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N-Amination of Pyrrole and Indole Heterocycles with Monochloramine (NH_2Cl)

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Abstract: A survey of several electrophilic ammonia reagents for the N-amination of indole- and pyrrole-containing heterocycles revealed that monochloramine (NH_2Cl) is an excellent reagent for this transformation. Pyrroles and indoles containing a variety of substitution were aminated on nitrogen with isolated yields ranging from 45% to 97%.

Safe, efficient, and economical processes for the introduction of pendant NH_2 functionality onto carbon and nitrogen anions are limited in practicality by the requirement of stoichiometric electrophilic nitrogen transfer reagents. Until improved processes for the direct NH_2^+ transfer onto carbon and nitrogen centers is discovered, such reagents (Figure 1) will remain the most widely used for reactions of this type. The varying availability, high cost, and potentially dangerous properties of many of these reagents preclude their utility in scaleable reaction processes. In fact, two recent reports highlight the continued interest in novel NH_2^+ transfer reagents whose improved physical and chemical properties make them more amenable to widespread use in organic synthesis.[1,2]

Heterocycle N-aminations have been reported using various methods and reagents, primarily those derived from hydroxylamine (Figure 1),[3−7] but inspection of these reports reveal that the generality of the common reagents is limited. For example, early work identified hydroxylamine-*O*-sulfonic acid (HOSA)[3] as a capable reagent for reactions of this type, but it failed for substrates containing base-sensitive functionality. Additionally, heterocycle N-amination with HOSA suffers from poor substrate conversion requiring chromatographic separation of the products from the starting materials. *O*-(2,4-Dinitrophenyl)-hydroxylamine (DnpONH$_2$, **1**) has been utilized as an electrophilic source of nitrogen for various types of reactions including heterocycle N-aminations.[4] Previous studies have demonstrated that reaction of pyrrole **2a** with **1** affords 1-aminopyrrole **3a** in 85−90% yield (Table 1, entry 1) on a multigram scale.[8] However, **1** is not readily available and has the potential for detonation.[9] Additionally, the reaction waste

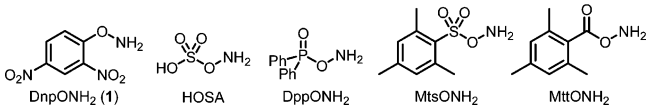
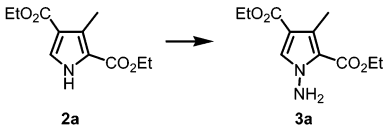
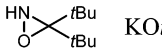


FIGURE 1. Common reagents for NH_2^+ transfer reactions onto heterocyclic nitrogens.[12]

TABLE 1. Survey of NH_2^+ Transfer Reagents for the Conversion of 2a to 3a



2a **3a**

Entry	Reagent	Base	Solvent	**3a**[a] (% yield)
1	**1**	NaH	DMF	85–90
2	HOSA	KO*t*Bu	DMF	4–12[b]
3	HOSA	KH	DMF	0
4	HOSA	KOH	DMF	0
5	HOSA	KO*t*Bu	tol/H_2O	3–5[b,c]
6	HOSA	DBU	tol/H_2O	3–5[b,c]
7	HOSA	NaOEt	EtOH	0
8		KO*t*Bu	DMF	6–7[d]
9	NH_2Cl	NaH	DMF	89
10	NH_2Cl	KO*t*Bu	DMF	89

[a] Isolated. [b] HPLC conversion after 1 h at room temperature (YMC S5 ODS-A, 4.6 mm × 50 mm; 10% MeOH/water/0.2% H_3PO_4 gradient to 90% MeOH/water/0.2% H_3PO_4, 4 mL/min, 8 min gradient, 220 nm). [c] Bu_4NBr added as phase transfer catalyst. [d] HPLC conversion after 3 days.

