Supporting Information for

A new ferrocenyl bisphosphorus ligand for asymmetric hydrogenation of α-methylene-γ-keto-carboxylic acids

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General remarks

All reactions were performed in the argon-filled glovebox or under nitrogen using standard Schlenk techniques, unless otherwise noted. Solvents were dried with standard procedures and degassed with N₂. Column chromatography was performed using 200~400 mesh silica gel. Thin layer chromatography (TLC) was performed on EM reagents 0.25 mm silica 60-F plates. ¹H, ¹³C, and ³¹P NMR spectrum were recorded on Bruker-400, with CDCl₃ as the solvent and tetramethylsililane (TMS) as the internal standard. Chemical shifts were reported in ppm, upfield to TMS (0.00 ppm) for and relative to CDCl₃ (7.26 ppm, 77.3 ppm) for ¹H NMR and ¹³C NMR. Data are reported as: multiplicity (s = singlet, d = doublet, dd = double of doublet, t = triplet, dt = double of triplet, q = quartet, m = multiplet), coupling constant in hertz (Hz) and signal area integration in natural numbers. ¹³C NMR and ³¹P NMR analysis were run with decoupling. HPLC analysis was conducted on an Agilent 1260 Series instrument. High resolution mass spectrum was obtained on Thermo LTQ XL Orbitrap. Unless otherwise noted, all reagents and solvents were purchased from commercial suppliers and used without further purification.

The substrates for asymmetric hydrogenation were prepared according to the literature procedures. [¹] The absolute configuration of products 3 was determined by comparison of optical data with those reported by the literature. [¹c]

Synthesis of ligand t-Bu-Wudaphos

1. Synthesis of the intermediate 1

To an oven dried Schlenk flask (100 mL) was added (S)-Ugi’s amine (10 mmol, 2.57 g) and 20 mL of dry Et₂O under N₂ atmosphere. The resulting solution was cooled to -78 °C and t-BuLi (11 mmol, 1.5 M in pentane, 7.6 mL) was added carefully and dropwise. After the addition, the solution was allowed to warm to room
temperature (rt) and stirred for 1.5 h. The Schlenk flask was cooled to -78 °C and PCl₃ (10 mmol, 1.0 mL) was added in one portion. The yellow suspension was allowed to warm to rt and stirred for 1.5 h. The Schlenk flask was cooled to -78 °C and borane protected ((di-tert-butylphosphino)methyl)lithium (11 mmol, prepared by treating borane protected di-tert-butyl(methyl)phosphine[2] with s-BuLi in an 1:1.1 molar ratio under 0 °C for 1.0 h in Et₂O) was added dropwise and the resulting suspension was allowed to warm to rt and stirred for 1.5 h. The Schlenk flask was cooled to -78 °C again and CH₃MgCl (3.0 M in Et₂O, 3.7 mL) was added dropwise. The resulting yellow suspension was allowed to warm to rt and stirred for 3 h. Water (20 mL) was added into the Schlenk flask and the solution was stirred for 10 min. The organic phase was separated and the aqueous phase was extracted by ethyl acetate (30 mL X 3). The organic phases were combined, dried and concentrated under reduced pressure. The residue was purified by column chromatography to give the desired product 1 as a yellow solid (2.04g, 43% yield). [α]D²⁰ = 22.000 (c 0.100, CHCl₃); HRMS (ESI) calculated for C₂₄H₄₅BFeNP₂⁺ [M + H⁺]: 476.2464; found: 476.2462. ¹H NMR (400 MHz, CDCl₃): δ 4.31 (s, 1H), 4.26 (s, 1H), 4.22 (d, J = 0.9 Hz, 1H), 4.15 (dd, J = 11.6, 4.8 Hz, 1H), 4.12 – 4.03 (m, 5H), 2.30 (t, J = 14.8 Hz, 2H), 2.06 (s, 6H), 1.61 (d, J = 4.1 Hz, 3H), 1.42 – 1.34 (m, 9H), 1.25 (d, J = 6.5 Hz, 3H), 1.18 (d, J = 12.4 Hz, 9H), 0.66 (brs, 1H), 0.40 (brs, 1H), 0.21 (brs, 1H) ppm; ¹³C NMR (101 MHz, CDCl₃) δ 95.92, 69.84 (d, J = 3.6 Hz), 69.56, 68.14, 67.82 (d, J = 5.3 Hz), 56.71 (d, J = 7.6 Hz), 39.73, 32.72 (dd, J = 51.9, 26.0 Hz), 28.25 (d, J = 6.5 Hz), 27.72, 25.19, 21.85 (dd, J = 32.7, 18.7 Hz), 12.29 (d, J = 12.7 Hz), 7.21 ppm; ³¹P NMR (162 MHz, CDCl₃): δ 43.02 (s), -48.34 (d, J = 25.8 Hz) ppm.

2. Synthesis of the t-Bu-Wudaphos

![Synthesis of the t-Bu-Wudaphos](image)

To an oven dried Schlenk flask (100 mL) was added the intermediate 1 (4 mmol,
1.90 g), DABCO (4.8 mmol, 540 mg) and 50 mL of dry toluene under N₂ atmosphere. The reaction system was heated to 80 °C and stirred for 8 h. The resulting solution was concentrated under reduced pressure. The residue was purified by column chromatography to give the desired product t-Bu-Wudaphos (air stable yellow solid, 1.40 g, 76% yield). [α]D²⁰ = 25.385 (c 0.130, CHCl₃); HRMS (ESI) calculated for C₂₄H₄₂FeNP₂⁺ [M + H⁺]: 462.2136; found: 462.2130. ¹H NMR (400 MHz, CDCl₃): δ 4.29 (brs, 1H), 4.26 – 4.20 (m, 2H), 4.15 (qd, J = 6.7, 2.5 Hz, 1H), 4.08 (s, 5H), 2.08 (s, 6H), 2.06 – 2.03 (m, 1H), 1.75 – 1.61 (m, 1H), 1.47 (d, J = 4.1 Hz, 3H), 1.24 (d, J = 6.8 Hz, 3H), 1.21 (d, J = 11.2 Hz, 9H), 1.06 (d, J = 11.1 Hz, 9H) ppm; ¹³C NMR (101 MHz, CDCl₃): δ 96.31 (d, J = 22.3 Hz), 81.47 (dd, J = 16.4, 15.0 Hz), 70.16, 69.41, 67.67, 67.33 (d, J = 5.9 Hz), 56.88 (d, J = 7.3 Hz), 39.69, 31.86 (dd, J = 20.8, 2.6 Hz), 31.33 (dd, J = 22.0, 8.5 Hz), 29.78 (dd, J = 13.1, 4.4 Hz), 29.52 (d, J = 13.5 Hz), 25.10 (dd, J = 33.5, 18.1 Hz), 10.35 (dd, J = 11.0, 6.9 Hz), 7.51 ppm; ³¹P NMR (162 MHz, CDCl₃): δ 20.29 (d, J = 107.5 Hz), -49.86 (d, J = 107.6 Hz) ppm.

