Supporting Information for:

Nickel or Phenanthroline Mediated Intramolecular Arylation of sp^3 C–H Bonds Using Aryl Halides

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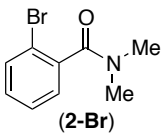
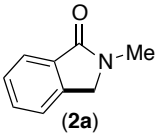
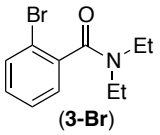
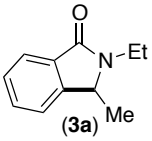
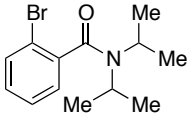
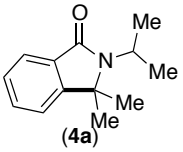
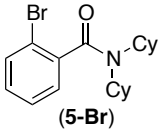
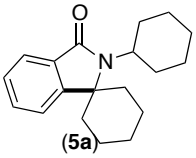
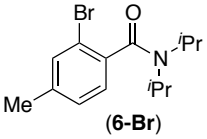
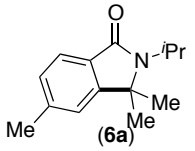
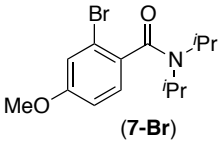
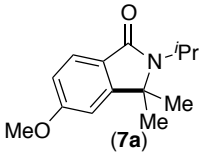
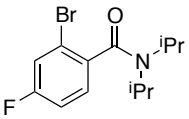
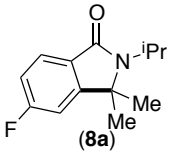
General Procedures: NMR spectra were obtained on a Bruker 400 (399.96 MHz for ^{1}H; 100.57 MHz for ^{13}C) spectrometer. ^{1}H NMR chemical shifts are reported in parts per million (ppm) relative to TMS, with the residual solvent peak used as an internal reference. Multiplicities are reported as follows: singlet (s), doublet (d), doublet of doublets (dd), triplet of doublets (td), triplet (t), multiplet (m), septet (sept). IR spectra were obtained on a Thermo scientific Nicolet iS5 iD5 ATR spectrometer. Melting points were obtained on a Thomas Hoover melting point apparatus.

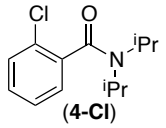
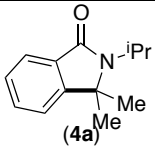
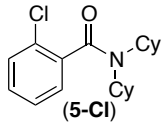
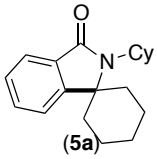
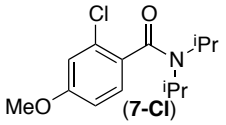
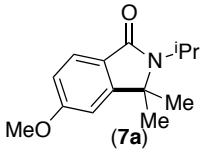
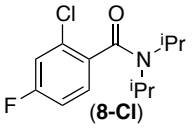
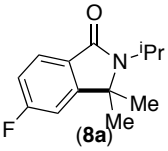
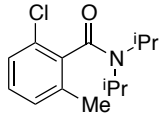
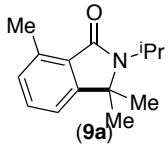
Materials and Methods: Rubidium carbonate, 1,10-phenanthroline, anhydrous sodium tert-butoxide, tricyclohexylphosphine tetrafluoroborate, diethyl amine, 2-chlorobenzoyl chloride, anhydrous diisopropylamine, dicyclohexylamine, diisopropylethyl amine, galvinoxyl free radical, TEMPO, thionyl chloride and anhydrous triethylamine were obtained from Aldrich and used as received. $Ni(COD)_2$ was obtained from Strem chemicals and used as received. 2-bromo-4-methyl-benzoic acid, 2-chloro-5-methyl benzoic acid, 2-chloro-4-fluoro benzoyl chloride, 2-bromo-5-methyl benzoic acid, 2-bromo-4,5-dimethoxy benzoic acid and 2-bromo-3-fluoro benzoic acid were obtained from Matrix Scientific and used as received. 2-Chloro-6-methyl benzoic acid, 2-chloro-4-methoxy benzoic acid and 2-bromo-4-methoxy benzoic acid were obtained from Ark Pharm and used as received. Anhydrous Cs_2CO_3 and anhydrous K_3PO_4 were obtained from Acros Organics and used as received. 2-bromobenzoyl chloride and disecbutylamine were obtained from TCI America and used as received. 2-bromo-5-methoxy benzoic acid was obtained from alfa aesar and used as received. 2-bromo-4-fluoro benzoyl chloride was obtained from Oakwood products Inc. and used as received. Substrates **1-Br** and **2-Br** were prepared using literature procedures.[1] Anhydrous xylene and anhydrous dioxane was obtained from Aldrich and used as received. Anhydrous dichloromethane and anhydrous diethyl ether were purified using Glass Contour solvent purification system column composed of neutral alumina. Toluene was purified using Glass Contour solvent purification system column composed of neutral alumina and a copper catalyst. *N*,*N*-dimethylformamide was purified using Glass Contour solvent purification system by passing through a column packed with molecular sieves. Other solvents were obtained from Fisher Chemical or VWR Chemical and used without further purification. Flash chromatography was performed on EM Science silica gel 60 (0.040–0.063 mm particle size, 230–400 mesh) and thin layer chromatography was performed on Analtech TLC plates pre-coated with silica gel 60 F_{254}.

Direct Comparison of ^{1}H NMR Yields of Arylation Products in Table 2 Under Ni- and Phenanthroline Catalysis:

entry	substrate	product	*Conditions A* yield[a,b]	*Conditions B* yield[c,b]
1	 (**2-Br**)	 (**2a**)	<10%	<10%
2	 (**3-Br**)	 (**3a**)	53%	55%
3	 (**4-Br**)	 (**4a**)	76%	88%
4	 (**5-Br**)	 (**5a**)	92%	99%
5	 (**6-Br**)	 (**6a**)	83%	95%
6	 (**7-Br**)	 (**7a**)	82%	trace
7	 (**8-Br**)	 (**8a**)	53%	13%

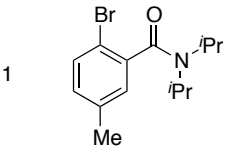
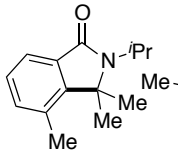
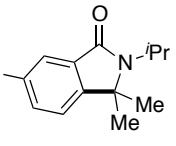
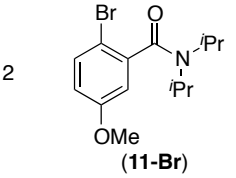
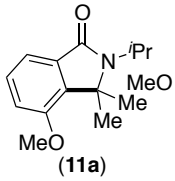
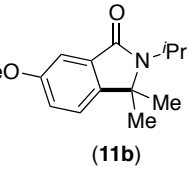
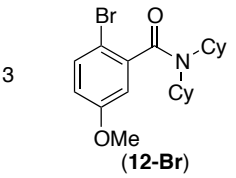
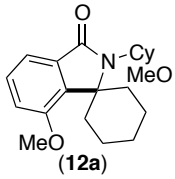
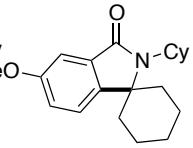
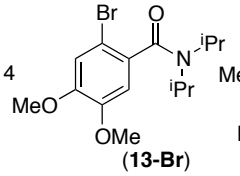
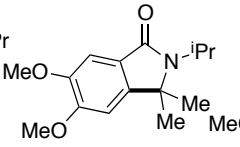
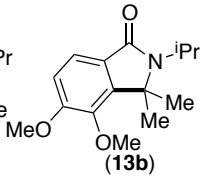
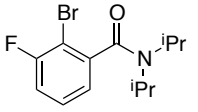
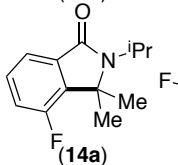
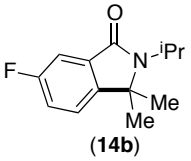
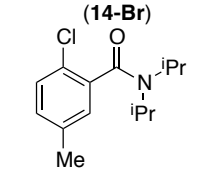
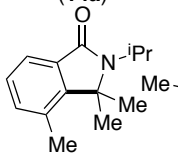
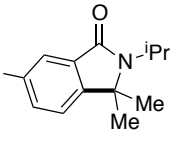
[a] Conditions A: $Ni(COD)_2$ (0.1 equiv), NaO*t*Bu (1.5 equiv), dioxane (0.25 M in substrate), 145 °C. [b] Yields determined by ^{1}H NMR spectroscopic analysis of the crude reaction mixtures against 1,4-dinitrobenzene as the internal standard. [c] Conditions B: 1,10-phenanthroline (0.2 equiv), NaO*t*Bu (1.5 equiv), dioxane (0.25 M in substrate), 145 °C.

Direct Comparison of ^{1}H NMR Yields of Arylation Products in Table 3 Under Ni- and Phenanthroline Catalysis:

entry	substrate	product	*Conditions A* yield[a,b]	*Conditions B* yield[c,b]
1	 (**4-Cl**)	 (**4a**)	81%	45%
2	 (**5-Cl**)	 (**5a**)	82%	68%
3	 (**7-Cl**)	 (**7a**)	71%	trace
4	 (**8-Cl**)	 (**8a**)	67%	trace
5	 (**9-Cl**)	 (**9a**)	76%	46%

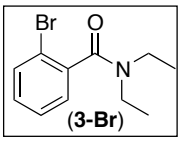
[a] Conditions A: $Ni(COD)_2$ (0.1 equiv), NaO*t*Bu (1.5 equiv), dioxane (0.25 M in substrate), 145 °C. [b] Yields determined by ^{1}H NMR spectroscopic analysis of the crude reaction mixtures against 1,4-dinitrobenzene as the internal standard. [c] Conditions B: 1,10-phenanthroline (0.2 equiv), NaO*t*Bu (1.5 equiv), dioxane (0.25 M in substrate), 145 °C.

