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Nickel-Catalyzed Intramolecular Nucleophilic Addition of Aryl Halides to Aryl Ketones for the Synthesis of Benzofuran Derivatives

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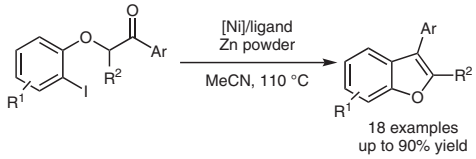

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Abstract A nickel-catalyzed intramolecular nucleophilic addition reaction of aryl halides to aryl ketones for the formation of benzofuran derivatives has been developed. A number of substrates bearing electron-donating or electron-withdrawing groups were subjected to the standard reaction conditions, giving the corresponding products in moderate to good yields.

Key words nickel, zinc powder, intramolecular addition, cyclization, benzofuran

Benzofuran moieties are ubiquitous structural skeletons[1] that are present in both natural products and synthetic pharmaceuticals and have remarkable biological and therapeutic activities[2] (Figure 1 [3]). Several synthetic strategies for the construction of benzofuran skeletons from different starting materials have been developed.[4] Phenols have attracted much attention as starting materials (Scheme 1, eq. 1, 2). Among the strategies, transition-metal-catalyzed cross-coupling reactions have emerged as an alternative and have attracted much attention for their atom and step economy.[5]

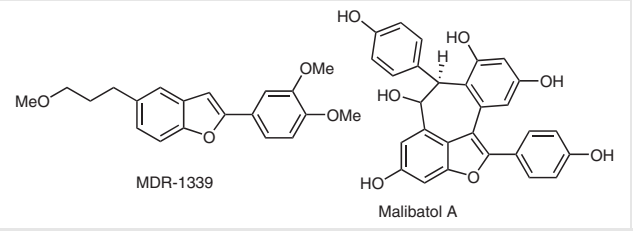
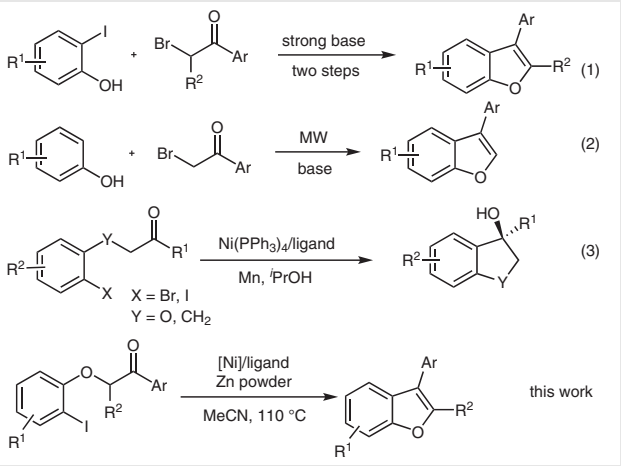


Figure 1 Example natural products or drugs containing benzofuran moieties

The oxidative addition of aromatic or vinyl halides to palladium or nickel salts for the formation of C–C bonds is one of the most efficient strategies in organic synthesis.[6] Well-established methods for the construction of C–C bonds through Pd(0)/Ni(0)-catalyzed cross-coupling include the Kumada–Corriu reaction[7] and the Negishi[8] and Suzuki[8a,9] couplings. The scope and application of these reactions has been fully explored. These methods have reliable yields and good functional-group tolerance. However, these strategies usually suffer from some drawbacks, including the need for strong bases, multistep processes, and harsh reaction conditions. The synthesis of benzofurans via nickel-catalyzed intramolecular nucleophilic addition has been less explored than other methods. Recently, Huang, Lv, and co-workers have described a highly enantioselective and straightforward nickel-catalyzed protocol to construct chiral 3-hydroxy-2,3-dihydrobenzofurans with high yield, good functional-group tolerance, and excellent enantio-

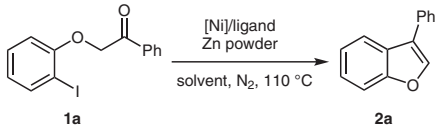


Scheme 1 Synthetic methods for the construction of benzofurans

selectivity (Scheme 1, eq. 3).[10] However, the development of a simple and highly efficient nickel-catalyzed intramolecular nucleophilic addition reaction to synthesize benzofurans remains highly desirable. Herein, we report a simple and convenient protocol for the formation of benzofuran derivatives that is conducted through a nickel-catalyzed intramolecular nucleophilic addition process (Scheme 1).

