 (d, J = 10.4 Hz, 1H), 3.45 (dd, J = 17.2, 8.4 Hz, 1H), 3.20 (t, J = 10.4 Hz, 1H), 2.86 (dd, J = 17.2, 2.8 Hz, 1H).

13C NMR (101 MHz, CDCl₃) δ 196.4, 162.6, 159.9, 142.0, 138.6, 137.0, 135.8, 133.1, 132.0, 129.0, 128.9, 128.6, 128.4, 128.3, 128.1, 128.0, 127.5, 127.4, 126.9, 110.0, 77.7, 53.7, 47.7, 41.8.

HPLC (iPrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min, tₘ = 50.743 min (major).

2-((5R,6R,7R)-2-(4-methoxyphenyl)-6,7-diphenyl-6,7-dihydro-5H-pyranono[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (3q)

White solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 5:1 dr, 48 mg).

m.p.: 98-101 °C.

$[\alpha]_{D}^{22} = -14.0$ (c =1.0, CH$_2$Cl$_2$, 97% ee).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.87 – 7.77 (m, 4H), 7.50 (m, 1H), 7.38 (m, 2H), 7.24 – 7.11 (m, 6H), 6.97 (m, 6H), 5.37 (ddd, $J$ = 10.8, 8.4, 2.4 Hz, 1H), 4.35 (d, $J$ = 10.4 Hz, 1H), 3.45 (dd, $J$ = 16.8, 8.0 Hz, 1H), 3.20 (t, $J$ = 10.4 Hz, 1H), 2.87 (dd, $J$ = 17.2, 2.8 Hz, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.3, 165.0, 162.6, 159.7, 142.0, 138.6, 136.9, 133.0, 129.8, 128.8, 128.4, 128.3, 128.0, 127.9, 127.6, 127.5, 127.4, 127.3, 115.9, 115.7, 109.4, 77.5, 53.6, 47.6, 41.7.

HPLC (Ih i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min), $t_{R}$ = 40.042 min (minor), $t_{R}$ = 47.171 min (major).

HRMS (ESI): [M+H]$^+$ calcd for [C$_{33}$H$_{28}$NO$_3$S]$^+$: 518.1784, found: 518.1786

2-((5R,6R,7R)-2-(4-fluorophenyl)-6,7-diphenyl-6,7-dihydro-5H-pyranono[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (3r)

White solid (PE/EtOAc/DCM = 10:1:1, 96 % isolated yield, 6:1 dr, 48.6 mg).

m.p.: 96-98 °C.

$[\alpha]_{D}^{22} = -14.0$ (c =1.0, CH$_2$Cl$_2$, 97% ee).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.87 – 7.77 (m, 4H), 7.50 (t, $J$ = 7.2 Hz, 1H), 7.38 (t, $J$ = 7.6 Hz, 2H), 7.24 – 7.11 (m, 6H), 6.97 (m, 6H), 5.37 (ddd, $J$ = 10.8, 8.0, 2.8 Hz, 1H), 4.35 (d, $J$ = 10.4 Hz, 1H), 3.45 (dd, $J$ = 16.8, 8.0 Hz, 1H), 3.20 (t, $J$ = 10.4 Hz, 1H), 2.87 (dd, $J$ = 17.2, 2.8 Hz, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.3, 165.0, 162.6 (J = 10.3 Hz), 159.7, 142.0, 138.6, 136.9, 133.0, 129.8 (J = 2 Hz), 128.8, 128.4, 128.3, 128.1, 127.9, 127.6, 127.5, 127.4, 127.3, 115.8 (J = 122 Hz), 109.4, 77.5, 53.6, 47.6, 41.7.

HPLC (LH i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min), $t_{R}$ = 28.185 min (minor), $t_{R}$ = 45.243 min (major).

HRMS (ESI): [M+H]$^+$ calcd for [C$_{32}$H$_{25}$FNO$_2$S]$^+$: 506.1585, found: 506.1583
2-((5R,6R,7R)-2-(3-chlorophenyl)-6,7-diphenyl-6,7-dihydro-5H-pyran0[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (3s)

White solid (PE/EtOAc/DCM = 10:1:1, 94% isolated yield, 6:1 dr, 48.6 mg).

m. p.: 96-98 °C.

$[\alpha]^{25}_D = -10.0 \ (c = 1.0, \ CH_2Cl_2, 89% \ ee)$.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.90 – 7.81 (m, 3H), 7.70 (m, 1H), 7.52 (m, 1H), 7.40 (m, 2H), 7.35 – 7.24 (m, 3H), 7.22 – 7.11 (m, 6H), 7.01 (d, $J = 6.8$ Hz, 2H), 6.94 (m, 2H), 5.38 (ddd, $J = 10.8$, 8.4, 2.8 Hz, 1H), 4.38 (d, $J = 8.0$ Hz, 1H), 3.50 – 3.41 (dd, $J = 17.2$ Hz, 8.4 Hz 1H), 3.21 (t, $J = 10.4$ Hz, 1H), 2.86 (dd, $J = 17.2$, 2.8 Hz, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 196.4, 162.2, 159.9, 141.9, 138.6, 136.9, 135.1, 134.9, 133.1, 130.0, 129.8, 128.9, 128.4, 128.1, 128.0, 127.5, 127.4, 125.7, 123.7, 110.4, 77.6, 77.3, .53.6, 47.7, 41.7.

HPLC (IF i-PrOH/ n-hexane = 90:10), flow rate = 1.0 mL/min), $t_R = 20.39$ min (minor),$t_R = 30.23$ min (major).

HRMS (ESI): [M+H]$^+$ calcd for $[C_{32}H_{31}ClNO_3]$: 522.1289, found: 522.1291

2-((5R,6R,7R)-7-(3,4-difluorophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran0[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (3t)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 8:1 dr, 50.2 mg).

m. p.: 72-74 °C.

$[\alpha]^{25}_D = -16.0 \ (c = 1.0, \ CH_2Cl_2, 99% \ ee)$.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.50 (m, 1H), 7.43 – 7.30 (m, 5H), 7.25 – 7.14 (m, 3H), 7.06 (m, 3H), 6.75 (m, 1H), 6.64 – 6.54 (m, 1H), 5.39 (ddd, $J = 10.4$, 8.4, 2.4 Hz, 1H), 4.72 (d, $J = 10.4$ Hz, 1H), 3.45 (dd, $J = 17.2$, 8.4 Hz, 1H), 3.28 (t, $J = 10.4$ Hz, 1H), 2.88 (dd, $J = 16.8$, 2.4 Hz, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 196.2, 164.7, 163.9, 163.1 ($J = 48$ Hz), 161.7 ($J = 48$ Hz), 160.6 ($J = 48$ Hz), 159.8, 159.2 ($J = 48$ Hz), 153.4, 138.0, 136.9, 133.0, 130.3, 130.0, 128.9, 128.8, 128.4, 128.3, 128.1, 127.7, 125.6, 124.9 ($J = 12$ Hz), 124.7 ($J = 12$ Hz), 111.7 ($J = 16$ Hz), 111.5 ($J = 16$ Hz), 108.0, 103.7 ($J = 104$ Hz), 77.6, 52.1, 41.6.

HPLC (IH, i-PrOH/ n-hexane/DCM = 91:4:5), flow rate = 1.0 mL/min), $t_R = 45.533$ min (major).

HRMS (ESI): [M+H]$^+$ calcd for $[C_{32}H_{31}F_2ClNO_3]$ : 524.1490, found: 524.1492
2-((5R,6R,7R)-2,7-diphenyl-6-(p-tolyl)-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (4a)

Brown solid (PE/EtOAc/DCM = 10:1:1, 98% isolated yield, 7:1 dr, 49.3 mg).

m. p.: 96-98 °C.

[$\alpha$]D₂⁰ = -27.0 (c =1.0, CH₂Cl₂, 99% ee).

1H NMR (400 MHz, CDCl₃) δ 7.83 (m, J = 6.8, 2.8 Hz, 4H), 7.54 – 7.46 (m, 1H), 7.43 – 7.28 (m, 5H), 7.17 (dd, J = 6.8, 3.6 Hz, 3H), 7.05 – 6.81 (m, 6H), 5.34 (m, J = 10.4, 8.0, 2.4 Hz, 1H), 4.35 (d, J = 10.0 Hz, 1H), 3.43 (dd, J = 16.8, 8.0 Hz, 1H), 3.16 (t, J = 10.4 Hz, 1H), 2.88 (dd, J = 16.8, 2.4 Hz, 1H), 2.23 (s, 3H).

13C NMR (101 MHz, CDCl₃) δ 196.6, 164.0, 159.9, 142.3, 137.1, 137.1, 135.6, 133.6, 133.0, 129.9, 129.6, 128.8, 128.4, 128.3, 128.2, 128.1, 127.3, 125.7, 109.6, 77.8, 53.4, 47.7, 41.9, 21.1.

HPLC (IF, i-PrOH/ n-hexane= 83/17), flow rate = 1.0 mL/min), tₘ = 33.799 min (major).


2-((5R,6R,7R)-6-(4-chlorophenyl)-2,7-diphenyl-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (4b)

Yellow liquid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 10:1 dr, 50.0 mg).

[$\alpha$]D₂⁰ = -16.0 (c =1.0, CH₂Cl₂, 99% ee).

1H NMR (400 MHz, CDCl₃) δ 7.83 (td, J = 6.9, 2.6 Hz, 4H), 7.54 – 7.46 (m, 1H), 7.43 – 7.28 (m, 5H), 7.17 (dd, J = 6.6, 3.6 Hz, 3H), 7.05 – 6.81 (m, 6H), 5.34 (ddd, J = 10.7, 8.2, 2.7 Hz, 1H), 4.35 (d, J = 10.3 Hz, 1H), 3.43 (dd, J = 17.0, 8.2 Hz, 1H), 3.16 (t, J = 10.5 Hz, 1H), 2.88 (dd, J = 16.9, 2.5 Hz, 1H), 2.23 (s, 3H).

13C NMR (101 MHz, CDCl₃) δ 196.3, 164.1, 159.9, 140.7, 138.3, 136.9, 133.3, 133.0, 130.0, 129.3, 129.0, 128.8, 128.5, 128.4, 128.1, 127.6, 125.7, 108.7, 77.5, 53.7, 47.1, 41.6.

HPLC (IF, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min), tₘ = 17.337 min (major).

2-((5R,6R,7R)-2,7-diphenyl-6-(m-tolyl)-6,7-dihydro-5H-pyran[2,3-d][thiazol-5-yl]-1-phenylethano-1-one (4c)

White solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 7:1 dr, 46.8 mg).

m. p.: 77-80 °C.

\[\alpha\]_D^20 = -26.0 (c = 1.0, CH_2Cl_2, 94% ee).

