SUPPORTING INFORMATION

for

Chiral Cobalt-Catalyzed Enantioselective Aerobic Oxidation of $\alpha$–Hydroxy Esters

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General considerations

Cobalt(II) acetate tetrahydrate and 2,2,6,6-tetramethyl-piperidin-1-oxyl (TEMPO) were purchased from Sigma-Aldrich chemical company and used as received. (S)-BINAM purchased from Gerchem Labs Pvt. Ltd. Hyderabad, India. Thin-layer chromatography (TLC) was performed using Merck silica gel 60 F254 precoated plates (0.25 mm) and visualized by UV fluorescence quenching. Silica gel for column chromatography (particle size 100-200 mesh) purchased from SRL India. Optical rotations were measured with Autopol IV - Rudolph Research Analytical Polarimeter. $^1$H and $^{13}$C NMR spectra were recorded on a Bruker 400 MHz instrument. $^1$H NMR spectra were reported relative to Me$_4$Si (δ 0.0 ppm) or residual CHCl$_3$ (δ 7.26 ppm). $^{13}$C NMR were reported relative to CDCl$_3$ (δ 77.16 ppm). FTIR spectra were recorded on a Nicolet 6700 spectrometer and are reported in frequency of absorption (cm$^{-1}$). High resolution mass spectra (HRMS) were recorded on Q-Tof Micro mass spectrometer. The enantiomeric excess (%ee) of α-hydroxy esters were determined by JASCO uv-2070 plus HPLC and Shimadzu UFLC systems using Daicel chemical industries, Ltd ChiralPAK AS-H (0.46cm φ x 25cm) column. $^1$H and $^{13}$C NMR and HRMS Spectral data have been included for all compounds. HPLC spectra for the %ee determination of all optically active α-hydroxy esters are given in this supporting information.

Synthesis of Ligand L5

Scheme 1
Experimental Procedure

Synthesis of L5:\: In a 50 mL two neck round bottom flask equipped with reflux condenser, a mixture of L1 (502.7 mg, 1.77 mmol) and salicylaldehyde (0.38 mL, 3.54 mmol) in ethanol (20 mL) was taken and refluxed for 6 hours. The reaction mixture was cooled to room temperature, the solution was filtered off. The solvent was removed under reduced pressure and the residue was recrystallized from benzene : hexane (1:3, V/V) to give L5 (740 mg, 85\%) as a yellow compound. Mp 181 °C (lit.\^1 181-183 °C); R\_f 0.41 (in hexanes : ethyl acetate, 80:20 V/V); [α]D\_25 = 509.2 (c = 0.5 in chloroform ); \(^1\)H NMR (400 MHz, CDCl\_3): δ 12.12 (s, 2H), 8.69 (s, 2H), 8.13 (d, J = 9.2 Hz, 2H), 8.00 (d, J = 8 Hz, 2H), 7.67 (d, J = 8.8 Hz, 2H), 7.46-7.50 (m, 2H), 7.27-7.33 (m, 4H), 7.19-7.23 (m, 4H), 6.78-6.82 (m, 2H), 6.73 (d, J = 8 Hz, 2H); \(^13\)C NMR (100 MHz, CDCl\_3): δ 161.9, 160.8, 143.8, 133.2, 132.8, 132.5, 132.2, 130.0, 129.5, 128.3, 127.0, 126.5, 125.9, 119.3, 118.7, 117.1, 116.9; IR (Neat) 3056, 1608, 1282, 750 cm\(^{-1}\); HRMS (m/z): [M+1]\(^+\) calcld for C\(_{34}\)H\(_{25}\)N\(_2\)O\(_2\), 493.1916; found, 493.1917.

General experimental procedure for oxidative kinetic resolution

A mixture of L5 (49.2 mg, 0.1 mmol) and Cobalt(II) acetate tetrahydrate (25 mg, 0.1 mmol) in 8 mL of toluene was stirred at room temperature for 10 min, TEMPO (7.82 mg, 0.05 mmol) was then added to the reaction mixture. After stirring for 5 min, (±)-Hydroxy-phenyl-acetic acid methyl ester (166 mg, 1 mmol) was added and then reaction stirred under an O\(_2\) atmosphere (using O\(_2\) balloon) for 11 hours at 90 °C. The reaction mixture was concentrated and the resulting residue was purified by silica gel column chromatography (eluents: hexanes-ethylacetate) to give the Methyl phenylglyoxylate (75.5 mg, yield 46\%) and unreacted Hydroxy-phenyl-acetic acid methyl ester (78 mg, yield 47\%).

