Supporting Information

Asymmetric Radical Addition of Ethers to Enantiopure *N-p*-Toluenesulfinyl Aldimines, Mediated by Dimethylzinc–Air

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General

All melting points are uncorrected. IR spectra were expressed in cm^{-1} . ^1H NMR (500 or 400 MHz) and ^{13}C NMR (125 or 100 MHz) spectra were measured in CDCl_3 . Chemical shifts and coupling constants are presented in ppm δ and Hz respectively. Abbreviations are as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. Column chromatography was carried out with silica gel.

Preparation of ethers

2,2-Dimethyl-1,3-dioxolane (**2**)¹ and 4,4,5,5-tetramethyl-1,3-dioxolane (**10**)² were prepared according to known procedures described in the literature.

Preparation of chiral *N*-*p*-toluenesulfinyl aldimines **1a–1g:** the imines were prepared according to known literature procedure.³ The spectroscopic data, ^1H and ^{13}C NMR, IR, and MS, and specific rotation of **1a**,⁴ **1d**,⁵ **1e**,⁶ and **1g**⁶ were in agreement with those reported.

(*S,E*)-4-Methyl-*N*-(2-methylbenzylidene)benzenesulfinamide (**1b**)

Recrystallization from hexane gave **1b** as colorless prisms of mp 62–64 °C: R_f 0.72 (EtOAc/hexane 70/30). $[\alpha]_D^{25} +153$ (c 0.235, CHCl_3). ^1H NMR (500 MHz): 2.40 (s, 3H), 2.60 (s, 3H), 7.22–7.28 (m, 2H), 7.32 (d, $J = 7.9$, 2H), 7.38 (ddd, $J = 1.2$, 7.6, 7.6, 1H), 7.64 (d, $J = 8.3$, 2H), 7.92 (d, $J = 8.1$, 1H), 9.03 (s, 1H). ^{13}C NMR (125 MHz): 19.7 (CH_3), 21.3 (CH_3), 124.8 (CH), 126.3 (CH), 129.4 (CH), 129.9 (CH), 131.3 (CH), 131.9 (C), 132.2 (CH), 139.7 (C), 141.7 (C), 142.0 (C), 159.4 (CH). IR (KBr): 2924, 1589, 1481, 1450, 1366, 1288, 1227, 1080, 810, 764, 702, 625. EIMS (m/z): 257 (M^+), 209, 192, 141, 139 ($\text{SOC}_6\text{H}_4\text{CH}_3$), 118 ($\text{M}^+ - \text{SOC}_6\text{H}_4\text{CH}_3$), 91 ($\text{C}_6\text{H}_4\text{CH}_3$), 85. HRMS-EI: $[\text{M}^+]$ calcd for $\text{C}_{15}\text{H}_{15}\text{NOS}$, 257.0874; found, 257.0871.

(1) Sanderson, J. R.; Lin, J. J.; Duranleau, R. G.; Yeakey, E. L.; Marquis, E. T. *J. Org. Chem.* **1988**, *53*, 2859–2861.

(2) Willy, W. E.; Binsch, G.; Eliel, E. L. *J. Am. Chem. Soc.* **1970**, *92*, 5394–5402.

(3) Davis, F. A.; Zhang, Y.; Andemichael, Y.; Fang, T.; Fanelli, D. L.; Zhang, H. *J. Org. Chem.* **1999**, *64*, 1403–1406.

(4) Davis, F. A.; Reddy, R. E.; Szewczyk, J. M. *J. Org. Chem.* **1995**, *60*, 7037–7039.

(5) Moreau, P.; Essiz, M.; Mérour, J.-Y.; Bouzard, D. *Tetrahedron: Asymmetry* **1997**, *8*, 591–598.

(6) Davis, F. A.; Reddy, R. E.; Szewczyk, J. M.; Reddy, G. V.; Portonovo, P. S.; Zhang, H.; Fanelli, D.; Reddy, R. T.; Zhou, P.; Carroll, P. J. *J. Org. Chem.* **1997**, *62*, 2555–2563.

(*S,E*)-4-Methyl-*N*-(4-methylbenzylidene)benzenesulfinamide (1c**).**

Recrystallization from ethyl acetate–hexane gave **1c** as colorless prisms of mp 100–102 °C: R_f 0.67 (EtOAc/hexane 70/30). $[\alpha]_D^{25} +67$ (c 0.50, CHCl_3). ^1H NMR (500 MHz): 2.398 (s, 3H), 2.404 (s, 3H), 7.26 (d, $J = 7.9$, 2H), 7.31 (d, $J = 8.1$, 2H), 7.63 (d, $J = 8.1$, 2H), 7.74 (d, $J = 7.9$, 2H), 8.72 (s, 1H). ^{13}C NMR (125 MHz): 21.4 (CH_3), 21.7 (CH_3), 124.9 (CH), 129.7 ($2 \times \text{CH}$), 129.9 (CH), 131.4 (C), 141.7 (C), 142.0 (C), 143.5 (C), 160.6 (CH). IR (KBr): 2368, 1597, 1566, 1103, 810, 710. EIMS (m/z): 257 (M^+), 240, 209, 192, 141, 139 ($\text{SOC}_6\text{H}_4\text{CH}_3$), 118 ($\text{M}^+ - \text{SOC}_6\text{H}_4\text{CH}_3$), 91 ($\text{C}_6\text{H}_4\text{CH}_3$). Anal. Calcd. for $\text{C}_{15}\text{H}_{15}\text{NOS}$: C, 70.01; H, 5.87; N, 5.44. Found: C, 69.60; H, 5.89, N, 5.31.

