Supplementary Material for:

Direct Reductive Amination of Aldehydes and Ketones Using Phenylsilane: Catalysis by Dibutyltin Dichloride

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General Methods

Reagents were purchased from commercial suppliers and were used without purification unless otherwise noted. Anhydrous tetrahydrofuran was purchased from Fluka Chemika. Dibutyltin dichloride (96%) was purchased from Aldrich Chemical Company. All reactions were performed in borosilicate test tubes with magnetic stirring. Reactors were assembled open to the air, and placed under nitrogen after the addition of all reagents. Chromatography was performed using manual injection on an ISCO SQ16 chromatograph with 10 g prepacked RediSep™ silica cartridges, and gradients of either ethyl acetate-hexane (anilines) or 2 M methanolic ammonia-dichloromethane (alkylamines). ^{1}H and ^{13}C NMR spectra were recorded on a Bruker spectrometer. Chemical shifts are reported in parts per million downfield from an internal Me_4Si standard. In cases where reactions were monitored by ^{1}H NMR, samples were prepared by dissolving an aliquot of the crude reaction mixture (approx. 0.04 mL) in $CDCl_3$ (approx. 1 mL). Melting points are uncorrected and were obtained on a MelTemp apparatus. Combustion analyses were performed by Desert Analytics.

Representative Procedure for the Reductive Amination of 4-Methoxybenzaldehyde with Aniline

A solution of 4-methoxybenzaldehyde (0.18 mL, 1.5 mmol, 1.0 eq) in THF (0.3 mL) was treated with aniline (0.14 mL, 1.5 mmol, 1.0 eq) and dibutyltin dichloride (9 mg, $3x10^{-2}$ mmol, 0.02 eq). The resulting yellow solution was allowed to stir for 2 min, and treated with phenylsilane (0.20 mL, 1.7 mmol, 1.1 eq). After 2 h, thin layer chromatography showed no remaining aniline. The colorless reaction was diluted with

10% ethyl acetate-hexane (approx. 3 mL). To fully dissolve solids, 50% ethyl acetate-hexane (approx. 0.5 mL) was added. Chromatography of the solution using a gradient of ethyl acetate-hexane (0-3%) gave the product.

***N*-(4-Methoxybenzyl)aniline.**[1,2] Yield: 265 mg (83%); colorless oil which solidified on standing; mp 49-51 °C (Lit.[2] mp 44-45 °C); ^{1}H spectral data were in agreement with published values;[1] ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 158.9, 148.1, 131.3, 129.2, 128.8, 117.6, 114.0, 112.9, 55.3, 47.8 (Lit.[1] 155.6, 148.2, 130.5, 129.2, 128.8, 117.5, 114.2, 112.8, 55.3, 47.8); Anal. Calcd for $C_{14}H_{15}NO$: C, 78.84; H, 7.09; N 6.57. Found: C, 78.72; H, 7.24; N, 6.53.

***N*-benzylaniline.**[3] Reaction time: 2 h; yield: 219 mg (80%); colorless oil; spectral properties were in agreement with those previously reported.[3]

***N*-[(4-Nitrophenyl)methyl]aniline.**[1] Reaction time: 2 h; yield: 292 mg (85%); orange oil; ^{1}H spectral data were in agreement with published values;[1] ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 147.5, 147.3, 147.2, 129.4, 127.7, 123.9, 118.2, 112.9, 47.6 (Lit.[1] 157.3, 147.5, 147.3, 129.3, 127.6, 123.8, 118.1, 112.8, 47.5); Anal. Calcd for $C_{13}H_{12}N_2O_2$: C, 68.41; H, 5.30; N 12.27. Found: C, 68.33; H, 5.43; N, 12.17.

***N*-[(4-Iodophenyl)methyl]aniline.** Reaction time: 2 h; yield: 398 mg (86%); colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 7.66-6.57 (m, 9 H), 4.27 (s, 2 H), 4.07-4.00 (br s, 1 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 147.7, 139.2, 137.6, 129.3, 117.8, 112.9, 92.4, 47.7; Anal. Calcd for $C_{13}H_{12}IN$: C, 50.51; H, 3.91; N 4.53. Found: C, 50.88; H, 4.14; N, 4.54.

