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Article

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The Development of a Palladium-Catalyzed Tandem Addition/Cyclization for Construction of Indole Skeletons

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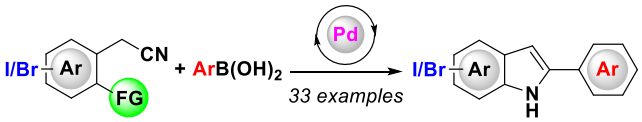


ABSTRACT: A palladium-catalyzed tandem addition/cyclization of 2-(2-aminoaryl)acetonitriles with arylboronic acids has been developed for the first time, achieving a new strategy for direct construction of indole skeletons. This system shows good functional group tolerance and remarkable chemoselectivity. Especially, the halogen (e.g. bromo and iodo) substituents are amenable for further synthetic elaborations thereby broadening the diversity of the products. Preliminary mechanistic experiments indicate that this transformation involves sequential nucleophilic addition followed by an intramolecular cyclization.

INTRODUCTION

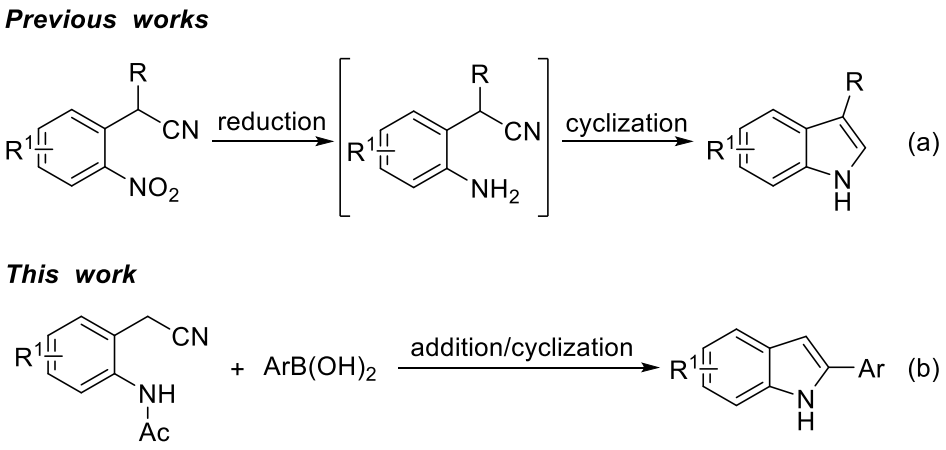
Transition-metal-catalyzed transformations of the activated organonitriles play an important role in both synthetic and medicinal chemistry due to their well-recognized chemical versatility.[1] It is well known, however, that aliphatic nitriles (e.g. acetonitrile)

have been used as solvents or ligands in organometallic reactions presumably due to the inherently inert nature of nitriles.[2] The catalytic carbopalladation of nitriles, pioneered by the Larock group[3] and a considerable development within the past few years, provided a conceptual basis for several other groups[4] and our group.[5] We recently reported tandem addition and cyclization for the synthesis of isoquinolines by catalytic carbopalladation of aromatic nitriles.[6]

Compared to aromatic nitriles, nucleophilic addition reactions of aliphatic nitriles are limited by insufficient electrophilic activation. On the other hand, aliphatic nitriles are used as carbon pronucleophiles in carbon-carbon bond forming reactions in different modes of aliphatic nitriles activation, such as α-cyano carbanions or metalated nitriles.[7] Despite the remarkable progress made to date, the development of a practical and general approach to *N*-heterocycles using aliphatic nitriles as the reaction partners remains a tremendous challenge.

Indoles are a class of important structural motifs because of their ubiquity in natural products, bioactive compounds, and other functional molecules.[8] Hence, effective methods for the construction of indoles have been actively pursued during the past several decades.[9] Pschorr-Hoppe indole synthesis,[10-13] one of the most common approaches in which indole and its derivatives were prepared from the reduction of 2-(2-nitroaryl)acetonitriles has been followed by subsequent intramolecular cyclization. The direct intramolecular cyclization of 2-(2-aminoaryl)acetonitriles provided an alternative route to indole by the use of bipyridine-based PNN Ru(II) pincer complex/H_2 (4 bar),[14] Pd-C/H_2 (balloon).[15] Notably, the expansion of the substrate

scope was not investigated. Recently, Chung[16] reported a cobalt–rhodium heterobimetallic nanoparticle-catalyzed tandem reductive cyclization of 2-(2-nitroaryl)-acetonitriles to indoles (Scheme 1a). However, these methods are applicable to the synthesis of 3-substituted indoles only. We envisioned that a Pd-catalyzed sequential nucleophilic addition followed by an intramolecular cyclization of functionalized nitriles using arylboronic acids as coupling partner could offer a new and complementary method for the 2-arylindoles.



Scheme 1. Synthesis of Indoles from Nitriles

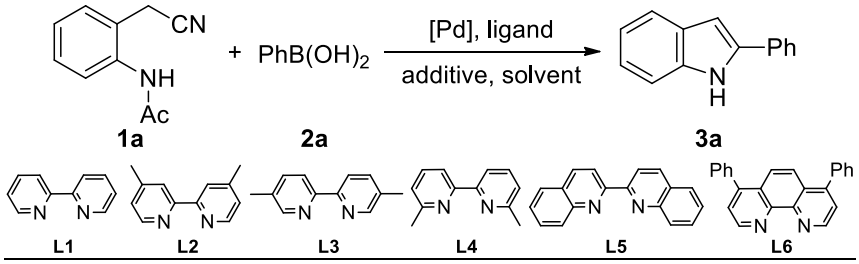
Although transformation of nitriles into various functional groups has been well-established, aliphatic nitriles as substrate candidates involved in the transition-metal-catalyzed tandem addition and cyclization processes with organoboron reagents for the synthesis of indoles have not been achieved to date. As part of the continuing efforts in our laboratory toward the development of novel transition metal-catalyzed coupling reactions with organoboron reagents.[5-6,17] Herein, we report the first example of palladium-catalyzed tandem addition/cyclization for the synthesis of structurally diverse 2-substituted indoles (Scheme 1b).

