Catalytic access to 4-(sec-alkyl)anilines via 1,6-conjugate addition of Grignard reagents to in situ generated aza-p-quinone methides

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1. General Experimental Information

All reactions using oxygen- and/or moisture-sensitive materials were carried out with anhydrous solvents under a nitrogen atmosphere using standard Schlenk techniques. Flash column chromatography was performed using Merck 60 Å 230–400 mesh silica gel. Thin layer chromatography was performed using 0.25 mm E. Merck silica plates (60F-254). Unless otherwise indicated, the anilines were visualized using UV lamp, and other common staining solutions as phosphomolibdic acid and KMnO₄ staining. NMR data was collected on Varian VXR400 (1H at 400.0 MHz; 13C at 100.58 MHz) equipped with a 5 mm z-gradient broadband probe. Chemical shifts are reported in parts per million (ppm) relative to residual solvent peak (CDCl₃, δ H: 7.26 ppm; 13C: 77.16 ppm). Coupling constants are reported in Hertz. Multiplicity is reported with the usual abbreviations (s: singlet, d: doublet, dd: doublet of doubles, t: triplet, dt: doublet of triplets, q: quartet, dq: doublet of quartets, m: multiplet). Exact mass spectra were recorded on a LTQ Orbitrap XL apparatus with ESI ionization. Enantiomeric excess (ee) were determined by chiral HPLC analysis using a Shimadzu LC-10ADVP HPLC equipped with a Shimadzu SPD-M10AVP diode array detector.

2. General Chemicals

Unless otherwise indicated, reagents and substrates were purchased from commercial sources and used as received. Solvents not required to be dry were purchased as technical grade and used as received. Other dry solvents were freshly collected from a dry solvent purification system prior to use. Inert atmosphere experiments were performed with standard Schlenk techniques with dried (P₂O₅) nitrogen gas. Grignard reagents were purchased from Sigma-Aldrich unless noted: EtMgBr, MeMgBr (3.0 M in Et₂O); iBuMgBr, nPentMgBr, nHexMgBr, cyclopentylMgBr (2.0 M in Et₂O). Chiral ligands (L1-L6, L8, L9, L12-L28, L30, L32, L33) were purchased from Sigma Aldrich and Solvias. All reported compounds were characterized by ¹H and ¹³C NMR and compared with literature data. All new compounds were fully synthesized following the literature procedures.

3. Catalytic reactions for the synthesis of racemic 4-(sec alkyl)anilines

General procedure

To a previously dried Schlenk flask under nitrogen, CuBr (5.0 mol%) and ligand DPPF (6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (1.0 equiv.) was added in 1 mL of DCM, followed by the addition of Grignard reagent (3 equiv.). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3).

4-(sec-butyl)aniline (2a)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.010 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.20 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of ethyl magnesium bromide (Aldrich, 3.0 M solution in Et₂O, 0.2 mL, 0.6 mmol, 3.0 equiv). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2a as a colourless liquid (27.46 mg, 0.184 mmol, 92%). The spectroscopic data matched with those reported in the literature.¹

1H NMR (400 MHz, CDCl₃) δ 6.98 (d, J = 8.2 Hz, 2H), 6.65 (d, J = 8.1 Hz, 2H), 3.52 (br s, 2H), 2.53 – 1.50 (m, 2H), 1.19 (d, J = 7.0 Hz, 3H); 1.81 (t, J = 7.4 Hz, 3H).

13C NMR (151 MHz, CDCl₃) δ 144.2, 138.1, 127.9, 115.4, 40.9, 31.5, 22.2, 12.4.

¹ (a) Duursma, A.; Boiteau, J.-G.; Lefort, L.; Boogers, J. A. F.; de Vries, A. H. M.; de Vries, J. G.; Minnaard, A. J.; Feringa, B. L. J. Org. Chem. 2004, 69, 8045–8052. (b) Alexakis, A.; Polet, D.; Rosset, S.; March, S. J. Org. Chem. 2004, 69, 5660–5667.

² Ireland T.; Tappe K.; Grossheimann G.; Knochel P. Chem. Eur. J. 2002, 8, 843-852.

³ Joshi-Pangu, A.; Ganesh, M.; Biscoe, M. R. Org. Lett. 2011, 13, 1218-1221.
HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{10}H_{15}NH 150.1283, found 150.1276.

4-isopropylaniline (2b)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et_{2}O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30°C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of methyl magnesium bromide (Aldrich, 3.0 M solution in Et_{2}O, 0.2 mL, 0.2 mmol, 3.0 equiv). The reaction mixture was stirred for 20h. The reaction was quenched with NH_{4}Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2b as a colourless liquid (19.2 mg, 0.142 mmol, 71%). The spectroscopic data matched with those reported in the literature.\(^3\)

\[^{1}\text{H NMR} (600 \text{ MHz, CDCl}_{3}) \delta 7.04 \text{ (d, } J = 8.3 \text{ Hz, } 2\text{H}), 6.65 \text{ (d, } J = 8.4 \text{ Hz, } 2\text{H}), 3.39 \text{ (br. s, } 2\text{H}), 2.84 - 2.82 \text{ (m, } 1\text{H}), 1.22 \text{ (d, } J = 7.0 \text{ Hz, } 6\text{H}).\]

\[^{13}\text{C NMR} (151 \text{ MHz, CDCl}_{3}) \delta 144.1, 139.3, 127.2, 115.4, 33.3, 24.4.\]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{9}H_{13}N 136.1121, found 136.1118.

4-(hexan-3-yl)aniline (2c)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et_{2}O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of propyl magnesium bromide (Aldrich, 2.0 M solution in Et_{2}O, 0.3 mL, 0.6 mmol, 3.0 equiv). The reaction mixture was stirred for 20h. The reaction was quenched with NH_{4}Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2c as a colourless liquid (30.2 mg, 0.185 mmol, 92%).

\[^{1}\text{H NMR} (600 \text{ MHz, CDCl}_{3}) \delta 7.12 - 6.82 \text{ (m, } 2\text{H}), 6.72 - 6.54 \text{ (m, } 2\text{H}), 3.27 \text{ (br s, } 2\text{H}), 2.63 - 2.57 \text{ (m, } 1\text{H}), 1.70 - 1.40 \text{ (m, } 2\text{H}), 1.36 - 1.10 \text{ (m, } 2\text{H}), 1.19 \text{ (d, } J = 7.0 \text{ Hz, } 3\text{H}), 0.87 \text{ (t, } J = 7.4 \text{ Hz, } 3\text{H}).\]

\[^{13}\text{C NMR} (151 \text{ MHz, CDCl}_{3}) \delta 144.1, 138.4, 127.8, 115.4, 41.0, 38.9, 22.6, 21.0, 14.3.\]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{11}H_{17}N 164.1439, found 164.1433.

4-(heptan-2-yl)aniline (2d)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et_{2}O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of pentyl magnesium bromide (Aldrich, 2.0 M solution in Et_{2}O, 0.3 mL, 0.6 mmol, 3.0 equiv). The reaction mixture was stirred for 20h. The reaction was quenched with NH_{4}Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2d as a colourless liquid (32.0 mg, 0.185 mmol, 92%).

\[^{1}\text{H NMR} (600 \text{ MHz, CDCl}_{3}) \delta 6.98 \text{ (d, } J = 8.3 \text{ Hz, } 2\text{H}), 6.65 \text{ (d, } J = 8.3 \text{ Hz, } 2\text{H}), 3.38 \text{ (br s, } 2\text{H}), 2.60 - 2.55 \text{ (m, } 1\text{H}), 1.55 - 1.46 \text{ (m, } 2\text{H}), 1.30 - 1.13 \text{ (m, } 9\text{H}), 0.87 \text{ (t, } J = 6.9 \text{ Hz, } 3\text{H}).\]

\[^{13}\text{C NMR} (151 \text{ MHz, CDCl}_{3}) \delta 144.1, 138.4, 127.8, 115.4, 39.2, 38.8, 32.0, 29.6, 27.8, 22.7, 14.2.\]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{13}H_{21}NH 192.1752, found 192.1747

4-(5-methylhexan-2-yl)aniline (2e)
To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of isopentyl magnesium bromide (Aldrich, 2.0 M solution in Et₂O, (0.3 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2e as a colourless liquid (35.1 mg, 0.183 mmol, 92%).

1H NMR (600 MHz, CDCl₃) δ 6.98 (d, J = 8.3 Hz, 2H), 6.64 (d, J = 8.3 Hz, 2H), 3.29 (br. s, 2H), 2.59 – 2.50 (m, 1H), 1.56 – 1.37 (m, 3H), 1.19 (d, J = 6.9 Hz, 3H), 1.16 – 1.00 (m, 2H), 0.84 (d, J = 2.3 Hz, 3H), 0.82 (d, J = 2.3 Hz, 3H).

13C NMR (151 MHz, CDCl₃) δ 144.0, 138.5, 127.8, 115.4, 39.5, 37.2, 36.5, 28.3, 22.8, 22.7.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₃H₂₁N 192.1752, found 192.1742.

4-(1-cyclopentylethyl)aniline (2f)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 ºC, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of cyclopentyl magnesium bromide (Aldrich, 2.0 M solution in Et₂O, (0.3 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2f as colourless liquid (37.7 mg, 0.199 mmol, >99%).

1H NMR (600 MHz, CDCl₃) δ 6.97 (d, J = 8.3 Hz, 2H), 6.64 (d, J = 8.3 Hz, 2H), 3.36 (br s, 2H), 2.33 (dq, J = 9.4, 6.9 Hz, 1H), 1.91 – 1.85 (m, 2H, CH₂), 1.65 – 1.39 (m, 5H), 1.22 – 1.17 (m, 4H), 1.06 – 0.91 (m, 1H).

13C NMR (151 MHz, CDCl₃) δ 143.9, 138.7, 128.1, 115.4, 47.9, 45.4, 31.9, 31.5, 25.5, 25.2, 21.7.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₃H₁₉N 190.1590, found 190.1591.

4-(1-phenylethyl)aniline (2g)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 ºC, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of phenyl magnesium bromide (Aldrich, 3.0 M solution in Et₂O, (0.2 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2g as a colourless liquid (24.4 mg, 0.124 mmol, 62%). The spectroscopic data matched with those reported in the literature. 4

1H NMR (600 MHz, CDCl₃) δ 7.33 – 7.27 (m, 2H), 7.26 – 7.23 (m, 2H), 7.22 – 7.17 (m, 1H), 7.07 – 7.03 (m, 2H), 6.66 (d, J = 8.0 Hz, 2H), 4.10 (q, J = 7.2 Hz, 1H), 3.25 (br s, 2H), 1.63 (d, J = 7.2 Hz).