***N*-Cinnamylaniline.**[1] Reaction time: 2 h; yield: 220 mg (70%); colorless oil; spectral properties were in agreement with those previously reported.[1]

***N*-[(2-Benzyloxyphenyl)methyl]aniline.**[4] Reaction time: 3 h; yield: 356 mg (82%); colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 7.44-7.29 (m, 6 H), 7.21 (dt, J_1 = 7.8 Hz, J_2 = 1.8 Hz, 1 H), 7.17-7.11 (m, 2 H), 6.95-6.89 (m, 2 H), 6.68 (tt, J_1 = 7.3 Hz, J_2 = 1.2 Hz, 1 H), 6.63-5.96 (m, 2 H), 5.11 (s, 2 H), 4.39 (s, 2 H), 4.15 (s,

1 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 156.5, 148.3, 137.0, 129.2, 128.9, 128.6, 128.2, 127.9, 127.8, 127.2, 120.9, 117.3, 113.1, 111.7, 69.9, 43.6.

***N*-[(4-Methoxyphenyl)methyl], *N*-methylaniline.**[5] Reaction time: 15 h; yield: 283 mg (83%); colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 7.24-7.11 (m, 4 H), 6.86-6.77 (m, 5 H), 4.45 (s, 2 H), 3.77 (s, 3 H), 2.97 (s, 3 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 158.6, 149.8, 130.9, 129.1, 128.0, 116.5, 113.9, 112.5, 56.0, 55.2, 38.3.

***N*-[(4-Methoxyphenyl)methyl]-4-methoxyaniline.**[6] Reaction time: 2 h; yield: 300 mg (82%); white crystalline solid; mp 91-93 °C (Lit.[6] mp 93-95 °C); ^{1}H spectral data were in agreement with published values;[6] ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 158.8, 152.2, 142.5, 131.6, 128.8, 114.9, 114.1, 114.0, 55.8, 55.3, 48.7.

***N*-[(4-Methoxyphenyl)methyl]-4-nitroaniline.** Reaction time: 23 h; yield: 328 mg (85%) yellow crystalline solid; mp 140-141 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 8.08 (d, J = 9.0 Hz, 2 H), 7.26 (d, J = 8.6 Hz, 2 H), 6.9 (d, J = 8.6 H, 2 H), 6.57 (d, J = 9.0 Hz, 2 H), 4.78 (br m, 1 H), 4.35 (d, J = 5.5 Hz, 2 H), 3.81 (s, 3 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 159.3, 153.0, 138.3, 129.3, 128.8, 126.4, 114.3, 111.3, 55.35, 47.20; Anal. Calcd for $C_{14}H_{14}N_2O_3$: C, 65.11; H, 5.46; N 10.85. Found: C, 65.02; H, 5.41; N, 10.76.

***N*-[(4-Methoxyphenyl)methyl]-2-(1,1-dimethylethyl)aniline.** Reaction time: 2 h; yield: 310 mg (77%) colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 7.31 (d, J = 8.8 Hz, 2 H), 7.26 (dd, J_1 = 7.8 Hz, J_2 = 1.8 Hz, 1 H), 7.11 (ddd, J_1 = 8.8 Hz, J_2 = 7.2 Hz, J_3 = 1.6 Hz, 1 H), 6.91-6.87 (m, 2 H), 6.73-6.63 (m, 2 H), 4.31 (d, J = 3.3 Hz, 2 H), 4.17 (br s, 1 H), 3.81 (s, 3 H), 1.41 (s, 9 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 158.8, 146.1, 133.2, 131.5, 128.8, 127.2, 126.1, 117.2, 114.1, 111.9, 55.3, 48.4, 34.2, 29.9; Anal. Calcd for $C_{18}H_{23}NO$: C, 80.26; H, 8.61; N 5.20. Found: C, 80.15; H, 8.75; N, 5.26.

***N*-α-Phenethylphenylamine.**[7] Reaction time: 17 h; yield: 206 mg (70%); colorless oil; spectral properties were in agreement with those previously reported.[7]

***N*-(2-Octyl)-4-nitroaniline.** Reaction time: 21 h; yield: 326 mg (87%); yellow oil; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 8.09-8.05 (m, 2 H), 6.51-6.47 (m, 2 H), 4.37 (d, J = 8.6 H), 3.61-3.50 (m, 1 H), 1.62-1.24 (m, 10 H), 1.23 (d, *J* = 6.7 Hz, 3 H), 0.88 (t, *J* = 6.9 Hz, 3 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 152.8, 137.4, 126.6, 111.1, 48.6, 36.9, 31.8, 29.2, 26.0, 22.6, 20.5, 14.1; Anal. Calcd for $C_{14}H_{22}N_2O_2$: C, 67.17; H, 8.86; N 11.19. Found: C, 67.42; H, 9.08; N, 11.44.