RESULTS AND DISCUSSION

Initially, the readily available *N*-(2-(cyanomethyl)phenyl)acetamide (**1a**) and phenylboronic acid (**2a**) were chosen as model substrates and extensive investigations were conducted for the screening of reaction conditions including catalysts, ligands, additives, and solvents. As shown in Table 1, the desired 2-phenylindole (**3a**) was isolated in 49% yield when the combination of $Pd(OAc)_2$, 2,2′-bipyridine (**L1**), and trifluoroacetic acid (TFA) was employed in THF-H_2O under N_2 atmosphere (entry 1). Among the various additives that we screened (entries 2-6), CF_3SO_3H (TfOH) was the most effective and gave the highest yield of 63% (entry 4). An investigation of the effect of the solvent (entries 4 and 7-11) revealed that the use of THF-H_2O as the solvent achieved the best result (63%, entry 4). Replacement of $Pd(OAc)_2$ with other Pd(II) catalysts, including $PdCl_2$, $Pd(CF_3CO_2H)_2$, and $Pd(acac)_2$, resulted in lower yields (entries 4 and 12-14). But this reaction did not work using Pd(0) such as $Pd(PPh_3)_4$ as a catalyst (entry 15). It is generally believed that fluoride could be of particular value in boronic acid coupling reactions.[18] To our delight, the yield increased to 81% when 2 equiv of KF was added in the reaction (entry 16). The choice of ligand play a key role in transition metal-catalyzed organic reactions. Among bidentate nitrogen ligands (**L1**-**L6**), 5,5'-dimethyl-2,2'-bipyridine (**L3**) was found to efficiently promote the reaction and afforded **3a** in 91% yield (entry 18). In contrast, little to no product **3a** was detected using steric ligands, such as 6,6'-dimethyl-2,2'-bipyridine (**L4**) and 2,2'-biquinoline (**L5**) as the ligand (entries 19-20). Alternative fluoride sources other than KF proved to be less efficient in this transformation (entry 22). The reaction failed to improve the yield

under an oxygen or air atmosphere (entries 23-24). The reaction did not work if either Pd catalyst or the ligand was absent (entries 25-26). It is worth noting that the reaction of 2-(2-aminophenyl)acetonitrile with **2a** under the reaction conditions of entry 18 afforded **3a** in 43% yield.

Table 1. **Optimization of Reaction Conditions**[a]

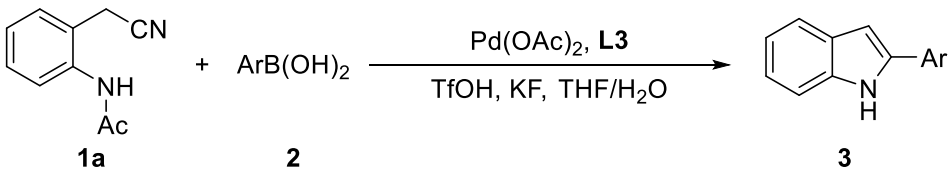


entry	Pd catalyst	ligand	additive	solvent	yield (%)[b]
1	$Pd(OAc)_2$	**L1**	TFA	THF-H_2O	49
2	$Pd(OAc)_2$	**L1**	CH_3SO_3H	THF-H_2O	59
3	$Pd(OAc)_2$	**L1**	$PhSO_3H$	THF-H_2O	60
4	$Pd(OAc)_2$	**L1**	TfOH	THF-H_2O	63
5	$Pd(OAc)_2$	**L1**	CSA	THF-H_2O	54
6	$Pd(OAc)_2$	**L1**	HCl	THF-H_2O	0
7	$Pd(OAc)_2$	**L1**	TfOH	2MeTHF-H_2O	33
8	$Pd(OAc)_2$	**L1**	TfOH	EtOH-H_2O	49
9	$Pd(OAc)_2$	**L1**	TfOH	toluene-H_2O	27
10	$Pd(OAc)_2$	**L1**	TfOH	dioxane-H_2O	20
11	$Pd(OAc)_2$	**L1**	TfOH	DMSO-H_2O	trace
12	$PdCl_2$	**L1**	TfOH	THF-H_2O	15
13	$Pd(CF_3CO_2)_2$	**L1**	TfOH	THF-H_2O	49
14	$Pd(acac)_2$	**L1**	TfOH	THF-H_2O	60
15	$Pd(PPh_3)_4$	**L1**	TfOH	THF-H_2O	0
16	$Pd(OAc)_2$	**L1**	TfOH	THF-H_2O	81[c]
17	$Pd(OAc)_2$	**L2**	TfOH	THF-H_2O	74[c]
18	**$Pd(OAc)_2$**	**L3**	**TfOH**	**THF-H_2O**	**91**[c]
19	$Pd(OAc)_2$	**L4**	TfOH	THF-H_2O	0[c]
20	$Pd(OAc)_2$	**L5**	TfOH	THF-H_2O	trace[c]
21	$Pd(OAc)_2$	**L6**	TfOH	THF-H_2O	42[c]
22	$Pd(OAc)_2$	**L3**	TfOH	THF-H_2O	81[d]
23	$Pd(OAc)_2$	**L3**	TfOH	THF-H_2O	51[e]
24	$Pd(OAc)_2$	**L3**	TfOH	THF-H_2O	78[f]
25		**L3**	TfOH	THF-H_2O	0
26	$Pd(OAc)_2$		TfOH	THF-H_2O	0