Direct Comparison of ^{1}H NMR Yields and Site-Selectivities of Arylation Products in Table 4 Under Ni- and Phenanthroline Catalysis:

				yield (selectivity)	
				Conditions	
entry	substrate	major product	minor product	***A***[a,b]	***B***[c,b]
1	 (**10-Br**)	 (**10a**)	 (**10b**)	84% (1.1:1)[d]	96% (1.3:1)[d]
2	 (**11-Br**)	 (**11a**)	 (**11b**)	71% (2.0:1)[d]	92% (1.7:1)[d]
3	 (**12-Br**)	 (**12a**)	 (**12b**)	83% (1.3:1)[d]	95% (1.3:1)[d]
4	 (**13-Br**)	 (**13a**)	 (**13b**)	73% (2.2:1)[d]	trace
5	 (**14-Br**)	 (**14a**)	 (**14b**)	90% (2.7:1)[d]	trace
6	 (**10-Cl**)	 (**10a**)	 (**10b**)	76% (1.2:1)[d]	74% (1.4:1)[d]

[a] Reaction conditions: $Ni(COD)_2$ (0.1 equiv), NaO*t*Bu (1.5 equiv), dioxane (0.25 M in substrate), 145 °C. [b] Yields determined by ^{1}H NMR spectroscopic analysis of the crude reaction mixtures against 1,4-dinitrobenzene as the internal standard. [c] Reaction conditions: 1,10-phenanthroline (0.2 equiv), NaO*t*Bu (1.5 equiv), dioxane (0.25 M in substrate), 145 °C. [d] Selectivities determined by ^{1}H NMR spectroscopic analysis of the crude reaction mixtures.

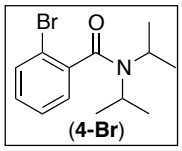
Synthesis and Characterization of Bromide Substrates in Table 2:



(**3-Br**)

To a 100 mL Schlenk flask containing 2-bromobenzoyl chloride (1.75 g, 7.97 mmol, 1.0 equiv), in anhydrous CH_2Cl_2 (25 mL) was added diethylamine (1.14 g, 15.6 mmol, 2.0 equiv) dropwise at 0 °C. The resulting mixture was allowed to stir at room temperature for 0.5 h. The reaction mixture was then diluted with CH_2Cl_2, transferred to a separatory funnel and extracted with saturated aqueous $NaHCO_3$ (1 x 50 mL) and saturated aqueous NH_4Cl (1 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 30/70 hexanes/EtOAc (R_f = 0.71 in 30% hexanes/70% ethyl acetate) to afford product **3-Br** as a clear oil (2.02 g, 99% yield).

^{1}H NMR ($CDCl_3$): δ 7.54 (d, *J* = 7.9 Hz, 1H), 7.32 (t, *J* = 7.4 Hz, 1H), 7.24-7.18 (multiple peaks, 2H), 3.85-3.76 (m, 1H), 3.35-3.27 (m, 1H), 3.17-3.07 (multiple peaks, 2H), 1.25 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 168.4, 138.7, 132.6, 129.8, 127.45, 127.36, 119.1, 42.6, 38.8, 13.8, 12.4. IR (neat): 2974, 1630, 1426, 1363, 1290, 1103, 765, 750, 736, 625 cm^{-1}. HRMS $[M+H]^+$Calcd for $C_{11}H_{14}BrNO$ 256.0332; Found: 256.0330.

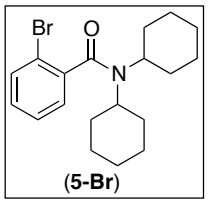


(**4-Br**)

To a 100 mL Schlenk flask containing a solution of *N*,*N*-diisopropylamine (1.39 g, 13.7 mmol, 1.50 equiv), in anhydrous Et_2O (45 mL) was added ^{i}Pr$_2$NEt (2.4 mL, 13.7 mmol, 1.50 equiv).[1] The reaction mixture was cooled to 0 ºC using an ice bath and 2-bromobenzoyl chloride (2.00 g, 9.11 mmol, 1.00 equiv) was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 1h. The reaction mixture was then diluted with EtOAc (40 mL) and transferred to a separatory funnel and extracted with brine (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 80/20 hexanes/EtOAc to 60/40 hexanes/EtOAc (R_f = 0.35 in 80% hexanes/20% ethyl acetate) to afford product **4-Br** as a white solid (1.10 g, 42% yield); mp = 146-147 °C.

^{1}H NMR ($CDCl_3$): δ 7.53 (d, *J* = 8.0 Hz, 1H), 7.30 (td, *J* = 7.5, 1,2 Hz, 1H), 7.20-7.15 (multiple peaks, 2H), 3.58 (sept, *J* = 6.6 Hz, 1H), 3.51 (sept, *J* = 6.8 Hz, 1H), 1.57 (d, *J* = 6.7 Hz, 3H), 1.55 (d, *J* = 6.6 Hz, 3H), 1.22 (d, *J* = 6.7 Hz, 3H), 1.05 (d, *J* = 6.7 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 168.1, 140.1, 132.8, 129.4, 127.5, 126.5, 118.8, 51.1, 45.9, 20.7, 20.61, 20.55, 20.0. IR (neat): 2977, 1626,

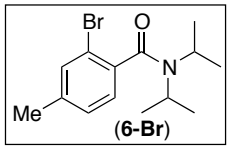
1439, 1424, 1370, 1340, 1032, 1020, 772, 736, 615, 578 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{13}H_{18}BrNO$ 284.0645; Found: 284.0646.



(**5-Br**)

To a 100 mL Schlenk flask containing a solution of dicyclohexylamine (2.48 g, 13.7 mmol, 1.50 equiv), in anhydrous Et_2O (45 mL) was added $^{i}Pr_2NEt$ (1.77 g, 13.7 mmol, 1.50 equiv).[1] The reaction mixture was cooled to 0 °C using an ice bath and 2-bromobenzoyl chloride (2.00 g, 9.11 mmol, 1.00 equiv) was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 15 h. The reaction mixture was then diluted with EtOAc (40 mL) and transferred to a separatory funnel and extracted with brine (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 75/25 hexanes/EtOAc (R_f = 0.35 in 80% hexanes/20% ethyl acetate) to afford product **5-Br** as a white solid (2.14 g, 64% yield); mp = 127-129 °C.

^1H NMR ($CDCl_3$): δ 7.53 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.29 (td, *J* = 7.5, 1.2 Hz, 1H), 7.17 (td, *J* = 7.7, 1.8 Hz, 1H), 7.13 (dd, *J* = 7.4, 1.8 Hz, 1H), 3.11-3.02 (multiple peaks, 2H), 2.72-2.60 (multiple peaks, 2H), 2.00-1.39 (multiple peaks, 12H), 1.35-1.20 (multiple peaks, 3H), 1.10-0.85 (multiple peaks, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 168.4, 140.2, 132.7, 129.3, 127.4, 126.4, 118.8, 60.1, 56.1, 31.2, 31.0, 29.8, 29.5, 26.6, 26.5, 25.62, 25.56, 25.3, 25.0. IR (neat): 2921,1632, 1431, 1366, 1314, 1183, 1130, 990, 892, 761, 749, 740, 725, 692, 648, 596 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{19}H_{26}BrNO$ 364.1271; Found: 364.1271.



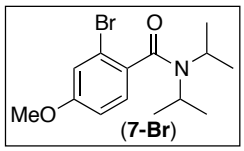
(**6-Br**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-bromo-4-methylbenzoic acid (400 mg, 1.86 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (2 drops) and $SOCl_2$ (266 mg, 2.24 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 °C for 2.5 h and then cooled to room temperature to afford a solution of the intermediate benzoyl chloride. Two such reactions were conducted and the solution of the 2-bromo-4-methylbenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (565 mg, 5.58 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (37 mL) was added Et_3N (1.13 g, 11.2 mmol, 3.00 equiv) under

a N_2 atmosphere. The reaction mixture was cooled to 0 ºC using an ice bath and the solution of the 2-bromo-4-methylbenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 15 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 80/20 to 70/30 hexanes/EtOAc (R_f = 0.44 in 75% hexanes/25% ethyl acetate) to afford product **6-Br** as a white solid (719 mg, 65% yield); mp = 119-120 °C.

^{1}H NMR ($CDCl_3$): δ 7.36 (s, 1H), 7.10 (d, *J* = 7.7 Hz, 1H), 7.04 (d, *J* = 7.7 Hz, 1H), 3.60 (sept, *J* = 6.7 Hz, 1H), 3.49 (sept, *J* = 6.8 Hz, 1H), 2.32 (s, 3H), 1.56 (d, *J* = 6.7 Hz, 3H), 1.54 (d, *J* = 6.7 Hz, 3H), 1.21 (d, *J* = 6.7 Hz, 3H), 1.04 (d, *J* = 6.7 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 168.3, 139.6, 137.2, 133.1, 128.2, 126.3, 118.6, 51.1, 45.9, 20.8, 20.7, 20.6, 20.5, 20.1. IR (neat): 2969, 1627, 1602, 1437, 1369, 1337, 1210, 1046, 1028, 832, 808, 589 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{20}BrNO$ 298.0801; Found: 298.0799.



