A High Efficient Three-Component-Coupling of Aldehyde, Alkyne, and Amines Catalyzed via C-H Activation Catalyzed by Gold in Water

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Supporting Information

All experiments were carried out under an inert atmosphere of nitrogen. Water was deoxygenated by nitrogen. Flash column chromatography was performed over SORBENT silica gel 30-60 μ m. ^1H -NMR and ^{13}C -NMR spectra were acquired by Varian 400 MHz and 100 MHz, respectively, and referenced to the internal solvent signals. IR spectra were recorded by Thermo-Nicolet Interferometer. GC/MS data were obtained by HP 5890 Series II Gas Chromatograph & HP5989A Mass Spectrometer. HRMS were made by Bin Xin of Institute of Chemistry, CAS.

Typical procedure (entry 4, Table 1): A mixture of AuBr_3 (4mg, 0.01mmol) benzaldehyde (101 μL , 1.0 mmol), piperidine (105 μL , 1.1 mmol), phenylacetylene (150 μL , 1.5 mmol), water (1mL) was stirred at 100 $^\circ\text{C}$ oil bath for 12h under N_2 . Analysis of the resulting mixture by ^1H NMR showed the conversion in 100%. The oil was separated from water and directly isolated by flash chromatography with silica to give propargyl amine in quantitative yield.

***N*-(1,3-Diphenyl-2-propynyl)piperidine.** CA Registry Number: [1036-21-1].

IR (liquid film): $\nu_{\max}$ 3060(m), 2933(s), 2749(m), 1598(s), 1489(s), 1450(s), 1321(s), 1154(s), 756(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.67-7.62(m, 2H), 7.55-7.50(m, 2H), 7.40-7.26(m, 6H), 4.81(s, 1H), 2.61-2.50(m, 4H), 1.70-1.50(m, 4H), 1.50-1.40(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 138.89, 132.05, 128.75, 128.50, 128.29 (two signals overlap), 127.66, 123.59, 88.01, 86.34, 62.63, 59.93, 26.44, 24.69; MS m/z (%) 275(M^+ , 27), 274(14), 232(7), 198(90), 191(100), 165(8), 115(10), 84(7); HRMS calcd for $\text{C}_{20}\text{H}_{22}\text{N}$ ($\text{M}+1$) 276.1747, found 276.1748.

***N*-[1-(4-Methylphenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 2933(s), 2804(s), 2748(m), 1598(m), 1510(s), 1318(s), 1154(s), 1092(s), 847(m), 755(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.61-7.56(m, 4H), 7.42-7.34(m, 3H), 7.23(d, $J=8.0\text{Hz}$, 2H), 4.83(s, 1H), 2.68-2.56(m, 4H), 2.42(s, 3H), 1.73-1.58(m, 4H), 1.58-1.45(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 137.36, 135.90, 132.10, 129.06, 128.77, 128.57, 128.30, 123.72, 87.92, 86.70, 62.48, 62.41, 50.99, 26.52, 24.80, 21.44; MS m/z (%) 289(M^+ , 22), 288(9), 205(100), 198(33), 189(8), 165(3), 115(7), 84(7); HRMS calcd for $\text{C}_{21}\text{H}_{24}\text{N}$ ($\text{M}+1$) 290.1903, found 290.1906.

***N*-[1-(4-Ethylphenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 2932(s), 2853(s), 2748(m), 1598(m), 1510(s), 1318(m), 1154(m), 1092(m), 852(m), 755(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.55-7.48(m, 4H), 7.35-7.29(m, 3H), 7.18(d, $J=8.4\text{Hz}$, 2H), 4.75(s, 1H), 2.65(q, $J=7.6\text{Hz}$, 2H), 2.60-2.49(m, 4H), 1.65-1.50(m, 4H), 1.50-1.38(m, 2H), 1.24(t, $J=7.6\text{Hz}$, 3H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 143.70, 135.99, 132.05, 128.78, 128.50, 128.23, 127.80, 123.65, 87.79, 86.65, 62.41, 50.90, 28.78, 26.42, 24.71, 15.86; MS m/z (%) 303(M^+ , 33), 302(13), 274(11), 219(100), 204(19), 198(32), 115(4), 84(19); HRMS calcd for $\text{C}_{22}\text{H}_{26}\text{N}$ ($\text{M}+1$) 304.2060, found 304.2062.