H NMR (400 MHz, CDCl_3) \(\delta\) 7.85 (d, \(J = 7.1\) Hz, 4H), 7.59 – 7.47 (m, 1H), 7.47 – 7.29 (m, 6H), 7.26 – 7.12 (m, 4H), 7.04 – 6.71 (m, 4H), 5.41 – 5.29 (m, 1H), 4.30 (d, \(J = 10.2\) Hz, 1H), 3.57 – 3.32 (m, 2H), 2.99 (dd, \(J = 17.0, 1.9\) Hz, 1H),

C NMR (101 MHz, CDCl_3) \(\delta\) 196.4, 163.9, 159.8, 142.2, 138.6, 138.4, 137.0, 133.5, 133.0, 129.8, 128.9, 128.7, 128.6, 128.3, 128.2, 128.1, 128.0, 127.2, 125.6, 109.5, 77.6, 53.6, 47.5, 41.8, 21.3.

HPLC (If, i-PrOH/ n-hexane = 83/17), flow rate = 1.0 mL/min, \(t_m = 31.33\) min (major), \(t_r = 38.60\) min (major).


2-((5R,6R,7R)-6-(2-methoxyphenyl)-2,7-diphenyl-6,7-dihydro-5H-pyran[2,3-d][thiazol-5-yl]-1-phenylethano-1-one (4d)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 92% isolated yield, 7:1 dr, 47.8 mg).

m. p.: 90–92 °C.

\[\alpha\]_D^20 = -34.0 (c = 1.0, CH_2Cl_2, 99% ee).

H NMR (400 MHz, CDCl_3) \(\delta\) 7.91 – 7.79 (m, 2H), 7.36 (m, \(J = 6.7, 3.6\) Hz, 3H), 7.20 – 7.10 (m, 3H), 7.03 (d, \(J = 7.8\) Hz, 2H), 6.98 – 6.79 (m, 4H), 5.00 (ddd, \(J = 11.4, 8.3, 3.3\) Hz, 1H), 4.35 – 4.25 (m, 1H), 3.62 (s, 3H), 3.07 (t, \(J = 10.5\) Hz, 1H), 2.61 (dd, \(J = 16.2, 8.3\) Hz, 1H), 2.46 (dd, \(J = 16.2, 3.3\) Hz, 1H), 2.27 (s, 3H).

C NMR (101 MHz, CDCl_3) \(\delta\) 196.4, 163.9, 159.8, 159.7, 142.1, 140.2, 137.0, 133.5, 133.0, 129.9, 129.9, 128.7, 128.4, 128.3, 128.1, 128.0, 127.3, 125.6, 120.6, 114.3, 112.6, 109.4, 77.5, 55.1, 53.7, 47.6, 41.7.

HPLC (AD, i-PrOH/ n-hexane = 80/20), flow rate = 1.0 mL/min, \(t_m = 36.81\) min (major).

1-(2-methoxyphenyl)-2-((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyran[2,3-d]thiazol-5-yl)ethan-1-one (4e)

White solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 7:1 dr, 49.7 mg).

\[ \text{m. p.: 73-74 °C.} \]

\[ \alpha^D_{	ext{DMSO}} = -5.0 \text{ (c =1.0, CH}_{2}\text{Cl}_2, 99\% \text{ ee).} \]

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.92 – 7.78 (m, 4H), 7.50 (m, $J = 7.2$ Hz, 1H), 7.43 – 7.30 (m, 5H), 7.23 – 7.00 (m, 7H), 6.84 (m, $J = 7.2$ Hz, 1H), 6.68 (d, $J = 8.2$ Hz, 1H), 5.39 (ddd, $J = 10.8$, 8.4, 2.8 Hz, 1H), 4.94 (s, 1H), 3.52 – 3.21 (m, 5H), 2.87 (dd, $J = 16.8$, 2.8 Hz, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.7, 163.7, 157.5, 137.1, 133.6, 132.9, 129.8, 128.7, 128.5, 128.3, 128.1, 128.0, 127.0, 125.7, 121.0, 111.2, 109.6, 55.4, 42.0, 29.7.

HPLC (iH, i-PrOH/n-hexane/DCM = 91/4/5), flow rate = 1.0 mL/min), $t_R = 28.757$ min (major)

HRMS (ESI): [M+H]$^+$ calcd for [C$_{33}$H$_{35}$NO$_3$S]$^+$: 518.1784, found: 518.1784

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2-((5R,6R,7R)-2,7-diphenyl-6-((thiophen-3-yl)-6,7-dihydro-5H-pyran[2,3-d]thiazol-5-yl)-1-phenylethan-1-one (4f)

White solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 4:1 dr, 46.0 mg).

\[ \text{m. p.: 143-146 °C.} \]

\[ \alpha^D_{	ext{DMSO}} = -1.0 \text{ (c =1.0, CH}_{2}\text{Cl}_2, 99\% \text{ ee).} \]

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.85 (m, $J = 7.2$ Hz, 4H), 7.59 – 7.47 (m, 1H), 7.47 – 7.29 (m, 6H), 7.26 – 7.12 (m, 4H), 7.04 – 6.71 (m, 4H), 5.41 – 5.29 (m, 1H), 4.30 (d, $J = 10.0$ Hz, 1H), 3.57 – 3.32 (m, 2H), 2.99 (dd, $J = 16.8$, 2.8 Hz, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 196.3, 164.0, 159.9, 142.2, 138.9, 137.0, 133.4, 133.1, 129.9, 128.7, 128.4, 128.3, 128.1, 127.9, 127.3, 126.7, 126.2, 125.6, 122.9, 109.0, 77.4, 49.3, 47.6, 41.8.

HPLC (iH, i-PrOH/n-hexane/DCM = 91/4/5), flow rate = 1.0 mL/min), $t_R = 46.791$ min (major).

HRMS (ESI): [M+H]$^+$ calcd for [C$_{36}$H$_{37}$NO$_3$S]$^+$: 494.1243, found: 494.1242
1-(4-methoxyphenyl)-2-((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyran[2,3-d]thiazol-5-yl)ethan-1-one (4g)

White solid (PE/EtOAc/DCM = 10:1:1, 89% isolated yield, 6:1 dr, 46.0 mg).

m. p.: 80-82 °C.

$[\alpha]D^2$ = -22.0 (c =1.0, CHCl$_3$, 99% ee).

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.82 (d, J = 7.2 Hz, 1H), 7.33 (s, 1H), 7.14 (dd, J = 7.7, 4.0 Hz, 1H), 6.99 (s, 1H), 6.92 (d, J = 3.6 Hz, 1H), 6.86 (d, J = 6.8 Hz, 4H), 5.43 – 5.28 (m, 1H), 4.35 (d, J = 10.4, 1H), 3.81 (s, 3H), 3.37 (dd, 16.8 Hz, 8.0 Hz,1H), 3.16 (t, 10.8 Hz,1H), 2.80 (dd, J = 16.8 Hz, 2.8 Hz,1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 194.9, 163.9, 163.4, 159.8, 142.2, 138.8, 133.5, 130.4, 130.2, 129.8, 128.8, 128.7, 128.4, 128.2, 128.0, 127.4, 127.2, 125.6, 113.5, 109.4, 77.7, 55.4, 53.7, 47.7, 41.3.

HPLC (AD, i-PrOH/ n-hexane = 80/20), flow rate = 1.0 mL/min, $t_r$ = 47.72 min (major), $t_R$ = 60.828 min (major).

HRMS (ESI): [M+H]$^+$ calcld for [C$_{24}$H$_{24}$O$_4$S]$^+$: 518.1784, found: 518.1784

1-(4-pentyphenyl)-2-((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyran[2,3-d]thiazol-5-yl)ethan-1-one (4h)

White solid (PE/EtOAc/DCM = 10:1:1, 90% isolated yield, 6:1 dr, 50.0 mg).

m. p.: 83-84 °C.

$[\alpha]D^2$ = -15.0 (c =1.0, CHCl$_3$, 99% ee).

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.89 – 7.80 (m, 2H), 7.75 (d, J = 8.4 Hz, 2H), 7.35 (dd, J = 4.0, 2.8 Hz, 3H), 7.24 – 7.10 (m, 8H), 7.07 – 6.89 (m, 4H), 5.37 (ddd, J = 10.8, 8.4, 2.8 Hz, 1H), 4.36 (d, J = 10.4 Hz, 1H), 3.43 (dd, J = 16.8, 8.4 Hz, 1H), 3.20 (t, J = 10.4 Hz, 1H), 2.83 (dd, J = 16.8, 2.8 Hz, 1H), 2.68 – 2.54 (m, 2H), 1.59 (dd, J = 15.2, 7.4 Hz, 2H), 1.38 – 1.22 (m, 4H), 0.88 (t, J = 6.8 Hz, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 196.1, 163.9, 159.9, 148.8, 142.2, 138.8, 134.7, 133.5, 129.9, 128.8, 128.7, 128.5, 128.3, 128.0, 127.4, 127.3, 125.7, 109.4, 77.6, 53.8, 47.8, 417, 35.9, 31.4, 30.7, 22.5, 14.0.

HPLC (IH, i-PrOH/ n-hexane/DCM = 94/1/5), flow rate = 1.0 mL/min, $t_r$ = 12.904 min (major).

HRMS (ESI): [M+H]$^+$ calcld for [C$_{47}$H$_{40}$NO$_4$S]$^+$: 558.2461, found: 558.2460
1-(m-tolyl)-2-((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)ethan-1-one (4i)

White solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 6:1 dr, 46.6 mg).

\[ \text{m.p.: 83-86 °C.} \]

\[ [\alpha]^{22}_D = -5.0 (c =1.0, \text{CH}_2\text{Cl}_2, 97\% \text{ ee}). \]

\[ ^1\text{H NMR (400 MHz, CDCl}_3) \delta 7.85 \text{ (m, 2H), 7.63 \text{ (m, 2H), 7.39 -- 7.26 (m, 5H), 7.24 -- 7.10 (m, 6H), 7.07 -- 6.89 (m, 4H), 5.37 \text{ (ddd, } J = 10.8, 8.4, 2.8 \text{ Hz, 1H), 4.36 (d, } J = 10.0 \text{ Hz, 1H), 3.44 \text{ (dd, } J = 17.2, 8.4 \text{ Hz, 1H), 3.20 (t, } J = 10.4 \text{ Hz, 1H), 2.85 \text{ (dd, } J = 17.2, 2.8 \text{ Hz, 1H), 2.37 (s, 3H).} \]

\[ ^{13}\text{C NMR (101 MHz, CDCl}_3) \delta 196.7, 163.9, 159.8, 142.1, 138.8, 138.2, 137.1, 133.8, 133.5, 129.9, 128.8, 128.7, 128.6, 128.4, 128.3, 128.0, 127.4, 127.3, 125.7, 125.3, 109.4, 77.6, 53.8, 47.8, 41.9, 21.3. \]

\[ \text{HPLC (IC, i-PrOH/ n-hexane = 80/20), flow rate = 1.0 mL/min, } t_R = 34.604 \text{ min (major), } t_R = 39.219 \text{ min (minor);} \]

\[ \text{HRMS (ESI): [M+H]^+ calcd for [C}_{33}\text{H}_{28}\text{NO}_2\text{S}^+: 502.1835, found: 502.1833} \]
1-(3-chlorophenyl)-2-(((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyran-2,3-d|thiazol-5-yl|ethan-1-one (4j)

White solid (PE/EtOAc/DCM = 10:1:1, 97% isolated yield, 7:1 dr, 50.6 mg).

