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Approach to Trisubstituted 3-Aminopyrrole Derivatives by $Yb(OTf)_3$-Catalyzed [4+1] Annulation of 2-Azadiene with Me_3SiCN

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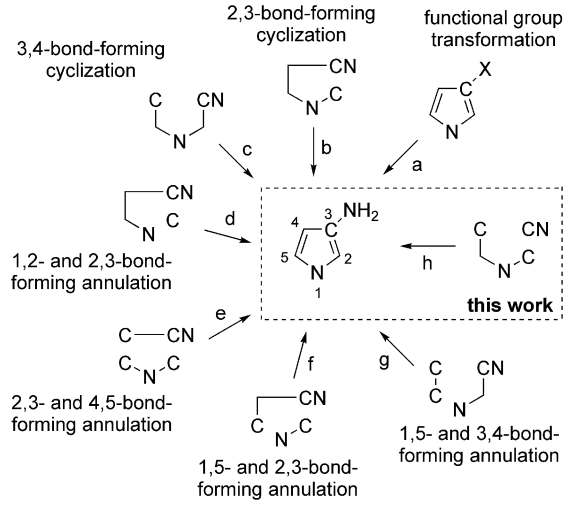
In the present study, we found a novel approach to the simple and practical synthesis of 3-aminopyrrole derivatives through the four-component coupling reaction of a functionalized silane, a nitrile, an aldehyde, and trimethylsilyl cyanide by $Yb(OTf)_3$-catalyzed annulation of a 2-azabutadiene with trimethylsilyl cyanide. In this paper, we also disclose a single-step transformation of the 3-aminopyrrole framework into the pyrrolo[3,4-*b*]pyridin-4-one skeleton.

Introduction

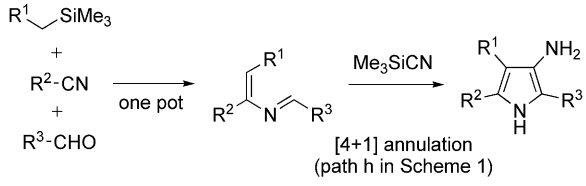
3-Aminopyrrole derivatives are found in many natural products and in a variety of biologically active substances,[1] such as distamycin A[2] and netropsin,[3] and they are useful building blocks in synthetic chemistry.[4] To date, a number of approaches to the construction of the pyrrole skeleton have been reported by many organic and pharmaceutical chemists,[5–9] and general synthetic methods for the synthesis of 3-aminopyrrole derivatives are shown in Scheme 1: (i) functional group transformation of pyrrole derivatives such as 3-hydroxypyrroles,[10] 3-nitropyrroles,[11] 3-arylazopyrroles,[12] and pyrrol-3-carboxylic acids[13] (path a); (ii) 2,3-bond-forming[14] or 3,4-bond-forming[15] cyclization (paths b and c); and (iii) 1,2- and 2,3-bond-forming,[16] 2,3- and 4,5-bond-forming,[17] 1,5- and 2,3-bond-forming,[18] and 1,5- and 3,4-bond-forming[19] annulation (paths d–g). To the best of our knowledge, there are few examples of the preparation of a 3-aminopyrrole derivative by 2,3- and 3,4-bond-forming annulation (path h).[20] Moreover, the previous methods require two equivalents of $TiCl_4$ as an additive,[20a] unavailable reagents such as a tungsten carbene complex[20b] and a multifunctionalized triazine,[20c] a multistep synthesis, and low temperature,[20a] which lead to low selectivity and a decline in product yields.

Thus, on the basis of our previous work,[21] we envisioned a facile and efficient approach for the preparation of 3-aminopyrrole derivatives, in which the intermolecular coupling reaction of a functionalized silane, a nitrile, and an aldehyde would initially form a 2-azabutadiene derivative followed by the Lewis acid catalyzed annulation of the



Scheme 1. Approach to the synthesis of 3-aminopyrrole derivative.

formed 2-azabutadiene with trimethylsilyl cyanide to produce the desired 3-aminopyrrole derivative (Scheme 2). Herein, we report the efficient and facile synthesis of 3-aminopyrrole derivatives by a four-component coupling reaction from a functionalized silane, a nitrile, an aldehyde, and trimethylsilyl cyanide. We also disclose a novel approach to the single-step synthesis of pyrrolo[3,4-*b*]pyridin-4-one de-



Scheme 2. This work.

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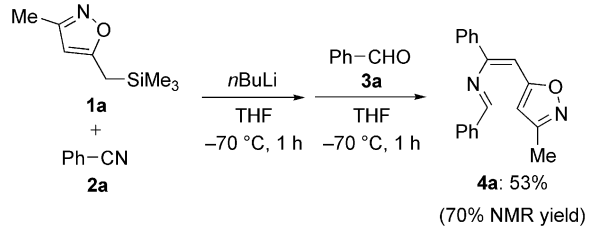
rivatives starting from the 3-aminopyrrole containing an isoxazole group by the reductive ring-opening reaction of the isoxazole ring.

Results and Discussion

On the basis of our previous work, we first examined the one-pot, three-component coupling reaction of a functionalized silane, an aromatic nitrile, and an aromatic aldehyde, leading to the preparation of 2-azabutadiene derivatives (Scheme 3).[22,23] For example, when the reaction of 3-methyl-5-(trimethylsilyl)methylisoxazole (**1a**) with benzonitrile (**2a**) was carried out in THF at –70 °C for 1 h in the presence of *n*BuLi, followed by the addition of benzaldehyde (**3a**), desired 2-azadiene **4a** was obtained in 53% yield. The structure of the 2-azadiene framework was unambiguously determined by spectroscopy and by X-ray structure analysis of isolated compound **4d**.

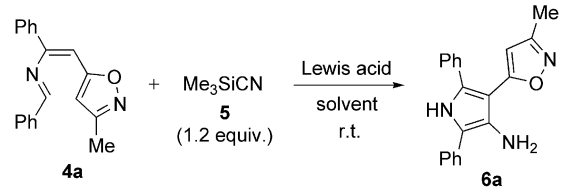


Scheme 3. One-pot synthesis of 2-azadiene **4a**.