The substrate 2-(2-iodophenoxy)-1-phenylethanone[11] (**1a**) was chosen to optimize the reaction conditions, and the results are shown in Table 1. Firstly, in the presence of $Ni(dppp)_2Cl_2$ (5 mol%), 2,2′-bipyridine (10 mol%), and Zn powder (2 equiv), the product 3-phenylbenzofuran (**2a**) was isolated in 17% yield under an N_2 atmosphere (Table 1, entry 1). Absence of the ligand or Ni catalyst resulted in no target product being detected by GC-MS analysis (Table 1, entries 2, 3). These results prompted us to pursue more efficient reaction conditions. A series of ligands, including PCy_3, S-Phos (2-dicyclohexylphosphino-2′,6′-dimethoxybiphenyl), DABCO (1,4-diazabicyclo[2.2.2]octane), and 1,10-Phen (1,10-phenanthroline), were tested. The results indicated that 1,10-Phen was the most efficient ligand (Table 1, entries 4–7). Subsequently, various solvents, including MeOH, toluene, DCE, THF, and PrCN, were investigated, and MeCN was found to give the best yield (Table 1, entries 7–12). Then, four other nickel catalysts, $Ni(OTf)_2$, $Ni(PPh_3)_2Br_2$, $Ni(cod)_2Cl_2$, and $NiCl_2{\cdot}6H_2O$, were examined. The results demonstrated that all of the nickel catalysts had reactivity for the cyclization, with $Ni(OTf)_2$ and $Ni(dppp)_2Cl_2$ providing the best yields (Table 1, entries 6, 13–16). The effect of temperature was also evaluated; an increased or decreased reaction temperature reduced the yield of the target product (Table 1, entries 17, 18). Finally, an increase in the loading of Zn powder or decrease in the amount of [Ni] and ligand also decreased the yield of **2a** (Table 1, entries 19, 20).

Table 1 Screening for Optimal Conditions[a]



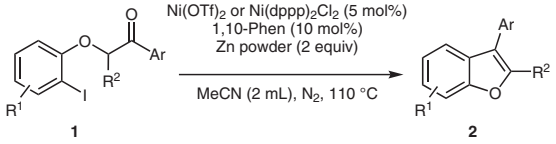
1a **2a**

Entry	[Ni]	Ligand	Solvent	Yield[b]
1	$Ni(dppp)_2Cl_2$	2,2′-bpy	MeCN	17
2	$Ni(dppp)_2Cl_2$	–	MeCN	ND
3	–	–	MeCN	ND
4	$Ni(dppp)_2Cl_2$	PCy_3	MeCN	ND
5	$Ni(dppp)_2Cl_2$	S-Phos	MeCN	ND
6	$Ni(dppp)_2Cl_2$	DABCO	MeCN	trace
7	$Ni(dppp)_2Cl_2$	1,10-Phen	MeCN	89
8	$Ni(dppp)_2Cl_2$	1,10-Phen	MeOH	67
9	$Ni(dppp)_2Cl_2$	1,10-Phen	toluene	20
10	$Ni(dppp)_2Cl_2$	1,10-Phen	DCE	19
11	$Ni(dppp)_2Cl_2$	1,10-Phen	THF	trace
12	$Ni(dppp)_2Cl_2$	1,10-Phen	PrCN	50
13	$Ni(OTf)_2$	1,10-Phen	MeCN	90
14	$Ni(PPh_3)_2Br_2$	1,10-Phen	MeCN	39
15	$Ni(cod)_2Cl_2$	1,10-Phen	MeCN	trace
16	$NiCl_2{\cdot}6H_2O$	1,10-Phen	MeCN	72
17[c]	$Ni(dppp)_2Cl_2$	1,10-Phen	MeCN	69
18[d]	$Ni(dppp)_2Cl_2$	1,10-Phen	MeCN	trace
19[e]	$Ni(dppp)_2Cl_2$	1,10-Phen	MeCN	46
20[f]	$Ni(dppp)_2Cl_2$	1,10-Phen	MeCN	61

[a] Reaction conditions: **1a** (0.2 mmol), [Ni] (10 mol%), ligand (10 mol%), Zn powder (2 equiv) in solvent (2 mL) under N_2 at 110 °C for 24 h.
[b] Isolated yield.
[c] At 130 °C.
[d] At 80 °C.
[e] Zn powder (3 equiv).
[f] [Ni] (3 mol%), ligand (6 mol%).

