Supporting Information

Catalytic asymmetric carbonyl-ene reaction of
\(\beta,\gamma\)-unsaturated \(\alpha\)-ketoesters with 5-methyleneoxazolines**

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1. General remarks

$^1$H NMR spectra were recorded on commercial instruments (400 MHz). Chemical shifts were reported in ppm from tetramethylsilane with the solvent resonance as the internal standard (CDCl$_3$, $\delta = 7.26$). Spectra are reported as follows: chemical shift ($\delta$ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz), integration, and assignment. $^{13}$C NMR spectra were collected on commercial instruments (100 MHz) with complete proton decoupling. Chemical shifts are reported in ppm from the tetramethylsilane with the solvent resonance as internal standard (CDCl$_3$, $\delta = 77.0$). The enantiomeric excess was determined by HPLC analysis on commercial chiral columns. Optical rotations were measured on a commercial polarimeter and reported as follows: $[\alpha]_D^T$ (c = g/100 mL, solvent).

HR-ESIMS spectra were recorded using a commercial apparatus and methanol or acetonitrile was used to dissolve the sample. Unless otherwise indicated, reagents obtained from commercial sources were used without further purification. Solvents were dried and distilled prior to use according to the standard methods. The N,N'-dioxides were prepared according to the previous reports.

2. General procedure for the carbonyl-ene reaction

(a) General procedure for the preparation of the racemic products

To a test tube, racemic ligand L-PiPr$_2$ (0.01 mmol), Mg(OTf)$_2$ (0.01 mmol), and CH$_2$Cl$_2$ (0.5 mL) were added, stirring at room temperature for 30 min. Subsequently, $\beta,\gamma$-unsaturated $\alpha$-ketoesters 1 or 4 (0.1 mmol) and methyleneoxazoline 2 (3.0 equiv) were added, and the reaction mixture was stirred at 30 ºC for 24 h. The crude mixture was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 3/1) to afford the desired product.

(b) General procedure for the catalytic asymmetric reaction

A dry reaction tube was charged with L-PiPr$_2$-Mg(OTf)$_2$ (1:1, 10 mol% or 5 mol%) and $\beta,\gamma$-unsaturated $\alpha$-ketoesters 1 or 4 (0.1 mmol). CH$_2$Cl$_2$ (1.0 mL) was added, and the mixture was stirred at 30 ºC for 0.5 h. Then, the methyleneoxazolines 2 (1.3 equiv) was added to the reaction mixture. After being stirred at 30 ºC for 30 h, the crude reaction mixture was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 3/1) to afford the desired product.

(c) Asymmetric carbonyl-ene reaction of 4j on a gram scale.

A flask (25 mL) was charged with Mg(OTf)$_2$ (64.5 mg, 0.2 mmol), L-PiPr$_2$ (129.8 mg, 0.2 mmol) and 2-oxo-3-ynoate 4j (4.0 mmol). Then, CH$_2$Cl$_2$ (10 mL) was added and the mixture was stirred at 30 ºC for 0.5 h. Finally, the methyleneoxazoline 2a (1.3 equiv) and CH$_2$Cl$_2$ (10 mL) were added under stirring. The reaction mixture was stirred at 30 ºC for 30 h. After evaporation of the solvents, the residue was purified by flash chromatography (petroleum ether/ethyl acetate = 5/1) on silica gel to afford the
product 5j as a colourless viscous liquid (1.42 g, 99% yield, 99% ee).

3. Experimental procedure for the transformations of the products 5j

(a) Experimental procedure for the reduction of the ester group

![Chemical structure](image)

NaBH₄, MeOH
0 °C to RT, 2h

To a solution of adduct 5j (89.4 mg, 0.25 mmol) in CH₃OH (2.0 mL) was added NaBH₄ (37.8 mg, 4.0 equiv) at 0 °C. The mixture was allowed to stir at room temperature for 2 h. Excess of NaBH₄ was quenched with cold water. The mixture was extracted with CH₂Cl₂, and the organic layer was dried over anhydrous Na₂SO₄ and then was evaporated by rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1) to afford 10 (63.3 mg, 80% yield) as a white solid.

(b) Experimental procedure for the transformation of the alkynyl group

![Chemical structure](image)

K₂CO₃, EtOH, 2h

To a solution of adduct 5j (107.2 mg, 0.30 mmol) in EtOH (2.0 mL) was added K₂CO₃ (165.9 mg, 4.0 equiv) at 0 °C. The mixture was allowed to stir for at room temperature 2 h, the crude reaction mixture was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 3/1) to afford the corresponding product 11 (77.0 mg, 90% yield) as a colourless viscous liquid.

To a solution of 11 (71.3 mg, 0.25 mmol) and benzyl azide (66.6 mg, 2.0 equiv) in a mixture of t-BuOH/H₂O (1:1) (2 mL) were added solutions of sodium ascorbate (9.9 mg, 0.2 equiv) in 0.5 mL water and CuSO₄·5H₂O (6.2 mg, 0.1 equiv) in 0.5 mL water. The reaction mixture was stirred at room temperature for 24 h and then was quenched with water and filtered over celite. The crude product was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 1/1) to provide 12 (99.5 mg, 95% yield) as a colourless viscous liquid.

4. Other conditions of the catalytic asymmetric carbonyl-ene reaction

![Chemical structure](image)
<table>
<thead>
<tr>
<th>Entry(^a)</th>
<th>Metal</th>
<th>additive</th>
<th>Yield((%))(^b)</th>
<th>ee((%))(^c)</th>
<th>1,2-/1,4-(^d)</th>
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<tbody>
<tr>
<td>1</td>
<td>Zn(OTf)(_2)</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Cu(OTf)(_2)</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Sc(OTf)(_3)</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Y(OTf)(_3)</td>
<td>-</td>
<td>99</td>
<td>85</td>
<td>70/30</td>
</tr>
<tr>
<td>5</td>
<td>Co(BF(_4))(_2)·6H(_2)O</td>
<td>-</td>
<td>25</td>
<td>98</td>
<td>97/3</td>
</tr>
<tr>
<td>6</td>
<td>Er(OTf)(_3)</td>
<td>-</td>
<td>95</td>
<td>80</td>
<td>66/34</td>
</tr>
<tr>
<td>7</td>
<td>Mg(OTf)(_2)</td>
<td>-</td>
<td>93</td>
<td>&gt;99</td>
<td>99:1</td>
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<tr>
<td>8</td>
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<td>3 Å MS</td>
<td>Trace</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>Mg(OTf)(_2)</td>
<td>4 Å MS</td>
<td>Trace</td>
<td>-</td>
<td>-</td>
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<tr>
<td>10</td>
<td>Mg(OTf)(_2)</td>
<td>5 Å MS</td>
<td>Trace</td>
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<td>-</td>
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</table>

\(^a\) Unless otherwise noted, the reactions were performed with 1a (0.1 mmol) and 1.3 equiv. of 2 in CH\(_2\)Cl\(_2\) (1.0 mL) at 30 °C for 30 h. \(^b\) Combined yield of 1,2-adduct and 1,4-adduct. \(^c\) Determined by HPLC analysis on a chiral stationary phase. \(^d\) Determined by \(^1\)H NMR spectroscopy and chiral HPLC analysis.

5. Proposed mechanism

(a) Nonlinear effect

(b) Control reaction
The control reaction indicated that the hydrogens on the allylic position were necessary for the reaction. The reaction was inhibited when one hydrogen was replaced by methyl group, and no adduct was obtained when 2c bearing no hydrogen on the allylic position.