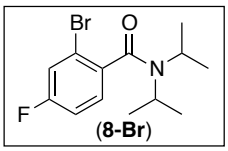
(**7-Br**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-bromo-4-methoxy benzoic acid (400 mg, 1.73 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (2 drops) and $SOCl_2$ (247 mg, 2.08 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 ºC for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-bromo-4-methoxybenzoyl chloride. Two such reactions were conducted and the solution of the 2-bromo-4-methoxybenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (526 mg, 5.19 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (17 mL) was added Et_3N (1.05 g, 10.4 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 ºC using an ice bath and the solution of the 2-bromo-4-methoxybenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 18 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 75/25 hexanes/EtOAc (R_f = 0.35 in 75% hexanes/25% ethyl acetate) to afford product **7-Br** as a white solid (733 mg, 67% yield); mp = 99-101 °C.

^{1}H NMR ($CDCl_3$): δ 7.09 (d, *J* = 8.4 Hz, 1H), 7.08 (d, *J* = 2.4 Hz, 1H), 6.84 (dd, *J* = 8.4, 2.4 Hz, 1H), 3.78 (s, 3H), 3.63 (sept, *J* = 6.7 Hz, 1H), 3.50 (sept, *J* = 6.8 Hz, 1H), 1.55 (d, *J* = 6.6 Hz, 3H), 1.53 (d,

J = 6.6 Hz, 3H), 1.21 (d, J = 6.7 Hz, 3H), 1.04 (d, J = 6.7 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$: δ 168.2, 159.6, 132.7, 127.2, 119.4, 117.9, 113.6, 55.5, 51.1, 45.8, 20.8, 20.62, 20.58, 20.1. IR (neat): 2966, 1621, 1600, 1434, 1368, 1339, 1294, 1270, 1231, 1212, 1195, 1155, 1040, 859, 802, 594 cm^{-1}. HRMS $[M+Na]^+$ Calcd for $C_{14}H_{20}BrNO_2$ 336.0570; Found: 336.0569.

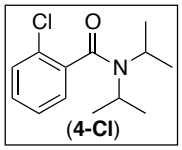


(**8-Br**)

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (607 mg, 6.00 mmol, 1.50 equiv), in anhydrous Et_2O (20 mL) was added $^iPr_2NEt$ (0.99 mL, 6.00 mmol, 1.50 equiv). The reaction mixture was cooled to 0 ºC using an ice bath and 2-bromo-4-fluorobenzoyl chloride (950 mg, 4.00 mmol, 1.00 equiv) was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 1h. The reaction mixture was then diluted with EtOAc (20 mL) and transferred to a separatory funnel and extracted with brine (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 85/15 hexanes/EtOAc (R_f = 0.37 in 85% hexanes/15% ethyl acetate) to afford product **8-Br** as a light yellow solid (956 mg, 79% yield); mp = 98-99 °C.[1]

^1H NMR ($CDCl_3$): δ 7.30 (dd, J = 8.3, 2.4 Hz, 1H), 7.15 (dd, J = 8.4, 5.8 Hz, 1H), 7.04 (td, J = 8.3, 2.4 Hz, 1H), 3.56 (sept, J = 6.7 Hz, 1H), 3.52 (sept, J = 6.8 Hz, 1H), 1.55 (d, J = 6.5 Hz, 3H), 1.54 (d, J = 6.5 Hz, 3H), 1.22 (d, J = 6.7 Hz, 3H), 1.05 (d, J = 6.7 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 167.4, 161.7 ($^1J_{C\text{-}F}$ = 250 Hz), 136.4 ($^4J_{C\text{-}F}$ = 3.7 Hz), 127.6 ($^3J_{C\text{-}F}$ = 8.4 Hz), 120.2 ($^2J_{C\text{-}F}$ = 24 Hz), 119.3 ($^3J_{C\text{-}F}$ = 9.5 Hz), 114.9 ($^2J_{C\text{-}F}$ = 21 Hz), 51.2, 46.0, 20.7, 20.6, 20.0 (One of the carbons is coincidentally overlapping). IR (neat): 2969, 1628, 1594, 1439, 1371, 1338, 1254, 1211, 1044, 1029, 883, 869, 833, 813, 593, 585 cm^{-1}. HRMS $[M+Na]^+$ Calcd for $C_{13}H_{17}BrFNO$ 324.0370; Found: 324.0365.

Synthesis and Characterization of Chloride Substrates in Table 3:

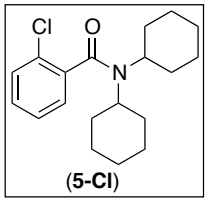


(**4-Cl**)

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (1.39 g, 13.7 mmol, 1.50 equiv), in anhydrous Et_2O (46 mL) was added $^iPr_2NEt$ (1.77 g, 13.7 mmol, 1.50 equiv). The reaction mixture was cooled to 0 ºC using an ice bath and 2-chlorobenzoyl chloride (1.59 g, 9.09 mmol, 1.00 equiv) was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 1h. The reaction mixture was then diluted with EtOAc (40 mL) and transferred to a separatory funnel and extracted with brine (3 x 50 mL). The organic layer was dried over

$MgSO_4$, concentrated and chromatographed on a silica gel column using 75/25 hexanes/EtOAc (R_f = 0.43 in 75% hexanes/25% ethyl acetate) to afford product **4-Cl** as a white solid (1.15 g, 53% yield); mp = 126-128 °C.[1]

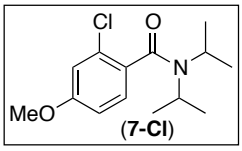
^{1}H NMR ($CDCl_3$): δ 7.39-7.34 (m, 1H), 7.28-7.24 (multiple peaks, 2H), 7.21-7.18 (m, 1H), 3.59 (sept, *J* = 6.7 Hz, 1H), 3.52 (sept, *J* = 6.8 Hz, 1H), 1.57 (d, *J* = 6.8 Hz, 3H), 1.56 (d, *J* = 6.8 Hz, 3H), 1.20 (d, *J* = 6.7 Hz, 3H), 1.05 (d, *J* = 6.7 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.4, 138.0, 130.0, 129.6, 129.3, 127.0, 126.6, 51.1, 45.9, 20.8, 20.64, 20.56, 20.1. IR (neat): 2972, 1624, 1590, 1440, 1431, 1370, 1340, 1210, 1053, 1032, 775, 742, 714, 615, 578 cm^{-1}. HRMS [M+H]$^+$ Calcd for $C_{13}H_{18}ClNO$ 240.1150; Found: 240.1147.



(**5-Cl**)

To a 100 mL Schlenk flask containing a solution of dicyclohexylamine (2.48 g, 13.7 mmol, 1.5 equiv), in anhydrous Et_2O (46 mL) was added ^{i}Pr$_2$NEt (1.77 g, 13.7 mmol, 1.5 equiv). The reaction mixture was cooled to 0 °C using an ice bath and 2-chlorobenzoyl chloride (1.59 g, 9.09 mmol, 1.0 equiv) was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 1h. The reaction mixture was then diluted with EtOAc (40 mL) and transferred to a separatory funnel and extracted with brine (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 85/15 hexanes/EtOAc (R_f = 0.41 in 85% hexanes/15% ethyl acetate) to afford product **5-Cl** as a white solid (2.24g, 77% yield); mp = 115-119 °C.[1]

^{1}H NMR ($CDCl_3$): δ 7.39-7.35 (m, 1H), 7.29-7.24 (multiple peaks, 2H), 7.19-7.15 (m, 1H), 3.14-3.02 (multiple peaks, 2H), 2.72-2.58 (multiple peaks, 2H), 1.94-0.83 (multiple peaks, 18H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.6, 138.1, 129.9, 129.5, 129.2, 126.9, 126.4, 60.0, 56.1, 31.2, 31.1, 29.9, 29.5, 26.6, 26.5, 25.65, 25.59, 25.3, 25.0. IR (neat): 2923, 1633, 1435, 1364, 1313, 1126, 991, 765, 748, 708, 656, 601 cm^{-1}. HRMS [M+H]$^+$ Calcd for $C_{19}H_{26}ClNO$ 320.1776; Found: 320.1779.



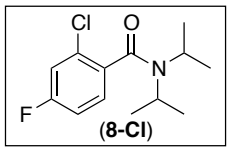
(**7-Cl**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-chloro-4-methoxybenzoic acid (400 mg, 2.14 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (2 drops) and $SOCl_2$ (306 mg, 2.57 mmol, 1.20 equiv). The vial was

sealed with a teflon lined cap and the reaction mixture was stirred at 80 °C for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-chloro-4-methoxybenzoyl chloride. Two such reactions were conducted and the solution of the 2-chloro-4-methoxybenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (651 mg, 6.43 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (43 mL) was added Et_3N (1.30 g, 12.9 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 °C using an ice bath and the solution of the 2-chloro-4-methoxybenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 15 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 80/20 to 70/30 hexanes/EtOAc (R_f = 0.39 in 75% hexanes/25% ethyl acetate) to afford product **7-Cl** as a white solid (874 mg, 76% yield); mp = 92-94 °C.

^{1}H NMR ($CDCl_3$): δ 7.09 (d, *J* = 8.4 Hz, 1H), 6.89 (d, *J* = 2.4 Hz, 1H), 6.79 (dd, *J* = 8.5, 2.4 Hz, 1H), 3.78 (s, 3H), 3.62 (sept, *J* = 6.7 Hz, 1H), 3.49 (sept, *J* = 6.8 Hz, 1H), 1.54 (d, *J* = 6.8 Hz, 3H), 1.53 (d, *J* = 6.8 Hz, 3H), 1.19 (d, *J* = 6.6 Hz, 3H), 1.04 (d, *J* = 6.6 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.5, 159.7, 130.8, 130.5, 127.3, 114.8, 113.1, 55.5, 51.0, 45.8, 20.8, 20.62, 20.56, 20.1. IR (neat): 2968, 1616, 1602, 1436, 1369, 1339, 1300, 1288, 1271, 1237, 1213, 1195, 1048, 1024, 860, 846, 809, 595 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{20}ClNO_2$ 270.1255; Found: 270.1254.

