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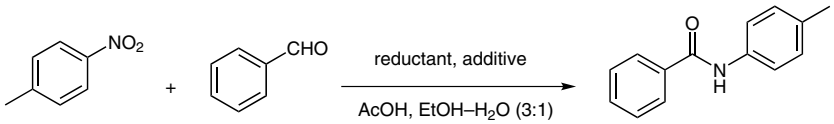
Cooperation of a Reductant and an Oxidant in One Pot To Synthesize Amides from Nitroarenes and Aldehydes

Guozhu Sheng[a]
Xia Wu[b]
Xiuhua Cai[a]
Wei Zhang*[a]

[a] College of Chemistry and Pharmaceutical Science, Qingdao Agricultural University No. 700, The Great Wall Road, Chengyang District, Qingdao City, Shandong Province, P. R. of China
zhangwei@qau.edu.cn
[b] College of Agronomy and Plant Protection, Qingdao Agricultural University No. 700, The Great Wall Road, Chengyang District, Qingdao City, Shandong Province, P. R. of China



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Abstract The reductant zinc powder and the oxidant sodium chlorate were used together in an appropriate ratio in one pot under ambient conditions, to provide an environmentally friendly, effective, and convenient method for the synthesis of aromatic amides in good yields from nitroarenes and aldehydes in the green solvents alcohol and water under atmospheric conditions. The good results indicate that reductants and oxidants with opposing properties can not only be used together without any adverse effects, but also improve the reaction yield through their cooperation.

Key words nitroarenes, aldehydes, amides, synthetic methods, one pot

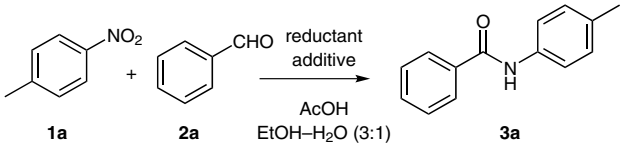
Oxidation and reduction reactions are two opposite process, so the oxidant and reductant with opposite properties are usually used separately to avoid mutual influence; in this work the reductant zinc power and oxidant sodium chlorate were used in a one-pot process to improve the reaction yield through their cooperation.

The amide bond is common in natural products and pharmaceuticals.[1] Amides have been the focus of much recent research, and many new methods for the synthesis of amides from aldehydes and amines have been developed. Gold is a useful catalyst that can catalyze the synthesis of amides from aldehydes and amines, as reported by Li et al.[2] Also, hydrotalcite-supported gold nanoparticles have been used to catalyze the synthesis of amides from an alcohol and an amine.[3] Hong,[4,6] Madsen,[5] and Naota[7] and co-workers have reported methods for the synthesis of amides from amines using different ruthenium catalysts and other reaction mediums. But if amides were to be synthesized directly from nitroarenes, the number of reaction stages and the costs would be greatly reduced in industrial production.[8–11] Hence nitroarenes have been studied as a nitrogen source for amide synthesis. Gu and co-workers[12] have use nanowire to catalyze the heterogeneous hydrogenation of nitroarenes with carboxylic acids to give the corresponding amides. A novel one-step reductive acetamidation of nitroarenes mediated by thioacetate anion in thioacetic acid via in situ catalytic regeneration was developed and applied to an efficient synthesis of Acetaminophen.[13] Liu and co-workers[14] constructed amides from nitroarenes by one-pot tandem reduction–cyclization with sodium dithionite. Jain et al.[15] have reported manganese dioxide catalyzed amide bond formation directly from aldehydes and nitroarenes in chloroform (60 °C, 12 h, under N_2), which was the first report of synthesis of amides directly from nitroarenes and aldehydes in one pot.

Considering the increasing importance of green chemistry in organic synthesis, a facile, one-pot, effective, and readily accessible procedure for the synthesis of aromatic amides from aldehydes and nitroarenes different from those reported above was studied. Using this method, aromatic amides are easily obtained from nitroarenes and aldehydes, catalyzed by the cooperation of zinc powder as a reductant and sodium chlorate as an oxidant in an appropriate ratio in one pot in the presence of acetic acid in the green solvents ethanol and water at a mild temperature of 35 °C.

Commercially available 4-nitrotoluene (**1a**) and benzaldehyde (**2a**) were selected as model substrates to synthesize *N*-(4-tolyl)benzamide (**3a**) (Table 1).

