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Supporting Information

Catalytic Asymmetric Conjugate Addition of Diorganozinc Reagents to α,β-Unsaturated Sulfones

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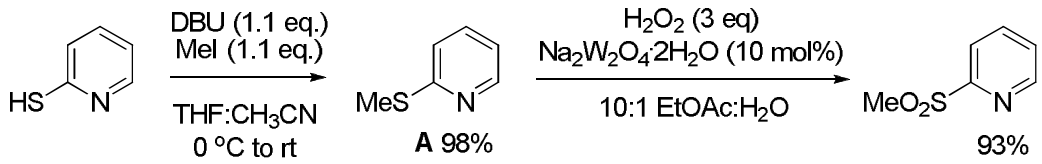
General Information:

All reactions were carried out under a nitrogen atmosphere using flame dried glassware. Toluene was distilled over sodium. All solvents were stored under nitrogen atmosphere. All copper-salts were purchased from Aldrich or Acros and used without further purification. Diorganozinc reagents were purchased from Aldrich [Me_2Zn (2.0 M in toluene), Et_2Zn (1.0 M in hexane), *i*-Pr_2Zn (1.0M in toluene), Bu_2Zn (1.0 M in heptane), Ph_2Zn (solid)]. Racemic 1,4-addition products were synthesized by reaction of the α,β-unsaturated sulfones (**3**) with the corresponding Grignard reagent (1.2 eq) at –20 °C in THF in the presence of CuI (1.5 eq).

Chromatography: Merck silica gel type 9385 230-400 mesh, TLC: Merck silica gel 60, 0.25 mm. Components were visualized by staining with a solution of a mixture of $KMnO_4$ (10 g) and K_2CO_3 (10 g) in H_2O (500 mL). Progress and conversion of the reaction were determined by GC-MS (GC, HP6890: MS HP5973) with an HP1 or HP5 column (Agilent Technologies, Palo Alto, CA). Mass spectra were recorded on a AEI-MS-902 mass spectrometer (EI+), a LTQ Orbitrap XL (ESI+) or an Applied Biosystems Q-Star XL mass spectrometer. ^{1}H- and ^{13}C-NMR were recorded on a Varian AMX400 (400 and 100.59 MHz, respectively) or a Varian VXR300 (300 and 75 MHz, respectively) using $CDCl_3$ as solvent. Chemical shift values are reported in ppm with the solvent resonance as the internal standard ($CHCl_3$: δ 7.26 for ^{1}H, $CDCl_3$: δ 77.0 for ^{13}C). Data are reported as follows: chemical shifts, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, br = broad, m = multiplet), coupling constants (Hz), and integration. Optical rotations were measured on a *Schmidt + Haensch* polarimeter (Polartronic MH8) with a 10 cm cell (*c* given in g/100 mL). Enantioselectivities were determined by HPLC analysis using a Shimadzu LC-10AD*VP* HPLC equipped with a Shimadzu SPD-M10A*VP* diode array detector. Melting points were measured using a Büchi Melting Point B-545.

Experimental Section:

Synthesis of methyl 2-pyridyl sulfone[1]

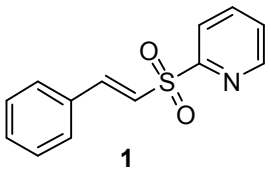


To a solution of 2-mercaptopyridine (11.11 g, 100 mmol) in dry THF (200 mL) and CH_3CN (20 mL), cooled to 0 ^oC, was added DBU (16.75 g, 110 mmol). The resulting mixture was stirred at 0 ^oC for 5 min before MeI (15.61 g, 110 mmol) was slowly added. The ice bath was removed and the mixture was stirred overnight. The reaction mixture was washed with water (100 mL) and the aqueous layer was extracted with EtOAc (3 x 100 mL). The combined organic layers were dried ($MgSO_4$), filtered and concentrated. The residue was purified by flash chromatography (*n*-hexane-EtOAc 2:1) to afford the methyl 2-pyridyl sulfide (**A**) as a colorless oil; yield: 12.26 g (98%). ^{1}H-NMR (300 MHz): δ 8.42 (m, 1H), 7.47 (m, 1H), 7.16 (m, 1H), 6.96 (m, 1H), 2.55 (s, 3H). ^{13}C-NMR (75 MHz): δ 159.9, 149.3, 135.6, 121.3, 119.0, 13.1.

