Supplementary Material (ESI) for Chemical Communications

Highly efficient conjugate reduction of α,β-unsaturated nitriles catalyzed by copper/xanthene-type bisphosphine complexes

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Experimental

General Methods. Toluene was distilled from sodium benzophenone ketyl under nitrogen. $Cu(OAc)_2$, $Cu(OAc)_2 \cdot H_2O$, and other chemicals were purchased from Aldrich and used as received. (*E*)-Cinnamonitrile (**3a**) was purchased from Aldrich and other nitrile substrates (**3a-3j**) were synthesized from the corresponding aldehydes or ketones with diethyl (cyanomethyl)phosphonate by the Horner-Wadsworth-Emmons procedure.[1] All reactions were carried out under a nitrogen atmosphere, in oven-dried Schlenk flasks and run two or more times. Flash chromatography was performed on silica gel from Merck (70–230 mesh). All ^{1}H NMR spectra were obtained on Varian Mercury 400 systems and reported parts per million (ppm) downfield from tetramethylsilane. ^{13}C NMR spectra are reported in ppm referenced to deuteriochloroform (77.2 ppm). Infrared spectra (IR) were obtained on Magma-IR560 and are recorded in cm^{-1}.

General Procedure for the Conjugate Reduction of α,β-Unsaturated Nitriles (Table 2): $Cu(OAc)_2 \cdot H_2O$ (3.0 mg, 0.015 mmol) and Xantphos (8.7 mg, 0.015 mmol) were placed in an oven-dried Schlenk tube and toluene (0.5 mL) was added under nitrogen. PMHS (0.12 mL, 2 mmol) was added to the reaction mixture and the reaction was stirred for 20–30 min at room temperature. α,β-Unsaturated nitrile substrate (0.5 mmol) was added by syringe, followed by *t*-BuOH (0.18 mL, 2 mmol). The reaction tube was washed with toluene (0.5 mL), sealed, and stirred at room temperature until no starting material was detected by TLC. The reaction mixture was quenched with water and transferred to a round-bottom flask with an aid of Et_2O (10 mL), and then NaOH (2.5 M, 1.2 mL) was added. The biphasic mixture was stirred vigorously for 0.5 h. The layers were separated and the aqueous layer was extracted with Et_2O (3 x 20 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, and concentrated.

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[1] Wadsworth, W. S.; Emmons, W. D., *J. Am. Chem. Soc.*, 1961, **83**, 1733

The product was purified by Kugelrohr distillation or silica gel chromatography.

3-Phenyl-propionitrile (Table 2, **4a**): Using the general procedure ($Cu(OAc)_2 \cdot H_2O$ and Xantphos), the title compound was isolated as a colorless oil by silica gel chromatography in 92% yield: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.33–7.20 (m, 5H), 2.95 (t, *J* = 7.3 Hz, 2H), 2.61 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.2, 129.0, 128.4, 127.4, 119.4, 31.9, 19.7; IR (neat) 2930, 2250, 1450 cm^{-1}.

3-(4-Methoxyphenyl)-propionitrile (Table 2, **4b**): Using the general procedure ($Cu(OAc)_2 \cdot H_2O$ and Xantphos), the title compound was isolated as a colorless oil by silica gel chromatography in 89% yield: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.12 (d, *J* = 8.4 Hz, 2H), 6.84 (d, *J* = 8.4 Hz, 2H), 3.78 (s, 3H), 2.89 (t, *J* = 6.9 Hz, 2H), 2.57 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 158.7, 130.3, 129.5, 119.5, 114.3, 55.6, 31.1, 20.0; IR (neat) 2930, 2250, 1450, 1130 cm^{-1}.

3-(2-Chlorophenyl)-propionitrile (Table 2, **4c**): Using the general procedure ($Cu(OAc)_2 \cdot H_2O$ and Xantphos), the title compound was isolated as a colorless oil by silica gel chromatography in 90% yield: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.39–7.20 (m, 4H), 3.09 (t, *J* = 7.3 Hz, 2H), 2.68 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 135.6, 133.8, 130.9, 129.9, 129.0, 127.5, 130.0, 17.8; IR (neat) 2950, 2250, 1430, 756 cm^{-1}.

3-(4-Fluorophenyl)-propionitrile (Table 2, **4d**): Using the general procedure ($Cu(OAc)_2 \cdot H_2O$ and DPEphos), the title compound was isolated as a colorless oil by Kugelrohr distillation in 87% yield: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.18 (dd, *J* = 8.5 Hz, 5.5 Hz, 2H), 7.00 (t, *J* = 8.5 Hz, 2H), 2.93 (t, *J* = 7.3 Hz, 2H), 2.59 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 163.2, 160.8, 133.99, 130.1, 119.2, 115.9, 115.7, 31.1, 19.9; IR (neat) 2930, 2250, 1510, 1220 cm^{-1}.