**Preparation of compounds 2m and 8**

1. Preparation of compound 2m

The following is a modified literature procedure. [¹c] To an oven dried Schlenk flask with DCM (5 mL) was added AlCl₃ (20 mmol, 2.67 g) portion-wise under argon atmosphere. 3-methylenedihydrofuran-2,5-dione (10 mmol, 1.12 g) was then added and the oxydibenzene (15 mmol, 2.55 g) was added dropwise. The resulting suspension was stirred at rt for 2 h. After the reaction, the suspension was poured into ice water (20 mL) and conc. HCl aqueous solution (5 mL) was added dropwise. Hexane (30 mL) was then added and the mixture was then stirred for 20 min and filtered. The filtrate was washed with 3M HCl solution (30 mL X 1), PE (30 mL X 2) and dried. The crude product was further recrystallized with PE/EA as the solvent to
give the pure product 2m as a white solid (2.54 g, 90% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)) δ 8.01–7.93 (m, 2H), 7.41 (dd, \(J = 8.4, 7.5\) Hz, 2H), 7.25–7.18 (m, 1H), 7.12–7.06 (m, 2H), 7.05–6.98 (m, 2H), 6.53 (s, 1H), 5.81 (s, 1H), 3.97 (s, 2H) ppm. \(^{13}\)C NMR (101 MHz, CDCl\(_3\)): δ 195.51, 171.53, 162.51, 155.63, 134.33, 131.18, 131.09, 130.88, 130.36, 124.97, 120.52, 117.59, 41.36 ppm.

2. Preparation of compound 8

The compound 10 was synthesized according to the reported procedure.\(^{[1d]}\) A mixture of 10 mmol of benzaldehyde, 10 mmol of 3-benzoylepropionic acid, 10 mmol of sodium acetate and 5 mL of acetic anhydride was heated under reflux for 10 h until crystals separated. After cooling, the reaction was poured into water, and the solid product was filtered, washed with water and finally recrystallized from 95% ethanol. Pure product was easily obtained by filtration (compound 10, 1.32 g, 53% yield). The compound 8 was synthesized according to a modified literature procedure.\(^{[1e]}\) A mixture of 0.21 g (5.3 mmol) of sodium hydroxide, 5.3 mmol of the compound 10 and 30 mL of ethanol/water (V/V = 2:1) was heated under reflux for 6 hours and then allowed to cool room temperature. After evaporation of ethanol, HCl (20%) was added until the mixture was acidified (pH 1). The aqueous layer was extracted with ethyl acetate (3 × 10 mL). The combined extracts were washed with a saturated solution of NaCl (20 mL), dried over Na\(_2\)SO\(_4\), and evaporated in vacuo. The residue was purified by column chromatography (eluant: DCM/MeOH (V/V) = 15:1) to give the product 8 (a white solid, 1.27 g, 90% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)): δ 8.13 (s, 1H), 8.01 (d, \(J = 7.4\) Hz, 2H), 7.59 (t, \(J = 7.4\) Hz, 1H), 7.48 (t, \(J = 7.6\) Hz, 2H), 7.36–7.30 (m, 5H), 4.21 (s, 2H) ppm. \(^{13}\)C NMR (101 MHz, CDCl\(_3\)): δ 197.40, 172.64, 144.64, 136.75, 135.23, 133.64, 129.38, 129.17, 128.95, 128.59, 126.50, 38.15 ppm.
General procedure for the asymmetric hydrogenation

In an argon-filled glove box, [Rh(NBD)\(_2\)]BF\(_4\) (0.01 mmol) and \(t\)-Bu-Wudaphos (0.011 mmol) were dissolved in THF (1.0 mL) and stirred for 45 min. 0.1 mL of the resulting solution was transferred by syringe into the vials charged with different substrates (0.1 mmol for each). Additional THF was added to bring the total reaction volume to 1.0 mL. The vials were subsequently transferred into an autoclave which was charged with hydrogen (10 bar). The reaction was then stirred at rt for 12 h. The hydrogen gas was released slowly and carefully in a well-ventilated hood. The solution was passed through a short column of silica gel (eluent: EtOAc) to remove the metal complex and concentrated to give compounds 3. The ee values of compounds 3 were then determined by HPLC analysis on a chiral stationary phase.

The following products can be obtained following the procedures for asymmetric hydrogenation.

>99% conv., 98% ee, white solid; \([\alpha]_D^{20} = -32.9\) (c 0.240, CHCl\(_3\)); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 7.98-7.96\) (m, 2H), 7.59-7.55 (m, 1H), 7.47 (t, \(J = 8.0\) Hz, 2H), 3.48 (dd, \(J = 17.6\), 7.6 Hz, 1H), 3.21-3.12 (m, 1H), 3.06 (dd, \(J = 17.6\), 5.2 Hz, 1H), 1.32 (d, \(J = 7.2\) Hz, 3H) ppm; \(^{13}\)C NMR (101 MHz, CDCl\(_3\)): \(\delta 198.16, 182.28, 136.71, 133.59, 128.90, 128.32, 41.97, 35.06, 17.36\) ppm. The enantiomeric excess of 3a was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 : 5, flow rate = 1.0 mL/min, uv-vis detection at \(\lambda = 230\) nm, \(t_R = 17.9\) min (major), 22.6 min (minor).

>99% conv., 98% ee, white solid; \([\alpha]_D^{20} = -42.6\) (c 0.385, CHCl\(_3\)); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta 7.87\) (d, \(J = 8.0\) Hz, 2H), 7.26 (d, \(J = 8.0\) Hz, 2H), 3.45 (dd, \(J = 8.0\) Hz, 2H), 2.18 (t, \(J = 8.0\) Hz, 2H), 1.32 (d, \(J = 7.2\) Hz, 3H) ppm; \(^{13}\)C NMR (101 MHz, CDCl\(_3\)): \(\delta 198.16, 182.28, 136.71, 133.59, 128.90, 128.32, 41.97, 35.06, 17.36\) ppm. The enantiomeric excess of 3b was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 : 5, flow rate = 1.0 mL/min, uv-vis detection at \(\lambda = 230\) nm, \(t_R = 17.9\) min (major), 22.6 min (minor).
18.0, 7.6 Hz, 1H), 3.19 – 3.11 (m, 1H), 3.04 (dd, J = 17.6, 5.6 Hz, 1H), 2.42 (s, 3H), 1.31 (d, J = 6.8 Hz, 3H) ppm; $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 197.87, 182.20, 144.41, 134.27, 129.56, 128.45, 41.88, 35.12, 21.94, 17.37 ppm. The enantiomeric excess of 3b was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 :5, flow rate = 1.0 mL/min, uv-vis detection at $\lambda$ = 254 nm, t$_R$ = 17.0 min (major), 22.8 min (minor).