(*S,E*)-4-Methyl-*N*-(naphthalene-2ylmethylene)benzenesulfinamide (1f**).**

Recrystallization from ethyl acetate–hexane gave **1f** as colourless prisms of mp 139–140 °C: R_f 0.46 (EtOAc/hexane 30/70). $[\alpha]_D^{20} +230$ (c 0.995, CHCl_3). ^1H NMR (500 MHz): 2.41 (s, 3H), 7.33 (d, $J = 7.9$, 2H), 7.54–7.60 (m, 2H), 7.68 (d, $J = 8.3$, 2H), 7.86–7.89 (m, 2H), 7.94 (d, $J = 7.9$, 1H), 8.02 (dd, $J = 1.5$, 8.6, 1H), 8.22 (brs, 1H), 8.91 (s, 1H). ^{13}C NMR (125 MHz): 21.3 (CH_3), 123.9 (CH), 124.8 (CH), 126.9 (CH), 127.9 (CH), 128.3 (CH), 128.8 (CH), 129.1 (CH), 129.9 (CH), 131.5 (C), 132.7 (CH), 132.8 (C), 135.4 (C), 141.7 (C), 141.8 (C), 160.7 (CH). IR (KBr): 3055, 1605, 1489, 1358, 1173, 1096, 810, 748, 702. EIMS (m/z): 293 (M^+), 245, 153, 140, 139 ($\text{SOC}_6\text{H}_4\text{CH}_3$), 127 ($\text{M}^+ - \text{CNSOC}_6\text{H}_4\text{CH}_3$), 92, 91 ($\text{C}_6\text{H}_4\text{CH}_3$), 77. HRMS-EI: $[\text{M}^+]$ calcd for $\text{C}_{18}\text{H}_{15}\text{NOS}$, 293.0874; found, 293.0876.

General procedure for the radical addition of ethers to imine 1a. *N*-[*(R)*-((*R*)-2,2-Dimethyl-1,3-dioxolan-4-yl)(phenyl)methyl]-4-methylbenzenesulfonamide and *N*-[*(R)*-((*S*)-2,2-dimethyl-1,3-dioxolan-4-yl)(phenyl)methyl]-4-methylbenzenesulfonamide (**3**).

A dry three-neck round bottom flask was equipped with a stirrer bar and (*S,E*)-4-Methyl-*N*-(benzylidene)benzenesulfinamide (**1a**) (243 mg, 1 mmol). The flask was filled with argon after evacuation and refill with argon (3 times). 2,2-Dimethyl-1,3-dioxolane (**2**) (27.6 mL, 250 mmol) was added at room temperature. To the stirred solution was added dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane), the argon source was replaced with a NaOH drying tube and air was injected into the reaction mixture *via* a air bubbler at a rate of 0.5 mL/h. The reaction mixture was stirred for 29 h at room temperature after which dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane) was added and the reaction mixture stirred for a further 19.5 h. Dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane) was added to the reaction mixture and the reaction mixture was stirred for a further 21.5 h followed by quenching with saturated aqueous sodium bicarbonate (20 mL). The mixture was extracted with ethyl acetate (3 × 20 mL). The combined organic extracts were washed with brine (20 mL), dried over Na₂SO₄, filtered, and concentrated under reduced pressure to give the crude product as a pale yellow oil. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.5 h, dilution with dichloromethane (10 mL) followed by washing with saturated aqueous sodium bicarbonate (3 × 15 mL). The organic layer was dried over Na₂SO₄, filtered, and concentrated under reduced pressure to give the crude product (72:28 mixture of diastereoisomers) as a cloudy oil which was purified by flash column chromatography (acetone/hexane 20/80) to give **3** (236 mg, 65%) as a 71:29 mixture of diastereoisomers, as a white solid of mp 91.5–93 °C: *R*_f 0.13 (ethyl acetate/hexane 20/80). [α]_D²⁵ –20 (*c* 0.97, CHCl₃), 21% ee and 67% ee for (*R,R*)-diastereoisomer and (*R,S*)-diastereoisomer respectively (HPLC, Daicel Chiralpak AS, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, for (*R,R*)-diastereoisomer, major 68.6 min and minor 94.6 min; for (*R,S*)-diastereoisomer, minor 24.2 min and major 36.2 min). All spectroscopic data are in agreement with those reported.⁷

(7) Yamada, K.; Yamamoto, Y.; Maekawa, M.; Tomioka, K. *J. Org. Chem.* **2004**, *69*, 1531–1534.

