Primary Amides. A General Nitrogen Source for Catalytic Asymmetric Aminohydroxylation of Olefins.

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Supporting Information:

All ^{1}H NMR spectra taken on a Bruker AMX-400 spectrometer in $CDCl_3$ using TMS as a standard at 0.0 ppm. All ^{13}C NMR spectra taken on the same machine at 100 MHz in $CDCl_3$ using $CDCl_3$ as a standard at 77.0 ppm. All enantiomeric excesses determined at 206nm on a Chiracel og or ob column eluting 15% iPrOH in hexanes at 1.0 ml/min. Regioselectivities were determined by comparison to known conpounds, or by fragmentation patterns using electron ionization mass spectrometery.

1a [*N*-bromobutyramide]
M.p. 30-33°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=5.64 (br, 1H, N*H*), 2.38 (t, *J*=7.6Hz, 2H, COCH_2), 1.72 (sextet, *J*=7.6Hz, 2H, CH_2CH$_3$), 0.96 (t, *J*=7.6Hz, 3H, CH_3).

1b [*N*-bromochloroacetamide] Spectroscopic data matches literature (ref. 7b).

1c [*N*-bromophenylacetamide], **1e** [*N*-bromobenzamide] Spectroscopic data matches literature (ref. 7c).

1d [*N*-bromocyclohexylcarboxamide]
M.p. 81-82°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=5.52 (br, 1H, N*H*), 2.38 (tt, *J*=11.9, 3.8Hz, 1H, C*H*), 1.87 (d, *J*=13.8Hz, 2H, CH_2), 1.80 (dd, *J*=9.4, 3.2Hz, 2H, CH_2), 1.68 (m, 2H), 1.51 (q, *J*=12.1Hz, 2H, CH_2), 1.26 (m, 2H, CH_2).

1f [*N*-bromo-4-methoxy-benzamide] Spectroscopic data matches literature (T. Imamoto, Y. Tsuno, Y. Yukawa, *Bull. Chem. Soc. Japan* **1971**, *44*, 1632-1638.)

2a [isopropyl-(2R,3S)-3-(butyramido)-2-hydroxy-3-phenyl propanoate]
M.p. 81-82°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.40-7.33 (m, 4H, Ar*H*), 7.32-7.27 (m, 1H, Ar*H*), 6.26 (d, *J*=8.9Hz, 1H, N*H*), 5.58 (dd, *J*=9.5, 1.9Hz, 1H, C*H*NH), 5.12 (septet, *J*=6.2Hz, 1H, C*H*(CH$_3$)), 4.48 (dd, *J*=3.5, 2.2Hz, 1H, C*H*OH), 3.23 (d, *J*=3.8Hz, 1H, O*H*), , 1.65 (tq, *J*=7.6, 7.6Hz, 2H, CH_2CH$_3$), 1.30 (dd, *J*=6.0, 6.0Hz, 6H, iPr CH_3), 0.93 (t, *J*=4.0Hz, 3H, CH$_2$CH_3); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=172.46, 172.17, 139.02, 128.59, 127.71, 126.83, 73.24, 70.88, 54.01, 38.62, 21.68, 21.54, 19.20, 13.71; HR-MS (MALDI): calc'd for $C_{16}H_{23}NO_4Na$ [M+Na$^+$]: 316.1525, found: 316.1534. $[\alpha]_D^{25}$ (c=1, $CHCl_3$) +27.0. Retention time (og) / area % : (major) 7.97 min / 97.6%, (minor) 12.87 min / 2.4%.

2b [isopropyl-(2R,3S)-3-(2-chloroacetamido)-2-hydroxy-3-phenyl propanoate]
M.p. 108-109°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.50 (d, *J*=9.2Hz, 1H, N*H*), 7.41-7.28 (m, 5H, Ar*H*), 5.53 (dd, *J*=9.2, 2.4Hz, 1H, C*H*NH), 5.10 (septet, *J*=6.2Hz, 1H, C*H*(CH$_3$)), 4.49 (dd, *J*=3.8, 2.2Hz, 1H, C*H*OH), 4.06 (s, 2H, CH_2Cl), 3.26 (d, *J*=4.0Hz, 1H, O*H*), 1.30 (dd, *J*=6.5, 7.3Hz, 6H, iPr CH_3); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=172.00, 165.21, 137.85, 128.68, 128.07, 126.82, 73.01, 71.09, 54.51, 42.58, 21.68, 21.58; HR-MS (MALDI): calc'd for $C_{14}H_{18}NO_4ClNa$ [M+Na$^+$]: 322.0822, found: 322.0834. Retention time (og) / area % : (major) 11.33 min / 97.6%, (minor) 13.70 min / 2.4%.