Hydroxy-phenyl-acetic acid methyl ester: Colorless oil; R\_f 0.33; (hexanes : ethyl acetate, 80:20 v/v); [α]D\_30 = -108.7 (c = 1 in CHCl\_3 ); \(^1\)H NMR (400 MHz, CDCl\_3): δ 7.44-7.41 (m, 2H), 7.40-7.33 (m, 3H), 5.18 (d, J = 5.6 Hz, 1H), 3.77 (s, 3H), 3.14 (d, J = 5.6 Hz, 1H); \(^13\)C NMR (100 MHz, CDCl\_3): δ 174.3, 138.4, 128.8, 128.7, 126.7, 73.0, 53.2; IR
(Neat) 3457, 2954, 1735, 1221, 1071 cm\(^{-1}\); HRMS (m/z): [MNa\(^+\)] calcd for C\(_9\)H\(_{10}\)O\(_3\)Na\(_1\), 189.0528; found, 189.0526. The enantiomeric excess (\(\%\text{ee}\)) was determined to be 78% by HPLC using ChiralPAK AS-H column (25% i-PrOH/ hexanes, 1 mL/min, 220 nm): \(t_R\) (minor, 5.1 min), \(t_R\) (major, 5.6 min).

Methyl phenylglyoxylate: Colorless oil; \(R_f\) 0.63; (hexanes : ethyl acetate, 80:20 v/v): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 8.02 (d, \(J = 7.6\) Hz, 2H), 7.67 (t, \(J = 7.2\) Hz, 1H), 7.52 (t, \(J = 7.6\) Hz, 2H), 3.99 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 186.1, 164.1, 135.0, 132.4, 130.1, 128.9, 52.8 ; IR (Neat) 2963, 1741, 1688, 1208, 1003 cm\(^{-1}\); HRMS (m/z): [MNa\(^+\)] calcd for C\(_9\)H\(_8\)O\(_3\)Na\(_1\), 187.0371; found, 187.0374.

Spectral data for all \(\alpha\)-hydroxy esters and \(\alpha\)-keto esters

Colorless oil; \(R_f\) 0.33; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30}\) = -108.7 (c = 1 in CHCl\(_3\)); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.44-7.41 (m, 2H), 7.40-7.33 (m, 3H), 5.18 (d, \(J = 5.6\) Hz, 1H), 3.77 (s, 3H), 3.14 (d, \(J = 5.6\) Hz, 1H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 174.3, 138.4, 128.8, 128.7, 126.7, 73.0, 53.2; IR (Neat) 3457, 2954, 1735, 1221, 1071 cm\(^{-1}\); HRMS (m/z): [MNa\(^+\)] calcd for C\(_9\)H\(_{10}\)O\(_3\)Na\(_1\), 189.0528; found, 189.0526. The enantiomeric excess (\(\%\text{ee}\)) was determined to be 78% by HPLC using ChiralPAK AS-H column (25% i-PrOH/ hexanes, 1 mL/min, 220 nm): \(t_R\) (minor, 5.1 min), \(t_R\) (major, 5.6 min).

Colorless oil; \(R_f\) 0.38; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30}\) = -127.7 (c = 1 in CHCl\(_3\)); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.40-7.45 (m, 2H),
7.30-7.39 (m, 3H), 5.16 (d, \(J = 5.6\) Hz, 1H), 4.13-4.32 (m, 2H), 3.46 (d, \(J = 5.6\) Hz, 1H), 1.23 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 173.7, 138.5, 128.6, 128.4, 126.6, 73.0, 62.2, 14.0;\) IR (Neat) 3460, 2982, 1728, 1182, 1065 cm\(^{-1}\); HRMS (\(m/z\)): [MNa\(^{+}\)] calcd for C\(_{10}\)H\(_{12}\)O\(_3\)Na\(_{1}\), 203.0684; found, 203.0687. The enantiomeric excess (\(\%\text{ee}\)) was determined to be 97% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): \(t_R\) (minor, 8.7 min), \(t_R\) (major, 9.2 min).

Colorless oil; \(R_f\) 0.35; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30} = -67.9\ (c = 1\) in CHCl\(_3\)); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 7.40-7.45\) (m, 2H), 7.29-7.38 (m, 3H), 5.17 (d, \(J = 6\) Hz, 1H), 4.06-4.17 (m, 2H), 3.48-3.56 (m, 1H), 1.60 (sextet, \(J = 7.2\) Hz, 2H), 0.82 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 173.9, 138.6, 128.6, 128.4, 126.6, 72.9, 67.7, 21.9, 10.2;\) IR (Neat) 3453, 2968, 1730, 1180, 1064 cm\(^{-1}\); HRMS (\(m/z\)): [MNa\(^{+}\)] calcd for C\(_{11}\)H\(_{14}\)O\(_3\)Na\(_{1}\), 217.0841; found, 217.0843. The enantiomeric excess (\(\%\text{ee}\)) was determined to be 91% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 220 nm): \(t_R\) (minor, 7.4 min), \(t_R\) (major, 8.5 min).