(c) X-ray crystallographic structure of the product 3a

Single crystal of 3a [C_{21}H_{19}NO_{4}] was obtained from the mixed solvents of ethyl acetate and petroleum ether. CCDC 1046971 contains the supplementary crystallographic data which can be obtained free of charge from The Cambridge Crystallographic Data Centere via www.ccdc.cam.ac.uk/data_request/cif.

(d) X-ray crystallographic structure of the product 5b
Single crystal of 5b [C_{22}H_{19}NO_{4}] was obtained from the mixed solvents of ethyl acetate and petroleum ether. CCDC 1047008 contains the supplementary crystallographic data which can be obtained free of charge from The Cambridge Crystallographic Data Centre via [www.ccdc.cam.ac.uk/data_request/cif](http://www.ccdc.cam.ac.uk/data_request/cif).
6. Characterization of the hetero-en reaction products

(R,E)-methyl 2-hydroxy-4-phenyl-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3a

(C$_{21}$H$_{19}$NO$_{4}$) a white amorphous solid, m. p. 96 – 98 °C; 92% yield, >99% ee. [α]$_D^{20}$ = +36.9 (c = 1.16 in CH$_2$Cl$_2$). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 75/25, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 8.45 min (major), 12.13 min (minor). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.87 (m, 2H), 7.38 – 7.27 (m, 5H), 7.27 – 7.20 (m, 2H), 7.20 – 7.14 (m, 1H), 6.90 (s, 1H), 6.84 (d, $J$ = 15.8 Hz, 1H), 6.32 (d, $J$ = 15.8 Hz, 1H), 3.76 (s, 4H), 3.34 (d, $J$ = 15.2 Hz, 1H), 3.10 (d, $J$ = 15.2 Hz, 1H).

$^{13}$C NMR (100 MHz, CDCl$_3$) δ 174.23, 161.37, 147.35, 135.96, 131.11, 130.18, 128.77, 128.68, 128.40, 128.17, 127.50, 126.85, 126.77, 126.13, 76.73, 53.48, 36.38. ESI-HRMS: calcd for C$_{21}$H$_{20}$NO$_{4}$+$^+$(M+H$^+$)) 350.1387, found 350.1388.

(R,E)-ethyl 2-hydroxy-4-phenyl-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3b

(C$_{22}$H$_{21}$NO$_{4}$) a yellow amorphous solid, m. p. 80 – 82 °C; 85% yield, >99% ee. [α]$_D^{20}$ = +35.0 (c = 1.09 in CH$_2$Cl$_2$). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 7.70 min (major), 12.03 min (minor). $^1$H NMR (400 MHz, CDCl$_3$) δ 8.05 – 7.77 (m, 2H), 7.40 – 7.28 (m, 5H), 7.21 (dt, $J$ = 22.6, 5.3 Hz, 3H), 6.92 (s, 1H), 6.85 (d, $J$ = 15.8 Hz, 1H), 6.33 (d, $J$ = 15.8 Hz, 1H), 4.31 – 4.07 (m, 2H), 3.70 (s, 1H), 3.35 (d, $J$ = 15.2 Hz, 1H), 3.12 (d, $J$ = 15.2 Hz, 1H), 1.23 (t, $J$ = 7.1 Hz, 3H). $^{13}$C NMR (101 MHz, CDCl$_3$) δ 173.75, 161.37, 147.44, 136.04, 131.03, 130.15, 128.76, 128.67, 128.57, 128.13, 127.54, 126.84, 126.75, 126.12, 76.54, 62.86, 36.28, 14.24. ESI-HRMS: calcd for C$_{22}$H$_{22}$NO$_{4}$+$^+$(M+H$^+$)) 364.1543, found 364.1536.
(R,E)-isopropyl 2-hydroxy-4-phenyl-2-((2-phenyloxazol-5-yl)methyl)but-3-enenate 3c

\[(\text{C}_{23}\text{H}_{23}\text{NO}_4)^+\) a white amorphous solid, m. p. 64 – 67°C; 87% yield, >99% ee. \([\alpha]_D^{20} = +36.2\) (c = 1.29 in \(\text{CH}_2\text{Cl}_2\)). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, \(\lambda = 254\) nm, retention time: 6.74 min (major), 9.87 min (minor). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.89 (dd, \(J = 6.7, 3.0\) Hz, 2H), 7.40 – 7.28 (m, 5H), 7.27 – 7.15 (m, 3H), 6.93 (s, 1H), 6.85 (d, \(J = 15.8\) Hz, 1H), 6.32 (d, \(J = 15.8\) Hz, 1H), 5.01 (dt, \(J = 12.5, 6.3\) Hz, 1H), 3.75 (s, 1H), 3.34 (d, \(J = 15.2\) Hz, 1H), 3.11 (d, \(J = 15.2\) Hz, 1H), 1.20 (dd, \(J = 10.8, 6.3\) Hz, 6H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 173.24, 161.26, 147.54, 136.12, 130.97, 130.13, 128.75, 128.67, 128.10, 127.56, 126.84, 126.73, 126.14, 76.44, 70.95, 36.14, 21.81, 21.76. ESI-HRMS: calcd for \(\text{C}_{23}\text{H}_{24}\text{NO}_4^+\) ([M+H\(^+\)]) 378.1700, found 378.1701.
(R,E)-methyl 4-(3-chlorophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3d

(C_{21}H_{18}ClNO_4) a yellow viscous liquid; 90% yield, >99% ee. [α]_D^{20} = +29.1 (c = 1.42 in CH_2Cl_2). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 9.33 min (major), 10.47 min (minor).

^{1}H NMR (400 MHz, CDCl_3) δ 7.95 (d, J = 3.6 Hz, 2H), 7.41 (s, 4H), 7.25 (d, J = 8.7 Hz, 3H), 6.99 (s, 1H), 6.87 (d, J = 15.7 Hz, 1H), 6.43 (d, J = 15.8 Hz, 1H), 3.86 (s, 4H), 3.42 (d, J = 15.2 Hz, 1H), 3.19 (d, J = 15.2 Hz, 1H).

^{13}C NMR (100 MHz, CDCl_3) δ 174.01, 161.42, 147.11, 137.85, 134.60, 130.23, 129.91, 129.87, 129.84, 128.78, 128.07, 127.43, 126.84, 126.54, 126.12, 125.28, 76.63, 53.57, 36.38.

ESI-HRMS: calcd for C_{21}H_{19}ClNO_4+ ([M+H]^+) 384.1003, found 384.0993, calcd for C_{21}H_{19}ClNO_4+ ([M+H]^+) 386.0973, found 386.0989.

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(R,E)-methyl 2-hydroxy-4-(3-methoxyphenyl)-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3e

(C_{22}H_{21}NO_5) a yellow viscous liquid; 92% yield, 99% ee. [α]_D^{20} = +31.0 (c = 1.43 in CH_2Cl_2). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 10.24 min (major), 23.20 min (minor). ^{1}H NMR (400 MHz, CDCl_3) δ 7.96 (dd, J = 6.5, 2.9 Hz, 2H), 7.52 – 7.34 (m, 3H), 7.24 (d, J = 7.9 Hz, 1H), 7.04 – 6.86 (m, 4H), 6.85 – 6.72 (m, 1H), 6.40 (d, J = 15.8 Hz, 1H), 3.86 (s, 3H), 3.81 (s, 3H), 3.77 (d, J = 6.5 Hz, 1H), 3.44 (d, J = 15.2 Hz, 1H), 3.19 (d, J = 15.2 Hz, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 174.19, 161.38, 159.83, 147.28, 137.38, 131.03, 130.20, 129.67, 128.78,
128.66, 127.49, 126.78, 126.12, 119.45, 113.80, 112.15, 76.68, 55.27, 53.52, 36.35. 

