

Cu-Mediated C-H Cyanation of Arenes Using *N,N*-Dimethylformamide (DMF) as the “CN” Source

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Supporting Information

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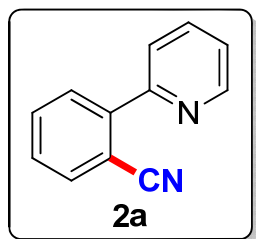
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General Remarks.

All manipulations were conducted with Schlenk tube. ¹H-NMR spectra were recorded on a Bruker AVANCE III-400 spectrometers. Chemical shifts (in ppm) were referenced to tetramethylsilane ($\delta = 0$ ppm) in CDCl₃ as an internal standard. ¹³C-NMR spectra were obtained by using the same NMR spectrometers and were calibrated with CDCl₃ ($\delta = 77.00$ ppm). High Resolution Mass spectra were recorded using a Fourier Transform Ion Cyclotron Resonance Mass Spectrometer (APEX IV, Bruker). Mass spectra were recorded using a PE SCLEX QSTAR spectrometer. The 2-phenylpyridine substrates were prepared according to the literature.¹ Unless otherwise noted, materials obtained from commercial suppliers were used without further purification.

Analytical data for compounds 2

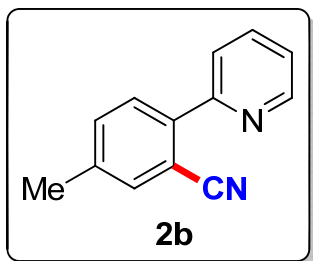
2-(Pyridin-2-yl)benzonitrile (**2a**)²



Typical procedure: CuBr (114.8 mg, 0.8 mmol), substrate 2-phenylpyridine **1a** (62.1 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) were added to a 25 mL Schlenk tube under O₂ (1 atm), followed by addition of 3 mL DMF. The reaction mixture was vigorously stirred at 135 °C for 48h as monitored by TLC. After cooling down to room

temperature, 10 mL brine was added in the solution and extracted with ethyl acetate (10 mL \times 3). The combined organic layer was dried over anhydrous MgSO₄. The solvent was concentrated *in vacuo* and the residue was purified by flash chromatography on a short silica gel (eluent: petroleum ether/ethyl acetate = 5:1) to afford 44.0 mg (61%) of **2a**. **2a**: ¹H NMR (CDCl₃, 400 MHz): $\delta = 8.78$ (d, $J = 4.4$ Hz, 1H), 7.86-7.78 (m, 4H), 7.72-7.68 (m, 1H), 7.53-7.49 (m, 1H), 7.38-7.34 (m, 1H); ¹³C NMR (CDCl₃, 100 MHz): $\delta = 155.2, 149.9, 143.5, 136.8, 134.1, 132.8, 130.0, 128.7, 123.3, 123.2, 118.7, 111.1$ ppm; IR (neat): $\nu = 3064.0, 2224.3, 1585.4, 1300.6, 761.2$ cm⁻¹; MS (EI) m/z 181.3 (100) [M]⁺.

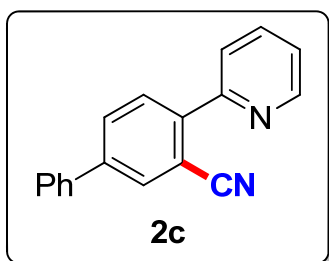
5-Methyl-2-(pyridin-2-yl)benzonitrile (**2b**)²



The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(*p*-tolyl)pyridine **1b** (67.7 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 56.0 mg (70%) of **2b**. **2b**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.77-8.75 (m, 1H), 7.82-7.73 (m, 3H), 7.60 (s, 1H), 7.50-7.48 (m, 1H), 7.35-7.31 (m, 1H), 2.44 (s, 3H); ¹³C

NMR (CDCl₃, 100 MHz): δ = 155.2, 149.8, 140.7, 139.1, 136.7, 134.4, 133.7, 129.8, 123.0, 118.9, 110.7, 20.8 ppm; IR (neat): ν = 3065.3, 2224.6, 1585.7, 1562.7, 1462.9, 1439.2, 1152.9, 761.6 cm⁻¹; MS (EI) *m/z* 194.2 (100) [M]⁺.