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(1) Boyles, D. C.; Curran, T. T.; Partlett, R. V., III. *Org. Proc. Res. Dev.* **2002**, *6*, 230.
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(8) Hunt, J. Unpublished results.

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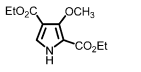
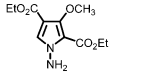
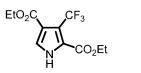
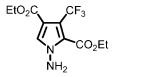
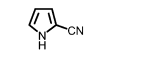
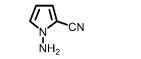
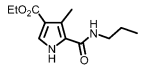
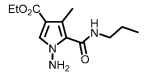
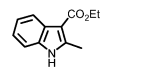
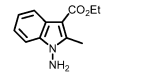
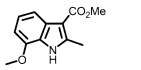
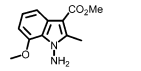
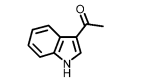
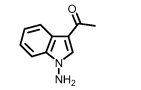
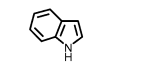
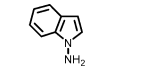
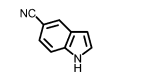
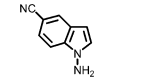
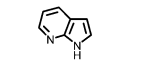
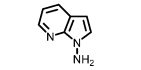
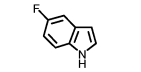
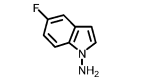
TABLE 2. *N*-Amino Heterocycles Prepared with NH_2Cl

Entry	Heterocycle		Product		Method[a] (rxn concn)	Reaction Time (h)	%Yield[b] (HPLC conv)[c]
1		**2b**		**3b**	A	0.5	88
2		**2c**		**3c**	A	5	88
3		**2d**		**3d**	A	0.5	44 (>95)
4		**2e**		**3e**	A	0.5	89
5		**2f**		**3f**	A	0.5	88
6		**2g**		**3g**	A	0.5	88
7		**2h**		**3h**	A	0.5	95
8a		**2i**		**3i**	A (0.5 M)	1	– (50)
8b					B (0.5 M)	2	– (66)
8c					B (0.33M)	0.25	– (73)
8d					B (0.25M)	0.25	72 (>95)
9a		**2j**		**3j**	A	6	50 (83)
9b					B	0.25	89
10a		**2k**		**3k**	A	6	44 (50)
10b					B	0.25	97
11a		**2l**		**3l**	A	3	– (50)
11b					B	0.25	45 (>95)[c,d]

[a] Method A: 1.2 equiv of NaH as base. Method B: 2.0 equiv of KO*t*Bu as base. [b] Isolated. [c] HPLC conditions: (YMC S5 ODS-A, 4.6 mm × 50 mm; 10% MeOH/water/0.2% H_3PO_4 gradient to 90% MeOH/water/0.2% H_3PO_4, 4 mL/min, 8 min gradient, 220 nm). [d] **3l** decomposed rapidly in air.

stream contains the highly toxic 2,4-dinitrophenol,[10] which is also potentially explosive.[11] Finally, only 8.1% (NH_2 content by mass) of **1** is used in the reaction, making the overall process inefficient. We now report our efforts to identify optimal NH_2^+ transfer reaction processes for the preparation of *N*-amino heterocycles, specifically, 1-aminopyrroles and 1-aminoindoles.

Utilizing diethyl 3-methylpyrrole-2,4-dicarboxylate (**2a**) as a test substrate, we surveyed several NH_2^+ transfer reagents for the synthesis of **3a** (Table 1). Under similar conditions as those using **1**, the commercially available HOSA gave moderate conversion of **2a** to **3a** (entry 2). Phase transfer catalyzed reactions (entries 5 and 6) gave poor yields of **3a**, as did 3,3′-di-*tert*-butyloxaziridine[13] (entry 8). *O*-(Mesitylenesulfonyl)-hydroxylamine ($MtsONH_2$)[5] and *O*-(diphenylphosphinyl)-hydroxylamine ($DppONH_2$)[6] did not offer a synthetic advantage over **1** and were not pursued for large-scale reactions.[14]