ESI-HRMS: calcd for C_{22}H_{22}NO_5^+ ([M+H]^+) 380.1492, found 380.1500.

(R,E)-methyl 4-(4-fluorophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3f

(C_{21}H_{18}FNO_4) a yellow viscous liquid; 80% yield, 99% ee. [α]_D^{20} = +33.4 (c = 0.86 in CH_2Cl_2). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 17.64 min (minor), 20.60 min (major). ^1H NMR (400 MHz, CDCl_3) δ 8.05 – 7.89 (m, 2H), 7.50 – 7.32 (m, 5H), 7.08 – 6.95 (m, 3H), 6.89 (d, J = 15.8 Hz, 1H), 6.33 (d, J = 15.8 Hz, 1H), 3.87 (s, 3H), 3.83–3.69 (m, 1H), 3.43 (d, J = 15.2 Hz, 1H), 3.19 (d, J = 15.2 Hz, 1H). ^13C NMR (100 MHz, CDCl_3) δ 174.18, 163.85, 161.39, 147.23, 132.12 (d, J = 3.3 Hz), 130.22, 129.96, 128.78, 128.42 (d, J = 8.0 Hz), 128.00 (d, J = 2.1 Hz), 127.46, 126.79, 126.10, 115.66 (d, J = 21.5 Hz), 76.61, 53.54, 36.39. ESI-HRMS: calcd for C_{21}H_{18}FNO_4^+ ([M+H]^+) 368.1293, found 368.1301.
(R,E)-methyl 4-(4-chlorophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3g

\[(\text{C}_{21}\text{H}_{19}\text{ClNO}_4)\] a yellow amorphous solid, m. p. 98 – 101 °C; 91% yield, >99% ee. \([\alpha]_D^{20} = +37.3\) (c = 1.37 in CH₂Cl₂). HPLC DAICEL CHIRALCEL IC, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 11.23 min (major), 12.23 min (minor). ¹H NMR (400 MHz, CDCl₃) δ 8.10 – 7.84 (m, 2H), 7.50 – 7.38 (m, 3H), 7.36 – 7.25 (m, 4H), 6.99 (s, 1H), 6.88 (d, \(J = 15.8\) Hz, 1H), 6.39 (d, \(J = 15.8\) Hz, 1H), 3.87 (s, 3H), 3.73 (s, 1H), 3.42 (d, \(J = 15.2\) Hz, 1H), 3.19 (d, \(J = 15.2\) Hz, 1H). ¹³C NMR (100 MHz, CDCl₃) δ 174.07, 161.42, 147.13, 134.46, 133.83, 130.22, 129.96, 128.90, 128.38, 128.05, 127.47, 126.83, 126.10, 76.62, 53.57, 36.38. ESI-HRMS: calcd for \(\text{C}_{21}\text{H}_{19}\text{ClNO}_4^+ (\text{M+H}^+)\) 384.1003, found 384.0992, calcd for \(\text{C}_{21}\text{H}_{19}\text{ClNO}_4^+ (\text{M+H}^+)\) 386.0973, found 386.0988.

(R,E)-methyl 4-(4-bromophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3h

\[(\text{C}_{21}\text{H}_{19}\text{BrNO}_4)\] a yellow amorphous solid, m. p. 116 – 118 °C; 83% yield, >99% ee. \([\alpha]_D^{20} = +32.4\) (c = 1.49 in CH₂Cl₂). HPLC DAICEL
CHIRALCEL IC, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 17.51 min (major), 19.18 min (minor). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.95 – 7.80 (m, 2H), 7.39 – 7.28 (m, 5H), 7.21 – 7.13 (m, 2H), 6.90 (s, 1H), 6.77 (d, \(J = 15.8\) Hz, 1H), 6.32 (d, \(J = 15.8\) Hz, 1H), 3.77 (s, 4H), 3.33 (d, \(J = 15.2\) Hz, 1H), 3.10 (d, \(J = 15.2\) Hz, 1H). \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 174.02, 161.40, 147.15, 134.92, 131.78, 130.22, 129.10, 128.78, 128.36, 127.45, 126.83, 126.10, 121.99, 76.66, 53.55, 36.37.

\[\text{ESI-HRMS: calcd for } \text{C}_{21}\text{H}_{19}\text{BrNO}_4^+ ([M+H]^+) 428.0497, \text{ found } 428.0490, \text{ calcd for } \text{C}_{21}\text{H}_{19}\text{BrNO}_4^+ ([M+H]^+) 430.0477, \text{ found } 430.0475.\]

(R,E)-methyl 2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)-4-p-tolylbut-3-enoate 3i

(C\(_{22}\text{H}_{22}\text{NO}_4\)) a yellow amorphous solid, m. p. 122 – 124 °C; 73% yield, >99% ee. \([\alpha]_D^{30} = +39.4\) (c = 0.63 in CH\(_2\)Cl\(_2\)). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 75/25, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 7.51 min (major), 8.85 min (minor). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.96 (dd, \(J = 6.7, 2.9\) Hz, 2H), 7.46 – 7.38 (m, 3H), 7.30 (d, \(J = 8.0\) Hz, 2H), 7.13 (d, \(J = 7.9\) Hz, 2H), 6.99 (s, 1H), 6.89 (d, \(J = 15.8\) Hz, 1H), 6.35 (d, \(J = 15.8\) Hz, 1H), 3.85 (s, 3H), 3.75 (d, \(J = 12.6\) Hz, 1H), 3.43 (d, \(J = 15.2\) Hz, 1H), 3.19 (d, \(J = 15.2\) Hz, 1H), 2.34 (s, 3H). \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 174.32, 161.35, 147.40, 138.09, 133.16, 130.95, 130.16, 129.37, 128.76, 127.54, 127.31, 126.75, 126.12, 76.70, 53.45, 36.37, 21.26. ESI-HRMS: calcd for C\(_{22}\text{H}_{22}\text{NO}_4^+ ([M+H]^+) 364.1543, found 364.1539.
(R,E)-methyl
2-hydroxy-4-(4-methoxyphenyl)-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3j

(C$_{22}$H$_{21}$NO$_5$) a yellow amorphous solid, m. p. 100 – 103 ºC; 68% yield, >99% ee. [$\alpha$]$_D^{20}$ = +35.6 (c = 1.01 in CH$_2$Cl$_2$). HPLC: DIACEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, $\lambda$ = 254 nm, retention time: 31.97 min (minor), 38.83 min (major). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.99 – 7.78 (m, 2H), 7.39 – 7.30 (m, 3H), 7.26 (d, $J$ = 8.5 Hz, 2H), 6.90 (s, 1H), 6.78 (dd, $J$ = 12.0, 3.3 Hz, 3H), 6.18 (d, $J$ = 15.8 Hz, 1H), 3.77 (s, 3H), 3.72 (s, 3H), 3.67 (s, 1H), 3.35 (d, $J$ = 15.2 Hz, 1H), 3.10 (d, $J$ = 15.2 Hz, 1H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 173.32, 160.27, 158.58, 146.40, 129.43, 129.10, 127.70, 127.63, 127.02, 126.48, 125.65, 125.05, 113.01, 75.63, 54.27, 52.37, 35.34. ESI-HRMS: calcd for C$_{22}$H$_{22}$NO$_5$ ((M+H$^+$)) 380.1492, found 380.1490.