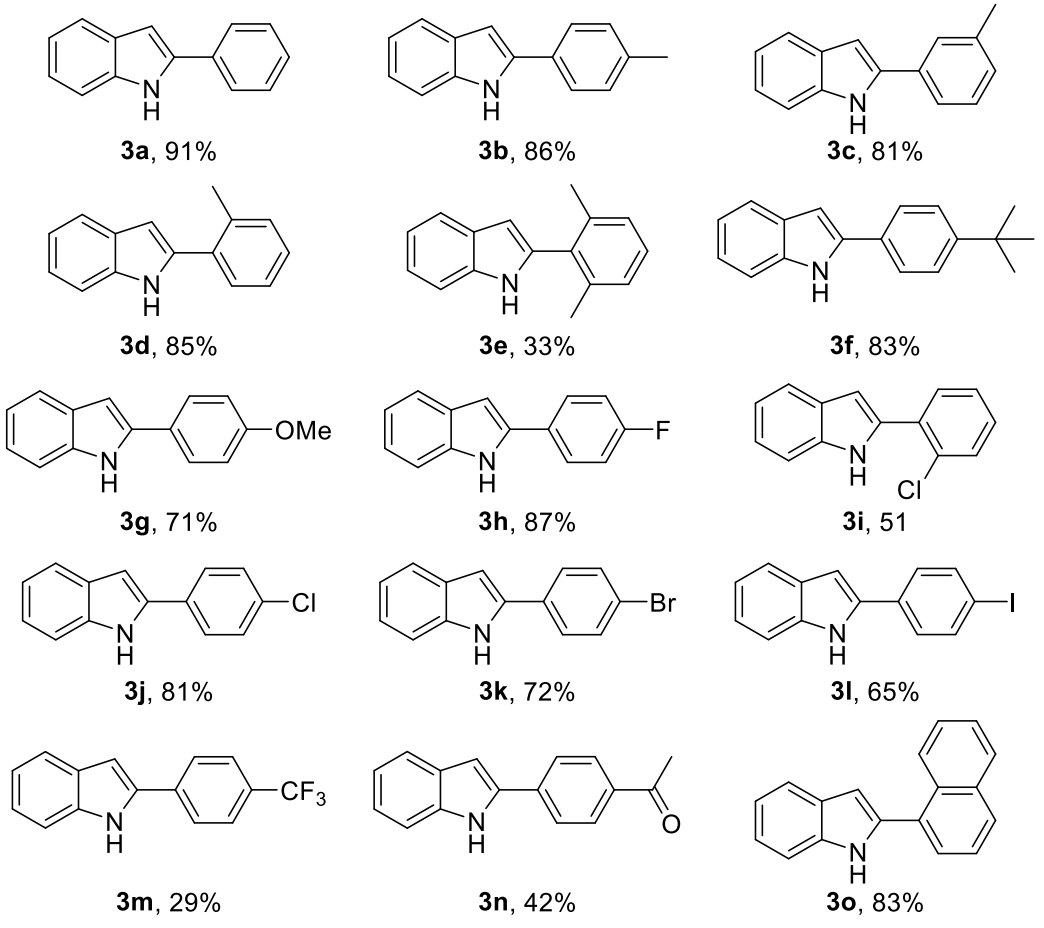
[a] Unless otherwise noted, reaction conditions were as follows: **1a** (0.3 mmol), **2a** (0.6 mmol), Pd catalyst (5 mol %), ligand (10 mol %), additive (10 equiv), solvent/H_2O (1.5mL/2.0 mL), 80 °C, 48 h, N_2. [b] Isolated yield. [c] With KF (2 equiv). [d] With CsF (2 equiv). [e] Under O_2 atmosphere. [f] Under air atmosphere. TsOH = *p*-$MeC_6H_4SO_3H$, TfOH = CF_3SO_3H, CSA = Camphorsulfonic acid.

Having thus identified optimal conditions for the tandem addition/cyclization, we next examined the scope of arylboronic acids with **1a** to test the feasibility of preparing a variety of 2-arylindoles. As illustrated in Table 2, the reactivity of *para*-, *meta*-, and *ortho*-tolylboronic acid were evaluated, and the corresponding desired **3b**, **3c** and **3d**, were isolated in 86%, 81% and 85% yield, respectively. These results demonstrated that steric effects of substituents had no obvious effects on the reaction. However, a relatively large sterically hindered arylboronic acid, such as 2,6-dimethylphenylboronic acid could also be used as the reaction partner, affording the desired product **3e** in 33% yield. The electronic properties of the substituents on the phenyl ring of the arylboronic acids affected the yields of the reaction to some extent. 2-(4-(*tert*-Butyl)phenyl)indole (**3f**) and 2-(4-methoxyphenyl)indole (**3g**) were achieved in 83% and 71% yield, respectively. Introduction of the moderately electron-withdrawing fluoro, chloro, bromo and iodo group on the phenyl ring of the arylboronic acids were well tolerated, and the corresponding desired product **3h-3l** were obtained in 51-87% yields. It is noteworthy that these halogen-substituted products are useful handles for further synthetic elaborations. However, the use of substrates bearing the relatively strong electron-withdrawing trifluoromethyl and acetyl group at the *para*-position decreased the yield of **3m** and **3n** to 29% and 42%, respectively. Notably, treatment of 1-naphthylboronic acid with **1a** also proceeded smoothly and gave the desired product **3o** in 83% yield.

Table 2 Synthesis 2-Arylindole Derivatives[a]



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



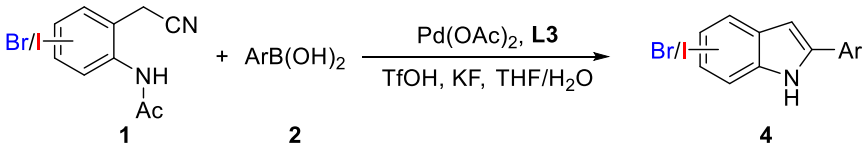
[a] Conditions: **1a** (0.3 mmol), **2** (0.6 mmol), $Pd(OAc)_2$ (5 mol %), **L3** (10 mol %), TfOH (10 equiv), KF (2 equiv), THF/H_2O (1.5mL/2.0 mL), 80 °C, 48 h, N_2. [b] Isolated yield.

Next, arylboronic acids were further reacted with different *N*-(2-(cyanomethyl)aryl)acetamides bearing bromo or iodo groups under the optimal conditions to afford a set of diverse bromo- or iodo- substituted indoles in 47-84% yield (Table 3). Initially, the tandem reaction of *N*-(4-bromo-2-(cyanomethyl)phenyl)acetamide (**1b**) with different arylboronic acids were performed.