With this optimized procedure in hand, we aimed to expand the scope of the coupling reaction by screening a range of substrates **1**; the results are summarized in Table 2. Initially, the electronic effects of substrates **1** were examined. The results indicated that substrates bearing electron-withdrawing or electron-donating groups were well tolerated in the reaction and produced the corresponding products in moderate to good yields. For example, substrates **1b–1d**, possessing electron-donating groups on the ring, were suitable for the cyclization, giving the target products in moderate yields (Table 2, entries 1–3). Similar results were achieved when substrates **1e–1g** were employed for this transformation (Table 2, entries 4–6). Use of the sterically hindered substrates **1h** and **1i** resulted in the corresponding products **2h** and **2i** being isolated in 54% and 23% yields, respectively (Table 2, entries 7, 8). Interestingly, two bromo-substituted substrates **1j** and **1k** also performed well in this transformation, producing the de-brominated product **2a** in moderate yields (Table 2, entries 9, 10). The bromine atoms were reduced by the Zn powder. Compounds with substitutions on the Ar group were also investigated and shown to be good substrates for the cyclization. For example, compounds **1l** and **1m**, bearing Me and OMe groups on the Ar ring, reacted smoothly to afford products **2j** and **2k** in 89% and 59% yields, respectively (Table 2, entries 11, 12). The halo-containing substrates **1n–1q** facilitated the reaction, and the cyclization products **2l–2o** were obtained in 27%–65% yields (Table 2, entries 13–16). Substrate **1r** also served as an efficient substrate and furnished product **2p** in 75% yield (Table 2, entry 17). Use of substrate **1s** resulted in a 65% yield of target product **2q**, isolated under standard conditions (Table 2, entry 18). Gratifyingly, when 2-(2-iodophenoxy)-1-phenylpropan-1-one (**1t**) was subjected to the reaction, the 2,3-disubstituted benzofuran **2r** was afforded in 55% yield (Table 2, entry 19). Cyclization of the bromo-containing substrate **1u** also proceeded rapidly to give a 30% yield of product **2a** (Table 2, entry 20).

Table 2 Exploration of the Scope of Substrates **1**[a]