(R,E)-methyl
4-(biphenyl-4-yl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3k

(C$_{27}$H$_{23}$NO$_4$) a yellow amorphous solid, m. p. 70 –
73 °C; 86% yield, >99% ee. [α]_D^{20} = +28.5 (c = 1.43 in CH₂Cl₂). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 11.70 min (major), 13.38 min (minor). ^1^H NMR (400 MHz, CDCl₃) δ 7.97 (dd, J = 6.5, 2.8 Hz, 2H), 7.58 (dd, J = 10.0, 8.1 Hz, 4H), 7.51 – 7.30 (m, 8H), 7.00 (s, 1H), 6.96 (d, J = 15.8 Hz, 1H), 6.45 (d, J = 15.8 Hz, 1H), 3.86 (s, 3H), 3.82 (s, 1H), 3.45 (d, J = 15.2 Hz, 1H), 3.21 (d, J = 15.2 Hz, 1H).

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ESI-HRMS: calcd for C₂₁H₁₈F₂NO₄⁺ ([M+H⁺]) 426.1700, found 426.1695.

(R,E)-methyl

4-(2,6-difluorophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3l

(C₂₁H₁₈F₂NO₄) a white amorphous solid, m. p. 95 – 97 °C; 64% yield, >99% ee. [α]_D^{20} = +52.9 (c = 1.00 in CH₂Cl₂). HPLC DAICEL CHIRALCEL IC, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 10.77 min (major), 14.14 min (minor). ^1^H NMR (400 MHz, CDCl₃) δ 7.97 (dd, J = 6.6, 3.0 Hz, 2H), 7.49 – 7.37 (m, 3H), 7.16 (td, J = 8.2, 4.1 Hz, 1H), 7.01 (t, J = 8.1 Hz, 2H), 6.93 – 6.83 (m, 2H), 6.78 (d, J = 16.2 Hz, 1H), 3.87 (s, 3H), 3.83 (d, J = 5.9 Hz, 1H), 3.44 (d, J = 15.2 Hz, 1H), 3.21 (d, J = 15.2 Hz, 1H).

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ESI-HRMS: calcd for C₂₁H₁₈F₂NO₄⁺ ([M+H⁺]) 386.1198, found 386.1207.
(R,E)-methyl
4-(2,6-dimethylphenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enolate 3m

\[
\text{MeOOC-H-OH} \quad \begin{array}{c}
\text{N} \\
\text{O}
\end{array} \quad \begin{array}{c}
\text{N} \\
\text{O}
\end{array}
\]

\((\text{C}_3\text{H}_3\text{NO}_4)\) a colourless viscous liquid; 93% yield, 98% ee. \([\alpha]_D^{20} = +16.2\) (c = 1.40 in \(\text{CH}_2\text{Cl}_2\)). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, \(\lambda = 254\) nm, retention time: 8.39 min (major), 9.21 min (minor). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.98 (dd, \(J = 6.6, 3.1\) Hz, 2H), 7.56 – 7.31 (m, 3H), 7.15 – 6.98 (m, 4H), 6.91 (d, \(J = 16.1\) Hz, 1H), 5.93 (d, \(J = 16.1\) Hz, 1H), 3.87 (s, 3H), 3.75 (s, 1H), 3.43 (d, \(J = 15.2\) Hz, 1H), 3.25 (d, \(J = 15.2\) Hz, 1H), 2.23 (s, 6H). \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 174.47, 161.37, 147.37, 135.89, 135.80, 133.48, 130.20, 129.20, 128.78, 127.81, 127.53, 126.98, 126.83, 126.14, 76.69, 73.47, 36.09, 20.83. ESI-HRMS: calcd for \(\text{C}_23\text{H}_{24}\text{NO}_4^+\ (\text{[M+H]}^+)\) 378.1700, found 378.1710.
(R,E)-methyl 2-hydroxy-4-(naphthalen-2-yl)-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3n

\[
(C_{25}H_{21}NO_4) \quad \text{a yellow amorphous solid, m. p. 151 – 155 °C; 75% yield, >99% ee.} \quad [\alpha]_D^{20} = +44.2 \quad (c = 0.90 \text{ in CH}_2\text{Cl}_2). \quad \text{HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 85/15, flow rate = 1.0 mL/min,} \quad \lambda = 254 \text{ nm, retention time: 16.83 min (major), 18.80 min (minor).} \quad \text{^1H NMR (400 MHz, CDCl}_3) \delta 7.88 (dd, J = 6.3, 2.7 Hz, 2H), 7.76 – 7.65 (m, 4H), 7.52 (d, J = 8.4 Hz, 1H), 7.41 – 7.26 (m, 5H), 7.11 – 6.83 (m, 2H), 6.45 (d, J = 15.8 Hz, 1H), 3.77 (d, J = 10.7 Hz, 4H), 3.38 (d, J = 15.2 Hz, 1H), 3.14 (d, J = 15.2 Hz, 1H). \quad \text{^13C NMR (101 MHz, CDCl}_3) \delta 174.26, 161.41, 147.35, 133.55, 133.40, 133.23, 131.21, 130.21, 128.79, 128.66, 128.35, 128.13, 127.71, 127.51, 127.22, 126.82, 126.43, 126.21, 126.14, 123.64, 76.82, 53.55, 36.45. \quad \text{ESI-HRMS: calcd for C}_{25}H_{22}NO_4^+ ([M+H]^+) 400.1543, found 400.1540.\]

(R,E)-methyl 2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)-4-(thiophen-2-yl)but-3-enoate 3o

\[
(C_{19}H_{18}NO_4S) \quad \text{a yellow amorphous solid, m. p. 106 – 110 °C; 90% yield, >99% ee.} \quad [\alpha]_D^{20} = +36.1 \quad (c = 1.01 \text{ in CH}_2\text{Cl}_2). \quad \text{HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 75/25, flow rate = 1.0 mL/min,} \quad \lambda = 254 \text{ nm, retention time: 7.81 min (major), 11.69 min (minor).} \quad \text{^1H NMR (400 MHz, CDCl}_3) \delta 8.03 – 7.75 (m, 2H), 7.39 – 7.28 (m, 3H), 7.11 (d, J = 5.0 Hz, 1H), 7.03 – 6.76 (m, 4H), 6.16 (d, J = 15.5 Hz, 1H), 3.77 (s, 4H), 3.32 (d, J = 15.2 Hz, 1H), 3.09 (d, J = 15.2 Hz, 1H). \quad \text{^13C NMR (100 MHz, CDCl}_3) \delta 174.07, 161.41, 147.35, 133.55, 133.40, 133.23, 131.21, 130.19, 128.79, 128.66, 128.35, 128.13, 127.71, 127.51, 127.22, 126.82, 126.43, 126.21, 126.14, 123.64, 76.82, 53.55, 36.45. \quad \text{ESI-HRMS: calcd for C}_{19}H_{18}NO_4S^+ ([M+H]^+) 356.0951, found 356.0955.\]

515
(R,E)-methyl 4-cyclohexyl-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-enoate 3p