Colorless oil; \(R_f\) 0.49; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30} = -173.5\ (c = 2\) in CHCl\(_3\)); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 7.29-7.34\) (m, 2H), 7.15-7.25 (m, 3H), 5.02 (d, \(J = 6\) Hz, 1H), 4.94 (septet, \(J = 6\) Hz, 1H), 3.77 (d, \(J = 4.4\) Hz, 1H), 1.15 (d, \(J = 6\) Hz, 3H), 0.98 (d, \(J = 6\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 173.3, 138.6, 128.6, 128.4, 126.5, 73.0, 70.2, 21.8, 21.5;\) IR (Neat) 3458, 2982, 1726, 1181, 1098 cm\(^{-1}\); HRMS (\(m/z\)): [MNa\(^{+}\)] calcd for C\(_{11}\)H\(_{14}\)O\(_3\)Na\(_{1}\), 217.0841; found, 217.0845. The enantiomeric excess (\(\%\text{ee}\)) was determined to be 84% by HPLC using ChiralPAK.
AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 220 nm): t<sub>R</sub> (major, 6.7 min), t<sub>R</sub> (minor, 7.2 min).

Colorless oil; R<sub>f</sub> 0.32; (hexanes : ethyl acetate, 80:20 v/v):

[α]<sup>D</sup> <sub>30</sub> = -62.9 (c = 1 in CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.39-7.44 (m, 2H), 7.28-7.38 (m, 3H), 5.16 (d, J = 5.2 Hz, 1H), 4.10-4.22 (m, 2H), 3.53 (d, J = 3.6 Hz, 1H), 1.51-1.60 (m, 2H), 1.24 (sextet, J = 7.6 Hz, 2H), 0.85 (t, J = 7.6 Hz, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ 173.8, 138.5, 128.6, 128.4, 126.6, 72.9, 66.0, 30.4, 18.9, 13.6; IR (Neat) 3469, 2959, 1731, 1180, 1066 cm<sup>-1</sup>; HRMS (m/z): [MNa]<sup>+</sup> calcd for C<sub>12</sub>H<sub>16</sub>O<sub>3</sub>Na, 231.0997; found, 231.0996. The enantiomeric excess (%<em>ee</em>) was determined to be 90% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 220 nm): t<sub>R</sub> (minor, 6.2 min), t<sub>R</sub> (major, 8.3 min).

Colorless oil; R<sub>f</sub> 0.54; (hexanes : ethyl acetate, 80:20 v/v):

[α]<sup>D</sup> <sub>30</sub> = -118.7 (c = 1.3 in CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.43 (d, J = 7.6 Hz, 2H), 7.28-7.39 (m, 3H), 5.18 (d, J = 5.2 Hz, 1H), 3.98-4.00 (m, 2H), 3.53 (d, J = 5.6 Hz, 1H), 1.87 (septet, J = 6.4 Hz, 1H), 0.81 (dd, J = 6.8 Hz, 2.8 Hz, 6H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ 173.9, 138.6, 128.6, 128.5, 126.6, 72.9, 72.2, 27.8, 18.9; IR (Neat) 3482, 2962, 1735, 1183, 1099 cm<sup>-1</sup>; HRMS (m/z): [MNa]<sup>+</sup> calcd for C<sub>12</sub>H<sub>16</sub>O<sub>3</sub>Na, 231.0997; found, 231.0995. The enantiomeric excess (%<em>ee</em>) was determined to be 84% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 220 nm): t<sub>R</sub> (minor, 5.7 min), t<sub>R</sub> (major, 7.2 min).
Colorless oil; \( R_f \) 0.42; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30} = -88.2 \ (c = 1 \ \text{in CHCl}_3\); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 7.40-7.45 (m, 2H), 7.29-7.39 (m, 3H), 5.16 (d, \( J = 5.6 \) Hz, 1H), 4.12-4.18 (m, 2H), 3.49 (d, \( J = 5.6 \) Hz, 1H), 1.53-1.62 (m, 2H), 1.12-1.128 (m, 4H), 0.83 (t, \( J = 7.2 \) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 173.9, 138.6, 128.7, 128.5, 126.7, 73.0, 66.4, 28.2, 27.9, 22.3, 14.0; IR (Neat) 3446, 2957, 2872, 1731, 1183, 1067 cm\(^{-1}\); HRMS (m/z): \([\text{MNa}]^+\) calcd for C\(_{13}\)H\(_{18}\)O\(_3\)Na\(_1\), 245.1154; found, 245.1157. The enantiomeric excess (\%ee) was determined to be 94% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): \( t_R \) (minor, 6.5 min), \( t_R \) (major, 8.5 min).

Colorless oil; \( R_f \) 0.35; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30} = -80.7 \ (c = 1 \ \text{in CHCl}_3\); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 7.39-7.44 (m, 2H), 7.30-7.38 (m, 3H), 5.15 (d, \( J = 5.6 \) Hz, 1H), 4.12-4.25 (m, 2H), 3.49 (d, \( J = 5.6 \) Hz, 1H), 1.43-1.56 (m, 3H), 0.85 (d, \( J = 6.4 \) Hz, 3H), 0.82 (d, \( J = 6.4 \) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 173.9, 138.6, 128.7, 128.5, 126.6, 73.0, 65.0, 37.2, 25.0, 22.5, 22.4; IR (Neat) 3445, 2958, 1731, 1183, 1067 cm\(^{-1}\); HRMS (m/z): \([\text{MNa}]^+\) calcd for C\(_{13}\)H\(_{18}\)O\(_3\)Na\(_1\), 245.1154; found, 245.1157. The enantiomeric excess (\%ee) was determined to be 98% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): \( t_R \) (minor, 5.9 min), \( t_R \) (major, 8.4 min).