**m. p.:** 92-95 °C.

\[ \Delta \theta^2 \theta = -5.0 \ (c = 1.0, \ CHCl_3, \ 94\% \ ee) \]

**1H NMR (400 MHz, CDCl₃)** δ 7.85 (m, 2H), 7.63 (m, 2H), 7.39 – 7.26 (m, 5H), 7.24 – 7.10 (m, 6H), 7.07 – 6.89 (m, 4H), 5.37 (dd, J = 10.8, 8.0, 2.8 Hz, 1H), 4.36 (d, J = 10.0 Hz, 1H), 3.44 (dd, J = 16.8, 8.0 Hz, 1H), 3.20 (t, J = 10.4 Hz, 1H), 2.85 (dd, J = 17.2, 2.8 Hz, 1H), 2.37 (s, 3H).

**13C NMR (101 MHz, CDCl₃)** δ 195.2, 164.0, 159.6, 142.0, 138.5, 138.4, 134.7, 133.4, 132.9, 129.9, 129.7, 128.9, 128.7, 128.4, 128.3, 128.2, 128.0, 127.5, 127.3, 126.2, 125.6, 109.5, 77.5, 53.6, 47.6, 41.8.

**HPLC** (IH, i-PrOH/ n-hexane/DCM = 94/1/5), flow rate = 1.0 mL/min), tᵣ = 14.048 min (minor), tᵣ = 24.264 min (major).

**HRMS (ESI):** [M+H]+ calcd for [C₁₂H₉ClNO₃S]⁺: 522.1289, found: 522.1290

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1-(o-toly)-2-(((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-pyran-2,3-d|thiazol-5-yl|ethan-1-one (4k)

White solid (PE/EtOAc/DCM = 10:1:1, 88% isolated yield, 5:1 dr, 44.0 mg).

**m. p.:** 69-70 °C.

\[ \Delta \theta^2 \theta = -10.0 \ (c = 1.0, \ CHCl_3, \ 94\% \ ee) \]

**1H NMR (400 MHz, CDCl₃)** δ 7.90 – 7.79 (m, 2H), 7.53 – 7.27 (m, 7H), 7.25 – 7.09 (m, 9H), 7.00 (d, J = 6.6 Hz, 2H), 6.92 (m, 2H), 5.29 (dd, J = 10.8, 8.0, 2.8 Hz, 1H), 4.36 (d, J = 10.4, 1H), 3.33 (dd, J = 16.8, 8.0 Hz, 1H), 3.17 (t, J = 10.4 Hz, 1H), 2.84 (dd, J = 16.8, 2.8 Hz, 1H), 2.44 (s, 3H).

**13C NMR (101 MHz, CDCl₃)** δ 196.3, 164.0, 159.8, 138.0, 137.0, 133.4, 133.1, 130.1, 128.9, 128.8, 128.5, 128.3, 128.1, 127.7, 125.7, 124.9, 111.8, 111.5, 108.0, 104.0, 103.8, 77.7, 52.2, 41.6, 29.7.

**HPLC** (IH, i-PrOH/ n-hexane/DCM = 94/1/5), flow rate = 1.0 mL/min), tᵣ = 11.274 min (minor), tᵣ = 12.349 min (major).

**HRMS (ESI):** [M+H]+ calcd for [C₁₀H₁₀NO₂S]⁺: 502.1835, found: 502.1834

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1-((5R,6R,7R)-2,6,7-tri phenyl-6,7 dihydro-5H-pyra no[2,3-d]thiazol-5-yl)propan-2-one (4l)

White solid (PE/EtOAc/DCM = 10:1:1, 91% isolated yeild, 9:1 dr, 39.0 mg).

m. p.: 86-88 °C.

$[\alpha]_D^{20} = -7.0$ (c =1.0, CH₂Cl₂, 98% ee).

$^1$H NMR (400 MHz, CDCl₃) δ 7.85 (m, J = 5.6, 3.0, 1.5 Hz, 2H), 7.69 – 7.59 (m, 2H), 7.44 – 7.25 (m, 6H), 7.24 – 7.10 (m, 6H), 7.09 – 6.86 (m, 4H), 5.37 (ddd, J = 10.8, 8.2, 2.7 Hz, 1H), 4.36 (d, J = 10.3 Hz, 1H), 3.44 (dd, J = 17.0, 8.2 Hz, 1H), 3.20 (t, J = 10.5 Hz, 1H), 2.85 (dd, J = 16.9, 2.7 Hz, 1H), 2.36 (s, 3H).

$^{13}$C NMR (101 MHz, CDCl₃) δ 196.7, 163.9, 159.8, 142.1, 138.8, 138.2, 137.0, 133.8, 133.5, 129.9, 128.8, 128.7, 128.6, 128.4, 128.0, 127.4, 127.3, 125.7, 125.3, 109.4, 77.6, 53.7, 47.7, 41.8, 21.3.

HPLC (IH, i-PrOH/ n-hexane/DCM = 94/1/5), flow rate = 1.0 mL/min, $t_{R}$ = 34.604 min (minor), $t_R$ = 39.219 min (major).

HRMS (ESI): [M+H]$^+$ calcd for [C₂₇H₂₃NO₂S]: 426.1522, found: 426.1521

1-(3,5-dimethyl-1H-pyrazol-1-yl)-2-((5R,6R,7R)-2,6,7-tri phenyl-6,7 dihydro-5H-pyra no[2,3-d]thiazol-5-yl)ethan-1-one (5a)

White solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yeild, 8:1 dr, 48.5 mg).

m. p.: 85-88 °C.

$[\alpha]_D^{20} = -14.0$ (c =1.0, CH₂Cl₂, 99% ee).

$^1$H NMR (600 MHz, cdcl₃) δ 7.96 – 7.75 (m, 2H), 7.36 (d, J = 3.0 Hz, 3H), 7.24 – 7.08 (m, 6H), 7.08 – 6.82 (m, 4H), 5.90 (s, 1H), 5.32 (m, 1H), 4.35 (d, J = 10.2 Hz, 1H), 3.71 (dd, J = 17.0, 9.0 Hz, 1H), 3.20 (t, J = 10.8 Hz, 1H), 3.02 (dd, J = 16.8, 2.4 Hz, 1H), 2.50 (s, 3H), 2.18 (s, 3H).

$^{13}$C NMR (101 MHz, CDCl₃) δ 170.4, 159.9, 151.8, 144.2, 142.1, 138.6, 133.5, 129.9, 128.8, 128.7, 128.5, 128.3, 128.1, 127.4, 127.3, 125.7, 111.2, 109.5, 77.8, 53.4, 47.8, 39.0, 14.5, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 93/7), flow rate = 1.0 mL/min, $t_R$ = 49.205 min (minor);

HRMS (ESI): [M+H]$^+$ calcd for [C₇H₆N₂O₂S]: 506.1897, found: 506.1899
2-((5R,6R,7R)-6-(4-bromophenyl)-2,7-diphenyl-6,7-dihydro-5H-pyra[2,3-d]thiazol-5-yl)-1-(3,5-dimethyl-1H-pyrazol-1-yl)ethan-1-one (5b)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 13:1 dr, 54.2 mg).

**m. p.:** 94-96 °C.

[α]D20 = -37.0 (c =1.0, CH2Cl2, 98% ee).

1H NMR (400 MHz, CDCl3) δ 7.99 – 7.77 (m, 2H), 7.48 – 7.13 (m, 8H), 7.01 (d, J = 6.8 Hz, 2H), 6.80 (d, J = 8.4 Hz, 2H), 5.90 (s, 1H), 5.41 – 5.18 (ddd, 10.8 Hz, 8.0 Hz, 2.8 Hz, 1H), 4.32 (d, J = 10.0 Hz, 1H), 3.70 (dd, J = 17.2, 9.2 Hz, 1H), 3.14 (t, J = 10.4 Hz, 1H), 3.02 (dd, J = 17.2, 2.8 Hz, 1H), 2.50 (s, 3H), 2.18 (s, 3H).

13C NMR (101 MHz, CDCl3) δ 170.3, 164.2, 159.9, 151.9, 144.2, 141.2, 138.2, 133.4, 131.5, 130.1, 129.7, 128.9, 128.8, 128.4, 127.6, 125.7, 121.2, 111.2, 108.6, 77.8, 53.4, 47.3, 38.9, 14.5, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min, tR = 33.13 min (major), tR = 49.953 min (minor).


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1-((3,5-dimethyl-1H-pyrazol-1-yl)-2-((5R,6R,7R)-2,7-diphenyl-6-(p-tolyl)-6,7-dihydro-5H-pyra[2,3-d]thiazol-5-yl)ethan-1-one (5c)

White solid (PE/EtOAc/DCM = 10:1:1, 99% isolated yield, 13:1 dr, 51.3 mg).

**m. p.:** 168-169 °C.

[α]D20 = -7.0 (c =1.0, CH2Cl2, 99% ee).

1H NMR (400 MHz, Chloroform-d) δ 7.85 (m, J = 6.8, 2.8 Hz, 2H), 7.36 (m, J = 3.2, 2.8 Hz, 3H), 7.23 – 7.06 (m, 3H), 7.06 – 6.77 (m, 6H), 5.89 (s, 1H), 5.28 (ddd, J = 11.2, 8.9, 2.8 Hz, 1H), 4.33 (d, J = 10.4 Hz, 1H), 3.68 (ddd, J = 16.8, 9.2 Hz, 1H), 3.16 (t, J = 10.4 Hz, 1H), 3.04 (dd, J = 16.8, 2.8 Hz, 1H), 2.49 (s, 3H), 2.24 (s, 3H), 2.18 (s, 3H).