Table 1 Effects of Different Reductants and Additives on the Synthesis of *N*-(4-Tolyl)benzamide (**3a**)[a]



1a **2a** **3a**

Entry	Reductant (equiv)	Additives (equiv)	Yield[b] (%)
1	Fe (4)	–	0
2	Zn (4)	–	17
3	Zn (4)	NaOMe (2)	0
4	Zn (4)	KOH (2)	0
5	Zn (4)	K_2CO_3 (2)	0
6	Zn (4)	pyridine (2)	0
7	Zn (4)	$ZnCl_2$ (2)	12
8[c]	Zn (4)	$ZnCl_2$ (2)	3
9	Zn (4)	$K_4Fe(CN)_6{\cdot}3H_2O$ (2)	26
10	Zn (4)	$CdCl_2{\cdot}2.5H_2O$ (2)	13
11	Zn (4)	$MnSO_4{\cdot}H_2O$ (2)	22
12	Zn (4)	$NH_4Fe(SO_4)_2$ (2)	27
13	Zn (4)	$Cu(OAc)_2$ (2)	0
14	Zn (4)	CuCl (2)	0
15	Zn (4)	NaClO (2)	24
16	Zn (4)	H_2O_2 (2)	13
17	Zn (4)	$NaClO_3$ (2)	40
18	Zn (4)	$NaClO_3$ (1)	84
19	Zn (4)	$NaClO_3$ (0.5)	60
20	Zn (4)	$KMnO_4$ (1)	0
21	Zn (4)	ZnO (1)	22
22	Zn (4)	CuO (1)	6
23	Zn (4)	MgO (1)	12

[a] Reaction conditions: 4-nitrotoluene (**1a**, 0.5 g, 3.7 mmol) dissolved in EtOH–H_2O (9 mL/3 mL) at 35 °C; sequential addition of PhCHO (**2a**, 0.5 mL, 5.2 mmol), reductant, AcOH (0.4 mL, 7.4 mmol), and additive; stirring, 35 °C, 45 min.
[b] Isolated yield.
[c] The temperature of the reaction was –15 °C.

Zinc and acetic acid have been utilized as a reducing agent for the synthesis of amides from acyl chloride,[16] hence zinc powder was selected as the reducing reagent. As shown in Table 1,*N*-(4-tolyl)benzamide (**3a**) was obtained in 17% yield with zinc powder without any additives; iron powder was found to be ineffective in this reaction (entries 1 and 2). In order to improve the yield, additives (dehydrogenating agent, oxidant,[17,18] and base[19,20]) reported in the literature to be useful in this reaction were added to the reaction system. Sodium methoxide, potassium hydroxide, potassium carbonate, and pyridine were tested; however, no reaction was observed (entries 3–6); a trace of red solid was obtained, which was identified as 4-(dimethylamino)azobenzene with pyridine as a base. The addition of potassium ferrocyanide, manganese(II) sulfate monohydrate, and ammonium iron(III) sulfate were then examined; the yield improved slightly to 26%, 22%, and 27%, respectively (entries 9, 11, and 12), which might be due to the oxidizability of the metal ions. However, copper(II) acetate and copper(I) chloride prevented the generation of the target product. Other metal ions, such as those from zinc chloride and cadmium chloride, were ineffective in this reaction (entries 7 and 10). Next, various oxidants were tested, for example sodium hypochlorite, sodium chlorate, hydrogen peroxide, and potassium permanganate. The corresponding amide was obtained in lower yield when hydrogen peroxide was added compared with zinc powder only, which may be because its oxidation strength was so high that it influenced the reductive ability of zinc powder (entry 16). The yield improved slightly to 24% when sodium hypochlorite was added (entry 15). No amide was obtained when potassium permanganate was added, which might be due to its strong oxidation properties (entry 20). Sodium chlorate proved to be the most effective oxidant for this reaction. When the oxidant loading was increased to 2.0 equivalents, the yield decreased significantly. Hence, 1.0 equivalent of sodium chlorate was necessary for this reaction (entries 17 and 18). Hence, zinc powder was chosen as the reductant and sodium chlorate as the additive. The ratio of 4-nitrotoluene, benzaldehyde, zinc powder, sodium chlorate, and acetic acid was 1:1.4:4:1:2.