(C_{21}H_{26}NO_4) a yellow viscous liquid; 63% yield, >99% ee. \([\alpha]_{D}^{20} = +30.2\) (c = 0.97 in CHCl_3). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, \(\lambda = 254\) nm, retention time: 5.10 min (minor), 5.69 min (major). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.89\) (dd, \(J = 6.5, 3.0\) Hz, 2H), 7.45 – 7.23 (m, 3H), 6.88 (s, 1H), 5.86 (dd, \(J = 15.5, 6.7\) Hz, 1H), 5.54 (dd, \(J = 15.5, 0.8\) Hz, 1H), 3.75 (s, 3H), 3.42 (s, 1H), 3.24 (d, \(J = 15.2\) Hz, 1H), 3.02 (d, \(J = 15.2\) Hz, 1H), 1.99 – 1.82 (m, 1H), 1.69 – 1.53 (m, 4H), 1.29 – 0.86 (m, 6H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 173.70, 160.15, 146.61, 137.22, 129.06, 127.69, 126.50, 125.54, 125.52, 125.03, 75.27, 52.22, 39.14, 35.16, 31.58, 25.02, 24.89. ESI-HRMS: calcd for C\(_{21}\)H\(_{26}\)NO\(_4\)\(^{+}\) ([M+H\(^{+}\)]) 356.1856, found 356.1852.
methyl (R,E)-2-hydroxy-2-((2-(3-methoxyphenyl)oxazol-5-yl)methyl)-4-phenylbut-3-enate 3q

(C$_{22}$H$_{21}$NO$_3$) a colourless viscous liquid; 98% yield, >99% ee. [α]$_D^{20}$ = +29.4 (c = 1.48 in CH$_2$Cl$_2$).

HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 8.27 min (major), 13.44 min (minor). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.52 – 7.39 (m, 2H), 7.32 (d, J = 7.3 Hz, 2H), 7.27 – 7.10 (m, 4H), 6.98 – 6.77 (m, 3H), 6.33 (d, J = 15.8 Hz, 1H), 3.97 – 3.68 (m, 7H), 3.34 (d, J = 15.2 Hz, 1H), 3.10 (d, J = 15.2 Hz, 1H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 174.22, 161.26, 159.84, 147.42, 135.95, 131.10, 129.87, 128.68, 128.65, 128.38, 128.17, 126.84, 126.73, 118.58, 116.85, 110.65, 76.70, 55.38, 53.46, 36.37. ESI-HRMS: calcd for C$_{22}$H$_{21}$NO$_5$ (M+H$^+$) 380.1492, found 380.1490.

methyl (R,E)-2-hydroxy-4-phenyl-2-((2-(p-tolyl)oxazol-5-yl)methyl)but-3-enate 3r

(C$_{22}$H$_{22}$NO$_4$) a colourless viscous liquid; 95% yield, >99% ee. [α]$_D^{20}$ = +34.9 (c = 1.42 in CH$_2$Cl$_2$).

HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 7.56 min (major), 11.09 min (minor). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.76 (d, J = 8.1 Hz, 2H), 7.36 – 7.07 (m, 7H), 6.91 – 6.77 (m, 2H), 6.32 (d, J = 16.0 Hz, 1H), 4.00 – 3.62 (m, 4H), 3.33 (d, J = 15.2 Hz, 1H), 3.09 (d, J = 15.2 Hz, 1H), 2.28 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 174.23, 161.61, 147.42, 135.99, 131.06, 129.47, 128.67, 128.44, 128.15, 126.85, 126.59, 126.10, 124.82, 76.74, 53.44, 36.41, 21.51. ESI-HRMS: calcd for C$_{22}$H$_{22}$NO$_5$ (M+H$^+$) 364.1543, found 364.1549.
(E)-N-(tert-butyl)-2-oxo-4-phenylbut-3-enamide 8

(E)-N-(tert-butyl)-2-hydroxy-4-phenyl-2-((2-phenyloxazol-5-yl)methyl)but-3-enamide 9

(E)-N-(tert-butyl)-2-oxo-4-phenylbut-3-enamide 8

(C_{14}H_{17}NO_{2}) a yellow solid, \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.83 (d, \(J = 16.2\) Hz, 1H), 7.74 (d, \(J = 16.2\) Hz, 1H), 7.65 – 7.52 (m, 2H), 7.41 – 7.24 (m, 3H), 7.00 (s, 1H), 1.36 (s, 9H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 186.38, 160.55, 147.69, 134.48, 131.38, 129.11, 129.03, 118.25, 51.35, 28.35.

(E)-N-(tert-butyl)-2-hydroxy-4-phenyl-2-((2-phenyloxazol-5-yl)methyl)but-3-enamide 9

(C_{24}H_{26}N_{2}O_{3}) a yellow viscous liquid; 18% yield, >99% ee. \([\alpha]_{D}^{20} = +64.2 \text{ (c = 0.27 in CH}_2\text{Cl}_2\text{). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \(\lambda = 254\) nm, retention time: 7.12 min (minor), 9.61 min (major). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.99 – 7.78 (m, 2H), 7.40 – 7.14 (m, 8H), 6.94 (s, 1H), 6.67 (d, \(J = 16.1\) Hz, 1H), 6.56 – 6.42 (m, 2H), 3.45 (d, \(J = 15.3\) Hz, 1H), 3.31 – 2.97 (m, 2H), 1.24 (s, 9H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 170.11, 160.48, 146.55, 134.96, 129.49, 129.33, 128.80, 127.73, 127.60, 127.02, 126.08, 125.83, 125.74, 125.18, 76.57, 50.13, 35.15, 27.57. ESI-HRMS: calced for C_{24}H_{26}N_{2}O_{3}^+ ([M+H^+] ) 391.2016, found 391.2021.
methyl 2-hydroxy-2-phenyl-3-(2-phenyloxazol-5-yl)propanoate 7

(C\(_{19}\)H\(_{17}\)NO\(_4\)) a colourless viscous liquid; 95% yield, >99% ee. 

\([\alpha]_D^{20} = -6.7 \text{ (c 2.34 in CH}_2\text{Cl}_2)\). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, \(\lambda = 254 \text{ nm}, \text{retention time: 7.07 min (major), 8.88 min (minor).}\) 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta = 8.03 – 7.84 \text{ (m, 2H), 7.74 – 7.58 \text{ (m, 2H), 7.52 – 7.28 \text{ (m, 6H), 6.93 \text{ (s, 1H), 4.02 \text{ (s, 1H), 3.83 \text{ (s, 3H), 3.73 \text{ (d, J = 15.6 Hz, 1H), 3.39 \text{ (d, J = 15.2 Hz, 1H).}\)}}}}\) 

\(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta = 174.33, 161.20, 147.69, 140.54, 130.14, 128.76, 128.53, 128.32, 127.52, 126.75, 126.10, 125.45, 77.61, 53.58, 36.63. ESI-HRMS: calcd for C\(_{19}\)H\(_{17}\)NNaO\(_4\)\(^+\) ([M+Na\(^+\)]) 346.1050, found 346.1060.