The annulation of prepared 2-azabutadiene **4a** with trimethylsilyl cyanide (Me_3SiCN) to afford 3-aminopyrrole derivative **6a** was examined, and the results are summarized in Table 1. When the model reaction was performed without a Lewis acid catalyst, desired pyrrole derivative **6a** was not obtained (Table 1, Entry 1). Addition of a typical Lewis acid as an additive, such as $InCl_3$, $ZnCl_2$, $Cu(OTf)_2$, and $AlCl_3$, promoted the annulation to give desired product **6a**, but the yields were rather low (Table 1, Entries 2–5). The structure of the pyrrole skeleton was unambiguously determined by X-ray diffraction of crystallized compound **6g**. To enhance the yield, when $Yb(OTf)_3$ was employed, the product yield was drastically increased (Table 1, Entries 7–9). Because both Et_2O and toluene gave a slightly decent yield, THF was the most suitable reaction solvent (Table 1, Entries 10 and 11). Consequently, the reaction described in Entry 7 proved to be the optimal conditions for annulation, as shown in Table 1.

To extend the scope of the $Yb(OTf)_3$-catalyzed annulation, we next examined the reaction of various 2-azabutadienes with trimethylsilyl cyanide, leading to 3-aminopyrrole derivatives under our optimal conditions. These results are summarized in Table 2. When R^3 was a 4-chlorophenyl group, desired pyrrole derivative **6b** was produced in excellent yield (Table 2, Entry 2). By contrast, when R^3 was a 4-methoxyphenyl group, the desired reaction proceeded, but the yield of product **6c** was moderate (Table 2, Entry 3). Similarly, the use of 2-azabutadienes **4e**–**i**, containing a 4-methoxyphenyl group or a 4-chlorophenyl group as R^2, produced the corresponding pyrrole derivatives **6e**–**i** in good yields (Table 2, Entries 5–9). On the other hand, 2-azabutadiene **4j**, with a pyridin-3-yl group as R^3, gave desired product **6j**, but the yield was low (Table 2, Entry 10). Surprisingly, when 2-azabutadiene **4k** having a pyridin-4-yl group instead of a 3-methylisoxazol-5-yl group as R^1 was employed, the reaction was complete in the presence of only 0.05 equiv. of $Yb(OTf)_3$ within only 2 h to give pyrrole **6k** in 83% yield (Table 2, Entry 11).

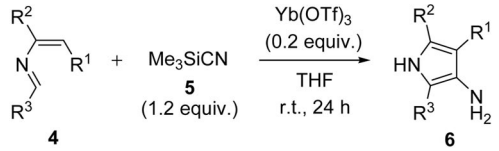
Table 1. Examination of synthesis of 3-aminopyrrole **6a**.

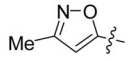


Entry	Lewis acid (equiv.)	Solvent	Time [h]	Yield [%][a]
1	none	THF	24	NR
2	$InCl_3$ (0.2)	THF	24	30
3	$ZnCl_2$ (0.2)	THF	24	31
4	$Cu(OTf)_2$ (0.2)	THF	24	trace
5	$AlCl_3$ (0.2)	THF	24	20
6	$Hf(OTf)_4$ (0.2)	THF	24	53
7	$Yb(OTf)_3$ (0.2)	THF	24	(75)
8	$Yb(OTf)_3$ (0.1)	THF	48	76
9	$Yb(OTf)_3$ (0.4)	THF	12	72
10	$Yb(OTf)_3$ (0.2)	Et_2O	24	68
11	$Yb(OTf)_3$ (0.2)	PhMe	24	65

[a] NMR yield (isolated yield); NR = no reaction.

Table 2. Single-step synthesis of 3-aminopyrrole **6**.

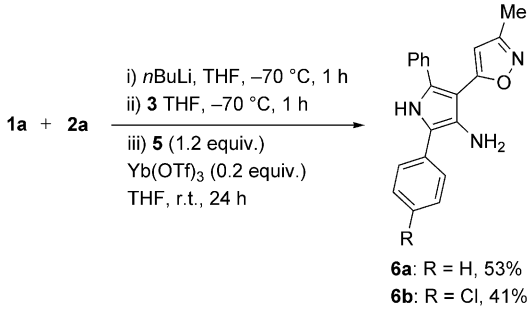


Entry	Azadiene **4**				Pyrrole	Yield
	R^1	R^2	R^3		**6**	[%][a]
1		Ph	Ph	**4a**	**6a**	75
2		Ph	4-ClC_6H_4	**4b**	**6b**	87
3		Ph	4-$MeOC_6H_4$	**4c**	**6c**	51
4		4-ClC_6H_4	Ph	**4d**	**6d**	77
5		4-ClC_6H_4	4-ClC_6H_4	**4e**	**6e**	73
6		4-ClC_6H_4	4-$MeOC_6H_4$	**4f**	**6f**	80
7		4-$MeOC_6H_4$	Ph	**4g**	**6g**	75
8		4-$MeOC_6H_4$	4-ClC_6H_4	**4h**	**6h**	83
9		4-$MeOC_6H_4$	4-$MeOC_6H_4$	**4i**	**6i**	62
10		Ph	3-Py	**4j**	**6j**	30
11[b]		4-$MeOC_6H_4$	Ph	**4k**	**6k**	83

[a] Isolated yield. [b] Reaction time = 2 h; $Yb(OTf)_3$ = 0.05 equiv.

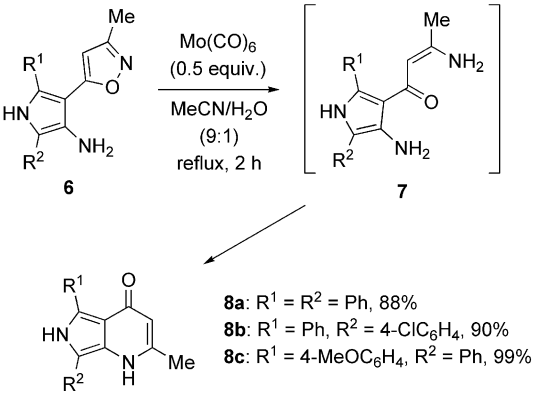
To apply the four-component coupling reaction using a functionalized silane, a nitrile, an aldehyde, and trimethylsilyl cyanide, we next attempted the one-pot synthesis of 3-aminopyrrole derivative **6** (Scheme 4). When the reaction

was carried out under the above optimal conditions, the desired reaction successfully proceeded to give pyrrole derivatives **6a** and **6b** in 53 and 41% yield, respectively.



