Supporting information for
Copper nitrate-catalyzed oxidative coupling of unactivated C(sp³)–H bonds of ethers and alkanes with N-hydroxyphthalimide: synthesis of N-hydroxyimide esters

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1. General information:

All reagents were obtained from commercial suppliers and used without further purification (Tert-butyl ethers were synthesized according to *Tetrahedron Lett.*, 2012, 53, 641). TLC analysis was performed using pre-coated glass plates. Silica gel for column chromatography was purchased from Qingdao Haiyang Chemical Co., Ltd. $^1$H NMR and $^{13}$C NMR were recorded with Bruker instrument at 600 and 150 MHz, respectively, and TMS was used as internal standard. The following abbreviations (or combinations thereof) were used to explain multiplicities: s = singlet, d = doublet, dd = doublet of doublets, t = triplet, q = quartet, m = multiplet, br = broad. Coupling constants, $J$ were reported in Hertz unit (Hz). Mass spectra were measured with Thermo Finnigan LCQ-Advantage. High resolution mass spectral (HRMS) analyze were measured on a Bruker micro TOF-Q II instrument using ESI or EI techniques. The structures of known compounds were further corroborated by comparing their $^1$H NMR, $^{13}$C NMR and MS data with those of literature.

2. General experimental procedure:

General procedure for the Cu(NO$_3$)$_2$·3H$_2$O catalyzed coupling reaction of ethers and alkanes with NHPI.

The ethers or alkanes 1 (4.0 mL), NHPI (1.0 mmol) and Cu(NO$_3$)$_2$·3H$_2$O (0.05 mmol) were added to CH$_3$CN (4.0 mL) in a 25 mL flame-dried flask. The solution was stirred for given reaction time as shown in scheme 2 under O$_2$ (balloon) at 80 °C. After the reaction, the solvents were removed under reduced pressure and the residue was washed with saturated NaHCO$_3$ and then extracted with EtOAc (2 × 20 mL). The combined organic layers were dried over anhydrous Na$_2$SO$_4$ and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether/EtOAc) to afford the corresponding products.

General procedure for synthesis of N-hydroximide esters from tert-butyl ethers.

The tert-butyl ethers 4 (2.0 mL), NHPI (1.0 mmol) and Cu(NO$_3$)$_2$·3H$_2$O (0.05 mmol) were added to CH$_3$CN (4.0 mL) in a 25 mL flame-dried flask. The solution was stirred for 10 h under O$_2$ (balloon) at 80 °C. After the reaction, the solvents were removed under reduced pressure and the residue was washed with saturated NaHCO$_3$ and then extracted with EtOAc (2 × 20 mL). The combined...
organic layers were dried over anhydrous Na$_2$SO$_4$ and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether/EtOAc) to afford the corresponding products.
H and 13C NMR data

2-(tetrahydrofuran-2-yloxy)isoindoline-1,3-dione (3a):
White solid, m.p. 132-133 °C. \(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.85-7.82 (m, 2H), 7.76-7.73 (m, 2H), 5.80 (d, \(J = 4.8\) Hz, 1H), 4.38-4.34 (m, 1H), 4.05-4.01 (m, 1H), 2.34-2.29 (m, 1H), 2.28-2.22 (m, 1H), 2.15-2.10 (m, 1H), 2.00-1.94 (m, 1H). \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \(\delta\) 163.9, 134.3, 129.1, 123.4, 108.8, 69.2, 30.8, 22.6. IR (KBr): \(v\) 3443, 3010, 2999, 2978, 1731, 1380, 1138, 971, 879, 700, 520 cm\(^{-1}\).

2-(5-methyltetrahydrofuran-2-yloxy)isoindoline-1,3-dione (3b):
White solid, m.p. 124-126 °C. \(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.85-7.83 (m, 2H), 7.76-7.74 (m, 2H), 5.81-5.79 (m, 1H), 4.74-4.71 (m, 1H), 2.34-2.31 (m, 1H), 2.28-2.25 (m, 2H), 1.54-1.49 (m, 1H), 1.27 (dd, \(J = 6.6, 3.0\) Hz, 3H). \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \(\delta\) 163.9, 134.3, 129.1, 123.4, 108.9, 30.6, 30.2, 20.5.