13C NMR (151 MHz, CDCl₃) δ 147.2, 136.9, 129.7, 128.5, 128.4, 127.6, 125.9, 115.5, 115.4, 44.0, 22.2.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₄H₁₅N 198.1277, found 198.1274.

4-(1-(p-tolyl)ethyl)aniline (2h)

4 Li, X.; Feng, Y.; Lin, L.; Zou, G. J. Org. Chem. 2012, 77, 10991–10995.
To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry EtO (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of p-tolyl magnesium chloride (Aldrich, 0.5 M solution in EtO, (1.2 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2h as a colourless liquid (30.1 mg, 0.142 mmol, 71%). The spectroscopic data matched with those reported in the literature.⁵

\(^1\)H NMR (600 MHz, CDCl₃) δ 7.14 – 7.06 (m, 4H), 7.04 – 6.97 (m, 2H), 6.66 – 6.57 (m, 2H), 4.03 (q, J = 7.2 Hz, 1H), 3.28 (br s, 2H), 2.31 (s, 3H), 1.60 (d, J = 7.2 Hz, 3H).

\(^1^3\)C NMR (151 MHz, CDCl₃) δ 144.2, 137.1, 135.4, 130.2, 129.1, 128.5, 127.5, 115.5, 43.6, 22.3, 21.1.

HRMS (ESI-TOF): m/z [M+H]⁺ Calcd. for C₁₅H₁₇NH 212.1434, found 212.1430

4-(1-(4-chlorophenyl)ethyl)aniline (2i)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry EtO (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of 4-chlorophenyl magnesium bromide (Aldrich, 1.0 M solution in EtO, (0.6 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2i as a colourless liquid (32.0 mg, 0.138 mmol, 69%).

\(^1\)H NMR (600 MHz, CDCl₃) δ 7.24 (d, J = 8.5 Hz, 2H), 7.14 (d, J = 8.5 Hz, 2H), 6.99 (d, J = 8.4 Hz, 2H), 6.63 (d, J = 8.4 Hz, 2H), 4.03 (q, J = 7.2 Hz, 1H), 3.45 (br s, 2H), 1.57 (d, J = 7.2 Hz, 3H).

\(^1^3\)C NMR (151 MHz, CDCl₃) δ 145.7, 136.2, 131.6, 129.0, 128.5, 128.5, 116.8, 115.5, 43.5, 22.1.

HRMS (ESI-TOF): m/z [M+H]⁺ Calcd. for C₁₄H₁₄ClNH 232.0884, found 232.0887

4-(but-3-en-2-yl)aniline (2j)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.010 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry EtO (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of vinyl magnesium bromide (Aldrich, 1.0 M solution in EtO, (0.6 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2j (19.7 mg, 0.134 mmol, 67%) as a colourless liquid. The spectroscopic data matched with those reported in the literature.⁶

\(^1\)H NMR (600 MHz, CDCl₃) δ 7.09 – 6.93 (m, 2H), 6.66 – 6.64 (m, 2H), 5.98 (ddd, J = 16.9, 10.3, 6.4 Hz, 1H), 5.07 – 4.84 (m, 2H), 3.44 – 3.29 (m, 1H), 3.38 (br s, 2H), 1.32 (d, J = 7.0 Hz, 3H).

\(^1^3\)C NMR (151 MHz, CDCl₃) δ 144.5, 144.0, 135.9, 128.1, 115.4, 112.6, 42.4, 20.9.

HRMS (ESI-TOF): m/z [M+H]⁺ Calcd. for C₁₀H₁₃NH 148.1121, found 148.1117

4-(4-phenylbutan-2-yl)aniline (2k)

⁵ Wang, X.; Wang, H.; Zhao, K.; Li, T.; Liu, S.; Yuan, H.; Shi, F. J. Catal. 2021, 394, 18–29.
⁶ Movahhed, S.; Westphal, J.; Dindaroğlu, M.; Falk, A.; Schmalz, H. G. Chem. - Eur. J. 2016, 22, 7381–7384.
To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.010 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 °C, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of phenethyl magnesium bromide (Aldrich, 1.0 M solution in THF, (0.6 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2k as a colourless liquid (31.0 mg, 0.138 mmol, 69%).

1H NMR (600 MHz, CDCl₃) δ 7.29 – 7.24 (m, 2H), 7.18 – 7.15 (m, 1H), 7.15 – 7.12 (m, 2H), 7.01 (d, J = 8.3 Hz, 2H), 6.66 (d, J = 7.9 Hz, 2H), 3.19 (br s, 2H), 2.63 (d, J = 7.1 Hz, 1H), 2.51 (t, J = 8.0 Hz, 2H), 1.92 – 1.80 (m, 2H), 1.23 (d, J = 6.9 Hz, 3H).

13C NMR (151 MHz, CDCl₃) δ 142.9, 137.8, 128.5, 128.5, 128.3, 127.9, 125.7, 115.6, 40.3, 38.8, 34.1, 22.9.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₆H₁₉NH 226.1590, found 226.1589

4-(1-phenylpropan-2-yl)aniline (2l)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 ºC, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of benzyl magnesium bromide (Aldrich, 2.0 M solution in Et₂O, (0.3 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2l as a colourless liquid (28.0 mg, 0.133 mmol, 66%).

1H NMR (600 MHz, CDCl₃) δ 7.29 – 7.24 (m, 2H), 7.18 – 7.15 (m, 1H), 7.15 – 7.12 (m, 2H), 7.01 (d, J = 8.3 Hz, 2H), 6.66 (d, J = 7.9 Hz, 2H), 3.19 (br s, 2H), 2.63 (d, J = 7.1 Hz, 1H), 2.51 (t, J = 8.0 Hz, 2H), 1.92 – 1.80 (m, 2H), 1.23 (d, J = 6.9 Hz, 3H).

13C NMR (151 MHz, CDCl₃) δ 144.3, 141.2, 137.4, 129.3, 128.1, 127.9, 125.8, 115.3, 45.4, 41.1, 21.5.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₅H₁₇NH 212.1439, found 212.1435

(6-hex-5-en-3-yl)aniline (2m)

To a previously dried Schlenk flask under nitrogen, CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand DPPF (6.7 mg, 0.012 mmol, 6.0 mol%) were added in dry Et₂O (1 mL) and DCM (1 mL). After stirring for 10 min, the solution was cooled down to -30 ºC, and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM, followed by the addition of allyl magnesium bromide (Aldrich, 3.0 M solution in Et₂O, (0.2 mL, 0.6 mmol, 3.0 equiv)). The reaction mixture was stirred for 20h. The reaction was quenched with NH₄Cl sat sol (5 mL) and extracted with DCM (x3). The crude was purified by flash column chromatography using DCM as eluent to afford the corresponding product 2m as a colourless liquid (24.3 mg, 0.151 mmol, 75%).

1H NMR (600 MHz, CDCl₃) δ 7.02 – 6.95 (m, 2H), 6.65 (d, J = 8.4 Hz, 2H), 5.75 – 5.68 (m, 1H), 5.14 – 4.76 (m, 2H), 3.23 (br s, 2H), 2.71 – 2.68 (m, 1H), 2.41 – 2.08 (m, 2H), 1.21 (d, J = 7.0 Hz, 3H).

13C NMR (151 MHz, CDCl₃) δ 144.2, 141.2, 137.4, 129.3, 128.1, 127.9, 125.8, 115.3, 45.4, 41.1, 21.5.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₁H₁₅NH 162.1283, found 162.1277.

4. Enantioselective Catalytic reaction for the Synthesis of chiral anilines

4.1. Screening of ligands
General procedure

To a previously dried Schlenk flask under nitrogen, CuBr•SMe₂ (5.0 mol%) and ligand (6.0 mol%) were added and dissolved in dry DCM (2 mL). After 15 min stirring at room temperature the solution was cooled down to -50 °C and the substrate (0.2 mmol, 1.0 equiv.) was added in 1mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0M solution in Et₂O, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction was quenched with NaHCO₃ sat. sol., and extracted with DCM (3 x 5 mL), dried over Na₂SO₄, filtered and removed under vaccum. The resulting residue was purified by flash column chromatography using the appropriate eluent (generally DCM). The enantiomeric ratio was determined by analytical HPLC using a chiral column.
| Entry | Time | Ligand | Temp. (°C) | Conversion (%) | Yield (%) | e.r. |
|-------|------|--------|------------|----------------|-----------|------|
| 1     | 16h  | --     | -50        | 99 (2a: 2b: 92:8) | 52        | 50:50 |
| 2     | 20h  | L17, SL-J004-1 | -50        | Full (2a: 2b: 83: 17) | 91        | 60:40 |
| 3     | 20h  | L12, SL-T001-2 | -50        | Full (2a: 2b: 87: 13) | 57        | 85:15 |
| 4     | 20h  | L5, (R,R)-BPE | -50        | Full (2a: 2b: 90: 10) | 97        | 50:50 |
| 5     | 16h  | L3, SL-T002-2 | -50        | Full (2a: 2b: 100: 0) | >99       | 50:50 |
| 6     | 16h  | L10     | -50        | >99 (2a:2b: 99:1) | 60        | 15:85 |
| 7     | 16h  | L11     | -50        | >99 (2a:2b: 99:1) | 63        | 15:85 |
| 8     | 16h  | L13, SL-M002-1 | -50        | Full (2a: 2b: 99: 1) | >99       | 50:50 |
| 9     | 16h  | L4, (R)-SEPHOS | -50        | >77 (2a: 2b: 86:14) | 80        | 50:50 |
| 10    | 16h  | L14, (R)-DMSEPHOS | -50        | 93 (2a: 2b: 92:8) | 60        | 28:72 |
| 11    | 16h  | L15, (R)-DTBMSEPHOS | -50        | 96 (2a: 2b: 93:7) | 85        | 33:66 |
| 12    | 16h  | L8, (R)-BINAP | -50        | full (2a: 2b: 99:1) | >99       | 30:70 |
| 13    | 16h  | L16, (R)-Tol-BINAP | -50        | 73 (2a: 2b: 99:1) | 56        | 28.5:71.5 |
|   |   |       |   |   |   |   |
|---|---|---|---|---|---|---|
| 14 | 16 h | **L1**, SL-J002-1 | -50 | 94 | (2a: 2b: 100:0) | 59 | 33:66 |
| 15 | 16 h | **L18**, SL-J009-1 | -50 | 99 | (2a: 2b: 97:3) | 90 | 66:34 |
| 16 | 16 h | **L19**, SL-J003-1 | -50 | 99 | (2a: 2b: 93:7) | 90 | 40:60 |
| 17 | 16 h | **L20**, SL-F356-1 | -50 | Full | (2a: 2b: 82:18) | 89 | 50:50 |
| 18 | 16 h | **L21**, SL-W001-1 | -50 | Full | (2a: 2b: 93:7) | 52 | 37.5:62.5 |
| 19 | 16 h | **L22**, SL-W002-1 | -50 | 88 | (2a: 2b: 99:1) | 52 | 48.5:51.5 |
| 20 | 16 h | **L23**, SL-W003-1 | -50 | Full | (2a: 2b: 98:2) | 60 | 47.5:52.5 |
| 21 | 16 h | **L24**, SL-W009-1 | -50 | mixture |   | 66 | 37:63 |
| 22 | 16 h | **L25**, SL-W008-1 | -50 | Full | (2a: 2b: 83:17) | 61 | 50:50 |
| 23 | 16 h | **L26**, SL-A116-1 | -50 | 89 | (2a: 2b: 97:3) | 36 | 54:46 |
| 24 | 16 h | **L27**, SL-N004-1 | -50 | Complex mixture |   | 7 | 46:54 |
| 25 | 16 h | **L12**, SL-T001-1 | -50 | Full | (2a: 2b: 95:5) | 64 | 17:83 |
| 26 | 16 h | **L28**, (R,R)-Me-DUPHOS | -50 | Full | (2a: 2b: 96:4) | 42 | 51:49 |
| 27 | 16 h | **L7** | -50 | >99 |   | >99 | 30:70 |
| 28 | 16 h | **L29** | -50 | >99 |   | 80 | 28:72 |
| 29 | 16 h | **L31** | -50 | >99 | (2a: 2b: 92:8) | 75 | 28.5:71.5 |
| 30 | 16 h | **L6** | -50 | 88 | (2a: 2b: 87:13) | 59 | 50:50 |
| 31 | 16 h | **L30** | -50 | >99 | (2a: 2b: 77:33) | 77 | 61:39 |
| 32 | 16 h | **L32** | -50 | mixture | traces |   | 50:50 |
| 33 | 16 h | **L33** | -50 | >99 |   | 30 | 50:50 |