We were intrigued by several communications reporting the amination of amides with monochloramine (NH_2Cl) for the synthesis of acylhydrazines.[15] By modifying this method, we found that treatment of **2a** with NaH or KO*t*Bu (1.2 equiv) followed by anhydrous ethereal NH_2Cl (1.2 equiv) produced **3a** in greater than 93% conversion and 89% isolated yield on 1-mmol scale (Table 1, entries 9 and 10). To our knowledge, this represents the first application of NH_2Cl for aromatic heterocycle N-aminations. Ethereal NH_2Cl is readily prepared from NH_4Cl, NH_4OH, and bleach,[16] and the reaction byproducts are enviromentally benign. Furthermore, this transformation is highly efficient: 31% of the reagent is consumed in the reaction as compared to 8.1% for **1**.

Following this discovery, we sought to apply this reaction to other heterocyclic systems containing an acidic NH. As detailed in Table 2, this reaction works well for pyrroles (entries 1−4) containing a variety of functional groups. Diethyl 3-methoxypyrrole-2,4-dicarboxylate (**2b**) and diethyl 3-trifluoromethylpyrrole-2,4-

(9) Compound **1** has a reported decomposition onset temperature of 90−110 °C with an energy of 2308 J/g; see ref 1. Subsequent studies in our laboratories confirmed these results, although a lower energy of decomposition was observed: 1269 J/g, onset 105 °C.

(10) Rat oral LD_{50} = 30 mg/kg.

(11) Detonation of a reaction using **1** and KH has been reported: Radhakrishna, A. S.; Loudon, G. M. *J Org. Chem*. **1979**, *44*, 4836.

(12) We have adopted the annotation of Friestad for the compounds in Figure 1; see ref 2.

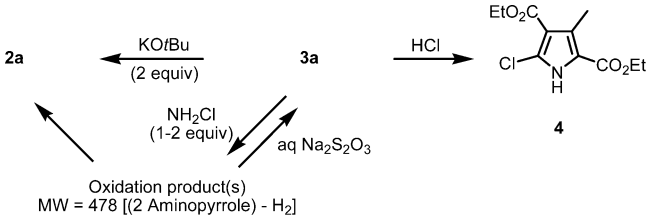
(13) Choong, I. C.; Ellman, J. A. *J. Org. Chem*. **1999**, *64*, 6528.

(14) $DppONH_2$ has given similar results as **1**.

(15) (a) Metlesics, W.; Tavares, R. F.; Sternbach, L. H. *J. Org. Chem*. **1965**, *30*, 1311. (b) Karady, S.; Ly, M. G.; Pines, S. H.; Sletzinger, M. *J. Org. Chem*. **1971**, *36*, 1949. (c) Khatib, A. A.; Sisler, H. H. *Inorg. Chem*. **1990**, *29*, 309.

(16) (a) Jaffari, G. A.; Nunn, A. J. *J Chem. Soc. C* **1971**, 823. (b) Goehring, R. R. In *Encyclopedia of Reagents for Organic Synthesis*; Paquette, L. A., Ed.; Wiley: New York, 1995; Vol. 2, pp 1052−1053. (c) See also: Theilacker, W.; Wegner, E. *Angew. Chem*. **1960**, *72*, 127.

SCHEME 1. Reactions of *N*-Aminopyrrole 3a



dicarboxylate (**2c**, entries 1 and 2) were aminated in 88% yield, whereas 2-cyanopyrrole (entry 3) was N-aminated with high conversion (>95% HPLC) to afford **3d**,[3i] albeit in low isolated yield.[17] Chemoselective pyrrole N-amination in the presence of a pendant monosubstituted amide was anticipated on the basis of pK_a differences of the pyrrole[18] and amide NH. As shown in entry 4, N-amination of **2e** afforded **3e** in high yield; amination of the C-2 amide nitrogen was not observed.