To a solution of **A** (12.26 g, 98 mmol) in EtOAc (125 mL) was added H_2O (15 mL) and $Na_2WO_4 \cdot 2H_2O$ (3.23 g, 9.8 mmol). The resulting mixture was cooled to 0 ^oC before a 30% solution of H_2O_2 (30 mL, 294 mmol) was added dropwise. The reaction mixture was stirred at 0 ^oC for 30 min and at room temperature for 1 h. Then it was cooled to 0 ^oC and saturated aqueous $NaHSO_3$ (25 mL) was added slowly. The organic layer was separated and the aqueous layer was extracted with EtOAc (2 x 50 mL). The combined organic layers were dried ($NaSO_4$), filtered and concentrated. The residue was purified by flash chromatography (*n*-hexane-EtOAc 2:1) to afford the sulfone as a colorless oil; yield: 14.35 g (93%). ^{1}H-NMR (300 MHz): δ 8.77-8.70 (m, 1H), 8.12-7.89 (m, 2H), 7.62-7.49 (m, 1H), 3.21 (s, 3H). ^{13}C-NMR (75 MHz): δ 157.8, 149.9, 138.3, 127.4, 121.0, 39.9.

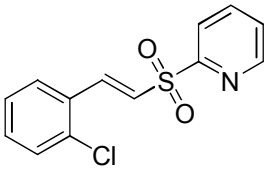
[1] Llamas, T; Arrayás, R. G.; Carretero, J. C. *Angew. Chem. Int. Ed.* **2007**, *46*, 3329-3332

General procedure for the synthesis of α,β-unsaturated sulfones (1a-1i): To a solution of 20 mmol of 2-(methylsulfonyl)pyridine (3.14 g) in dry THF (40 mL), cooled to −78 °C, was added a 1.6 M solution of *n*-BuLi in hexane (13.75 mL, 22 mmol, 1.1 eq). The mixture was stirred at −78 °C for 30 min followed by addition of the corresponding aldehyde (22 mmol, 1.1 eq.) at −78 °C and the reaction mixture was slowly warmed to room temperature. The reaction mixture was quenched with aqueous saturated NH_4Cl (25 mL). The organic layer was separated and the aqueous layer was extracted with EtOAc (3 x 50 mL). The combined organic layers were dried with $MgSO_4$, filtered and concentrated *in vacuo*. Generally, the crude alcohol can be used without further purification for the next dehydration step. The crude alcohol (20 mmol) was dissolved in dry DCM (150 mL) under nitrogen atmosphere and DMAP (9.77 g, 80 mmol, 4 eq.) was added and the reaction mixture was cooled down to 0 °C. Subsequently, methanesulfonyl chloride (4.58 g, 40 mmol, 2 eq.) was added and the mixture was stirred while slowly warming to room temperature overnight. The reaction mixture was quenched with aqueous saturated NH_4Cl (100 mL). The layers were separated and the aqueous layer was extracted with DCM (3 x 50 mL). The combined organic layers were dried with $MgSO_4$, filtered and the solvent evaporated *in vacuo*. The crude product was purified by flash chromatography on silica gel to yield the α,β-unsaturated sulfone in moderate to good yield (31-75%).



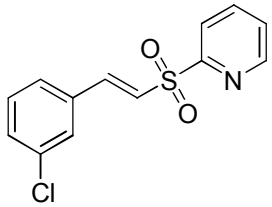
1

(*E*)-2-(styrylsulfonyl)pyridine (1a)[2]: White solid, mp: 101.6 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.75 (br d, *J* = 4.7 Hz, 1H), 8.15 (dt, *J*= 7.7, 0.9 Hz, 1H), 7.96 (dt, *J* = 7.7, 7.7, 1.5 Hz, 1H), 7.79 (d, *J* = 15.5 Hz, 1H), 7.63-7.58 (m, 3H), 7.46 – 7.38 (m, 3H), 7.12 (d, *J* = 15.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.5, 150.4, 145.1, 138.2, 132.3, 131.4, 129.1, 128.8, 127.1, 124.5, 121.9. HRMS (EI+, *m/z*): calcd. for $C_{13}H_{11}NO_2S$ $[M]^+$: 245.0510; found: 245.0502. Anal. Calcd for $C_{13}H_{11}NO_2S$: C, 63.65; H, 4.52; N, 5.71; S, 13.04. Found: C, 63.43; H, 4.57; N, 5.50; S, 13.05.