2-(tetrahydro-2H-pyran-2-yloxy)isoindoline-1,3-dione (3c):
White solid, m.p. 123-124 °C. \(^1\)H NMR (600 MHz, CDCl\(_3\)) \(\delta\) 7.84-7.82 (m, 2H), 7.75-7.72 (m, 2H), 5.42 (d, \(J = 1.8\) Hz, 1H), 4.54-4.50 (m, 1H), 3.68-3.65 (m, 1H), 2.13-2.10 (m, 1H), 1.99-1.92 (m, 1H), 1.87-1.81 (m, 1H), 1.74-1.68 (m, 3H). \(^{13}\)C NMR (125 MHz, CDCl\(_3\)) \(\delta\) 163.8, 134.3, 129.2, 123.4, 103.1, 62.3, 27.7, 24.8, 17.6.

2-(1,4-dioxan-2-yloxy)isoindoline-1,3-dione (3d):
White solid, m.p. 185-187 °C. \(^1\)H NMR (600
MHz, CDCl$_3$) $\delta$ 7.88-7.86 (m, 2H), 7.78-7.77 (m, 2H), 5.27 (d, $J$ = 1.8, 1H), 4.90-4.85 (m, 1H), 4.18 (d, $J$ = 12.6 Hz, 1H), 3.91 (dd, $J$ = 11.4, 2.4 Hz, 1H), 3.85-3.80 (m, 2H), 3.57 (dd, $J$ = 11.4, 2.4 Hz, 1H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 163.6, 134.5, 129.0, 123.6, 99.5, 66.2, 66.0, 60.9.

2-(1-ethoxyethoxy)isoindoline-1,3-dione (3e): Oil. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.85-7.83 (m, 2H), 7.77-7.75 (m, 2H), 5.32 (q, $J$ = 5.4 Hz, 1H), 4.19-4.15 (m, 1H), 3.85-3.80 (m, 1H), 1.53 (d, $J$ = 5.4 Hz, 3H), 1.24 (t, $J$ = 7.2 Hz, 3H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 164.3, 134.4, 129.1, 123.4, 106.4, 63.6, 18.9, 15.0. IR (KBr): $\nu$ 3441, 3015, 2978, 1737, 1710, 1463, 1137, 976, 881, 698, 522 cm$^{-1}$.

2-((tert-butoxymethoxy)isoindoline-1,3-dione (3f): White solid, m.p. 93-95 °C. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.85-7.82 (m, 2H), 7.76-7.74 (m, 2H), 5.28 (s, 2H), 1.39 (s, 9H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 163.8, 134.4, 129.1, 123.4, 95.0, 28.3. IR (KBr): $\nu$ 3441, 3015, 2978, 1737, 1710, 1463, 1137, 976, 881, 698, 522 cm$^{-1}$.

2-(cyclopentylxomethoxy)isoindoline-1,3-dione (3g): White solid, m.p. 71-73 °C. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.85-7.82 (m, 2H), 7.76-7.73 (m, 2H), 5.17 (s, 2H), 4.79-4.76 (m, 1H), 1.86-1.81 (m, 2H), 1.72-1.68 (m, 4H), 1.60-1.57 (m, 2H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 163.7, 134.4, 129.1, 123.4, 97.8, 80.3, 32.1, 23.4. IR (KBr): $\nu$ 3426, 3013, 2946, 2869, 1727, 1466, 1136, 968, 870, 701, 520 cm$^{-1}$.
2-(2-bromo-1-(2-bromoethoxy)ethoxy)isoindoline-1,3-dione (3h): White solid, m.p. 112-114 °C. 