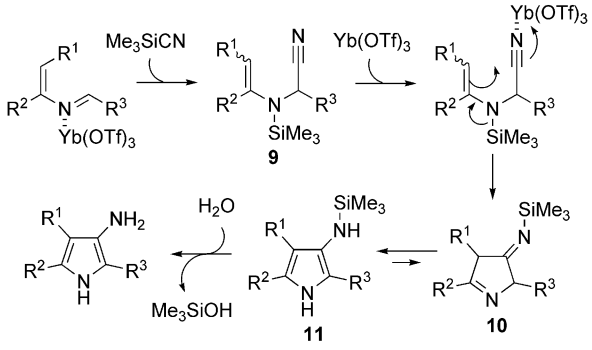
Scheme 4. One-pot synthesis of 3-aminopyrrole **6**.

Finally, to illustrate the utility of an isoxazole group, we examined the skeletal transformation of prepared 3-aminopyrroles **6** into pyrrolo[3,4-*b*]pyridin-4-one derivatives **8** (Scheme 5). When product **6a** was treated with 0.5 equiv. of $Mo(CO)_6$,[21f] rather than expected pyrrole derivative **7a**, pyrrolopyridine derivative **8a** was obtained in 88% yield through the reductive ring opening of the isoxazole followed by intramolecular cyclization.



Scheme 5. Synthesis of pyrrolo[3,4-*b*]pyridin-4-ones **8**.

A plausible mechanism for the Yb(OTf)$_3$-catalyzed annulation is shown in Scheme 6. First, coordination of Yb(OTf)$_3$ to the nitrogen atom of the 2-azadiene facilitated the attack of the azadiene by a cyanide ion, which led to the formation of intermediate **9**. Practically, when the reaction



Scheme 6. A plausible mechanism.

of azadiene **4a** with Me_3SiCN was treated with a catalytic amount of Yb(OTf)$_3$, intermediate **9a** was isolated in 70% yield.[24] Yb(OTf)$_3$-catalyzed intramolecular cyclization of intermediate **9** then occurred to produce corresponding intermediate **10** with a shift of the silyl group.[25] Finally, aromatization of intermediate **10** worked as the driving force to produce the desired 3-aminopyrrole derivative after conventional aqueous workup.

Conclusions

Thus far, we have outlined the process for a novel, simple, and practical synthesis of 3-aminopyrrole derivatives through the Yb(OTf)$_3$-catalyzed annulation of 2-azabutadiene with trimethylsilyl cyanide, and the four-component coupling reaction of a functionalized silane, a nitrile, an aldehyde, and trimethylsilyl cyanide. Also detailed is the transformation of 3-aminopyrroles with an isoxazolyl group into pyrrolo[3,4-*b*]pyridin-4-one derivatives through a reductive ring-opening reaction and subsequent intramolecular cyclization.

Experimental Section

General Methods: Column chromatography was performed by using Silica gel 60 and aluminum oxide 90 active neutral. THF, Et_2O, and toluene were distilled from sodium–benzophenone and dried with 5 Å MS or 4 Å MS. Prior to use, 3,5-dimethylisoxazole, trimethylsilyl chloride, benzonitrile, and benzaldehyde were distilled. Other materials were commercially available and were used without further purification. Using a previously reported procedure,[26] 4-(trimethylsilyl)methylpyridine (**1b**) was prepared. All reactions were carried out under a nitrogen atmosphere, unless otherwise noted. ^{1}H NMR spectra were measured at 500 or 300 MHz by using tetramethylsilane as an internal standard. ^{13}C NMR spectra were measured at 125 or 75 MHz by using the center peak of chloroform (δ =77.0 ppm) as an internal standard. High-resolution mass spectra were measured by using NBA (3-nitrobenzyl alcohol) as a matrix.

1b:[26] Colorless liquid. B.p. 76 °C/5 Torr (ref.[27] 73–74 °C/4.5 Torr). ^{1}H NMR (300 MHz, $CDCl_3$, 25 °C): δ = –0.05 (s, 9 H, -Si*Me*$_3$), 2.03 (s, 2 H, Ar-*CH*$_2$-SiMe$_3$), 6.84 (d, $^3J_{H,H}$ = 4.5 Hz, 2 H, Ar-*H*), 8.32 (d, $^3J_{H,H}$ = 4.5 Hz, 2 H, Ar-*H*) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = –2.1, 27.3, 123.4, 149.2, 150.1 ppm. MS (FA): *m*/*z* (%) = 166 (100) [M + H].

Procedure for the Synthesis of 1a: To a THF solution (120 mL) of diisopropylamine (55.6 g, 0.550 mol) was added *n*BuLi (1.5 M in hexane, 0.550 mol) at –70 °C, and the mixture was stirred at the same temperature. After 30 min, 3,5-dimethylisoxazole (48.6 g, 0.500 mol) was added dropwise, and the mixture was stirred for 1 h at –70 °C. Trimethylsilyl chloride (54.3 g, 0.500 mol) was gradually added to the solution at –70 °C, and the mixture was stirred for 1 h at the same temperature and then for 1 h at room temperature. To quench the reaction, a saturated aqueous solution of NH_4Cl was added to the mixture. The mixture was extracted several times with Et_2O, and the combined organic extracts were dried with Na_2SO_4, filtered, and then concentrated under reduced pressure. The residue was purified by distillation under reduced pressure to give 3-methyl-5-(trimethylsilyl)methylisoxazole (**1a**; 68.6 g, 81%) as

a colorless liquid. B.p. 109–110 °C/32 Torr (ref.[28] 43 °C/0.6 Torr). ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 0.03 (s, 9 H, -Si*Me*$_3$), 2.12 (s, 2 H, Ar-*CH*$_2$-SiMe$_3$), 2.18 (s, 3 H, Ar-*Me*), 5.57 (s, 1 H, Ar-*H*) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = –1.8, 11.3, 17.6, 99.9, 159.7, 171.9 ppm. MS (FA): *m*/*z* (%) = 170 (100) [M + H].