1 **2**

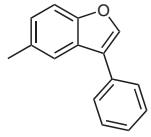
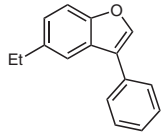
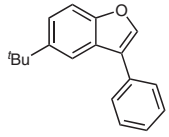
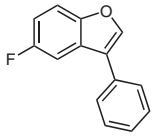
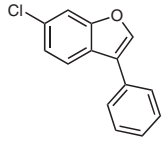
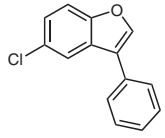
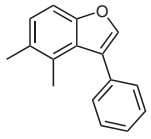
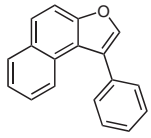
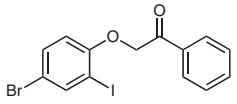
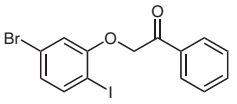
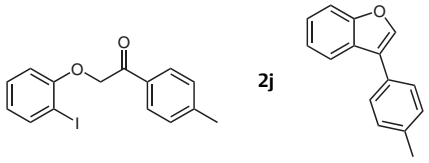
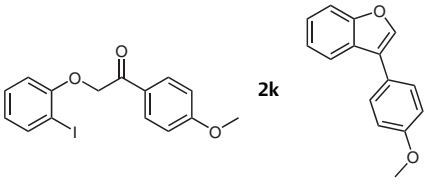
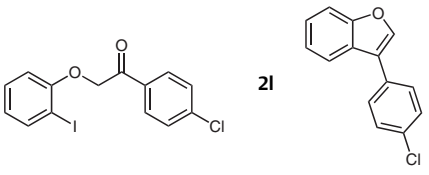
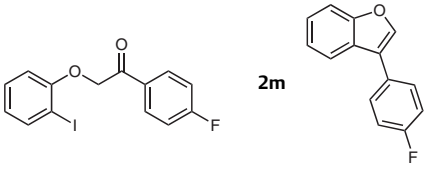
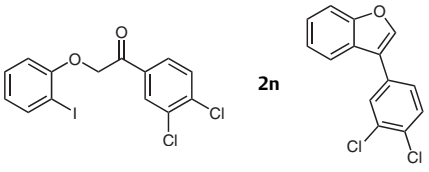
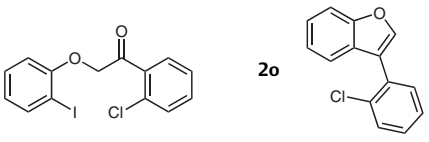
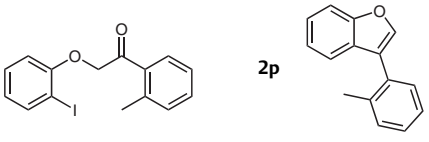
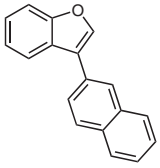
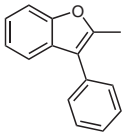
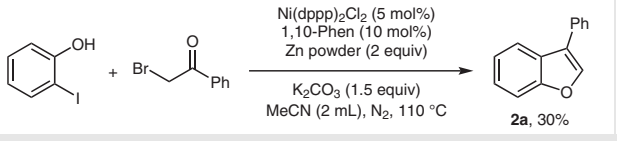
Entry	1	2	Products	Yield (%)[b]
1[c]	**1b**	**2b**		55
2[c]	**1c**	**2c**		70
3[c]	**1d**	**2d**		46
4[c]	**1e**	**2e**		75
5[c]	**1f**	**2f**		79
6[c]	**1g**	**2g**		48
7	**1h**	**2h**		54
8	**1i**	**2i**		23
9[c]	**1j**	**2a**		61
10[c]	**1k**	**2a**		63
11[c]	**1l**	**2j**		89
12[c]	**1m**	**2k**		59
13	**1n**	**2l**		32
14[c]	**1o**	**2m**		65
15	**1p**	**2n**		41
16[c]	**1q**	**2o**		27
17[c]	**1r**	**2p**		75

Table 2 (continued)

Entry	1	2	Products	Yield (%)[b]
18	1s	2q		65
19	1t	2r		55
20	1u	2a		30

[a] Reaction conditions: **1a** (0.2 mmol), $Ni(OTf)_2$ (10 mol%), 1,10-Phen (10 mol%), Zn powder (2 equiv) in MeCN (2 mL) under N_2 at 110 °C for 24 h.
[b] Isolated yield.
[c] $Ni(dppp)_2Cl_2$ (10 mol%) was used.

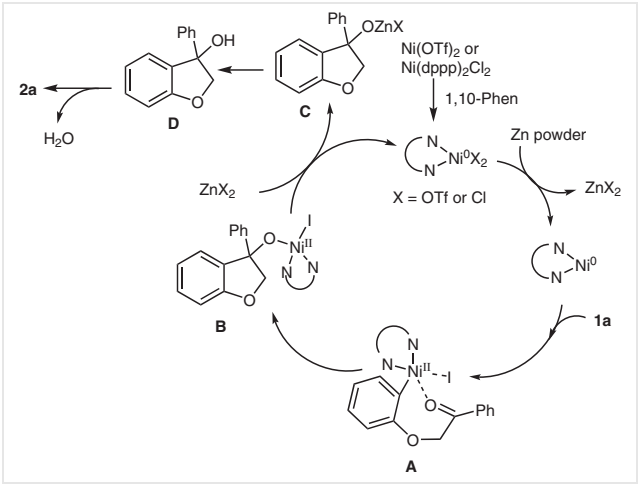
The synthesis of benzofuran **2a** through a one-pot method was also achieved (Scheme 2). The reaction of 2-iodophenol with 2-bromo-1-phenylethanone proceeded well in the presence of $Ni(dppp)_2Cl_2$, ligand, Zn powder, K_2CO_3, and MeCN and led to the formation of target **2a** in 30% yield.