Colorless oil; \( R_f \) 0.47; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30} = -70.3 \ (c = 1 \ \text{in CHCl}_3\); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 7.42 (d, \( J = \)}
7.2 Hz, 2H), 7.29-7.39 (m, 3H), 5.16 (d, \( J = 5.6 \) Hz, 1H), 4.15 (t, \( J = 6.8 \) Hz, 2H), 3.50 (d, \( J = 5.6 \) Hz, 1H), 1.52-1.60 (m, 2H), 1.15-1.28 (m, 6H), 0.84 (t, \( J = 7.2 \) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 173.9, 138.6, 128.7, 128.5, 126.6, 73.0, 66.5, 31.3, 28.5, 25.4, 22.6, 14.0; IR (Neat) 3464, 2956, 2930, 2858, 1731, 1455, 1182, 1067 cm\(^{-1}\); HRMS (m/z): [MNa\(^+\)] calcd for C\(_{14}\)H\(_{20}\)O\(_3\)Na\(_1\), 259.1310; found, 259.1310. The enantiomeric excess (\( \%\text{ee} \)) was determined to be 98% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): \( t_R \) (minor, 6.1 min), \( t_R \) (major, 8.2 min).

White solid; mp = 56 °C (lit. 53-54 °C); \( R_f \) 0.48; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30} = -86.7 \) (c = 1 in CHCl\(_3\) ); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 7.40 (d, \( J = 7.2 \) Hz, 2H), 7.28-7.38 (m, 3H), 5.04 (s, 1H), 3.52 (bs, 1H), 1.40 (s, 9H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 173.0, 139.1, 128.5, 128.2, 126.5, 83.2, 73.1, 27.9; IR (Neat) 3476, 2977, 2930, 1729, 1157, 912 cm\(^{-1}\); HRMS (m/z): [MNa\(^+\)] calcd for C\(_{12}\)H\(_{16}\)O\(_3\)Na\(_1\), 231.0997; found, 231.0997. The enantiomeric excess (\( \%\text{ee} \)) was determined to be 98% by HPLC using ChiralPAK OD-H column (25% i-PrOH/ hexanes, 0.5 mL/min, 200 nm): \( t_R \) (minor, 8.0 min), \( t_R \) (major, 11.3 min).

Colorless oil; \( R_f \) 0.32; (hexanes : ethyl acetate, 80:20 v/v): \([\alpha]_D^{30} = -90.5 \) (c = 0.4 in CHCl\(_3\) ); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 7.41-7.46 (m, 2H), 7.30-7.40 (m, 3H), 5.78-5.89 (m, 1H), 5.21 (s, 2H), 5.15-5.19 (m, 1H), 4.60-4.72 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 173.3, 138.4, 131.2, 128.6, 128.5, 126.6, 118.7, 73.0, 66.4; IR (Neat) 3442, 2932, 1731, 1596, 1454, 1212, 1164 cm\(^{-1}\); HRMS (m/z): [MNa\(^+\)] calcd for C\(_{11}\)H\(_{12}\)O\(_3\)Na\(_1\), 215.0684; found, 215.0686. The enantiomeric excess (\( \%\text{ee} \)) was determined to be 99.9% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): \( t_R \) (major, 5.1 min).
White solid; mp = 62 °C (lit. 63-64 °C); R$_f$ 0.30; (hexanes : ethyl acetate, 70:30 v/v): $[\alpha]^D_{30} = -129.1$ ($c = 1$ in CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.33 (dd, $J = 2.0$ Hz, 6.8 Hz, 2H), 6.90 (dd, $J = 2.0$ Hz, 6.8 Hz, 2H), 5.13 (d, $J = 5.6$ Hz, 1H), 3.81 (s, 3H), 3.76 (s, 3H), 3.39 (d, $J = 5.6$ Hz, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 174.5, 159.9, 130.6, 128.1, 114.2, 72.6, 55.4, 53.1; IR (Neat) 3452, 2948, 1738, 1248, 913 cm$^{-1}$; HRMS (m/z): [MNa]$^+$ calcd for C$_{10}$H$_{12}$O$_4$Na$_1$, 219.0997; found, 219.0995. The enantiomeric excess (%ee) was determined to be 90% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): t$_R$ (major, 21.5 min), t$_R$ (minor, 24.8 min).