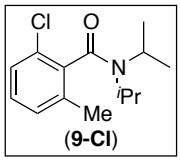


(**8-Cl**)

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (1.39 g, 13.7 mmol, 1.50 equiv), in anhydrous Et_2O (46 mL) was added ^{i}Pr$_2$NEt (1.77 g, 13.7 mmol, 1.50 equiv). The reaction mixture was cooled to 0 °C using an ice bath and 2-chloro-4-fluorobenzoyl chloride (1.76 g, 9.11 mmol, 1.00 equiv) was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 1h. The reaction mixture was then diluted with EtOAc (40 mL) and transferred to a separatory funnel and extracted with brine (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 80/20 hexanes/EtOAc (R_f = 0.38 in 80% hexanes/20% ethyl acetate) to afford product **8-Cl** as a white solid (1.80 g, 77% yield); mp = 105-107 °C.[1]

^{1}H NMR ($CDCl_3$): δ 7.17 (dd, *J* = 8.5, 6.0 Hz, 1H), 7.12 (dd, *J* = 8.6, 2.4 Hz, 1H), 6.99 (td, *J* = 8.3, 2.5 Hz, 1H), 3.56 (sept, *J* = 6.7 Hz, 1H), 3.51 (sept, *J* = 6.8 Hz, 1H), 1.55 (d, *J* = 6.8 Hz, 3H), 1.54 (d, *J* = 6.8 Hz, 3H), 1.20 (d, *J* = 6.7 Hz, 3H), 1.05 (d, *J* = 6.7 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 166.6, 161.9 ($^1J_{C\text{-}F}$ = 249 Hz), 134.3 ($^4J_{C\text{-}F}$ = 3.9 Hz), 131.1 ($^3J_{C\text{-}F}$ = 10 Hz), 127.8 ($^3J_{C\text{-}F}$ = 8.8 Hz), 117.1 ($^2J_{C\text{-}F}$ = 25

Hz), 114.4 ($^2J_{C\text{-}F}$ = 21 Hz), 51.1, 46.0, 20.8, 20.6, 20.1 [One of the carbons is coincidentally overlapping]. IR (neat): 2967, 1626, 1598, 1442, 1371, 1339, 1261, 1212, 1156, 1050, 1032, 923, 896, 884, 848, 824, 814, 586 cm^{-1}. HRMS $[M+Na]^+$ Calcd for $C_{13}H_{17}ClFNO$ 280.0875; Found: 280.0888.



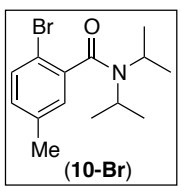
(**9-Cl**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-chloro-6-methylbenzoic acid (500 mg, 2.93 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (2 drops) and $SOCl_2$ (418 mg, 3.52 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 °C for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-chloro-6-methylbenzoyl chloride. Two such reactions were conducted and the solution of the 2-chloro-6-methylbenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N*,*N*-diisopropylamine (890 mg, 8.79 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (40 mL) was added Et_3N (1.78 g, 17.6 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 °C using an ice bath and the solution of 2-chloro-6-methylbenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 15 h. The reaction mixture was then transferred to a separatory funnel and extracted with brine (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 85/15 to 80/20 hexanes/EtOAc (R_f = 0.37 in 80% hexanes/20% ethyl acetate) to afford product **9-Cl** as a white solid (232 mg, 16% yield); mp = 142-143 °C.

^1H NMR ($CDCl_3$): δ 7.18 (d, *J* = 7.8 Hz, 1H), 7.13 (t, *J* = 7.6 Hz, 1H), 7.09 (d, *J* = 7.4 Hz, 1H), 3.59 (sept, *J* = 6.6 Hz, 1H), 3.52 (sept, *J* = 6.8 Hz, 1H), 2.31 (s, 3H), 1.60 (d, *J* = 7.4 Hz, 3H), 1.58 (d, *J* = 7.2 Hz, 3H), 1.21 (d, *J* = 6.6 Hz, 3H), 1.11 (d, *J* = 6.7 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 166.9, 137.3, 136.0, 130.1, 128.6, 128.5, 126.7, 51.2, 46.1, 21.2, 20.8, 20.5, 20.2, 19.1. IR (neat): 2980, 1623, 1445, 1370, 1334, 787, 759 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{20}ClNO$ 254.1306; Found: 254.1302.

Synthesis and Characterization of Substrates in Table 4:

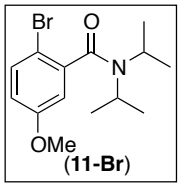


(**10-Br**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-bromo-5-methylbenzoic acid (500 mg, 2.33 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (3 drops) and $SOCl_2$ (332 mg, 2.79 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 °C for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-bromo-5-methylbenzoyl chloride. Two such reactions were conducted and the solution of the 2-bromo-5-methylbenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (706 mg, 6.98 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (23 mL) was added Et_3N (1.41 g, 14.0 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 °C using an ice bath and the solution of the 2-bromo-5-methylbenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 19 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 85/15 hexanes/EtOAc (R_f = 0.32 in 85% hexanes/15% ethyl acetate) to afford product **10-Br** as a white solid (803 mg, 58% yield); mp = 159-161 °C.

^1H NMR ($CDCl_3$): δ 7.40 (d, *J* = 8.0 Hz, 1H), 7.02-6.97 (multiple peaks, 2H), 3.61 (sept, *J* = 6.7 Hz, 1H), 3.51 (sept, *J* = 6.8 Hz, 1H), 2.29 (s, 3H), 1.58 (d, *J* = 6.8 Hz, 3H), 1.55 (d, *J* = 6.8 Hz, 3H), 1.23 (d, *J* = 6.7 Hz, 3H), 1.06 (d, *J* = 6.7 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 168.3, 139.8, 137.6, 132.5, 130.3, 127.1, 115.4, 51.1, 45.9, 20.84, 20.79, 20.6, 20.5, 20.0. IR (neat): 2961, 1626, 1441, 1370, 1338, 1209, 1044, 1023, 832, 804, 622, 594 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{20}BrNO$ 298.0801; Found: 298.0799.



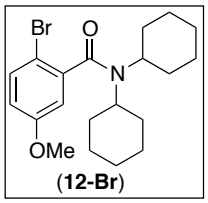
(**11-Br**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-bromo-5-methylbenzoic acid (500 mg, 2.16 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (3 drops) and $SOCl_2$ (309 mg, 2.60 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 °C for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-bromo-5-methoxybenzoyl chloride. [2]

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (330 mg, 3.25 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (22 mL) was added Et_3N (657 mg, 6.49 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 °C using an ice bath and the

solution of the 2-bromo-5-methoxybenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 19 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 75/25 hexanes/EtOAc (R_f = 0.24 in 80% hexanes/20% ethyl acetate) to afford product **11-Br** as a white solid (224 mg, 33% yield); mp = 172-174 °C.[2]

^{1}H NMR ($CDCl_3$): δ 7.41 (d, *J* = 8.6 Hz, 1H), 6.74 (dd, *J* = 8.7, 2.9 Hz, 1H), 6.70 (d, *J* = 2.7 Hz, 1H), 3.78 (s, 3H), 3.62 (sept, *J* = 6.7 Hz, 1H), 3.51 (sept, *J* = 6.8 Hz, 1H), 1.57 (d, *J* = 6.8 Hz, 3H), 1.55 (d, *J* = 6.7 Hz, 3H), 1.24 (d, *J* = 6.7 Hz, 3H), 1.07 (d, *J* = 6.6 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.9, 159.0, 140.7, 133.6, 115.6, 111.9, 109.1, 55.6, 51.1, 45.9, 20.9, 20.7, 20.5, 20.0. IR (neat): 2966, 1625, 1466, 1456, 1440, 1370, 1338, 1288, 1272, 1235, 1171, 1144, 1033, 1016, 876, 828, 803, 603 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{20}BrNO_2$ 314.0750; Found: 314.0746.



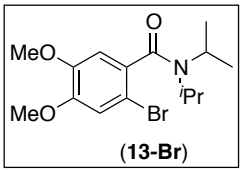
(**12-Br**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-bromo-5-methoxy benzoic acid (500 mg, 2.16 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (2 drops) and $SOCl_2$ (309 mg, 2.60 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 ºC for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-bromo-5-methoxybenzoyl chloride. Two such reactions were conducted and the solution of the 2-bromo-5-methoxybenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N,N*-dicyclohexylamine (1.18 g, 6.49 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (43 mL) was added Et_3N (1.31 g, 13.0 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 ºC using an ice bath and the solution of the 2-bromo-5-methoxybenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 15 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 85/15 hexanes/EtOAc (R_f = 0.28 in 85% hexanes/15% ethyl acetate) to afford product **12-Br** as a white solid (305 mg, 18% yield); mp = 162-163 °C.

^{1}H NMR ($CDCl_3$): δ 7.40 (d, *J* = 8.8 Hz, 1H), 6.73 (dd, *J* = 8.8, 3.0 Hz, 1H), 6.67 (d, *J* = 3.0 Hz, 1H), 3.76 (s, 3H), 3.17-3.01 (multiple peaks, 2H), 2.72-2.59 (multiple peaks, 2H), 2.05-1.40 (multiple peaks, 12H), 1.35-1.20 (multiple peaks, 3H), 1.12-0.85 (multiple peaks, 3H). ^{13}C{^{1}H} NMR

($CDCl_3$): δ 168.1, 158.9, 140.9, 133.5, 115.5, 111.8, 109.1, 60.0, 56.1, 55.5, 31.3, 31.0, 29.9, 29.4, 26.6, 26.5, 25.62, 25.58, 25.3, 25.0. IR (neat): 2926, 1637, 1566, 1455, 1434, 1361, 1311, 1291, 1235, 1120, 1053, 1014, 992, 873, 809, 602 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{20}H_{28}BrNO_2$ 394.1376; Found: 394.1386.