Scheme 2 One-pot method for the synthesis of **2a**

Based on previous reports, as well as our experimental results,[12] a possible mechanism is outlined in Scheme 3. Initially, the nickel salts combine with the bidentate ligand 1,10-Phen and are then reduced to Ni(0) by the Zn powder. This is followed by oxidative addition of **1a** to generate the Ni(II) species **A**. The Ni(II) species **A**, through an intramolecular nucleophilic addition process, produces intermediate **B**. Subsequently, transmetalation of **B** by ZnX_2 leads to the Zn intermediate **C** and regeneration of the Ni catalyst. Finally, intermediate **C**, via demetallization and dehydration processes, affords the target product **2a**.

In summary, we have developed a nickel-catalyzed intramolecular nucleophilic addition reaction for the formation of benzofuran derivatives. Various functional groups were tolerated well under the standard reaction conditions, regardless of electronic effects, and the target products were formed in moderate to good yields.



Scheme 3 Proposed mechanism

Chemicals were either purchased or purified by standard techniques. ^1H NMR and ^{13}C NMR spectra were measured on a 500 MHz spectrometer (^1H: 500 MHz, ^{13}C: 125 MHz), using $CDCl_3$ as the solvent with TMS as an internal standard at r.t. Chemical shifts are given in δ relative to TMS, and the coupling constants *J* are given in Hz. High-resolution mass spectra were recorded on an ESI-Q-TOF mass spectrometer. All reactions were conducted under a nitrogen atmosphere by using standard Schlenk techniques. Column chromatography was performed by using EM silica gel 60 (300–400 mesh).

Benzofurans 2a–2r; General Procedure

A flame-dried Schlenk tube with a magnetic stirring bar was charged with **1** (0.2 mmol), $Ni(OTf)_2$ (5 mol%), Zn powder (2 equiv), 1.10-Phen (10 mol%), and MeCN (2 mL) under a nitrogen atmosphere. The reaction mixture was stirred at 110 °C for 16 h. After the reaction completed, the reaction mixture was filtered and evaporated under vacuum. The residue was purified by flash column chromatography (hexane) to afford the desired products.

3-Phenylbenzofuran (2a)[2]

Yellow oil (32.2 mg, 83% yield).

^1H NMR (500 MHz, $CDCl_3$): δ = 7.74 (d, *J* = 8.0 Hz, 1 H), 7.67 (s, 1 H), 7.54 (d, *J* = 8.0 Hz, 2 H), 7.44 (d, *J* = 8.0 Hz, 1 H), 7.36 (t, *J* = 7.5 Hz, 2 H), 7.27–7.23 (m, 2 H), 7.20 (t, *J* = 7.5 Hz, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.8, 141.3, 132.1, 128.9, 127.5, 127.4, 126.5, 124.5, 123.0, 122.3, 120.4, 111.7.

LRMS (EI, 70 eV): *m*/*z* (%) = 193 (M^+, 100), 165 (98), 164 (66), 194 (34), 166 (31).

5-Methyl-3-phenylbenzofuran (2b)[2]

Yellow oil (22.9 mg, 55% yield).

^1H NMR (500 MHz, $CDCl_3$): δ = 7.66 (s, 1 H), 7.58–7.57 (m, 3 H), 7.42–7.37 (m, 3 H), 7.30 (t, *J* = 7.0 Hz, 1 H), 7.09 (d, *J* = 8.0 Hz, 1 H), 2.41 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 154.2, 141.4, 132.4, 132.2, 128.8, 127.4, 127.3, 126.5, 125.7, 122.0, 120.1, 111.2, 21.4.

LRMS (EI, 70 eV): *m*/*z* (%) = 206 (M^+, 100), 207 (33), 206 (31), 164 (23), 178 (22), 177 (19), 89 (16).