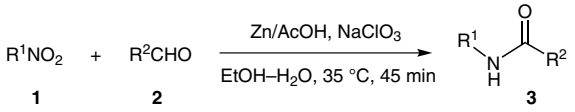
Evidently, an organic process performed in a toxic solvent does not meet the strict safety requirements of industrial applications, so research into non-contaminating solvents is of great importance. Therefore, the green solvents ethanol and water (in 3:1 ratio), in which most nitroarenes and aldehydes can dissolve, were selected. The optimal reaction was achieved at 35 °C. Importantly, the optimized reaction did not require chromatographic purification of the product, a major advance towards the concept of an ideal synthesis.

With the optimized reaction conditions established, the scope of the reaction with different nitro compounds and different aldehydes was investigated (Table 2).

To investigate the scope of the reaction, a variety of different substituted benzaldehydes **2** and 4-nitrotoluene (**1a**) were subjected to the standard reaction conditions. The corresponding amides **3a**–**d**,**o** were obtained in moderate to good yields, as shown in Table 2. A series of functional groups, including hydroxy, double bonds, methyl, methoxy, chloro, ethoxycarbonyl, and acetyl, were tolerated under the optimal reaction conditions, and the desired products were obtained in moderate to good yields.

Aromatic heterocycles exist in many active molecules that also contain an amide bond.[21,22] 2-nitrofuran and 2-nitropyridine with various benzaldehydes were selected as model substrates to be studied (Table 2, entries 16–19). The

Table 2 Reaction of Nitroarenes and Aldehydes under Optimized Conditions[a]



1 2 3

Entry	R^1	R^2	Amides	Yield[b] (%)
1	4-MeC_6H_4	Ph	**3a**	84
2	4-MeC_6H_4	4-ClC_6H_4	**3b**	79
3	4-MeC_6H_4	4-FC_6H_4	**3c**	81
4	4-MeC_6H_4	2-HOC_6H_4	**3d**	61
5	4-MeC_6H_4	CH=CHPh	**3o**	53
6	4-$MeOC_6H_4$	4-ClC_6H_4	**3e**	50
7	Ph	Ph	**3f**	65
8	Ph	4-ClC_6H_4	**3g**	67
9	4-ClC_6H_4	Ph	**3h**	60
10	4-ClC_6H_4	4-ClC_6H_4	**3i**	71
11	4-ClC_6H_4	2-HOC_6H_4	**3j**	51
12	4-$EtO_2CC_6H_4$	4-ClC_6H_4	**3k**	77
13	4-AcC_6H_4	Ph	**3l**	72
14	4-AcC_6H_4	2-HOC_6H_4	**3m**	67
15	4-AcC_6H_4	4-ClC_6H_4	**3n**	73
16	2-furyl	Ph	**3s**	75
17	2-furyl	4-MeC_6H_4	**3t**	90
18	2-furyl	4-AcC_6H_4	**3u**	81
19	2-pyridyl	4-FC_6H_4	**3r**	15

[a] Reaction conditions: nitroarene (1.0 g, 1 equiv), aldehyde (1 equiv), Zn powder (4 equiv), AcOH (2 equiv), $NaClO_3$ (1 equiv), EtOH–H_2O (15 mL/5 mL), 35 °C, 45 min.
[b] Isolated yield.

results showed that the heterocycles, especially those containing a furan ring that is readily destroyed by oxidation, were not affected by the reaction and the products were obtained in high yields. Hence the oxidant and reductant selected in this study not only did not influence each other, but also had high selectivity without affecting other functional groups.

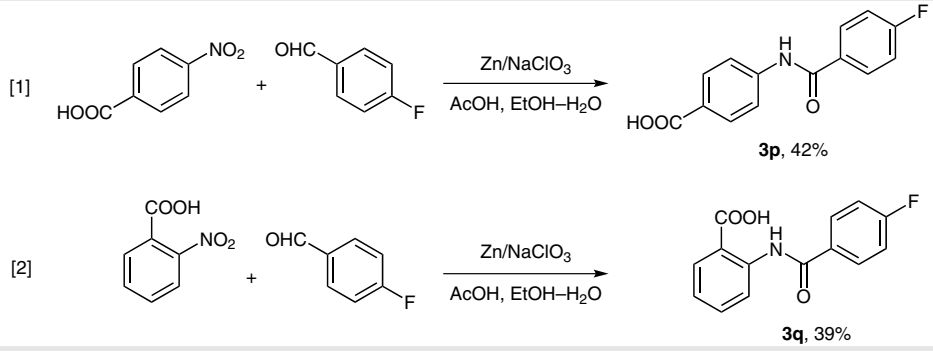
Amide bond construction is frequently used for peptide synthesis,[1] but the reaction yield is low because of the coexistence of amino and carboxylic acid groups in substrate amino acids. The reaction yield might be improved if the amino group was replaced by the nitro group; the 2- and 4-nitrobenzoic acid were selected as model substrates (Scheme 1). The results showed that the existence of the carboxylic acid group did not affect the reaction to give **3p** and **3q**, which lays the foundations for the synthesis of peptides using a nitro carboxylic acid instead of an amino acid.