(R)-methyl 2-hydroxy-4-phenyl-2-(2-phenyloxazol-5-yl)methyl)but-3-ynoate 5a

(C\(_{21}\)H\(_{17}\)NO\(_4\)) a yellow amorphous solid, m. p. 78 – 81 °C; 99% yield, >99% ee. \([\alpha]_D^{20} = -17.4 \text{ (c 1.31 in CH}_2\text{Cl}_2)\). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \(\lambda = 254 \text{ nm}, \text{retention time: 13.48 min (minor), 19.29 min.}\)
(major). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.98 (dd, $J = 6.6, 2.9$ Hz, 2H), 7.42 (dd, $J = 9.6, 6.0$ Hz, 5H), 7.37 – 7.27 (m, 3H), 7.09 (s, 1H), 4.23 – 3.98 (m, 1H), 3.91 (s, 3H), 3.54 (s, 2H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 171.65, 161.56, 146.56, 131.95, 130.24, 129.06, 128.76, 128.33, 127.43, 127.25, 126.19, 121.54, 86.40, 85.83, 70.39, 54.00, 37.01. ESI-HRMS: calcd for C$_{21}$H$_{18}$NO$_4$ $^+$ ([M+H$^+$]) 348.1230, found 348.1230.

(R)-ethyl 2-hydroxy-4-phenyl-2-((2-phenyloxazol-5-yl)methyl)but-3-ynoate 5b

(C$_{22}$H$_{20}$NO$_4$) a yellow amorphous solid, m. p. 81 – 83 °C; 98% yield, >99% ee. $[\alpha]_D^{20} = -14.7$ (c = 1.29 in CH$_2$Cl$_2$). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, $\lambda = 254$ nm, retention time: 12.49 min (minor), 19.10 min (major). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.90 (d, $J = 3.4$ Hz, 2H), 7.33 (dd, $J = 9.6, 5.8$ Hz, 5H), 7.28 – 7.14 (m, 3H), 7.01 (s, 1H), 4.27 (q, $J = 7.1$ Hz, 2H), 4.11 (s, 1H), 3.45 (s, 2H), 1.25 (t, $J = 7.1$ Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 171.15, 161.47, 146.71, 131.92, 130.20, 129.00, 128.74, 128.33, 127.46, 127.21, 126.20, 121.67, 86.68, 85.64, 70.35, 63.37, 36.85, 14.10. ESI-HRMS: calcd for C$_{22}$H$_{20}$NO$_4$ $^+$ ([M+H$^+$]) 362.1387, found 362.1387.
(R)-ethyl 2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)-4-(m-tolyl)but-3-ynoate 5c

(C_{23}H_{21}NO_{4}) a yellow viscous liquid; 91% yield, 98% ee. [α]_{D}^{20} = -14.7 (c = 1.48 in CH_{2}Cl_{2}). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 11.84 min (minor), 16.63 min (major). \(^1\)H NMR (400 MHz, CDCl_{3}) δ 8.03 – 7.77 (m, 2H), 7.41 – 7.22 (m, 3H), 7.21 – 6.99 (m, 5H), 4.27 (q, \(J = 7.1 \text{ Hz} \)), 4.11 (s, 1H), 3.45 (s, 2H), 2.20 (s, 3H), 1.25 (t, \(J = 7.1 \text{ Hz} \)), \(^13\)C NMR (100 MHz, CDCl_{3}) δ 170.13, 160.39, 145.70, 136.98, 131.42, 129.14, 128.83, 127.92, 127.69, 127.16, 126.40, 126.13, 125.14, 120.38, 85.23, 84.80, 69.28, 62.29, 35.79, 20.11, 13.05. ESI-HRMS: calcld for C_{23}H_{22}NO_{4} ([M+H]^+ ) 376.1543, found 376.1542.

(R)-ethyl 4-((4-fluorophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-ynoate 5d

(C_{22}H_{18}FNO_{4}) a yellow viscous liquid; 99% yield, >99% ee. [α]_{D}^{20} = -13.1 (c = 1.82 in CH_{2}Cl_{2}). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 11.09 min (minor), 15.50 min (major). \(^1\)H NMR (400 MHz, CDCl_{3}) δ 7.97 – 7.82 (m, 2H), 7.33 (ddd, \(J\)).
= 7.5, 4.3, 2.2 Hz, 5H), 7.01 (s, 1H), 6.91 (t, J = 8.7 Hz, 2H), 4.28 (q, J = 7.1 Hz, 2H), 4.07 (s, 1H), 3.45 (s, 2H), 1.26 (t, J = 7.1 Hz, 3H). \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 170.03, 163.08, 160.52 (d, J = 14.2 Hz), 145.57, 132.86 (d, J = 8.4 Hz), 129.20, 127.71, 126.36, 126.17, 125.13, 116.68 (d, J = 3.5 Hz), 114.63 (d, J = 22.0 Hz), 85.33 (d, J = 1.2 Hz), 83.57, 69.26, 62.40, 35.78, 13.06. ESI-HRMS: calcd for \(\text{C}_{22}\text{H}_{19}\text{FNO}_4^+\) ([M+H\(^+\)]\(^+\)) 380.1293, found 380.1292.

\begin{table}
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Retention Time & Area & \% Area & Height \\
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(R)-ethyl 4-(4-chlorophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-ynoate 5e

\(\text{(C}_{22}\text{H}_{18}\text{ClNO}_4\text{)}\) a yellow amorphous solid, m. p. 74 – 76 °C; 99% yield, 99% ee. [\(\alpha\)]\(^D\)\(^{20}\) = –9.5 (c = 1.80 in \(\text{CH}_2\text{Cl}_2\)). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \(\lambda = 254\) nm, retention time: 11.48 min (minor), 16.49 min (major). \(^1^H\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.97 – 7.82 (m, 2H), 7.38 – 7.31 (m, 3H), 7.30 – 7.26 (m, 1H), 7.19 (dd, J = 6.6, 2.0 Hz, 3H), 7.01 (s, 1H), 4.28 (q, J = 7.1 Hz, 2H), 4.07 (s, 1H), 3.45 (s, 2H), 1.27 (t, J = 7.1 Hz, 3H). \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 169.95, 160.47, 145.49, 134.08, 132.10, 129.22, 127.71, 127.65, 126.34, 126.19, 125.13, 119.06, 86.52, 83.47, 69.26, 62.45, 35.76, 13.06. ESI-HRMS: calcd for \(\text{C}_{22}\text{H}_{19}\text{FNO}_4^+\) ([M+H\(^+\)]\(^+\)) 396.1003, found 396.0992, \(\text{C}_{22}\text{H}_{19}\text{FNO}_4^+\) ([M+H\(^+\)]\(^+\)) 398.0973, found 398.0984.

\begin{table}
\begin{tabular}{|c|c|c|c|}
\hline
Retention Time & Area & \% Area & Height \\
\hline
1 & 11.094 & 47300 & 0.34 & 2382 \\
2 & 15.504 & 13835260 & 99.66 & 460778 \\
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\end{table}
(R)-ethyl 4-(4-bromophenyl)-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-ynoate 5f

\( \text{C}_{22}\text{H}_{18}\text{BrNO}_{4} \) a yellow viscous liquid; 97% yield, >99% ee. \([\alpha]_{D}^{20} = -8.6 \ (c = 1.35 \text{ in CH}_2\text{Cl}_2)\). 
HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \( \lambda = 254 \) nm, retention time: 12.08 min (minor), 18.02 min (major). 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta 7.95 - 7.82 \ (m, 2H), 7.39 - 7.26 \ (m, 5H), 7.23 - 7.13 \ (m, 2H), 7.00 \ (s, 1H), 4.37 \ (q, J = 7.1 \text{ Hz}, 2H), 3.43 \ (s, 2H), 1.24 \ (t, J = 7.1 \text{ Hz}, 3H) \). 

\(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \( \delta 170.94, 161.49, 146.59, 133.32, 131.61, 130.28, 128.76, 127.34, 127.21, 126.19, 123.37, 120.59, 87.85, 84.58, 70.37, 63.42, 36.80, 14.11 \). 