Indoles containing electron-withdrawing groups were N-aminated in high yield (entries 5−7) under the standard conditions. Of noteworthy importance, 3-acetyl indole (**2h**), previously reported to be inert to N-amination using HOSA,[3d] underwent rapid conversion in high yield to **3h** using this method. Indole (**2i**, entry 8a) reacted to 50% conversion using NaH as base. Similarly, 5-cyanoindole (**2j**, entry 9a), 7-aza-indole (**2k**, entry 10a), and 5-fluoroindole (**2l**, entry 11a) also halted at moderate levels of conversion. Although these levels of conversion are comparable to aminations of indoles using HOSA or $DppONH_2$,[3d,6a] demonstration of this reagent as a superior alternative to the existing methods would require higher levels of conversion and isolated yields. We therefore focused our efforts on the amination of indole (**2i**) to demonstrate the generality of this methodology. Attempts were made to enhance conversion with additional NH_2Cl and/or NaH; however, these all failed. Extended reaction times (16 h) did not increase the overall conversion nor did extended exposure to NaH before NH_2Cl addition. We initially theorized that poor conversion could be explained by the pK_a differences of indole and the substituted indoles in Table 1. However, another possibility is that 1-aminoindole under these conditions is not stable,[19] and in the case of a slowly reacting substrate, N-deamination becomes a competitive process. This reverse process is not unprecedented. In two separate reports, Somei and Belley have observed the deamination of 1-aminoindoles in the presence of base or for extended reaction times.[3d,l] N-Deamination has also been observed for **3a**. When exposed to 2 equiv of KO*t*Bu in DMF, **3a** decomposes almost quantitatively to pyrrole **2a** within 15 min at room temperature (Scheme 1). Although the mechanism of this reverse process is not known, this may account for the poor yields associated with N-aminations of heterocycles with HOSA. Returning to the problem of poor conversion for indole and indoles **2j**−**l**, we found that by using 2 equiv of KO*t*Bu and freshly prepared NH_2Cl, N-amination of these molecules was instantaneous with no additional conversion after 2 min. Additionally, reaction concentration had a significant effect for the synthesis of **3i**. Reduced initial concentration in DMF led to higher conversion levels (entries 8b−d) as a result of increased solubilization of the formed indole anion. These improved conditions allowed for a 72% isolated yield of **3i**.

TABLE 3. Relationship Between Base and Chloropyrrole (4) Formation

entry	NH_2Cl (equiv)	KO*t*Bu (equiv)	pH	yield **3a** (%)	yield **4** (%)
1	1.2	1.0	3−4	75	25
2	1.2	2.0	11	95	<5

Having demonstrated the generality of this reaction, we next turned to multigram-scale reactions. The preferred solvent system of NH_2Cl in ether was reevaluated along with alternatives to $CaCl_2$ as a drying agent for the NH_2Cl preparation. The solubility of NH_2Cl in THF, MTBE, ethyl acetate, toluene, and water was determined to be 0.17, 0.09, 0.12, 0.05, and 0.04 M, respectively.[20] Evaluation of these solutions for the conversion of **2a** to **3a** revealed that MTBE solutions gave conversion levels equivalent to ether/NH_2Cl solutions. Ethyl acetate/NH_2Cl solutions proceeded to a maximal 40−45% conversion, whereas THF, toluene, and water solutions of NH_2Cl failed to give substantial conversion to **3a**. K_2CO_3 was found to be an equivalent drying agent to $CaCl_2$, giving solutions with <0.03% water.[21] The concentration of NH_2Cl routinely obtained in MTBE dried with K_2CO_3 was 0.12M.

On a 5-g scale, amination of **2a** proceeded rapidly with 95% HPLC conversion to **3a**. However, following a water quench, extractive workup, and concentration, the starting pyrrole **2a** was recovered. Assessment of the stability of **3a** under the reaction conditions revealed that **3a** reacts with excess NH_2Cl to give an oxidation product,[22] which can be reverted to the aminopyrrole by treatment with aqueous $Na_2S_2O_3$ (Scheme 1). Accordingly, a modified quenching procedure utilizing aqueous $Na_2S_2O_3$ was employed allowing for isolation of **3a** in 86% yield and 99.5% purity.