$>$99% conv., 99% ee, white solid; [\alpha]_D^{20} = -33.9 (c 0.440, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.95 (d, J = 8.9 Hz, 2H), 6.93 (d, J = 8.9 Hz, 2H), 3.87 (s, 3H), 3.42 (dd, J = 17.5, 7.7 Hz, 1H), 3.19 – 3.09 (m, 1H), 3.02 (dd, J = 17.6, 5.5 Hz, 1H), 1.31 (d, J = 7.1 Hz, 3H) ppm; $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 196.74, 182.19, 163.89, 130.62, 129.83, 114.01, 55.76, 41.63, 35.13, 17.38 ppm. The enantiomeric excess of 3c was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 :5, flow rate = 1.0 mL/min, uv-vis detection at $\lambda$ = 254 nm, t$_R$ = 46.3 min (major), 60.4 min (minor).

$>$99% conv., 98% ee, white solid; [\alpha]_D^{20} = -39.3 (c 0.450, CHCl$_3$); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.90 (d, J = 8.3 Hz, 2H), 7.31 (d, J = 8.2 Hz, 2H), 3.45 (dd, J = 17.6, 7.5 Hz, 1H), 3.21 – 3.09 (m, 1H), 3.09 – 2.99 (m, 1H), 2.98-2.91 (m, 1H), 1.30 (d, J = 7.1 Hz, 3H), 1.26 (d, J = 6.9 Hz, 6H) ppm; $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 197.86, 182.34, 155.11, 134.63, 128.60, 126.97, 41.89, 35.13, 34.52, 23.93, 17.35 ppm. The enantiomeric excess of 3d was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 :5, flow rate = 1.0 mL/min, uv-vis detection at $\lambda$ = 254 nm, t$_R$ = 12.9 min (major), 16.9 min (minor).
99% conv., 97% ee, white solid; [α]_D^{20} = -36.2 (c 0.425, CHCl₃); ¹H NMR (400 MHz, CDCl₃): δ 7.92 (d, J = 8.5 Hz, 2H), 7.48 (d, J = 8.5 Hz, 2H), 3.46 (dd, J = 17.6, 7.5 Hz, 1H), 3.22 – 3.10 (m, 1H), 3.04 (dd, J = 17.6, 5.7 Hz, 1H), 1.34 (s, 9H), 1.31 (d, J = 7.1 Hz, 3H) ppm; ¹³C NMR (101 MHz, CDCl₃): δ 197.88, 182.45, 157.30, 134.19, 128.31, 125.83, 41.89, 35.38, 35.15, 31.33, 17.35 ppm. The enantiomeric excess of 3e was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 :5, flow rate = 1.0 mL/min, uv-vis detection at λ = 230 nm, t_R = 10.3 min (major), 15.2 min (minor).

>99% conv., 98% ee, white solid; [α]_D^{20} = -31.5 (c 0.425, CHCl₃); ¹H NMR (400 MHz, CDCl₃): δ 7.47 (s, 1H), 7.20 – 7.10 (m, 2H), 3.39 (dd, J = 17.8, 8.0 Hz, 1H), 3.18 – 3.08 (m, 1H), 2.96 (dd, J = 17.8, 5.4 Hz, 1H), 2.43 (s, 3H), 2.36 (s, 3H), 1.30 (d, J = 7.2 Hz, 3H) ppm; ¹³C NMR (101 MHz, CDCl₃): δ 202.21, 182.31, 137.44, 135.46, 132.50, 132.17, 129.41, 44.76, 35.32, 21.19, 21.14, 17.30 ppm. The enantiomeric excess of 3f was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 :5, flow rate = 1.0 mL/min, uv-vis detection at λ = 254 nm, t_R = 10.9 min (major), 16.7 min (minor).

>99% conv., > 99% ee, white solid; [α]_D^{20} = -34.2 (c 0.503, CHCl₃); ¹H NMR (400 MHz, CDCl₃): δ 7.63 (d, J = 8.5 Hz, 1H), 7.06 (d, J = 7.1 Hz, 2H), 3.38 (dd, J = 17.6, 8.0 Hz, 1H), 3.16 – 3.06 (m, 1H), 2.96 (dd, J = 17.6, 5.4 Hz, 1H), 2.48 (s, 3H), 2.35 (s, 3H), 1.29 (d, J = 7.2 Hz, 3H) ppm; ¹³C NMR (101 MHz, CDCl₃): δ 201.32, 182.32, 142.48, 139.22, 134.47, 133.20, 129.44, 126.59, 44.44, 35.39, 21.90, 21.65, 17.31 ppm. The enantiomeric excess of 3g was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95 :5, flow rate = 1.0 mL/min, uv-vis detection at λ = 254 nm, t_R = 14.5 min (major), 26.2 min (minor).
>99% conv., 91% ee, white solid; [α]D20 = −35.1 (c 0.305, CHCl3); 1H NMR (400 MHz, CDCl3): δ 7.50 (d, J = 1.6 Hz, 1H), 7.27 – 7.14 (m, 2H), 3.40 (dd, J = 17.7, 7.9 Hz, 1H), 3.19 – 3.09 (m, 1H), 3.03 – 2.86 (m, 2H), 2.44 (s, 3H), 1.31 (d, J = 7.2 Hz, 3H), 1.26 (d, J = 6.9 Hz, 6H) ppm; 13C NMR (101 MHz, CDCl3): δ 202.33, 182.41, 146.59, 137.59, 135.84, 132.26, 129.79, 126.89, 44.80, 35.35, 33.96, 24.25, 21.15, 17.29 ppm. The enantiomeric excess of 3h was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95:5, flow rate = 1.0 mL/min, uv-vis detection at λ = 230 nm, tR = 6.8 min (major), 7.9 min (minor).

>99% conv., 98% ee, white solid; [α]D20 = −36.9 (c 0.325, CHCl3); 1H NMR (400 MHz, CDCl3): δ 8.02 – 7.97 (m, 2H), 7.16 – 7.10 (m, 2H), 3.44 (dd, J = 17.8, 7.9 Hz, 1H), 3.19 – 3.10 (m, 1H), 3.01 (dd, J = 17.8, 5.3 Hz, 1H), 1.32 (d, J = 7.2 Hz, 3H) ppm; 13C NMR (101 MHz, CDCl3): δ 196.56, 182.33, 166.12 (d, J = 255.0 Hz), 133.16 (d, J = 3.0 Hz), 130.97 (d, J = 9.4 Hz), 116.01 (d, J = 21.9 Hz), 41.86, 35.09, 17.37 ppm. The enantiomeric excess of 3i was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 95:5, flow rate = 1.0 mL/min, uv-vis detection at λ = 210 nm, tR = 19.5 min (major), 22.6 min (minor).