13C NMR (101 MHz, CDCl3) δ 170.4, 163.9, 159.7, 151.8, 144.1, 142.2, 136.2, 135.4, 133.5, 129.9, 129.4, 128.7, 128.3, 128.1, 127.2, 125.7, 111.1, 109.6, 78.0, 53.0, 47.6, 39.1, 2=1.0, 14.5, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min, tR = 40.181 min (major), tR = 56.688 min (minor).


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2-((5R,6R,7R)-6-(4-chlorophenyl)-2,7-diphenyl-6,7-dihydro-5H-pyano[2,3-d]thiazol-5-yl)-1-(3,5-dimethyl-1H-pyrazol-1-yl)ethan-1-one (5d)

White solid (PE/EtOAc/DCM = 10:1:1, 93% isolated yield, 11:1 dr, 50.3 mg).

m. p.: 176-178 °C.

[α]_D^20 = -27.0 (c = 1.0, CH₂Cl₂, 99% ee).

H NMR (400 MHz, CDCl₃) δ 7.85 (dd, J = 3, 5 Hz, 1H), 7.42 – 7.28 (m, 3H), 7.17 (m, 5H), 7.03 – 6.85 (m, 4H), 5.91 (s, 1H), 5.33 – 5.19 (m, 1H), 4.29 (d, J = 10.4 Hz, 1H), 3.64 (dd, J = 16.8, 8.4 Hz, 1H), 3.20 (t, J = 10.4 Hz, 1H), 3.09 (dd, J = 16.8, 3.2 Hz, 1H), 2.49 (s, 3H), 2.18 (s, 3H).

C NMR (101 MHz, CDCl₃) δ 170.1, 164.1, 159.6, 151.9, 144.2, 141.7, 137.0, 133.4, 133.3, 130.0, 129.8, 128.9, 128.76, 128.4, 128.0, 127.5, 125.7, 111.3, 109.2, 77.6, 52.9, 47.7, 39.0, 14.4, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min, t_R = 30.673 min (major).


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1-(3,5-dimethyl-1H-pyrazol-1-yl)-2-((5R,6R,7R)-2,7-diphenyl-6-(m-tolyl)-6,7-dihydro-5H-pyano[2,3-d]thiazol-5-yl)ethan-1-one (5e)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 95% isolated yield, 8:1 dr, 51.3 mg).

m. p.: 99-102 °C.

[α]_D^20 = -5.0 (c = 1.0, CH₂Cl₂, 97% ee).

H NMR (400 MHz, CDCl₃) δ 7.93 – 7.81 (m, 2H), 7.44 – 7.32 (m, 3H), 7.22 – 7.13 (m, 4H), 7.08 (t, J = 7.6 Hz, 1H), 7.01 – 6.88 (m, 3H), 6.80 (d, J = 9.5 Hz, 2H), 5.91 (s, 1H), 5.36 – 5.24 (m, 1H), 4.35 (d, J = 10.0 Hz, 1H), 3.70 (dd, J = 16.8, 9.2 Hz, 1H), 3.15 (t, J = 10.8 Hz, 1H), 3.03 (dd, J = 17.2, 2.8 Hz, 1H), 2.50 (s, 3H), 2.23 (s, 3H), 2.19 (s, 3H).

C NMR (101 MHz, CDCl₃) δ 144.2, 142.2, 138.4, 138.3, 133.5, 129.9, 128.8, 128.5, 128.3, 128.2, 128.1, 127.2, 125.7, 111.2, 109.6, 77.9, 53.3, 47.6, 39.0, 21.4, 14.5, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min, t_R = 29.178 min (major), t_s = 49.0 min (minor).

1-(3,5-dimethyl-1H-pyrazol-1-yl)-2-((5R,6S,7R)-2,7-diphenyl-6-(thiophen-2-yl)-6,7-dihydro-5H-pyran[2,3-d]thiazol-5-yl)ethan-1-one (5f)

White solid (PE/EtOAc/DCM = 10:1:1, 98% isolated yield, 6:1 dr, 50.0 mg).

m. p.: 146-147 °C.

[α]D20 = -15.0 (c =1.0, CH2Cl2, 99% ee).

1H NMR (600 MHz, Chloroform-d) δ 7.84 (m, 2H), 7.39 – 7.32 (m, 3H), 7.25 – 7.18 (m, 3H), 7.16 (m, 1H), 7.07 – 7.00 (m, 2H), 6.82 (dd, J = 4.8, 3.0 Hz, 1H), 6.68 (dd, J = 3.6, 1.2 Hz, 1H), 5.92 (d, J = 1.2 Hz, 1H), 5.22 (ddd, J = 10.8, 9.0, 3.0 Hz, 1H), 4.36 (d, J = 10.2 Hz, 1H), 3.75 (dd, J = 17.4, 9.0 Hz, 1H), 3.63 (t, J = 10.2 Hz, 1H), 3.19 (dd, J = 17.4, 3.0 Hz, 1H), 2.53 (d, J = 1.1 Hz, 3H), 2.19 (s, 3H).

13C NMR (151 MHz, cdcl3) δ 170.2, 165.0, 159.9, 152.0, 144.0, 140.6, 133.5, 130.1, 128.8, 128.0, 127.4, 126.6, 126.3, 125.9, 125.0, 111.2, 72.4, 46.5, 45.5, 38.1, 14.4, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min), tR = 35.996 min (major).


2-((5R,6R,7R)-7-(4-bromophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran[2,3-d]thiazol-5-yl)-1-(3,5-dimethyl-1H-pyrazol-1-yl)ethan-1-one (5g)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 87% isolated yield, 11:1 dr, 50.8 mg).

m. p.: 78-80 °C.

[α]D20 = -11.0 (c =1.0, CH2Cl2, 99% ee).

1H NMR (400 MHz, Chloroform-d) δ 7.99 – 7.77 (m, 2H), 7.47 – 7.13 (m, 8H), 7.12 – 6.93 (m, 2H), 6.91 – 6.70 (m, 2H), 5.90 (d, J = 1.2 Hz, 1H), 5.30 (ddd, J = 10.8, 8.8, 2.8 Hz, 1H), 4.32 (d, J = 10.4 Hz, 1H), 3.70 (dd, J = 17.2, 9.2 Hz, 1H), 3.14 (t, J = 10.4 Hz, 1H), 3.02 (dd, J = 17.2, 2.8 Hz, 1H), 2.50 (s, 3H), 2.18 (s, 3H).

13C NMR (101 MHz, CDCl3) δ 170.3, 164.2, 159.9, 151.9, 144.2, 141.2, 138.2, 133.4, 131.5, 130.1, 129.7, 128.9, 128.8, 128.4, 127.6, 125.7, 121.2, 111.2, 108.6, 77.8, 53.4, 47.3, 38.9, 14.5, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min), tR = 42.521 min (major).

2-((5R,6R,7R)-7-(4-chlorophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran-2,3-dithiazol-5-yl)-1-(3,5-dimethyl-1H-pyrazol-1-yl)ethan-1-one (5h)

White solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 9:1 dr, 51.8 mg).

m. p.: 124-126 °C.

[α]D22 = -22.0 (c =1.0, CH₂Cl₂, 99% ee).

1H NMR (400 MHz, Chloroform-d) δ 8.02 – 7.74 (m, 2H), 7.53 – 7.31 (m, 3H), 7.25 – 7.09 (m, 5H), 7.00 (d, J = 7.2 Hz, 2H), 6.85 (d, J = 8.4 Hz, 2H), 5.90 (s, 1H), 5.30 (dd, J = 11.2, 8.8, 2.8 Hz, 1H), 4.33 (d, J = 10.4 Hz, 1H), 3.70 (dd, J = 16.8, 8.8 Hz, 1H), 3.14 (t, J = 10.8 Hz, 1H), 3.02 (dd, J = 17.2, 2.8 Hz, 1H), 2.50 (s, 3H), 2.17 (s, 3H).

13C NMR (101 MHz, CDCl₃) δ 170.2, 164.2, 159.8, 151.9, 144.1, 140.6, 138.2, 133.3, 133.0, 130.0, 129.3, 128.8, 128.5, 127.6, 125.7, 111.2, 108.6, 77.7, 53.4, 47.2, 38.9, 14.5, 13.7.

HPLC (IC, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min), tR = 32.774 min (major).

HRMS (ESI): [M+H]+ calc for C₃₁H₂₇ClN₃O₂S+: 540.1507, found: 540.1508
2-((5R,6R,7R)-7-(2-bromo-4-fluorophenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran[2,3-d][thiazol-5-yl]-1-(3,5-dimethyl-1H-pyrazol-1-yl)ethan-1-one (5i)

Yellow solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 12:1 dr, 57.5 mg).

**m.p.:** 74-76 °C.

\[\alpha\] \sub{D}{20} = -11.0 (c =1.0, CHCl\textsubscript{3}, 99% ee).

\textsuperscript{1}H NMR (400 MHz, Chloroform-d) \(\delta\) 7.85 (m, 2H), 7.51 – 7.32 (m, 3H), 7.28 – 7.13 (m, 4H), 7.13 – 6.89 (m, 4H), 5.90 (d, \(J = 1.1\) Hz, 1H), 5.32 (ddd, \(J = 10.8, 8.0, 2.8\) Hz, 1H), 4.72 (d, \(J = 10.8\) Hz, 1H), 3.70 (ddd, \(J = 17.2, 9.2\) Hz, 1H), 3.27 (t, \(J = 10.4\) Hz, 1H), 3.04 (dd, \(J = 17.2, 2.8\) Hz, 1H), 2.50 (3, 3H), 2.18 (s, 3H).

\textsuperscript{13}C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 170.2, 164.1, 160.3 (\(J = 250.0\) Hz), 159.8, 159.0, 151.9, 144.2, 137.7, 133.3, 130.7, 130.1, 128.9, 128.8, 128.3 (\(J = 4.3\) Hz), 128.1, 127.8, 127.7, 125.7, 121.3 (\(J = 4.3\) Hz), 119.1, (\(J = 25.7\) Hz) 111.2, 107.6, 77.9, 51.8, 38.9, 14.5, 13.7.

HPLC (IC, iPrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min, \(t_r\) = 72.481 min (major).