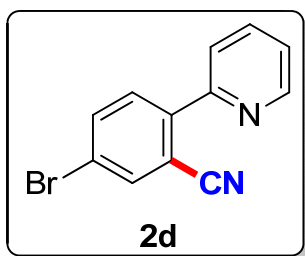
4-(Pyridin-2-yl)-[1,1'-biphenyl]-3-carbonitrile (**2c**)²



The reaction of CuBr (114.8 mg, 0.8 mmol), 2-([1,1'-biphenyl]-4-yl)pyridine **1c** (92.5 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 59.8 mg (59%) of **2c**. **2c**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.79 (d, *J* = 4.4 Hz, 1H), 8.00 (d, *J* = 2.0 Hz, 1H), 7.95-7.88 (m, 2H),

7.84 (d, *J* = 3.6 Hz, 2H), 7.63-7.61 (m, 2H), 7.51-7.48 (m, 2H) 7.45-7.42 (m, 1H) 7.37-7.34 (m, 1H); ¹³C NMR (CDCl₃, 100 MHz): δ = 154.8, 149.9, 141.9, 138.3, 136.8, 132.5, 131.3, 130.4, 129.1, 128.5, 127.0, 123.3, 123.1, 118.7, 111.4 ppm; IR (neat): ν = 2225.2, 1763.2, 1585.3, 1464.4, 1242.7, 762.0 cm⁻¹; MS (EI) *m/z* 256.1 (100) [M]⁺.

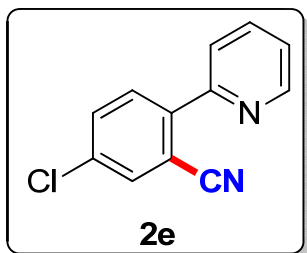
5-Bromo-2-(pyridin-2-yl)benzonitrile (**2d**)³



The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(4-bromophenyl)pyridine **1d** (93.6 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 52.5 mg (51%) of **2d**. **2d**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.74 (d, *J* = 4.4 Hz, 1H), 7.89 (d, *J* = 2.0 Hz, 1H), 7.84-7.71 (m, 4H), 7.36-7.33 (m,

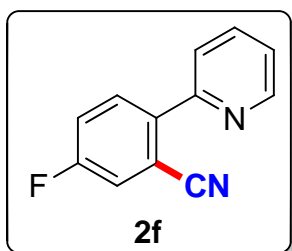
1H); ¹³C NMR (CDCl₃, 100 MHz): δ = 154.1, 149.9, 142.1, 136.9, 136.3, 136.0, 131.3, 123.5, 122.9, 122.5, 117.2, 112.6 ppm; MS (EI) *m/z* 258.0 (100) [M]⁺.

5-Chloro-2-(pyridin-2-yl)benzonitrile (**2e**)²



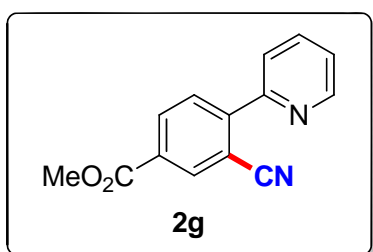
The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(4-chlorophenyl)pyridine **1e** (75.6 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 44.0 mg (52%) of **2e**. **2e**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.77 (d, *J* = 4.8 Hz, 1H), 7.86-7.77 (m, 4H), 7.66 (dd, *J* = 8.4 Hz, *J* = 2.0, 1H), 7.39-7.36 (m, 1H); ¹³C NMR (CDCl₃, 100 MHz): δ = 154.1, 150.0, 141.8, 136.9, 134.9, 133.6, 133.1, 131.3, 123.6, 123.0, 117.4, 112.4 ppm; IR (neat): ν = 2228.1, 1591.1, 1460.8, 1430.2, 1097.9, 860.0, 783.7 cm⁻¹; MS (EI) *m/z* 214.0 (100) [M]⁺.