Reaction conditions: CuBr•SMe₂ (5.0 mol%), ligand L (6.0 mol%) in dry DCM (2 mL). The substrate 1a (0.2 mmol, 1.0 equiv.) in 1 mL of DCM. After 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, (3.0 equiv.) Reaction time (16-20h).

[a] Determined by NMR
[b] Isolated yield
[c] The enantiomeric ratio was determined by analytical chiral HPLC using a OJ-H column and 98:2 Heptane:iPropanol, 1mL/min.

S9
4.2. Synthesis of chiral 4-(sec alkyl)anilines

General procedure for the catalytic reaction

To a previously dried Schlenk flask under nitrogen, CuBr (5.0 mol%) and ligand (6.0 mol%) were added and dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature the solution was cooled down to -50 °C and the substrate (0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction was quenched with NaHCO₃ sat. sol., and extracted with DCM (3 x 5 mL), dried over Na₂SO₄ anh. filtered and removed under vacuum. The resulting residue was purified by flash column chromatography using DCM. The enantiomeric ratio was determined by analytical HPLC.

General procedure for the synthesis of the racemic product (HPLC separation)

To a previously dried Schlenk flask under nitrogen, CuBr (5.0 mol%) was added and dissolved in dry DCM (1 mL) and Et₂O (1 mL). The solution was cooled down and the substrate (0.2 mmol, 1.0 equiv.) was added in 1 mL of solvent. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction was quenched with NaHCO₃ sat. sol., and extracted with DCM (3 x 5 mL), dried over Na₂SO₄ anh. filtered and removed under vacuum. The resulting residue was purified by flash column chromatography using DCM.

(R)-4-(sec-butyl)aniline ((R)-2a)

To a previously dried Schlenk flask under nitrogen, CuBr (5.0 mol%) and ligand (6.0 mol%) were added and dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature the solution was cooled down to -50 °C and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of solvent. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction was quenched with NaHCO₃ sat. sol., and extracted with DCM (3 x 5 mL), dried over Na₂SO₄ anh., filtered and removed under vacuum. The resulting residue was purified by flash column chromatography using DCM to afford the corresponding aniline 2a as a colourless liquid (23.2 mg, 0.156 mmol, 78%). The enantiomeric ratio was found to be 87:13 e.r. by analytical HPLC OD-H 98:2 iPrOH Heptane 1 mL/min, λ = 242 nm, tr (major): 14.8 min, tr (minor): 16.3 min.). The spectroscopic data matched with those reported in the literature.³

¹H NMR (400 MHz, CDCl₃) δ 6.98 (d, J = 8.2 Hz, 2H), 6.65 (d, J = 8.1 Hz, 2H), 3.52 (br s, 2H), 2.53 – 2.44 (m, 1H), 1.57 – 1.50 (m, 2H), 1.19 (d, J = 7.0 Hz, 3H), 0.81 (t, J = 7.4 Hz, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 144.2, 138.1, 127.9, 115.4, 40.9, 31.5, 22.2, 12.4.

HRMS (ESI-TOF): m/z [M+H]⁺ Calcd. for C₁₀H₁₅NH 150.1283, found 150.1276.
Scale up: To a previously dried Schlenk flask under nitrogen, CuBr (5.0 mol%) and ligand (6.0 mol%) were added and dissolved in dry DCM (5 mL) and Et₂O (5 mL). After 15 min stirring at room temperature the solution was cooled down to -50 °C and the substrate (275 mg, 1.0 mmol, 1.0 equiv.) was added in 5 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, 1.0 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction was quenched with NaHCO₃ sat. sol., and extracted with DCM (3 x 5 mL), dried over Na₂SO₄ anh., filtered and removed under vaccum. The resulting residue was purified by flash column chromatography using DCM to afford the corresponding aniline 2a as a colourless liquid (126.4 mg, 0.847 mmol, 85%). The enantiomeric ratio was found to be 87:13 e.r. by analytical HPLC OD-H 98:2 iPrOH Heptane 1 mL/min, λ= 242 nm, tr (major): 14.8 min, tr (minor): 16.3 min.}

| Peak# | Ret. Time | Area    | Height  | % Area |
|-------|-----------|---------|---------|--------|
| 1     | 14.772    | 14246992| 785898  | 86.749 |
| 2     | 16.297    | 2176137 | 109159  | 13.250 |
| Total | 16423129  | 895056  |         | 100,000|
### Table 1

| Peak | Ret. Time | Area     | Height    | % Area |
|------|-----------|----------|-----------|--------|
| 1    | 14,663    | 4761397  | 283156    | 49,800 |
| 2    | 16,164    | 4799622  | 253855    | 50,200 |
| Total|           | 9561019  | 537041    | 100.00 |

- **Retention Time**: 14.772 min
- **Compound Name**: 
- **Spectrum Operation**: None

### Table 2

| Peak | Ret. Time | Area     | Height    | % Area |
|------|-----------|----------|-----------|--------|
|      |           | 203.62   | 235.48    |        |
|      |           | 266.39   | 260.88    |        |
|      |           | 382.06   | 443.06    |        |
|      |           | 645.48   | 766.49    |        |

- **Retention Time**: 16.297 min
- **Compound Name**: 
- **Spectrum Operation**: None

### Table 3

| Peak | Ret. Time | Area     | Height    | % Area |
|------|-----------|----------|-----------|--------|
|      |           | 266.20   | 201.18    |        |
|      |           | 371.17   | 47352.70  |        |
|      |           | 582.68   |           |        |

- **Retention Time**: 
- **Compound Name**: 
- **Spectrum Operation**: None
Substrate Scope

(S)-4-(hexan-3-yl)aniline ((S)-2n)

CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (60.7 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, 0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2n as a colourless liquid (24.9 mg, 0.14 mmol, 70%). The enantiomeric ratio was found to be 82:18 e.r. by analytical HPLC OB-H 95:5 heptane: iPrOH 0.5 mL/min, λ = 245 nm, tr (minor): 19.1 min, tr (major): 21.8 min. (Due to the poor separation of the product (S)-2n in the HPLC, the ee of this compound was determined from the corresponding acetamide derivative.)

1H NMR (600 MHz, CDCl₃) δ 6.92 (d, J = 8.3 Hz, 2H), 6.64 (d, J = 8.3 Hz, 2H), 3.44 (br s, 2H), 2.32 - 2.27 (m, 1H), 1.65 – 1.52 (m, 2H), 1.51 – 1.44 (m, 2H), 1.21 – 1.10 (m, 2H), 0.84 (t, J = 7.4 Hz, 3H), 0.76 (t, J = 7.4 Hz, 3H).

13C NMR (151 MHz, CDCl₃) δ 144.1, 136.4, 128.6, 115.3, 46.8, 39.1, 30.0, 20.9, 14.3, 12.4.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₂H₁₉NH 178.1596, found 178.1590.

<Chromatogram>

<Peak Table>

| Peak | Ret. Time | Area     | Height  | Area%   |
|------|-----------|---------|---------|--------|
| 1    | 19.129    | 978688  | 18088   | 18.121 |
| 2    | 21.814    | 4422109 | 61863   | 81.879 |
| Total|           | 5400797 | 79950   | 100.000|
(S)-4-(octan-3-yl)aniline ((S)-2o)
CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and EtO (1 mL). After 15 min stirring at room temperature, the
solution was cooled down and the substrate (66.3 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, 0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20 h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2o as a colourless liquid (31.9 mg, 0.155 mmol, 78%). Enantiomeric ratio was found to be 80:20 e.r. by analytical HPLC in OB-H column 99.5:0.5 Heptane: iPrOH, 0.5 mL/min, λ = 239 nm, tr (major): 20.2 min, tr (minor): 21.8 min.

¹H NMR (400 MHz, CDCl₃) δ 6.98 (d, J = 8.2 Hz, 2H), 6.65 (d, J = 8.2 Hz, 2H), 3.38 (br s, 2H), 2.60–2.55 (m, 1H), 1.66–1.46 (m, 4H), 1.30–1.13 (m, 11H), 0.87 (t, J = 7.0 Hz, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 144.2, 138.4, 127.8, 115.4, 39.2, 38.8, 32.0, 29.6, 27.8, 22.8, 22.7, 14.2.