General Procedure for the Synthesis of 2-Azadienes 4a–j: To a THF solution (15 mL) of **1a** (847 mg, 5.00 mmol) was added *n*BuLi (1.5 M in hexane, 5.50 mmol) at –70 °C, and the reaction mixture was stirred at the same temperature. After 1 h, benzonitrile (**2a**; 516 mg, 5.00 mmol) was added to the solution by syringe, and the solution was further stirred for 1 h at –70 °C, then for 1 h at room temperature. Benzaldehyde (**3a**; 531 mg, 5.00 mmol) was added to the solution at –70 °C, and the mixture was stirred for 1 h at the same temperature, then for 1 h at room temperature. To quench the reaction, water (30 mL) was added to the mixture at 0 °C. The mixture was extracted several times with AcOEt, and the combined organic extracts were dried with Na_2SO_4, filtered, and then concentrated under reduced pressure. The residue was purified by neutral Al_2O_3 chromatography (hexane/AcOEt) to give **4a** (764 mg, 53%) as a yellow solid ($CHCl_3$/hexane).

4a: M.p. 87.2–87.4 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.14 (s, 3 H, Ar-*Me*), 6.04 (s, 1 H), 6.35 (s, 1 H), 7.26–7.31 (m, 3 H, Ar-*H*), 7.40–7.48 (m, 5 H, Ar-*H*), 7.84 (d, $^3J_{H,H}$ = 6.5 Hz, 2 H, Ar-*H*), 8.18 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.5, 101.0, 103.6, 127.0, 128.7, 129.0, 129.1, 132.2, 135.4, 137.1, 153.7, 159.8, 163.9, 167.6 ppm. MS (FA): *m*/*z* (%) = 288 (100) [M]$^+$. $C_{19}H_{16}N_2O$ (288.34): calcd. C 79.14, H 5.59, N 9.72; found C 79.06, H 5.50, N 9.73.

4b: Yield: 662 mg, 41%, yellow solid ($CHCl_3$/hexane). M.p. 120.1–121.0 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.25 (s, 3 H, Ar-*Me*), 6.09 (s, 1 H), 6.44 (s, 1 H), 7.38–7.42 (m, 3 H, Ar-*H*) 7.41–7.51 (m, 4 H, Ar-*H*), 7.87 (d, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 8.25 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.5, 101.4, 103.7, 127.0, 128.7, 129.2, 129.4, 130.1, 133.9, 137.0, 138.4, 153.4, 159.8, 164.5, 167.4 ppm. MS (FA): *m*/*z* (%) = 323 (100) [M + H]$^+$. $C_{19}H_{15}ClN_2O$ (322.79): calcd. C 70.70, H 4.68, N 8.68; found C 70.83, H 4.62, N 8.62.

4c: Yield: 1.10 g, 69%, yellow solid ($CHCl_3$/hexane). M.p. 119.5–120.7 °C. ^{1}H NMR (300 MHz, $CDCl_3$, 25 °C): δ = 2.24 (s, 3 H, Ar-*Me*), 3.90 (s, 3 H, Ar-O*Me*), 6.13 (s, 1 H), 6.43 (s, 1 H), 7.03 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.37–7.39 (m, 3 H, Ar-*H*), 7.49–7.53 (m, 2 H, Ar-*H*), 7.88 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 8.19 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.5, 55.5, 100.9, 103.4, 114.5, 127.1, 128.4, 128.7, 129.0, 130.8, 137.4, 154.0, 159.8, 163.0, 163.0, 167.8 ppm. MS (FA): *m*/*z* (%) = 319 (100) [M + H]$^+$. $C_{20}H_{18}N_2O_2$ (318.37): calcd. C 75.45, H 5.70, N 8.80; found C 75.45, H 5.71, N 8.80.

4d: Yield: 775 mg, 48%, yellow solid ($CHCl_3$/hexane). M.p. 92.8–92.9 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.23 (s, 3 H, Ar-*Me*), 6.11 (s, 1 H), 6.42 (s, 1 H), 7.35 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.44 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.52–7.59 (m, 3 H, Ar-*H*), 7.93 (d, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 8.27 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 11.4, 100.9, 103.7, 128.1, 128.9, 129.0, 129.0, 132.4, 135.1, 135.2, 135.5, 152.5, 159.8, 164.2, 167.2 ppm. MS (FA): *m*/*z* (%) = 323 (100) [M + H]$^+$. $C_{19}H_{15}ClN_2O$ (322.79): calcd. C 70.70, H 4.68, N 8.68; found C 70.84, H 4.71, N 8.69.

4e: Yield: 679 mg, 38%, yellow solid ($CHCl_3$/hexane). M.p. 174.1–175.1 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.24 (s, 3 H, Ar-*Me*), 6.07 (s, 1 H), 6.40 (s, 1 H), 7.36 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.43 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.50 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.86 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 8.23 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.4, 101.3, 103.8, 128.1, 128.9, 129.4, 130.2, 133.7, 135.2, 135.4, 138.6, 152.3, 159.8, 162.8, 167.1 ppm. MS (FA): *m*/*z* (%) = 358 (100) [M + H]$^+$. $C_{19}H_{14}Cl_2N_2O$ (357.23): calcd. C 63.88, H 3.95, N 7.84; found C 63.95, H 3.97, N 7.80.

4f: Yield: 759 mg, 43%, yellow solid ($CHCl_3$/hexane). M.p. 158.7–160.1 °C. ^{1}H NMR (300 MHz, $CDCl_3$, 25 °C): δ = 2.24 (s, 3 H, Ar-*Me*), 3.90 (s, 3 H, Ar-O*Me*), 6.11 (s, 1 H), 6.40 (s, 1 H), 7.03 (d, $^3J_{H,H}$ = 8.7 Hz, 2 H, Ar-*H*), 7.35 (d, $^3J_{H,H}$ = 8.7 Hz, 2 H, Ar-*H*), 7.45 (d, $^3J_{H,H}$ = 8.7 Hz, 2 H, Ar-*H*), 7.88 (d, $^3J_{H,H}$ = 8.7 Hz, 2 H, Ar-*H*), 8.17 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 11.5, 55.5, 100.8, 103.5, 114.5, 128.2, 128.8, 130.9, 135.0, 135.8, 152.8, 159.8, 163.1, 163.3, 167.5 ppm. MS (FA): *m*/*z* (%) = 353 (100) [M + H]$^+$. $C_{20}H_{17}ClN_2O_2$ (352.81): calcd. C 68.09, H 4.86, N 7.94; found C 67.76, H 4.93, N 7.86.