>99% conv., 98% ee, white solid; [α]D20 = −41.0 (c 0.305, CHCl3); 1H NMR (400 MHz, CDCl3): δ 7.90 (d, J = 8.6 Hz, 2H), 7.43 (d, J = 8.6 Hz, 2H), 3.44 (dd, J = 17.8, 7.9 Hz, 1H), 3.19 – 3.09 (m, 1H), 3.00 (dd, J = 17.8, 5.2 Hz, 1H), 1.31 (d, J = 7.2 Hz, 3H) ppm; 13C NMR (101 MHz, CDCl3): δ 196.98, 182.21, 140.03, 135.02,
129.74, 129.22, 41.92, 35.07, 17.37 ppm. The enantiomeric excess of \(3j\) was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 9:5, flow rate = 1.0 mL/min, uv-vis detection at \(\lambda = 254\) nm, \(t_R = 19.3\) min (major), 26.0 min (minor).

\[
\begin{align*}
\text{3j} & \quad \text{>99\% conv., 96\% ee, white; } [\alpha]_D^{20} = -35.0 \text{ (c 0.400, CHCl}_3); \\
1^H \text{ NMR (400 MHz, CDCl}_3); \delta 7.76 (d, J = 8.6 \text{ Hz, 2H}), 7.54 (d, J = 8.6 \text{ Hz, 2H}), 3.36 (dd, J = 17.8, 8.0 \text{ Hz, 1H}), 3.13 – 3.03 (m, 1H), 2.93 (dd, J = 17.8, 5.2 \text{ Hz, 1H}), 1.25 (d, J = 7.2 \text{ Hz, 3H}) \text{ ppm;} \\
13^C \text{ NMR (101 MHz, CDCl}_3); \delta 197.15, 181.87, 135.43, 132.23, 129.85, 128.80, 41.90, 34.99, 17.38 \text{ ppm.}
\end{align*}
\]

The enantiomeric excess of \(3k\) was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 9:5, flow rate = 1.0 mL/min, uv-vis detection at \(\lambda = 254\) nm, \(t_R = 22.6\) min (major), 32.2 min (minor).

\[
\begin{align*}
\text{3k} & \quad \text{>99\% conv., 98\% ee, white; } [\alpha]_D^{20} = -61.7 \text{ (c 0.360, CHCl}_3); \\
1^H \text{ NMR (400 MHz, CDCl}_3); \delta 8.43 (s, 1H), 7.96 (dd, J = 8.6, 1.5 \text{ Hz, 1H}), 7.89 (d, J = 8.0 \text{ Hz, 1H}), 7.81 (t, J = 7.9 \text{ Hz, 2H}), 7.57 – 7.45 (m, 2H), 3.60 – 3.50 (m, 1H), 3.19 – 3.10 (m, 2H), 1.30 (d, J = 7.0 \text{ Hz, 3H}) \text{ ppm;} \\
13^C \text{ NMR (101 MHz, CDCl}_3); \delta 198.13, 181.67, 135.95, 134.08, 132.73, 130.13, 129.86, 128.84, 128.78, 128.06, 127.10, 123.99, 42.07, 35.13, 17.46 \text{ ppm.}
\end{align*}
\]

The enantiomeric excess of \(3l\) was determined by chiral HPLC analysis on Chiralpak OJ-H column. Conditions: hexane/isopropanol = 9:5, flow rate = 1.0 mL/min, uv-vis detection at \(\lambda = 230\) nm, \(t_R = 42.2\) min (major), 67.0 min (minor).
>99% conv., 96% ee, white solid; $[\alpha]_D^{20} = -6.8$ (c 0.340, CHCl$_3$). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.98–7.91 (m, 2H), 7.44–7.36 (m, 2H), 7.24–7.17 (m, 1H), 7.07 (dt, $J$ = 9.0, 1.8 Hz, 2H), 7.03–6.97 (m, 2H), 3.43 (dd, $J$ = 17.7, 7.8 Hz, 1H), 3.24–3.08 (m, 1H), 3.01 (dd, $J$ = 17.7, 5.4 Hz, 1H), 1.31 (d, $J$ = 7.2 Hz, 3H) ppm. $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 196.74, 181.87, 162.43, 155.65, 131.40, 130.63, 130.34, 124.93, 120.47, 117.57, 41.77, 35.09, 17.40 ppm. The enantiomeric excess of 3m was determined by chiral HPLC analysis on Chiralpak AD-H column. Conditions: hexane/isopropanol = 95 :5, flow rate = 1.0 mL/min, uv-vis detection at $\lambda$ = 210 nm, $t_R$ = 41.0 min (minor), 45.6 min (major).

>99% conv., 93% ee, white solid; $[\alpha]_D^{20} = -6.6$ (c 0.52, CHCl$_3$). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 3.01 – 2.85 (m, 2H), 2.47 – 2.41 (m, 3H), 1.61 – 1.53 (m, 2H), 1.35 – 1.29 (m, 2H), 1.22 (d, $J$ = 7.1 Hz, 3H), 0.91 (t, $J$ = 7.3 Hz, 3H) ppm; $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 209.50, 182.08, 45.68, 42.86, 34.81, 26.06, 22.54, 17.16, 14.11 ppm. The enantiomeric excess of 3n was determined by chiral HPLC analysis on Chiralpak OJ-H column after esterification with BnOH in the presence of DCC and DMAP. Conditions: hexane/isopropanol = 99 :1, flow rate = 1.0 mL/min, uv-vis detection at $\lambda$ = 210 nm, $t_R$ = 18.0 min (minor), 19.8 min (major).