In this research, the synthesis of amides from nitroarenes and aldehydes using the reductant zinc cooperating with the oxidant sodium chlorate in an appropriate ratio in one pot was examined. The results suggest that reductants and oxidants with opposing properties can not only be used together in some reactions without affecting each other but also improve the reaction yield through their cooperation. The method developed is green and very easy to perform. It is a significant advance in the synthesis of the amide bond in green organic chemistry.

All chemicals were obtained from Sigma-Aldrich Chemical Company and used as received. The ^1H and ^{13}C NMR spectra were recorded on a Bruker-Avance 500 MHz instrument. HRMS analyses were conducted on a Waters Q-Tof Ultima Global mass spectrometer.

Amides 3; General Procedure

Nitroarene (1 mmol) was dissolved in EtOH (3 mL). H_2O (1 mL) was added to reaction system. Then aldehyde (1.4 equiv), zinc powder (4 equiv), AcOH (2 equiv), and $NaClO_3$ (1 equiv) were added to the solution. The mixture was stirred at 35 °C for 45 min. Then the mixture was filtered under vacuum in order to remove unreacted zinc. H_2O (4 mL) was added to the filtrate, and the solution was extracted with EtOAc (3 × 10 mL). The organic layer was washed with brine, dried (anhyd Na_2SO_4), and evaporated under vacuum. Then the crude products were recrystallized (EtOAc).



Scheme 1 The reaction of 2- and 4-nitrobenzoic acid

N-(4-Tolyl)benzamide (3a)

White solid; yield: 177 mg (84%); mp 126–127 °C (EtOAc) [Lit.[23] 158–159 °C (EtOH)].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.4 (d, *J* = 9 Hz, 2 H), 7.9 (s, 1 H), 7.67 (d, *J* = 8.2 Hz, 2 H), 7.46–7.49 (m, 3 H), 7.28 (d, *J* = 12 Hz, 2 H), 2.4 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.82, 140.24, 134.24, 130.88, 130.77, 129.69, 129.04, 128.68, 121.52, 21.23.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{14}ON$: 212.1070; found: 212.1065.

4-Chloro-*N*-(4-tolyl)benzamide (3b)

White solid; yield: 193 mg (79%); mp 157–158 °C [Lit.[24] 158–159 °C].

^{1}H NMR (600 MHz, $CDCl_3$, TMS): δ = 8.34 (d, *J* = 8.8 Hz, 2 H), 7.9 (s, 1 H), 7.65 (d, *J* = 8.3 Hz, 2 H), 7.44 (d, *J* = 6 Hz, 2 H), 7.28 (d, *J* = 12 Hz, 2 H), 2.4 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.63, 140.47, 136.22, 133.03, 130.17, 129.74, 129.25, 128.94, 121.44, 21.24.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{13}ClON$: 246.0680; found: 246.0680.

4-Fluoro-*N*-(4-tolyl)benzamide (3c)

White solid; yield: 185 mg (81%); mp 155–156 °C (EtOAc) [Lit.[25] 176 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.47 (d, *J* = 4 Hz, 2 H), 7.9 (s, 1 H), 7.6 (d, *J* = 8.4 Hz, 2 H), 7.3 (d, *J* = 10 Hz, 2 H), 7.2 (d, *J* = 16 Hz, 2 H), 2.4 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.62, 140.34, 131.33, 131.25, 131.24, 129.73, 127.24, 121.46, 115.95, 21.23.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{13}FON$: 230.0976; found: 230.0974.