ESI-HRMS: calcd for \( \text{C}_{22}\text{H}_{19}\text{BrNO}_{4}^+ \ ([M+H]^+) \) 440.0497, found 440.0497, calcd for \( \text{C}_{22}\text{H}_{19}\text{BrNO}_{4}^+ \ ([M+H]^+) \) 442.0477, found 442.0484.

(R)-ethyl 2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)-4-(p-tolyl)but-3-ynoate 5g

\( \text{C}_{23}\text{H}_{21}\text{NO}_{4} \) a yellow viscous liquid; 90% yield, 99% ee. \([\alpha]_{D}^{20} = -10.3 \ (c = 1.48 \text{ in CH}_2\text{Cl}_2)\). 
HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \( \lambda = 254 \) nm, retention
time: 13.26 min (minor), 25.18 min (major). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.99 – 7.82 (m, 2H), 7.38 – 7.28 (m, 3H), 7.24 (d, $J = 8.1$ Hz, 2H), 7.01 (d, $J = 6.2$ Hz, 3H), 4.26 (q, $J = 7.1$ Hz, 2H), 4.11 (s, 1H), 3.45 (s, 2H), 2.25 (s, 3H), 1.25 (t, $J = 7.1$ Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 171.23, 161.45, 146.79, 139.22, 131.82, 130.20, 129.08, 128.74, 127.45, 127.16, 126.20, 118.57, 86.02, 85.84, 70.37, 63.33, 36.86, 21.54, 14.11. ESI-HRMS: calcd for C$_{23}$H$_{22}$NO$_4$ $^+$ ([M+H$^+$]) 376.1543, found 376.1546.

(R)-ethyl 2-hydroxy-4-(4-methoxyphenyl)-2-((2-phenyloxazol-5-yl)methyl)but-3-ynoate 5h

(C$_{23}$H$_{22}$NO$_5$) a yellow viscous liquid; 96% yield, 99% ee. $[\alpha]_{D}^{20} = -8.9$ (c = 1.60 in CH$_2$Cl$_2$). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, $\lambda = 254$ nm, retention time: 20.21 min (minor), 51.62 min (major). $^1$H NMR (400 MHz, CDCl$_3$) δ 8.07 – 7.90 (m, 2H), 7.48 – 7.32 (m, 5H), 7.09 (s, 1H), 6.81 (d, $J = 8.7$ Hz, 2H), 4.35 (q, $J = 7.1$ Hz, 2H), 4.21 (s, 1H), 3.79 (s, 3H), 3.53 (s, 2H), 1.33 (t, $J = 7.1$ Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 171.26, 161.42, 160.08, 146.84, 133.43, 130.19, 128.74, 127.46, 127.14, 126.18, 113.94, 113.67, 85.71, 85.40, 70.39, 63.29, 55.31, 36.88, 14.11. ESI-HRMS: calcd for C$_{23}$H$_{22}$NO$_5$ $^+$ ([M+H$^+$]) 392.1492, found 392.1504.
(R)-ethyl 4-cyclohexyl-2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-ynoate 5i

(C\textsubscript{22}H\textsubscript{25}NO\textsubscript{4}) a colourless viscous liquid; 92% yield, >99% ee. \([\alpha]_D^{20} = -15.1 (c = 1.56 \text{ in CH}_2\text{Cl}_2)\).

HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \(\lambda = 254 \text{ nm}\), retention time: 10.92 min (minor), 13.42 min (major).

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.90 (\text{dd, } J = 6.5, 3.0 \text{ Hz, 2H}), 7.34 (\text{dd, } J = 5.1, 1.7 \text{ Hz, 3H}), 6.96 (\text{s, 1H}), 4.33 – 4.12 (\text{m, 2H}), 3.89 (\text{s, 1H}), 3.33 (\text{s, 2H}), 2.46 – 2.19 (\text{m, 1H}), 1.61 (\text{dd, } J = 30.4, 6.8 \text{ Hz, 4H}), 1.45 – 1.30 (\text{m, 3H}), 1.27 – 1.16 (\text{m, 6H}).\n
\(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 170.58, 160.22, 145.99, 129.08, 127.66, 126.46, 125.09, 89.67, 77.12, 68.91, 61.97, 35.93, 31.09, 27.73, 24.73, 23.52, 13.02.\n
ESI-HRMS: calcd for C\textsubscript{22}H\textsubscript{26}NO\textsubscript{4}\(^+\) ([M+H\(^+\)]) 368.1856, found 368.1868.

(R)-ethyl 2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)-4-(trimethylsilyl)but-3-ynoate 5j

(C\textsubscript{19}H\textsubscript{23}NO\textsubscript{4}Si) a colourless viscous liquid; 98% yield, >99% ee. \([\alpha]_D^{20} = -17.5 (c = 1.25 \text{ in CH}_2\text{Cl}_2)\).

HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \(\lambda = 254 \text{ nm}\), retention time: 6.26 min (minor), 9.14 min (major). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.96 (\text{dd, } J = 6.5, 2.8 \text{ Hz, 2H}),\)
7.55 – 7.32 (m, 3H), 7.02 (s, 1H), 4.42 – 4.19 (m, 2H), 4.05 (s, 1H), 3.42 (s, 2H), 1.31 (t, J = 7.1 Hz, 3H), 0.15 (s, 9H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 171.61, 162.00, 147.24, 130.82, 129.36, 128.07, 127.71, 126.80, 102.97, 91.48, 70.78, 63.88, 37.31, 14.64, 0.28. ESI-HRMS: calcd for C\(_{19}\)H\(_{24}\)NO\(_4\)Si\(^+\) ([M+H\(^+\)]) 358.1469, found 358.1465.

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**methyl (R)-2-hydroxy-2-((2-(3-methoxyphenyl)oxazol-5-yl)methyl)-4-phenylbut-3-ynoate 5k**

A yellow viscous liquid; 99% yield, >99% ee. \([\alpha]_D^{20} = -15.7 \ (c = 1.74 \ \text{in CH}_2\text{Cl}_2)\). HPLC DAICEL CHIRALCEL ID, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, \(\lambda = 254 \ \text{nm}, \) retention time: 13.44 min (minor), 16.84 min (major). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.54 – 7.39 (m, 2H), 7.37 – 7.29 (m, 2H), 7.27 – 7.13 (m, 4H), 7.00 (s, 1H), 6.92 – 6.77 (m, 1H), 4.30 (s, 1H), 3.81 (s, 3H), 3.72 (s, 3H), 3.44 (s, 2H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 171.61, 161.43, 159.82, 146.69, 131.93, 129.85, 129.04, 128.53, 128.33, 127.17, 121.54, 118.67, 116.95, 110.69, 86.49, 85.81, 70.40, 55.37, 53.93, 37.00. ESI-HRMS: calcd for C\(_{22}\)H\(_{20}\)NO\(_5\)\(^+\) ([M+H\(^+\)]) 378.1336, found 378.1336.

\[
\text{Retention Time} & \quad \text{Area} & \quad \% \text{Area} & \quad \text{Height} \\
1 & 13.446 & 7531049 & 49.27 & 273940 \\
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\]
methyl (R)-2-hydroxy-4-phenyl-2-((2-(p-tolyl)oxazol-5-yl)methyl)but-3-ynoate 5l  
(C_{22}H_{19}NO_4) a yellow viscous liquid; 99% yield, >99% ee. [α]_D^{20} = −15.6 (c = 1.60 in CH_2Cl_2).  
HPLC DAICEL CHIRALCEL ID,  
n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 12.92 min (minor), 22.88 min (major).  