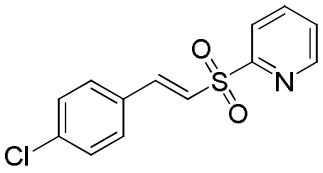


[2] Desrosiers, J.–N.; Bechara, W. S.; Charette, A. B. *Org. Lett.*, **2008**, *10*, 2315-2318

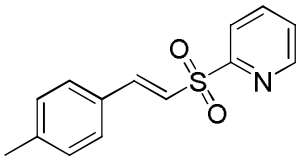
(*E*)-2-(2-chlorostyrylsulfonyl)pyridine (1b): White solid. mp: 108 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.82 (d, *J* = 4.6 Hz, 1H), 8.29-8.19 (m, 2H), 8.04 (td, *J* = 7.8, 1.6 Hz, 1H), 7.79-7.57 (m, 2H), 7.50 (d, *J* = 7.6 Hz, 1H), 7.46-7.30 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.0, 150.2, 140.4, 138.2, 135.2, 132.0, 130.3, 130.2, 128.2, 127.2, 127.1, 121.7. HRMS (ESI+, *m/z*): calcd. for $C_{13}H_{11}ClNO_2S$ $[M + H]^+$: 280.0193; found: 280.0186.



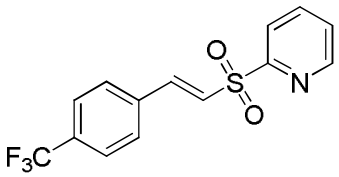
(*E*)-2-(3-chlorostyrylsulfonyl)pyridine (1c): White solid. mp: 92 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.66 (d, *J* = 4.7 Hz, 1H), 8.07 (d, *J* = 7.8 Hz, 1H), 7.91 (td, *J* = 7.8, 1.7 Hz, 1H), 7.63 (d, *J* = 15.5 Hz, 1H), 7.48 (ddd, *J* = 7.6, 4.7, 0.9 Hz, 1H), 7.42-7.37 (m, 1H), 7.35-7.20 (m, 3H), 7.09 (d, *J* = 15.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.8, 150.2, 143.0, 138.2, 134.7, 133.8, 130.9, 130.2, 128.1, 127.2, 126.8, 126.0, 121.8. HRMS (ESI+, *m/z*): calcd. for $C_{13}H_{11}ClNO_2S$ $[M + H]^+$: 280.0193; found: 280.0186.



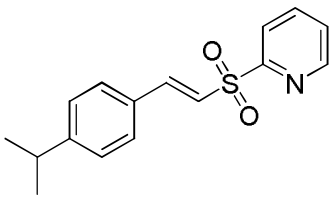
(*E*)-2-(4-chlorostyrylsulfonyl)pyridine (1d): White solid. mp: 155.5-156.2 °C ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.73 (ddd, *J* = 4. 7, 1.6, 0.8 Hz, 1H), 8.14 (td, *J* = 7.9, 1.0 Hz, 1H), 7.96 (dt, *J* = 7.8, 1.7 Hz, 1H), 7.72 (d, *J* = 15.5 Hz, 1H), 7.53 (ddd, *J* = 7.7, 4.7, 1.1 Hz, 1H), 7.48-7.44 (m, 2H), 7.39-7.35 (m, 2H), 7.09 (d, *J* = 15.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.3, 150.3, 143.5, 138.2, 137.4, 130.8, 129.8, 129.3, 127.1, 125.1, 121.8. HRMS (ESI+, *m/z*): calcd. for $C_{13}H_{11}ClNO_2S$ $[M + H]^+$: 280.0193; found: 280.0192.



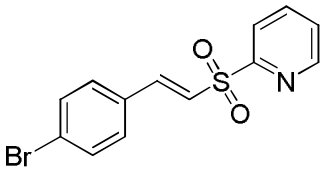
(*E*)-2-(4-methylstyrylsulfonyl)pyridine (1e): White solid. mp: 124 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.72 (d, *J* = 4.6 Hz, 1H), 8.12 (d, *J* = 7.8 Hz, 1H), 7.94 (m, 1H), 7.73 (d, *J* = 15.5 Hz, 1H), 7.54-7.47 (m, 1H), 7.40 (dd, *J* = 8.0, 1.2 Hz, 2H), 7.19 (d, *J* = 7.1 Hz, 2H), 7.04 (dd, *J* = 15.5, 2.0 Hz, 1H), 2.35 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.6, 150.3, 145.0, 142.0, 138.1, 129.7, 129.5, 128.7, 127.0, 123.3, 121.7, 21.5. HRMS (ESI+, *m/z*): calcd. for $C_{14}H_{14}NO_2S$ $[M + H]^+$: 260.0739; found: 260.0742.