4-Methyl-*N*-[(*R*)-phenyl(*R*)-tetrahydrofuran-2-yl)methyl]benzenesulfonamide and 4-methyl-*N*-[(*R*)-phenyl(*S*)-tetrahydrofuran-2-yl)methyl]benzenesulfonamide (7).

Carried out according to the general procedure using **1a** (243 mg, 1 mmol), tetrahydrofuran (**6**) (20.3 mL, 250 mmol), and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction mixture was stirred for 4 h at room temperature. Work-up gave the crude product as a pale yellow oil. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.5 h. Work-up gave the crude product (75:25 mixture of diastereoisomers) as a white solid which was purified by flash column chromatography (acetone/hexane 5/95) to give **7** (290 mg, 88%) as a 75:25 mixture of diastereoisomers, as a white solid of mp 133–135 °C: *R*_f 0.69 (ethyl acetate/chloroform 10/90). [α]²⁵_D –12.6 (*c* 1.01, CHCl₃), 16% ee and 59% ee for (*R,R*)-diastereoisomer and (*R,S*)-diastereoisomer respectively (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 0.5 mL/min, 254 nm, for (*R,R*)-diastereoisomer, major 38.4 min and minor 48.8 min; for (*R,S*)-diastereoisomer, minor 46.0 min and major 61.3 min). All spectroscopic data are in agreement with those reported.⁸

(*R*)-*N*-[(Benzo-1,3-dioxolan-2-yl)(phenyl)methyl]-4-methylbenzenesulfonamide (9).

Carried out according to the general procedure using **1a** (243 mg, 1 mmol), 1,3-benzodioxole (**8**) (28.7 mL, 250 mmol), and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction mixture was stirred for 24 h at room temperature after which dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane) was added and the reaction mixture stirred for a further 22 h. Work-up gave the crude product as a pale yellow oil. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.75 h. Work-up gave the crude product as a brown oil which was purified by flash column chromatography (ethyl acetate/hexane

(8) Yamada, K.; Fujihara, H.; Yamamoto, Y.; Miwa, Y.; Taga, T.; Tomioka, K. *Org. Lett.* **2002**, *4*, 3509–3511.

10/90 to 20/80) to give **9** (163 mg, 43%) as a white solid; mp 134–135 °C (colorless prisms, recrystallized from ethyl acetate–hexane): R_f 0.24 (ethyl acetate/hexane 25/75). $[\alpha]_D^{25}$ –34.4 (c 1.00, CHCl_3), 51% ee (HPLC, Chiralcel OD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, minor 12.8 min and major 19.3 min). ^1H NMR (500 MHz): 2.37 (s, 3H), 4.83 (dd, J = 8.5, 2.5, 1H), 5.33 (d, J = 8.5 1H), 6.22 (d, J = 2.5, 1H), 6.55 (m, 1H), 6.67–6.75 (m, 3H), 7.11 (d, J = 7.6, 2H), 7.22–7.26 (m, 5H), 7.54 (d, J = 8.3, 2H). ^{13}C NMR (125 MHz): 21.3 (CH_3), 59.6 (CH), 108.3 (CH), 108.4 (CH), 110.1 (CH), 121.5 (CH), 121.6 (CH), 127.0 (CH), 127.8 (CH), 128.2 (CH), 128.4 (CH), 129.2 (CH), 134.6 (C), 137.6 (C), 143.0 (C), 146.9 (C), 147.0 (C). IR (KBr): 3302, 3252, 1601, 1485, 1458, 1423, 1327, 1238, 1165, 1088, 1061, 903, 810, 702, 664. EIMS (m/z): 381 (M^+), 260 ($\text{M}^+ - \text{C}_7\text{H}_5\text{O}_2$), 226 ($\text{M}^+ - \text{tosyl}$), 211 ($\text{M}^+ - \text{C}_6\text{H}_5\text{CHC}_7\text{H}_5\text{O}_2$), 155 (tosyl), 121 ($\text{C}_7\text{H}_5\text{O}_2$), 91 ($\text{C}_6\text{H}_4\text{CH}_3$), 77 (C_6H_5). Anal. Calcd. for $\text{C}_{21}\text{H}_{19}\text{NO}_4\text{S}$: C, 66.12; H, 5.02; N, 3.67. Found: C, 66.06; H, 5.00. N, 3.73.

(*R*)-4-Methyl-*N*-[phenyl(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]benzenesulfonamide (11a).