>99% conv., 95% ee, colorless oil; $[\alpha]_D^{20} = -11.5$ (c 0.900, CHCl$_3$). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.99 – 2.93 (m, 2H), 2.62 – 2.55 (m, 1H), 1.21 (d, $J$ = 6.7 Hz, 3H), 1.15 (s, 9H) ppm; $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 214.30, 182.32, 44.17, 40.29, 34.90, 26.64, 17.17 ppm. The enantiomeric excess of 3o was determined by chiral HPLC analysis on Chiralpak OJ-H column after esterification with BnOH in the presence of DCC and DMAP. Conditions: hexane/isopropanol = 99 :1, flow rate = 1.0 mL/min, uv-vis detection at $\lambda$ = 210 nm, $t_R$ = 10.2 min (minor), 11.8 min (major).
>99% conv., 96% ee, colorless oil; \([\alpha]_D^{20} = -13.5\) (c 0.635, CHCl₃). ¹H NMR (400 MHz, CDCl₃): \(\delta 3.08 – 2.95\) (m, 2H), \(2.67\) (dd, \(J = 17.2, 5.0\) Hz, 1H), \(1.96 – 1.90\) (m, 1H), \(1.23\) (d, \(J = 7.0\) Hz, 3H), \(1.05\) (dd, \(J = 4.5, 2.9\) Hz, 2H), \(0.92 – 0.88\) (m, 2H) ppm; ¹³C NMR (101 MHz, CDCl₃): \(\delta 209.19, 181.60, 46.38, 34.84, 20.90, 17.18, 11.23, 11.16\) ppm. The enantiomeric excess of 3p was determined by chiral HPLC analysis on Chiralpak OJ-H column after esterification with BnOH in the presence of DCC and DMAP. Conditions: hexane/isopropanol = 99 :1, flow rate = 1.0 mL/min, uv-vis detection at \(\lambda = 210\) nm, \(t_R = 25.1\) min (minor), 32.2 min (major).

>99% conv., 95% ee, colorless oil; \([\alpha]_D^{20} = -11.9\) (c 0.655, CHCl₃). ¹H NMR (400 MHz, CDCl₃): \(\delta 2.99 – 2.89\) (m, 2H), \(2.52\) (dd, \(J = 17.3, 4.8\) Hz, 1H), \(2.37 – 2.31\) (m, 1H), \(1.87 – 1.77\) (m, 4H), \(1.68 – 1.66\) (m, 1H), \(1.38 – 1.17\) (m, 8H) ppm; ¹³C NMR (101 MHz, CDCl₃): \(\delta 212.34, 182.14, 51.00, 43.77, 34.74, 28.61, 28.58, 26.07, 25.89, 25.84, 17.20\) ppm. The enantiomeric excess of 3q was determined by chiral HPLC analysis on Chiralpak OJ-H column after esterification with BnOH in the presence of DCC and DMAP. Conditions: hexane/isopropanol = 99 :1, flow rate = 1.0 mL/min, uv-vis detection at \(\lambda = 205\) nm, \(t_R = 15.3\) min (minor), 19.7 min (major).

>99% conv., 98% ee, white solid; \([\alpha]_D^{20} = 3.7\) (c 0.295, CHCl₃); ¹H NMR (400 MHz, CDCl₃): \(\delta 7.87\) (d, \(J = 7.5\) Hz, 2H), \(7.53\) (t, \(J = 7.3\) Hz, 1H), \(7.40\) (t, \(J = 7.4\) Hz, 2H), \(7.33 – 7.26\) (m, 2H), \(7.21\) (d, \(J = 7.3\) Hz, 3H), \(3.48 – 3.28\) (m, 2H), \(3.20\) (dd, \(J = 13.7, 4.1\) Hz, 1H), \(2.98\) (dd, \(J = 21.2, 7.6\) Hz, 1H), \(2.84\) (dd, \(J = 13.3, 8.1\) Hz, 1H)
ppm. $^{13}$C NMR (101 MHz, CDCl$_3$): $\delta$ 198.50, 180.81, 138.67, 136.65, 133.55, 129.35, 128.89, 128.82, 128.32, 126.97, 42.36, 39.21, 37.65 ppm. The enantiomeric excess of 9 was determined by chiral HPLC analysis on Chiralpak AD-H column. Conditions: hexane/isopropanol = 95 : 5, flow rate = 1.0 mL/min, uv-vis detection at $\lambda = 210$ nm, $t_R = 35.8$ min (minor), 41.9 min (major).
NMR spectra
HPLC spectra

Data File E:\DATA\WB...151107\DAD-OJ1-2-90-10-WE-20151107-2 2015-11-07 31-12-35\080-0801.D
Sample Name: G2Y-6-94-5-RA

Acq. Operator : SYSTEM
Seq. Line : 8
Acq. Instrument : 1260HPLC-DAD
Location : Vial 80
Injection Date : 11/7/2015 2:31:30 PM
Injection Volume : 5.000 µl

Acq. Method : E:\DATA\WB\KEIB-20151107\DAD-OJ1-2-90-10-WE-20151107-2 2015-11-07 11-12-35
\DAD-OJ1(1-8)-95-5-1.0ML-ALLNM-45MIN.M
Last changed : 11/7/2015 12:28:53 PM by SYSTEM
Analysis Method : E:\DATA\WB\KEIB-20151107\DAD-OJ1-2-90-10-WE-20151107-2 2015-11-07 11-12-35
\DAD-OJ1(1-8)-95-5-1.0ML-ALLNM-45MIN.M (Sequence Method)
Last changed : 9/5/2016 9:49:28 PM by SYSTEM
(modified after loading)

Additional Info : Peak(s) manually integrated

Area Percent Report

Signal
Multiplier : 1.0000
Dilution : 1.0000
Do not use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD D, Sig=230,4 Ref-off

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Totals : 1.0146E+6 302,96738

*** End of Report ***
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Sample Name: hmr-1-75-1

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Injection Date : 3/31/2016 5:56:27 AM  Inj : 1
Injection Volume : 5.000 µl
Acq. Method : E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\DAD-OJ(1-6)-95-5-1.OML-ALL-45MIN.M
Last changed : 3/30/2016 10:58:50 PM by SYSTEM
Analysis Method : E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\DAD-OJ(1-6)-95-5-1.OML-ALL-45MIN.M (sequence Method)
Last changed : 2/10/2017 8:03:40 PM by SYSTEM
(modified after loading)
Additional Info : Peaks(s) manually integrated

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD D, S1g=230.4 Ref-off

Peak RetTime Type Width Area Height Ares
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----|--------|--------|---------|---------|--------|
1 17.902 RH 0.4515 1.18501e4  380.66229 99.0713
2 22.647 MM 0.7386 111.17309  2.50857  0.9287

Totals : 1.19703e4 383.17087

1260HPLC-VWD 2/10/2017 8:04:28 PM SYSTEM
Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISSTDs

Signal 1: DAD B, Slg=254.4 Ref-off

Peak RetTime Type Width Area Height Ares
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<td>0.6791</td>
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Totals:
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1260HPLC-DAD 9/3/2016 7:27:29 PM SYSTEM
**Data File**: E:\DATA\HEV\HEV-2-NAL\HEV-2NAI-RAC 2016-03-30 20-31-11\072-1701.D