$^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.89-7.88 (m, 2H), 7.82-7.81 (m, 2H), 5.30 (dd, $J = 8.4$, $3.0$ Hz, 1H), 4.58-4.54 (m, 1H), 4.23-4.19 (m, 2H), 3.78 (dd, $J = 10.8$, $3.0$ Hz, 1H), 3.60-3.58 (m, 2H), 3.56-3.52 (m, 1H).

$^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 164.1, 134.9, 128.9, 123.8, 107.9, 69.9, 29.5.

2-(methoxymethoxy)isoindoline-1,3-dione (3i): White solid, m.p. 122-124 °C. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.87-7.86 (m, 2H), 7.78-7.77 (m, 2H), 5.14 (s, 2H), 3.74 (s, 3H).

$^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 163.6, 134.5, 129.0, 123.5, 101.3, 57.8. IR (KBr): $\nu$ 3454, 3027, 2961, 2831, 1718, 1637, 1132, 1098, 967, 878, 701, 519 cm$^{-1}$.

2-(1-(butylthio)butoxy)isoindoline-1,3-dione (3j): Oil. $^1$H NMR (600 MHz, DMSO-$d_6$) $\delta$ 7.90-7.87 (m, 4H), 5.37-5.35 (m, 1H), 2.89-2.85 (m, 1H), 2.75-2.70 (m, 1H), 2.00-1.96 (m, 1H), 1.81-1.76 (m, 1H), 1.52-1.47 (m, 4H), 1.37-1.32 (m, 2H), 0.93 (t, $J = 7.2$ Hz, 3H), 0.87-0.86 (m, 3H). $^{13}$C NMR (125 MHz, DMSO-$d_6$) $\delta$ 164.1, 135.4, 129.0, 123.8, 93.9, 35.7, 31.7, 29.0, 21.9, 19.2, 14.0, 13.9. IR (KBr): $\nu$ 3456, 3047, 2961, 2866, 1735, 1685, 1136, 1082, 881, 698, 522 cm$^{-1}$.

2-(cyclohexyloxy)isoindoline-1,3-dione (3k): White solid, m.p. 116-118 °C. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.78-7.75 (m, 2H), 7.69-7.66 (m, 2H), 4.18-4.14 (m, 1H), 1.97-1.95 (m, 2H), 1.79-1.78 (m,
2-(cyclooctyloxy)isoindoline-1,3-dione (3l): White solid, m.p. 107-109 °C. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.85-7.82 (m, 2H), 7.76-7.73 (m, 2H), 4.43-4.39 (m, 1H), 2.02-1.98 (m, 2H), 1.95-1.89 (m, 2H), 1.85-1.79 (m, 2H), 1.61-1.47 (m, 8H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 164.5, 134.4, 129.1, 123.4, 88.8, 30.0, 27.1, 25.3, 22.9. IR (KBr): $\nu$ 3451, 3031, 2967, 2859, 1741, 1637, 1196, 1045, 979, 890, 696, 519 cm$^{-1}$. HRMS (ESI) calcd for [M+Na]$^+$ C$_{15}$H$_{17}$NNaO$_4$, m/z 298.1050, found 298.1041.

1,3-dioxoisindolin-2-yl-acetate (5a): Yellow oil. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.89-7.87 (m, 2H), 7.80-7.78 (m, 2H), 2.4 (s, 3H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 169.7, 162.0, 134.7, 128.9, 124.0, 17.6. IR (KBr): $\nu$ 3448, 3037, 2930, 2843, 1787, 1743, 1639, 1141, 1004, 969, 879, 697, 521 cm$^{-1}$. HRMS (ESI) calcd for [M+Na]$^+$ C$_{15}$H$_{17}$NNaO$_4$, m/z 298.1050, found 298.1041.