HRMS (ESI-TOF): m/z [M+H]⁺ Calcd. for C₁₄H₂₃NH 206.1909, found 206.1903
CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (70.3 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0M solution in Et₂O, (0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20 h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2p as a colourless liquid (26.3 mg, 0.117 mmol, 58%). The enantiomeric ratio was found to be 12:88 e.r. by analytical HPLC in OD-H 98:2 heptane: iPrOH 1 mL/min, λ= 239 nm, tr (minor): 19.7 min, tr (major): 21.6 min.

**[1H NMR](#) (400 MHz, CDCl₃) δ 7.23 – 7.19 (m, 2H), 7.16 – 7.09 (m, 1H), 7.03 (d, J = 7.1 Hz, 2H), 6.90 (d, J = 8.3 Hz, 2H), 6.61 (d, J = 8.3 Hz, 2H), 3.30 (br s, 2H), 2.91 – 2.74 (m, 2H), 2.65 – 2.57 (m, 1H), 1.73 – 1.63 (m, 1H), 1.59 – 1.48 (m, 1H), 0.76 (t, J = 7.4 Hz, 3H).

**[13C NMR](#) (101 MHz, CDCl₃) δ 144.3, 141.3, 135.4, 129.3, 128.7, 128.1, 125.7, 115.3, 49.0, 43.8, 28.6, 12.3.

**HRMS (ESI-TOF):** m/z [M+H]+ Calcd. for C₁₆H₁₉NH 226.1596, found 226.1590

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(S)-4-(1-phenylbutan-2-yl)aniline ((S)-2p)

![Chemical Structure](attachment:chemical_structure.png)

CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (70.3 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0M solution in Et₂O, (0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20 h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2p as a colourless liquid (26.3 mg, 0.117 mmol, 58%). The enantiomeric ratio was found to be 12:88 e.r. by analytical HPLC in OD-H 98:2 heptane: iPrOH 1 mL/min, λ= 239 nm, tr (minor): 19.7 min, tr (major): 21.6 min.

**[1H NMR](#) (400 MHz, CDCl₃) δ 7.23 – 7.19 (m, 2H), 7.16 – 7.09 (m, 1H), 7.03 (d, J = 7.1 Hz, 2H), 6.90 (d, J = 8.3 Hz, 2H), 6.61 (d, J = 8.3 Hz, 2H), 3.30 (br s, 2H), 2.91 – 2.74 (m, 2H), 2.65 – 2.57 (m, 1H), 1.73 – 1.63 (m, 1H), 1.59 – 1.48 (m, 1H), 0.76 (t, J = 7.4 Hz, 3H).

**[13C NMR](#) (101 MHz, CDCl₃) δ 144.3, 141.3, 135.4, 129.3, 128.7, 128.1, 125.7, 115.3, 49.0, 43.8, 28.6, 12.3.

**HRMS (ESI-TOF):** m/z [M+H]+ Calcd. for C₁₆H₁₉NH 226.1596, found 226.1590
(S)-4-(5-methylhexan-3-yl)aniline ((S)-2q)

CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (63.5 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0M solution in Et₂O, 0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2q as a colourless liquid (34.9 mg, 0.182 mmol, 91%). The enantiomeric ratio was found to be 79:21 e.r. by analytical chiral HPLC using as chiral column OB-H 98:2 heptane: iPrOH 1 mL/min, λ= 239 nm, tr (major): 6.1 min, tr (minor): 6.8 min.).

¹H NMR (400 MHz, CDCl₃) δ 6.94 (d, J = 7.9 Hz, 2H), 6.65 (d, J = 7.9 Hz, 2H), 3.54 (br s, 2H), 2.42–2.35 (m, 1H), 1.63–1.52 (m, 1H), 1.51–1.41 (m, 2H), 1.41–1.30 (m, 2H), 0.83 (dd, J = 11.1, 5.8 Hz, 6H), 0.75 (t, J = 7.3 Hz, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 144.0, 136.4, 128.6, 115.4, 46.2, 44.7, 30.5, 25.5, 23.8, 22.0, 12.3.

HRMS (ESI-TOF): m/z [M+H]⁺ Calcd. for C₁₃H₂₁NH 192.1752, found 192.1747
CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (60.3 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0M solution in Et₂O, 0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2r as a colourless liquid (26.2 mg, 0.149 mmol, 75%). The enantiomeric ratio was found to be 86:14 e.r by analytical HPLC OJ-H column 98:2 Heptane: iPrOH, 1 mL/min, λ = 226 nm, τ (major): 23.2 min, τ (minor): 26.8 min.

^1H NMR (600 MHz, CDCl₃) δ 6.94 (d, J = 8.3 Hz, 2H), 6.65 (d, J = 8.3 Hz, 2H), 5.80 – 5.56 (m, 1H), 4.95 (dt, J = 17.1, 1.8 Hz, 1H), 4.90 (ddt, J = 10.1, 2.2, 1.1 Hz, 1H), 3.65 (br s, 2H), 2.40 – 2.17 (m, 2H), 1.71 – 1.64 (m, 1H), 1.55 – 1.42 (m, 1H), 0.77 (t, J = 7.4 Hz, 3H).

^13C NMR (151 MHz, CDCl₃) δ 144.0, 137.7, 135.7, 128.6, 115.5, 115.4, 46.9, 41.2, 29.1, 12.2.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₂H₁₇NH 176.1439, found 176.1434
CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (69.5 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0 M solution in Et₂O, 0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20 h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2s as a colourless liquid (41.4 mg, 0.187 mmol, 93%). The enantiomeric ratio was found to be 48:52 e.r. by analytical HPLC in OB-H 98:2 heptane: iPrOH 1 mL/min, λ = 250 nm, tr (enant): 17.4 min, tr (enant): 19.2 min.

\[ ^1 \text{H NMR (600 MHz, CDCl}_3) \delta \text{6.91 (d, J = 8.3 Hz, 2H), 6.64 (d, J = 8.3 Hz, 2H), 3.32-3.26 (m, 5H), 2.42 - 2.26 (m, 1H), 1.64 - 1.44 (m, 6H), 1.27 - 1.09 (m, 2H), 0.75 (t, J = 7.4 Hz, 3H).} \]

\[ ^13 \text{C NMR (151 MHz, CDCl}_3) \delta \text{144.1, 136.2, 128.6, 115.4, 73.0, 58.6, 47.1, 36.7, 29.9, 29.9, 24.3, 12.3.} \]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₄H₂₃NOH 222.1858, found 222.1850

(S)-4-(7-methoxyheptan-3-yl)aniline ((S)-2s)
CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et<sub>2</sub>O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (68.9 mg, 0.2 mmol, 1.0 equiv.) was added in 1mL of DCM. After stirring for an additional 10 min, EtMgBr (Aldrich, 3.0M solution in Et<sub>2</sub>O, (0.2 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO<sub>3</sub> sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2t as a colourless liquid (38.7 mg, 0.177 mmol, 89%). The enantiomeric ratio was found to be 67:33 e.r. by analytical HPLC in OJ-H 99.5:0.5 heptane: iPrOH 1 mL/min, λ= 252 nm, tr (minor): 12.8 min, tr (major): 17.7 min.

<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.00 (s, 2H), 4.28 (br s, 2H), 2.48 – 2.42 (m, 1H), 1.57 – 1.46 (m, 2H), 1.17 (d, J = 7.0 Hz, 3H), 0.81 (t, J = 7.4 Hz, 3H).

<sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 138.4, 137.9, 126.5, 119.7, 40.8, 31.2, 22.0, 12.3.

HRMS (ESI-TOF): m/z [M+H]<sup>+</sup> Calcd. for C<sub>10</sub>H<sub>13</sub>Cl<sub>2</sub>NH 218.0503, found 218.0498
| Peak# | Ret. Time | Area     | Height |
|-------|-----------|----------|--------|
| 1     | 12.766    | 1970227  | 29281  |
| 2     | 17.696    | 3950803  | 41389  |
| Total |           | 5921029  | 70670  |

Area: %
- 33,275
- 66,725
- 100,000

Retention Time: 12.766 min
Compound Name: 
Spectrum Operation: None

| Peak# | Ret. Time | Area     | Height |
|-------|-----------|----------|--------|
| 1     | 13.144    | 861863   | 12025  |
| 2     | 16.527    | 871937   | 12538  |
| Total |           | 1733800  | 24562  |

Area: %
- 49,709
- 50,291
- 100,000

Retention Time: 17.696 min
Compound Name: 
Spectrum Operation: None

| Peak# | Ret. Time | Area     | Height |
|-------|-----------|----------|--------|
|       |           |          |        |
|       |           |          |        |
|       |           |          |        |

Retention Time: 
Compound Name: 
Spectrum Operation: None

S26
Grignard screening

(R)-4-(heptan-2-yl)aniline ((R)-2d)

CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, pentyl MgBr (Aldrich, 2.0M solution in Et₂O, (0.3 mL, 3.0 equiv.)) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2d as a colourless liquid (27.1 mg, 0.142 mmol, 71%). The enantiomeric ratio was found to be 22:78 e.r. by analytical HPLC in OB-H column 99.5:0.5 Heptane: iPrOH, 0.5 mL/min, λ = 239 nm, tr (minor): 26.8 min, tr (major): 31.4 min.

¹H NMR (600 MHz, CDCl₃) δ 6.98 (d, J = 8.3 Hz, 2H), 6.65 (d, J = 8.3 Hz, 2H), 3.38 (br s, 2H), 2.60 – 2.55 (m, 1H), 1.55 – 1.46 (m, 2H), 1.30 – 1.13 (m, 9H), 0.87 (t, J = 6.9 Hz, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 144.1, 138.4, 127.8, 115.4, 39.2, 38.8, 32.0, 29.6, 27.8, 22.7, 14.2.

HRMS (ESI-TOF): m/z [M+H]⁺ Calcd. for C₁₃H₂₁NH 192.1752, found 192.1747
(R)-4-(octan-3-yl)aniline ((R)-2o)
CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1 mL of DCM. After stirring for an additional 10 min, pentyl MgBr (Aldrich, 2.0M solution in Et₂O, 0.3 mL, 0.6 mmol, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 20 as a colourless liquid (27.1 mg, 0.142 mmol, 71%). The enantiomeric ratio was found to be 75:25 e.r. by analytical HPLC in OB-H column 99.5:0.5 Heptane: iPrOH, 0.5 mL/min, λ= 242 nm, tr (minor): 20.8 min, tr (major): 22.3 min.).