Carried out according to the general procedure using **1a** (243 mg, 1 mmol), 4,4,5,5-tetramethyldioxolane (**10**) (36.5 mL, 250 mmol), and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction mixture was stirred for 32 h at room temperature after which dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane) were added and the reaction mixture was stirred for a further 13 h. Work-up gave the crude product as a pale yellow oil which was purified flash column chromatography (isopropanol/hexane 10/90) followed by ethyl acetate/hexane (15/85) to give **11a** (263 mg, 67%) as a white solid: R_f 0.59 (ethyl acetate/chloroform 10/90). $[\alpha]_D^{25}$ –32.6 (c 1.01, CHCl_3), 83% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 10.4 min and minor 12.8 min). All spectroscopic data are in agreement with those reported.⁷

(*R*)-*N*-(2-*tert*-Butoxy-1-phenylethyl)-4-methylbenzenesulfonamide (13).

Carried out according to the general procedure using **1a** (243 mg, 1 mmol), *tert*-butyl methyl ether (**12**) (29.8 mL, 250 mmol), and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction

mixture was stirred for 21 h at room temperature after which dimethylzinc (6 ml, 6 mmol, 1.0 M in hexane) was added and the reaction mixture was stirred for a further 28 h. Dimethylzinc (9 ml, 9 mmol, 1.0 M in hexane) was added to the reaction mixture and the reaction mixture was stirred for 21 h at room temperature after which dimethylzinc (12 ml, 12 mmol, 1.0 M in hexane) was added and the reaction mixture was stirred for a further 21 h. Work-up gave the crude product as a pale yellow oil. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.5 h. Work-up gave the crude product as a pale yellow oil which was purified by flash column chromatography (ethyl acetate/hexane 10/90) to give **13** (89 mg, 27%) as a cream solid: R_f 0.59 (ethyl acetate/chloroform 10/90). $[\alpha]_D^{25}$ -35.4 (c 1.18, CHCl_3), 41% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 0.5 mL/min, 254 nm, major 17.9 min and minor 19.1 min). All spectroscopic data are in agreement with those reported.⁷

General procedure for radical addition of dioxolane **10** to imines **1**.

(*R*)-4-Methyl-*N*-[phenyl(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]benzenesulfonamide (**11a**).

A 50 mL dry three-neck round bottom flask was equipped with a stirrer bar and **1a** (243 mg, 1 mmol). The flask was filled with argon after evacuation and refill with argon (3 times). 4,4,5,5-tetramethyldioxolane (**10**) (18.3 mL, 125 mmol) was added at room temperature. To the stirred solution was sequentially added boron trifluoride etherate (0.13 mL, 1 mmol) and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The argon source was replaced with a NaOH drying tube and air was injected into the reaction mixture *via* a air bubbler at a rate of 0.5 mL/h. The reaction mixture stirred for 2 h followed by quenching with saturated aqueous sodium bicarbonate (20 mL). The mixture was extracted with ethyl acetate (3 × 20 mL). The combined organic extracts were washed with brine (20 mL), then dried over Na_2SO_4 , filtered, and concentrated under reduced pressure to give the crude product as a pale yellow oil. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.5 h, dilution with dichloromethane (10 mL) followed by washing with saturated aqueous sodium bicarbonate (3 × 15 mL). The organic layer was then dried over Na_2SO_4 , filtered, and concentrated under reduced pressure to give the crude product as a colorless oil which was purified by flash column chromatography (isopropanol/hexane 10/90) to give **11a** (359 mg, 92%) as a white solid:

$[\alpha]_D^{25} -30.3$ (c 1.00, CHCl_3), 80% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 10.7 min and minor 13.1 min).

(*R*)-4-Methyl-*N*-[(2-methylphenyl)(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]benzenesulfonamide (11b**).**

According to the general procedure using (*S,E*)-4-Methyl-*N*-(2-methylbenzylidene)benzenesulfinamide (**1b**) (258 mg, 1 mmol), 4,4,5,5-tetramethyl-1,3-dioxolane (**10**) (18.3 mL, 125 mmol), boron trifluoride etherate (0.13 mL, 1 mmol), and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction mixture stirred for 21 h at room temperature after which boron trifluoride etherate (0.26 mL, 2 mmol) and dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane) were added and the reaction mixture stirred for a further 24 h. Work-up gave the crude product as a pale yellow oil. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.75 h. Work-up gave crude product as a pale yellow slurry which was purified by flash column chromatography (isopropanol/hexane 10/90) to give **11b** (245 mg, 61%) as colorless needle-like crystals; mp 102–104 °C (colorless prisms, recrystallized from ethyl acetate–hexane): R_f 0.57 (ethyl acetate/chloroform 10/90). $[\alpha]_D^{25} -14.1$ (c 1.01, CHCl_3), 75% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 0.5 mL/min, 254 nm, major 19.5 min and minor 20.7 min). ^1H NMR (400 MHz): 0.93 (s, 3H), 1.01 (s, 3H), 1.10 (s, 3H), 1.11 (s, 3H), 2.31 (s, 3H), 2.33 (s, 3H), 4.69 (dd, $J = 6.0, 4.3$, 1H), 5.04 (d, $J = 4.3$, 1H), 5.23 (d, $J = 6.0$, 1H), 6.93 (ddd, $J = 2.1, 5.0, 5.0$, 1H), 7.01–7.09 (m, 5H), 7.48 (d, $J = 8.3$, 2H). ^{13}C NMR (125 MHz): 19.4 (CH_3), 21.2 (CH_3), 21.9 (CH_3), 22.0 (CH_3), 23.4 (CH_3), 23.6 (CH_3), 56.3 (CH), 82.5 (C), 82.6 (C), 101.1 (CH), 125.5 (CH), 127.0 (CH), 127.2 (CH), 127.8 (CH), 128.9 (CH), 129.8 (CH), 134.7 (C), 136.3 (C), 137.4 (C), 142.7 (C). IR (KBr): 3279, 2978, 2932, 2877, 1450, 1412, 1373, 1327, 1157, 1088, 1065, 1034, 664. EIMS (m/z): 274 ($\text{M}^+ - \text{C}_7\text{H}_{13}\text{O}_2$), 248 ($\text{M}^+ - \text{tosyl}$), 212, 155 (tosyl), 129 ($\text{C}_7\text{H}_{13}\text{O}_2$), 91 ($\text{C}_6\text{H}_4\text{CH}_3$). Anal. Calcd. for $\text{C}_{22}\text{H}_{29}\text{NO}_4\text{S}$: C, 65.48; H, 7.24; N, 3.47. Found: C, 65.57; H, 7.25. N, 3.48.