Colorless oil; R$_f$ 0.35; (hexanes : ethyl acetate, 80:20 v/v): $[\alpha]^D_{30} = -82.6$ ($c = 1$ in CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.30 (d, $J = 8$ Hz, 2H), 7.18 (d, $J = 8$ Hz, 2H), 5.15 (d, $J = 5.6$ Hz, 1H), 3.76 (s, 3H), 3.40 (d, $J = 5.6$ Hz, 1H), 2.35 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 174.4, 138.4, 135.5, 129.4, 126.6, 72.9, 53.0, 21.3; IR (Neat) 3477, 2952, 1738, 1081, 921 cm$^{-1}$; HRMS (m/z): [MNa]$^+$ calcd for C$_{10}$H$_{12}$O$_3$Na$_1$, 203.1048; found, 203.1043. The enantiomeric excess (%ee) was determined to be 90% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): t$_R$ (major, 10.3 min), t$_R$ (minor, 12.1 min).
White solid; mp = 64 °C; Rf 0.29; (hexanes : ethyl acetate, 80:20 v/v): [α]D

30 = -55.8 (c = 1 in CHCl3); 1H NMR (400 MHz, CDCl3): δ 7.70 (d, J = 8 Hz, 2H), 7.18 (d, J = 8 Hz, 2H), 5.12 (s, 1H), 3.76 (s, 3H), 3.47 (bs, 1H); 13C NMR (100 MHz, CDCl3): δ 173.7, 138.0, 137.8, 128.6, 94.4, 72.4, 72.5, 53.3; IR (Neat) 3443, 2937, 1737, 1224, 1244, 1077 cm−1; HRMS (m/z): [MHNa]+ calcd for C9H10O3I1Na1, 315.9570; found, 315.9572. The enantiomeric excess (%ee) was determined to be 99.64% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): tR (major, 11.0 min), tR (minor, 12.4 min).

Colorless oil; Rf 0.25; (hexanes : ethyl acetate, 80:20 v/v): [α]D

30 = -83.0 (c = 1 in CHCl3); 1H NMR (400 MHz, CDCl3): δ 7.50 (d, J = 8.4 Hz, 2H), 7.31 (d, J = 8 Hz, 2H), 5.14 (d, J = 4.4 Hz, 1H), 3.77 (s, 3H), 3.47 (d, J = 4.8 Hz, 1H); 13C NMR (100 MHz, CDCl3): δ 173.8, 137.3, 131.9, 128.4, 122.7, 72.4, 63.3; IR (Neat) 3401, 2952, 1739, 1252, 913 cm−1; HRMS (m/z): [MHNa]+ calcd for C9H10O3Br1Na1, 267.9711; found, 267.9713. The enantiomeric excess (%ee) was determined to be 85% by HPLC using ChiralPAK AS-H column (10% i-PrOH/ hexanes, 1 mL/min, 190 nm): tR (minor, 8.9 min), tR (major, 10.4 min).

Colorless oil; Rf 0.63; (hexanes : ethyl acetate, 80:20 v/v): 1H NMR (400 MHz, CDCl3): δ 8.02 (d, J = 7.6 Hz, 2H), 7.67 (t, J = 7.2 Hz, 1H), 7.52 (t, J = 7.6 Hz, 2H), 3.99 (s, 3H); 13C NMR (100 MHz, CDCl3): δ 186.1, 164.1, 135.0, 132.4,
130.1, 128.9, 52.8; IR (Neat) 2963, 1741, 1688, 1208, 1003 cm\(^{-1}\); HRMS (m/z): \([\text{MH}]^+\) calcd for C\(_9\)H\(_9\)O\(_3\), 165.0552; found, 165.0547.

Colorless oil; \(R_f\) 0.69; (hexanes : ethyl acetate, 80:20 v/v): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.99-8.04 (m, 2H), 7.66 (t, \(J = 7.6\) Hz, 1H), 7.52 (t, \(J = 7.6\) Hz, 2H), 4.46 (q, \(J = 7.2\) Hz, 2H), 1.43 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 186.4, 163.8, 134.9, 132.4, 130.0, 128.9, 62.3, 14.1; IR (Neat) 2984, 2920, 1732, 1686, 1196, 1175 cm\(^{-1}\); HRMS (m/z): \([\text{MNa}]^+\) calcd for C\(_{10}\)H\(_{10}\)O\(_3\)Na\(_1\), 201.0528; found, 201.0528.

Colorless oil; \(R_f\) 0.76; (hexanes : ethyl acetate, 80:20 v/v): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.98-8.03 (m, 2H), 7.63-7.68 (m, 1H), 7.51 (t, \(J = 8\) Hz, 2H), 4.35 (t, \(J = 6.8\) Hz, 2H), 1.81 (Sextet, \(J = 7.2\) Hz, 2H), 1.01 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 186.6, 164.1, 135.0, 132.6, 130.1, 129.0, 67.9, 22.0, 10.4; IR (Neat) 2970, 1736, 1690, 1199, 1177, 991 cm\(^{-1}\); HRMS (m/z): \([\text{MNa}]^+\) calcd for C\(_{11}\)H\(_{12}\)O\(_3\)Na\(_1\), 215.0684; found, 215.0683.

Colorless oil; \(R_f\) 0.75; (hexanes : ethyl acetate, 80:20 v/v): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.98-8.02 (m, 2H), 7.63-7.68 (m, 1H), 7.51 (t, \(J = 8\) Hz, 2H), 5.33 (Septet, \(J = 6\) Hz, 1H), 1.41 (d, \(J = 6\) Hz, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 186.8, 163.7, 134.9, 132.5, 130.0, 128.9, 70.7, 21.8; IR (Neat) 2984, 2920, 1728, 1687,
1201, 1176, 1101, 986 cm\(^{-1}\); HRMS (m/z): [MNa]\(^+\) calcd for C\(_{11}\)H\(_{12}\)O\(_3\)Na\(_1\), 215.0684; found, 215.0681.