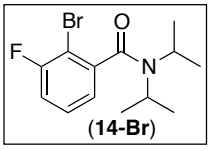


(**13-Br**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-bromo-4,5-dimethoxybenzoic acid (500 mg, 1.92 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (2 drops) and $SOCl_2$ (273 mg, 2.30 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 ºC for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-bromo-4,5-dimethoxybenzoyl chloride. Two such reactions were conducted and the solution of the 2-bromo-4,5-dimethoxybenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (581 mg, 5.75 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (38 mL) was added Et_3N (1.16 g, 11.5 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 ºC using an ice bath and the solution of the 2-bromo-4-5-dimethoxybenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 15 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 70/30 hexanes/EtOAc (R_f = 0.37 in 70% hexanes/30% ethyl acetate) to afford product **13-Br** as a white solid (785 mg, 60% yield); mp = 119-121 °C.

^1H NMR ($CDCl_3$): δ 6.99 (s, 1H), 6.67 (s, 1H), 3.88 (s, 3H), 3.85 (s, 3H), 3.65 (sept, *J* = 6.7, 1H), 3.51 (sept, *J* = 6.8 Hz, 1H), 1.56 (d, *J* = 6.8 Hz, 6H), 1.24 (d, *J* = 6.6 Hz, 3H), 1.07 (d, *J* = 6.7 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): 168.1, 149.2, 148.5, 132.1, 115.3, 109.2, 109.0, 56.11, 56.09, 51.1, 45.9, 20.9, 20.66, 20.50, 20.0. IR (neat): 2975, 1625, 1597, 1506, 1442, 1368, 1329, 1255, 1213, 1196, 1169, 1044, 1027, 879, 820, 789, 753, 650, 612 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{15}H_{22}BrNO_3$ 344.0856; Found: 344.0860.

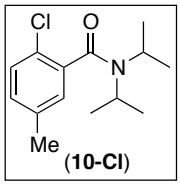


(**14-Br**)

To a 20 mL scintillation vial containing a magnetic stirbar and a solution of 2-bromo-3-fluorobenzoic acid (500 mg, 2.28 mmol, 1.00 equiv) in anhydrous toluene (8.0 mL) were added anhydrous DMF (3 drops) and $SOCl_2$ (326 mg, 2.74 mmol, 1.20 equiv). The vial was sealed with a teflon lined cap and the reaction mixture was stirred at 80 ºC for 2.5 h and then cooled to room temperature to afford a solution of the intermediate 2-bromo-3-fluorobenzoyl chloride. Two such reactions were conducted and the solution of the 2-bromo-3-fluorobenzoyl chloride obtained from each reaction was combined for the next step.[2]

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (693 mg, 6.85 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (46 mL) was added Et_3N (1.39 g, 13.7 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 ºC using an ice bath and the solution of the 2-bromo-3-fluorobenzoyl chloride obtained in the first step was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 15 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 75/25 hexanes/EtOAc (R_f = 0.34 in 75% hexanes/25% ethyl acetate) to afford product **14-Br** as a white solid (1.13 g, 82% yield); mp = 132-134 °C.

^{1}H NMR ($CDCl_3$): δ 7.29 (td, *J* = 7.9, 5.0 Hz, 1H), 7.07 (td, *J* = 8.4, 1.4 Hz, 1H), 6.96 (d, *J* = 7.5 Hz, 1H), 3.56 (sept, *J* = 6.7 Hz, 1H), 3.52 (sept, *J* = 6.8 Hz, 1H), 1.57 (d, *J* = 6.9 Hz, 3H), 1.55 (d, *J* = 7.0 Hz, 3H), 1.22 (d, *J* = 6.7 Hz, 3H), 1.06 (d, *J* = 6.7 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 166.8 ($^4J_{C\text{-}F}$ = 2.5 Hz), 159.1($^1J_{C\text{-}F}$ = 248 Hz), 142.2, 129.2 ($^3J_{C\text{-}F}$ = 7.8 Hz), 121.8 ($^4J_{C\text{-}F}$ = 3.7 Hz), 115.8 ($^2J_{C\text{-}F}$ = 22 Hz), 106.3 ($^2J_{C\text{-}F}$ = 22 Hz), 51.2, 46.1, 20.7, 20.6, 20.5, 20.0. IR (neat): 2970, 2959, 2933, 1625, 1438, 1428, 1340, 817, 790 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{13}H_{17}BrFNO$ 302.0550; Found: 302.0542.



(10-Cl)

To a 100 mL Schlenk flask containing a solution of *N,N*-diisopropylamine (675 mg, 6.67 mmol, 1.50 equiv), in anhydrous CH_2Cl_2 (34.5 mL) was added Et_3N (1.35 g, 13.3 mmol, 3.00 equiv) under a N_2 atmosphere. The reaction mixture was cooled to 0 ºC using an ice bath and solution of 2-chloro-5-methylbenzoyl chloride (840 mg, 4.44 mmol, 1.00 equiv) in anhydrous CH_2Cl_2 (10.0 mL) was added to it dropwise. The resulting mixture was allowed to stir at room temperature for 40 h. The reaction mixture was then transferred to a separatory funnel and extracted with H_2O (3 x 50 mL). The organic layer was dried over $MgSO_4$, concentrated and chromatographed on a silica gel column using 80/20 hexanes/EtOAc (R_f = 0.38 in 80% hexanes/20% ethyl acetate) to afford product **10-Cl** as a white solid (742 mg, 66% yield); mp = 152-155 °C.[2]

^{1}H NMR ($CDCl_3$): δ 7.22 (d, *J* = 8.2 Hz, 1H), 7.05 (d, *J* = 8.2 Hz, 1H), 6.99 (s, 1H), 3.61 (sept, *J* = 6.7 Hz, 1H), 3.50 (sept, *J* = 6.8 Hz, 1H), 2.30 (s, 3H), 1.553 (d, *J* = 6.8 Hz, 3H), 1.549 (d, *J* = 6.8 Hz, 3H), 1.20 (d, *J* = 6.7 Hz, 3H), 1.05 (d, *J* = 6.7 Hz, 3H). $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 167.5, 137.7, 137.0, 130.0, 129.2, 127.0, 126.8, 51.0, 45.8, 20.79, 20.76, 20.6, 20.5, 20.1. IR (neat): 2962, 2929, 1625, 1443, 1370, 1339, 1210, 1053, 1034, 833, 806, 628, 622, 599 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{20}ClNO$ 254.1306; Found: 254.1311.

General procedures for Arylations (Tables 2-4):

General Procedure **A** (phenanthroline catalysis) for solid substrates: To a 20 mL scintillation vial containing a magnetic stir bar was added substrate and 1,10-phenanthroline and the vial was taken into the glove box. To this vial, NaOtBu and anhydrous dioxane were added in the glove box. The vial was sealed with a Teflon lined cap, taken out of the glove box and the reaction mixture was allowed to stir at the 145 °C for the indicated time. The reaction mixture was cooled to room temperature and filtered through a 1.5 inch plug of silica gel, eluting with EtOAc (100 mL). The filtrate was concentrated and chromatographed on a silica gel column to afford the product.

General Procedure **B** (phenanthroline catalysis) for liquid substrates: To a 20 mL scintillation vial containing a magnetic stir bar was added 1,10-phenanthroline and the vial was taken into the glove box. To this vial, NaOtBu and a solution of substrate in anhydrous dioxane were added in the glove box. The vial was sealed with a Teflon lined cap, taken out of the glove box and the reaction mixture was allowed to stir at 145 °C for the indicated time. The reaction mixture was cooled to room temperature and filtered through a 1.5 inch plug of silica gel, eluting with EtOAc (100 mL). The filtrate was concentrated and chromatographed on a silica gel column to afford the product.

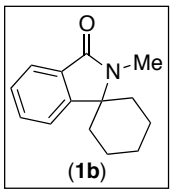
General Procedure **C** (Ni catalysis) for solid substrates: To an oven dried 20 mL scintillation vial containing a magnetic stir bar and the substrate was added $Ni(COD)_2$, NaOtBu and anhydrous dioxane in the glove box. The vial was sealed with a Teflon lined cap, taken out of the glove box and the reaction mixture was allowed to stir at the 145 °C for the indicated time. The reaction mixture was cooled to room temperature and filtered through a 1.5 inch plug of silica gel, eluting

with EtOAc (100 mL). The filtrate was concentrated and chromatographed on a silica gel column to afford the product.

Control reactions:

Control reactions in the absence of the catalyst were run for each substrate. These reactions afforded either little (upto ~10%) or none of the desired product. The only exception was the control reaction of substrate **3-Br** that led to 23% of the desired product in the absence of any catalyst.

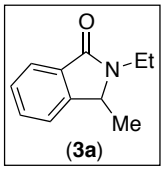
Procedures and Spectral Characterization of Arylation Products in Table 2



(**1b**)

Following general procedure **A**, **1-Br** (148 mg, 0.500 mmol, 1.00 equiv), phenanthroline (18.0 mg, 0.100 mmol, 0.20 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.50 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 70/30 hexanes/EtOAc to 50/50 hexanes/EtOAc (R_f = 0.20 in 70% hexanes/30% ethyl acetate) yielded product **1b** as a yellow solid (43.8 mg, 41% yield); mp = 78-82 °C.