1-Piperidinecarboxylic acid, 4-(4-nitrophenylamino)-, 1,1-dimethylethyl ester. Reaction time: 12 h; yield: 415 mg (86%); yellow amorphous solid; mp 177-178 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 8.11-8.05 (m, 2 H), 6.56-6.51 (m, 2 H), 4.47 (d, *J* = 7.8 Hz, 1 H), 4.10 (br s, 2 H), 3.60-3.48 (m, 1 H), 2.95 (t, *J* = 12.4 H, 2 H), 2.09-2.01 (m, 2 H), 1.47 (s, 9 H), 1.46-1.35 (m, 2 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 154.7, 152.0, 138.1, 126.5, 111.4, 79.9, 50.0, 42.4, 32.0, 28.4; Anal. Calcd for $C_{16}H_{23}N_3O_4$: C, 59.80; H, 7.21; N 13.07. Found: C, 59.91; H, 7.42; N, 12.85.

8-Phenylamino-1,4-Dioxaspiro[4.5]decane. Reaction time: 3 h; yield: 319 mg (91%); white crystalline solid; mp 112-113 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 7.19-7.13 (m, 2 H), 6.67 (tt, J_1 = 7.2 Hz, J_2 = 1.0 Hz, 1 H), 6.61-6.57 (m, 2 H), 3.96 (s, 4 H), 3.52 (s, 1 H), 3.42-3.33 (m, 1 H), 2.10-2.01 (m, 2 H), 1.84-1.46 (m, 6 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 147.0, 129.3, 117.4, 113.5, 108.3, 64.4, 64.3, 50.5, 33.1, 30.0; Anal. Calcd for $C_{14}H_{19}NO_2$: C, 72.07; H, 8.21; N 6.00. Found: C, 72.14; H, 8.43; N, 6.05.

Representative Procedure for the Reductive Amination of 4-Methoxybenzaldehyde with Piperidine

A solution of 4-methoxybenzaldehyde (0.18 mL, 1.5 mmol, 1.0 eq) in THF (0.3 mL) was treated with piperidine (0.14 mL, 1.5 mmol, 1.0 eq) and dibutyltin dichloride (9 mg, $3x10^{-2}$ mmol, 0.02 eq). The resulting colorless solution was allowed to stir for 2 min, and placed in a water bath. Phenylsilane (0.20 mL, 1.7 mmol, 1.1 eq) was added dropwise over 4 min, and the reaction was stirred for 16 h. The colorless reaction was diluted with dichloromethane (approx. 3 mL). Chromatography of the solution using a gradient of 2 M methanolic ammonia-dichloromethane (0-3%) gave the product.

1-[(4-Methoxyphenyl)methyl]-piperidine.[8] Yield: 217 mg (70%); colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 7.24-7.20 (m, 2 H), 6.86-6.82 (m, 2 H), 3.79 (s, 3 H), 3.41 (s, 2 H), 2.35 (br s, 4 H), 1.59-1.53 (m, 4 H), 1.45-1.38 (m, 2 H) [Lit.[8]: δ_H (90 MHz, $CDCl_3$): 1.35 (brm, 6H), 2.31 (brm, 4H), 3.34 (s, 2H), 6.76 and 7.13 (AA'BB', 4H)]; ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 158.6, 130.6, 130.4, 113.4, 63.2, 55.2, 54.4, 26.0, 24.4; Anal. Calcd for $C_{13}H_{19}NO$: C, 76.06; H, 9.33; N 6.82. Found: C, 75.84; H, 9.03; N, 6.96.

1-[(4-Methoxyphenyl)methyl]-morpholine.[9] Reaction time: 16 h; yield: 242 mg (78%); colorless oil; spectral properties were in agreement with those previously reported.[9]

1-[(4-Methoxyphenyl)methyl]-4-phenyl-piperazine.[10] Reaction time: 16 h; yield: 285 mg (67%); white amorphous solid; mp 104-105 °C (Lit.[10] 107.5-108.5 °C); ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) 7.31-7.22 (m, 4 H), 6.93-6.81 (m, 5 H), 3.81 (s, 3 H), 3.51 (s, 2 H), 3.21-3.17 (m, 4 H), 2.61-2.57 (m, 4 H); ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 158.8, 151.4, 130.4, 129.9, 129.1, 119.6, 116.0, 113.6, 62.4, 55.3, 53.0, 49.1.

***N,N*-Diethyl-4-methoxy-benzenemethanamine.**[9] Reaction time: 16 h; yield: 143 mg (49%); colorless oil; ^{1}H spectral data was in agreement with published values;[9] ^{13}C NMR ($CDCl_3$ 101 MHz): δ (ppm) 158.5, 131.8, 130.1, 113.51, 56.8, 55.2, 46.5, 11.7.

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