***N*-[1-(4-Methoxyphenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 2998(s), 2932(s), 2748(m), 1610(s), 1511(s), 1302(s), 1169(s), 1036(s), 849(s), 756(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.61-7.54(m, 4H), 7.38-7.32(m, 3H), 6.96-6.91(m, 2H), 4.78(s, 1H), 3.82(s, 3H), 2.65-2.52(m, 4H), 1.70-1.53(m, 4H), 1.53-1.41(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 159.24, 132.07, 130.96, 129.93, 128.56, 128.30, 123.66, 113.65, 87.90, 86.72, 62.06, 55.49, 50.90, 26.49, 24.79; MS m/z (%) 305(M^+ , 13), 221(100), 206(6), 198(5), 178(10), 155(4), 115(4), 84(4); HRMS calcd for $\text{C}_{21}\text{H}_{24}\text{NO}$ ($\text{M}+1$) 306.1852, found 306.1864.

***N*-[1-(4-Trifluoromethylphenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 3058(m), 2936(s), 2855(s), 2750(m), 1620(s), 1490(s), 1325(s), 1123(s), 1067(s), 858(m), 755(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.81(d, $J=8.0\text{Hz}$, 2H), 7.64(d, $J=8.0\text{Hz}$, 2H), 7.58-7.2(m, 2H), 7.40-7.34(m, 3H), 4.85(s, 1H), 2.62-2.51(m, 4H), 1.71-1.53(m, 4H), 1.53-1.42(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 143.20, 132.08, 129.90(q, $J=32.1\text{Hz}$), 128.60, 128.60, 128.55, 125.25, 124.52(q, $J=271.1\text{Hz}$), 88.80, 85.16, **62.26**, 62.19, 50.95, 26.41, 24.58; MS m/z (%) 343(M^+ , 221), 300(9), 259(69), 198(100), 189(16), 115(11), 84(6); HRMS calcd for $\text{C}_{21}\text{H}_{22}\text{F}_3\text{N}$ ($\text{M}+1$) 344.1621, found 344.1620.

***N*-[1-(4-Chlorophenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 3055(m), 2934(s), 2852(s), 2748(s), 1667(m), 1597(m), 1487(s), 1317(s), 1154(s), 1089(s), 852(m), 809(s), 755(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.65-7.61(m, 2H), 7.59-7.54(m, 2H), 7.40-7.34(m, 5H), 4.80(s, 1H), 2.62-2.54(m, 4H), 1.71-1.54(m, 4H), 1.54-1.45(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 137.62, 133.45, 132.10, 130.07, 128.61, 128.48 (two signals overlap), 123.38, 88.55, 85.65, 62.04, 61.95, 50.90, 26.48, 24.70; MS m/z (%) 311(M^+ , 8), 309(M^+ , 24), 308(13), 266(6), 227(33), 225(100), 198(58), 188(31), 165(3), 115(9), 84(7); HRMS calcd for $\text{C}_{20}\text{H}_{21}\text{ClN}$ ($\text{M}+1$) 310.1357, found 310.1355.

***N*-[1-(3-Chlorophenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 3060(m), 2934(s), 2852(s), 2749(s), 1596(s), 1489(s), 1317(s), 1155(s), 1097(s), 862(m), 794(s), 754(s), 689(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.74-7.72(m, 1H), 7.62-7.55(m, 3H), 7.41-7.34(m, 3H), 7.34-7.29(m, 2H), 4.82(s, 1H), 2.65-2.55(m, 4H), 1.72-1.57(m, 4H), 1.57-1.47(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 141.29, 134.37, 132.14, 129.61, 128.82, 128.76, 128.63, 128.54, 127.93, 126.89, 123.35, 88.68, 85.39, 62.22, 62.13, 50.97, 26.48, 24.69; MS m/z (%) 311(M^+ , 6), 309(M^+ , 18), 308(8), 266(6), 227(19), 225(57), 198(100), 188(26), 115(12), 84(10); HRMS calcd for $\text{C}_{20}\text{H}_{21}\text{ClN}$ ($\text{M}+1$) 310.1357, found 310.1350.