5-Ethyl-3-phenylbenzofuran (2c)

Yellow oil (31.1 mg, 70% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.75 (s, 1 H), 7.65–7.63 (m, 3 H), 7.49–7.44 (m, 3 H), 7.37 (t, *J* = 7.5 Hz, 1 H), 7.19 (d, *J* = 8.5 Hz, 1 H), 2.77 (q, *J* = 7.5 Hz, 2 H), 1.29 (t, *J* = 7.5 Hz, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 154.4, 141.5, 139.2, 132.3, 128.9, 127.5, 127.4, 126.5, 124.8, 122.1, 119.0, 111.4, 29.0, 16.4.

LRMS (EI, 70 eV): *m*/*z* (%) = 205 (M^+, 100), 220 (64), 206 (32), 221 (25), 177 (17).

HRMS (ESI): calcd for $C_{16}H_{14}ONa^+$ ([M + Na]$^+$): 245.0937; found: 245.0939.

5-(*tert*-Butyl)-3-phenylbenzofuran (2d)[3]

Yellow oil (23.0 mg, 46% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.72 (s, 1 H), 7.65 (s, 1 H), 7.55 (d, *J* = 7.5 Hz, 2 H), 7.41–7.38 (m, 3 H), 7.34–7.29 (m, 2 H), 1.31 (s, 9 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 154.0, 146.1, 141.5, 132.3, 129.0, 127.6, 127.3, 126.1, 122.5, 122.4, 116.3, 111.0, 34.8, 31.9.

LRMS (EI, 70 eV): *m*/*z* (%) = 233 (M^+, 100), 234 (46), 248 (31), 249 (28), 104 (16).

5-Fluoro-3-phenylbenzofuran (2e)[3]

Yellow oil (31.8 mg, 75% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.67 (s, 1 H), 7.46 (d, *J* = 7.0 Hz, 2 H), 7.37–7.32 (m, 4 H), 7.26 (t, *J* = 7.5 Hz, 1 H), 6.97–6.92 (m, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 159.5 (J_{C-F} = 236.3 Hz), 152.0, 142.9, 131.5, 129.0, 127.7, 127.3, 122.6, 112.42, 112.40, 112.3 (J_{C-F} = 13.8 Hz), 106.0 (J_{C-F} = 25.0 Hz).

LRMS (EI, 70 eV): *m*/*z* (%) = 211 (M^+, 100), 182 (64), 212 (26), 183 (21), 91(14).

6-Chloro-3-phenylbenzofuran (2f)[8]

Yellow oil (36.0 mg, 79% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.63–7.59 (m, 2 H), 7.48–7.43 (m, 3 H), 7.37–7.34 (m, 2 H), 7.26 (t, *J* = 7.5 Hz, 1 H), 7.16 (d, *J* = 8.5 Hz, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.8, 141.8, 131.4, 130.5, 129.0, 127.7, 127.4, 125.2, 123.7, 122.2, 120.9, 112.3.

LRMS (EI, 70 eV): *m*/*z* (%) = 227 (M^+, 100), 164 (82), 226 (40), 228 (33), 163 (26), 82 (25), 229 (24), 162 (21), 165 (14).

5-Chloro-3-phenylbenzofuran (2g)[3]

Yellow oil (22.0 mg, 48% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.65 (s, 1 H), 7.62 (s, 1 H), 7.44 (d, *J* = 8.0 Hz, 2 H), 7.33 (t, *J* = 7.5 Hz, 2 H), 7.30 (d, *J* = 8.5 Hz, 1 H), 7.24 (d, *J* = 7.5 Hz, 1 H), 7.16 (d, *J* = 8.5 Hz, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 154.1, 142.5, 131.2, 129.0, 128.7, 127.8, 127.7, 127.4, 124.8, 122.0, 120.1, 112.7.

LRMS (EI, 70 eV): *m*/*z* (%) = 226 (M^+, 100), 164 (63), 227 (40), 228 (37), 165 (26), 82 (23), 163 (18).

4,5-Dimethyl-3-phenylbenzofuran (2h)

White solid (24.1 mg, 54% yield), mp 50–52 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.62 (s, 1 H), 7.57 (d, *J* = 7.5 Hz, 2 H), 7.51 (s, 1 H), 7.40 (t, *J* = 7.5 Hz, 2 H), 7.28 (t, *J* = 7.5 Hz, 1 H), 7.26 (s, 1 H), 2.32 (s, 3 H), 2.30 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 154.8, 140.6, 133.7, 132.5, 131.6, 128.9, 127.4, 127.2, 124.3, 121.8, 120.4, 112.1, 20.4, 20.1.