Subsequent studies also revealed that in the presence of an excess of NH_2Cl relative to base (Table 3, entry 1) lower yields of **3a** were achieved and a new product, diethyl 2-chloro-4-methylpyrrole-3,5-dicarboxylate (**4**, Scheme 1), was observed. Control experiments with aqueous HCl confirmed our hypothesis that **3a** was degraded under the acidic reaction conditions to chloropyrrole **4** (Scheme 1). Final modifications using 2.0 equiv of KO*t*Bu with 1.2−1.4 equiv of NH_2Cl while maintaining efficient stirring and N_2 sparge during NH_2Cl addition were found to be optimal (entry 2), allowing for the preparation **3a** in 90% yield on a 75-g scale.

(17) Aminopyrrole **3d** had significant water solubility contributing to the poor isolated yield due to losses on workup.

(18) The pK_a of **2a** was determined to be 8.7 ± 0.2 using the spectrophotometric titration method.

(19) Aminoindoles **3i** and **3l** were noticeably less stable than aminoindoles containing electron-withdrawing groups. Extended reaction times were accompanied with significant degradation of product. This was also observed upon aqueous workup and careful attention was made to exclude oxygen from the workup process.

(20) The concentration of NH_2Cl in solution was determined by iodometric titration.

(21) Water content was determined using a Karl Fischer titration instrument.

(22) This oxidation product was observed by LCMS. Interestingly, amines and alcohols can be oxidized upon prolonged exposure to NH_2Cl: $2PhNH_2 + 2NH_2Cl \rightarrow PhN{=}NPh + 2NH_4Cl$; see ref 16a.

In summary, we have discovered and developed a simplified and practical procedure for the electrophilic amination of heterocycles using NH_2Cl, a reagent that is easily prepared from inexpensive precursors. We believe this alternative N-amination reaction process is superior to those utilizing HOSA or other synthetic NH_2^+ transfer reagents, offering a safer and more economical synthesis of *N*-amino heterocycles.

Experimental Section

All starting materials were commercial grade and used without further purification. Pyrroles **2a**−**e**[23] and indole **2g**[24] are available using known synthetic procedures.

Preparation of Anhydrous Ethereal Monochloramine.[16] NH_4Cl (3 g, 56 mmol) in ether (110 mL) was cooled to −5 °C, and concentrated NH_4OH (4.7 mL) was added via pipet. Commercial bleach (Clorox, 72 mL) was then added via addition funnel over 15 min. The mixture was stirred for 15 min, the layers were separated, and the organic layer was washed with brine (1 × 35 mL). The organic layer was dried over powdered $CaCl_2$ in a freezer for 1 h and stored at −40 °C. Approximate concentration is 0.15 M.

General Amination Procedure. Diethyl 1-Amino-3-methylpyrrole-2,4-dicarboxylate (3a). Method A. To a solution of pyrrole **2a** (1 mmol) in DMF (2 mL) was added NaH (1.2 mmol), and the reaction was stirred for 45 min at room temperature. NH_2Cl (8 mL, ca. 0.15 M in ether) was added via syringe while maintaining a nitrogen sparge. The reaction was monitored by HPLC until completion. The reaction was then quenched with saturated aqueous $Na_2S_2O_3$, diluted with water, and extracted into ether. The ether layer was dried, filtered, and concentrated in vacuo to give diethyl 1-amino-3-methylpyrrole-2,4-dicarboxylate (**3a**) in 89% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (s, 1H), 4.85 (br s, 2H), 4.35 (q, J = 7.1 Hz, 2H), 4.26 (q, J = 7.1 Hz, 2H), 2.57 (s, 3H), 1.39 (t, J = 7.1 Hz, 3H), 1.33 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 162.9, 132.4, 130.7, 120.0, 111.9, 60.8, 60.0, 14.8, 14.7, 14.4; HRMS (ESI) m/z 240.1200 (M^+), calcd for $C_{11}H_{16}N_2O_4$ 240.1100. Anal. Calcd for $C_{11}H_{16}N_2O_4$: C, 54.99; H, 6.71; N, 11.66. Found: C, 54.65; H, 6.54; N, 11.85. **Method B.** Substitute 2.0 equiv KO*t*Bu for NaH.