***N*-[1-(4-Bromophenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 3054(m), 2933(s), 2852(s), 2749(s), 1598(m), 1485(s), 1317(s), 1154(s), 1089(s), 847(m), 807(s), 755(s), 690(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.63-7.57(m, 4H), 7.53-7.52(m, 2H), 7.42-7.35(m, 3H), 4.81(s, 1H), 2.65-2.56(m, 4H), 1.74-1.58(m, 4H), 1.58-1.47(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 138.19, 132.16, 131.49, 130.50, 128.66, 128.55, 123.40, 121.74, 88.67, 85.62, 62.13, 62.05, 50.90, 26.54, 24.76; MS m/z (%) 355(M^+ , 20), 353(M^+ , 21), 312(6), 310(6), 271(83), 269(82), 198(100), 189(68), 163(7), 115(15), 84(11); HRMS calcd for $\text{C}_{20}\text{H}_{21}\text{BrN}$ ($\text{M}+1$) 356.0831 and 354.0852, found 356.0832 and 354.0847.

***N*-[1-(3-Bromophenyl)-3-phenyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 3057(m), 2934(s), 2852(s), 2748(m), 1667(m), 1593(s), 1489(s), 1317(s), 1154(s), 1069(s), 861(s), 793(s), 755(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.89-7.87(m, 1H), 7.66-7.62(m, 1H), 7.59-7.55(m, 2H), 7.48-7.44(m, 1H), 7.41-7.34(m, 3H), 7.29-7.23(m, 1H), , 4.81(s, 1H), 2.65-2.56(m, 4H), 1.72-1.58(m, 4H), 1.58-1.45(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 141.54, 132.15, 131.71, 131.66, 130.87, 129.93, 128.64, 128.55, 127.37, 123.33, 122.66, 88.72, 85.36, 62.16, 62.08, 50.98, 26.47, 24.69; MS m/z (%) 355(M^+ , 9), 353(M^+ , 9), 312(4), 310(4), 271(27), 269(27), 198(100), 189(33), 163(4), 115(11), 84(10); HRMS calcd for $\text{C}_{20}\text{H}_{21}\text{BrN}$ ($\text{M}+1$) 356.0831 and 354.0852, found 356.0831 and 354.0848.

α -(Phenylethynyl)-*N,N*-di-2-propenylbenzenemethanamine. CA Registry number: [499775-83-6]. IR (liquid film): $\nu_{\max}$ 3079(s), 2816(s), 1642(m), 1599(m), 1490(s), 1448(s), 1276(m), 1112(m), 920(s), 756(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.75-7.69(m, 2H), 7.60-7.54(m, 2H), 7.42-7.26(m, 6H), 5.95-5.83(m, 2H), 5.35-5.27(m, 2H), 5.20-5.15(m, 2H), 5.14(s, 1H), 3.35-3.28(m, 2H), 3.12-3.04(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 139.55, 136.74, 132.12, 128.60, 128.54, 128.41, 128.37, 127.68, 123.52, 117.68, 88.16, 85.57, 56.78, 53.81; MS m/z (%) 287(M^+ , 7), 286(12), 246(6), 210(25), 191(100), 165(9), 115(7), 68(2); HRMS calcd for $\text{C}_{21}\text{H}_{20}\text{N}$ ($\text{M}+1$) 288.1747, found 288.1748.