¹H NMR (400 MHz, CDCl₃) δ 6.98 (d, J = 8.2 Hz, 2H), 6.65 (d, J = 8.2 Hz, 2H), 3.38 (br s, 2H), 2.60 – 2.55 (m, 1H), 1.66 – 1.46 (m, 2H), 1.30 – 1.13 (m, 11H), 0.87(t, J = 7.0 Hz, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 144.2, 138.4, 127.8, 115.4, 39.2, 38.8, 32.0, 29.6, 27.8, 22.8, 22.7, 14.2.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₄H₂₃NH 206.1909, found 206.1903
(R)-4-(5-methylhexan-2-yl)aniline ((R)-2e)
CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1mL of DCM. After stirring for an additional 10 min, Isopentyl MgBr (Aldrich, 2.0M solution in Et₂O, (0.3 mL, 3.0 equiv.)) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2e as a colourless liquid (23.4 mg, 0.122 mmol, 61%). The enantiomeric ratio was found to be 39:61 e.r. by analytical HPLC in OB-H column 98:2 Heptane: iPrOH, 0.5 mL/min, λ = 226 nm, tr (minor): 19.6 min, tr (major): 24.4min.

\(^1\)H NMR (400 MHz, CDCl₃) δ 6.99 (d, J = 8.0 Hz, 2H), 6.64 (d, J = 8.0 Hz, 2H), 3.35 (br. s, 2H), 2.59 – 2.50 (m, 1H), 1.58 – 1.45 (m, 3H), 1.20 (d, J = 7.0 Hz, 3H), 1.18 – 0.96 (m, 2H), 0.85 (d, J = 3.0 Hz, 3H), 0.84 (d, J = 3.0 Hz, 3H).

\(^{13}\)C NMR (151 MHz, CDCl₃) δ 144.1, 138.5, 127.8, 115.4, 39.5, 37.2, 36.5, 28.3, 22.8, 22.7.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₃H₂₁N 192.1752, found 192.1742.
(R)-4-(1-cyclopentylethyl)aniline ((R)-2f)

CuBr (1.4 mg, 0.01 mmol, 5.0 mol%) and ligand Taniaphos T001-2 (8.3 mg, 0.012 mmol, 6.0 mol%) were dissolved in dry DCM (1 mL) and Et₂O (1 mL). After 15 min stirring at room temperature, the solution was cooled down to -50 °C and the substrate (55.1 mg, 0.2 mmol, 1.0 equiv.) was added in 1mL of DCM. After stirring for an additional 10 min, cyclopentyl MgBr (Aldrich, 2.0M solution in Et₂O, 0.3 mL, 3.0 equiv.) was added. The reaction mixture was stirred overnight (16-20h). The reaction is quenched with NaHCO₃ sat sol. (5 mL) and extracted with DCM (x3). The residue was purified by flash column chromatography in DCM to afford the corresponding aniline 2f as a colourless liquid (20.1 mg,
0.106 mmol, 53%). The enantiomeric ratio was found to be 85:15 e.r. by analytical HPLC in OD-H column 98:2 Heptane: iPrOH, 1 mL/min, λ= 254 nm, tr (major): 15.2 min, tr (minor): 17.8 min.

$^1$H NMR (600 MHz, CDCl$_3$) δ 6.97 (d, J = 8.3 Hz, 2H), 6.64 (d, J = 8.3 Hz, 2H), 3.36 (br s, 2H), 2.33 (dq, J = 9.4, 6.9 Hz, 1H), 1.91 – 1.85 (m, 2H), 1.65 – 1.39 (m, 5H), 1.22 – 1.17 (m, 4H), 1.06 – 0.91 (m, 1H).

$^{13}$C NMR (151 MHz, CDCl$_3$) δ 143.9, 138.7, 128.1, 115.4, 47.9, 45.4, 31.9, 31.5, 25.5, 25.2, 21.7.

HRMS (ESI-TOF): m/z [M+H]$^+$ Calcd. for C$_{13}$H$_{19}$N 190.1590, found 190.1591
### PDA Ch1 254nm

| Peak# | Ret. Time | Area  | Height |
|-------|-----------|-------|--------|
| 1     | 15,168    | 561432| 29088  |
| 2     | 17,709    | 560851| 23148  |
| Total |           | 1122283| 52236  |

#### Retention Time
- 15.173 min
- 17.767 min

#### Compound Name
- :*
- :*

#### Spectrum Operation
- None
- None

#### % Area
- 50.025
- 49.974
- 100.000
5. Derivatizations

(R)-N-(4-(sec-butyl)phenyl)-4-methylbenzenesulfonamide (3)

p-Toluenesulfonyl chloride (165.8 mg, 0.870 mmol, 1.1 equiv) is added to a solution of aniline (118.0 mg, 0.791 mmol, 1.0 equiv) in pyridine (3.2 mL, 39.534 mmol, 50.0 equiv) at 0 °C. The resulting solution is stirred at 25 °C overnight (24h). The solvent is removed in vacuo in order to remove the pyridine. The residue is dissolved in water and it is extracted with DCM (3x). The collected organic phases are dried over MgSO₄, filtered and the resulting residue is purified by silica gel column chromatography with pentane:ethyl acetate (7/3) as the eluent affording the desired sulfonamide 3 as a white solid (232.0 mg, 0.767 mmol, 97%). The enantiomeric ratio was found to be 87:13 e.r. by analytical HPLC in OD-H column 98:2 Heptane: iPrOH, 1 mL/min, λ= 227 nm, tr (minor): 40.6 min, tr (major): 43.1 min.)

1H NMR (600 MHz, CDCl₃) δ 7.62 (d, J = 8.3 Hz, 2H), 7.24 – 7.16 (m, 2H), 7.04 (d, J = 8.4 Hz, 2H), 6.96 (d, J = 8.3 Hz, 2H), 6.43 – 6.39 (m, 1H), 2.55 – 2.49 (m, 1H), 2.38 (s, 3H), 1.62 – 1.42 (m, 2H), 1.17 (d, J = 6.9 Hz, 3H), 0.76 (t, J = 7.4 Hz, 3H).

13C NMR (151 MHz, CDCl₃) δ 145.4, 143.8, 136.4, 134.1, 129.7, 128.0, 127.4, 122.5, 41.2, 31.3, 21.8, 21.7, 12.2.

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C₁₇H₂₁NO₂SH 304,1321, found 304.1322

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PDA Multi 1 227nm,4nm

| Peak# | Ret. Time | Area   | Height |
|-------|-----------|--------|--------|
| 1     | 40.641    | 9694445| 153082 |
| 2     | 43.165    | 1401873| 20292  |
| Total |           | 11996318| 173374 |

% Area

| Area | %     |
|------|-------|
| 87,366 | 100.00 |
| 12,634  | 14.04  |

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S35
| Peak# | Ret. Time | Area   | Height |
|------|-----------|--------|--------|
| 1    | 42.386    | 736086 | 11986  |
| 2    | 44.657    | 737120 | 11317  |
| Total|           | 1473206| 23303  |

% Area

|       |
|-------|
| Area  |
| 49.964|
| 50.035|
| 100.000|

Retention Time : 44.657 min
Compound Name : None
Spectrum Operation : None
6. Synthesis of the substrates

6.1. Method A

6.1.1. Synthesis of an alcohol derivative

**General procedure:** To a solution of 4-bromobenzaldehyde (1.0 equiv) in anhydrous THF (0.5 M) was added a solution of Grignard reagent (2.1 equiv) dropwise at room temperature. The resulting solution was stirred overnight, and the reaction mixture was quenched with saturated NH₄Cl aqueous solution (20 mL) and extracted with diethyl ether (x3). The combined organic layers were dried over anhydrous Na₂SO₄, then concentrated under vacuum to afford a crude, which was purified by column chromatography.

1-(4-bromophenyl)propan-1-ol (1'b)

The product was synthesized following general procedure and it was obtained after flash column chromatography in silica gel (Pentane: EtOAc, 9:1) to afford a colourless liquid (2.15 g, 74%). The spectroscopic data matched with those reported in the literature.⁷

**¹H NMR (400 MHz, CDCl₃) δ 7.44 (d, J = 8.4 Hz, 2H), 7.18 (d, J = 8.4 Hz, 2H), 4.53 (t, J = 6.5 Hz, 1H), 1.87 – 1.43 (m, 2H), 0.87 (t, J = 7.4 Hz, 3H).**

**¹³C NMR (101 MHz, CDCl₃) δ 143.6, 131.6, 127.8, 121.3, 75.4, 32.0, 10.1.**

1-(4-bromophenyl)butan-1-ol (1'n)

⁷ It was not possible to obtain HRMS of those compounds. However, upon derivatization into the corresponding sulfones, the characterization was possible.

⁸ Wei, D.; Roisnel, T.; Darcel, C.; Clot, E.; Sortais, J.-B.; *Chem. Cat. Chem.* 2017, 9, 80-83.
The product was synthesized following general procedure and it was obtained after flash column chromatography in silica gel (Pentane: EtOAc, 9:1) to afford the alcohol as a colourless liquid (1.01 g, 41%). The spectroscopic data matched with those reported in the literature.\(^9\)

\(^{1}\text{H NMR (400 MHz, CDCl}_3\text{)} \delta 7.46 (d, J = 8.3 Hz, 2H), 7.22 (d, J = 8.2 Hz, 2H), 4.77 – 4.43 (m, 1H), 1.84 – 1.54 (m, 3H), 1.51 – 1.14 (m, 2H), 0.93 (t, J = 7.4 Hz, 3H).

\(^{13}\text{C NMR (151 MHz, CDCl}_3\text{)} \delta 144.0, 131.6, 127.8, 121.3, 73.9, 41.4, 19.0, 14.0.

\(1\text{-}(4\text{-bromophenyl})\text{hexan-1-ol (1'}\text{')}\)

The product was synthesized following general procedure and it was obtained after flash column chromatography in silica gel (Pentane: EtOAc 20:1 - 9:1) as a white solid (0.55 g, 79%). The spectroscopic data matched with those reported in the literature.\(^10\)

\(^{1}\text{H NMR (400 MHz, CDCl}_3\text{)} \delta 7.46 (d, J = 8.4 Hz, 2H), 7.22 (d, J = 8.4 Hz, 2H), 4.63 (t, J = 6.5 Hz, 1H), 1.92 – 1.56 (m, 3H), 1.46 – 1.32 (m, 1H), 1.32 – 1.17 (m, 5H), 0.97 – 0.70 (m, 3H).