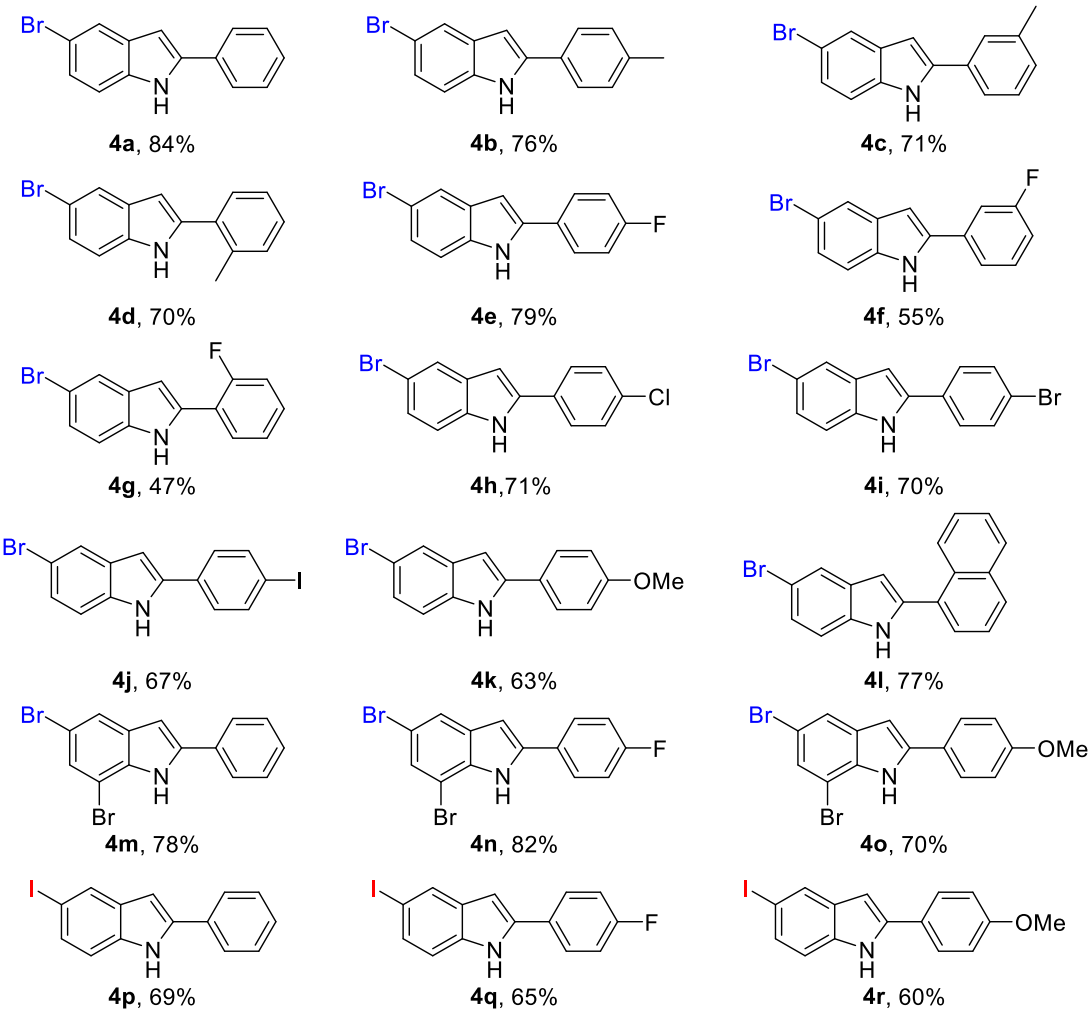
Functional groups such as methyl, methoxy, halogen and naphthyl were well tolerated. The mono-substituent positions at the phenyl moiety of arylboronic acids were examined, and the results demonstrated that steric effects of substituents had some effects on the reaction. For example, **1b** reacted with *para*-, *meta*- and *ortho*-tolylboronic acid efficiently and afforded **4b**, **4c**, and **4d** in 76%, 71%, and 70% yields, respectively. However, the reaction of **1b** with *para*-, *meta*- and *ortho*-fluorophenylboronic acid was investigated, 79% of **4e** and 62% of **4f** were isolated, while the yield of **4g** was decreased to 47%. The electronic properties of the substituents on the phenyl ring of the arylboronic acids affected the yields of the reaction to some extent. In general, the arylboronic acids bearing an electron-withdrawing substituent (e.g., F, Cl, Br, and I) (**4e**, **4h**, **4i**, and **4j**) produced a slightly higher yield of cyclization products than those analogues bearing an electron-donating substituent (e.g., OMe) (**4k**). It is worth noting that 77% yield of 5-bromo-2-(naphthalen-1-yl)indole (**4l**) was isolated when 1-naphthboronic acid was used as the substrate. Additionally, other halogen substituted *N*-(2-(cyanomethyl)aryl)acetamides were further investigated. Treatment of *N*-(4,5-dibromo-2-(cyanomethyl)phenyl)acetamide with $PhB(OH)_2$, *p*-$(F)C_6H_4B(OH)_2$, and *p*-$(OMe)C_6H_4B(OH)_2$ under the optimized conditions afforded the corresponding desired products **4m**, **4n**, and **4o** in 78%, 82%, and 70% yields, respectively, indicating that the arylboronic acids bearing an electron-withdrawing substituent (e.g., F) were more favourable than those analogues bearing an electron-donating substituent (e.g., OMe). Finally, *N*-(2-(cyanomethyl)-4-iodophenyl)acetamide reacted with $PhB(OH)_2$, *p*-$(F)C_6H_4B(OH)_2$, and *p*-$(OMe)C_6H_4B(OH)_2$ to give the

corresponding desired products **4p**, **4q**, and **4r** in 60-69% yields. These results revealed that this protocol shows remarkable chemoselectivity and substrate scope tolerating bromo, and iodo substituents (commonly used for cross-coupling reactions).

Table 3 Synthesis of Bromo- or Iodo-substituted Indoles[a]



1 2 4



4a, 84% **4b**, 76% **4c**, 71%

4d, 70% **4e**, 79% **4f**, 55%

4g, 47% **4h**,71% **4i**, 70%

4j, 67% **4k**, 63% **4l**, 77%

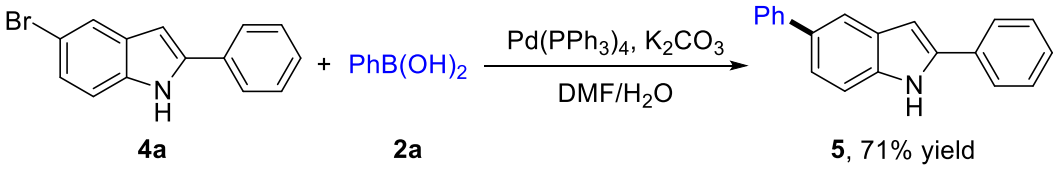
4m, 78% **4n**, 82% **4o**, 70%

4p, 69% **4q**, 65% **4r**, 60%

[a] Conditions: **1** (0.3 mmol), **2** (0.6 mmol), $Pd(OAc)_2$ (5 mol %), **L3** (10 mol %), TfOH (10 equiv), KF (2 equiv), THF/H_2O (1.5mL/2.0 mL), 80 °C, 48 h, N_2. [b] Isolated yield.

