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Aminoarenethiolate-Copper(I) Catalyzed Amination of Aryl Bromides

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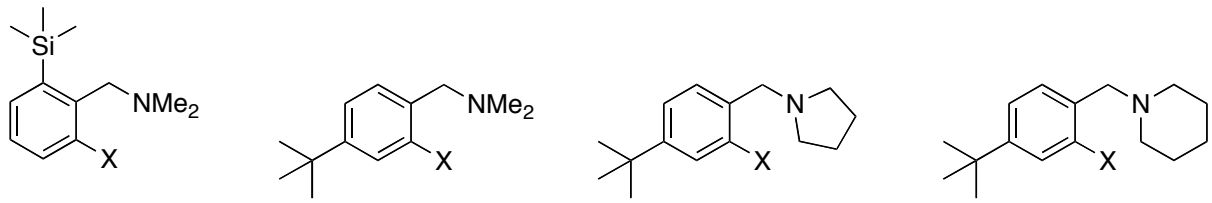
Supporting information

General. All reactions were performed using Schlenk techniques under an inert atmosphere unless stated otherwise. All solvents were carefully dried and distilled prior to use. Chemicals were purchased from Across or Aldrich. Chlorotrimethylsilane was distilled and passed through basic alumina prior to use. ^{1}H and ^{13}C NMR spectra were recorded on a Varian Inova 300 MHz spectrometer. The chemicals shifts (δ) are presented in ppm referenced to residual solvent resonances. Gas chromatography analyses were performed on a Perkin Elmer Clarus 500 GC equipped with an Alltech EC-5 column (30 m × 0.32 mm).



2 **4** **5** **6**

a: X=H; **b**: X=SSiMe$_3$; **c**: X=SCu

Copper(I) chloride

A preheated solution of Cu_2SO_4•$5H_2O$ (99.9 g, 0.40 mmol) and NaCl (25.9 g, 0.44 mmol) in 400 mL of water at 65 °C is slowly added (1.5 h) to a solution of NaOH (14.4 g, 0.36 mmol) in 400 mL of water and stirred for 1 h. After cooling, the mixture is transferred under nitrogen in a filter where the resulting solid is washed first with an aqueous solution of acetic acid (2 mL in 800 mL of water), with an aqueous solution of $NaHSO_3$ (1 g in 800 mL of water), acetone (800 mL), technical ether (1 L), pre-dry ether (1 L) and dry ether (1 L). The resulting

solid is then transferred to a Schlenk tube under nitrogen and dried under vacuum to afford copper(I) chloride as a white solid (31.7 g, 0.32 mmol, 80%).

1-trimethylsilyl-2-(dimethylamino)methylbenzene 2a

To a solution of 1-bromo-2-(dimethylamino)methylbenzene (7.0 g, 33.8 mmol) in 150 mL of THF at –78 ºC was slowly added 50 mL of *tert*-BuLi (1.5 M in pentane, 74.5 mmol). The mixture was stirred for 1 hour at –50 ºC. The reaction mixture was then allowed to reach 0 ºC and 9.5 mL of trimethylsilylchloride (75 mmol) was added. The resulting solution was stirred 2 h at room temperature. HCl (4 M) was added, the aqueous layer was washed with ether. The aqueous solution was then basified with NaOH (4 M) and after extraction with diethyl ether, the combined organic layers were dried over magnesium sulfate. After filtration, the solvent was removed under reduced pressure to afford a yellow oil (6.4 g, 31.1 mmol, 92%).

^{1}H NMR (300.1 MHz, 298 K, $CDCl_3$): δ 7.54 (d, 1H, ^{3}J= 7.50 Hz, C*H*, Ar), 7.46 (d, 1H, ^{3}J= 7.50 Hz, C*H*, Ar), 7.36 (t, 1H, ^{3}J= 7.95 Hz, C*H*, Ar), 7.26 (t, 1H, ^{3}J= 7.35 Hz, C*H*, Ar), 3.54 (s, 2H, CH_2), 2.24 (s, 6H, $N(CH_3)_2$), 0.35 (s, 9H, $Si(CH_3)_3$).

^{13}C NMR (75.5 MHz, 298 K, $CDCl_3$): δ 145.1, 138.7, 134.7, 129.0, 128.8, 126.2 (Ar, *C*), 64.5 (NCH_2), 45.2 ($N(CH_3)_2$), 0.9 ($Si(CH_3)_3$).