![n-Butyl phenylglyoxylate](image)

Colorless oil; R\(_f\) 0.74; (hexanes : ethyl acetate, 80:20 v/v): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.98-8.03 (m, 2H), 7.63-7.69 (m, 1H), 7.48-7.54 (m, 2H), 4.40 (t, \(J = 6.8\) Hz, 2H), 1.77 (Quintet, \(J = 6.8\) Hz, 2H), 1.45 (Sextet, \(J = 7.6\) Hz, 2H), 0.94-1.0 (m, 3H); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 186.6, 164.1, 135.0, 132.6, 130.1, 129.0, 66.2, 30.6, 19.1, 13.7; IR (Neat) 2961, 2875, 1733, 1687, 1196, 1175 cm\(^{-1}\); HRMS (m/z): [MNa]\(^+\) calcd for C\(_{12}\)H\(_{14}\)O\(_3\)Na\(_1\), 229.0841; found, 229.0845.

![\(t\)-Butyl phenylglyoxylate](image)

Colorless oil; R\(_f\) 0.74; (hexanes : ethyl acetate, 80:20 v/v): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.98-8.03 (m, 2H), 7.64-7.69 (m, 1H), 7.49-7.55 (m, 2H), 4.18 (d, \(J = 6.8\) Hz, 2H), 2.09 (Septet, \(J = 7.2\) Hz, 1H), 1.01 (d, \(J = 6.8\) Hz, 6H); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 186.7, 164.2, 135.0, 132.6, 130.1, 129.0, 72.2, 27.8, 19.1; IR (Neat) 2964, 1733, 1687, 1196, 995 cm\(^{-1}\); HRMS (m/z): [MNa]\(^+\) calcd for C\(_{12}\)H\(_{14}\)O\(_3\)Na\(_1\), 229.0841; found, 229.0839.

![\(n\)-Pentyl phenylglyoxylate](image)

Colorless oil; R\(_f\) 0.67; (hexanes : ethyl acetate, 80:20 v/v): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.98-8.02 (m, 2H), 7.63-7.68 (m, 1H), 7.51 (t, \(J = 8\) Hz, 2H), 4.38 (t, \(J = 6.8\) Hz, 2H), 1.78 (Quintet, \(J = 7.2\) Hz, 2H), 1.30-1.45(m, 4H), 0.914 (t, \(J = 7.2\) Hz, 3H); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 186.6, 164.1, 135.0, 132.6, 130.1, 129.0,
66.5, 28.3, 28.0, 22.4, 14.0; IR (Neat) 2958, 2934, 2872, 1733, 1687, 1196, 1175 cm\(^{-1}\);
HRMS (m/z): [MNa]\(^+\) calc for C\(_{13}\)H\(_{16}\)O\(_3\)Na\(_1\), 243.0997; found, 243.0994.

Colorless oil; R\(_f\) 0.71; (hexanes : ethyl acetate, 80:20 v/v):
\(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 7.98-8.02\) (m, 2H), 7.66 (t, \(J = 7.6\) Hz, 1H), 7.51 (t, \(J = 7.6\) Hz, 2H), 4.42 (t, \(J = 7.2\) Hz, 2H), 1.75 (q, \(J = 6.8\) Hz, 1H), 1.67 (q, \(J = 6.8\) Hz, 2H), 0.96 (d, \(J = 6.4\) Hz, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 186.6, 164.1, 135.0, 132.5, 130.1, 129.0, 65.0, 37.1, 34.2, 25.0, 22.5\); IR (Neat) 2959, 1732, 1687, 1196, 1174 cm\(^{-1}\);
HRMS (m/z): [MNa]\(^+\) calc for C\(_{13}\)H\(_{16}\)O\(_3\)Na\(_1\), 243.0997; found, 243.0992.

Colorless oil; R\(_f\) 0.65; (hexanes : ethyl acetate, 80:20 v/v):
\(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 7.98-8.02\) (m, 2H), 7.62-7.68 (m, 1H), 7.48-7.54 (m, 2H), 4.35-4.41 (m, 2H), 1.77 (Quintet, \(J = 7.2\) Hz, 2H), 1.37-1.44(m, 2H), 1.26-1.34 (m, 4H), 0.85-0.92 (m, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 186.5, 164.1, 134.9, 132.5, 130.0, 128.9, 66.4, 31.3, 28.4, 25.5, 22.5, 14.0\); IR (Neat) 2957, 2931, 2860, 1733, 1687, 1194, 1174 cm\(^{-1}\); HRMS (m/z): [MNa]\(^+\) calc for C\(_{14}\)H\(_{18}\)O\(_3\)Na\(_1\), 257.1154; found, 257.1155.