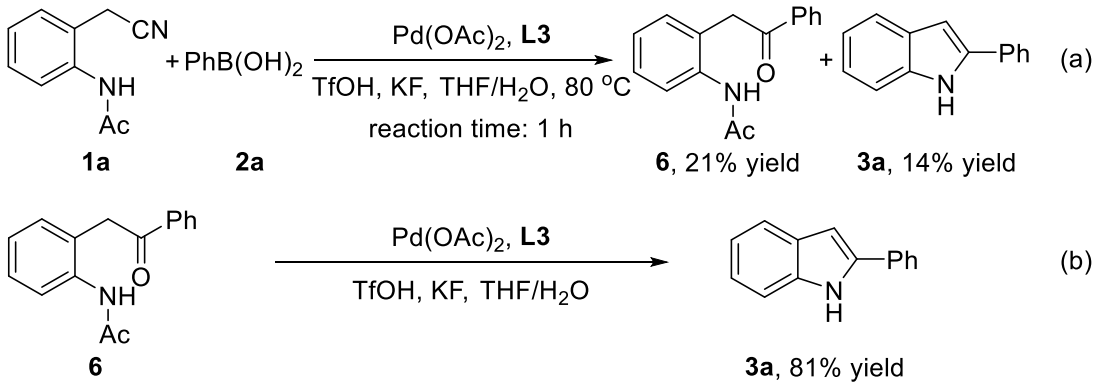
The bromo- or iodo-substituted indoles produced by this chemistry should be amenable for further synthetic elaborations thereby broadening the diversity of

substituted indoles. For example, the bromo- or iodo- substituted indoles produced by this strategy can be further functionalized by applying palladium-catalyzed coupling reactions. We found that 2,5-diphenylindole (**5**) was obtained in 71% yield from the coupling reaction of 5-bromo-2-phenylindole with **2a** (Scheme 2).



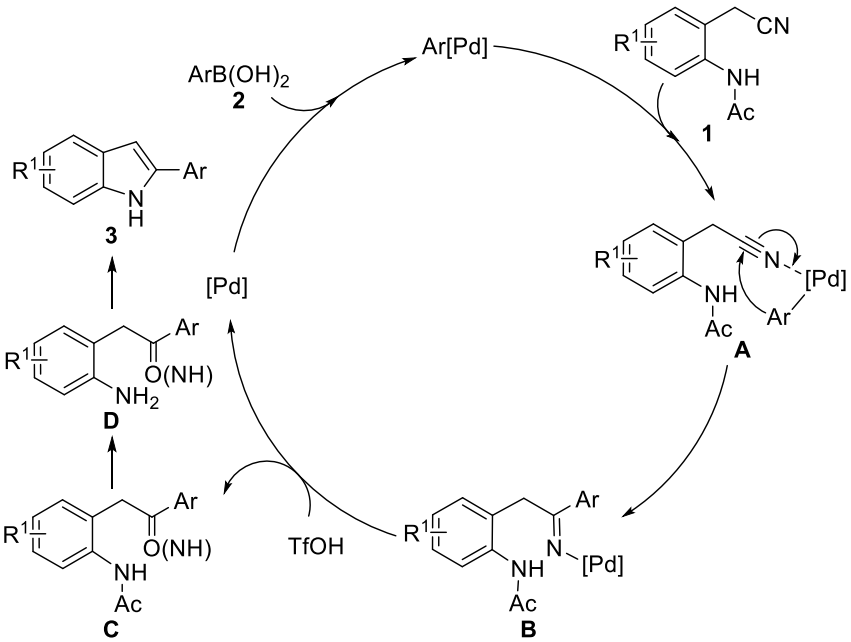
Scheme 2 Synthetic Elaboration of **4a**

To elucidate the reaction mechanism for the formation of indoles, two control experiments were performed was listed in Scheme 3. The ketone intermediate *N*-(2-(2-oxo-2-phenylethyl)phenyl)acetamide (**6**) was successfully isolated in 21% yield accompanied by the formation of **3a** when the reaction time was shortened to 1 h (Scheme 3a). Additionally, the ketone intermediate **6** was converted into the desired product **3a** in 81% yield under the standard conditions (Scheme 3b), suggesting that compound **6** is the key intermediate for the transformation.



Scheme 3 Control Experiments

On the basis of the above mentioned results and relevant reports in the literature, a possible mechanism for the formation of indoles is proposed in Scheme 4. The first step may involve the transmetallation between the Pd(II) catalyst and arylboronic acid to give the Pd-aryl species, which was followed by the coordination of nitrile affording intermediate **A**. Next, intramolecular carbopalladation of nitrile generates the imine Pd(II) complex **B**. Protonation of the imine Pd(II) complex **B** by TfOH, which delivers the ketone or ketimine intermediate **C** and regenerates the Pd(II) catalyst. Deacetylation of the ketone or ketimine intermediate **C** gives the intermediate **D** under acidic conditions. Finally, intramolecular cyclization of the intermediate **D** yields the corresponding indoles as the desired products. Preliminary mechanistic experiments indicate that this transformation involves sequential nucleophilic addition followed by an intramolecular cyclization. However, a detailed mechanism of this transformation remains unclear at the current stage.



Scheme 4 Plausible Reaction Mechanism

CONCLUSIONS

In summary, we have developed an efficient strategy for the synthesis of structurally diverse indoles by palladium-catalyzed tandem addition/cyclization of aliphatic nitriles with arylboronic acids. Especially, this system shows remarkable chemoselectivity and substrate scope tolerating chloro, fluoro, bromo, and iodo substituents, leading to a further synthetic elaborations thereby broadening the diversity of the products. Further studies to extend this catalytic system to the preparation of other *N*-heterocycles are currently underway in our laboratories.

EXPERIMENTAL SECTION

General Information. Melting points are uncorrected. ^{1}H NMR and ^{13}C NMR spectra were measured on a 500 MHz spectrometer (^{1}H at 500 MHz, ^{13}C at 125 MHz), using $CDCl_3$ or DMSO-d_6 as the solvent with tetramethylsilane (TMS) as an internal standard at room temperature. Chemical shifts are given n δ relative to TMS, and the coupling constants *J* are given in hertz. High-resolution mass spectra were recorded on an ESI-Q-TOF mass spectrometer. *N*-(2-(2-oxo-2-phenylethyl)phenyl)acetamide (**6**) was synthesized according to the method described in the literature.[19] Other commercially obtained reagents were used without further purification. All reactions under nitrogen atmosphere were conducted using standard Schlenk techniques. Column chromatography was performed using EM silica gel 60 (300−400 mesh).

General Procedure for the Synthesis of Indoles. Under N_2 atmosphere, nitriles **1** (0.3 mmol), arylboronic acids **2** (0.6 mmol), $Pd(OAc)_2$ (5 mol %), **L3** (10 mol %), TfOH

(10 equiv), KF (2 equiv), THF (1.5 mL), and H_2O (2.0 mL) were successively added into a Schlenk reaction tube. The reaction mixture was stirred vigorously at 80 ℃ for 48 h. After the reaction equilibrium, the mixture was poured into ethyl acetate, which was washed with saturated $NaHCO_3$ (2 × 10 mL) and then brine (1 × 10 mL). After the aqueous layer was extracted with ethyl acetate, the combined organic layers were dried over anhydrous Na_2SO_4 and evaporated under vacuum. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 8:1) to afford the desired products **3a-3o** and **4a-4r**.