1-*tert*-butyl-4-(dimethylamino)methylbenzene 4a

An excess of dimethylamine (10 mL, excess) was added at 0 ºC to a solution of 4-*tert*-butylbenzylbromide (7.8 g, 36 mmol) in 100 mL of dichloromethane and the resulting mixture was stirred overnight at room temperature. All volatiles were removed under reduced pressure and 100 mL of an aqueous solution of sodium hydroxide 4 M was added. The mixture was extracted with diethyl ether and the combined organic layers dried over magnesium sulfate. After filtration, the solvent was removed under reduced pressure to afford a yellow oil (6.2 g, 32 mmol, 89 %).

^{1}H NMR (300.1 MHz, 298 K, $CDCl_3$): δ 7.34 (d, 2H, ^{3}J= 8.10 Hz, C*H*, Ar), 7.22 (d, 2H, ^{3}J= 8.30 Hz, C*H*, Ar), 3.39 (s, 2H, CH_2), 2.24 (s, 6H, $N(CH_3)_2$), 1.32 (s, 9H, $C(CH_3)_3$).

1-*tert*-butyl-4-(pyrrolidinyl)methylbenzene 5a

Same procedure as **4a** starting from 4-*tert*-butylbenzylbromide (5.0 g, 22 mmol) and 6.2 mL of pyrrolidine (88 mmol, excess), affording a yellowish oil (3.8 g, 17 mmol, 79%).

^{1}H NMR (300.1 MHz, 298 K, $CDCl_3$): δ 7.34 (d, 2H, ^{3}J= 8.40 Hz, C*H*, Ar), 7.26 (d, 2H, ^{3}J= 8.10 Hz, C*H*, Ar), 3.60 (s, 2H, CH_2), 2.52 (m, 4H, N(CH_2)$_2$), 1.79 (m, 4H, (CH_2)$_2$), 1.33 (s, 9H, C(CH_3)$_3$).
^{13}C NMR (75.5 MHz, 298 K, $CDCl_3$): δ 145.6, 136.2, 128.5, 125.0 (Ar, *C*), 60.3 (N*C*H$_2$), 54.4 (N(*C*H$_2$)$_2$), 34.4 (*C*(CH$_3$)$_3$), 31.5 (C(*C*H$_3$)$_3$), 23.4 ((-(*C*H$_2$)$_2$-).

1-*tert*-butyl-4-(piperidinyl)methylbenzene 6a

Same procedure as **4a** starting from 4-*tert*-butylbenzylbromide (5.0 g, 22 mmol) and 8.7 mL of piperidine (88 mmol, excess), affording a light yellow oil (4.15 g, 18.0 mmol, 82 %).
^{1}H NMR (300.105 MHz, 298 K, $CDCl_3$): δ 7.32 (d, 2H, ^{3}J= 8.70 Hz, C*H*, Ar), 7.23 (d, 2H, ^{3}J= 8.10 Hz, C*H*, Ar), 3.44 (s, 2H, NCH_2), 2.38 (m, 4H, N(CH_2)$_2$), 1.55 (m, 4H, -(CH_2)-), 1.43 (m, 2H, CH_2), 1.32 (s, 9H, C(CH_3)$_3$).

1-trimethylsilylsulfanyl-2-(dimethylamino)methyl-3-trimethylsilylbenzene 2b

15.3 mL of *tert*-BuLi (1.5 M in pentane, 23 mmol) was added to a solution of **2a** (4.0 g, 21 mmol) in pentane at –80 ºC and the mixture was allowed to reach room temperature. After stirring the solution overnight, 100 mL of cold THF (–60 ºC) was added. Sublimed sulfur (0.74 g, 23 mmol) was added and after 4 hours at –60 ºC the reaction mixture was allowed to warm slowly to 0 ºC, and subsequently 2.9 mL of trimethylsilylchloride (23 mmol) was added. After stirring for 1 hour all volatiles were removed *in vacuo*. The residue was redissolved in 30 mL of hexane. The resulting solution was separated from the LiCl precipitate *via* decantation. The hexane solution was concentrated under vacuum leaving the product as a yellow oil (5.0 g, 18 mmol, 84%).
^{1}H NMR (300.1 MHz, 298 K, C_6D_6): δ 7.53 (d, 2H, ^{3}J= 8.70 Hz, C*H*, Ar), 6.94 (t, 1H, ^{3}J= 8.70 Hz, C*H*, Ar), 3.99 (s, 2H, NCH_2), 1.99 (s, 6H, N(CH_3)$_2$), 0.32 (s, 9H, Si(CH_3)$_3$), 0.11 (s, 9H, SSi(CH_3)$_3$).
^{13}C NMR (75.5 MHz, 298 K, C_6D_6): δ 148.6, 141.9, 137.4, 135.2, 132.0, 126.3 (Ar, *C*), 60.8 (N*C*H$_2$), 44.5 (N(*C*H$_3$)$_2$), 1.1 (Si(*C*H$_3$)$_3$), 0.91 (Si(*C*H$_3$)$_3$).