HRMS (ESI): [M+H] \(+\) calcd for [C\(_{37}\)H\(_{37}\)BrF\(_{12}\)N\(_{2}\)O\(_{2}\)S]: 602.0908, 604.0887 found: 602.0906, 604.0889

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1-((3,5-dimethyl-4,5-dihydro-1H-pyrazol-1-yl)-2-((5R,6R,7R)-7-(2-methoxyphenyl)-2,6-diphenyl-6,7-dihydro-5H-pyran[2,3-d][thiazol-5-yl)ethan-1-one (5j)

White solid (PE/EtOAc/DCM = 10:1:1, 90% isolated yield, 8:1 dr, 48.2 mg).

**m.p.:** 118-121 °C.

\[\alpha\] \sub{D}{20} = -17.0 (c =1.0, CH\(_2\)Cl\(_2\), 91% ee).

\textsuperscript{1}H NMR (400 MHz, Chloroform-d) \(\delta\) 8.01 – 7.75 (m, 2H), 7.35 (m, 3H), 7.23 – 6.95 (m, 7H), 6.94 – 6.56 (m, 2H), 5.90 (d, \(J = 1.1\) Hz, 1H), 5.34 (ddd, \(J = 10.4, 9.2, 2.8\) Hz, 1H), 4.92 (s, 1H), 3.72 (ddd, \(J = 16.8, 9.2\) Hz, 1H), 3.41 (s, 4H), 3.01 (dd, \(J = 17.2, 2.8\) Hz, 1H), 2.50 (d, \(J = 1.0\) Hz, 3H), 2.18 (s, 3H).

\textsuperscript{13}C NMR (101 MHz, CDCl\textsubscript{3}) \(\delta\) 170.5, 163.1, 159.5, 157.1, 151.7, 144.1, 138.9, 133.7, 129.7, 128.7, 128.6, 128.3, 127.1, 125.6, 120.7, 111.1, 110.8, 110.0, 77.9, 55.2, 39.1, 14.5, 13.7.

HPLC (IC, iPrOH/ n-hexane = 97/3), flow rate = 1.0 mL/min, \(t_s\) = 48.431 min (major), \(t_r\) = 56.497 min (minor).

HRMS (ESI): [M+H] \(+\) calcd for [C\(_{37}\)H\(_{37}\)O\(_{2}\)N\(_{2}\)S]: 536.2002, found: 536.2004
methyl 2-(((5R,6R,7R)-2,7-diphenyl-6-(p-tolyl)-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)acetate (6c)

White solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 44 mg).

\[ \text{White solid (PE/EtOAc/DCM = 10:1:1, 96% isolated yield, 44 mg).} \]

m. p.: 96-99 °C.

\[ \alpha \] = -14.0 (c = 1.0, CH₂Cl₂, 98% ee).

\(^1\text{H NMR (400 MHz, CDCl}_3\text{)} \delta 7.93 \text{ (dd, } J = 6.5, 3.1 \text{ Hz, 2H), 7.81 \text{ (d, } J = 7.3 \text{ Hz, 2H), 7.53 \text{ (s, 1H), 7.43} \text{ – 7.37 (m, 5H), 7.07 \text{ (q, } J = 6.0 \text{ Hz, 4H), 6.90} \text{ (d, } J = 6.5 \text{ Hz, 2H), 5.52} \text{ – 5.40 (m, 1H), 4.96 \text{ (d, } J = 6.4 \text{ Hz, 1H), 3.59 \text{ (m, 2H), 3.16} \text{ (dd, } J = 17.9, 8.0 \text{ Hz, 1H).} \]

\(^{13}\text{C NMR (101 MHz, CDCl}_3\text{)} \delta 196.6, 164.5, 160.2, 144.8, 139.7, 136.6, 133.4, 133.3, 130.2, 128.9, 128.8, 128.6, 128.0, 127.7, 127.4, 127.3, 125.7, 105.5, 72.7, 50.5, 44.4, 40.7.

\( \text{HPLC (Ic, i-PrOH/ n-hexane = 90/10), flow rate = 1.0 mL/min), } t_R = 38.015 \text{ min (major), } t_R = 48.184 \text{ min (minor) HRMS (ESI): [M+H}^+ \text{ caledf for [C}_{28}\text{H}_{26}\text{NO}_3\text{S}^+]^+: 456.1628, \text{ found: 456.1626} \)

1-phenyl-2-((5S,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)ethan-1-one (3a-minor)

White solid (PE/EtOAc/DCM = 10:1:1, 95% isolated yield, 46.3 mg, 99% ee).

m. p.: 68-69 °C.

\(^1\text{H NMR (400 MHz, CDCl}_3\text{)} \delta 7.91 \text{ – 7.79 (m, 2H), 7.36 \text{ (dd, } J = 6.4, 3.6 \text{ Hz, 3H), 7.20} \text{ – 7.10 (m, 3H), 7.03 \text{ (d, } J = 7.8 \text{ Hz, 2H), 6.98} \text{ – 6.79 (m, 4H), 5.00 \text{ (ddd, } J = 11.2, 8.4, 3.6 \text{ Hz, 1H), 4.35} \text{ – 4.25 (m, 1H), 3.62 \text{ (s, 3H), 3.07 \text{ (t, } J = 10.4 \text{ Hz, 1H), 2.61 \text{ (dd, } J = 16.0, 8.0 \text{ Hz, 1H), 2.46 \text{ (dd, } J = 16.0, 3.6 \text{ Hz, 1H), 2.27 \text{ (s, 3H),}} \]

\(^{13}\text{C NMR (101 MHz, CDCl}_3\text{)} \delta 170.7, 164.0, 160.0, 142.0, 137.0, 135.2, 133.5, 129.9, 129.5, 128.7, 128.3, 128.0, 127.2, 125.6, 109.7, 78.2, 52.9, 51.8, 47.3, 38.4, 21.0.

\( \text{HPLC (IH, i-PrOH/ n-hexane/DCM = 92/3/5), flow rate = 1.0 mL/min), ts = 12.779min (major), ts = 14.048min (minor). HRMS (ESI): [M+H}^+ \text{ caledf for [C}_{32}\text{H}_{26}\text{NO}_2\text{S}^+]^+: 488.1679, \text{ found: 488.1680} \)
1-phenyl-2-((5R,6R,7R)-2,6,7-triphenyl-6,7-dihydro-5H-pyrano[2,3-d]thiazol-5-yl)ethan-1-ol-xia (7a-major)

White solid (PE/EtOAc/DCM = 5:1:1, 38% isolated yield, 74.5 mg).

m. p.: 151-152 °C.

$[\alpha]_{D}^{20} = 15.0$ (c =1.0, CH$_2$Cl$_2$, 98% ee).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.80 (m, $J = 6.8$, 2H), 7.44 – 7.21 (m, 8H), 7.21 – 6.98 (m, 6H), 6.85 (m, $J = 6.4$, 2.8 Hz, 2H), 6.75 (m, $J = 6.4$, 2.8 Hz, 2H), 5.15 (t, $J = 7.2$ Hz, 1H), 4.37 (td, $J = 10.0$, 2.4 Hz, 1H), 4.13 (d, $J = 10.4$ Hz, 1H), 3.17 (s, 1H), 3.01 (t, $J = 10.3$ Hz, 1H), 2.20 (m, 1H), 1.80 (m, 1H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 164.0, 159.6, 144.0, 142.0, 138.9, 133.4, 129.9, 128.8, 128.6, 128.4, 128.2, 127.9, 127.6, 127.2, 127.2, 126.5, 125.7, 109.7, 79.9, 71.9, 54.3, 47.6, 42.0.

HPLC (IH, i-PrOH/ n-hexane/DCM = 92/3/5), flow rate = 1.0 mL/min), $t_{R} = 25.399$ min (major).

HRMS (ESI): [M+H]$^+$ calcd for [C$_{33}$H$_{28}$NO$_3$S]$^+$: 490.1835, found: 490.1836

5 X-ray Crystallographic Data
5. 1. Preparation of crystal.

3a-major: The pure compounds (50 mg) of 3a-major was dissolved in CDCl3 and removed in NMR tube. After the NMR experiments were finished, the tube was placed in the lab for about one week, during which the crystal was formed. The X-ray was detected after the crystal was formed. The X-ray data was detected by Smart APEX II which was purchased from Bruker.

3a-minor: The pure compounds (50 mg) of 3a-minor was dissolved in DCM in the small bottle, and then the CH3OH was added slowly until a small amount of precipitation occurs. Continue to add a small amount of DCM to dissolve the precipitate. Place the small bottle in a dry and ventilated place for about one week, during which the crystal was formed. The X-ray data was detected by Smart APEX II which was purchased from Bruker.

3e: The pure compounds (50 mg) of 3e was dissolved in DCM in the small bottle, and then the CH3OH was added slowly until a small amount of precipitation occurs. Continue to add a small amount of DCM to dissolve the precipitate. Place the small bottle in a dry and ventilated place for about one week, during which the crystal was formed. The X-ray data was detected by Smart APEX II which was purchased from Bruker.
5. 2 X-ray Crystallographic Data

<table>
<thead>
<tr>
<th>Bond precision:</th>
<th>C-C = 0.0046 Å</th>
<th>Wavelength=1.54184</th>
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<tbody>
<tr>
<td>Cell:</td>
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<td>b=13.0537(3)</td>
</tr>
<tr>
<td>alpha=90</td>
<td>beta=90</td>
<td>gamma=90</td>
</tr>
<tr>
<td>Temperature:</td>
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<td></td>
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<tr>
<td>Volume</td>
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</tr>
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<td>P 21 21 21</td>
</tr>
<tr>
<td>Hall group</td>
<td>P 2ac 2ab</td>
<td>P 2ac 2ab</td>
</tr>
<tr>
<td>Moiety formula</td>
<td>C32 H25 N O2 S</td>
<td>C32 H25 N O2 S</td>
</tr>
<tr>
<td>Sum formula</td>
<td>C32 H25 N O2 S</td>
<td>C32 H25 N O2 S</td>
</tr>
<tr>
<td>Mr</td>
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<td>487.59</td>
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<td>Dx.g cm-3</td>
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<td>Z</td>
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<tr>
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<tr>
<td>F000'</td>
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<tr>
<td>h,k,lmax</td>
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<td>14,16,20</td>
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<tr>
<td>Nref</td>
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<td>5047</td>
</tr>
<tr>
<td>Tmin,Tmax</td>
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<td>0.436,1.000</td>
</tr>
<tr>
<td>Tmin'</td>
<td>0.897</td>
<td></td>
</tr>
</tbody>
</table>

Correction method= # Reported T Limits: Tmin=0.436 Tmax=1.000
AbsCorr = MULTI-SCAN
Data completeness= 1.65/0.93    Theta(max)= 77.584
R(reflections)= 0.0374( 4304)    wR2(reflections)= 0.1010( 5047)
S = 1.042    Npar= 325