Typical Procedure for the Synthesis of 2,5-Diphenylindole (5). Under N_2 atmosphere, to a 25 mL sealed tube containing **4a** (54.4 mg, 0.2 mmol), $Pd(PPh_3)_4$ (4.6 mg, 2.0 mol%), phenylboronic acid (27 mg, 0.22 mmol), and K_2CO_3 (138 mg, 1.0 mmol) were added DMF (1 mL) and water (1 mL). The reaction mixture was stirred vigorously and heated to 85 °C for 12 h. After the reaction mixture was cooled down to room temperature, aqueous HCl (1.0 M) was added to quench the reaction. The mixture was then extracted with ethyl acetate (10 mL × 3). All organic fractions were combined and washed with water and brine, dried over Na_2SO_4 and concentrated in vacuo. The resulting crude product was purified by flash column chromatography on silica gel (petroleum ether/ethyl acetate = 8:1) to afford product **5**.

*2-Phenyl-1H-indole (**3a**)*: White solid (52.6 mg, 91%), mp 189-190 °C (lit.[20] 186-188.6 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.52 (s, 1H), 7.86 (d, J = 7.5 Hz, 2H), 7.53 (d, J = 8.0 Hz, 1H), 7.46 (t, J = 7.5 Hz, 2H), 7.40 (d, J = 8.0 Hz, 1H), 7.31 (t, J = 7.5 Hz, 1H), 7.10 (t, J = 8.0 Hz, 1H), 7.00 (t, J = 7.5 Hz, 1H), 6.90 (s, 1H); ^{13}C NMR

(125 MHz, DMSO-d_6) δ 137.6, 137.1, 132.2, 128.9, 128.6, 127.4, 125.0, 121.5, 120.0, 119.3, 111.3, 98.6.

*2-(p-Tolyl)-1H-indole (**3b**)*: White solid (53.4 mg, 86%), mp 219.6-220 °C (lit.[20] 217.9-219.5 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.45 (s, 1H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.50 (d, *J* = 8.0 Hz, 1H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.27 (d, *J* = 7.5 Hz, 2H), 7.09-7.06 (m, 1H), 7.00-6.96 (m, 1H), 6.83 (s, 1H), 2.34 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 138.1, 137.7, 136.7, 129.7, 129.6, 129.4, 125.1, 122.1, 120.5, 120.2, 110.8, 99.4, 21.2.

*2-(m-Tolyl)-1H-indole (**3c**)*: White solid (50.6 mg, 81%), mp 138-139 °C (lit.[21] 140-142 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ11.48 (s, 1H), 7.70 (s, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.52 (d, *J* = 7.5 Hz, 1H), 7.39 (d, *J* = 8.0 Hz, 1H), 7.34 (t, *J* = 8.0 Hz, 1H), 7.13 (d, *J* = 7.5 Hz, 1H), 7.08 (t, *J* = 8.0 Hz, 1H), 6.99 (t, *J* = 7.5 Hz, 1H), 2.38 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 138.0, 137.7, 137.0, 132.1, 128.8, 128.6, 128.0, 125.5, 122.2, 121.4, 119.9, 119.3, 111.2, 98.5, 21.1.

*2-(o-Tolyl)-1H-indole (**3d**)*: Pale-yellow solid (52.7 mg, 85%), mp 93-94 °C (lit.[21] 92-93 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.27 (s, 1H), 7.57-7.55 (m, 2H), 7.41 (d, *J* = 8.0 Hz, 1H), 7.35-7.26 (m, 3H), 7.11 (t, *J* = 7.0 Hz, 1H), 7.01 (t, *J* = 7.0 Hz,1H), 6.58 (s, 1H), 2.48 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 137.3, 135.4, 130.9, 129.0, 128.3, 127.5, 125.9, 121.2, 119.9, 119.0, 111.2, 101.7, 21.0.

*2-(2,6-Dimethylphenyl)-1H-indole (**3e**)*: Pale-yellow solid (21.8 mg, 33%), mp 144-145 °C (lit.[22] 146-147 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.10 (s, 1H), 7.54 (d, *J* = 8.0 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 1H), 7.23 (t, *J* = 7.5 Hz, 1H), 7.15 (d, *J* = 7.5 Hz, 2H),

7.09-7.05 (m, 1H), 7.02-6.99 (m, 1H), 8.30-8.29 (m, 1H), 2.12 (s, 6H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 137.4, 136.2, 133.4, 128.2, 128.0, 127.1, 120.5, 119.6, 118.7, 111.0, 100.7, 20.3.

*2-(4-(tert-Butyl)phenyl)-1H-indole (**3f**):* White solid (61.8 mg, 83%), mp 198-199 °C (lit.[23] not reported). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.47 (s, 1H), 7.78 (d, *J* = 8.5 Hz, 2H), 7.51 (d, *J* =8.0 Hz, 1H), 7.47 (d, *J* = 8.0 Hz, 2H), 7.39 (d, *J* = 8.0 Hz, 1H), 7.08 (t, *J* = 7.5 Hz, 1H), 6.98 (t, *J* = 7.5 Hz, 1H), 6.83 (s, 1H), 1.32 (s, 9H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 149.9, 137.7, 137.0, 129.4, 128.7, 125.6, 124.7, 121.3, 119.8, 119.2, 111.2, 98.1, 34.3, 31.0.

*2-(4-Methoxyphenyl)-1H-indole (**3g**)*: Pale-yellow solid (47.5 mg, 71%), mp 228-229 °C. (lit.[20] 227.4-230.8 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.40 (s, 1H), 7.79 (d, *J* = 9.0 Hz, 2H), 7.49 (d, *J* = 8.0 Hz, 1H), 7.37 (d, *J* = 8.0 Hz, 1H), 7.07-7.02 (m, 3H), 6.98-6.95 (m, 1H), 6.76 (s, 1H), 3.80 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 158.8, 137.7, 136.9, 128.8, 126.3, 124.9, 121.0, 119.6, 119.2, 114.3, 111.0, 97.3, 55.2 .