(*R*)-4-Methyl-*N*-[(4-methylphenyl)(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]benzenesulfonamide (11c**).**

Carried out according to the general procedure using (*S,E*)-4-Methyl-*N*-(4-methylbenzylidene)benzenesulfinamide (**1c**) (278 mg, 1 mmol), 4,4,5,5-tetramethyl-1,3-dioxolane (**10**) (18.3 mL, 125 mmol), boron trifluoride etherate (0.13 mL, 1 mmol) and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction mixture stirred for 5 h. Work-up gave the crude product as a white solid. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.5 h. Work-up gave the crude product as a pale yellow oil which was purified by flash column chromatography (isopropanol/hexane 10/90) to give **11c** (276 mg, 77%) as a white solid; mp 84–85 °C (colorless prisms, recrystallized from ethyl acetate–hexane): R_f 0.53 (ethyl acetate/chloroform 10/90). $[\alpha]_D^{25}$ –42.9 (c 1.01, CHCl₃), 81% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 11.7 min and minor 15.9 min). ¹H NMR (400 MHz): 0.97 (s, 3H), 0.98 (s, 3H), 1.10 (s, 3H), 1.11 (s, 3H), 2.27 (s, 3H), 2.36 (s, 3H), 4.29 (dd, J = 6.4, 3.9, 1H), 5.03 (d, J = 3.9, 1H), 5.18 (d, J = 6.4, 1H), 6.98 (d, J = 8.1, 2H), 7.04 (d, J = 8.1, 2H), 7.12 (d, J = 8.1, 2H), 7.55 (d, J = 8.1, 2H). ¹³C NMR (100 MHz): 21.0 (CH₃), 21.3 (CH₃), 22.0 (CH₃), 22.2 (CH₃), 23.7 (CH₃), 23.8 (CH₃), 60.5 (CH), 82.6 (C), 82.8 (C), 100.9 (CH), 127.3 (CH), 128.1 (CH), 128.7 (CH), 129.1 (CH), 133.6 (C), 137.3 (C), 137.6 (C), 142.9 (C). IR (KBr): 3279, 2986, 2924, 2870, 1443, 1396, 1327, 1165, 1088, 1026, 810, 671. EIMS (m/z): 274 (M^+ – C₇H₁₃O₂), 248 (M^+ – tosyl), 212, 155 (tosyl), 129 (C₇H₁₃O₂), 101, 91 (C₆H₄CH₃), 83. Anal. Calcd. for C₂₂H₂₉NO₄S: C, 65.48; H, 7.24; N, 3.47. Found: C, 65.65; H, 7.27. N, 3.48.

(*R*)-*N*-[(4-Chlorophenyl)(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]-4-methylbenzenesulfonamide (11d**)**

Carried out according to the general procedure using (*S,E*)-4-Methyl-*N*-(4-chlorobenzylidene)benzenesulfinamide (**1d**) (278 mg, 1 mmol), 4,4,5,5-tetramethyl-1,3-dioxolane