4g: Yield: 796 mg, 50%, yellow solid ($CHCl_3$/hexane). M.p. 123.8–124.9 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.22 (s, 3 H, Ar-*Me*), 3.84 (s, 3 H, Ar-O*Me*), 6.05 (s, 1 H), 6.38 (s, 1 H), 6.91 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.46 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.51–7.57 (m, 3 H, Ar-*H*), 7.94 (d, $^3J_{H,H}$ = 7.0 Hz, 2 H, Ar-*H*), 8.28 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 11.5, 55.3, 99.0 103.0, 114.1, 128.3, 129.0, 129.0, 129.5, 132.2, 135.5, 153.6, 159.8, 160.4, 163.9, 167.9 ppm. MS (FA): *m*/*z* (%) = 319 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{20}H_{19}N_2O_2$ [M + H]$^+$ 319.1447; found 319.1467.

4h: Yield: 529 mg, 30%, yellow solid ($CHCl_3$/hexane). M.p. 178.7–179.3 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.23 (s, 3 H, Ar-*Me*), 3.84 (s, 3 H, Ar-O*Me*), 6.01 (s, 1 H), 6.36 (s, 1 H), 6.92 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.43 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.50 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.87 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 8.25 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.5, 55.4, 99.4, 103.1, 114.1, 128.3, 129.3, 129.4, 130.1, 133.9, 138.4, 153.3, 159.8, 160.5, 162.4, 167.7 ppm. MS (FA): *m*/*z* (%) = 353 (100) [M + H]$^+$. $C_{20}H_{17}ClN_2O_2$ (352.81): calcd. C 68.09, H 4.86, N 7.94; found C 67.99, H 5.18, N 7.94.

4i: Yield: 610 mg, 35%, yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.22 (s, 3 H, Ar-*Me*), 3.82 (s, 3 H, Ar-O*Me*), 3.89 (s, 3 H, Ar-O*Me*), 6.05 (s, 1 H), 6.35 (s, 1 H), 6.90 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.03 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.45 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.88 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 8.18 (s, 1 H, -N=*CH*-Ar) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.4, 55.3, 55.4, 98.8, 102.7, 114.0, 114.4, 128.2, 128.4, 129.7, 130.7, 153.9, 159.7, 160.3, 162.9, 168.0 ppm. MS (FA): *m*/*z* (%) = 349 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{21}H_{20}N_2O_3$ [M]$^+$ 348.1474; found 348.1501.

4j: Yield: 477 mg, 33%, yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.25 (s, 3 H, Ar-*Me*), 6.15 (s, 1 H), 6.44 (s, 1 H), 7.38–7.42 (m, 3 H, Ar-*H*), 7.46–7.49 (m, 3 H, Ar-*H*), 8.31 (td, $^3J_{H,H}$ = 8.0 Hz, $^4J_{H,H}$ = 2.0 Hz, 1 H, Ar-*H*), 8.34 (s, 1 H, -N=*CH*-Ar), 8.76 (dd, $^3J_{H,H}$ = 4.5 Hz, $^4J_{H,H}$ = 2.0 Hz, 1 H, Ar-*H*), 9.05 (d, $^4J_{H,H}$ = 2.0 Hz, 1 H, Ar-*H*) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.3, 102.1, 104.0, 123.9, 126.9, 128.6, 129.1, 130.9, 135.1, 136.6, 150.8, 152.6, 153.0, 159.6, 161.1, 167.0 ppm. MS (FA): *m*/*z* (%) = 290 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{18}H_{16}N_3O$ [M + H]$^+$ 290.1293; found 290.1289.

Procedure for the Synthesis of 2-Azadiene 4k: To a THF solution (15 mL) of 4-(trimethylsilyl)methylpyridine (**1b**, 457 mg, 5.00 mmol) was added MeLi (1 M in Et_2O, 5.50 mmol) at room temperature, and the reaction mixture was heated at 60 °C. After 1 h, anisonitrile (666 mg, 5.00 mmol) was added to the solution by

syringe at room temperature, and the solution was stirred at the same temperature. After 1 h, benzaldehyde (531 mg, 5.00 mmol) was added to the mixture, and the reaction mixture was stirred for 1 h at room temperature. To quench the reaction, water (30 mL) was added to the mixture at 0 °C. The mixture was extracted several times with AcOEt, and the combined organic extracts were dried with Na_2SO_4, filtered, and then concentrated under reduced pressure. The residue was purified by neutral Al_2O_3 chromatography (hexane/AcOEt) to give **4k** (629 mg, 40%) as a yellow solid ($CHCl_3$/hexane). M.p. 191.2–192.4 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 3.84 (s, 3 H, Ar-O*Me*), 6.24 (s, 1 H, Ar-*CH*=CAr-), 6.92 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.42–7.45 (m, 4 H, Ar-*H*), 7.49–7.54 (m, 3 H, Ar-*H*), 7.89 (d, $^3J_{H,H}$ = 6.0 Hz, 2 H, Ar-*H*), 8.26 (s, 1 H, -N=*CH*-Ar), 8.47 (d, $^3J_{H,H}$ = 6.0 Hz, 2 H, Ar-*H*) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 55.3, 112.6, 114.0, 123.9, 128.6, 128.9, 129.0, 130.7, 132.0, 135.7, 144.2, 149.5, 153.9, 160.1, 163.3 ppm. MS (FA): *m*/*z* (%) = 315 (100) [M + H]$^+$. $C_{21}H_{18}N_2O$ (314.38): calcd. C 80.23, H 5.77, N 8.91; found C 80.04, H 6.15, N 8.75.