4-Hydroxy-*N*-(4-tolyl)benzamide (3d)

Yellow solid; yield: 138 mg (61%); mp 143–144 °C [Lit.[26] 145–147 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 13.4 (s, 1 H), 8.6 (s, 1 H), 7.38 (d, *J* = 8 Hz, 2 H), 7.19–7.24 (m, 4 H), 7.02 (d, *J* = 8 Hz, 2 H), 6.9 (d, *J* = 4 Hz, 1 H), 2.4 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 161.74, 161.09, 145.84, 136.96, 132.94, 132.15, 130.04, 121.04, 119.29, 119.04, 117.22, 21.38 (1).

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{14}O_2N$: 228.1019; found: 228.1024.

4-Chloro-*N*-(4-methoxyphenyl)benzamide (3e)

White solid; yield: 131 mg (50%); mp 186–187 °C (EtOAc) [Lit.[27] 208–209 °C (AcOH)].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.34 (d, *J* = 8 Hz, 2 H), 7.86 (s, 1 H), 7.72 (d, *J* = 8 Hz, 2 H), 7.44 (d, *J* = 8 Hz, 2 H), 6.97 (d, *J* = 8 Hz, 2 H), 3.87 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 160.76, 142.23, 136.16, 132.58, 130.10, 129.34, 128.95, 123.04, 114.11, 55.72.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{13}O_2NCl$: 262.0629; found: 262.0628.

***N*-Phenylbenzamide (3f)**

Yellow solid; yield: 128 mg (65%); mp 162–163 °C [Lit.[28] 164–165 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 7.19–7.23 (m, 3 H), 7.08 (q, *J* = 8 Hz, 2 H), 6.95 (q, *J* = 8 Hz, 2 H), 6.66 (t, *J* = 7.2 Hz, 1 H), 6.52 (d, *J* = 7.6 Hz, 2 H), 4.55–4.98 (dd, *J* = 7.2 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.45, 138.13, 129.26, 128.32, 127.62, 127.54, 127.35, 117.81, 113.71.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{12}ON$: 198.0913; found: 198.0912.

4-Chloro-*N*-phenylbenzamide (3g)

White solid; yield: 155 mg (67%); mp 196–197 °C [Lit.[29] 198 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 7.21 (d, *J* = 8.4 Hz, 2 H), 7.1 (t, *J* = 8 Hz, 2 H), 6.9 (d, *J* = 8.4 Hz, 2 H), 6.69 (t, *J* = 7.2 Hz, 1 H), 6.49 (d, *J* = 8 Hz, 2 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 145.92, 136.44, 133.59, 129.36, 128.86, 128.70, 118.30, 113.75.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{11}ONCl$: 232.0524; found: 232.0529.

***N*-(4-Chlorophenyl)benzamide (3h)**

White solid; yield: 139 mg (60%); mp 179–180 °C [Lit.[30] 181–182 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.38 (d, *J* = 8 Hz, 2 H), 7.9 (s, 1 H,), 7.74 (d, *J* = 8 Hz, 2 H), 7.47–7.50 (m, 3 H), 7.46 (d, *J* = 8 Hz, 2 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.43, 135.81, 134.73, 131.30, 130.42, 129.35, 129.17, 128.77, 123.09.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{11}ONCl$: 232.0524; found: 232.0523.

4-Chloro-*N*-(4-chlorophenyl)benzamide (3i)

Yellow solid; yield: 188 mg (71%); mp 134–135 °C [Lit.[31] 132–133 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.35 (d, *J* = 8 Hz, 2 H), 7.9 (s, 1 H), 7.74 (d, *J* = 8 Hz, 2 H), 7.4–7.5 (m, 4 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.24, 136.04, 130.28, 129.42, 129.06, 129.01, 127.13, 123.73, 123.02.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{10}ONCl_2$: 266.0134; found: 266.0137.

***N*-(4-Chlorophenyl)-2-hydroxybenzamide (3j)**

Yellow solid; yield: 126 mg (51%); mp 176–177 °C [Lit.[32] 175–176 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 12.39 (s, 1 H), 8.05 (s, 1 H), 7.9 (d, *J* = 8.4 Hz, 2 H), 7.4–7.5 (m, 3 H), 7.20 (d, *J* = 8 Hz, 1 H), 7.04 (d, *J* = 8 Hz, 1 H), 6.92 (t, $J_1 = J_2$ = 8 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 160.04, 144.51, 141.18, 136.50, 135.03, 133.00, 129.58, 123.17, 120.57, 119.44, 116.74.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{11}O_2NCl$: 248.0473; found: 248.0473.