\(^{13}\text{C NMR (101 MHz, CDCl}_3\text{)} \delta 146.6, 134.1, 130.3, 123.7, 76.5, 41.7, 34.3, 28.0, 25.2, 16.7.

\(1\text{-}(4\text{-bromophenyl})\text{-2-phenylethan-1-ol (1'}\text{p})\)

The product was synthesized following general procedure and it was obtained after flash column chromatography in silica gel (Pentane: EtOAc 9:1), affording the compound as a white solid (1.18 g, 39%). The spectroscopic data matched with those reported in the literature.\(^11\)

\(^{1}\text{H NMR (400 MHz, CDCl}_3\text{)} \delta 7.56 – 7.36 (m, 2H), 7.30 (d, J = 7.4 Hz, 2H), 7.27 – 7.18 (m,3H), 7.19 – 7.08 (m, 2H), 4.87 (dd, J = 8.3, 5.1 Hz, 1H), 3.04 – 2.92 (m, 2H).

\(^{13}\text{C NMR (101 MHz, CDCl}_3\text{)} \delta 145.4, 140.1, 134.1, 132.1, 131.2, 130.3, 129.4, 124.0, 77.3, 48.7.

\(1\text{-}(4\text{-bromophenyl})\text{-3-methylbutan-1-ol (1'}\text{q})\)

The product was synthesized following general procedure and it was obtained after flash column chromatography in silica gel (Pentane: EtOAc, 9:1) to afford a colourless liquid (0.59 g, 90%). The spectroscopic data matched with those reported in the literature.\(^8\)

\(^{1}\text{H NMR (400 MHz, CDCl}_3\text{)} \delta 7.44 (d, J = 8.3 Hz, 2H), 7.18 (d, J = 8.3 Hz, 2H), 4.66 (dd, J = 7.9, 5.3 Hz, 1H), 2.20 (br s, 1H), 1.82 – 1.54 (m, 2H), 1.50 – 1.40 (m, 1H), 0.93 (dd, J = 6.3, 2.0 Hz, 6H).

\(^{13}\text{C NMR (151 MHz, CDCl}_3\text{)} \delta 144.3, 131.6, 127.7, 121.3, 72.2, 24.9, 23.2, 22.3.

\(^9\) Tanwar, L.; Börgel, J.; Ritter, T. J. Am. Chem. Soc. 2019, 141, 17983–17988.

\(^{10}\) Patent: US2008/221220 A1, 2008.

\(^{11}\) Lovinger, G. J.; Aparece, M. D.; Morken, J. P. J. Am. Chem. Soc. 2017, 139, 3153–3160.
1-(4-bromophenyl)but-3-en-1-ol (1’s)

The product was synthesized following general procedure and using a solution of a freshly prepared Grignard reagent, it was obtained after flash column chromatography (Pentane: EtOAc, 9:1 -- 1:1), affording a yellow liquid (1.83 g, 96%).

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.44 (d, J = 8.4 Hz, 2H), 7.19 (dd, J = 8.5, 2.1 Hz, 2H), 4.64 - 4.60 (m, 1H), 3.35 - 3.32 (m, 2H), 3.29 (s, 3H), 1.87 (br s, 1H), 1.81 - 1.61 (m, 2H), 1.61 - 1.51 (m, 2H), 1.51 - 1.24 (m, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 146.4, 134.1, 130.2, 123.9, 76.4, 75.2, 61.2, 41.5, 32.0, 25.0.

6.1.2. Synthesis of an amino sulfone derivative

General procedure

Step 1: A 20 mL-screw capped vial was charged with aryl bromide 1’ (1.0 equiv), CuI (0.1 equiv) and DMEDA (1.5 equiv) in NH$_3$ (25 equiv. or completely full vial) and DMSO (2.5 mL). The vial was flushed with nitrogen and capped. The solution was stirred overnight at 130 °C. The resulting intense blue suspension was cooled down to room temperature, extracted with EtOAc (× 3). The organic layers were separated, and the organic layer is dried over Na$_2$SO$_4$, filtered, and concentrated. The residue was purified by flash column chromatography (Hexane/EtOAc =7/3-1/1) affording an aniline substrate 1” which was directly employed in the next step (decomposes easily).

Step 2: To a Schlenk under nitrogen, it was added a mixture of sodium p-toluensulfinate (1.0 equiv) and p-toluenesulfonic acid monohydrate (1.5 equiv) and dry DCM (0.5 M). Then, the aniline substrate 1”
was added to the mixture, and a precipitate was formed immediately. The resulting suspension was stirred either 2h or overnight, then quenched by adjusting to pH 8 with saturated Na₂CO₃ aqueous solution. The organic layer was separated, and the aqueous layer was extracted with DCM (× 3). The combined organic layers were dried over anhydrous Na₂SO₄, concentrated under vacuum to afford the corresponding sulfone 1. The solid was purified by trituration with diethyl ether and hexane.

4-(1-tosylpropyl)aniline (1b)

Step 1: The product was synthesized following general procedure and it was obtained after flash column chromatography in silica gel (hexane/EtOAc =7/3-1/1) to afford the corresponding aniline as a colourless oil 1''b (0.96 g, 68%).

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Step 1: The product was synthesized following general procedure and it was obtained after flash column chromatography (hexane/EtOAc =7/3-1/1), to afford the corresponding aniline 1''o (1.05 g, 88%).

\[ \text{H NMR (400 MHz, CDCl}_3\text{): } \delta 7.13 \text{ (d, J = 8.2 Hz, 2H), 6.67 \text{ (d, J = 8.3 Hz, 2H), 4.54} \text{ (t, J = 6.9 Hz, 1H), 1.85 - 1.71} \text{ (m, 1H), 1.71 - 1.58} \text{ (m, 2H), 1.44 - 1.12} \text{ (m, 8H), 0.86} \text{ (t, J = 5.7 Hz, 3H).} \]

Step 2: The product was synthesized following general procedure to afford a solid that was purified by trituration with pentane and diethyl ether afforded a pure sulfone as a pale yellow solid 1o (0.06 g, 5%).

\[ \text{H NMR (400 MHz, CDCl}_3\text{): } \delta 7.41 \text{ (d, J = 8.0 Hz, 2H), 7.17 \text{ (d, J = 8.0 Hz, 2H), 6.88 \text{ (d, J = 8.1 Hz, 2H), 6.60 \text{ (d, J = 8.1 Hz, 2H), 4.34 \text{ (br s, 2H), 3.90} \text{ (dd, J = 11.7, 3.6 Hz, 1H), 2.39 \text{ (s, 3H), 2.36 - 2.28} \text{ (m, 1H), 2.08 - 1.98} \text{ (m, 1H), 1.32 - 0.96} \text{ (m, 6H), 0.83 - 0.79} \text{ (m, 3H).} } \]

\[ \text{13C NMR (101 MHz, CDCl}_3\text{): } \delta 146.8, 144.2, 134.8, 131.0, 129.3, 129.2, 121.7, 115.0, 72.4, 71.1, 58.6, 29.3, 27.2, 23.6, 21.7. \]

\[ \text{HRMS (ESI-TOF): m/z [M+H]\text{+} \text{ Calcd. for } C_{19}H_{25}NO_2S_332.1684, \text{ found 332.1678} \]

4-(2-phenyl-1-tosylethyl)aniline (1p)

Step 1: The product was synthesized following general procedure and it was obtained after flash column chromatography (hexane/EtOAc =7/3-1/1) to yield the aniline 1''p (0.39 g, 51%).

\[ \text{H NMR (400 MHz, CDCl}_3\text{): } \delta 7.31 - 7.14 \text{ (m, 7 H), 6.67 - 6.65 \text{ (m, 2H), 4.79} \text{ (t, J = 6.7 Hz, 1H), 3.00} \text{ (d, J = 6.7 Hz, 2H).} \]

Step 2: The product was synthesized following general procedure to afford the corresponding sulfone after trituration with pentane and diethyl ether as a yellow solid 1p (0.23 g, 26%).

\[ \text{H NMR (400 MHz, DMSO-d}_6\text{): } \delta 7.52 \text{ (d, J = 8.3 Hz, 2H), 7.32 \text{ (d, J = 8.3 Hz, 2H), 7.21 - 6.96} \text{ (m, 5H), 6.78 \text{ (d, J = 8.5 Hz, 2H), 6.31 \text{ (d, J = 8.6 Hz, 2H), 5.08} \text{ (s, 2H), 4.58} \text{ (dd, J = 12.1, 3.5 Hz, 1H), 3.39 \text{ (dd, J = 14.0, 3.5 Hz, 1H), 3.28 - 3.17} \text{ (m, 1H), 2.35} \text{ (s, 3H).} } \]

\[ \text{13C NMR (101 MHz, DMSO-d}_6\text{): } \delta 149.2, 144.4, 137.7, 135.3, 131.3, 129.8, 129.4, 129.1, 128.6, 126.6, 117.8, 113.7, 68.2, 32.3, 19.9. \]

\[ \text{HRMS (ESI-TOF): m/z [M+K]\text{+} \text{ Calcd. for } C_{21}H_{21}NO_2SK 389.1399, \text{ found 389.1332} \]

4-(3-methyl-1-tosylbutyl)aniline (1q)

Step 1: The product was synthesized following general procedure and it was obtained after flash column chromatography (hexane/EtOAc =7/3-1/1) to afford the corresponding aniline 1''q (0.35 g, 67%).

\[ \text{H NMR (400 MHz, CDCl}_3\text{): } \delta 7.13 \text{ (d, J = 8.3 Hz, 2H), 6.65 \text{ (d, J = 8.3 Hz, 2H), 4.62} \text{ (dd, J = 7.9, 6.0 Hz, 1H), 2.91} \text{ (br s, 2H), 1.74 - 1.59} \text{ (m, 2H), 1.54 - 1.51} \text{ (m, 1H, CH), 0.92 \text{ (dd, J = 6.4, 4.5 Hz, 6H).} } \]

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Step 2: The product was synthesized following general procedure to afford a solid that was purified by trituration with diethyl ether and pentane to afford a white-yellow solid 1q (0.53 g, 87%).

$^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.33 (d, J = 8.3 Hz, 2H), 7.10 (d, J = 8.0 Hz, 2H), 6.78 (d, J = 8.0 Hz, 2H), 6.46 (d, J = 8.6 Hz, 2H), 3.91 (dd, J = 11.8, 3.9 Hz, 1H), 3.57 (br s, 2H), 2.31 (s, 3H), 2.15 – 1.64 (m, 2H), 2.05 – 1.93 (m, 1H), 0.81 (d, J = 6.6 Hz, 3H), 0.71 (d, J = 6.6 Hz, 3H).