75-g Procedure. Pyrrole **2a** (75 g, 0.33 mol) and KO*t*Bu (75 g, 0.67 mol) were dissolved in DMF (1.5 L) and stirred for 2 h at room temperature. While vigorously sparging with nitrogen, NH_2Cl (3.3 L, 0.15 M in MTBE) was added in portions of 300 mL over 20 min, and the reaction mixture was stirred for 5 min. HPLC analysis indicated <1% of residual **2a**. The reaction was then added to 2.0 L of aqueous $Na_2S_2O_3$ (100 g/L) while maintaining the temperature at less than 25 °C. After stirring overnight, the reaction mixture was allowed to phase split, and the layers were separated. The aqueous layer was back-extracted with 1.0 L of MTBE and the combined organic layers were washed water (2 × 1.0 L). The organic layer was distilled to a volume of 750 mL to give (**3a**) as 95.5 g/L solution in MTBE (90% yield).

Diethyl 1-Amino-3-methoxypyrrole-2,4-dicarboxylate (3b). 88% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (s, 1 H), 4.75 (br s, 2H), 4.28 (q, J = 7.1 Hz, 2H), 4.20 (q, J = 7.1 Hz, 2H), 3.83 (s, 3 H), 1.32 (t, J = 7.1 Hz, 3H), 1.27 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.9, 161.7, 151.8, 130.3, 113.3, 105.8, 63.3, 61.0, 60.3, 14.7, 14.7; MS (ESI) m/z 257.0 (M + H), calcd for $C_{11}H_{16}N_2O_5$ 256.1.

Diethyl 1-Amino-3-trifluoromethylpyrrole-2,4-dicarboxylate (3c). 88% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (s, 1H), 4.45 (br s, 2H), 4.23 (q, J = 7.2 Hz, 2H), 4.12 (q, J = 7.2 Hz, 2H), 1.22 (t, J = 7.2 Hz, 3H), 1.17 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.6, 161.1, 131.2, 123.3, 122.2 (CF_3, J = 280 Hz), 112.7, 62.5, 61.3, 14.5, 14.1; MS (DCI) m/z 293.9 (M^+), calcd for $C_{11}H_{13}N_2O_4F_3$ 294.1.

1-Amino-2-cyanopyrrole (3d).[3i] 44% yield.

Ethyl 1-Amino-2-(*n*-propylcarboxamido)-3-methylpyrrole-4-carboxylate (3e). 89% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (s, 1H), 6.05 (br s, 1H), 4.18 (q, J = 7.1 Hz, 2H), 3.33 (q, J = 6.4 Hz, 2H), 2.47 (s, 3H), 1.57 (m, 2H), 1.26 (t, J = 7.1 Hz, 3H), 0.93 (t, J = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 162.6, 130.5, 123.8, 123.1, 111.4, 60.0, 41.5, 23.4, 14.8, 12.2, 11.9; MS (ESI) m/z 254.1 (M + H), calcd for $C_{12}H_{19}N_3O_3$ 253.1. Anal. Calcd for $C_{12}H_{19}N_3O_3$: C, 56.90; H, 7.56; N, 16.59. Found: C, 57.07; H, 7.50; N, 16.36.