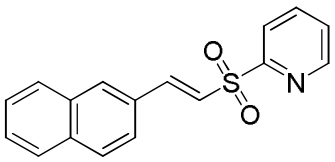
(*E*)-2-(4-(trifluoromethyl)styrylsulfonyl)pyridine (1f)[2]: White solid. mp: 136.8-137.5 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68 (d, *J* = 4.1 Hz, 1H), 8.10 (d, *J* = 7.8 Hz, 1H), 7.93 (m, 1H), 7.75 (d, *J* = 15.6 Hz, 1H), 7.59 (br s, 4H), 7.50 (dd, *J* = 7.6, 4.7 Hz, 1H), 7.21 (d, *J* = 15.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.8, 150.3, 142.8, 138.2, 135.5, 132.4 (q, $J_{C\text{-}F}$ = 43.5 Hz), 128.8, 127.3, 127.3, 125.8 (q, $J_{C\text{-}F}$ = 4.9 Hz), 123.4 (q, $J_{C\text{-}F}$ = 361 Hz), 121.6. The physical and spectroscopic properties were in accordance with those described in literature.[2]



(*E*)-2-(4-isopropylstyrylsulfonyl)pyridine (1g): White solid. mp: 74 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.72 (d, *J* = 3.0 Hz, 1H), 8.13 (d, *J* = 7.8 Hz, 1H), 7.95 (m, 1H), 7.75 (d, *J* = 15.5 Hz, 1H), 7.51 (m, 1H), 7.45 (d, *J* = 8.2 Hz, 2H), 7.25 (d, *J* = 8.2 Hz, 2H), 7.06 (d, *J* = 15.5 Hz, 1H), 3.02-2.77 (m, 1H), 1.23 (d, *J* = 3.3 Hz, 3H), 1.21 (d, *J* = 3.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.5, 152.9, 150.3, 145.1, 138.1, 129.9, 128.8, 127.1, 127.0, 123.3, 121.7, 34.0, 23.6. HRMS (EI+, *m/z*): calcd. for $C_{16}H_{17}NO_2S$ $[M]^+$: 287.0980; found: 287.0988.



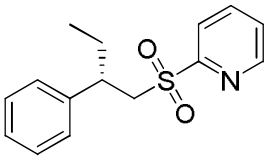
(*E*)-2-(4-bromostyrylsulfonyl)pyridine (1h): Orange solid. mp: 178 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.72 (dd, *J* = 4.6, 0.8 Hz, 1H), 8.13 (dd, *J* = 7.9, 0.7 Hz, 1H), 7.95 (td, *J* = 7.8, 1.5 Hz, 1H), 7.70 (d, *J* = 15.5 Hz, 1H), 7.56-7.46 (m, 3H), 7.37 (d, *J* = 7.7 Hz, 2H), 7.11 (dd, *J* = 15.5, 1.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.2, 150.3, 143.6, 138.2, 132.3, 131.2, 130.0, 127.2, 125.8, 125.2, 121.9. HRMS (ESI+, *m/z*): calcd. for $C_{13}H_{11}BrNO_2S$ $[M + H]^+$: 323.9688; found: 323.9687.



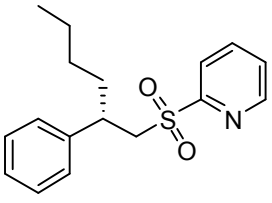
(*E*)-2-(2-(naphthalen-2-yl)vinylsulfonyl)pyridine (1i)[3]: White solid. mp: 148 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.74 (m, 1H), 8.16 (br d, *J* = 7.9 Hz, 1H), 7.99-7.87 (m, 3H), 7.87-7.75 (m, 3H), 7.58 (br d, *J* = 8.6 Hz, 1H), 7.56-7.46 (m, 3H), 7.21 (d, *J* = 15.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.4, 150.3, 145.0, 138.2, 134.4, 132.3, 131.4, 129.6, 127.8, 127.7, 127.1, 127.0, 124.5, 123.5, 121.8. The physical and spectroscopic properties were in accordance with those described in literature.[3]