LRMS (EI, 70 eV): *m*/*z* (%) = 220 (M^+, 100), 205 (40), 221 (35), 219 (27), 177 (20).

HRMS (ESI): calcd for $C_{16}H_{14}ONa^+$ ([M + Na]$^+$): 245.0937; found: 245.0929.

1-Phenylnaphtho[2,1-b]furan (2i)[5]

Yellow oil (11.3 mg, 23% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.99 (d, *J* = 8.0 Hz, 1 H), 7.94 (d, *J* = 8.0 Hz, 1 H), 7.77 (d, *J* = 9.0 Hz, 1 H), 7.70 (d, *J* = 10.0 Hz, 2 H), 7.61 (d, *J* = 6.5 Hz, 2 H), 7.52 (t, *J* = 7.5 Hz, 2 H), 7.47 (t, *J* = 7.5 Hz, 1 H), 7.43 (t, *J* = 7.5 Hz, 1 H), 7.35 (t, *J* = 7.5 Hz, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 153.2, 141.7, 133.1, 130.8, 129.9, 128.9, 128.6, 127.9, 126.0, 125.9, 124.5, 124.3, 123.4, 120.7, 112.6.

LRMS (EI, 70 eV): *m*/*z* (%) = 244 (M^+, 100), 215 (63), 213 (25), 245 (19).

3-(*p*-Tolyl)benzofuran (2j)[7]

Yellow oil (37.2 mg, 89% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.73 (d, *J* = 8.0 Hz, 1 H), 7.65 (s, 1 H), 7.44 (d, *J* = 7.5 Hz, 3 H), 7.24 (t, *J* = 7.5 Hz, 1 H), 7.21–7.17 (m, 3 H), 2.31 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.8, 141.0, 137.2, 129.6, 129.1, 127.4, 126.6, 124.4, 122.9, 122.1, 120.4, 111.7, 21.2.

LRMS (EI, 70 eV): *m*/*z* (%) = 206 (M^+, 100), 207 (32), 164 (23), 205 (17).

3-(4-Methoxyphenyl)benzofuran (2k)[2]

Yellow oil (26.4 mg, 59% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.73–7.64 (m, 2 H), 7.50–7.45 (m, 3 H), 7.28–7.21 (m, 2 H), 6.93 (d, *J* = 8.0 Hz, 2 H), 3.78 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 159.1, 155.7, 140.7, 128.6, 126.7, 124.5, 124.4, 122.8, 121.8, 120.3, 114.4, 111.7, 55.3.

LRMS (EI, 70 eV): *m*/*z* (%) = 222 (M^+, 100), 207 (67), 152 (45), 223 (41), 151 (26).

3-(4-Chlorophenyl)benzofuran (2l)[8]

Yellow oil (14.6 mg, 32% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.66 (d, *J* = 7.5 Hz, 1 H), 7.63 (s, 1 H), 7.44–7.42 (m, 3 H), 7.31 (d, *J* = 8.5 Hz, 2 H), 7.24 (t, *J* = 7.0 Hz, 1 H), 7.19 (t, *J* = 7.5 Hz, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.8, 141.4, 133.3, 130.5, 129.1, 128.6, 126.1, 124.7, 123.1, 121.2, 120.1, 111.8.

LRMS (EI, 70 eV): *m*/*z* (%) = 227 (M^+, 100), 164 (89), 226 (48), 228 (38), 82 (29), 163 (26), 229 (25), 162 (24), 165 (24).

3-(4-Fluorophenyl)benzofuran (2m)[4]

Yellow oil (27.2 mg, 65% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.67 (d, *J* = 7.5 Hz, 1 H), 7.63 (s, 1 H), 7.49–7.44 (m, 3 H), 7.26 (t, *J* = 7.5 Hz, 1 H), 7.21 (t, *J* = 7.5 Hz, 1 H), 7.06 (t, *J* = 8.5 Hz, 2 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 162.3 (J_{C-F} = 245.0 Hz), 155.7, 141.1, 129.1, 128.0, 126.4, 124.6, 123.0, 121.3, 120.1, 115.9 (J_{C-F} = 22.5 Hz), 111.8.