Displacement ellipsoids are drawn at 30% probability level
**Bond precision:**
\[ C-C = 0.0046 \text{ Å} \]

**Wavelength:**
\[ = 1.54184 \]

**Cell:**
\[
\begin{align*}
\text{a} &= 11.9830(2) \\
\text{b} &= 13.0537(3) \\
\text{c} &= 16.2653(3) \\
\alpha &= 90^\circ \\
\beta &= 90^\circ \\
\gamma &= 90^\circ
\end{align*}
\]

**Temperature:** 298 K

**Volume:**
\[
\begin{align*}
\text{Calculated} &= 2544.26(9) \\
\text{Reported} &= 2544.27(8)
\end{align*}
\]

**Space group:**
\[
\begin{align*}
\text{P 21 21 21} \\
\text{P 21 21 21}
\end{align*}
\]

**Hall group:**
\[
\begin{align*}
\text{P 2ac 2ab} \\
\text{P 2ac 2ab}
\end{align*}
\]

**Moiety formula:**
\[
\text{C32 H25 N O2 S}
\]

**Sum formula:**
\[
\text{C32 H25 N O2 S}
\]

**Mr:**
\[
\begin{align*}
\text{Calculated} &= 487.59 \\
\text{Reported} &= 487.59
\end{align*}
\]

**Dx,g cm\(^{-3}\):**
\[
\begin{align*}
\text{Calculated} &= 1.273 \\
\text{Reported} &= 1.273
\end{align*}
\]

**Z:**
\[
\begin{align*}
\text{Calculated} &= 4 \\
\text{Reported} &= 4
\end{align*}
\]

**Mu (mm\(^{-1}\):**
\[
\begin{align*}
\text{Calculated} &= 1.359 \\
\text{Reported} &= 1.359
\end{align*}
\]

**F000:**
\[
\begin{align*}
\text{Calculated} &= 1024.0 \\
\text{Reported} &= 1024.0
\end{align*}
\]

**F000'**
\[
\begin{align*}
\text{Calculated} &= 1028.04 \\
\text{Reported} &= 1028.04
\end{align*}
\]

**h,k,lmax:**
\[
\begin{align*}
\text{Calculated} &= 15,16,20 \\
\text{Reported} &= 14,16,20
\end{align*}
\]

**Nref:**
\[
\begin{align*}
\text{Calculated} &= 5428(3057) \\
\text{Reported} &= 5047
\end{align*}
\]

**Tmin, Tmax:**
\[
\begin{align*}
\text{Calculated} &= 0.907,0.934 \\
\text{Reported} &= 0.436,1.000
\end{align*}
\]

**Tmin'**
\[
\begin{align*}
\text{Calculated} &= 0.897 \\
\text{Reported} &=
\end{align*}
\]

**Correction method:**
\[
\begin{align*}
\text{Calculated} &= \text{Reported} \\
\text{T Limits:} &= \text{Tmin}=0.436 \text{ Tmax}=1.000
\end{align*}
\]

**AbsCorr**
\[
\begin{align*}
\text{Calculated} &= \text{MULTI-SCAN} \\
\text{Reported} &=
\end{align*}
\]

**Data completeness:**
\[
\begin{align*}
\text{Calculated} &= 1.65/0.93 \\
\text{Reported} &=
\end{align*}
\]

**Theta(max):**
\[
\begin{align*}
\text{Calculated} &= 77.584 \\
\text{Reported} &=
\end{align*}
\]

**R(reflections):**
\[
\begin{align*}
\text{Calculated} &= 0.0374(4304) \\
\text{Reported} &=
\end{align*}
\]

**wR2(reflections):**
\[
\begin{align*}
\text{Calculated} &= 0.1010(5047) \\
\text{Reported} &=
\end{align*}
\]

**S:**
\[
\begin{align*}
\text{Calculated} &= 1.042 \\
\text{Reported} &=
\end{align*}
\]

**Npar:**
\[
\begin{align*}
\text{Calculated} &= 325 \\
\text{Reported} &=
\end{align*}
\]

**Displacement ellipsoids are drawn at 30\% probability level.**
Bond precision: C-C = 0.0041 Å  
Wavelength=1.54184

Cell:  
a=12.0118(2)  
b=12.7811(2)  
c=16.9520(3)  
alpha=90  
beta=90  
gamma=90

Temperature: 303 K

Calculated  
Reported

Volume  
2602.54(8)  
2602.54(8)

Space group  
P 21 21 21  
P 21 21 21

Hall group  
P 2ac 2ab  
P 2ac 2ab

Moiety formula  
C33 H27 N O2 S  
C33 H27 N O2 S

Sum formula  
C33 H27 N O2 S  
C33 H27 N O2 S

Mr  
501.62  
501.61

Dx,g cm-3  
1.280  
1.280

Z  
4  
4

Mu (mm-1)  
1.343  
1.343

F000  
1056.0  
1056.0

F000'  
1060.11

h,k,lmax  
15,16,21  
14,15,21

Nref  
5435[ 3062]  
4657

Tmin,Tmax  
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0.099,1.000

Tmin'  
0.886

Correction method= MULTI-SCAN

Data completeness= 1.52/0.86  
Theta(max)= 75.994

R(reflections)= 0.0344( 4158)  
wR2(reflections)= 0.0895( 4657)

S = 1.007  
Npar= 336

Displacement ellipsoids are drawn at 30% probability level
6 The Discussion and Determination of Absolute Configuration of Compound 3a and Some Mechanism Verification Experiment

6.1 The Discussion and Determination of Absolute Configuration of Compound 3a

3a and 3a was a pair of enantiomers. The decision configuration of 3a is determined by X-ray crystal, while the relative configuration of 3a is determined by X-ray crystal. Both compounds are attacked by the same face, and the same three-dimensional configuration is obtained by one attack. Therefore, the absolute configuration of 3a can be determined. At the same time, it can also be determined that such substrate diastereomers produce in catalysts controlling unsaturated carbonyl compounds to produce dienolite.

6.2 Some mechanism verification experiment

\[
\text{Ph} \quad \overset{-} \to \quad \text{Ph} \\
\text{Ph} \quad \overset{-} \to \quad \text{Ph}
\]

We isolated the 0.5 mmol Z-alkene (in 20 mmol scale reaction) from the mixture of the corresponding acetophenone, phenylacetylene and KOrBu in DMSO. The by-products in the system were identified as Z-alkenes by NMR.

We placed Z-8, y-unsaturated ketone (Z)-2a (1.25eq) and 5-alkenylthiazolone 1a under optimal reaction conditions (0.1mmol, 10 mol% cat A, 0 °C), the minor product of 3a in the template reaction was obtained with good results (95% yield, >20:1 dr, 99% ee). Therefore, this results are consistent with the postulate mechanism in Figure 1 of manuscript.

7 HPLC and NMR Spectrogram
$^1$HNMR of 3a (400M, CDCl$_3$)

Crude $^1$HNMR of 3a (400M, CDCl$_3$)

$^{13}$CNMR of 3a (101M, CDCl$_3$)
Crude $^1$HNMR of 3b (400M, CDCl$_3$)

$^1$HNMR of 3b (400M, CDCl$_3$)
$^{13}$CNMR of 3b (101M, CDCl$_3$)
$^1$HNMR of 3c (400M, CDCl$_3$)

Crude $^1$HNMR of 3c (400M, CDCl$_3$)
$^{13}$CNMR of 3c (101M, CDCl$_3$)
$^1$HNMR of 3d (400M, CDCl$_3$)

Crude $^1$HNMR of 3d (400M, CDCl$_3$)

$^{13}$CNMR of 3d (101M, CDCl$_3$)
\textbf{HNMR of $3e$ (400M, CDCl$_3$)}

\begin{center}
\includegraphics[width=\textwidth]{hnmr}\end{center}

\textbf{Crude $^1$HNMR of $3e$ (400M, CDCl$_3$)}

\begin{center}
\includegraphics[width=\textwidth]{crude_hnmr}\end{center}
$^{13}$CNMR of 3e (101M, CDCl$_3$)
\(^1\)HNMR of \(3f\) (400M, CDCl\(_3\))

Crude \(^1\)HNMR of \(3f\) (400M, CDCl\(_3\))
$^{13}$CNMR of 3f (101M, CDCl$_3$)
\[1^\text{HNMR of 3g (400M, CDCl}_3)\]

Crude \[1^\text{HNMR of 3g (400M, CDCl}_3)\]
$^{13}$CNMR of 3g (101M, CDCl$_3$)
\textsuperscript{1}HNMR of 3h (400M, CDCl\textsubscript{3})

![HNMR谱图](image1)

Crude \textsuperscript{1}HNMR of 3h (400M, CDCl\textsubscript{3})

![HNMR谱图](image2)
$^{13}$CNMR of 3h (101M, CDCl3)
$^1$HNMR of 3i (400M, CDCl$_3$)

Crude $^1$HNMR of 3i (400M, CDCl$_3$)
$^{13}$CNMR of 3i (101M, CDCl$_3$)
$^1$HNMR of 3j (400M, CDCl$_3$)

Crude $^1$HNMR of 3j (400M, CDCl$_3$)
$^{13}$CNMR of 3j (101M, CDCl$_3$)
$^1$HNMR of 3k (400M, CDCl$_3$)

Crude $^1$HNMR of 3k (400M, CDCl$_3$)
$^{19}$FNMR of 3k (400M, CDCl$_3$)

$^{13}$CNMR of 3k (101M, CDCl$_3$)
$^1$HNMR of 3I (400M, CDCl$_3$)

Crude $^1$HNMR of 3I (400M, CDCl$_3$)
$^{13}$C NMR of 3I (101M, CDCl$_3$)
$^1$HNMR of \textbf{3m} (400M, CDCl$_3$)

Crude $^1$HNMR of \textbf{3m} (400M, CDCl$_3$)
$^{13}$CNMR of 3m (101M, CDCl$_3$)
$^1$HNMR of 3n (400M, CDCl)

Crude $^1$HNMR of 3n (400M, CDCl)
$^{13}$CNMR of $3n$ (101M, CDCl$_3$)
$^1$HNMR of 3o (400M, CDCl$_3$)

Crude $^1$HNMR of 3o (400M, CDCl$_3$)
$^{13}$CNMR of 3o (101M, CDCl$_3$)
$^1$HNMR of 3p (400M, CDCl$_3$)

Crude $^1$HNMR of 3p (400M, CDCl$_3$)
$^{13}$CNMR of 3p (101M, CDCl$_3$)
$^1$HNMR of 3q (400M, CDCl$_3$)