[3] Mauleón, P.; Carretero, J. C. *Org. Lett.* **2004**, *6*, 3195

General procedure for the conjugate addition of diorganozinc reagents to α,β-unsaturated sulfones: $Cu(OTf)_2$ (6.6 mg, 18.3 μmol, 7.3 mol%) and **L1** (14.8 mg, 27.5 μmol, 11 mol%) were dissolved in dry toluene (5.0 mL) under nitrogen atmosphere. The mixture was stirred for 30 min and cooled down to 0 ^{o}C and the diorganozinc reagent (3.2 eq) was added. After stirring for 15 min, the substrate (0.25 mmol, dissolved in 1.0 mL of toluene) was added over 3 h and the mixture was stirred for 24 h at 0 ^{o}C. Aqueous saturated NH_4Cl-solution (3 mL) was added and the mixture was warmed up to room temperature. The mixture was diluted with Et_2O and the layers were separated. The aqueous layer was extracted with DCM (3 x 10 mL) and the combined organic layers were dried with anhydrous Na_2SO_4, filtered and the solvent evaporated *in vacuo*. The crude material was purified by flash chromatography on silica to afford the pure product in moderate to good yield (46-86%).

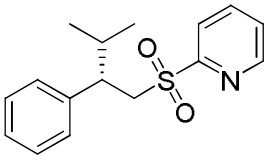


(*S*)-(+)-2-(2-phenylbutylsulfonyl)pyridine (2a)[1]: Colorless oil, yield: 70%. Enantiomeric excess: 91% determined by HPLC (Chiralcel AD 95:5 Heptane: *i*-PrOH: t_r (minor) 21.5 min, t_r (major) 23.8 min). $[\alpha]_D$ = +26.0 (*c* 2.4, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57 (dd, *J* = 4.5, 1.0 Hz, 1H), 7.72-7.66 (m, 2H), 7.39-7.32 (m, 1H), 7.11-7.00 (m, 3H), 6.99-6.95 (m, 2H), 3.95 (dd, *J* = 14.6, 8.6 Hz, 1H), 3.57 (dd, *J* = 14.6, 5.4 Hz, 1H), 3.21-3.12 (m, 1H), 1.93-1.81 (m, 1H), 1.64 (qdd, *J* = 14.2, 9.5, 7.3 Hz, 1H), 0.75 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.4, 149.9, 141.0, 137.7, 128.2, 127.8, 126.8, 126.7, 122.1, 57.5, 42.3, 29.5, 11.6. The physical and spectroscopic properties were in accordance with those described in literature.[1]

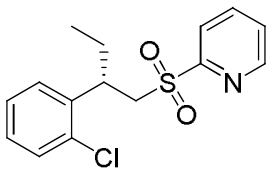


(+)-2-(2-phenylhexylsulfonyl)pyridine (2c): Colorless oil, yield: 73%. Enantiomeric excess: 66% determined by HPLC (Chiralcel OD-H 90:10 Heptane: *i*-PrOH: t_r (minor) 26.7 min, t_r (major) 33.6 min). $[\alpha]_D$ = +53.8 (*c* 0.7, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.59-8.54 (m, 1H), 7.75-7.63 (m, 2H), 7.40-7.29 (m, 1H), 7.13-7.00 (m, 3H), 7.00-6.92 (m, 2H), 3.95 (dd, *J* = 14.6, 8.7 Hz, 1H), 3.56 (dd, *J* = 14.6, 5.4 Hz, 1H), 3.29 -3.19 (m, 1H), 1.91-1.71 (m, 1H), 1.71-1.54 (m,

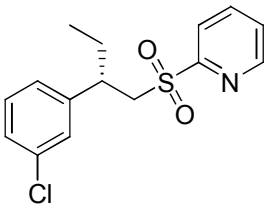
1H), 1.37-0.95 (m, 4H), 0.80 (t, *J* =7.2 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 157.5, 149.9, 141.4, 137.6, 128.3, 127.8, 126.7, 126.6, 122.1, 57.8, 40.6, 36.2, 29.1, 22.3, 13.8. HRMS (ESI+, *m/z*): calcd. for $C_{17}H_{21}NO_2S$ [M + H]$^+$: 304.13658; found: 304.13611.