Ethyl 4-[(4-Chlorobenzoyl)amino]benzoate (3k)

White solid; yield: 233 mg (77%); mp 197–198 °C (EtOAc).

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.38 (d, *J* = 8 Hz, 2 H), 8.18 (d, *J* = 8 Hz, 2 H), 7.96 (s, 1 H), 7.86 (d, *J* = 8 Hz, 2 H), 7.47 (d, *J* = 8 Hz, 2 H), 4.42 (q, 2 H), 1.43 (t, $J_1 = J_2$ = 8 Hz, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 165.34, 151.67, 136.91, 134.11, 131.99, 130.66, 129.08, 128.83, 121.73, 61.60, 14.33.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{16}H_{15}O_3NCl$: 304.0735; found: 304.0732.

N-(4-Acetylphenyl)benzamide (3l)

White solid; yield: 172 mg (72%); mp 180–181 °C (EtOAc) [Lit.[33] 205 °C ($CHCl_3$)].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.4 (m, 2 H), 8.1 (d, *J* = 8.4 Hz, 2 H), 8.0 (s, 1 H), 7.9 (d, *J* = 8.4 Hz, 2 H), 7.50–7.53 (m, 3 H), 2.66 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 196.82, 151.88, 137.97, 135.41, 131.56, 130.31, 129.49, 129.34, 128.83, 122.09, 26.92.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{14}O_2N$: 240.1019; found: 240.1017.

N-(4-Acetylphenyl)-2-hydroxybenzamide (3m)

Yellow solid; yield: 171 mg (67%); mp 167–168 °C (EtOAc) [Lit.[34] 205–207 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 12.46 (s, 1 H), 8.07–8.15 (m, 3 H), 7.92 (d, *J* = 8 Hz, 2 H), 7.49 (dd, J_1 = 15.6 Hz, J_2 = 1.6 Hz, 1 H), 7.23 (dd, J_1 = 8 Hz, J_2 = 1.6 Hz, 1 H), 7.05 (d, *J* = 8 Hz, 1 H), 6.93 (dd, J_1 = 15.2 Hz, J_2 = 8 Hz, 1 H), 2.68 (s, 3 H,).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 196.58, 160.29, 148.90, 141.93, 138.31, 135.33, 133.20, 129.60, 122.13, 120.63, 119.51, 116.65, 26.92.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{14}O_3N$: 256.0968; found: 256.0967.

N-(4-Acetylphenyl)-4-chlorobenzamide (3n)

Yellow solid; yield: 199 mg (73%); mp 164–165 °C (EtOAc).

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 8.39 (d, *J* = 8 Hz, 2 H), 8.09 (d, *J* = 8 Hz, 2 H), 7.99 (s, 1 H), 7.89 (d, *J* = 8 Hz, 2 H), 7.47 (d, *J* = 8 Hz, 2 H), 2.67 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 196.74, 151.66, 138.08, 136.98, 134.16, 130.44, 129.50, 129.10, 128.79, 122.00, 26.92.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{15}H_{13}O_2NCl$: 274.0629; found: 274.0630.

3-Phenyl-N-(4-tolyl)acryamide (3o)

Yellow solid; yield: 126 mg (53%); mp 154–157 °C [Lit.[35] 156–157 °C].

^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 7.8 (d, *J* = 12 Hz, 1 H), 7.7 (s, 1 H), 7.6 (d, *J* = 8 Hz, 2 H), 7.58 (d, *J* = 8 Hz, 2 H), 7.3–7.4 (m, 3 H), 7.25 (d, *J* = 7.6 Hz, 2 H), 7.14 (d, *J* = 16 Hz, 1 H), 2.4 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 145.12, 140.35, 139.75, 136.15, 135.99, 129.66, 129.49, 128.96, 127.53, 121.22, 119.18, 21.25.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{16}H_{16}ON$: 238.1226; found: 238.1221.

4-[(4-Fluorobenzoyl)amino]benzoic Acid (3p)

Brown solid; yield: 109 mg (42%); mp >300 °C [Lit.[36] 300 °C].