Crude $^1$HNMR of 3q (400M, CDCl$_3$)
$^{13}$CNMR of 3q (101M, CDCl$_3$)
$^1$HNMR of 3r (400M, CDCl$_3$)

Crude $^1$HNMR of 3r (400M, CDCl$_3$)
$^{19}$FNMR of 3k (400M, CDCl$_3$)

$^{13}$CNMR of 3r (101M, CDCl$_3$)
$^1$HNMR of 3s (400M, CDCl$_3$)

Crude $^1$HNMR of 3s (400M, CDCl$_3$)
$^{13}$CNMR of 3s (10.1 M, CDCl$_3$)

$^1$HNMR of 3t (400 M, CDCl$_3$)
Crude $^1$H NMR of 3t (400M, CDCl$_3$)

$^{19}$F NMR of 3t (400M, CDCl$_3$)
$^1$C NMR of 3t (101M, CDCl$_3$)
$^1$HNMR of 4a (400M, CDCl$_3$)

Crude $^1$H NMR of 4a (400M, CDCl$_3$)
$^{13}$CNMR of 4a (101M, CDCl$_3$)
$^1$HNMR of 4b (400M, CDCl$_3$)

Crude $^1$H NMR of 4b (400M, CDCl$_3$)
$^{13}$CNMR of $4b$ (101M, CDCl$_3$)
$^1$HNMR of 4c (400M, CDCl$_3$)

Crude $^1$H NMR of 4c (400M, CDCl$_3$)
$^{13}$CNMR of 4c (101M, CDCl$_3$)
$^1$HNMR of 4d (400M, CDCl$_3$)

Crude $^1$H NMR of 4d (400M, CDCl$_3$)
$^{13}$CNMR of **4d** (101M, CDCl$_3$)
$^1$HNMR of 4e (400M, CDCl$_3$)

Crude $^1$H NMR of 4e (400M, CDCl$_3$)
$^{13}$CNMR of 4e (101M, CDCl$_3$)
$^1$HNMR of 4f (400M, CDCl$_3$)

Crude $^1$H NMR of 4e (400M, CDCl$_3$)
$^{13}$CNMR of 4f (101M, CDCl$_3$)
$^1$HNMR of $4g$ (400M, CDCl$_3$)

Crude $^1$H NMR of $4e$ (400M, CDCl$_3$)
$^{13}$CNMR of 4g (101M, CDCl$_3$)
$^1$HNMR of 4h (400M, CDCl$_3$)

Crude $^1$H NMR of 4h (400M, CDCl$_3$)
$^{13}$CNMR of $4h$ (101M, CDCl$_3$)
$^1$HNMR of 4i (400M, CDCl$_3$)

Crude $^1$H NMR of 4h (400M, CDCl$_3$)
$^{13}$CNMR of 4i (101M, CDCl$_3$)
$^1$HNMR of 4j (400M, CDCl$_3$)

Crude $^1$H NMR of 4j (400M, CDCl$_3$)
$^{13}$CNMR of 4j (101M, CDCl$_3$)
$^1$HNMR of 4k (400M, CDCl$_3$)

Crude $^1$HNMR of 4k (400M, CDCl$_3$)
$\text{CNMR of 4k (101M, CDCl}_3\text{)}$
$^1$HNMR of 4l (400M, CDCl$_3$)

\[
\text{HNMR of 4l (400M, CDCl}_3\text{)}
\]

Curde $^1$HNMR of 4l (400M, CDCl$_3$)

\[
\text{Curde HNMR of 4l (400M, CDCl}_3\text{)}
\]
$^{13}$CNMR of 4k (101M, CDCl$_3$)
$^1$HNMR of 5a (600M, CDCl$_3$)

Crude $^1$HNMR of 5a (600M, CDCl$_3$)
$^{13}$CNMR of 5a (101M, CDCl$_3$)
$^1$HNMR of 5b (400M, CDCl$_3$)

Crude $^1$HNMR of 5b (400M, CDCl$_3$) Crude
$^{13}$CNMR of 5b (101M, CDCl$_3$)
$^1$HNMR of $5c$ (400M, CDCl$_3$)

Crude $^1$HNMR of $5c$ (400M, CDCl$_3$)
$^{13}$CNMR of 5c (101M, CDCl$_3$)
$^1$HNMR of 5d (400M, CDCl$_3$)

Crude $^1$HNMR of 5d (400M, CDCl$_3$)
$^{13}$CNMR of 5d (101M, CDCl$_3$)
$^1$HNMR of 5e (400M, CDCl$_3$)

Crude $^1$HNMR of 5e (400M, CDCl$_3$)
$^{13}$CNMR of 5e (101M, CDCl$_3$)
$^1$HNMR of 5f (400M, CDCl$_3$)

$^{13}$CNMR of 5f (101M, CDCl$_3$)
$^1$HNMR of 5g (400M, CDCl$_3$)

Crude $^1$HNMR of 5g (400M, CDCl$_3$)

$^{13}$CNMR of 5g (101M, CDCl$_3$)
$^1$HNMR of 5h (400M, CDCl$_3$)

![HNMR spectrum of 5h](image1)

Crude $^1$HNMR of 5h (400M, CDCl$_3$)

![Crude HNMR spectrum of 5h](image2)

$^{13}$CNMR of 5h (101M, CDCl$_3$)

![CNMR spectrum of 5h](image3)
$^1$HNMR of 5i (400M, CDCl$_3$)

Crude $^1$HNMR of 5i (400M, CDCl$_3$)

$^{13}$CNMR of 5i (101M, CDCl$_3$)

119
$^{19}\text{F NMR of } 5i \ (101\text{M, CDCl}_3)$
$^1$HNMR of 5j (400M, CDCl$_3$)

$^{13}$CNMR of 5j (101M, CDCl$_3$)
$^1$HNMR of 6c
(400M, CDCl$_3$)

$^{13}$CNMR of 6c (101M, CDCl$_3$)
$^1$HNMR of 7a-minor (400M, CDCl$_3$)

$^{13}$CNMR of 7a-minor (101M, CDCl$_3$)
$^1$HNMR of 7a-major (400M, CDCl$_3$)

$^{13}$CNMR of 7a-major (101M, CDCl$_3$)
D$_2$O exchange experiment of 7a-minor

D$_2$O exchange experiment of 7a-major
$^1$HNMR of 3a-minor (400M, CDCl$_3$)

$^{13}$CNMR of 3a-minor (101M, CDCl$_3$)
HPLC chromatogram of compound 3a [Chiralpak IH column, hexane: \textit{i}-PrOH= 93:7, 1.0 mL/min]

<table>
<thead>
<tr>
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<th>Time</th>
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<tbody>
<tr>
<td>1</td>
<td>34.9</td>
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<td>2</td>
<td>50.819</td>
<td>50.013</td>
</tr>
<tr>
<td>Total</td>
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<td>100.000</td>
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</tbody>
</table>

HPLC chromatogram of compound 3b [Chiralpak IF column, hexane: \textit{i}-PrOH = 85:15, 1.0 mL/min]

<table>
<thead>
<tr>
<th>#</th>
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<tbody>
<tr>
<td>1</td>
<td>21.854</td>
<td>49.638</td>
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<td>2</td>
<td>23.709</td>
<td>50.362</td>
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<tr>
<td>Total</td>
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<td>100.000</td>
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</table>

HPLC chromatogram of compound 3c [Chiralpak IH column, hexane: \textit{i}-PrOH= 93:7, 1.0 mL/min]

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<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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<tbody>
<tr>
<td>1</td>
<td>16.555</td>
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<td>23.668</td>
<td>49.626</td>
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</tbody>
</table>
HPLC chromatogram of compound 3d [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min]

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<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>7.991</td>
<td>50.328</td>
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<td>Total</td>
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<td>100.000</td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 3e [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min]

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<tr>
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<th>Time</th>
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<tbody>
<tr>
<td>1</td>
<td>8.444</td>
<td>51.541</td>
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<tr>
<td>2</td>
<td>12.404</td>
<td>48.459</td>
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<tr>
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HPLC chromatogram of compound 3f [Chiralpak IH column, hexane: i-PrOH = 90:10, 1.0 mL/min]

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<tr>
<th></th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34.767</td>
<td>53.191</td>
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<td>2</td>
<td>100.378</td>
<td>56.809</td>
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<tr>
<td>Total</td>
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<td>100.000</td>
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</tbody>
</table>

# Time Area(%) # Time Area(%)
HPLC chromatogram of compound 3g [Chiralpak OD column, hexane: i-PrOH = 80:20, 1.0 mL/min]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.609</td>
<td>49.354</td>
</tr>
<tr>
<td>2</td>
<td>38.178</td>
<td>50.646</td>
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<tr>
<td>Total</td>
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<td>100.000</td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 3h [Chiralpak IF column, hexane: i-PrOH: DCM = 91:4:5, 1.0 mL/min]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65.157</td>
<td>49.551</td>
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<tr>
<td>2</td>
<td>69.682</td>
<td>50.449</td>
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<td>Total</td>
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</table>

# Time Area(%)

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<tr>
<th>#</th>
<th>Time</th>
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# Time Area(%)

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<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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<tr>
<td>Total</td>
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<td>100.000</td>
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</tbody>
</table>
HPLC chromatogram of compound 3i [Chiralpak IH column, hexane: \(i\)-PrOH:DCM = 91:4:5, 1.0 mL/min]

<table>
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<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>21.509</td>
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<td>2</td>
<td>36.901</td>
<td>49.025</td>
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<tr>
<td>Total</td>
<td>100.000</td>
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</tr>
</tbody>
</table>

HPLC chromatogram of compound 3j [Chiralpak IH column, hexane: \(i\)-PrOH:DCM = 91:4:5, 1.0 mL/min]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28.582</td>
<td>48.653</td>
</tr>
<tr>
<td>2</td>
<td>45.18</td>
<td>51.347</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 3k [Chiralpak IH column, hexane: \(i\)-PrOH:DCM = 91:4:5, 1.0 mL/min]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.92</td>
<td>48.310</td>
</tr>
<tr>
<td>2</td>
<td>13.602</td>
<td>51.690</td>
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<tr>
<td>Total</td>
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<td></td>
</tr>
</tbody>
</table>
HPLC chromatogram of compound 3l [Chiralpak IH column, hexane: i-PrOH = 93:7, 1.0 mL/min ]
Racemic HPLC chromatogram   Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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<tbody>
<tr>
<td>1</td>
<td>24.296</td>
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<td>2</td>
<td>29.3</td>
<td>49.026</td>
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</tbody>
</table>