2-(4-Fluorophenyl)-1H-indole (***3h***): White solid (55.2 mg, 87%), mp 188-189 °C (lit.[24] 185 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.52 (s, 1H), 7.91-7.88 (m, 2H), 7.52 (d, *J* = 7.5 Hz, 1H), 7.39 (d, *J* = 8.0 Hz, 1H), 7.30 (t, *J* = 8.5 Hz, 2H), 7.11-7.08 (m, 1H), 7.01-6.98 (m, 1H), 6.86 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 162.5, 160.1, 137.1, 136.7, 128.9, 128.6, 127.0, 126.9, 121.5, 120.0, 119.4, 115.9, 115.7, 111.2, 98.6.

*2-(2-Chlorophenyl)-1H-indole (**3i**)*: White solid (34.9 mg, 51%), mp 86.3-87 °C (lit.[25] 86-87 °C) . ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.43 (s, 1H), 7.74 (d, *J* = 7.5 Hz, 1H), 7.61-7.58 (m, 2H), 7.49-7.43 (m, 2H), 7.41-7.37 (m, 1H), 7.14 (t, *J* = 7.5 Hz, 1H),

7.03 (t, *J* = 7.5 Hz, 1H), 6.88 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 136.5, 134.2, 131.3, 131.0, 130.6, 130.5, 129.0, 127.9, 127.4, 121.9, 120.3, 119.3, 111.4, 103.0.

*2-(4-Chlorophenyl)-1H-indole (**3j**)*: White solid (55.1 mg, 81%), mp 202-203 °C (lit.[20] 206.3-209 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.58 (s, 1H), 7.88 (d, *J* =8.5 Hz, 2H), 7.53 (t, *J* =7.5 Hz, 3H), 7.40 (t, *J* = 8.0 Hz, 1H), 7.11 (t, *J* = 7.5 Hz, 1H), 7.00 (t, *J* = 7.5 Hz, 1H), 6.93 (s, 1H); ^{13}CNMR (125MHz, DMSO-d_6) δ 137.2, 136.3, 131.7, 131.1, 128.9, 128.5, 126.6, 121.8, 120.1, 119.5, 111.3, 99.3.

*2-(4-Bromophenyl)-1H-indole (**3k**)*: White solid (58.5 mg, 72%), mp 211-212 °C (lit.[25] 212-213 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.57 (s, 1H), 7.82-7.80 (m, 2H), 7.66-7.64 (m, 2H), 7.53 (d, *J* = 7.0 Hz, 1H), 7.40 (d, *J* = 8.0 Hz, 1H), 7.12-7.09 (m, 1H), 7.01-6.99 (m, 1H), 6.94 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 137.2, 136.4, 131.8, 131.4, 128.5, 126.9, 121.9, 120.3, 120.1, 119.5, 111.3, 99.3.

*2-(4-Iodophenyl)-1H-indole (**3l**)*: White solid (61.9 mg, 65%), mp 234-235 °C (lit.[26] 220-222 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.57 (s, 1H), 7.82 (d, *J* = 8.5 Hz, 2H), 7.66 (d, *J* = 8.0 Hz, 2H), 7.53 (d, *J* = 8.0 Hz, 1H), 7.39 (d, *J* = 8.0 Hz, 1H), 7.11 (t, *J* = 8.5 Hz, 1H), 7.00 (t, *J* = 7.5 Hz, 1H), 6.94 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 137.6, 137.2, 136.5, 131.7, 128.5, 126.9, 121.9, 120.1, 119.5, 111.3, 99.3, 93.0.

*2-(4-(Trifluoromethyl)phenyl)-1H-indole (**3m**)*: White solid (22.7 mg, 29%), mp 231-232 °C (lit.[24] 235-236 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.76 (s, 1H), 8.06 (d, *J* = 7.5 Hz, 2H), 7.79 (d, *J* = 7.5 Hz, 2H), 7.57-7.45 (m, 2H), 7.18-7.04 (m, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 137.5, 136.1, 135.8, 128.4, 127.4, 127.2, 125.8, 125.7, 125.4, 125.3, 123.2, 122.4, 120.5, 119.6, 111.5, 100.7.

*1-(4-(1H-indol-2-yl)phenyl)ethan-1-one (**3n**)*: Pale-yellow solid (29.4 mg, 42%), mp 203-204 °C (lit.[20] 200.9-202.3 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.69 (s, 1H), 8.04 (d, *J* = 8.0 Hz, 2H), 8.00(d, *J* =8.0 Hz, 2H), 7.57 (d, *J* = 8.0 Hz, 1H), 7.43 (d, *J* = 8.5 Hz, 1H), 7.14 (t, *J* = 8.0 Hz, 1H), 7.09 (s, 1H), 7.02 (t, *J* = 7.5 Hz, 1H), 2.60 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 197.1, 137.6, 136.4, 136.3, 135.3, 128.9, 128.5, 124.8, 122.4, 120.4, 119.6, 111.5, 100.8, 26.6.

*2-(Naphthalen-1-yl)-1H-indole (**3o**)*: Pale-yellow solid (60.7 mg, 83%), mp 100-101 °C. (lit.[27] 97-99 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.54 (s, 1H), 8.33-8.31 (m, 1H), 8.04-8.02 (m, 1H), 7.98 (d, *J* = 8.0 Hz, 1H), 7.71 (d, *J* = 8.0 Hz, 1H), 7.64-7.58 (m, 4H), 7.45 (d, *J* = 8.0 Hz, 1H), 7.15 (t, *J* = 7.5 Hz, 1H), 7.06 (t, *J* = 7.5 Hz, 1H), 6.73 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 136.7, 136.4, 133.6, 130.9, 130.8, 128.4, 128.3, 128.1, 127.2, 126.6, 126.1, 125.4, 121.2, 120.0, 119.2, 111.3, 102.4.

*5-Bromo-2-phenyl-1H-indole (**4a**)*: White solid (68.2 mg, 84%), mp 192-193 °C. (lit.[25] 195-196 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.76 (s, 1H), 7.86 (d, *J* = 7.5 Hz , 2H), 7.72 (s , 1H), 7.48 (d, *J* = 8.0 Hz, 2H), 7.37-7.33 (m, 2H), 7.22-7.20 (m, 1H), 6.90 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 139.1, 135.8, 131.6, 130.5, 128.9, 127.8, 125.2,123.9, 122.1, 113.2, 111.8, 98.2.

*5-Bromo-2-(p-tolyl)-1H-indole (**4b**)*: White solid (65.4 mg, 76%), mp 239-240 °C. ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.70(s, 1H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.69 (d, *J* = 1.5 Hz, 1H), 7.34 (d, *J* = 8.5 Hz, 1H), 7.28 (d, *J*=7.5 Hz, 2H), 7.18 (dd, J_1 = 2.0 Hz , J_2 = 8.5 Hz, 1H), 6.83 (d, *J* = 1.5 Hz, 1H), 2.34 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 139.3, 137.3, 135.6, 130.6, 129.5, 128.8, 125.1, 123.7, 121.9, 113.1, 111.7, 97.6, 20.8.