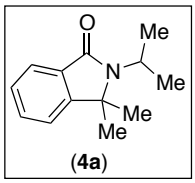
^{1}H NMR ($CDCl_3$): δ 7.85 (d, *J* = 7.0 Hz, 1H), 7.76 (d, *J* = 7.4 Hz, 1H), 7.47 (td, *J* = 7.4, 1.5 Hz, 1H), 7.42 (td, *J* = 7.4, 1.2 Hz, 1H), 3.01 (s, 3H), 2.01-1.82 (multiple peaks, 7H), 1.45-1.30 (multiple peaks, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.3, 150.5, 131.5, 130.4, 127.7, 123.6, 123.3, 64.2, 32.7, 24.6, 24.1, 22.3. IR (neat): 2940, 1680, 1471, 1417, 1394, 1050, 771, 697, 562 cm^{-1}. HRMS $[M+Na]^+$ Calcd for $C_{14}H_{17}NO$ 238.1202; Found: 238.1206.



(**3a**)

Following general procedure **B**, **3-Br** (128 mg, 0.50 mmol, 1.0 equiv), phenanthroline (18.0 mg, 0.10 mmol, 0.20 equiv), NaOtBu (72.1 mg, 0.75 mmol, 1.5 equiv) and anhydrous dioxane (2.0 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 55/45 hexanes/EtOAc to 50/50 hexanes/EtOAc (R_f = 0.31 in 55% hexanes/45% ethyl acetate) yielded product **3a** as a colorless oil (41.4 mg, 47% yield).

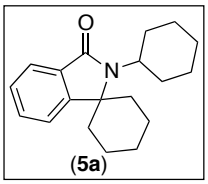
^{1}H NMR ($CDCl_3$): δ 7.82 (d, *J* = 7.5 Hz, 1H), 7.52 (td, *J* = 7.4, 1.1 Hz, 1H), 7.45-7.40 (multiple peaks, 2H), 4.56 (q, *J* = 6.7 Hz, 1H), 4.01-3.92 (m, 1H), 3.34-3.26 (m, 1H), 1.46 (d, *J* = 6.8 Hz, 3H), 1.24 (t, *J* = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.7, 146.8, 132.1, 131.2, 128.0, 123.4, 121.8, 55.1, 34.5, 18.1, 13.8. IR (neat): 2974, 1667, 1469, 1408, 1375, 1323, 759, 725, 694, 605 cm^{-1}. HRMS [M+Na]$^+$ Calcd for $C_{11}H_{13}NO$ 198.0889; Found: 198.0888.



(**4a**)

Following general procedure **A**, **4**-**Br** (150 mg, 0.528 mmol, 1.0 equiv), phenanthroline (19.1 mg, 0.106 mmol, 0.20 equiv), NaOtBu (76.1 mg, 0.792 mmol, 1.50 equiv) and anhydrous dioxane (2.11 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 22 h. Chromatography on a silica gel column using 70/30 hexanes/EtOAc (R_f = 0.39 in 70% hexanes/30% ethyl acetate) yielded product **4a** as a white solid (95.6 mg, 89% yield); mp = 138-141 °C.

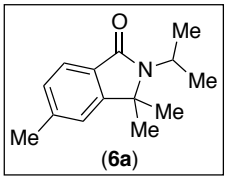
^{1}H NMR ($CDCl_3$): δ 7.72 (d, *J* = 7.5 Hz, 1H), 7.45 (td, *J* = 7.5, 1.2 Hz, 1H), 7.34 (td, *J* = 7.5, 1.0 Hz, 1H), 7.29 (d, *J* = 7.6 Hz, 1H), 3.60 (sept, *J* = 6.8 Hz, 1H), 1.51 (d, *J* = 6.8 Hz, 6H), 1.42 (s, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.0, 151.1, 131.8, 131.1, 127.6, 122.9, 120.5, 63.1, 44.4, 25.3, 20.3. IR (neat): 2969, 1671, 1416, 1344, 766, 698, 568 cm^{-1}. HRMS [M+Na]$^+$ Calcd for $C_{13}H_{17}NO$ 226.1202; Found: 226.1207.



(**5a**)

Following general procedure **A**, **5**-**Br** (192 mg, 0.528 mmol, 1.0 equiv), phenanthroline (19.1 mg, 0.106 mmol, 0.20 equiv), NaOtBu (76.1 mg, 0.792 mmol, 1.5 equiv) and anhydrous dioxane (2.11 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 22 h. Chromatography on a silica gel column using 80/20 hexanes/EtOAc (R_f = 0.37 in 80% hexanes/20% ethyl acetate) yielded product **5a** as a white solid (141.6 mg, 95% yield); mp = 162-165 °C.

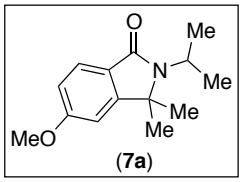
^{1}H NMR ($CDCl_3$): δ 7.76 (d, *J* = 7.0 Hz, 1H), 7.71 (d, *J* = 7.1 Hz, 1H), 7.43-7.34 (multiple peaks, 2H), 3.12-3.04 (m, 1H), 2.64-2.51 (multiple peaks, 2H), 1.94-1.21 (multiple peaks, 18H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.0, 149.9, 132.5, 130.1, 127.5, 123.1, 123.0, 65.8, 52.8, 32.9, 29.8, 26.4, 25.1, 24.5, 22.4. IR (neat): 2929, 2862, 1673, 1383, 756, 696, 560 cm^{-1}. HRMS [M+H]$^+$ Calcd for $C_{19}H_{25}NO$ 284.2009; Found: 284.1996.



(**6a**)

Following general procedure **A**, **6-Br** (149 mg, 0.500 mmol, 1.0 equiv), phenanthroline (18.0 mg, 0.100 mmol, 0.20 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 85/15 hexanes/EtOAc (R_f = 0.27 in 85% hexanes/15% ethyl acetate) yielded product **6a** as a white solid (97.6 mg, 90% yield); mp = 150-152 °C.

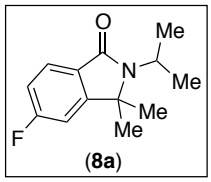
^{1}H NMR ($CDCl_3$): δ 7.61 (d, *J* = 7.6 Hz, 1H), 7.16 (d, *J* = 7.7 Hz, 1H), 7.10 (s, 1H), 3.59 (sept, *J* = 6.9 Hz, 1H), 2.40 (s, 3H), 1.51 (d, *J* = 6.9 Hz, 6H), 1.42 (s, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.2, 151.5, 141.6, 129.3, 128.7, 122.8, 121.0, 62.9, 44.3, 25.3, 21.8, 20.4. IR (neat): 2970, 1669, 1349, 786 701 cm^{-1}. HRMS $[M+Na]^+$ Calcd for $C_{14}H_{19}NO$ 240.1359; Found: 240.1359.



(**7a**)

Following general procedure **C**, **7-Br** (157 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.05 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 3 h. Chromatography on a silica gel column using 75/15/10 hexanes/CH_2Cl_2/acetone (R_f = 0.19 in 75% hexanes/15% CH_2Cl_2/10% Acetone) yielded product **7a** as a white solid (92.8 mg, 80% yield); mp = 136-138 °C.

^{1}H NMR ($CDCl_3$): δ 7.68 (d, *J* = 8.31H), 6.92 (dd, *J* = 8.3, 2.2 Hz, 1H), 6.80 (d, *J* = 2.2 Hz, 1H), 3.87 (s, 3H), 3.62 (sept, *J* = 6.8 Hz, 1H), 1.54 (d, *J* = 6.8 Hz, 6H), 1.45 (s, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.0, 162.5, 153.4, 124.6, 124.5, 113.8, 105.8, 62.8, 55.5, 44.4, 25.5, 20.5. IR (neat): 2980, 2970, 1664, 1621, 1417, 1378, 1365, 1350, 1289, 1226, 1213, 1194, 1170, 1066, 1030, 912, 847, 830, 786, 702, 670 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{19}NO_2$ 234.1489; Found: 234.1477.



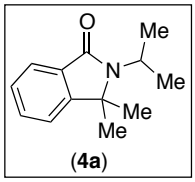
(**8a**)

Following general procedure **C**, **8-Br** (151 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.05 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL)

were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 75/20/5 hexanes/CH_2Cl_2/acetone (R_f = 0.23 in 75% hexanes/20% CH_2Cl_2/5% Acetone) yielded product **8a** as a white solid (66.8 mg, 60% yield); mp = 166-169 °C.

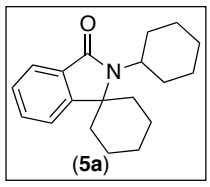
^{1}H NMR ($CDCl_3$): δ 7.72 (dd, *J* = 8.3, 5.1 Hz, 1H), 7.07 (td, *J* = 8.4, 2.1 Hz, 1H), 7.00 (dd, *J* = 8.2, 2.2 Hz, 1H), 3.61 (sept, *J* = 6.9 Hz, 1H), 1.53 (d, *J* = 6.8 Hz, 6H), 1.46 (s, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 166.2, 164.9 ($^1J_{C\text{-}F}$ = 248 Hz), 153.5 ($^3J_{C\text{-}F}$ = 8.5 Hz), 127.9 ($^4J_{C\text{-}F}$ = 2.1 Hz), 125.2 ($^3J_{C\text{-}F}$ = 9.5 Hz), 115.5 ($^2J_{C\text{-}F}$ = 23 Hz), 108.0 ($^2J_{C\text{-}F}$ = 24 Hz), 62.9, 44.7, 25.3, 20.4. IR (neat): 2973, 1670, 1623, 1413, 1376, 1350, 1222, 1185, 910, 835, 786, 698, 679 cm^{-1}. HRMS [M+H]$^+$ Calcd for $C_{13}H_{16}FNO$ 222.1289; Found: 222.1281.