α -(Phenylethynyl)-N, N-dibenzylbenzenemethanamine. IR (liquid film): $\nu_{\max}$ 3084(m), 3028(s), 2833(m), 2807(s), 1600(m), 1490(s), 1451(s), 1327(m), 1028(s), 745(s), 697(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 8.06-8.00(m, 2H), 7.92-7.87(m, 2H), 7.74-7.68(m, 4H), 7.64-7.53(m, 8H), 7.53-7.44(m, 4H), 5.24(s, 1H), 4.09(d, $J=13.6\text{Hz}$, 2H), 3.84(d, $J=13.6\text{Hz}$, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 140.04, 139.69, 132.53, 132.46, 129.43, 129.20, 128.93, 128.86, 128.68, 128.04, 127.59, 123.77, 89.26, 85.26, 56.65, 56.55, 55.19, 55.14; MS m/z (%) 387(M^+ , 14), 310(29), 296(18), 191(100), 165(8), 115(6), 91(61), 65(9); HRMS calcd for $\text{C}_{29}\text{H}_{26}\text{N}$ ($\text{M}+1$) 388.2060, found 388.2063.

1-(1-decyl-3-Phenyl-2-propynyl)piperidine. IR (liquid film): $\nu_{\max}$ 2928(s), 2854(s), 2750(w), 1598(m), 1489(s), 1325(m), 1156(s), 1099(s), 755(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.44-7.39(m, 2H), 7.31-7.25(m, 3H), 3.46(dd, $J_1=8.0\text{Hz}$, $J_2=7.6\text{Hz}$, 1H), 2.72-2.62(m, 2H), 2.50-2.40(m, 2H), 1.78-1.48(m, 10H), 1.48-1.18(m, 14H), 0.86(t, $J=6.8\text{Hz}$, 3H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 131.93, 128.39, 127.93, 123.84, 88.46, 85.80, 58.85, 50.78, 33.71, 32.13, 29.83, 29.83, 29.77, 29.64, 29.57, 27.12, 26.43, 24.81, 22.90, 14.33; MS m/z (%) 339(M^+ , 1), 241(1), 198(100), 130(3), 115(9), 86(3), 84(4); HRMS calcd for $\text{C}_{24}\text{H}_{38}\text{N}$ ($\text{M}+1$) 340.3000, found 340.2998.

1-[3-Phenyl-1-(2-phenylethyl)-2-propynyl]piperidine. IR (liquid film): $\nu_{\max}$ 3061(m), 2933(s), 2852(s), 2751(s), 1687(m), 1599(m), 1489(s), 1453(s), 1324(m), 1102(s), 755(s), 692(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.47-7.53(m, 2H), 7.34-7.20(m, 8H), 3.47(dd, $J_1=8.0\text{Hz}$, $J_2=7.6\text{Hz}$, 1H), 2.89-2.80(m, 1H), 2.80-2.71(m, 1H), 2.71-2.62(m, 2H), 2.51-2.42(m, 2H), 2.08-1.98(m, 2H), 1.70-1.52(m, 4H), 1.52-1.40(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 142.11, 132.05, 128.94, 128.94 128.64 (two signals overlap), 128.55, 128.16, 126.14, 123.79, 88.06, 86.35, 57.86, 50.85, 35.39, 33.19, 26.54, 24.91; MS m/z (%) 303(M^+ , 1), 198(100), 128(4), 115(21), 91(10), 65(2); HRMS calcd for $\text{C}_{22}\text{H}_{26}\text{N}$ ($\text{M}+1$) 304.2060, found 304.2061.

1-[1-(1-Ethylpropyl)-3-phenyl-2-propynyl]piperidine. IR (liquid film): $\nu_{\max}$ 3076(m), 2933(s), 2804(s), 2749(m), 1598(m), 1489(s), 1453(s), 1322(m), 1158(m), 1094(m), 755(s), 691(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.45-7.40(m, 2H), 7.32-7.25(m, 3H), 3.22(d, $J=10.0\text{Hz}$, 1H), 2.66-2.57(m, 2H), 2.44-2.35(m, 2H), 1.78-1.66(m, 1H), 1.66-1.50(m, 6H), 1.50-1.38(m, 4H), 0.90(t, $J=7.6\text{Hz}$, 3H), 0.84(t, $J=7.6\text{Hz}$, 3H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 131.94, 128.42, 127.81, 124.11, 88.32, 86.12, 61.69, 61.63, 41.70, 26.58, 25.00, 22.64, 21.03, 10.96, 10.02; MS m/z (%) 268[(M^+-1), 0.5], 241(1), 198(100), 141(2), 115(21), 86(1), 84(2); HRMS calcd for $\text{C}_{19}\text{H}_{28}\text{N}$ ($\text{M}+1$) 270.2216, found 270.2216.