(**10**) (18.3 mL, 125 mmol), boron trifluoride etherate (0.13 mL, 1 mmol), and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction mixture stirred for 5 h. Work-up gave the crude product as a white solid. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.5 h. Work-up gave the crude product as a pale yellow oil which was purified by flash column chromatography (isopropanol/hexane 10/90) to give **11d** (376 mg, 87%) as a white crystalline solid; mp 112–113 °C (colorless prisms, recrystallized from ethyl acetate–hexane): *R_f* 0.52 (ethyl acetate/chloroform 10/90). $[\alpha]_D^{25}$ –29.7 (*c* 1.01, CHCl₃), 82% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 13.1 min and minor 18.4 min). ¹H NMR (500 MHz): 0.93 (s, 3H), 0.96 (s, 3H), 1.11 (s, 3H), 1.12 (s, 3H), 2.37 (s, 3H), 4.32 (dd, *J* = 6.1, 4.0, 1H), 5.00 (d, *J* = 4.0, 1H), 5.19 (d, *J* = 6.1, 1H), 7.08 (d, *J* = 8.6, 2H), 7.13 (d, *J* = 8.6, 2H × 2), 7.53 (d, *J* = 8.6, 2H). ¹³C NMR (125 MHz): 21.3 (CH₃), 22.0 (CH₃), 22.1 (CH₃), 23.7 (CH₃), 23.8 (CH₃), 60.1 (CH), 82.7 (C), 83.0 (C), 100.4 (CH), 127.2 (CH), 129.0 (CH), 129.1 (CH), 129.7 (CH), 133.5 (C), 135.0 (C), 137.3 (C), 143.2 (C). IR (KBr): 3275, 1497, 1450, 1327, 116, 1088, 1030, 910, 817, 702, 667. EIMS (*m/z*): 296 (*M* + 2 – C₇H₁₃O₂), 294 (*M*⁺ – C₇H₁₃O₂), 212, 155 (tosyl), 129 (C₇H₁₃O₂), 101, 83. Anal. Calcd. for C₂₁H₂₆ClNO₄S: C, 59.49; H, 6.18; N, 3.30. Found: C, 59.54; H, 6.01. N, 3.25.

(*R*)-4-Methyl-*N*-[(4-methoxyphenyl)(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]benzenesulfonamide (11e**).**

Carried out according to the general procedure using (*S,E*)-4-Methyl-*N*-(4-methoxybenzylidene)benzenesulfinamide (**1e**) (274 mg, 1 mmol), 4,4,5,5-tetramethyl-1,3-dioxolane (**10**) (29.3 mL, 200 mmol), boron trifluoride etherate (0.13 mL, 1 mmol), and dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane). The reaction mixture stirred for 24 h at room temperature after which dimethylzinc (3 mL, 3 mmol, 1.0 M in hexane) was added and the reaction mixture stirred for a further 43.5 h after which dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane) was added and the reaction mixture stirred for a further 4 h. Work-up gave the crude product as a pale yellow oil which was purified by flash column chromatography (isopropanol/hexane 10/90) to give **11e** (291 mg, 69%) as a pale yellow amorphous; mp 97–99 °C (white solid, recrystallized from diethyl ether–hexane): *R_f* 0.40 (ethyl acetate/chloroform 10/90). $[\alpha]_D^{25}$ –31.5 (*c* 1.06, CHCl₃), 74% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 19.2 min and minor 24.8 min). ¹H NMR (400 MHz): 0.96 (s, 3H), 0.98 (s, 3H), 1.11 (s, 3H), 1.12 (s, 3H), 2.36 (s, 3H), 3.75

(s, 3H), 4.30 (dd, $J = 6.2, 3.9$, 1H), 5.02 (d, $J = 3.9$, 1H), 5.17 (d, $J = 6.2$, 1H), 6.70 (d, $J = 8.7$, 2H), 7.06 (d, $J = 8.7$, 2H), 7.13 (d, $J = 8.2$, 2H), 7.54 (d, $J = 8.2$, 2H). ^{13}C NMR (100 MHz): 21.3 (CH₃), 22.1 (CH₃), 22.2 (CH₃), 23.8 (CH₃), 23.9 (CH₃), 55.1 (CH₃), 60.2 (CH), 82.7 (C), 82.9 (C), 100.9 (CH), 113.4 (CH), 127.3 (CH), 128.6 (C), 129.2 (CH), 129.4 (CH), 137.6 (C), 142.9 (C), 159.2 (C). IR (KBr): 3279, 2986, 2932, 2862, 1612, 1512, 1443, 1327, 1250, 1157, 1088, 1034, 818, 617. EIMS (m/z): 290 ($\text{M}^+ - \text{C}_7\text{H}_{13}\text{O}_2$), 264 ($\text{M}^+ - \text{tosyl}$), 212, 155 (tosyl), 150, 135, 134, 130, 129 ($\text{C}_7\text{H}_{13}\text{O}_2$), 121, 101, 91 ($\text{C}_6\text{H}_4\text{CH}_3$). Anal. Calcd. for $\text{C}_{22}\text{H}_{29}\text{NO}_5\text{S}$: C, 62.98; H, 6.97; N, 3.34. Found: C, 62.75; H, 6.76. N, 3.42.