$^{13}$C NMR (151 MHz, CDCl$_3$) $\delta$ 146.8, 144.1, 134.8, 131.0, 129.2, 129.2, 121.8, 115.0, 69.7, 35.7, 25.3, 23.7, 21.7, 20.9.

HRMS (ESI-TOF): m/z [M+Na]$^+$ Calcd. for C$_{18}$H$_{23}$NO$_2$SNa 340.1347, found 340.1342.

4-(1-tosylbut-3-en-1-yl)aniline (1r)

Step 1: The product was synthesized following general procedure and it was obtained after flash column chromatography (hexane/EtOAc = 7/3-1/1) to afford the corresponding aniline $1''$r (1.17 g, 81%).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.14 (d, J = 8.3 Hz, 2H), 6.66 (d, J = 8.3 Hz, 2H), 5.79 (ddt, J = 17.2, 10.1, 7.1 Hz, 2H), 5.20 – 5.03 (m, 1H), 4.61 (t, J = 6.6 Hz, 1H), 2.99 (br s, 2H), 2.48 (t, J = 7.1 Hz, 2H).

Step 2: The product was synthesized following general procedure to afford a solid which was purified by trituration with pentane and diethyl ether to afford the corresponding sulfone as a white-beige solid $1r$ (0.85 g, 39%).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.46 – 7.37 (d, J = 8.1 Hz, 2H), 7.18 (d, J = 7.9 Hz, 2H), 6.87 (d, J = 7.4 Hz, 2H), 6.54 (d, J = 7.4 Hz, 2H), 5.63 – 5.41 (m, 1H), 5.04 (d, J = 17.0 Hz, 1H), 4.95 (d, J = 9.9 Hz, 1H), 3.98 (dd, J = 11.5, 3.6 Hz, 1H), 3.12 – 3.09 (m, 1H), 2.89 – 2.70 (m, 1H), 2.39 (s, 3H).

$^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 146.9, 137.0, 136.0, 136.0, 133.7, 131.9, 131.9, 131.8, 120.7, 117.6, 73.1, 34.5, 24.2.

HRMS (ESI-TOF): m/z [M+NH$_4$]$^+$ Calcd. for C$_{17}$H$_{19}$NO$_2$SNH$_4$ 319.1480, found 319.1475.

4-(5-methoxy-1-tosylpentyl)aniline (1s)

Step 1: The product was synthesized following general procedure and it was obtained after flash column chromatography (hexane/EtOAc = 7/3-1/1) to afford the aniline $1''$s as a yellow liquid (1.13 g, 99%).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.09 (d, J = 8.2 Hz, 2H), 6.61 (d, J = 8.2 Hz, 2H), 4.49 (t, J = 6.8 Hz, 1H), 3.32 (t, J = 6.6 Hz, 2H), 3.27 (s, 3H), 3.13 (br s, 2H), 1.81 – 1.71 (m, 1H), 1.70 – 1.60 (m, 1H), 1.55 (q, J = 7.0 Hz, 2H), 1.51 – 1.33 (m, 1H), 1.33 – 1.24 (m, 1H).

Step 2: The product was synthesized following general procedure to afford after trituration with diethyl ether and pentane the corresponding sulfone as a yellow solid $1s$ (0.87 g, 53%).

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.44 – 7.34 (m, 2H), 7.17 (dd, J = 8.2, 1.7 Hz, 2H), 6.85 (dd, J = 8.5, 2.1 Hz, 2H), 6.53 (dd, J = 8.6, 2.6 Hz, 2H), 3.89 (dd, J = 11.7, 3.6 Hz, 1H), 3.56 (br s, 2H), 3.29 – 3.25 (m, 3H).
2H), 3.24 (s, 3H), 2.37 (s, 3H), 2.58 – 2.17 (m, 1H), 2.15 – 1.90 (m, 1H), 1.72 – 1.34 (m, 2H), 1.34 – 1.04 (m, 2H).

$^{13}$C NMR (101 MHz, CDCl$_3$) δ 146.8, 144.2, 134.8, 131.0, 129.3, 129.2, 121.7, 115.1, 72.4, 71.1, 58.6, 29.3, 27.2, 23.6, 21.7.

HRMS (ESI-TOF): m/z [M+Na]$^+$ Calcd. for C$_{19}$H$_{25}$NO$_3$SNa 370.1453, found 370.1446

6.2. Method B

![Chemical structure diagram]

6.2.1. Synthesis of alcohols

General Procedure

To a previously dried Schlenk flask, it is added the corresponding ketone (1.0 equiv) and it is dissolved in EtOH (0.2 M). Next, NaBH$_4$ (2.0 equiv) was added and the schlenk is open for 15 minutes, to release the overpressure due to the formation hydrogen gas and then closed with a septum. The resulting mixture was stirred at r.t. overnight. Then, the solvent was removed in vacuo, dissolved in EtOAc and water, extracted with EtOAc (3 x) and the collected organic phases were dried over Na$_2$SO$_4$, filtered affording the alcohol 1$''$.

1-(4-aminophenyl)ethan-1-ol (1$''$a)

The product was synthesized following general procedure to afford the alcohol 1$''$a as a white solid (7.0 g, 98%). The spectroscopic data matched with those reported in the literature.$^{13}$

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.17 (d, J = 8.3 Hz, 2H), 6.67 (d, J = 8.4 Hz, 2H), 4.80 (q, J = 6.4 Hz, 1H), 3.65 (br s, 2H), 1.46 (d, J = 6.4 Hz, 3H)

$^{13}$C NMR (151 MHz, CDCl$_3$) δ 146.0, 136.0, 126.8, 115.2, 70.3, 24.9.

HRMS (ESI-TOF): m/z [M+H]$^+$ Calcd. for C$_8$H$_{11}$NOH 138.0919, found 138.0913

1-(4-amino-3,5-dichlorophenyl)ethan-1-ol (1$''$t)

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$^{13}$ Li, Z.; Yazaki, R.; Ohshima, T. Org. Lett., 2016, 18, 3350–3353.
The product was synthesized following general procedure to afford the alcohol as a grey solid 1''t (2.46 g, 97%).

\[ \text{H NMR (400 MHz, CDCl}_3\text{) } \delta 7.20 \text{ (s, 2H), 4.75 (q, J = 6.4 Hz, 1H), 1.44 (d, J = 6.4 Hz, 3H).} \]

\[ \text{C NMR (151 MHz, CDCl}_3\text{) } \delta 146.0, 136.0, 126.8, 115.2, 70.3, 24.9. \]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_8H_9Cl_2NOH 206.0139, found 206.0134

### 6.2.2. Synthesis of sulfones

#### General Procedure

To a Schlenk under nitrogen, it was added a mixture of sodium sulfinate (1.0 equiv) and p-toluenesulfonic acid monohydrate (1.5 equiv) and dry DCM (0.5 M). Then, the aniline substrate 1' was added to the mixture, and a precipitate was formed immediately. The resulting suspension was stirred either 2h or overnight, then quenched by adjusting to pH 8 with saturated Na_2CO_3 aqueous solution. The organic layer was separated, and the aqueous layer was extracted with DCM (× 3). The combined organic layers were dried over anhydrous Na_2SO_4, concentrated under vacuum to afford the corresponding sulfone 1. The solid was purified by trituration with diethyl ether and hexane.

**4-(1-tosylethyl)aniline (1a)**

The product was synthesized following general procedure to afford a solid that was purified by trituration with diethyl ether and pentane to afford a white solid 1a (1.2 g, 40%). The spectroscopic data matched with those reported in the literature.\(^{14}\)

\[ \text{H NMR (600 MHz, CDCl}_3\text{) } \delta 7.44 \text{ (d, J = 8.3 Hz, 2H), 7.20 (d, J = 8.3 Hz, 2H), 6.92 (d, J = 8.4 Hz, 2H), 6.57 (d, J = 8.4 Hz, 2H), 4.12 (q, J = 7.2 Hz, 1H), 3.99 (br s, 2H), 2.40 (s, 3H), 1.69 (d, J = 7.2 Hz, 3H).} \]

\[ \text{C NMR (151 MHz, CDCl}_3\text{) } \delta 146.5, 144.3, 134.3, 130.6, 129.4, 129.3, 123.67, 115.1, 65.6, 21.8, 14.3. \]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{15}H_{17}NO_2SH 276.1058, found 276.1053

**4-(1-(mesitylsulfonyl)ethyl)aniline (1aa)**

The product was synthesized following general procedure to afford a solid that was washed with pentane to afford the corresponding sulfone 1aa as a white solid (1.6 g, 82%).

\[ \text{H NMR (600 MHz, CDCl}_3\text{) } \delta 6.90 – 6.86 \text{ (m, 2H), 6.84 (s, 2H), 6.56 – 6.46 (m, 2H), 4.18 (q, J = 7.2 Hz, 1H), 3.59 (br s, 2H), 2.33 (s, 6H), 2.27 (s, 3H), 1.75 (d, J = 7.2 Hz, 3H).} \]

\[ \text{C NMR (151 MHz, CDCl}_3\text{) } \delta 147.0, 143.0, 140.9, 131.9, 131.8, 130.7, 123.1, 114.7, 64.6, 22.9, 21.1, 12.8. \]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{17}H_{21}NO_2SH 304.1371, found 304.1358

\(^{14}\) Yang, D. Y.; Han, O. S.; Liu, H. W. *J. Org. Chem.* **1989**, *54*, 5402-5406.
4-(1-(methylsulfonyl)ethyl)aniline (1ab)

The product was synthesized following general procedure to afford the corresponding sulfone 1ab as a white solid after trituration with diethyl ether (2.58 g, 89%).

\[ ^1H \text{ NMR (600 MHz, CDCl}_3 \text{)} \delta 7.18 \text{ (d, } J = 8.0 \text{ Hz, 2H), 6.66 \text{ (d, } J = 8.0 \text{ Hz, 2H), 4.07 (q, } J = 7.2 \text{ Hz, 1H), 3.75 (br s, 2H), 2.61 (s, 3H), 1.72 (d, } J = 7.2 \text{ Hz, 3H).} \]

\[ ^13C \text{ NMR (151 MHz, CDCl}_3 \text{)} \delta 147.4, 130.0, 123.6, 115.3, 64.4, 37.6, 13.5. \]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{9}H_{13}NO_{2}SH 200.0745, found 200.0740

2,6-dichloro-4-(1-tosylethyl)aniline (1t)

The product was synthesized following general procedure to afford the corresponding sulfone 1t after trituration with diethyl ether and pentane (2.54 g, 76%) as a white-grey solid.

\[ ^1H \text{ NMR (600 MHz, CDCl}_3 \text{)} \delta 7.49 \text{ (d, } J = 7.7 \text{ Hz, 2H), 7.25 \text{ (d, } J = 7.7 \text{ Hz, 2H), 6.95 \text{ (s, 2H), 4.51 (br s, 2H), 4.03 (q, } J = 7.0 \text{ Hz, 1H), 2.42 (d, } J = 2.2 \text{ Hz, 3H), 1.64 (dd, } J = 7.1, 2.0 \text{ Hz, 3H).} \]

\[ ^13C \text{ NMR (151 MHz, CDCl}_3 \text{)} \delta 145.0, 140.5, 133.7, 129.6, 129.4, 128.8, 123.6, 119.2, 64.9, 21.7, 14.2. \]

HRMS (ESI-TOF): m/z [M+H]+ Calcd. for C_{15}H_{15}Cl_{2}NO_{2}SH 344.0279, found 344.0273

7. X-ray crystallography (3)

The single crystal was obtained by dissolved the appropriate amount of compound 3 in ethyl acetate followed by the addition of pentane to furnish a saturated solution. The solution was then allowed to stand at room temperature to form the white thin needle-like crystal.