5-Fluoro-2-(pyridin-2-yl)benzonitrile (**2f**)²



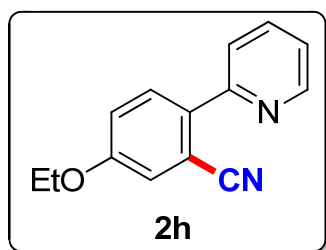
The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(4-fluorophenyl)pyridine **1f** (69.3 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 54.1 mg (43 %) of **2f**. **2f**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.76 (s, 1H), 7.87-7.75 (m, 3H), 7.49 (dd, *J* = 8.0 Hz, *J* = 2.0 Hz, 1H), 7.43-7.34 (m, 2H); ¹³C NMR (CDCl₃, 100 MHz): δ = 161.9 (d, *J*_{C-F} = 250.3 Hz), 154.1, 149.8, 139.8, 136.8, 132.0 (d, *J*_{C-F} = 8.1 Hz), 123.3, 122.9, 120.6 (d, *J*_{C-F} = 24.7 Hz), 120.4 (d, *J*_{C-F} = 20.4 Hz), 117.4, 112.3 (d, *J*_{C-F} = 9.1 Hz) ppm; IR (neat): ν = 3737.0, 3069.0, 2230.5, 1609.0, 1583.0, 1428.0, 1275.9, 1263.2, 1152.2, 884.4, 784.6 cm⁻¹; MS (EI) *m/z* 198.3 (100) [M]⁺.

Methyl 3-cyano-4-(pyridin-2-yl)benzoate (**2g**)³



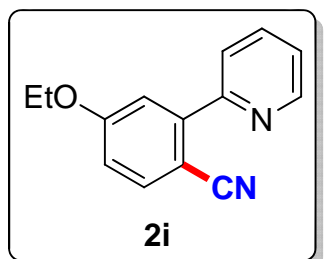
The reaction of CuBr (114.8 mg, 0.8 mmol), methyl 4-(pyridin-2-yl)benzoate **1g** (85.3 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 16.4 mg (17 %) of **2g**. **2g**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.80 (d, *J* = 4.8 Hz, 1H), 8.46 (d, *J* = 2.0 Hz, 1H), 8.31 (dd, *J* = 4.0, 1.6 Hz, 1H), 7.95 (d, *J* = 8.4 Hz, 1H), 7.89-7.82 (m, 2H), 7.41-7.38 (m, 1H), 3.98 (s, 3H); ¹³C NMR (CDCl₃, 100 MHz): δ = 165.0, 154.2, 150.11, 146.9, 137.0, 135.3, 133.5, 130.7, 130.2, 123.9, 123.4, 117.8, 111.4, 52.7 ppm; MS (EI) *m/z* 238.1 (100) [M]⁺.

5-Ethoxy-2-(pyridin-2-yl)benzonitrile (**2h**)



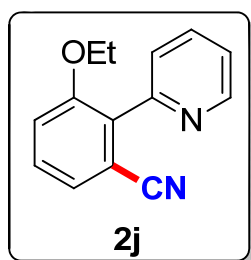
The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(4-ethoxyphenyl)pyridine **1h** (79.7 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 49.0 mg (58 %) of **2h**. **2h**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.73 (d, *J* = 4.0 Hz, 1H), 7.81-7.73 (m, 3H), 7.31-7.25 (m, 2H), 7.20-7.18 (m, 1H), 4.09 (q, *J* = 7.2 Hz, 2H), 1.44 (t, *J* = 6.8 Hz, 3H); ¹³C NMR (CDCl₃, 100 MHz): δ = 158.8, 154.9, 149.6, 136.6, 135.7, 131.2, 122.64, 122.61, 119.6, 118.9, 118.6, 111.5, 64.0, 14.4 ppm; IR (neat): ν = 2982.4, 2225.0, 1769.4, 1603.6, 1464.4, 1241.9, 1045.9, 786.5 cm⁻¹; HRMS *m/z* (ESI) calcd. for C₁₄H₁₃N₂O (M + H)⁺ 225.1028, found 225.1018.

4-Ethoxy-2-(pyridin-2-yl)benzonitrile (**2i**)



The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(3-ethoxyphenyl)pyridine **1i** (79.7 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 46.6 mg (52 %) of **2i**. **2i**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.75 (d, *J* = 3.2 Hz, 1H), 7.84-7.80 (m, 2H), 7.69 (d, *J* = 8.8 Hz, 1H), 7.34 (s, 2H), 6.98 (dd, *J* = 8.4 Hz, *J* = 2.0 Hz, 1H), 4.14 (q, *J* = 7.2 Hz, 2H), 1.44 (t, *J* = 6.4 Hz, 3H); ¹³C NMR (CDCl₃, 100 MHz): δ = 162.2, 155.2, 149.8, 145.4, 136.7, 135.6, 123.3, 123.2, 119.1, 115.6, 115.2, 102.3, 64.0, 14.5 ppm; IR (neat): ν = 2982.9, 2219.3, 1796.4, 1603.7, 1463.0, 1307.2, 1239.7, 1404.6, 762.0 cm⁻¹; HRMS *m/z* (ESI) calcd. for C₁₄H₁₃N₂O (M + H)⁺ 225.1028, found 225.1019.