1,3-dioxoisindolin-2-yl-heptanoate (5b): Yellow oil. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.90-7.88 (m, 2H), 7.80-7.79 (m, 2H), 2.4 (s, 3H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 169.7, 162.0, 134.7, 128.9, 123.9, 31.3, 31.0, 28.5, 24.6, 22.4, 14.0. IR (KBr): $\nu$ 3448, 3037, 2954, 2869, 1788, 1740, 1638, 1139, 1081, 877, 699, 521 cm$^{-1}$. HRMS (ESI) calcd for [M+Na]$^+$ C$_{15}$H$_{17}$NNaO$_4$, m/z 298.1050, found 298.1041.

1,3-dioxoisindolin-2-yl-octanoate (5c): Yellow oil. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.90-7.86 (m, 2H),
7.80-7.77 (m, 2H), 2.67-2.65 m, 2H), 1.801-1.76 (m, 2H), 1.43 (s, 2H), 1.33-1.30 (m, 6H), 0.90 (t, J =3.6 Hz, 3H). 13C NMR (125 MHz, CDCl3) δ 169.7, 162.0, 134.7, 129.0, 123.9, 31.6, 31.0, 28.8, 24.7, 22.6, 14.1. IR (KBr): ν 3448, 3035, 3026, 2964, 2879, 1789, 1743, 1642, 1149, 1077, 879, 698, 520 cm⁻¹. HRMS (ESI) calcd for [M+Na]+ C16H19NNaO4, m/z 312.1206, found 312.1202.

![5d](image)

1,3-dioxoisindolin-2-yl-benzoate (5d): White solid, m.p. 168-170 °C. 1H NMR (600 MHz, CDCl3) δ 8.22 (d, J = 7.8 Hz, 2H), 7.96-7.93 (m, 2H), 7.85-7.83 (m, 2H), 7.72 (t, J = 7.8 Hz, 1H), 7.56 (t, J = 7.8 Hz, 2H). 13C NMR (125 MHz, CDCl3) δ 162.8, 162.1, 134.9, 134.8, 130.7, 129.0, 128.9, 125.3, 124.0. IR (KBr): ν 3438, 3043, 3024, 2984, 2879, 1772, 1734, 1643, 1140, 1037,1022, 1008, 875, 697, 520 cm⁻¹.

**References**

Copies of $^1$H and $^{13}$C spectrum

3a ($^1$H, CDCl$_3$)

3a ($^{13}$C, CDCl$_3$)
3b ($^1$H, CDCl$_3$)

3b ($^{13}$C, CDCl$_3$)

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$3c$ ($^1H$, CDCl$_3$)

$3c$ ($^{13}C$, CDCl$_3$)
3d (\(^1\)H, CDCl\(_3\))

3d (\(^{13}\)C, CDCl\(_3\))
$3e \ (^{1}H, CDCl_{3})$

$3e \ (^{13}C, CDCl_{3})$
$3g$ ($^1H$, CDCl$_3$)

$3g$ ($^{13}C$, CDCl$_3$)
3i ($^1$H, CDCl$_3$)

3i ($^{13}$C, CDCl$_3$)
$3j^{(1}H, \text{DMSO-}d_6^{)}$

$3j^{(13}C, \text{DMSO-}d_6^{)}$
$3k \ (^{1}H, \text{CDCl}_{3})$

$3k \ (^{13}C, \text{CDCl}_{3})$
$3I \left( ^1H, \text{CDCl}_3 \right)$

$3I \left( ^{13}C, \text{CDCl}_3 \right)$
5a ($^1$H, CDCl$_3$)

5a ($^{13}$C, CDCl$_3$)
5b ($^1$H, CDCl$_3$)

5b ($^{13}$C, CDCl$_3$)
$5c \left( ^1H, CDCl_3 \right)$

$5c \left( ^{13}C, CDCl_3 \right)$
5d (\(^1\)H, CDCl\(_3\))

5d (\(^{13}\)C, CDCl\(_3\))
HRMS (ESI) spectra of 2,2,6,6-tetramethyl-1-(tetrahydrofuran-2-yloxy)piperidine (6)

2,2,6,6-tetramethyl-1-(tetrahydrofuran-2-yloxy)piperidine
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