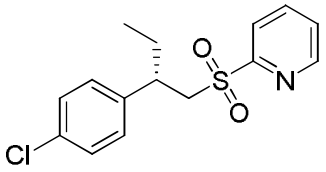
(*S*)-(+)-2-(3-methyl-2-phenylbutylsulfonyl)pyridine (2d)[3]: White solid, yield: 61%. mp: 88 ^{o}C. Enantiomeric excess: 85% determined by HPLC (Chiralcel OD-H 92:8 Heptane: *i*-PrOH: t_r (minor) 33.8 min, t_r (major) 46.5 min). $[\alpha]_D$ = +24.2 (*c* 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.52 (ddd, *J* = 4.7, 1.6, 0.9 Hz, 1H), 7.57 (td, *J* = 7.6, 2.0 Hz, 1H), 7.51 (dt, *J* = 4.0, 1.2 Hz, 1H), 7.29 (ddd, *J* = 7.5, 4.7, 1.3 Hz, 1H), 7.00-6.93 (m, 3H), 6.90-6.84 (m, 2H), 4.07 (dd, *J* = 14.8, 10.8 Hz, 1H), 3.64 (dd, *J* = 14.8, 3.5 Hz, 1H), 3.00 (ddd, *J* = 10.9, 7.5, 3.5 Hz, 1H), 1.94-1.81 (m, 1H), 0.95 (d, *J* = 6.7 Hz, 3H), 0.70 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.2, 149.7, 139.5, 137.5, 128.7, 127.8, 126.5, 126.4, 122.2, 55.5, 47.4, 33.4, 20.6, 19.7. HRMS (ESI+, *m/z*): calcd. for $C_{16}H_{20}NO_2S$ [M + H]$^+$: 290.12093; found: 290.12062. The physical and spectroscopic properties were in accordance with those described in literature.[3]



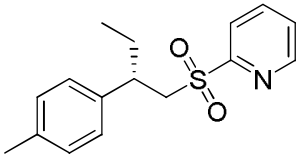
(+)-2-(2-(2-chlorophenyl)butylsulfonyl)pyridine (3): Colorless oil, yield: 85%. Enantiomeric excess: 70% determined by HPLC (Chiralpak AD-H 90:10 Heptane: *i*-PrOH: t_r (minor) 30.3 min, t_r (major) 32.7 min). $[\alpha]_D$ = +30.7 (*c* 3.3, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57 (br d, *J* = 3.9 Hz, 1H), 7.86 (d, *J* = 7.7 Hz, 1H), 7.76 (m, 1H), 7.41-7.35 (m, 1H), 7.15 (br d, *J* = 7.7 Hz, 1H), 7.07-6.96 (m, 3H), 3.96 (dd, *J* = 14.1, 7.9 Hz, 1H), 3.77-3.66 (m, 1H), 3.66-3.55 (m, 1H), 1.98-1.85 (m, 1H), 1.78-1.63 (m, 1H), 0.76 (t, *J* = 7.3, Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.0, 149.9, 138.5, 137.7, 134.0, 129.6, 128.7, 127.8, 126.9, 126.8, 122.1, 56.3, 38.1, 28.6, 11.2. HRMS (ESI+, *m/z*): calcd. for $C_{15}H_{17}ClNO_2S$ [M + H]$^+$: 310.0663; found: 310.0660.



(+)-2-(2-(3-chlorophenyl)butylsulfonyl)pyridine (4): Colorless oil, yield: 66%. Enantiomeric excess: 84% determined by HPLC (Chiralpak AD-H 90:10 Heptane: *i*-PrOH: t_r (minor) 23.6 min, t_r (major) 27.4 min). $[\alpha]_D$ = +44.7 (*c* 2.5, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57 (dd, *J* = 4.6, 1.0 Hz, 1H), 7.74-7.66 (m, 2H), 7.39-7.33 (m, 1H), 7.04-6.94 (m, 2H), 6.92-6.85 (m, 2H), 4.01-3.91 (m, 1H), 3.51 (dd, *J* = 14.7, 4.0 Hz, 1H), 3.17-3.07 (m, 1H), 1.89-1.75 (m, 1H), 1.67-1.54 (m, 1H), 0.75 (t, *J* = 6.9 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.2, 149.8, 143.0, 137.5, 134.0, 129.5, 127.8, 126.9, 126.9, 126.3, 121.9, 57.0, 42.2, 29.4, 11.5. HRMS (ESI+, *m/z*): calcd. for $C_{15}H_{17}ClNO_2S$ $[M + H]^+$: 310.0663; found: 310.0649.