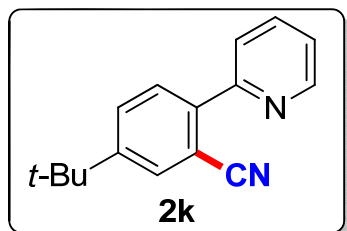
3-Ethoxy-2-(pyridin-2-yl)benzonitrile (**2j**)



The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(2-ethoxyphenyl)pyridine **1j** (79.7 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 52.9 mg (59 %) of **2j**. **2j**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.77 (d, *J* = 4.4 Hz, 1H), 7.93-7.75 (m, 1H), 7.55 (d, *J* = 8.0 Hz, 1H), 7.43-7.30 (m, 3H), 7.19 (d, *J* = 8.4 Hz, 1H), 4.04 (q, *J* = 7.2 Hz, 2H), 1.29 (t, *J* = 7.0 Hz, 3H); ¹³C NMR (CDCl₃, 100 MHz): δ = 156.4, 153.1, 149.4, 135.8, 133.3, 129.9, 125.5, 125.4, 122.9, 118.0, 116.7, 114.0, 64.7, 14.4 ppm; IR (neat): ν = 2982.2,

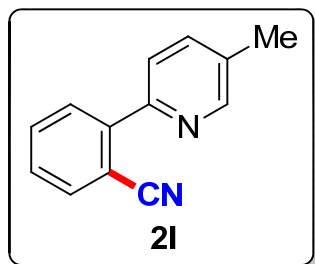
2929.9, 2229.0, 1591.6, 1452.2, 1267.3, 1058.5, 801.1, 747.3 cm^{-1} ; HRMS m/z (ESI) calcd. for $\text{C}_{14}\text{H}_{13}\text{N}_2\text{O}$ ($\text{M} + \text{H}$)⁺ 225.1028, found 225.1018.

5-(*tert*-Butyl)-2-(pyridin-2-yl)benzonitrile (**2k**)³



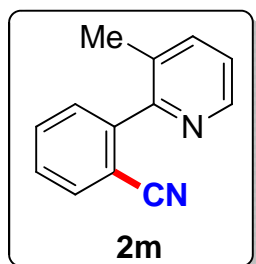
The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(4-(*tert*-butyl)phenyl)pyridine **1k** (84.5 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O_2 (1 atm) afforded 48.2 mg (51 %) of **2k**. **2k**: ^1H NMR (CDCl_3 , 400 MHz): δ = 8.76 (d, J = 4.0 Hz, 1H), 7.83-7.77 (m, 4H), 7.72-7.70 (m, 1H), 7.34-7.31 (m, 1H), 1.37 (s, 9H); ^{13}C NMR (CDCl_3 , 100 MHz): δ = 155.2, 152.3, 149.8, 140.6, 136.7, 131.0, 130.1, 129.7, 123.01, 122.97, 119.2, 110.6, 34.7, 30.9 ppm; IR (neat): ν = 2964.2, 2868.0, 2222.8, 1584.7, 1461.8, 1364.6, 1272.5, 842.3, 790.5 cm^{-1} ; HRMS m/z (ESI) calcd. for $\text{C}_{14}\text{H}_{13}\text{N}_2\text{O}$ ($\text{M} + \text{H}$)⁺ 237.1392, found 237.1381.

2-(5-Methylpyridin-2-yl)benzonitrile (**2l**)²



The reaction of CuBr (114.8 mg, 0.8 mmol), 5-methyl-2-phenylpyridine **1l** (67.7 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O_2 (1 atm) afforded 44.3 mg (57 %) of **2l**. **2l**: ^1H NMR (CDCl_3 , 400 MHz): δ = 8.60 (s, 1H), 7.83 (d, J = 7.6 Hz, 1H), 7.78 (d, J = 7.6 Hz, 1H), 7.69-7.62 (m, 3H), 7.50-7.46 (m, 1H), 2.41 (s, 3H); ^{13}C NMR (CDCl_3 , 100 MHz): δ = 152.5, 150.4, 143.5, 137.2, 134.0, 133.1, 132.7, 129.8, 128.4, 122.6, 118.8, 110.9, 18.2 ppm; IR (neat): ν = 2224.7, 1764.9, 1471.6, 1377.2, 1243.0, 775.9, 758.0 cm^{-1} ; MS (EI) m/z 194.0 (100) [M]⁺.