**Sample Name**: kmh-1-75-2

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**Acq. Operator**: SYSTEM  
**Seq. Line**: 17  
**Acq. Instrument**: 1260HPLC-DAD  
**Location**: Vial 72  
**Injection Date**: 3/31/2016 6:42:27 AM  
**Inj**: 1  
**Inj Volume**: 5.000 μl  
**Acq. Method**: E:\DATA\HEV\HEV-2-NAL\HEV-2NAI-RAC 2016-03-30 20-31-11\DAD-OJ(1-6)-95-5-1.OML-ALL-45MIN.H  
**Last changed**: 3/30/2016 10:58:50 PM by SYSTEM  
**Analysis Method**: E:\DATA\HEV\HEV-2-NAL\HEV-2NAI-RAC 2016-03-30 20-31-11\DAD-OJ(1-6)-95-5-1.OML-ALL-45MIN.H (Sequence Method)  
**Last changed**: 2/10/2017 8:52:56 PM by SYSTEM  
**Additional Info**: Peak(s) manually integrated

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**Area Percent Report**

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**Sorted By**: Signal  
**Multiplier**: 1.0000  
**Dilution**: 1.0000  
**Use Multiplier & Dilution Factor with ISSTDs**

**Signal 1**: DAD B, Sig-254,4 Ref-off

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**Totals**: 1.03119e4 307.59587

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1260HPLC-VWD 2/10/2017 8:53:03 PM SYSTEM  
Page 1 of 2
Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISSTDs

Signal 1: DAD E, S1g=254,4 Ref-off

Peak RetTime Type Width Area Height Ares
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1 46.260 MM 1.6337 5713.18262 58.28351 100.0000

Totals:
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Data File E:\DATA\GMC\GMC-16-1\DUI CL 2015-12-31 16-32-05\043-0501.D
Sample Name: kmm-1-38-2

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD D, Sig=230,4 Ref-off

Peak RetTime Type Width Area Height Ares
# [min] [min] [mAU*s] [mAU] %
--- | --------- | --------- | ------------ | --------- | --------- |
1 11.038 MM 0.4322 3430.66821 132.30887 50.9866
2 16.641 MM 0.6717 3417.44312 84.79080 49.9034

Totals : 6848.11133 217.09967

1260HPLC-DAD 9/5/2016 10:09:57 AM SYSTEM
Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISSTDs

Signal 1: DAD D, Sig=230,4 Ref-off

Peak Ret Time Type Width  Area  Height  Area %
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1  10.345  HN  0.3224  8082.22900  364.90959  96.39505
2  15.220  MM  0.8103  132.21848  2.71943  1.6095

Totals : 8214.43948 367.62502

1260HPLC=DAD 9/5/2016 9:36:09 AM SYSTEM
Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution  : 1.0000
Use Multiplier & Dilution Factor with ISOTDs

Signal 1: DAD B, Sig=254,4 Ref=off

Peak Ret Time Type Width Area Height Ares
# [min] [min] [mAU*s] [mAU] %
---|---|---|---|---|---|---|---|
1 11.394 HH 0.3196 6385.75000 320.85330 49.6792
2 16.766 EE 0.5895 8494.04297 211.98248 50.3208
Totals : 1.68798e4 600.83578

1260HPLC-DAD 9/3/2016 7:15:00 PM SYSTEM
Data File E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\073-2001.D
Sample Name: wmk-1-75-6

Acq. Operator : SYSTEM  Seq. Line : 20
Acq. Instrument : 1280HPLC-DAD  Location : Vial 75
Injection Date : 9/31/2016 9:45:35 AM  Inj. : 1
Inj Volume : 5.000 µl
Acq. Method : E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\DAD-OJ(1-6)-95-5-1.
OML-ALL-45MIN.M
Last changed : 3/30/2016 10:58:50 PM by SYSTEM
Analysis Method : E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\DAD-OJ(1-6)-95-5-1.
OML-ALL-45MIN.M (Sequence Method)
Last changed : 9/3/2016 8:02:21 PM by SYSTEM
(modified after loading)
Additional Info : Peak(s) manually integrated

Area Percent Report

Sorted By : Signal  Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD B, Blg=254.4 Ref-off

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Totals : 3828.53345 113.91030

1280HPLC-DAD 9/3/2016 8:02:32 PM SYSTEM  Page 1 of 2
Data File: E:\DATA\WS\WS-1-40\WSW 2016-01-02 21-17-06\013-1101.D
Sample Name: wsn-1-40-3

Acq. Operator: SYSTEM  Seq. Line: 11
Acq. Instrument: 1260HPLC-DAD  Location: Vial 13
Injection Date: 1/3/2016 12:23:23 AM  Inj #: 1
Injection Volume: 5.000 μl

Acq. Method: E:\DATA\WS\WSW-1-40\WSW 2016-01-02 21-17-06\DAD-OJ1(1-6)-95.5-1.0MLE-ALL-45MIN.M
Last changed: 6/2/2016 9:18:05 PM by SYSTEM
Analysis Method: E:\DATA\WS\WSW-1-40\WSW 2016-01-02 21-17-06\DAD-OJ1(1-6)-95.5-1.0MLE-ALL-45MIN.M (Sequence Method)
Last changed: 6/4/2016 4:18:17 PM by SYSTEM
(modified after loading)

Additional Info: Peak(a) manually integrated

![Graph showing chromatogram with peak areas]

Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISSTDs

Signal 1: DAD D, Sig=230,4 Ref-off

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Totals: 1.36934984 89.97699

1260HPLC-DAD 9/4/2016 4:16:33 PM SYSTEM
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Sample Name: HZ2-1-75-6

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Acq. Operator : SYSTEM            Seq. Line : 23
Acq. Instrument : 1260HPLC-DAD     Location : Vial 76
Injection Date : 9/31/2016 11:34:00 PM Inj : 1
Inj Volume : 5.000 μl
Acq. Method : E:\DATA\H2Z\H2Z-2-NAT\H2Z-2NAT-2HAC 2016-03-30 20-31-11\DAD-OJ1-6-95-5-1.
OML-ALL-45MIN.M
Last changed : 3/31/2016 11:46:38 PM by SYSTEM
(modified after loading)
Analysis Method : E:\DATA\H2Z\H2Z-2-NAT\H2Z-2NAT-2HAC 2016-03-30 20-31-11\DAD-OJ1-6-95-5-1.
OML-ALL-45MIN.M (Sequence Method)
Last changed : 9/4/2016 4:08:40 PM by SYSTEM
(modified after loading)
Additional Info : Peak(s) manually integrated

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Area Percent Report
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Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD 1, Sig=230.4 Ref-off (E:\DATA\H2Z\H2Z-2-NAT\H2Z-2NAT-2HAC 2016-03-30 20-31-11\076-2301.D)

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1260HPLC-DAD 9/4/2016 4:12:17 PM SYSTEM

Page 1 of 2
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Sample Name: WSN-1-33-B