General Procedure for the Synthesis of 3-Aminopyrrole 6: To a THF (1 mL) solution of 2-azadiene **4** (0.500 mmol) and trimethylsilyl cyanide (**5**, 59.5 mg, 0.600 mmol) was added Yb(OTf)$_3$ (62.0 mg, 0.100 mmol) at room temperature, and the reaction mixture was stirred for 24 h at the same temperature. To quench the reaction, a saturated aqueous solution of $NaHCO_3$ (5 mL) was added to the mixture. The mixture was extracted several times with $CHCl_3$, and the combined organic extracts were dried with anhydrous Na_2CO_3, filtered, and then concentrated under reduced pressure. The crude product was purified by SiO_2 column chromatography (hexane/AcOEt) to afford **6** in the yields shown in Table 2.

6a: Yield: 118 mg, 75%, colorless solid ($CHCl_3$/hexane). M.p. 157.9–158.0 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.20 (s, 3 H, Ar-*Me*), 3.83 (br., 2 H, Ar-*NH*$_2$), 5.79 (s, 1 H, Ar-*H*), 7.20 (t, $^3J_{H,H}$ = 7.5 Hz, 1 H, Ar-*H*), 7.33 (t, $^3J_{H,H}$ = 7.5 Hz, 1 H, Ar-*H*), 7.36–7.45 (m, 6 H, Ar-*H*), 7.50 (t, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 8.24 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.3, 100.0, 101.8, 116.1, 124.8, 125.7, 127.9, 128.0, 128.7, 129.1, 129.2, 130.5, 132.1, 132.2, 159.6, 166.7 ppm. MS (FA): *m*/*z* (%) = 315 (100) [M]$^+$. HRMS (FAB): calcd. for $C_{20}H_{17}N_3O$ [M]$^+$ 315.1372; found 315.1380.

6b: Yield: 152 mg, 87%, pale-yellow solid ($CHCl_3$/hexane). M.p. 165.7–165.8 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.21 (s, 3 H, Ar-*Me*), 3.86 (br., 2 H, Ar-*NH*$_2$), 5.79 (s, 1 H, Ar-*H*), 7.33–7.45 (m, 9 H, Ar-*H*), 8.16 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.3, 100.1, 102.1, 115.2, 125.8, 127.9, 128.2, 128.8, 129.3, 129.5, 130.7, 130.9, 131.1, 131.9, 159.7, 166.5 ppm. MS (FA): *m*/*z* (%) = 349 (100) [M]$^+$. $C_{20}H_{16}ClN_3O$ (349.81): calcd. C 68.67, H 4.61, N 12.01; found C 68.51, H 4.61, N 12.01.

6c: Yield: 88.1 mg, 51%, green solid ($CHCl_3$/hexane). M.p. 148.0–148.7 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.19 (s, 3 H, Ar-*Me*), 3.75 (br., 2 H, Ar-*NH*$_2$), 3.80 (s, 3 H, Ar-O*Me*), 5.79 (s, 1 H, Ar-*H*), 6.94 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.30 (t, $^3J_{H,H}$ = 7.5 Hz, 1 H, Ar-*H*), 7.36 (t, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 7.40–7.43 (m, 4 H, Ar-*H*), 8.25 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.3, 55.3, 100.0, 101.8, 114.6, 116.3, 124.9, 126.4, 127.8, 127.8, 128.0, 128.7, 129.7, 132.2, 157.8, 159.6, 166.8 ppm. MS (FA): *m*/*z* (%) = 345 (100) [M]$^+$. $C_{21}H_{19}N_3O_2$ (345.39): calcd. C 73.03, H 5.54, N 12.17; found C 73.03, H 5.76, N 12.08.

6d: Yield: 135 mg, 77%, pale-yellow solid ($CHCl_3$/hexane). M.p. 234.3–234.4 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.27 (s, 3 H, Ar-*Me*), 3.87 (br., 2 H, Ar-*NH*$_2$), 5.85 (s, 1 H, Ar-*H*), 7.24 (t, $^3J_{H,H}$ = 8.0 Hz, 1 H, Ar-*H*), 7.36–7.40 (m, 4 H, Ar-*H*), 7.44 (t, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 7.52 (d, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 7.97 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, [D$_6$]DMSO, 25 °C): δ = 11.0, 101.2, 101.3, 116.5, 124.8, 125.0, 128.2, 128.6, 128.6, 129.5, 129.8, 130.8, 131.7, 132.4, 159.4, 165.4 ppm. MS (FA): *m*/*z* (%) = 349 (100) [M]$^+$. $C_{20}H_{16}ClN_3O$ (349.81): calcd. C 68.67, H 4.61, N 12.01; found C 68.53, H 4.38, N 11.70.

6e: Yield: 140 mg, 73%, pale-yellow solid ($CHCl_3$/hexane). M.p. 233.8–234.0 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 2.26 (s, 3 H, Ar-*Me*), 3.85 (br., 2 H, Ar-*NH*$_2$), 5.83 (s, 1 H, Ar-*H*), 7.37–7.41 (m, 6 H, Ar-*H*), 7.45 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.98 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.4, 100.4, 102.4, 115.5, 125.9, 129.1, 129.1, 129.5, 129.5, 129.7, 130.3, 130.6, 131.4, 134.2, 159.8, 166.1 ppm. MS (FA): *m*/*z* (%) = 383 (100) [M]$^+$. $C_{20}H_{15}Cl_2N_3O$ (384.26): calcd. C 62.51, H 3.93, N 10.94; found C 62.31, H 3.78, N 10.81.

6f: Yield: 152 mg, 80%, pale-yellow solid ($CHCl_3$/hexane). M.p. 199.7–200.5 °C. ^{1}H NMR (500 MHz, [D$_6$]DMSO, 25 °C): δ = 2.22 (s, 3 H, Ar-*Me*), 3.78 (s, 3 H, Ar-O*Me*), 4.01 (br., 2 H, Ar-*NH*$_2$), 6.22 (s, 1 H, Ar-*H*), 6.99 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.39 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.44 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.59 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 11.09 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, $CDCl_3$, 25 °C): δ = 11.0, 55.1, 101.2, 101.2, 114.1, 116.8, 125.1, 126.6, 127.7, 128.2, 128.6, 129.3, 131.0, 131.5, 157.0, 159.4, 165.6 ppm. MS (FA): *m*/*z* (%) = 380 (100) [M + H]$^+$. $C_{21}H_{18}ClN_3O_2$ (379.84): calcd. C 66.40, H 4.78, N 11.06; found C 66.02, H 4.54, N 10.77.