Colorless oil; R\(_f\) 0.61; (hexanes : ethyl acetate, 80:20 v/v):
\(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 7.99-7.95\) (m, 2H), 7.64 (t, \(J = 7.6\) Hz, 1H), 7.51 (t, \(J = 7.6\) Hz, 2H), 1.61 (s, 9H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta 187.0, 163.9, 134.8, 132.7, 130.0, 129.0, 84.9, 28.2\); IR (Neat) 2927, 2861, 1730,1688,1211, 1149,985 cm\(^{-1}\); HRMS (m/z): [MNa]\(^+\) calc for C\(_{12}\)H\(_{14}\)O\(_3\)Na\(_1\), 229.0841; found, 229.0836.
Colorless oil; Rf 0.68; (hexanes : ethyl acetate, 80:20 v/v): $^1$H NMR (400 MHz, CDCl$_3$): δ 7.99-8.04 (m, 2H), 7.64-7.69 (m, 1H), 7.52 (t, J = 8 Hz, 2H), 5.97-6.08 (m, 2H), 5.32-5.49 (m, 1H, 1H), 4.88 (dt, J = 6 Hz, 1.2 Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 186.1, 163.5, 135.0, 132.5, 130.8, 130.0, 128.9, 120.0, 66.6; IR (Neat) 3067, 1738, 1687, 1599, 1451, 1194 cm$^{-1}$; HRMS (m/z): [MNa]$^+$ calcd for C$_{11}$H$_{10}$O$_3$Na$_1$, 213.0528; found, 213.0532.

White solid; mp = 52 °C (lit. 51-49 °C), Rf 0.54; (hexanes : ethyl acetate, 70:30 v/v): $^1$H NMR (400 MHz, CDCl$_3$): δ 8.01 (d, J = 8.8 Hz, 2H), 6.97 (d, J = 8.8 Hz, 2H), 3.96 (s, 3H), 3.89 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 184.6, 165.2, 132.8, 125.6, 114.4, 55.8, 52.8; IR (Neat) 2936, 2859, 1730, 1682, 1213, 1155, 993 cm$^{-1}$; HRMS (m/z): [MNa]$^+$ calcd for C$_{10}$H$_{11}$O$_4$, 195.0657; found, 195.0661.

Light yellow oil; Rf 0.70; (hexanes : ethyl acetate, 80:20 v/v): $^1$H NMR (400 MHz, CDCl$_3$): δ 7.96 (d, J = 8.4 Hz, 2H), 7.36 (d, J = 8 Hz, 2H), 4.02 (s, 3H), 2.49 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 184.9, 163.5, 129.5, 129.2, 128.9, 53.1, 21.2; IR (Neat) 1739, 1686, 1210, 1172, 913 cm$^{-1}$; HRMS (m/z): [MNa]$^+$ calcd for C$_{10}$H$_{11}$O$_3$Na$_1$, 202.0606; found, 202.0597.
White solid; mp = 58-60 °C; R_f 0.61; (hexanes : ethyl acetate, 80:20 v/v): ¹H NMR (400 MHz, CDCl₃): δ 7.87-7.91 (m, 2H), 7.74 (dd, J = 1.6 Hz, 8.4 Hz, 2H), 3.97 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 185.2, 163.5, 138.4, 131.8, 131.3, 104.0, 53.1; IR (Neat) 1739, 1689, 1209, 1173, 1002, 912 cm⁻¹; HRMS (m/z): [MHNa]⁺ caled for C₉H₈O₃I₁Na₁, 313.9416; found, 313.9428.

White solid; mp = 62 °C (lit. 63 °C), R_f 0.53; (hexanes : ethyl acetate, 80:20 v/v): ¹H NMR (400 MHz, CDCl₃): δ 7.91 (J = 8.8 Hz, 2H), 7.66 (d, J = 8.4 Hz, 2H), 3.98 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 184.8, 163.5, 132.5, 131.6, 131.4, 130.8, 53.1; IR (Neat) 1737, 1689, 1209, 1171, 1003, 907 cm⁻¹; HRMS (m/z): [MNa]⁺ caled for C₉H₇O₃Br₁Na₁, 264.9476; found, 264.9473.
Calculation of conversion C (%) using $^1$H NMR

Hydroxy-phenyl-acetic acid methyl ester
Conversion (C) = 49.7 %
Hydroxy-phenyl-acetic acid ethyl ester
Conversion (C) = 66.5%
Hydroxy-phenyl-acetic acid n-propyl ester
Conversion (C) = 68 %
Hydroxy-phenyl-acetic acid i-propyl ester
Conversion (C) = 57.5 %
Hydroxy-phenyl-acetic acid n-butyl ester
Conversion (C) = 67 %
Hydroxy-phenyl-acetic acid i-butyl ester
Conversion (C) = 60 %
Hydroxy-phenyl-acetic acid pentyl ester
Conversion (C) = 66 %
Hydroxy-phenyl-acetic acid i-amyl ester