1-trimethylsilylsulfanyl-3-*tert*-butyl-6-(dimethylamino)methylbenzene 4b

Same procedure as **2b** starting from 5.2 g of **4a** (27 mmol), affording a yellow oil (7.6 g, 22 mmol, 79 %).

^{1}H NMR (300.1 MHz, 298 K, C_6D_6): δ 7.61 (m, 1H, C*H*, Ar), 7.58 (s, 1H, C*H*, Ar), 7.16 (d, 1H, ^{3}J= 8.00 Hz, C*H*, Ar), 3.73 (s, 2H, NCH_2), 2.18 (s, 6H, N(CH_3)$_2$), 1.18 (s, 9H, C(CH_3)$_3$), 0.19 (s, 9H, Si(CH_3)$_3$).

^{13}C NMR (75.5 MHz, 298 K, C_6D_6): δ 149.5, 140.1, 136.1, 131.0, 129.9, 124.9 (Ar, *C*), 62.2 (N*C*H$_2$), 45.5 (N(*C*H$_3$)$_2$), 34.6 (*C*(CH$_3$)$_3$), 31.2 (C(*C*H$_3$)$_3$), 1.1 (Si(*C*H$_3$)$_3$).

1-trimethylsilylsulfanyl-3-*tert*-butyl-6-(pyrrolidinyl)methylbenzene 5b

Same procedure as **2b** starting from 3.8 g of **5a** (17.4 mmol), affording a yellow oil (4.6 g, 14 mmol, 82%).

^{1}H NMR (300.1 MHz, 298 K, C_6D_6): δ 7.63 (m, 3H, C*H*, Ar), 7.19 (d, 1H, ^{3}J= 7.90 Hz, C*H*, Ar), 3.97 (s, 2H, NCH_2), 2.52 (m, 4H, N(CH_2)$_2$), 1.58 (m, 4H, (CH_2)$_2$), 1.20 (s, 9H, C(CH_3)$_3$), 0.18 (s, 9H, Si(CH_3)$_3$).

^{13}C NMR (75.5 MHz, 298 K, C_6D_6): δ 149.4, 140.6, 133.8, 130.6, 129.8, 124.3 (Ar, *C*), 58.5 (N(*C*H$_2$)$_2$), 54.2 (N*C*H$_2$), 34.6 (*C*(CH$_3$)$_3$), 31.2 (C(*C*H$_3$)$_3$), 23,9 ((*C*H$_2$)$_2$), 1.0 (Si(*C*H$_3$)$_3$).

1-trimethylsilylsulfanyl-3-*tert*-butyl-6-(piperidinyl)methylbenzene 6b

Same procedure as **2b** starting from 4.7 g of **6a** (20.4 mmol), affording a yellow oil (6.3 g, 19 mmol, 92%).

^{1}H NMR (300.1 MHz, 298 K, C_6D_6): δ 7.64 (d, 1H, ^{3}J= 7.80 Hz, C*H*, Ar), 7.63 (s, 1H, C*H*, Ar), 7.18 (d, 1H, ^{3}J= 8.10 Hz, C*H*, Ar), 3.80 (s, 2H, NCH_2), 2.48 (m, 4H, N(CH_2)-), 1.48 (m, 4H, -CH_2-), 1.31 (m, 2H, -CH_2-), 1.18 (s, 9H, C(CH_3)$_3$), 0.18 (s, 9H, Si(CH_3)$_3$).

^{13}C NMR (75.5 MHz, 298 K, C_6D_6): δ 149.4, 140.0, 133.8, 131.0, 129.8, 124.2 (Ar, *C*), 54.9 (N(*C*H$_2$)$_2$), 53.1 (N*C*H$_2$), 34.2 (*C*(CH$_3$)$_3$), 31.3 (C(*C*H$_3$)$_3$), 26.5 (-*C*H$_2$-), 24.8 (*C*H$_2$), 1.1 (Si(*C*H$_3$)$_3$).

1-sulfanyl-2-(dimethylamino)methyl-3-trimethylsilylbenzene-copper(I) 2c

1.65 g of CuCl (16.7 mmol) in 30 mL of toluene was added to a solution of **2b** (5.0 g, 17.6 mmol) in 30 mL of toluene. The reaction mixture was stirred for 3 h at room temperature. The solvent was removed under vacuum and 30 mL of pentane was added. The resulting solution was then cooled to –30 ºC overnight. After filtration, the complex was isolated as a light yellow powder (4.8 g, 16 mmol, 95%).