Procedures and Spectral Characterization of Arylation Products in Table 3



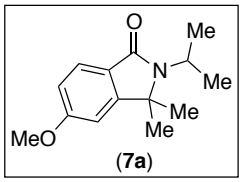
(**4a**)

Following general procedure **C**, **4-Cl** (120 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.050 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 80/20 hexanes/EtOAc (R_f = 0.30 in 80% hexanes/20% ethyl acetate) yielded product **4a** as a white solid (87.6 mg, 86% yield). The spectroscopic data was identical to the product isolated from the reaction of substrate **4-Br**.



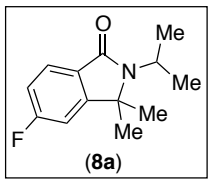
(**5a**)

Following general procedure **C**, **5-Cl** (160 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.05 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 80/20 EtOAc/hexanes (R_f = 0.44 in 80% hexanes/20% ethyl acetate) to afford product **5a** as a white solid (115 mg, 81% yield). The spectroscopic data was identical to the product isolated from the reaction of substrate **5-Br**.



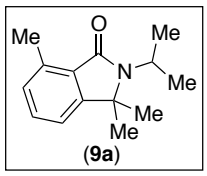
(**7a**)

Following general procedure **C**, **7-Cl** (134 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.05 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 1h. Chromatography on a silica gel column using 75/25 hexanes/EtOAc (R_f = 0.24 in 75% hexanes/75% ethyl acetate) yielded product **7a** as a white solid (76.5 mg, 66% yield). The spectroscopic data was identical to the product isolated from the reaction of substrate **7-Br**.



(**8a**)

Following general procedure **C**, **8-Cl** (129 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.05 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 17 h. Chromatography on a silica gel column using 80/20 hexanes/EtOAc (R_f = 0.34 in 80% hexanes/20% ethyl acetate) yielded product **8a** as a white solid (71.5 mg, 65% yield). The spectroscopic data was identical to the product isolated from the reaction of substrate **8-Br**.

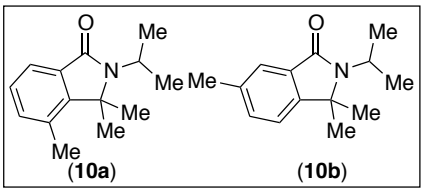


(**9a**)

Following general procedure **C**, **9-Cl** (100 mg, 0.394 mmol, 1.0 equiv), $Ni(COD)_2$ (10.8 mg, 0.039 mmol, 0.10 equiv), NaOtBu (56.8 mg, 0.591 mmol, 1.5 equiv) and anhydrous dioxane (1.58 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 90/10 hexanes/EtOAc (R_f = 0.21 in 90% hexanes/10% ethyl acetate) yielded product **9a** as a white solid (57.3 mg, 67% yield) mp = 128-131 °C.

^{1}H NMR ($CDCl_3$): δ 7.35 (t, *J* = 7.6 Hz, 1H), 7.15-7.12 (multiple peaks, 2H), 3.62 (sept, *J* = 6.8 Hz, 1H), 2.71 (s, 3H), 1.56 (d, *J* = 6.8 Hz, 6H), 1.45 (s, 6H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 168.1, 151.8, 137.2, 130.6, 129.8, 128.7, 117.9, 62.1, 44.3, 25.5, 20.5, 17.1. IR (neat): 2974, 1664, 1343, 808, 785, 703 cm^{-1}. HRMS $[M+Na]^+$ Calcd for $C_{14}H_{19}NO$ 240.1359; Found: 240.1354.

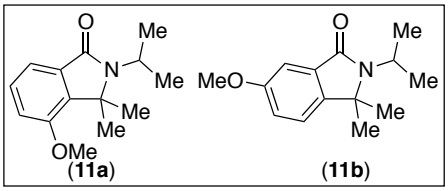
Procedures and Spectral Characterization of Arylation Products in Table 4



Following general procedure **A**, **10-Br** (149 mg, 0.500 mmol, 1.0 equiv), phenanthroline (18.0 mg, 0.100 mmol, 0.20 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 85/15 hexanes/EtOAc yielded a mixture of products **10a** and **10b** (101.3 mg, 93% yield).

Characterization of product **10a**: R_f = 0.19 in 85% hexanes/15% ethyl acetate. ^{1}H NMR ($CDCl_3$): δ 7.62 (d, *J* = 7.2 Hz, 1H), 7.31-7.24 (multiple peaks, 2H), 3.63 (sept, *J* = 6.8 Hz, 1H), 2.47 (s, 3H), 1.56 (d, *J* = 6.9 Hz, 6H), 1.53 (s, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 167.1, 148.0, 133.7, 132.6, 131.4, 127.8, 120.8, 64.1, 44.2, 22.8, 20.4, 18.6. IR (neat): 2970, 2930, 1677, 1415, 1377, 1347, 764, 715, 569 cm^{-1}. HRMS [M+Na]$^+$ Calcd for $C_{14}H_{19}NO$ 240.1359; Found: 240.1365.

Characterization of product **10b**: R_f = 0.26 in 85% hexanes/15% ethyl acetate; mp = 107-111 °C. ^{1}H NMR ($CDCl_3$): δ 7.56 (s, 1H), 7.30 (d, *J* = 7.7 Hz, 1H), 7.21 (d, *J* = 7.7 Hz, 1H), 3.62 (sept, *J* = 6.8 Hz, 1H), 2.41 (s, 3H), 1.54 (d, *J* = 6.9 Hz, 6H), 1.44 (s, 6H). ^{13}C{^{1}H} NMR (Acetone-d_6): δ 167.8, 150.8, 139.1, 134.0, 133.6, 124.3, 122.5, 64.2, 45.5, 26.5, 22.0, 21.5. IR (neat): 2966, 2927, 1672, 1440, 1372, 1365, 1341, 828, 794, 709, 572 cm^{-1}. HRMS [M+Na]$^+$ Calcd for $C_{14}H_{19}NO$ 240.1359; Found: 240.1356.

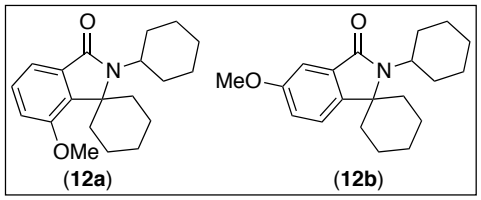


Following general procedure **A**, **11-Br** (157 mg, 0.500 mmol, 1.00 equiv), phenanthroline (18.0 mg, 0.100 mmol, 0.20 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.50 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 80/20 hexanes/EtOAc yielded a mixture of products **11a** and **11b** (109.2 mg, 94% yield).

Characterization of product **11a**: R_f = 0.46 in 70% hexanes/30% ethyl acetate; mp = 132-136 °C. ^{1}H NMR ($CDCl_3$): δ 7.37-7.32 (multiple peaks, 2H), 6.95 (dd, *J* = 7.1, 1.7 Hz, 1H), 3.87 (s, 3H), 3.61 (sept, *J* = 6.8 Hz, 1H), 1.53 (d, *J* = 6.8 Hz, 6H), 1.51 (s, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 166.9, 154.1,

137.7, 134.0, 129.2, 115.0, 112.8, 63.3, 55.3, 44.1, 22.8, 20.4. IR (neat): 2975, 1681, 1602, 1490, 1345, 1264, 1055, 961, 759, 561 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{19}NO_2$ 234.1489; Found: 234.1480.

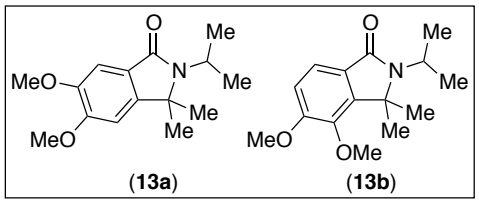
Characterization of product **11b**: R_f = 0.40 in 70% hexanes/30% ethyl acetate. ^1H NMR ($CDCl_3$): δ 7.25 (d, *J* = 2.4 Hz, 1H), 7.22 (d, *J* = 8.3 Hz, 1H), 7.05 (dd, *J* = 8.3, 2.5 Hz, 1H), 3.83 (s, 3H), 3.62 (sept, *J* = 6.8 Hz, 1H), 1.54 (d, *J* = 6.8 Hz, 6H), 1.44 (s, 6H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 167.1, 159.8, 143.6, 133.3, 121.5, 119.4, 105.8, 63.3, 55.6, 44.6, 25.5, 20.4. IR (thin film, CH_2Cl_2): 2970, 1679, 1493, 1346, 1278 cm^{-1}. HRMS $[M+H]^+$ Calcd for $C_{14}H_{19}NO_2$ 234.1489; Found: 234.1493.



Following general procedure **A**, **12**-**Br** (197 mg, 0.500 mmol, 1.0 equiv), phenanthroline (18.0 mg, 0.100 mmol, 0.20 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.50 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 85/15 hexanes/EtOAc yielded a mixture of products **12a** and **12b** (147 mg, 94% yield). HRMS $[M+H]^+$ Calcd for $C_{20}H_{27}NO_2$ 314.2115; Found: 314.2110. The isolated product was further purified on a silica gel column using 70/30 hexanes/Et_2O to obtain almost pure samples of **12a** and **12b** for spectral characterization.