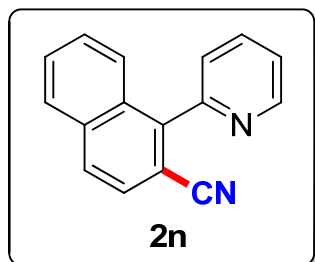
2-(3-Methylpyridin-2-yl)benzonitrile (**2m**)⁴



The reaction of CuBr (114.8 mg, 0.8 mmol), 3-methyl-2-phenylpyridine **1m** (67.7 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O_2 (1 atm) afforded 39.6 mg (51 %) of **2m**. **2m**: ^1H NMR (CDCl_3 , 400 MHz): δ = 8.57 (d, J = 4.4 Hz, 1H), 7.79-7.77 (m, 1H), 7.70-7.64

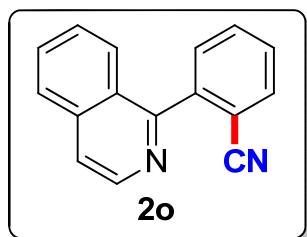
(m, 2H), 7.53-7.49 (m, 2H), 7.28 (dd, $J = 8.0$ Hz, $J = 4.8$ Hz, 1H), 2.27 (s, 3H); ^{13}C NMR (CDCl_3 , 100 MHz): $\delta = 155.5, 147.2, 144.4, 138.5, 133.0, 132.6, 131.6, 130.0, 128.4, 123.5, 117.8, 112.5, 19.0$ ppm; IR (neat): $\nu = 2925.1, 2226.5, 1763.8, 1440.2, 1424.7, 1736.5, 1443.1, 1051.7, 762.8$ cm^{-1} ; MS (EI) m/z 193.2 (100) $[\text{M}]^+$.

1-(Pyridin-2-yl)-2-naphthonitrile (**2n**)²



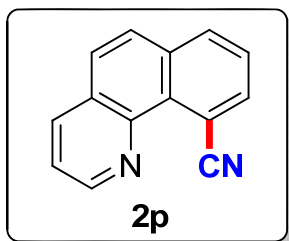
The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(naphthalen-1-yl)pyridine **1n** (82.1 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (1 mL) under O_2 (1 atm) afforded 41.4 mg (45 %) of **2n**. **2n**: ^1H NMR (CDCl_3 , 400 MHz): $\delta = 8.86$ (d, $J = 4.8$ Hz, 1H), 7.98-7.90 (m, 3H), 7.71 (d, $J = 8.4$ Hz, 2H), 7.65-7.59 (m, 2H), 7.54-7.50 (m, 1H), 7.47-7.44 (m, 1H); ^{13}C NMR (CDCl_3 , 100 MHz): $\delta = 155.2, 150.0, 144.4, 136.7, 135.0, 131.1, 129.4, 128.7, 128.3, 127.9, 126.8, 126.7, 125.6, 123.5, 118.5, 109.7$ ppm; IR (neat): $\nu = 2994.3, 2228.0, 1769.4, 1585.7, 1469.7, 1383.1, 1243.2, 811.7, 745.6$ cm^{-1} ; MS (EI) m/z 229.0 (100) $[\text{M}]^+$.