2c [isopropyl-(2R,3S)-3-(2-phenylacetamido)-2-hydroxy-3-phenyl propanoate]
M.p. 94-95°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.40-7.21 (m, 10H, Ar*H*), 6.32 (d, *J*=9.5Hz, 1H, N*H*), 5.53 (d, *J*=8.6Hz, 1H, C*H*NH), 5.03 (septet, *J*=6.2Hz, 1H, C*H*(CH$_3$)), 4.39 (m, 1H, C*H*OH), 3.58 (s, 2H, ArCH_2), 3.16 (d, *J*=3.8Hz, 1H, O*H*), 1.26 (d, *J*=6.5Hz, 3H, iPr CH_3), 1.19 (d, *J*=6.2Hz, 3H, iPr CH_3); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=172.26, 170.07, 138.57, 134.54, 129.37, 129.05, 128.52, 127.70, 127.48, 126.63, 73.16, 70.92, 54.09, 43.82, 21.64, 21.46; HR-MS (MALDI): calc'd for $C_{20}H_{23}NO_4Na$ [M+Na$^+$]: 364.1525, found: 364.1534. Retention time (ob) / area % : (major) 22.13 min / 96.4%, (minor) 42.47 min / 3.6%.

2d [isopropyl-(2R,3S)-3-(cyclohexylcarboxamido)-2-hydroxy-3-phenyl propanoate]
M.p. 140-141°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.40-7.31 (m, 4H, Ar*H*), 7.30-7.25 (m, 1H, Ar*H*), 6.28 (d, *J*=9.2Hz, 1H, N*H*), 5.56 (d, *J*=9.4Hz, 1H, C*H*NH), 5.08 (septet, *J*=6.2Hz, 1H, C*H*(CH_3)), 4.49 (m, 1H, C*H*OH), 3.23 (d, *J*=3.8Hz, 1H, O*H*), 2.12 (tt, *J*=11.6, 3.2Hz, 1H, c-hex C*H*), 1.88-1.72 (m, 4H, c-hex CH_2), 1.47-1.35 (m, 2H, c-hex CH_2), 1.29 (dd, *J*=6.8, 6.8Hz, 6H, iPr CH_3), 1.28-1.17 (m, 4H, c-hex CH_2); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=175.17, 172.50, 139.02, 128.52, 127.58, 126.73, 73.29, 70.80, 53.62, 45.48, 29.77, 29.50, 25.62, 21.67, 21.55; HR-MS (MALDI): calc'd for $C_{19}H_{27}NO_4Na$ [M+Na$^+$]: 356.1838, found: 356.1834. Retention time (og) / area % : (major) 6.47 min / 90.0%, (minor) 4.23 min / 10.0%.

2e [isopropyl-(2R,3S)-3-(benzamido)-2-hydroxy-3-phenyl propanoate]
M.p. 137-138°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.76 (d, *J*=8.1Hz, 2H, Ar*H*), 7.51 (tt, *J*=7.3, 2.2Hz, 1H, Ar*H*), 7.48-7.41 (m, 4H, Ar*H*), 7.36 (tt, *J*=7.6, 1.6Hz, 2H, Ar*H*), 7.29 (tt, *J*=7.3, 2.1Hz, 2H, Ar*H*), 7.02 (d, *J*=9.2Hz, 1H, N*H*), 5.77 (dd, *J*=9.2, 1.9Hz, 1H, C*H*NH), 5.11 (septet, *J*=6.2Hz, 1H, C*H*(CH_3)$_2$), 4.60 (dd, *J*=3.5, 2.2Hz, 1H, C*H*OH), 3.35 (d, *J*=3.2Hz, 1H, O*H*), 1.30 (d, *J*=6.2Hz, 3H, iPr CH_3), 1.25 (d, *J*=6.2Hz, 3H, iPr CH_3); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=172.27, 168.81, 138.64, 134.05, 131.55, 128.48 (2C), 127.62, 126.97, 126.79, 73.33, 70.63, 54.70, 21.55, 21.44; HR-MS (MALDI): calc'd for $C_{19}H_{21}NO_4Na$ [M+Na$^+$]: 350.1368, found: 350.1378. Retention time (og) / area % : (major) 8.50 min / 88.5%, (minor) 7.90 min / 11.6%.