Characterization of product **12a**: R_f = 0.41 in 70% hexanes/30% diethyl ether. ^1H NMR ($CDCl_3$): δ 7.38-7.33 (multiple peaks, 2H), 6.96 (dd, *J* = 7.5, 1.3 Hz, 1H), 3.87 (s, 3H), 3.69-3.61 (m, 1H), 2.70-2.58 (multiple peaks, 2H), 2.30-2.22 (multiple peaks, 2H), 2.04-1.21 (multiple peaks, 16H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 167.1, 153.8, 138.2, 134.5, 129.1, 115.2, 113.3, 65.9, 55.5, 55.1, 32.3, 29.7, 26.7, 25.2, 24.3, 22.1. IR (neat): 2922, 2848, 1679, 1488, 1450, 1406, 1368, 1344, 1315, 1293, 1266, 1081, 1036, 965, 812, 755, 689 cm^{-1}.

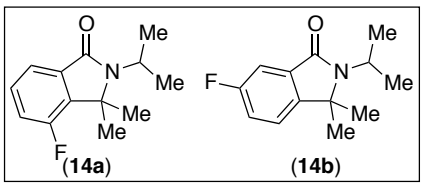
Characterization of product **12b**: mp = 102-107 °C. R_f = 0.49 in 70% hexanes/30% diethyl ether. ^1H NMR ($CDCl_3$): δ 7.65 (d, *J* = 8.4 Hz, 1H), 7.30 (d, *J* = 2.5 Hz, 1H), 7.01 (dd, *J* = 8.4, 2.6 Hz, 1H), 3.84 (s, 3H), 3.15-3.07 (m, 1H), 2.70-2.56 (multiple peaks, 2H), 2.00-1.21 (multiple peaks, 18H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 167.0, 159.6, 142.5, 134.2, 124.1, 118.2, 106.1, 65.7, 55.6, 53.0, 33.3, 30.0, 26.5, 25.2, 24.7, 22.6. IR (neat): 2928, 2853, 1681, 1491, 1445, 1435, 1372, 1344, 1315, 1293, 1261, 1240, 1172, 1107, 1081, 1034, 809, 760, 609, 582, 571 cm^{-1}.



Following general procedure **C**, **13-Br** (172 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.05 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was left to stir at 145 °C for 1 h. Chromatography on a silica gel column using 60/40 hexanes/EtOAc yielded yielded a mixture of product **13a** and **13b** (104.3 mg, 79% yield). The isolated product was further purified on a silica gel column using 45/55 petroleum ether/diethyl ether to obtain almost pure samples of **13a and 13b** for spectral characterization.

Characterization of product **13a**: mp = 132-135 °C. R_f = 0.23 in 45% petroleum ether/55% Ether. ^1H NMR ($CDCl_3$): δ 7.21 (s, 1H), 6.75 (s, 1H), 3.92 (s, 3H), 3.88 (s, 3H), 3.59 (sept, *J* = 6.9 Hz, 1H), 1.50 (d, *J* = 6.9 Hz, 6H), 1.41 (s, 6H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 167.3, 152.2, 149.3, 144.6, 124.1, 104.8, 102.8, 62.7, 56.12, 56.08, 44.5, 25.4, 20.5. IR (neat): 2966, 2933, 1666, 1617, 1499, 1458, 1429, 1390, 1372, 1354, 1303, 1248, 1209, 1191, 1169, 1059, 991, 868, 784, 769, 667 cm^{-1}. HRMS $[M+Na]^+$ Calcd for $C_{15}H_{21}NO_3$ 286.1414; Found: 286.1426.

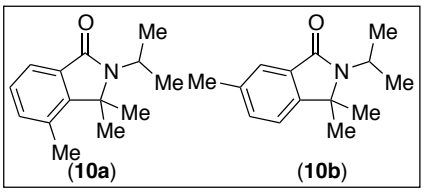
Characterization of product **13b**: mp = 132-135 °C. R_f = 0.22 in 45% petroleum ether/55% ether. ^1H NMR ($CDCl_3$): δ 7.48 (d, *J* = 8.2 Hz, 1H), 6.96 (d, *J* = 8.2 Hz, 1H), 3.93 (s, 3H), 3.92 (s, 3H), 3.59 (sept, *J* = 6.9 Hz, 1H), 1.53 (d, *J* = 6.8 Hz, 6H), 1.54 (s, 6H). $^{13}C\{^1H\}$ NMR ($CDCl_3$): δ 166.7, 155.2, 143.3, 142.8, 125.9, 118.8, 112.3, 63.0, 60.7, 56.1, 44.1, 23.7, 20.5. IR (neat): 2923, 1671, 1615, 1498, 1445, 1419, 1375, 1351, 1265, 1236, 1198, 1169, 1128, 1102, 1063, 1050, 1039, 968, 921, 865, 831, 818, 794, 743, 698, 673, 638, 623, 588, 577 cm^{-1}.



Following general procedure **C**, **14-Br** (151 mg, 0.500 mmol, 1.0 equiv), $Ni(COD)_2$ (13.8 mg, 0.05 mmol, 0.10 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 15 h. Chromatography on a silica gel column using 85/15 hexanes/EtOAc to 80/20 hexanes/EtOAc yielded a mixture of products **14a** and **14b** (88.2 mg, 80% yield). The isolated product was further purified on a silica gel column using 95/5 CH_2Cl_2/EtOAc to obtain almost pure samples of **14a** and **14b** for spectral characterization.

Characterization of product **14a**: R_f = 0.24 in 85% hexanes/15% ethyl acetate. ^{1}H NMR ($CDCl_3$): δ 7.57 (d, *J* = 7.5 Hz, 1H), 7.38 (td, *J* = 7.8, 4.5 Hz, 1H), 7.15 (t, *J* = 8.9 Hz, 1H), 3.63 (sept, *J* = 6.8 Hz, 1H), 1.56 (s, 6H), 1.55 (d, *J* = 6.9 Hz, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 166.0, 157.2 ($^1J_{C\text{-}F}$ = 249 Hz), 136.4 ($^2J_{C\text{-}F}$ = 16 Hz), 135.3 ($^3J_{C\text{-}F}$ = 4.3 Hz), 129.8 ($^3J_{C\text{-}F}$ = 6.6 Hz), 119.0 ($^4J_{C\text{-}F}$ = 3.7 Hz), 118.2 ($^2J_{C\text{-}F}$ = 20 Hz), 62.5 ($^3J_{C\text{-}F}$ = 2.9 Hz), 44.3, 23.8, 20.4. IR (neat): 2973, 1683, 1599, 1484, 1413, 1378, 1367, 1345, 1244, 1085, 994, 823, 816, 758, 652, 580, 566 cm^{-1}. HRMS [M+Na]$^+$ Calcd for $C_{13}H_{16}FNO$ 244.1108; Found: 244.1119.

Characterization of product **14b**: mp = 121-123 °C. R_f = 0.25 in 85% hexanes/15% ethyl acetate. ^{1}H NMR ($CDCl_3$): δ 7.42 (dd, *J* = 7.7, 2.4 Hz, 1H), 7.29 (dd, *J* = 8.3, 4.4 Hz, 1H), 7.19 (td, *J* = 8.6, 2.4 Hz, 1H), 3.62 (sept, *J* = 6.9 Hz, 1H), 1.54 (d, *J* = 6.8 Hz, 6H), 1.46 (s, 6H). ^{13}C{^{1}H} NMR ($CDCl_3$): δ 166.0 ($^4J_{C\text{-}F}$ = 3.4 Hz), 162.7 ($^1J_{C\text{-}F}$ = 245 Hz), 146.7, 134.1 ($^3J_{C\text{-}F}$ = 8.4 Hz), 122.1 ($^3J_{C\text{-}F}$ = 8.5 Hz), 118.5 ($^2J_{C\text{-}F}$ = 24 Hz), 109.8 ($^2J_{C\text{-}F}$ = 23 Hz), 63.1, 44.8, 25.5, 20.4. IR (neat): 2971, 1675, 1607, 1487, 1448, 1407, 1377, 1366, 1341, 1275, 1239, 1190, 1171, 1150, 1106, 870, 831, 819, 787, 726, 708, 579 cm^{-1}. HRMS [M+Na]$^+$ Calcd for $C_{13}H_{16}FNO$ 244.1108; Found: 244.1113.



Following general procedure **A**, **10-Cl** (127 mg, 0.500 mmol, 1.0 equiv), phenanthroline (18.0 mg, 0.100 mmol, 0.20 equiv), NaOtBu (72.1 mg, 0.750 mmol, 1.5 equiv) and anhydrous dioxane (2.00 mL) were combined in a 20 mL scintillation vial. The reaction mixture was allowed to stir at 145 °C for 16 h. Chromatography on a silica gel column using 85/15 hexanes/EtOAc (R_f = 0.23 in 85% hexanes/15% ethyl acetate) yielded a mixture of products **11a** and **11b** (88.9 mg, 82% yield). The spectroscopic data for **10a** and **10b** was identical to the products isolated from the reaction of substrate **10-Br**.

References:

1. (a) Rousseaux, S.; Gorelsky, S. I.; Chung, B. K. W.; Fagnou, K. *J. Am. Chem. Soc.* **2010**, *132*, 10692-10705. (b) Rousseaux, S.; Davi, M.; Sofack-Kreutzer, J.; Pierre, C.; Kefalidis, C. E.; Clot, E.; Fagnou, K.; Baudoin, O. *J. Am. Chem. Soc.* **2010**, *132*, 10706-10716.
2. De, S.; Ghosh, S.; Bhunia, S.; Sheikh, J. A.; Bisai, A. *Org. Lett.* **2012**, *14*, 4466-4469.