Acq. Operator : SYSTEM  Seq. Line : 5
Acq. Instrument : 1260HPLC-DAD  Location : Vial 75
Injection Date : 12/23/2015 6:16:07 PM  Inj : 1
Injection Volume : 5.000 μl
Acq. Method : E:\DATA\WGW\WSN-1-33\WSN-1-33A 2015-12-23 15-11-27\DAD\0J(1-6)-95-5-1.0ML-ALL-45MIN.M
Last changed : 12/23/2015 3:11:27 PM by SYSTEM
Analysis Method : E:\DATA\WGW\WSN-1-33\WSN-1-33A 2015-12-23 15-11-27\DAD\0J(1-6)-95-5-1.0ML-ALL-45MIN.M (Sequence Method)
Last changed : 9/5/2016 10:12:38 AM by SYSTEM
(modified after loading)
Additional Info : Peak(a) manually integrated

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISSTDs

Signal 1: DAD C, Sig=210.4 Ref-off

Peak RetTime Type Width  Area  Height  Ares
# [min]  [min]  [mAU*s]  [mAU]  %
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1  19.351  BV  0.4783  1.0281 1e4  317.07  03 50.3718
2  21.460  VB  0.5774  1.0129 3e4  253.94  75 49.6282
Totals :  2.04105 9e4  571.025 59

1260HPLC-DAD 9/5/2016 10:20:49 AM SYSTEM
Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD C, Sig=210,4 Ref-off

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Totals: 1.39027e+4 413.21520

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Sample Name: \{\n
Acq. Operator: SYSTEM
Acq. Instrument: 1280HPLC-DAD
Injection Date: 9/31/2016 4:38:07 PM
Inj: 1

Acq. Method: E:\DATA\HEX\HEX-2-NAP\HEX-2NAP-RAC 2016-03-30 20-31-11\DAD-0J(1-6)-95-5-1.
OPL-ALL-45MIN.M
Last changed: 9/31/2016 1:16:13 PM by SYSTEM
Analysis Method: E:\DATA\HEX\HEX-2-NAP\HEX-2NAP-RAC 2016-03-30 20-31-11\DAD-0J(1-6)-95-5-1.
OPL-ALL-45MIN.M (Sequence Method)
Last changed: 9/5/2016 10:31:01 AM by SYSTEM
(modified after loading)

Additional Info: Peak(s) manually integrated

Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD B, Sig=254,4 Ref-off

<table>
<thead>
<tr>
<th>Peak RetTime Type</th>
<th>Width</th>
<th>Area</th>
<th>Height</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>[min]</td>
<td>[min]</td>
<td>[mAU*]</td>
<td>[mAU]</td>
</tr>
<tr>
<td>-----</td>
<td>-------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>19.335</td>
<td>0.7295</td>
<td>6034.31055</td>
<td>137.85857</td>
</tr>
<tr>
<td>2</td>
<td>25.972</td>
<td>1.3019</td>
<td>75.16106 9.621809e-1</td>
<td>1.2302</td>
</tr>
</tbody>
</table>

Totals: 6109.47161 138.82075

1280HPLC-DAD 9/5/2016 10:31:05 AM SYSTEM
Data File E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\081-2801.D
Sample Name: win-1-75-11

Acq. Operator : SYSTEM
Seq. Line : 28
Acq. Instrument : 1260HPLC=DAD
Location : Vial 81
Injection Date : 9/31/2016 5:24:59 PM
Inj. Volume : 5.000 μl

Acq. Method : E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\DAD-0J(1-6)-95-5-1.
OML-ALL-45MIN.M
Last changed : 9/31/2016 11:46:38 PM by SYSTEM
Analysis Method : E:\DATA\HEY\HEY-2-NAI\HEY-2NAI-RAC 2016-03-30 20-31-11\DAD-0J(1-6)-95-5-1.
OML-ALL-45MIN.M (Sequence Method)
Last changed : 9/5/2016 10:49:42 AM by SYSTEM
(modified after loading)

Additional Info : Peak(s) manually integrated

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD B, Sig=254,4 Ref-off

Peak RetTime Type Width Area Height Area
# [min] [min] [nAU*s] [nAU] %
---- ----------- ----------- ----------- -----------
1 22.608 MM 0.9406 7078.52197 125.42750 96.1162
2 32.199 MM 1.7115 135.90642 1.32345 1.8838

Totals : 7214.42839 126.75995

1260HPLC=DAD 9/5/2016 10:39:31 AM SYSTEM

Page 1 of 2
Data File E:\DATA\WSS\WSS-1-73A\GWH 2016-03-30 06-20-57\G71-0201.D
Sample Name: GWH-1-73-1

Acq. Operator : SYSTEM
Acq. Instrument : 1260HPLC-DAD
Injection Date : 9/30/2016 6:32:48 AM
Injection : 1
Inj Volume : 5.000 µL

Acq. Method : E:\DATA\WSS\WSS-1-73A\GWH 2016-03-30 06-20-57\DAD-07(1-6)-95-5-1.OHL-ALL-45MIN.M
Last changed : 3/30/2016 6:42:23 AM by SYSTEM
(modified after loading)

Analysis Method : E:\DATA\WSS\WSS-1-73A\GWH 2016-03-30 06-20-57\DAD-07(1-6)-95-5-1.OHL-ALL-45MIN.M (Sequence Method)
Last changed : 9/5/2016 8:30:45 PM by SYSTEM
(modified after loading)

Additional Info : Peak(s) manually integrated

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD1, S=230,4 Ref-off (E:\DATA\WSS\WSS-1-73A\GWH 2016-03-30 06-20-57\G71-0201.D)

<table>
<thead>
<tr>
<th>Peak RetTime</th>
<th>Width</th>
<th>Area</th>
<th>Height</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[min]</td>
<td>[min]</td>
<td>[nAU's]</td>
<td>[nAU]</td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
<td>--------</td>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>42.885</td>
<td>1.4131</td>
<td>1.00733e4</td>
<td>118.81017</td>
</tr>
<tr>
<td>2</td>
<td>68.446</td>
<td>2.5070</td>
<td>9928.98828</td>
<td>66.00992</td>
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</tbody>
</table>

Total : 2000224 184.81909

1260HPLC-DAD 9/5/2016 8:33:23 PM SYSTEM
Data File E:\DATA\NV3NW-2016-9-5\WQ-3-19-RAC-2 2016-09-05 14-02-05\001-0701.D
Sample Name: wsw-1-175-12

Acq. Operator: SYSTEM
Acq. Instrument: 1260HPLC-DAD
Injection Date: 9/5/2016 4:14:58 PM
Inj t: 1
Inj Volume: 5.000 μL

Analysis Method: E:\DATA\NV3NW-2016-9-5\WQ-3-19-RAC-2 2016-09-05 14-02-05\DAD=OJ{1-6}=95=5
-1.0ML-ALL-45MIN.M
(modified after loading)