2f [isopropyl-(2R,3S)-3-(4-methoxybenzamido)-2-hydroxy-3-phenyl propanoate]
M.p. 149-151°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.73 (d, *J*=8.9Hz, 2H, MeOAr*H*), 7.44 (d, *J*=7.6Hz, 2H, Ar*H*), 7.35 (t, *J*=7.1, 2H, Ar*H*), 7.29 (d, *J*=7.3Hz, 1H, Ar*H*), 6.92 (d, *J*=8.6Hz, 2H, MeOAr*H*), 6.89 (d, *J*=9.4Hz, 1H, N*H*), 5.72 (dd, *J*=9.4, 2.0Hz, 1H, C*H*NH), 5.11 (septet, *J*=6.5Hz, 1H, C*H*(CH_3)), 4.58 (d, *J*=1.8Hz, 1H, C*H*OH), 3.84 (s, 3H, OCH_3), 3.27 (s, 1H, O*H*), 1.29 (d, *J*=6.2Hz, 3H, iPr CH_3), 1.23 (d, *J*=6.2Hz, 3H, iPr CH_3); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=172.47, 166.20, 162.33, 138.91, 128.84, 128.59, 127.72, 126.87, 126.46, 113.79, 73.44, 70.89, 55.38, 54.62, 21.65, 21.54; HR-MS (MALDI): calc'd for $C_{20}H_{23}NO_5Na$ [M+Na$^+$]: 380.1474, found: 380.1479. Retention time (og) / area % : (major) 16.17 min / 72.4%, (minor) 13.90 min / 28.6%.

3a [(2S)-2-(2-chloroacetamido)-1-(4-methoxyphenyl)-ethanol] (major isomer)
M.p. 103-105°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.25 (d, *J*=8.6Hz, 2H, Ar*H*), 7.18 (br, 1H, N*H*), 6.92 (d, *J*=8.6Hz, 2H, Ar*H*), 4.82 (dt, *J*=7.3, 4.8Hz, 1H, C*H*NH), 4.13 (d, *J*=15.1Hz, 1H, CH_2Cl), 4.07 (d, *J*=15.1Hz, 1H, CH_2Cl), 3.91 (d, *J*=5.1Hz, 2H, CH_2OH), 3.81 (s, 3H, OCH_3), 2.63 (br, 1H, O*H*); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=166.26, 159.30, 130.17, 127.78, 114.29, 65.96, 55.28 (2C), 42.61; HR-MS (MALDI): calc'd for $C_{11}H_{13}NO_2Cl$ [MH$^+$-$H_2$0]: 226.0635, found: 226.0628. . Retention time (ob) / area % : (major) 45.63 min / 98.6%, (minor) 41.37 min / 1.4%.

3b [(2S)-2-(2-chloroacetamido)-2-phenyl-ethanol]
M.p. 86-89°C; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.42-7.36 (m, 2H, Ar*H*), 7.35-7.30 (m, 2H, Ar*H*), 5.11 (dt, *J*=7.6, 4.7Hz, 1H, C*H*NH), 4.12 (dd, *J*=15.2, 23.5Hz, 2H, CH_2Cl), 3.94 (d, *J*=4.7, 2H, CH_2OH); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=166.28, 138.15, 128.94, 128.08. 126.56, 65.99, 55.75, 42.62; HR-MS (MALDI): calc'd for $C_{10}H_{12}NO_2ClNa$ [MH$^+$]: 214.0635, found: 214.0631. Retention time (og) / area % : (major) 9.97 min / 98.4%, (minor) 12.70 min / 1.6%.

3c [(2S)-2-(2-chloroacetamido)-3-phenyl-propanol]
Clear oil; ^{1}H NMR (400 MHz, $CDCl_3$, 20°C): δ=7.36-7.31 (m, 2H, Ar*H*), 7.29-7.20 (m, 3H, Ar*H*), 6.99 (br, 1H, N*H*), 4.07 (s, 2H, CH_2Cl), 3.99 (m, 1H, C*H*NH), 3.63 (ddd, *J*=13.8, 6.7, 3.0Hz, 1H, CH_2OH), 3.24 (ddd, *J*=13.5, 7.8, 5.1Hz, 1H, CH_2OH),), 2.84 (dd, *J*=13.5, 4.9Hz, 1H, ArCH_2),), 2.74 (dd, *J*=13.8, 8.4Hz, 1H, ArCH_2); ^{13}C NMR (100 MHz, $CDCl_3$, 20°C): δ=166.68, 137.11, 129.32, 128.80, 126.88, 71.64, 45.04, 42.58, 41.49; HR-MS (MALDI): calc'd for $C_{11}H_{13}NO_2Cl$ [M+Na$^+$]: 250.0611, found: 250.0615. . Retention time (ob) / area % : (major) 24.43 min / 75.1%, (minor) 23.30 min / 24.9%.