***N*-[3-Phenyl-1-(1-cyclohexenyl)-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 3060(m), 2931(s), 2856(s), 2805(s), 2213(w), 1602(m), 1492(s), 1450(s), 1319(s), 1271(s), 918(s), 729(s), 698(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.61-7.56(m, 2H), 7.37-7.30(m, 2H), 7.30-7.23(m, 1H), 6.20-6.15(m, 1H), 4.69(s, 1H), 2.54-2.42(m, 4H), 2.25-2.18(m, 2H), 2.15-2.09(m, 2H), 1.85-1.24(m, 8H), 1.23-1.18(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 139.22, 134.46, 128.73, 128.18, 127.50, 120.90, 89.91, 83.20, 62.53, 50.80, 29.94, 26.43, 25.85, 24.71, 22.62, 21.82; MS m/z (%) 279(M^+ , 20), 236(18), 202(87), 196(100), 167(97), 153(51), 141(31), 128(30), 115(69), 91(62); HRMS calcd for $\text{C}_{20}\text{H}_{26}\text{N}$ ($\text{M}+1$) 280.2060, found 280.2059.

***N*-[3-(4-Trifluoromethylphenyl)-1-triethylsilyl-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 2936(s), 2810(s), 2162(m), 1619(m), 1412(s), 1326(s), 1164(s), 1129(s), 1068(s), 858(m), 726(s) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.72(d, $J=8.4\text{Hz}$, 2H), 7.57(d, $J=8.4\text{Hz}$, 2H), 4.64(s, 1H), 2.50-2.37(m, 4H), 1.63-1.47(m, 4H), 1.46-1.36(m, 2H), 1.03(t, $J=8.0\text{Hz}$, 9H), 0.65(q, $J=8.0\text{Hz}$, 6H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 143.01, 129.63(q, $J=32.0\text{Hz}$), 128.84, 125.12(q, $J=3.8\text{Hz}$), 124.47(q, $J=270.5\text{Hz}$), 102.00, 90.58, 62.35, 50.62, 26.36, 24.60, 7.84, 4.77; MS m/z (%) 381(M^+ , 4), 266(10),

236(100), 213(8), 164(22), 115(12), 84(22); HRMS calcd for $C_{21}H_{31}F_3NSi$ ($M+1$) 382.2172, found 382.2175.

***N*-[3-(4-Trifluoromethylphenyl)-1-(1-cyclohexenyl)-2-propynyl]piperidine.** IR (liquid film): $\nu_{\max}$ 2935(s), 2856(m), 2808(m), 2213(w), 1619(s), 1411(s), 1326(s), 1163(s), 1126(s), 1068(s), 858(m), 681(m) cm^{-1} ; $^1\text{H-NMR}$ (CDCl_3 , 400MHz, ppm) δ 7.70(d, $J=8.4\text{Hz}$, 2H), 7.57(d, $J=8.4\text{Hz}$, 2H), 6.20-6.15(m, 1H), 4.70(s, 1H), 2.54-2.40(m, 4H), 2.24-2.17(m, 2H), 2.14-2.08(m, 2H), 1.70-1.46(m, 8H), 1.46-1.38(m, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 100MHz, ppm) δ 143.53, 134.96, 129.62(q, $J=32.0\text{Hz}$), 128.90, 125.11(q, $J=3.4\text{Hz}$), 124.48(q, $J=270.1\text{Hz}$), 120.63, 90.60, 82.06, 62.10, 50.83, 29.85, 26.36, 25.82, 24.55, 22.53, 21.73; MS m/z (%) 347(M^+ , 20), 304(11), 264(100), 235(43), 202(38), 167(34), 115(10), 81(25); HRMS calcd for $C_{21}H_{25}F_3N$ ($M+1$) 348.1933, found 348.1936.