6g: Yield: 130 mg, 75%, pale-yellow solid ($CHCl_3$/hexane). M.p. 195.3–195.6 °C. ^{1}H NMR (300 MHz, $CDCl_3$, 25 °C): δ = 2.23 (s, 3 H, Ar-*Me*), 3.84 (s, 3 H, Ar-O*Me*), 3.91 (br., 2 H, Ar-*NH*$_2$), 5.77 (s, 1 H, Ar-*H*), 6.94 (d, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 7.23 (t, $^3J_{H,H}$ = 7.5 Hz, 1 H, Ar-*H*), 7.36–7.44 (m, 4 H, Ar-*H*), 7.50 (d, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 7.99 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 12.4, 55.3, 99.6, 101.7, 114.2, 115.5, 124.5, 124.6, 125.6, 129.0, 129.2, 129.4, 130.6, 132.4, 159.6, 166.9 ppm. MS (FA): *m*/*z* (%) = 346 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{21}H_{20}N_3O_2$ [M + H]$^+$ 346.1556; found 346.1585.

6h: Yield: 158 mg, 83%, pale-yellow solid ($CHCl_3$/hexane). M.p. 212.5–212.9 °C. ^{1}H NMR (500 MHz, [D$_6$]DMSO, 25 °C): δ = 2.20 (s, 3 H, Ar-*Me*), 3.78 (s, 3 H, Ar-O*Me*), 4.20 (br., 2 H, Ar-*NH*$_2$), 6.08 (s, 1 H, Ar-*H*), 6.97 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.34 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.41 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.68 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 11.03 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, [D$_6$]DMSO, 25 °C): δ = 11.0, 55.1, 100.6, 100.7, 113.7, 114.3, 124.3, 126.0, 128.4, 128.4, 129.4, 130.1, 130.8, 131.6, 158.8, 159.2, 165.9 ppm. MS (FA): *m*/*z* (%) = 379 (100) [M]$^+$. $C_{21}H_{18}ClN_3O_2$ (379.84): calcd. C 66.40, H 4.78, N 11.06; found C 66.13, H 4.57, N 10.79.

6i: Yield: 116 mg, 62%, pale-yellow sold ($CHCl_3$/hexane). M.p. 158.7–160.0 °C. ^{1}H NMR (500 MHz, [D$_6$]DMSO, 25 °C): δ = 2.20 (s, 3 H, Ar-*Me*), 3.77 (s, 3 H, Ar-O*Me*), 3.78 (s, 3 H, Ar-O*Me*), 3.99 (br., 2 H, Ar-*NH*$_2$), 6.08 (s, 1 H, Ar-*H*), 6.96 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 6.98 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.33 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 7.58 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, Ar-*H*), 10.91 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, [D$_6$]DMSO, 25 °C): δ = 11.0, 55.1, 55.1, 100.3, 100.5, 113.7, 114.0, 115.6, 124.7, 125.5, 126.3, 128.2, 129.3, 129.3, 156.7, 158.6, 159.1, 166.3 ppm. MS (FA): *m*/*z* (%) = 375 (100) [M]$^+$. $C_{22}H_{21}N_3O_3$ (375.42): calcd. C 70.38, H 5.64, N1 1.19; found C 70.01, H 5.52, N 10.88.

6j: Yield: 47.5 mg, 30%, pale-yellow solid ($CHCl_3$/hexane). M.p. 242.4–142.5 °C. ^{1}H NMR (500 MHz, [D$_6$]DMSO, 25 °C): δ = 2.21 (s, 3 H, Ar-*Me*), 4.33 (br., 2 H, Ar-*NH*$_2$), 6.16 (s, 1 H, Ar-*H*), 7.32–

7.43 (m, 5 H, Ar-*H*), 8.03 (d, $^3J_{H,H}$ = 8.0 Hz, 1 H, Ar-*H*), 8.32 (d, $^3J_{H,H}$ = 5.0 Hz, 1 H, Ar-*H*), 8.92 (s, 1 H, Ar-*H*), 11.24 (br 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, [D$_6$]DMSO, 25 °C): δ = 11.0, 101.1, 101.2, 113.1, 123.5, 127.5, 128.0, 128.3, 128.7, 131.0, 131.2, 131.4, 131.8, 145.2, 145.9, 159.3, 165.5 ppm. MS (FA): *m*/*z* (%) = 317 (100) [M]$^+$. $C_{19}H_{16}N_4O$ (316.36): calcd. C 72.13, H 5.10, N 17.71; found C 71.91, H 4.90, N 17.46.

6k: Yield: 142 mg, 83%, yellow solid ($CHCl_3$/hexane). M.p. 219.4–220.0 °C. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 3.35 (br., 2 H, Ar-*NH*$_2$), 3.80 (s, 3 H, Ar-O*Me*), 6.83 (d, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 7.20–7.22 (m, 3 H, Ar-*H*), 7.26–7.28 (m, 2 H, Ar-*H*), 7.44 (t, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 7.55 (d, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 8.12 (br., 1 H, -*NH*-), 8.50 (d, $^3J_{H,H}$ = 5.0 Hz, 2 H, Ar-*H*) ppm. ^{13}C NMR (125 MHz, [D$_6$]DMSO, 25 °C): δ = 55.1, 111.0, 113.9, 116.0, 124.3, 124.4, 124.7, 124.8, 128.5, 128.9, 129.0, 129.1, 133.1, 143.3, 149.6, 158.2 ppm. MS (FA): *m*/*z* (%) = 342 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{22}H_{20}N_3O$ [M + H]$^+$ 342.1606; found 342.1607.