LRMS (EI, 70 eV): *m*/*z* (%) = 211 (M^+, 100), 182 (73), 212 (46), 183 (23), 91 (15).

3-(3,4-Dichlorophenyl)benzofuran (2n)

Yellow oil (21.5 mg, 41% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.70–7.67 (m, 2 H), 7.63 (s, 1 H), 7.47 (d, *J* = 8.5 Hz, 1 H), 7.44 (d, *J* = 8.0 Hz, 1 H), 7.37 (d, *J* = 8.0 Hz, 1 H), 7.29 (t, *J* = 7.5 Hz, 1 H), 7.24 (t, *J* = 7.5 Hz, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.8, 141.8, 133.1, 132.2, 131.4, 130.9, 129.1, 126.6, 125.8, 125.0, 123.4, 120.3, 120.0, 112.0.

LRMS (EI, 70 eV): *m*/*z* (%) = 261 (M^+, 100), 263 (67), 260 (43), 262 (42), 198 (29), 99 (16), 264 (15), 163 (13).

3-(2-Chlorophenyl)benzofuran (2o)

Yellow oil (12.3 mg, 27% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.76 (s, 1 H), 7.51–7.45 (m, 4 H), 7.29–7.23 (m, 3 H), 7.20 (t, *J* = 7.5 Hz, 1 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.0, 143.5, 133.5, 131.5, 130.6, 130.2, 128.9, 127.0, 126.8, 124.5, 122.9, 120.8, 119.2, 111.7.

LRMS (EI, 70 eV): *m*/*z* (%) = 226 (M^+, 100), 164 (73), 228 (38), 227 (37), 165 (27), 82 (25).

3-(*o*-Tolyl)benzofuran (2p)[4]

Yellow oil (31.2 mg, 75% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.62 (s, 1 H), 7.56 (d, *J* = 8.0 Hz, 1 H), 7.46 (d, *J* = 7.5 Hz, 1 H), 7.39 (d, *J* = 7.0 Hz, 1 H), 7.35–7.30 (m, 3 H), 7.29–7.24 (m, 2 H), 2.32 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.1, 142.2, 136.9, 130.9, 130.5, 130.4, 127.84, 127.83, 125.8, 124.4, 122.7, 121.4, 120.7, 111.6, 20.5.

LRMS (EI, 70 eV): *m*/*z* (%) = 206 (M^+, 100), 205 (74), 178 (34), 177 (29), 207 (29).

3-(Naphthalen-2-yl)benzofuran (2q)

White solid (31.5 mg, 65% yield), mp 59–61 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.03 (s, 1 H), 7.87–7.83 (m, 2 H), 7.81–7.77 (m, 3 H), 7.65 (d, *J* = 8.5 Hz, 1 H), 7.49 (d, *J* = 8.5 Hz, 1 H), 7.44–7.39 (m, 2 H), 7.31–7.24 (m, 2 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 155.9, 141.7, 133.7, 132.7, 129.5, 128.6, 127.9, 127.8, 126.4, 126.0, 125.9, 125.8, 124.6, 123.1, 122.2, 120.5, 111.8.

LRMS (EI, 70 eV): *m*/*z* (%) = 242 (M^+, 100), 243 (68), 213 (45), 107 (22), 214 (18).

HRMS (ESI): calcd for $C_{18}H_{12}ONa^+$ ([M + Na]$^+$): 267.0780; found: 267.0784.

2-Methyl-3-phenylbenzofuran (2r)[6]

Yellow oil (22.9 mg, 55% yield).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.50 (d, *J* = 7.5 Hz, 1 H), 7.44–7.37 (m, 5 H),7.28 (t, *J* = 7.0 Hz, 1 H), 7.20–7.14 (m, 2 H), 2.46 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 154.0, 151.3, 132.9, 128.9, 128.8, 128.7, 126.9, 123.5, 122.6, 119.3, 116.9, 110.7, 12.8.

LRMS (EI, 70 eV): *m*/*z* (%) = 206 (M^+, 100), 205 (51), 130 (30), 207 (30), 177 (21), 178 (17).

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Supporting Information

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