Conversion (C) = 58 %
Hydroxy-phenyl-acetic acid hexyl ester
Conversion (C) = 70 %
Hydroxy-p-tolyl-acetic acid tert-butyl ester
Conversion (C) = 73 %
Hydroxy-phenyl-acetic acid allyl ester
Conversion (C) = 60.9 %
(4-methoxyphenyl)-hydroxy-acetic acid methyl ester
Conversion (C) = 61.9 %
Hydroxy-p-tolyl-acetic acid methyl ester
Conversion (C) = 67.7 %
(4-iodophenyl)-hydroxy-acetic acid methyl ester
Conversion (C) = 74.5 %
(4-bromophenyl)-hydroxy-acetic acid methyl ester
Conversion (C) = 66 %
Hydroxy-phenyl-acetic acid methyl ester

(S)-Hydroxy-phenyl-acetic acid methyl ester
Flowrate: 1 ml/min
Mobile phase: 29% n-PrOH/hexanes
column: Diatom ChromPAK AS-H column

(S)-Hydroxy-phenyl-acetic acid methyl ester
Flowrate: 1 ml/min
Mobile phase: 29% n-PrOH/hexanes
column: Diatom ChromPAK AS-H column

$\text{ee} = 78\%$
Hydroxy-phenyl-acetic acid \( \alpha \)-amyl ester

Flow rate: 1 ml/min
Mobile phase: 10% \( \text{CH}_3\text{OH} \) /hexanes
Column: Diacel ChiralPAK AS-H column

\( \epsilon_{\alpha} = 98 \% \)
Hydroxy-phenyl-acetic acid allyl ester

\chem{(S)-\text{Hydroxy-phenyl-acetic acid allyl ester}}

- Flow rate: 1 ml/min
- Mobile phase: 10% MeOH
- Column: Diacel Chiralpak AS-H column

\text{ee} = 99.9\%
Hydroxy-phenyl-acetic acid n-propyl ester
Hydroxy-phenyl-acetic acid \textit{n}-butyl ester

\[ \text{\textit{(R)}-Hydroxy-phenyl-acetic acid \textit{n}-butyl ester} \]

flowrate: 1 ml/min
mobile phase: 10% i-PrOH/Hexanes
column: Diacel ChiralPAK AS-H column

$ee = 90\%$
Hydroxy-phenyl-acetic acid \( \alpha \)-propyl ester

\[
\text{LC-MS/MS}
\]

Flowrate: 1 ml/min
Mobile phase: 100% A (acetonitrile)
Column: Diacel ChiralPAK AS-H column

\( \alpha = 84 \% \)
Hydroxy-phenyl-acetic acid i-buty ester

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Hydroxy-phenyl-acetic acid i-buty ester

Flow rate: 1 ml/min
Mobile phase: 10% i-PrOH/hexanes
Column: Diol ChiralPAK AS-H column

$ee = 84\%$
**p-Iodophenyl-hydroxy-acetic acid methyl ester**

\[ \text{(a) (4-Iodophenyl) hydroxy-acetic acid methyl ester} \]

Flow rate: 1 ml/min
Mobile phase: 10% n-ProOH/Hexanes
Column: Diastel ChiralPAK AS-H column

\[ e^* = 99.64 \% \]
Hydroxy-\(p\)-tolyl-acetic acid methyl ester

- Flow rate: 1 ml/min
- Mobile phase: 10% \(\alpha\)-PrOH/Hexanes
- Column: Duolich ChiralPAK AS-H column

\(\text{ee} = 90\%\)
$p$-Methoxyphenyl-hydroxy-acetic acid methyl

$ee = 80 \%$
$p$-Bromophenyl-hydroxy-acetic acid methyl ester

\[
\text{\(4\)}(3\text{-}4\text{-bromophenyl})\text{-hydroxy-acetic acid methyl ester}
\]

flow rate: 1 mL/min
mobile phase: 10% PrOH/hexanes
column: Diactel Chiripak AS-H column

$\eta \eta = 85\%$
Hydroxy-phenyl-acetic acid ethyl ester

Chemical structure and chromatographic analysis details for Hydroxy-phenyl-acetic acid ethyl ester.
Hydroxy-phenyl-acetic acid $n$-penty ester

$\text{(S)-Hydroxy-phenyl-acetic acid penty ester}$
flow rate: 1 ml/min
mobile phase: 10% i-PrOH/thetane
column: Diacid ChiraPAK AS-H column

$\phi = 94 \%$
Hydroxy-phenyl-acetic acid \( n \)-hexyl ester

\[
\text{\( \text{OH} \quad \text{O} \quad \text{CH}_3 \quad \text{CH}_2 \quad \text{C}_6\text{H}_{13} \)}
\]

(\( \text{R} \))-Hydroxy-phenyl-acetic acid \( n \)-hexyl ester
flow rate: 1 ml/min
mobile phase: 10% \( \text{EtOH} \)/hexanes
column: Duolc ChiralPAK AS-H column

\[ \alpha = 98\% \]
Hydroxy-phenyl-acetic acid t-butyl ester

[Chemical structure image]

Flow rate: 0.5 milliliter
Mobile phase: 25% 2-ProOH/Hexanes
Column: Duolich ChiralPAK OD-H column

ee = 98%
Reference