A suitable crystal of compound 3 was mounted on top of a cryoloop and transferred into the cold (100 K) nitrogen stream of a Bruker D8 Venture diffractometer. Data collection and reduction was done using the Bruker software suite APEX3.\textsuperscript{15} The final unit cell was obtained from the xyz centroids of 2996 reflections after integration. A multi-scan absorption correction was applied, based on the intensities of symmetry-related reflections measured at different angular settings (SADABS).\textsuperscript{16} The structures were solved by direct methods using SHELXT,\textsuperscript{17} and refinement of the structure was performed using SHELXL.\textsuperscript{3} The hydrogen atoms were generated by geometrical considerations, constrained to idealized geometries and allowed to ride on their carrier atoms with an isotropic displacement parameter related to the equivalent displacement parameter of their carrier atoms, with the exception of the N-H hydrogen atoms which were allowed to refine freely. The Flack parameter indicated there was a small twin

\textsuperscript{15} Bruker (2016) APEX3, SAINT and SADABS. Bruker AXS Inc., Madison, Wisconsin, USA.

\textsuperscript{16} Sheldrick, G. M.; Acta Cryst. A, 2015, 71, 3-8.

\textsuperscript{17} Sheldrick, G. M.; Acta Cryst. C, 2015, 71, 3-8.
component present, which was refined using the BASF/TWIN commands, where the BASF refined to 0.005. Crystal data and details on data collection and refinement are presented in Table S1.

![Figure 1. X-Ray Structure compound 3, showing 50% probability ellipsoids.](image)

**Table S1. Crystallographic data for compound 3**

| Parameter          | Value                          |
|--------------------|--------------------------------|
| chem formula       | C_{17}H_{21}NO_{2}S            |
| Mr                 | 303.41                         |
| cryst syst         | monoclinic                     |
| color, habit       | colorless, needle              |
| size (mm)          | 0.311 x 0.141 x 0.036          |
| space group        | P2_1                           |
| a (Å)              | 11.1356(17)                    |
| b (Å)              | 6.3226(7)                      |
| c (Å)              | 23.245(3)                      |
| β (°)              | 100.343(10)                    |
| V (Å³)             | 1610.0(4)                      |
| Z                  | 4                              |
| \( \rho \text{calc}, \text{g.cm}^{-3} \) | 1.252                          |
| Radiation [Å]      | Cu Kα 1.54178                  |
| \( \mu (\text{Cu Kα}), \text{mm}^{-1} \) | 1.812                          |
| F(000)             | 648                            |
| temp (K)           | 100(2)                         |
| \( \text{\( \theta \)} \text{range (°)} \) | 1.932 – 72.854 |
| data collected (h,k,l) | -13:13; -6:7; -27:28     |
| no. of rflns collected | 19661                          |
| no. of indpdnt reflns | 5721                           |
| observed rflns \( F_o \geq 2.0 \sigma (F_o) \) | 5318                           |
| R(F) (%)           | 4.99                           |
| wR(F^2) (%)        | 12.90                          |
| GooF               | 1.024                          |
| weighting a,b      | 0.0698, 008566                 |
| params refined     | 394                            |
| min, max resid dens | -0.32, 0.734                  |
8. NMR Spectra

1b$^1$H NMR (400 MHz, CDCl$_3$)

1b$^{13}$C NMR (101 MHz, CDCl$_3$)
1'n $^1$H NMR (400 MHz, CDCl$_3$)

1'n $^{13}$C NMR (151 MHz, CDCl$_3$)
$^{13}$C NMR (101 MHz, CDCl$_3$)
$^1$p $^1$H NMR (400 MHz, CDCl$_3$)

$^1$p $^1$C NMR (101 MHz, CDCl$_3$)
$^{1}q$ $^1$H NMR (400 MHz, CDCl$_3$)

$^{1}q$ $^{13}$C NMR (151 MHz, CDCl$_3$)
$1^r\text{H NMR (400 MHz, CDCl}_3\text{)}$

$1^r\text{C NMR (75 MHz, CDCl}_3\text{)}$
$^{1}$s $^1$H NMR (400 MHz, CDCl$_3$)

$^{13}$C NMR (101 MHz, CDCl$_3$)
1b $^1$H NMR (400 MHz, CDCl$_3$)

1b $^{13}$C NMR (151 MHz, CDCl$_3$)
$^{1}$$H$ NMR (600 MHz, $CDCl_3$)

$^{13}C$ NMR (151 MHz, $CDCl_3$)
10 $^1$H NMR (400 MHz, CDCl$_3$)

10 $^{13}$C NMR (101 MHz, CDCl$_3$)
$^{1}H$ NMR (400 MHz, DMSO-$d_6$)

$^{13}C$ NMR (101 MHz, DMSO-$d_6$)
$^{1}H$ NMR (600 MHz, CDCl$_3$)

$^{13}C$ NMR (151 MHz, CDCl$_3$)
$1r^1H$ NMR (400 MHz, CDCl₃)

$1r^{13}C$ NMR (101 MHz, CDCl₃)
$^{13}$C NMR (101 MHz, CDCl$_3$)
$^{1}H$ NMR (400 MHz, CDCl$_3$)

$^{1}H$ NMR (101 MHz, CDCl$_3$)

$1a$ $^{1}H$ NMR (400 MHz, CDCl$_3$)

$1'a$ $^{1}H$ NMR (101 MHz, CDCl$_3$)
1a $^1$H NMR (600 MHz, CDCl$_3$)

1a $^{13}$C NMR (151 MHz, CDCl$_3$)
1aa $^1$H NMR (600 MHz, CDCl$_3$)

1aa $^{13}$C NMR (151 MHz, CDCl$_3$)
1ab $^1$H NMR (600 MHz, CDCl$_3$)

1ab $^{13}$C NMR (151 MHz, CDCl$_3$)
$^{1}t\text{H NMR (400 MHz, CDCl}_3\text{)}$

$^{1}t\text{C NMR (151 MHz, CDCl}_3\text{)}$
$\textbf{1t} \ ^1\text{H NMR (600 MHz, CDCl}_3\text{)}$

$\textbf{1t} \ ^{13}\text{C NMR (151 MHz, CDCl}_3\text{)}$
$2b^1\text{H NMR (600 MHz, CDCl}_3\text{)}$

$2b^{13}\text{C NMR (151 MHz, CDCl}_3\text{)}$
$^{1}$H NMR (600 MHz, CDCl$_3$)

2c $^{13}$C NMR (151 MHz, CDCl$_3$)
2e $^1$H NMR (600 MHz, CDCl$_3$)

2e $^{13}$C NMR (151 MHz, CDCl$_3$)
2f $^1$H NMR (600 MHz, CDCl$_3$)

2f $^{13}$C NMR (151 MHz, CDCl$_3$)
$2g^1\text{H NMR (600 MHz, CDCl}_3\text{)}$

$2g^{13}\text{C NMR (151 MHz, CDCl}_3\text{)}$
$2h^1$H NMR (600 MHz, CDCl$_3$)

$2h^{13}$C NMR (151 MHz, CDCl$_3$)
2i $^1$H NMR (600 MHz, CDCl$_3$)

2i $^{13}$C NMR (151 MHz, CDCl$_3$)
$2j$ $^1$H NMR (600 MHz, CDCl$_3$)

$2j$ $^{13}$C NMR (151 MHz, CDCl$_3$)
$^{1}H$ NMR (600 MHz, CDCl$_3$)

$^{13}C$ NMR (151 MHz, CDCl$_3$)
$^{1}H$ NMR (600 MHz, CDCl₃)

$^{13}C$ NMR (151 MHz, CDCl₃)
$2a$ $^1H$ NMR (400 MHz, CDCl$_3$)

$2a$ $^{13}$C NMR (151 MHz, CDCl$_3$)
$2n^1$H NMR (600 MHz, CDCl$_3$)

$2n^{13}$C NMR (151 MHz, CDCl$_3$)
2o \(^{1}H\) NMR (400 MHz, CDCl\(_3\))

2o \(^{13}C\) NMR (151 MHz, CDCl\(_3\))
$2p^1H$ NMR (400 MHz, CDCl$_3$)

$2p^{13}C$ NMR (101 MHz, CDCl$_3$)
$2q^{1}H$ NMR (400 MHz, CDCl$_3$)

$2q^{13}C$ NMR (151 MHz, CDCl$_3$)
$^{1}$H NMR (600 MHz, CDCl$_3$)

$^{13}$C NMR (151 MHz, CDCl$_3$)
2s $^1$H NMR (600 MHz, CDCl$_3$)

2s $^{13}$C NMR (151 MHz, CDCl$_3$)
$2t$ $^1$H NMR (600 MHz, CDCl$_3$)

$2t$ $^{13}$C NMR (151 MHz, CDCl$_3$)
2d $^1$H NMR (600 MHz, CDCl$_3$)

2d $^{13}$C NMR (151 MHz, CDCl$_3$)
$2e\ ^1H\text{ NMR (400 MHz, CDCl}_3\text{)}$

$2e\ ^{13}C\text{ NMR (151 MHz, CDCl}_3\text{)}$
3 $^1$H NMR (600 MHz, CDCl$_3$)

3 $^{13}$C NMR (151 MHz, CDCl$_3$)