^{1}H NMR (500 MHz, CD_3OD): δ = 8.57 (d, *J* = 3.2 Hz, 2 H), 8.45 (s, 1 H), 8.14 (d, *J* = 8.8 Hz, 2 H), 7.89 (d, *J* = 8.7 Hz, 2 H), 7.27 (s, 2 H).

^{13}C NMR (126 MHz, CD_3OD): δ = 165.26, 163.25, 149.91, 136.65, 132.42, 130.13, 126.93, 124.66, 121.70, 121.12, 115.28.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{14}H_{11}O_3NF$: 260.0717; found: 260.0715.

2-[(4-Fluorobenzoyl)amino]benzoic Acid (3q)

Brown solid; yield: 101 mg (39%); mp >300 °C (EtOAc) [Lit.[37] 183 °C].

^{1}H NMR (500 MHz, CD_3OD): δ = 8.07 (s, 1 H,), 8.06 (s, 1 H), 8.05 (d, *J* = 2.1 Hz, 2 H), 7.20 (d, *J* = 1.9 Hz, 1 H), 7.18 (s, 3 H), 7.17 (d, *J* = 1.8 Hz, 1 H).

^{13}C NMR (126 MHz, CD_3OD): δ = 167.29, 166.72, 164.72, 133.54, 132.02, 131.22, 127.00, 115.04, 114.86.

HRMS (ESI): *m*/*z* [M – H]$^+$ calcd for $C_{14}H_9O_3NF$: 258.0567; found: 258.0561.

4-Methyl-N-(2-pyridyl)benzamide (3r)

White solid, yield: 32 mg (15%); mp 120–121 °C [Lit.[38] 123.6–124.3 °C].

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.11 (d, *J* = 4.1 Hz, 1 H), 7.40 (dd, *J* = 15.5, 1.7 Hz, 1 H), 7.32 (dd, *J* = 8.3, 5.5 Hz, 2 H), 7.02 (t, *J* = 8.6 Hz, 2 H), 6.60 (dd, *J* = 6.9, 5.2 Hz, 1 H), 6.36 (d, *J* = 8.4 Hz, 1 H).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 163.01, 161.06, 158.43, 148.23, 137.45, 134.9, 128.94, 115.50, 115.33, 113.32, 106.88.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{12}H_{10}ON_2F$: 217.0772; found: 217.0770.

N-(2-Furyl)benzamide (3s)

Grayish-white solid; yield: 140 mg (75%); mp 119–120 °C [Lit.[39] 121–122 °C].

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.15 (s, 1 H), 8.01 (d, *J* = 3.4 Hz, 1 H), 7.79 (d, *J* = 6.7 Hz, 2 H), 7.58 (s, 1 H), 7.47 (q, *J* = 6.5 Hz, 3 H), 6.64 (d, *J* = 1.7 Hz, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.77, 147.52, 144.63, 129.95, 129.18, 124.27, 121.04, 116.48, 112.71.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{11}H_{10}O_2N$: 188.0706; found: 188.0703.

N-(2-Furyl)-4-methylbenzamide (3t)

Grayish-white solid; yield: 181 mg (90%); mp 132.0–132.9 °C (EtOAc) [Lit.[40] 108 °C (EtOH)].

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.12 (s, 1 H), 7.98 (d, *J* = 3.4 Hz, 1 H), 7.68 (d, *J* = 8.3 Hz, 2 H), 7.57 (d, *J* = 1.5 Hz, 1 H), 7.27 (d, *J* = 7.3 Hz, 2 H), 6.65–6.62 (m, 1 H), 2.41 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.62, 145.04, 144.43, 140.20, 129.66, 123.77, 120.77, 116.20, 112.65, 21.12.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{12}H_{12}O_2N$: 202.0863; found: 202.0859.

4-Acetyl-N-(2-furyl)benzamide (3u)

Yellow flake solid; yield: 185 mg (81%); mp 151.2–151.7 °C (EtOAc).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.24 (s, 1 H), 8.09 (s, 1 H), 8.08–8.05 (m, 2 H), 7.92 (d, *J* = 8.6 Hz, 2 H), 7.62 (d, *J* = 1.5 Hz, 1 H), 6.67 (dd, *J* = 3.4, 1.0 Hz, 1 H), 2.65 (s, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 196.56, 147.36, 145.26, 137.94, 129.41, 124.79, 121.19, 117.46, 112.93, 26.75.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{13}H_{12}O_3N$: 230.0812; found: 230.0812.

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Supporting Information

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