3-Furan-2-yl-propionitrile (Table 2, **4e**): Using the general procedure ($Cu(OAc)_2 \cdot H_2O$ and Xantphos), the title compound was isolated as a colorless oil by Kugelrohr distillation in 85% yield: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.32 (s, 1H), 6.29 (d, *J* = 2.0 Hz, 1H), 6.15 (d, *J* = 2.0 Hz, 1H), 2.98 (t, *J* = 7.3 Hz, 2H), 2.65 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 151.4, 142.1, 119.0, 110.6, 107.0, 24.6, 17.0; IR (neat) 2930, 2250, 1650, 1050 cm^{-1}.

3-Methyl-nonanenitrile (Table 2, **4f**): Using the general procedure ($Cu(OAc)_2 \cdot H_2O$ and Xantphos), the title compound was isolated as a colorless oil by Kugelrohr distillation in 80% yield: ^1H NMR ($CDCl_3$, 400 MHz) δ 2.31 (dd, *J* = 16.6 Hz, 5.9 Hz, 1H), 2.22 (dd, *J* = 16.6 Hz, 6.8 Hz, 1H), 1.86–1.81 (m, 1H), 1.44-1.20 (m, 10H), 1.06 (d, *J* = 7.0 Hz, 3H), 0.89 (t, *J* = 6.8 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 119.1, 36.2, 32.0, 30.8, 29.5, 27.1, 24.8, 22.9, 19.8, 14.4; IR (neat) 2930, 2250 cm^{-1}.

Cyclohexyl acetonitrile (Table 2, **4g**): Using the general procedure ($Cu(OAc)_2 \cdot H_2O$ and Xantphos), the title compound was isolated as a colorless oil by silica gel chromatography in 87% yield: ^1H NMR ($CDCl_3$, 400 MHz) δ 2.23 (d, *J* = 6.6 Hz, 2H), 1.84–1.63 (m, 5H), 1.33–1.02 (m, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 119.1, 35.1, 32.7, 26.1, 26.0, 25.0; IR (neat) 2910, 2240 cm^{-1}.

3-Phenyl-butyronitrile (Table 2, **4h**): Using the general procedure ($Cu(OAc)_2$ and DPEphos), the title compound was isolated as a colorless oil by silica gel chromatography in 87% yield: ^1H NMR ($CDCl_3$, 400 MHz) δ 7.34–7.21 (m, 5H), 3.14 (m, 1H), 2.60 (dd, *J* = 16.5 Hz, 6.5 Hz, 1H), 2.53 (dd, *J* = 16.5 Hz, 7.7 Hz, 1H), 1.45 (d, *J* = 5.9 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 163.2, 160.8, 133.9, 130.1, 119.2, 115.9, 115.7, 31.1, 19.9; IR (neat) 2980, 2250, 1450 cm^{-1}.

4-(2-Cyano-1-methyl-ethyl)-benzonitrile (Table 2, **4i**): Using the general procedure ($Cu(OAc)_2$ and DPEphos), the title compound was isolated as a white solid by silica gel chromatography in 84% yield: ^1H NMR ($CDCl_3$, 100 MHz) δ 7.64 (d, *J* = 8.2 Hz, 2H), 7.36 (d, *J* = 8.2 Hz, 2H), 3.24–3.22 (m, 1H), 2.61 (d, *J* = 6.9 Hz, 2H), 1.47 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR ($CDCl_3$, 400 MHz) δ 148.5, 132.8, 127.8, 118.8, 118.2, 111.3, 36.8, 26.1, 20.7; IR (neat) 2960, 2250, 2220, 1420 cm^{-1}.

4-Methyl-3-phenyl-pentanenitrile (Table 2, **4j**): Using the general procedure ($Cu(OAc)_2$ and DPEphos), the title compound was isolated as a colorless oil by silica gel chromatography in 94% yield: ^1H NMR ($CDCl_3$, 400 MHz) δ 7.34–7.16 (m, 5H), 2.72–2.62 (m, 3H), 2.09–2.04 (m, 1H), 1.03 (d, *J* = 6.9 Hz, 3H), 0.78 (d, *J* = 6.6 Hz ,3H); ^{13}C NMR ($CDCl_3$, 400 MHz) δ 141.2, 128.7, 127.9, 127.4, 119.1, 49.4, 32.4, 22.7, 21.1, 20.7; IR (neat) 2960, 22510, 1470 cm^{-1}.