HPLC chromatogram of compound 3m [Chiralpak IH column, hexane: i-PrOH = 93:7, 1.0 mL/min ]
Racemic HPLC chromatogram   Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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<tbody>
<tr>
<td>1</td>
<td>22.292</td>
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<td>2</td>
<td>32.702</td>
<td>50.867</td>
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<tr>
<td>Total</td>
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<td>100.000</td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 3n [Chiralpak AD column, hexane: i-PrOH = 80:20, 1.0 mL/min ]
Racemic HPLC chromatogram   Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>37.453</td>
<td>50.137</td>
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<tr>
<td>2</td>
<td>58.928</td>
<td>49.863</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

133
HPLC chromatogram of compound 3o [Chiralpak IH column, hexane: i-PrOH = 93:7, 1.0 mL/min ]

<table>
<thead>
<tr>
<th>#</th>
<th>Time (min)</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28.021</td>
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<tr>
<td>2</td>
<td>33.7</td>
<td>52.011</td>
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<tr>
<td>Total</td>
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</tr>
</tbody>
</table>

HPLC chromatogram of compound 3p [Chiralpak IF column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

<table>
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<tr>
<th>#</th>
<th>Time (min)</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50.83</td>
<td>49.433</td>
</tr>
<tr>
<td>2</td>
<td>60.555</td>
<td>50.567</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 3q [Chiralpak IH column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

<table>
<thead>
<tr>
<th>#</th>
<th>Time (min)</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>2</td>
<td>50.016</td>
<td>51.567</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

134
HPLC chromatogram of compound 3r [Chiralpak Ih column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

Racemic HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>27.941</td>
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<tr>
<td>2</td>
<td>46.127</td>
<td>49.139</td>
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<td>Total</td>
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</tbody>
</table>

Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28.185</td>
<td>1.588</td>
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<td>2</td>
<td>45.323</td>
<td>98.412</td>
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<td>Total</td>
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<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 3s [Chiralpak IF column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

Racemic HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.407</td>
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</tr>
<tr>
<td>2</td>
<td>31.001</td>
<td>50.567</td>
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<tr>
<td>Total</td>
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</tbody>
</table>

Chiral HPLC chromatogram

<table>
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<th>#</th>
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<tr>
<td>1</td>
<td>20.398</td>
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<td>30.23</td>
<td>94.462</td>
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</tbody>
</table>

HPLC chromatogram of compound 3t [Chiralpak IH column, hexane: i-PrOH: DCM = 91:4:5, 1.0 mL/min ]

Racemic HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38.053</td>
<td>51.017</td>
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<tr>
<td>2</td>
<td>49.058</td>
<td>48.983</td>
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<td>Total</td>
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Chiral HPLC chromatogram

<table>
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<th>#</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>45.533</td>
<td>100.000</td>
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<tr>
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</tbody>
</table>
HPLC chromatogram of compound 4a [Chiralpak IF column, hexane: i-PrOH = 83:17, 1.0 mL/min]

Racemic HPLC chromatogram | Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>35.233</td>
<td>50.660</td>
</tr>
<tr>
<td>2</td>
<td>41.878</td>
<td>49.340</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
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</tbody>
</table>

HPLC chromatogram of compound 4b [Chiralpak IH column, hexane: i-PrOH = 90:10, 1.0 mL/min]

Racemic HPLC chromatogram | Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.676</td>
<td>55.087</td>
</tr>
<tr>
<td>2</td>
<td>17.647</td>
<td>44.913</td>
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<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 4c [Chiralpak IF column, hexane: i-PrOH = 83:17, 1.0 mL/min]

Racemic HPLC chromatogram | Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.444</td>
<td>49.607</td>
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<tr>
<td>2</td>
<td>36.68</td>
<td>50.393</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
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</tbody>
</table>
HPLC chromatogram of compound 4d [Chiralpak AD column, hexane: i-PrOH = 80:20, 1.0 mL/min ]

Racemic HPLC chromatogram               Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37.02</td>
<td>49.430</td>
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<tr>
<td>2</td>
<td>79.33</td>
<td>50.570</td>
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<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 4e [Chiralpak IH column, hexane: i-PrOH: DCM = 91:4:5, 1.0 mL/min ]

Racemic HPLC chromatogram               Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.538</td>
<td>49.840</td>
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<tr>
<td>2</td>
<td>33.872</td>
<td>50.160</td>
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<tr>
<td>Total</td>
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</table>

HPLC chromatogram of compound 4f [Chiralpak IH column, hexane: i-PrOH: DCM = 91:4:5, 1.0 mL/min ]

Racemic HPLC chromatogram               Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>32.798</td>
<td>49.637</td>
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<td>2</td>
<td>47.58</td>
<td>50.363</td>
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<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

137
HPLC chromatogram of compound 4g [Chiralpak IF column, hexane: i-PrOH = 80:20, 1.0 mL/min ]

**Racemic HPLC chromatogram**

**Chiral HPLC chromatogram**

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52.107</td>
<td>48.379</td>
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<tr>
<td>2</td>
<td>58.52</td>
<td>51.621</td>
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<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 4h [Chiralpak IH column, hexane: i-PrOH:DCM = 94:1:5, 1.0 mL/min ]

**Racemic HPLC chromatogram**

**Chiral HPLC chromatogram**

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.005</td>
<td>46.851</td>
</tr>
<tr>
<td>2</td>
<td>13.509</td>
<td>53.149</td>
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<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 4i [Chiralpak IC column, hexane: i-PrOH = 80:20, 1.0 mL/min ]

**Racemic HPLC chromatogram**

**Chiral HPLC chromatogram**

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.616</td>
<td>48.590</td>
</tr>
<tr>
<td>2</td>
<td>32.013</td>
<td>51.410</td>
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<tr>
<td>Total</td>
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<td>100.000</td>
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</tbody>
</table>
HPLC chromatogram of compound 4j [Chiralpak IH column, hexane: \( \beta \)-PrOH = 9:5, 1.0 mL/min ]

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.417</td>
<td>50.248</td>
</tr>
<tr>
<td>2</td>
<td>30.874</td>
<td>49.752</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 4k [Chiralpak IH column, hexane: \( \beta \)-PrOH:DCM = 94:1:5, 1.0 mL/min ]

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.274</td>
<td>46.851</td>
</tr>
<tr>
<td>2</td>
<td>12.349</td>
<td>53.149</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 4l [Chiralpak IC column, hexane: \( \beta \)-PrOH = 80:20, 1.0 mL/min ]

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35.079</td>
<td>48.684</td>
</tr>
<tr>
<td>2</td>
<td>38.99</td>
<td>51.316</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>
HPLC chromatogram of compound 5a [Chiralpak IC column, hexane: i-PrOH = 97:3, 1.0 mL/min ]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48.845</td>
<td>50.064</td>
</tr>
<tr>
<td>2</td>
<td>76.691</td>
<td>49.936</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

Racemic HPLC chromatogram  Chiral HPLC chromatogram

HPLC chromatogram of compound 5b [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34.31</td>
<td>51.821</td>
</tr>
<tr>
<td>2</td>
<td>49.452</td>
<td>48.179</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

Racemic HPLC chromatogram  Chiral HPLC chromatogram

HPLC chromatogram of compound 5c [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41.724</td>
<td>50.805</td>
</tr>
<tr>
<td>2</td>
<td>55.73</td>
<td>49.195</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

Racemic HPLC chromatogram  Chiral HPLC chromatogram
HPLC chromatogram of compound **5d** [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.723</td>
<td>51.453</td>
</tr>
<tr>
<td>2</td>
<td>54.397</td>
<td>48.547</td>
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<tr>
<td>Total</td>
<td>100.000</td>
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</tr>
</tbody>
</table>

HPLC chromatogram of compound **5e** [Chiralpak IC column, hexane: i-PrOH = 93:7, 1.0 mL/min]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.585</td>
<td>50.367</td>
</tr>
<tr>
<td>2</td>
<td>45.926</td>
<td>49.633</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound **5f** [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35.756</td>
<td>51.528</td>
</tr>
<tr>
<td>2</td>
<td>42.032</td>
<td>48.472</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>
HPLC chromatogram of compound 5g [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43.627</td>
<td>50.665</td>
</tr>
<tr>
<td>2</td>
<td>63.558</td>
<td>49.335</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 5h [Chiralpak IC column, hexane: i-PrOH = 90:10, 1.0 mL/min ]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.663</td>
<td>50.169</td>
</tr>
<tr>
<td>2</td>
<td>48.97</td>
<td>49.831</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 5i [Chiralpak IC column, hexane: i-PrOH = 90:10,1.0 mL/min ]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61.747</td>
<td>51.650</td>
</tr>
<tr>
<td>2</td>
<td>80.187</td>
<td>48.350</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

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HPLC chromatogram of compound 5j [Chiralpak IC column, hexane: $^t$-PrOH = 97:3, 1.0 mL/min ]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47.368</td>
<td>48.848</td>
</tr>
<tr>
<td>2</td>
<td>57.056</td>
<td>51.152</td>
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<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 6c [Chiralpak IC column, hexane: $^t$-PrOH = 90:10, 1.0 mL/min ]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48.431</td>
<td>4.353</td>
</tr>
<tr>
<td>2</td>
<td>56.497</td>
<td>95.649</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

HPLC chromatogram of compound 7a-minor [Chiralpak IH column, hexane: $^t$-PrOH: DCM = 92:3:5, 1.0 mL/min ]

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.433</td>
<td>49.052</td>
</tr>
<tr>
<td>2</td>
<td>41.127</td>
<td>50.948</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.399</td>
<td>100.000</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>
HPLC chromatogram of compound **7a-major** [Chiralpak IH column, hexane: i-PrOH: DCM = 92:3:5, 1.0 mL/min ]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.1</td>
<td>50.173</td>
</tr>
<tr>
<td>2</td>
<td>16.14</td>
<td>49.827</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

Racemic HPLC chromatogram  Chiral HPLC chromatogram

HPLC chromatogram of compound **3a-minor** [Chiralpak Ic column, hexane: i-PrOH= 90:10, 1.0 mL/min ]

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>12.779</td>
<td>98.963</td>
</tr>
<tr>
<td>2</td>
<td>16.048</td>
<td>1.037</td>
</tr>
<tr>
<td>Total</td>
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<td>100.000</td>
</tr>
</tbody>
</table>

Racemic HPLC chromatogram  Chiral HPLC chromatogram

<table>
<thead>
<tr>
<th>#</th>
<th>Time</th>
<th>Area(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.551</td>
<td>49.558</td>
</tr>
<tr>
<td>2</td>
<td>38.241</td>
<td>50.402</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100.000</td>
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</tbody>
</table>