2-(Isoquinolin-1-yl)benzonitrile (**2o**)⁴



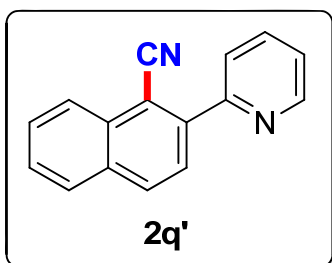
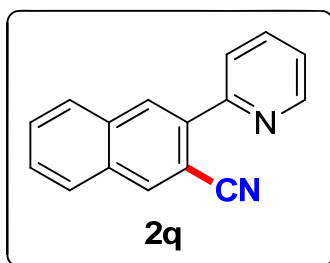
The reaction of CuBr (114.8 mg, 0.8 mmol), 1-phenylisoquinoline **1o** (82.1 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O_2 (1 atm) afforded 32.2 mg (35%) of **2o**. **2o**: ^1H NMR (CDCl_3 , 400 MHz): $\delta = 8.67$ (d, $J = 5.6$ Hz, 1H), 7.92 (d, $J = 8.0$ Hz, 1H), 7.86 (d, $J = 7.6$ Hz, 1H), 7.76-7.70 (m, 4H), 7.66 (d, $J = 7.2$ Hz, 1H), 7.61-7.54 (m, 2H); ^{13}C NMR (CDCl_3 , 100 MHz): $\delta = 157.0, 143.0, 142.2, 136.7, 133.4, 132.3, 130.9, 130.4, 128.8, 127.8, 127.2, 126.8, 126.4, 121.3, 117.7, 113.2$ ppm; IR (neat): $\nu = 2225.6, 1585.3, 1570.0, 1449.5, 1029.0, 792.5, 730.2$ cm^{-1} ; MS (EI) m/z 230.0 (100) $[\text{M}]^+$.

Benzo[h]quinoline-10-carbonitrile (**2p**)²



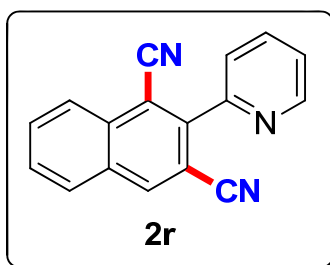
The reaction of CuBr (114.8 mg, 0.8 mmol), benzo[*h*]quinoline **1p** (71.7 mg, 0.4 mmol), 1,3-diphenyl-1,3-propanedione (44.9 mg, 0.2 mmol) in DMF (3 mL) under O₂ (1 atm), afforded 35.9 mg (44%) of **2p**. **2p**: ¹H NMR (CDCl₃, 400 MHz): δ = 9.14-9.13 (m, 1H), 8.21 (dd, *J* = 8 Hz, *J* = 1.6 Hz, 1H), 8.16-8.10 (m, 2H), 7.83-7.70 (m, 3H), 7.62 (dd, *J* = 8.0 Hz, *J* = 4.4 Hz, 1H); ¹³C NMR (CDCl₃, 100 MHz): δ = 148.4, 144.5, 136.2, 135.7, 134.0, 132.7, 130.7, 127.4, 127.2, 127.0, 126.9, 123.0, 120.7, 108.9 ppm; IR (neat): ν = 3434.9, 2210.6, 1619.2, 1511.0, 1424.0, 832.2, 717.0 cm⁻¹; MS (EI) *m/z* 204.3 (100) [M]⁺.

3-(Pyridin-2-yl)-2-naphthonitrile (**2q**)² and 2-(pyridin-2-yl)-1-naphthonitrile (**2q'**)²



The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(naphthalen-2-yl)pyridine **1q** (82.1 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 58.0 mg (63%) **2q** and **2q'** as a mixture (**2q**:**2q'** = 2.7:1).

2-(Pyridin-2-yl)naphthalene-1,3-dicarbonitrile (**2r**)²



The reaction of CuBr (114.8 mg, 0.8 mmol), 2-(naphthalen-2-yl)pyridine **1r** (82.1 mg, 0.4 mmol), benzil (21.0 mg, 0.1 mmol) in DMF (3 mL) under O₂ (1 atm) afforded 12.7 mg (12%) of **2r**. **2r**: ¹H NMR (CDCl₃, 400 MHz): δ = 8.89 (d, *J* = 4.4 Hz, 1H), 8.57 (s, 1H), 8.41 (d, *J* = 8.4 Hz, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 7.98-7.90 (m, 2H), 7.83-7.78 (m, 2H), 7.5045 (dd, *J* = 7.2, 5.2 Hz, 1H); ¹³C NMR (CDCl₃, 100 MHz): δ = 152.9, 150.3, 144.1, 139.7, 137.0, 133.7, 132.1, 131.4, 129.4, 129.0, 126.1, 124.9, 124.5, 116.8, 115.4, 111.7, 110.5; MS (EI) *m/z* 255.1 (100) [M]⁺.

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