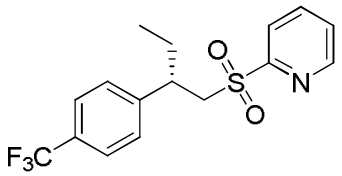


(+)-2-(2-(4-chlorophenyl)butylsulfonyl)pyridine (5): White solid, yield: 68%. mp: 81 ^{o}C. Enantiomeric excess: 89% determined by HPLC (Chiralpak AD-H 90:10 Heptane: *i*-PrOH: t_r (minor) 29.3 min, t_r (major) 31.6 min). $[\alpha]_D$ = +41.2 (*c* 2.6, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57-8.54 (m, 1H), 7.74-7.68 (m, 1H), 7.67-7.63 (m, 1H), 7.42-7.36 (m, 1H), 7.01 (d, *J* = 8.4 Hz, 2H), 6.90 (d, *J* = 8.3 Hz, 2H), 3.93 (dd, *J* = 14.7, 9.3 Hz, 1H), 3.54 (dd, *J* = 14.7, 4.9 Hz, 1H), 3.14 (ddd, *J* = 14.6, 9.7, 5.1 Hz, 1H), 1.89-1.75 (m, 1H), 1.59 (qdd, *J* = 14.4, 9.7, 7.4 Hz, 1H), 0.74 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.2, 149.8, 139.4, 137.7, 132.3, 129.2, 128.2, 126.7, 122.0, 57.3, 41.8, 29.3, 11.5. HRMS (ESI+, *m/z*): calcd. for $C_{15}H_{17}ClNO_2S$ $[M + H]^+$: 310.0663; found: 310.0663.

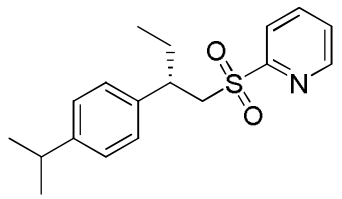


(+)-2-(2-*p*-tolylbutylsulfonyl)pyridine (6): Colorless oil, yield: 46%. Enantiomeric excess: 92% determined by HPLC (Chiralpak AD-H 90:10 Heptane: *i*-PrOH: t_r (minor) 24.6 min, t_r (major) 28.0 min). $[\alpha]_D$ = +34.4 (*c* 1.2,

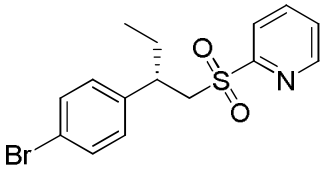
$CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57 (br d, *J* = 4.6 Hz, 1H), 7.68 (br d, *J* = 3.7 Hz, 2H), 7.40-7.33 (m, 1H), 6.86 (br s, 4H), 3.91 (dd, *J* = 14.6, 8.6 Hz, 1H), 3.56 (dd, *J* = 14.6, 5.5 Hz, 1H), 3.17-3.07 (m, 1H), 2.20 (s, 3H), 1.91-1.79 (m, 1H), 1.68-1.55 (m, 1H), 0.75 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.4, 149.8, 138.0, 137.5, 136.1, 128.9, 127.7, 126.5, 122.1, 57.7, 41.9, 29.3, 20.8, 11.6. HRMS (ESI+, *m/z*): calcd. for $C_{16}H_{20}NO_2S$ $[M + H]^+$: 290.1209; found: 290.1206.



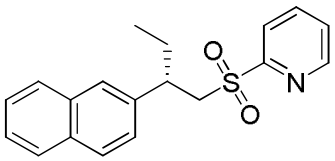
(*S*)-(+)-2-(2-(4-trifluoromethyl)phenyl)butylsulfonyl)pyridine (7)[2]: Yellow oil, yield: 84%. Enantiomeric excess: 96% determined by HPLC (Chiralpak AD-H 90:10 Heptane: *i*-PrOH: t_r (minor) 23.5 min, t_r (major) 24.8 min). $[\alpha]_D$ = +37.0 (*c* 3.6, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.53 (d, *J* = 4.6 Hz, 1H), 7.69-7.60 (m, 2H), 7.37-7.32 (m, 1H), 7.30 (br d, *J* = 7.9 Hz, 2H), 7.09 (d, *J* = 7.9 Hz, 2H), 4.02 (dd, *J* = 14.7, 9.6 Hz, 1H), 3.57 (dd, *J* = 14.8, 4.6 Hz, 1H), 3.29-3.19 (m, 1H), 1.93-1.80 (m, 1H), 1.73-1.59 (m, 1H), 0.77 (dt, *J* = 7.3, 1.9 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.2, 149.9, 145.0, 137.7, 128.9 (q, J_{C-F} = 32.5 Hz), 128.3, 126.8, 125.0 (q, J_{C-F} = 3.8 Hz), 123.9 (q, J_{C-F} = 273.0 Hz), 122.0, 57.0, 42.4, 29.4, 11.5. The physical and spectroscopic properties were in accordance with those described in literature.[2]