(*R*)-4-Methyl-*N*-[(naphth-2-yl)(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]benzenesulfonamide (11f**).**

Carried out according to the general procedure using (*S,E*)-4-methyl-*N*-(naphthalene-2-ylmethylene)benzenesulfinamide (**1f**) (293 mg, 1 mmol), 4,4,5,5-tetramethyl-1,3-dioxolane (**10**) (18.3 mL, 125 mmol), boron trifluoride etherate (0.26 mL, 2 mmol), and dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane). The reaction mixture stirred for 27 h at room temperature after which boron trifluoride etherate (0.26 mL, 2 mmol), dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane) was added and the reaction mixture stirred for a further 22 h. Work-up gave the crude product as a pale yellow oil. Dry dichloromethane (5 mL) and dry *m*-CPBA (173 mg, 1 mmol) were sequentially added to the crude product. The reaction mixture was stirred for 0.5 h. Work-up gave the crude product as a pale yellow oil which was purified by flash column chromatography (ethyl acetate/chloroform 10/90) to give **11f** (311 mg, 71%) as a white solid; mp (dec) 100–150 °C (white solid, recrystallized from diethyl ether–hexane): R_f 0.65 (ethyl acetate/chloroform 10/90). $[\alpha]_D^{25} -49.2$ (c 1.03, CHCl_3), 79% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 16.6 min and minor 20.0 min). ^1H NMR (400 MHz): 0.97 (s, 3H), 1.00 (s, 3H), 1.12 (s, 3H), 1.13 (s, 3H), 2.18 (s, 3H), 4.54 (dd, $J = 6.4, 3.9$, 1H), 5.15 (d, $J = 3.9$, 1H), 5.31 (d, $J = 6.4$, 1H), 6.94 (d, $J = 8.0$, 2H), 7.28 (m, 1H), 7.41–7.52 (m, 5H), 7.63–7.69 (m, 2H), 7.75 (m, 1H). ^{13}C NMR (100 MHz): 21.1 (CH₃), 22.0 (CH₃), 22.1 (CH₃), 23.80 (CH₃), 23.85 (CH₃), 60.8 (CH), 82.7 (C), 82.9 (C), 100.8 (CH), 125.8 (CH), 125.9 (CH), 127.2 (CH), 127.5 (CH), 127.61 (CH), 127.65 (CH), 127.9 (CH), 129.0 (CH), 132.8 (C), 132.9 (C), 133.7 (C), 137.5 (C), 143.0 (C). IR (KBr): 3310, 3233, 2978, 2916, 2870, 2870, 1466, 1389, 1335, 1165, 1119, 1056, 1018, 810, 733, 664. EIMS (m/z): 310 ($\text{M}^+ - \text{C}_7\text{H}_{13}\text{O}_2$), 284 ($\text{M}^+ - \text{tosyl}$), 212, 155 (tosyl), 129 ($\text{C}_7\text{H}_{13}\text{O}_2$), 101, 91

(C₆H₄CH₃), 83. Anal. Calcd. for C₂₅H₂₉NO₄S: C, 68.31; H, 6.65; N, 3.19. Found: C, 68.47; H, 6.55. N, 3.18.

(R)-N-[(2-Furyl)(4,4,5,5-tetramethyl-1,3-dioxolan-2-yl)methyl]-4-methylbenzenesulfonamide (11g).

Carried out according to the general procedure using (*S,E*)-4-Methyl-*N*-(2-furylmethylidene)benzenesulfonamide (**1g**) (233 mg, 1 mmol), 4,4,5,5-tetramethyl-1,3-dioxolane (**10**) (18.3 mL, 125 mmol), boron trifluoride etherate (0.26 mL, 1 mmol) and dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane). The reaction mixture stirred for 31 h at room temperature after which boron trifluoride etherate (0.26 mL, 1 mmol), dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane) were added and the reaction mixture stirred for a further 65 h after which boron trifluoride etherate (0.26 mL, 1 mmol), dimethylzinc (6 mL, 6 mmol, 1.0 M in hexane) were added and the reaction mixture stirred for a further 84 h. Work-up gave the crude product as a pale yellow oil which was purified by flash column chromatography (ethyl acetate/chloroform 10/90) to give **11g** (188 mg, 50%) as a pale yellow amorphous; mp 81–82 °C (recrystallized from diethyl ether–hexane): *R_f* 0.52 (ethyl acetate/chloroform 10/90). [α]_D²⁵ –22.9 (*c* 1.00, CHCl₃), 70% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 13.3 min and minor 16.4 min). ¹H NMR (400 MHz): 0.98 (s, 3H), 1.00 (s, 3H), 1.16 (s, 6H), 2.37 (s, 3H), 4.55 (dd, *J* = 8.5, 3.3, 1H), 5.17 (d, *J* = 8.5, 1H), 5.19 (d, *J* = 3.3, 1H), 6.09 (d, *J* = 3.2, 1H), 6.16 (dd, *J* = 3.2, 1.7, 1H), 7.17–7.18 (m, 3H), 7.60 (d, *J* = 8.3, 2H). ¹³C NMR (100 MHz): 21.3 (CH₃), 22.0 (CH₃), 22.1 (CH₃), 23.6 (CH₃), 23.7 (CH₃), 54.4 (CH), 82.7 (C), 83.0 (C), 99.4 (CH), 109.0 (CH), 110.2 (CH), 127.1 (CH), 129.2 (CH), 137.6 (C), 142.2 (CH), 143.0 (C), 149.5 (C). IR (KBr): 3279, 2978, 2932, 2870, 1443, 1396, 1335, 1157, 1088, 1018, 910, 810, 741, 664, 556. EIMS (*m/z*): 250 (*M*⁺ – C₇H₁₃O₂), 224 (*M*⁺ – tosyl), 212, 155 (tosyl), 129 (C₇H₁₃O₂), 101, 91 (C₆H₄CH₃), 83. Anal. Calcd. for C₁₉H₂₅NO₅S: C, 60.14; H, 6.64; N, 3.69. Found: C, 60.04; H, 6.50. N, 3.73.