^{1}H NMR (300.1 MHz, 356 K, C_6D_6): δ 7.98 (d, 1H, ^{3}J= 7.80 Hz, C*H*, Ar), 7.17 (d, 1H, ^{3}J= 7.20 Hz, C*H*, Ar), 6.96 (t, 1H, ^{3}J= 7.65 Hz, C*H*, Ar), 4.03 (s, 2H, CH_2), 2.20 (s, 6H, N(CH_3)$_2$), 0.17 (s, 9H, Si(CH_3)$_3$).

^{13}C NMR (75.5 MHz, 356 K, C_6D_6): δ 141.1, 137.7, 131.1, 129.1, 127.6, 125.5 (Ar, *C*), 64.9 (N*C*H$_2$), 46.7 (N(*C*H$_3$)$_2$), 1.9 (Si(*C*H$_3$)$_3$).

1-sulfanyl-3-*tert*-butyl-6-(dimethylamino)methylbenzene-copper(I) 4c

Same procedure as **2c** starting from 7.6 g of **4b** (27.3 mmol), affording a light yellow powder (7.1 g, 25 mmol, 91%).

^{1}H NMR (300.1 MHz, 298 K, C_6D_6): δ 7.99 (s, 1H, C*H*, Ar), 6.97 (d, 1H, ^{3}J= 8.10 Hz, C*H*, Ar), 6.70 (d, 1H, ^{3}J= 7.80 Hz, C*H*, Ar), 3.53 (s, 2H, CH_2), 2.07 (s, 6H, N(CH_3)$_2$), 1.21 (s, 9H, C(CH_3)$_3$).

^{13}C NMR (75.5 MHz, 298 K, C_6D_6): δ 151.1, 141.3, 133.0, 131.9, 131.7, 120.8 (Ar, *C*), 67.0 (N*C*H$_2$), 47.0 (N(*C*H$_3$)$_2$), 34.4 (*C*(CH$_3$)$_3$), 31.3 ((C(*C*H$_3$)$_3$).

1-sulfanyl-3-*tert*-butyl-6-(pyrrolidinyl)methylbenzene-copper(I) 5c

Same procedure as **2c** starting from 4.6 g of **5b** (14.2 mmol), affording a light yellow powder (3.6 g, 12 mmol, 81%).

^{1}H NMR (300.105 MHz, 348 K, C_6D_6): δ 7.99 (brs, 1H, C*H*, Ar), 6.95 (d, 1H, ^{3}J= 8.10 Hz, C*H*, Ar), 6.75 (d, 1H, ^{3}J= 7.80 Hz, C*H*, Ar), 3.76 (brs, 2H, CH_2), 2.46 (brs, 4H, N(CH_2)$_2$), 1.57 (brs, 4H, (CH_2)$_2$), 1.21 (s, 9H, C(CH_3)$_3$).

^{13}C NMR (75.469 MHz, 298 K, C_6D_6): δ 151.2, 141.6, 137.7 133.8, 131.5, 120.8 (Ar, *C*), 64.3 (N*C*H$_2$), 57.0 (N(*C*H$_2$)$_2$), 34.7 (*C*(CH$_3$)$_3$), 31.4 (C(*C*H$_3$)$_3$), 23.0 (-(*C*H$_2$)$_2$-),

1-sulfanyl-3-*tert*-butyl-6-(piperidinyl)methylbenzene-copper(I) 6c

Same procedure as **2c** starting from 6.3 g of **6b** (18.8 mmol), affording to a light yellow powder (4.7 g, 14 mmol, 75%).

^{1}H NMR (300.1 MHz, 333 K, C_6D_6): δ 7.95 (s, 1H, C*H*, Ar), 6.96 (d, 1H, ^{3}J= 8.10 Hz, C*H*, Ar), 6.79 (d, 1H, ^{3}J= 7.80 Hz, C*H*, Ar), 3.76 (s, 2H, NCH_2), 2.33 (br s, 4H, N(CH_2)-), 1.55 (br s, 4H, -CH_2-), 1.26 (s, 9H, C(CH_3)$_3$), 1.10 (br s, 2H, -CH_2-).

^{13}C NMR (75.5 MHz, 298 K, C_6D_6): δ 150.6, 141.9, 133.2, 132.6, 130.9, 120.5 (*C*, Ar), 67.3 (N*C*H$_2$), 56.9 (N(*C*H$_2$)$_2$), 31.4 (*C*(CH$_3$)$_3$), 29.6 (C(*C*H$_3$)$_3$), 24.8 (-(*C*H$_2$)$_2$-), 24.2 (*C*H$_2$).