(+)-2-(2-(4-isopropylphenyl)butylsulfonyl)pyridine (8): Colorless oil, yield: 52%. Enantiomeric excess: 90% determined by HPLC (Chiralcel OD 95:5 Heptane: *i*-PrOH: t_r (minor) 26.5 min, t_r (major) 32.9 min). $[\alpha]_D$ = +43.0 (*c* 2.1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.55 (d, *J* = 3.7 Hz, 1H), 7.69-7.61 (m, 2H), 7.35-7.29 (m, 1H), 6.88 (m, 4H), 3.98 (dd, *J* = 14.7, 8.9 Hz, 1H), 3.53 (dd, *J* = 14.7, 5.2 Hz, 1H), 3.19-3.08 (m, 1H), 2.81-2.69 (m, 1H), 1.90-1.78 (m, 1H), 1.68-1.55 (m, 1H), 1.15 (d, *J* = 6.9 Hz, 6H), 0.76 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.4, 149.8, 147.0, 138.2, 137.5, 127.7, 126.6, 126.2, 122.1, 57.6, 42.0, 33.5, 29.5, 24.0, 23.9, 11.6. HRMS (EI+, *m/z*): calcd. for $C_{16}H_{18}NO_2S$ $[M - C_2H_5]^+$: 288.1058; found: 288.1065.



(+)-2-(2-(4-bromophenyl)butylsulfonyl)pyridine (9): White solid, yield: 86%. mp: 82.9 °C. Enantiomeric excess: 96% determined by HPLC (Chiralcel OD 95:5 Heptane: *i*-PrOH: t_r (minor) 24.4 min, t_r (major) 33.0 min). $[\alpha]_D$ = +45.0 (*c* 3.8, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.56 (br d, *J* = 4.1 Hz, 1H), 7.72 (dt, *J* = 7.7, 1.6 Hz, 1H), 7.64 (br d, *J* = 7.8 Hz, 1H), 7.40 (ddd, *J* = 7.5, 4.7, 1.1 Hz, 1H), 7.16 (br d, *J* = 8.4 Hz, 2H), 6.84 (br d, *J* = 8.4 Hz, 2H), 3.94 (dd, *J* = 14.7, 9.4 Hz, 1H), 3.54 (dd, *J* = 14.7, 4.9 Hz, 1H), 3.19-3.08 (m, 1H), 1.89-1.76 (m, 1H), 1.66-1.53 (m, 1H), 0.75 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.3, 149.9, 140.0, 137.7, 131.2, 129.7, 126.7, 122.0, 120.5, 57.3, 42.0, 29.3, 11.5. HRMS (ESI+, *m/z*): calcd. for $C_{15}H_{17}BrNO_2S$ $[M + H]^+$: 354.0158; found: 354.0152.



(*S*)-(+)-2-(2-(naphthalen-2-yl)butylsulfonyl)pyridine (10): White solid, yield: 83%. mp: 105 °C. Enantiomeric excess: 93% determined by HPLC (Chiralcel OD 95:5 Heptane: *i*-PrOH: t_r (minor) 26.5 min, t_r (major) 32.9 min). $[\alpha]_D$ = +55.0 (*c* 3.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.43-8.40 (m, 1H), 7.70-7.60 (m, 2H), 7.52 (dt, *J* = 8.2, 0.8 Hz, 2H), 7.44-7.37 (m, 3H), 7.31-7.26 (m, 1H), 7.09 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.05-7.01 (m, 1H), 4.10 (dd, *J* = 14.7, 9.4 Hz, 1H), 3.61 (dd, *J* = 14.7, 4.9 Hz, 1H), 3.34 (tt, *J* = 9.7, 5.0 Hz, 1H), 2.00-1.87 (m, 1H), 1.83-1.68 (m, 1H), 0.80 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.0, 149.5, 137.9, 136.9, 132.8, 132.1, 127.9, 127.3, 127.2, 127.0, 126.1, 125.8, 125.5, 125.2, 121.8, 57.5, 42.5, 29.3, 11.5. The physical and spectroscopic properties were in accordance with those described in literature.[2]

NMR Spectra of new compounds