Conversion of adducts 3 and 11a to alcohol 5: (*R*)-*N*-(2-hydroxy-1-phenylethyl)-4-methylbenzenesulfonamide.

From adduct 3.

According to the reported procedure,⁷ adduct **3** was converted to alcohol **5**; a white solid, mp 104–105 °C (recrystallized from diethyl ether, colorless prisms) (lit.⁹ mp 103–104 °C, recrystallized from diethyl ether): R_f 0.36 (ethyl acetate/hexane 50/50). $[\alpha]_D^{20}$ –26.6 (c 1.05, CHCl_3) (lit.⁹ $[\alpha]_D^{20}$ –85.5 (c 1.052, CHCl_3)), 32% ee (HPLC, Daicel Chiralcel OG, isopropanol/hexane = 10/30, 0.5 mL/min, 254 nm, major 18.3 min and minor 26.3 min).

From adduct 11a.

Titanium tetrachloride (0.120 mL, 1.10 mmol) was added dropwise to a stirred solution of (*R*)-**11a** (100 mg, 0.257 mmol, 83% ee) and triethylsilane (0.420 mL, 2.63 mmol) in dry dichloromethane (0.4 mL) at 0 °C. The reaction mixture was stirred for 24 h at 0 °C after which triethylsilane (0.210 mL, 1.31 mmol) and titanium tetrachloride (0.060 mL, 0.547 mmol) were added and the reaction mixture was stirred for a further 10 h at the same temperature. The reaction mixture was quenched with saturated aqueous sodium bicarbonate (3 mL) followed by extraction with dichloromethane (3 $\times$ 10 mL). The combined organic extracts were dried over Na_2SO_4 , filtered, and concentrated under reduced pressure to give the crude product as a pale yellow oil, which was purified by flash column chromatography (ethyl acetate/hexane 30/70) to give **5** (57 mg, 75%) as a white solid: $[\alpha]_D^{20}$ –70.5 (c 1.05, CHCl_3) (lit.⁹ $[\alpha]_D^{20}$ –85.5 (c 1.052, CHCl_3)), 83% ee (HPLC, Daicel Chiralcel OG, isopropanol/hexane = 10/30, 1.0 mL/min, 254 nm, major 18.0 min and minor 26.3 min).

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67% ee (HPLC, Daicel Chiralpak AS, *i*-PrOH/hexane = 10/90, 1.0 mL/min, 254 nm, minor 24.2 min and major 36.2 min).

21% ee (HPLC, Daicel Chiralpak AS, *i*-PrOH/hexane = 10/90, 1.0 mL/min, 254 nm, major 68.6 min and minor 94.6 min).

16% ee (HPLC, Daicel Chiralpak ADH, isopropanol/hexane = 10/90, 0.5 mL/min, 254 nm, major 38.4 min and minor 48.8 min).

59% ee (HPLC, Daicel Chiralpak ADH, isopropanol/hexane = 10/90, 0.5 mL/min, 254 nm, minor 46.0 min and major 61.3 min).

51% ee (HPLC, Chiralcel OD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, minor 12.8 min and major 19.3 min).

83% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 10.4 min and minor 12.8 min) (Table 1, entry 3).

41% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 0.5 mL/min, 254 nm, major 17.9 min and minor 19.1 min).

80% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 10.7 min and minor 13.1 min) (Table 2, entry 1).

75% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 0.5 mL/min, 254 nm, major 19.5 min and minor 20.7 min).

81% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 11.7 min and minor 15.9 min).

82% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 13.1 min and minor 18.4 min).

74% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 19.2 min and minor 24.8 min).

79% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 16.6 min and minor 20.0 min).

70% ee (HPLC, Daicel Chiralpak AD-H, isopropanol/hexane = 10/90, 1.0 mL/min, 254 nm, major 13.3 min and minor 16.4 min).

32% ee (HPLC, Daicel Chiralcel OG, isopropanol/hexane = 10/30, 0.5 mL/min, 254 nm, major 18.3 min and minor 26.3 min).

83% ee (HPLC, Daicel Chiralcel OG, isopropanol/hexane = 10/30, 0.5 mL/min, 254 nm, major 18.0 min and minor 26.3 min).