$^1$H NMR (400 MHz, CDCl_3) δ 7.78 (d, $J$ = 8.0 Hz, 2H), 7.39 – 7.31 (m, 2H), 7.28 – 7.16 (m, 3H), 7.11 (d, $J$ = 8.0 Hz, 2H), 6.98 (s, 1H), 4.29 (s, 1H), 3.81 (s, 3H), 3.43 (s, 2H), 2.28 (s, 3H).  
$^{13}$C NMR (100 MHz, CDCl_3) δ 171.64, 161.77, 146.24, 140.49, 131.94, 129.44, 129.01, 128.31, 127.04, 126.18, 121.59, 86.54, 85.78, 70.44, 53.91, 37.05, 21.49.  
ESI-HRMS: calcd for C_{22}H_{20}NO_4 $^+ ([M+H]^+)$ 362.1387, found 362.1382.
(R)-2-((2-phenyloxazol-5-yl)methyl)-4-(trimethylsilyl)but-3-yn-1,2-diol 10

(C$_{17}$H$_{21}$NO$_3$Si) a white amorphous solid, m. p. 110 – 113 °C; 80% yield, 98% ee. \([\alpha]_D^{20} = +2.0\) (c = 0.40 in CH$_2$Cl$_2$).

HPLC DAICEL CHIRALCEL IC, n-hexane/2-propanol = 90/10, flow rate = 1.0 mL/min, \(\lambda = 254\) nm, retention time: 11.42 min (major), 13.49 min (minor). \(^1\)H NMR (400 MHz, CDCl$_3$) \(\delta 7.98\) (dd, \(J = 6.6, 2.9\) Hz, 2H), 7.44 – 7.35 (m, 3H), 7.06 (s, 1H), 3.87 – 3.72 (m, 2H), 3.65 (dd, \(J = 10.8, 6.8\) Hz, 1H), 3.17 (q, \(J = 15.0\) Hz, 3H), 0.12 (s, 9H).

\(^{13}\)C NMR (100 MHz, CDCl$_3$) \(\delta 161.79, 148.36, 130.71, 129.20, 127.74, 127.09, 126.66, 105.34, 91.93, 71.11, 69.17, 35.15, 0.28\).

ESI-HRMS: calcd for C$_{17}$H$_{21}$NO$_3$Si\(^{+} ([M+H]^{+})\) 316.1363, found 316.1366.

(R)-ethyl 2-hydroxy-2-((2-phenyloxazol-5-yl)methyl)but-3-ynoate 11

(C$_{16}$H$_{15}$NO$_4$) a colourless viscous liquid; 90% yield, 98% ee. \([\alpha]_D^{20} = -21.8\) (c = 1.52 in CH$_2$Cl$_2$). HPLC DAICEL CHIRALCEL IB, n-hexane/2-propanol = 80/20, flow rate = 1.0 mL/min, \(\lambda = 254\) nm, retention time: 6.83 min (minor), 7.41 min (major). \(^1\)H NMR (400 MHz, CDCl$_3$) \(\delta 7.90\) (dd, \(J = 6.6, 2.9\) Hz, 2H), 7.42 – 7.30 (m, 3H), 6.98 (s, 1H), 4.27 (q, \(J = 7.1\) Hz, 2H), 3.92 (s, 1H), 3.38 (s, 2H), 2.53 (s, 1H), 1.27 (t, \(J = 7.1\) Hz, 3H). \(^{13}\)C NMR (100 MHz, CDCl$_3$) \(\delta 169.73, 148.36, 130.71, 129.20, 127.74, 127.09, 126.66, 105.34, 91.93, 71.11, 69.17, 35.15, 0.28\).

ESI-HRMS: calcd for C$_{16}$H$_{15}$NNaO$_4^{+} ([M+Na]^{+})$ 308.0893, found 308.0896.
(R)-ethyl 2-(1-benzyl-1H-1,2,3-triazol-5-yl)-2-hydroxy-3-(2-phenyloxazol-5-yl)propanoate 12

(C$_{23}$H$_{22}$N$_{4}$O$_{4}$) a yellow viscous liquid; 95% yield, 99% ee. [α]$_{(D)}^{20}$ = −1.0 (c = 1.97 in CH$_2$Cl$_2$). HPLC DAICEL CHIRALCEL IC, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 31.97 min (minor), 39.88 min (major). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.84 (dd, J = 6.3, 2.7 Hz, 2H), 7.44 (s, 1H), 7.37 − 7.21 (m, 6H), 7.17 − 7.06 (m, 2H), 6.85 (s, 1H), 5.40 (s, 2H), 4.35 (s, 1H), 4.27 − 4.08 (m, 2H), 3.79 (d, J = 15.4 Hz, 1H), 3.46 (d, J = 15.4 Hz, 1H), 1.17 (t, J = 7.1 Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 172.82, 161.28, 148.92, 147.20, 134.19, 130.15, 129.16, 128.87, 128.74, 128.18, 127.43, 126.93, 126.08, 121.76, 73.91, 63.15, 54.31, 35.30, 14.09. ESI-HRMS: calcd for C$_{23}$H$_{23}$N$_{4}$O$_{4}$ $^{+}$ ([M+H$^+$]) 419.1714, found 419.1726.

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$^{+}$ESI, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 31.941 min (minor), 39.883 min (major). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.36 (d, J = 5.3 Hz, 2H), 7.44 (s, 1H), 7.37 − 7.21 (m, 6H), 7.17 − 7.06 (m, 2H), 6.86 (s, 1H), 5.40 (s, 2H), 4.35 (s, 1H), 4.27 − 4.08 (m, 2H), 3.79 (d, J = 15.4 Hz, 1H), 3.46 (d, J = 15.4 Hz, 1H), 1.17 (t, J = 7.1 Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 172.82, 161.28, 148.92, 147.20, 134.19, 130.15, 129.16, 128.87, 128.74, 128.18, 127.43, 126.93, 126.08, 121.76, 73.91, 63.15, 54.31, 35.30, 14.09. ESI-HRMS: calcd for C$_{23}$H$_{23}$N$_{4}$O$_{4}$ $^{+}$ ([M+H$^+$]) 419.1714, found 419.1726.

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$^{+}$ESI, n-hexane/2-propanol = 70/30, flow rate = 1.0 mL/min, λ = 254 nm, retention time: 31.969 min (minor), 39.883 min (major). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.36 (d, J = 5.3 Hz, 2H), 7.44 (s, 1H), 7.37 − 7.21 (m, 6H), 7.17 − 7.06 (m, 2H), 6.86 (s, 1H), 5.40 (s, 2H), 4.35 (s, 1H), 4.27 − 4.08 (m, 2H), 3.79 (d, J = 15.4 Hz, 1H), 3.46 (d, J = 15.4 Hz, 1H), 1.17 (t, J = 7.1 Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 172.82, 161.28, 148.92, 147.20, 134.19, 130.15, 129.16, 128.87, 128.74, 128.18, 127.43, 126.93, 126.08, 121.76, 73.91, 63.15, 54.31, 35.30, 14.09. ESI-HRMS: calcd for C$_{23}$H$_{23}$N$_{4}$O$_{4}$ $^{+}$ ([M+H$^+$]) 419.1714, found 419.1726.

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7. References


8. Copies of $^1$H NMR and $^{13}$C NMR spectra for the reactants and the products