General Procedure for the One-pot Synthesis of 3-Aminopyrrole 6: To a THF solution (5 mL) of **1a** (339 mg, 2.00 mmol) was added *n*BuLi (1.5 M in hexane, 2.20 mmol) at –70 °C, and the reaction mixture was stirred at the same temperature. After 1 h, benzonitrile (**2a**, 206 mg, 2.00 mmol) was added to the solution by syringe, and the solution was further stirred for 1 h at –70 °C, then for 1 h at room temperature. Aldehyde **3** (2.00 mmol) was added to the solution at –70 °C, and the mixture was stirred for 1 h at the same temperature, then for 1 h at room temperature. Trimethylsilyl cyanide (**5**, 59.5 mg, 0.600 mmol) and Yb(OTf)$_3$ (62.0 mg, 0.100 mmol) were added to the mixture at room temperature, and the reaction mixture was stirred for 24 h at the same temperature. To quench the reaction, a saturated aqueous solution of $NaHCO_3$ (10 mL) was added to the mixture. The mixture was extracted several times with $CHCl_3$, and the combined organic extracts were dried with anhydrous Na_2CO_3, filtered, and then concentrated under reduced pressure. The crude product was purified by SiO_2 column chromatography (hexane/AcOEt) to afford **6a** and **6b** in 53 and 41% yield, respectively.

General Procedure for the Synthesis of Pyrrolo[3,4-*b*]pyridin-4-ones 8: To an MeCN (9 mL) and H_2O (1 mL) solution of pyrrole **5** (0.500 mmol) was added $Mo(CO)_6$ (66.0 mg, 0.250 mmol). The mixture was stirred at 100 °C. After 2.5 h, the volatile compounds were removed by evaporation in vacuo. The residue was purified by SiO_2 column chromatography (AcOEt) to give **8**.

8a: Yield: 132 mg, 88%, pale-yellow solid ($CHCl_3$/hexane). M.p. 188.6–189.7 °C. ^{1}H NMR (300 MHz, [D$_6$]DMSO, 25 °C): δ = 2.28 (s, 3 H Ar-*Me*), 5.49 (s, 1 H, Ar-*H*), 7.24–7.49 (m, 6 H, Ar-*H*), 7.69 (d, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 8.04 (d, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 10.46 (br., 1 H, -*NH*-), 12.04 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (75 MHz, [D$_6$]DMSO, 25 °C): δ = 19.4, 106.4, 113.5, 114.1, 126.1, 126.6, 126.8, 127.3, 127.5, 127.8, 128.6, 129.0, 131.0, 131.7, 149.0, 176.5 ppm. MS (FA): *m*/*z* (%) = 301 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{20}H_{17}N_2O$ [M + H]$^+$ 301.1341; found 301.1347.

8b: Yield: 151 mg, 90%, pale-yellow solid ($CHCl_3$/hexane). M.p. 292 °C (decomp.). ^{1}H NMR (500 MHz, [D$_6$]DMSO, 25 °C): δ = 2.27 (s, 3 H, Ar-*Me*), 5.48 (s, 1 H, Ar-*H*), 7.27 (t, $^3J_{H,H}$ = 8.0 Hz, 1 H, Ar-*H*), 7.38 (t, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 7.51 (d, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 7.69 (d, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 8.01 (d, $^3J_{H,H}$ = 8.0 Hz, 2 H, Ar-*H*), 10.45 (br., 1 H, -*NH*-), 12.07 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, [D$_6$]DMSO, 25 °C): δ = 19.4, 106.6, 112.8, 113.4, 126.8, 127.4, 127.8, 128.1, 128.4, 128.5, 129.0, 129.8, 130.3, 131.6, 148.9, 176.3 ppm. MS (FA): *m*/*z* (%) = 335 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{20}H_{16}ClN_2O$ [M + H]$^+$ 335.0951; found 335.0956.

8c: Yield: 164 mg, 99%, pale-yellow solid ($CHCl_3$/hexane). M.p. 256.6–257.0 °C. ^{1}H NMR (500 MHz, [D$_6$]DMSO, 25 °C): δ = 2.26 (s, 3 H, Ar-*Me*), 3.79 (s, 3 H, Ar-O*Me*), 5.45 (s, 1 H, Ar-*H*), 6.94 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 7.26 (t, $^3J_{H,H}$ = 7.5 Hz, 1 H, Ar-*H*), 7.46 (t, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 7.67 (d, $^3J_{H,H}$ = 7.5 Hz, 2 H, Ar-*H*), 7.99 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, Ar-*H*), 10.37 (br., 1 H, -*NH*-), 11.88 (br., 1 H, -*NH*-) ppm. ^{13}C NMR (125 MHz, [D$_6$]-DMSO, 25 °C): δ = 19.4, 55.1, 106.3, 112.9, 113.1, 124.4, 125.7, 126.6, 127.5, 127.6, 128.6, 130.3, 131.1, 148.8, 158.3, 176.6 ppm. MS (FA): *m*/*z* (%) = 331 (100) [M + H]$^+$. HRMS (FAB): calcd. for $C_{21}H_{19}N_2O_2$ [M + H]$^+$ 331.1447; found 331.1449.

Supporting Information (see footnote on the first page of this article): Detailed experimental procedures and characterization data for novel compounds, ORTEP diagram of **4d** and **6g**, X-ray data for **4d** and **6g**, and copies of the ^{1}H and ^{13}C NMR spectra of the novel products.

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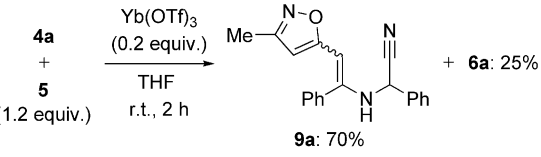
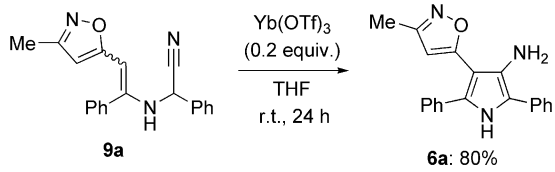


[25] When the intramolecular cyclization of intermediate **9a** was carried out in THF at room temperature for 24 h in the presence of $Yb(OTf)_3$ (0.2 equiv.), 3-aminopyrrole **6a** was obtained in 80% yield. Also, see details in the Supporting Information.



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