Ethyl 1-Amino-2-methylindole-3-carboxylate (3f). 88% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (m, 1H), 7.22−7.13 (m, 3H), 4.15 (br s, 2H), 4.29 (q, J = 7.1 Hz, 2H), 2.61 (s, 3H), 1.36 (t, J = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 146.8, 136.9, 124.9, 122.5, 122.3, 121.6, 108.6, 102.0, 59.8, 15.0, 11.6; MS (ESI) m/z 219.1 (M + H), calcd for $C_{12}H_{14}N_2O_2$ 218.1. Anal. Calcd for $C_{12}H_{14}N_2O_2$: C, 66.04; H, 6.47; N, 12.84. Found: C, 65.79; H, 6.22; N, 12.57.

Methyl 1-Amino-2-methyl-7-methoxyindole-3-carboxylate (3g). 88% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, J = 8.1 Hz, 1H), 7.00 (t, J = 8.1 Hz, 1H), 6.55 (d, J = 7.9 Hz, 1H), 4.25 (br s, 2H), 3.84 (s, 3H), 3.82 (s, 3H), 2.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.8, 146.9, 146.7, 127.2, 125.2, 122.5, 114.4, 103.3, 101.6, 55.8, 51.0, 11.5; MS (ESI) m/z 235.1 (M + H), calcd for $C_{12}H_{14}N_2O_3$ 234.1. Anal. Calcd for $C_{12}H_{14}N_2O_3$: C, 61.53; H, 6.02; N, 11.96. Found: C, 61.49; H, 5.85; N, 11.78.

1-Amino-3-acetylindole (3h). 95% yield; ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.22 (s, 1H), 8.16 (d, J = 7.9 Hz, 1H), 7.54 (d, J = 8.1 Hz, 1H), 7.27 (t, J = 8.0 Hz, 1H), 7.20 (t, J = 7.6 Hz, 1H), 6.26 (s, 2 H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.4, 138.0, 137.7, 124.2, 122.9, 122.4, 121.6, 113.2, 110.7, 27.6; MS (ESI) m/z 175.1 (M + H), calcd for $C_{10}H_{10}N_2O$ 174.1. Anal. Calcd for $C_{10}H_{10}N_2O$: C, 68.95; H, 5.79; N, 16.08. Found: C, 68.68; H, 5.62; N, 15.92.

1-Aminoindole (3i).[3d] 73% yield.

1-Amino-5-cyanoindole (3j). 89% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (s, 1H), 7.52 (d, J = 8.3 Hz, 1H), 7.46 (dd, J = 8.4, 1.4 Hz, 1H), 7.28 (d, J = 3.3 Hz, 1H), 6.49 (d, J = 3.3, 1H), 4.75 (br s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.3, 131.7, 126.5, 126.0, 124.8, 120.7, 109.7, 102.8, 100.3; MS (ESI) m/z 158.0 (M + H), calcd for $C_9H_7N_3$ 157.1. Anal. Calcd for $C_9H_7N_3$: C, 68.77; H, 4.48; N, 26.73. Found: C, 68.10; H, 4.41; N, 26.65.

1*H*-Pyrrolo[2,3-*b*]pyridine-1-amine (3k).[3h] 97% yield.

1-Amino-5-fluoroindole (3l). 45% yield; ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.45 (q, J = 4.7 Hz, 1H), 7.33 (d, J = 3.2 Hz, 1H), 7.27 (dd, J = 10.0, 2.4 Hz, 1H), 6.99 (dt, J = 9.3, 2.5 Hz, 1H), 6.29 (d, J = 5.0 Hz, 1H), 5.98 (s, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 157.3, 133.6, 132.0, 126.1, 110.9, 109.7, 105.0, 97.8; MS (ESI) m/z 151.1 (M + H), calcd for $C_8H_7N_2F$ 150.1.

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Supporting Information Available: ^{1}H and ^{13}C NMR spectra for **3b**,**c**,**j**,**l** and **4** and characterization data for **3d**,**i**,**k** and **4**. This material is available free of charge via the Internet at http://pubs.acs.org.

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