Additional Info: Peak(s) manually integrated

Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD D, Sig=230,4 Ref-off

<table>
<thead>
<tr>
<th>#</th>
<th>RetTime Type</th>
<th>Width</th>
<th>Area</th>
<th>Height</th>
<th>Area %</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>42.159 RB</td>
<td>1.3528</td>
<td>1.8779e+6</td>
<td>171.85948</td>
<td>99.0530</td>
</tr>
<tr>
<td>2</td>
<td>67.067 MM</td>
<td>1.4412</td>
<td>1.7853e+5</td>
<td>2.35724</td>
<td>0.9470</td>
</tr>
</tbody>
</table>

Totals: 1.89590e+6 173.93572

1260HPLC-VWD 2/10/2017 9:05:29 PM SYSTEM
Page 1 of 2

60
Sorted By :  Signal
Multiplier :  1.0000
Dilution :  1.0000
Do not use Multiplier & Dilution Factor with ISTDs

Signal 1: VWD A, Wavelength=210 nm

<table>
<thead>
<tr>
<th>#</th>
<th>RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area</th>
<th>Height</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.999</td>
<td>BB</td>
<td>1.0526</td>
<td>2599.48291</td>
<td>36.55666</td>
<td>2.0022</td>
</tr>
<tr>
<td>2</td>
<td>45.567</td>
<td>VB</td>
<td>1.3483</td>
<td>1.27229e5</td>
<td>1373.98499</td>
<td>97.9979</td>
</tr>
</tbody>
</table>

Totals : 1.29828e5 1410.54065

1260HPLC-DAD 7/22/2017 4:17:34 PM SYSTEM
Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISSTDs

Signal 1: DAD1 B, Sig=210,4 Ref=off

Peak RetTime Type Width Area Height Area
#. [min] [min] [mAU*s] [mAU] %
-- -------------- -------------- -------------- --------------
1 10.807 BB 0.2177 8224.67969 579.01904 49.9209
2 12.250 BB 0.2535 8250.75888 497.45221 50.0791

Total: 1.64754e4 10764.7125
Area Percent Report

<table>
<thead>
<tr>
<th>Signal</th>
<th>Multiplier</th>
<th>Dilution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Use Multiplier & Dilution Factor with ISSTDs

Signal: DAD B, Sig=210,4 Ref-off

<table>
<thead>
<tr>
<th>Peak RetTime Type</th>
<th>Width [min]</th>
<th>Area [mAU*s]</th>
<th>Height [mAU]</th>
<th>Ares %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.196</td>
<td>749.75635</td>
<td>49.9331</td>
<td></td>
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<tr>
<td>2</td>
<td>34.086</td>
<td>475.02005</td>
<td>50.0669</td>
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</tr>
</tbody>
</table>

Totals: 1224.77640

1260HPLC-DAD 9/3/2016 9:00:57 PM SYSTEM
Data File E:\DATA\W9W\W9-1-114\(OD-M-ME(D)-95-5 2016-07-07 08:26-28\044-0501.D

Sample Name: W9-1-114-3-1

Acq. Operator : SYSTEM  Seq. Line : 5
Acq. Instrument : 1260HPLC-DAD  Location : Vial 44
Injection Date : 7/7/2016 10:15:18 AM  Inj : 1
Inj Volume : 5.000 µl
Acq. Method : E:\DATA\W9W\W9-1-114\(OD-M-ME(D)-95-5 2016-07-07 08:26-28\DAD-OJ[1-6]-99-1
-1.0ML-5UL-45MIN-ALL.M
Last changed : 7/7/2016 11:11:30 AM by SYSTEM
(modified after loading)
Analysis Method : E:\DATA\W9W\W9-1-114\(OD-M-ME(D)-95-5 2016-07-07 08:26-28\DAD-OJ[1-6]-99-1
-1.0ML-5UL-45MIN-ALL.M [Sequence Method]
Last changed : 9/3/2016 8:57:48 PM by SYSTEM
(modified after loading)
Additional Info : Peak(s) manually integrated

Area Percent Report

Signal 1: DAD 8, Sig=210,4 Ref=off

Peak RetTime Type Width Area Height Area %
#  [min] [min] [mAU*s] [mAU] %
----- ------ ------ ------ ------ ---
1 25.127 BB 0.4217 2086.11328 76.58176 2.1039
2 32.234 BB 1.0624 9.692064 4 117.5.1477 97.8941
Total : 9.40131e+ 1249.5953

1260HPLC-DAD 9/3/2016 8:58:22 PM SYSTEM
Data File E:\DATA\WNL\WNL-3-175-1\WNL-3-175-1 2016-06-27 22:45-34\032-0701.D
Sample Name: ccy-7-99-3

Acq. Operator: SYSTEM
Seq. Line: 7
Acq. Instrument: 1260HPLC-DAD
Location: Vial 32
Injection Date: 6/28/2016 2:17:32 AM
Injection Volume: 5.00 µL
Inj: 1

Acq. Method: E:\DATA\WNL\WNL-3-175-1\WNL-3-175-1 2016-06-27 22:45-34\DAD=DJ(1-6)-99-1-1.OML=5UL=45MIN=ALL.M
Last changed: 6/27/2016 19:46:18 PM by SYSTEM

Analysis Method: E:\DATA\WNL\WNL-3-175-1\WNL-3-175-1 2016-06-27 22:45-34\DAD=DJ(1-6)-99-1-1.OML=5UL=45MIN=ALL.M (Sequence Method)
Last changed: 9/3/2016 5:27:22 PM by SYSTEM
(modified after loading)

Additional Info: Peak(s) manually integrated

Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISSTDs

Signal 1: DAD A, Sig=205,4 Ref-off

Peak RetTime Type Width Area Height Ares
# [min] [min] [mAU*sec] [mAU] %
---|------|------|-----------|------|---
1 15.495 VH 0.3197 1.41013e4 669.61841 49.9133
2 20.482 BB 0.4220 1.41503e4 506.41763 30.0867

Totals: 2.82516e4 1176.03604

1260HPLC-DAD 9/3/2016 5:27:43 PM SYSTEM
Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000
Do not use Multiplier & Dilution Factor with ISSTDs

Signal 1: WVD1 A, Wavelength=210 nm

<table>
<thead>
<tr>
<th>#</th>
<th>Width</th>
<th>Area</th>
<th>Height</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.442</td>
<td>0.1726</td>
<td>114.14</td>
<td>11.42</td>
</tr>
<tr>
<td>2</td>
<td>9.288</td>
<td>0.1361</td>
<td>136.75</td>
<td>11.49</td>
</tr>
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</table>

Totals : 277.6868 237.22434
Reference