IR (KBr): 3444, 1540, 1497, 1444, 1308, 1278, 1049, 907, 875, 824, 798, 776, 734, 663, 650 cm^{-1}. HRMS (ESI) calcd for $C_{15}H_{12}BrN$ $[M + H]^+$: 286.0226, found 286.0232.

*5-Bromo-2-(m-tolyl)-1H-indole (**4c**)*: White solid (60.6 mg, 71%), mp 143-144 °C. ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.71 (s, 1H), 7.70-7.69 (m, 2H), 7.65 (d, J = 7.5 Hz, 1H), 7.37-7.34 (m, 2H), 7.19 (dd, J_1 = 2.0 Hz, J_2 = 8.5 Hz, 1H), 7.16 (d, J = 7.5 Hz, 1H), 6.86 (s, 1H), 2.38 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 139.3, 138.1, 135.7, 131.6, 130.5, 128.8, 128.5, 125.7, 123.8, 122.4, 122.0, 113.2, 111.8, 98.1, 21.1. IR (KBr): 3437, 1606, 1590, 1566, 1460, 1311, 1175, 1053, 867, 804, 771, 734, 685, 666 cm^{-1}. HRMS (ESI) calcd for $C_{15}H_{12}BrN$ $[M + H]^+$: 286.0226, found 286.0232.

*5-Bromo-2-(o-tolyl)-1H-indole (**4d**)*: White solid (60.2 mg, 70%), mp 104-105 °C (lit.[28] not reported). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.52 (s, 1H), 7.74 (s ,1H), 7.55-7.53 (m, 1H), 7.36 (d, J = 8.5 Hz,1H), 7.34-7.29 (m, 3H), 7.21 (d, J = 8.5 Hz, 1H), 6.57 (s, 1H), 2.46 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 138.9, 135.6, 135.0, 132.0, 130.9, 130.2, 129.1, 127.9, 126.0, 123.6, 122.0, 113.1, 111.6, 101.3, 20.9.

*5-Bromo-2-(4-fluorophenyl)-1H-indole (**4e**)*: White solid (68.9 mg, 79%), mp 179-180 °C (lit.[29] 178-179 °C). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.75 (s, 1H), 7.91-7.88 (m, 2H), 7.71 (d, J = 2.0 Hz, 1H), 7.36-7.31 (m, 3H), 7.21 (dd, J_1 = 2.0 Hz, J_2 = 8.5 Hz, 1H), 6.86 (d, J = 2.0 Hz, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 162.8, 160.8,138.2, 135.8, 130.5, 128.3, 127.3, 127.2, 124.0, 122.1, 116.0, 115.8, 113.2, 111.9, 98.2.

*5-Bromo-2-(3-fluorophenyl)-1H-indole (**4f**)*: White solid (47.9 mg, 55%), mp 171-172 °C. ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.83 (s, 1H), 7.72-7.70 (m, 3H), 7.52-7.48 (m, 1H), 7.38 (d, J = 8.5 Hz, 1H), 7.23 (dd , J_1 = 2.0 Hz, J_2 = 8.5 Hz, 1H), 7.18-7.14 (m,

1H), 6.97 (d, *J* = 2.0 Hz, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 163.6, 161.7, 137.8, 137.7, 135.8, 134.1, 134.0, 131.0, 130.9, 130.2, 124.5, 122.4, 121.3, 121.2, 114.5, 114.3, 113.3, 112.0, 111.8, 111.6, 99.3. IR (KBr): 3753, 3676, 3655, 3425, 1611, 1459, 1309, 1161, 781, 773 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_9BrFN$ $[M + H]^+$: 289.9975, found 289.9973.

*5-Bromo-2-(2-fluorophenyl)-1H-indole (**4g**)*: White solid (40.9 mg, 47%), mp 133.5-134 °C. ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.71 (s, 1H), 7.93-7.90 (m, 1H), 7.78 (d, *J* = 2.0 Hz, 1H), 7.42-7.33 (m, 4H), 7.25 (dd, J_1 = 2.0 Hz, J_2 = 8.5 Hz, 1H), 6.91 (d, *J* = 2.0 Hz, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 160.0, 158.0, 135.4, 132.9, 130.1, 129.6, 127.9, 125.0, 124.5, 122.4, 119.6, 116.6, 116.4, 113.4, 111.9, 102.0, 101.9. IR (KBr): 3868, 1577, 1456, 1318, 1207, 1175, 1108, 1050, 907, 880, 797, 757, 539, 501 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_9BrFN$ $[M + H]^+$: 289.9975, found 289.9973.

*5-Bromo-2-(4-chlorophenyl)-1H-indole (**4h**)*: White solid (65.5 mg, 71%), mp 188.5-189 °C. ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.81 (s, 1H), 7.88 (d, *J* = 8.5 Hz, 2H), 7.72 (d, *J* = 1.5 Hz, 1H), 7.54 (d, *J* = 8.5 Hz, 2H), 7.36 (d, *J* = 8.5 Hz, 1H), 7.21 (dd, J_1 = 1.5 Hz, J_2 = 8.5 Hz, 1H), 6.92 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 137.9, 135.8, 132.3, 130.5, 130.4, 129.0, 126.8, 124.3, 122.2, 113.3, 112.0, 98.8. IR (KBr): 3437, 1533, 1480, 1454, 1444, 1411, 1314, 1278, 1172, 1099, 1049, 1003, 908, 864, 791, 721, 665 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_9BrClN$ $[M + H]^+$: 305.9680, found 305.9682.

*5-Bromo-2-(4-bromophenyl)-1H-indole (**4i**)*: White solid, (73.5 mg, 70%), mp 161.7-162 °C. ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.82 (s, 1H), 7.79 (d, *J* = 8.5 Hz, 2H), 7.70(d, *J* = 1.5 Hz, 1H), 7.66 (d, *J* = 8.5 Hz, 2H), 7.36 (d, *J* = 8.5 Hz, 1H), 7.22 (dd, J_1

= 1.5 Hz, J_2 = 8.5 Hz, 1H), 6.90 (d, J = 1.5 Hz, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 137.9, 135.9, 131.9, 130.9, 130.4, 127.1, 124.3, 122.2, 120.8, 113.3, 112.0, 98.9. IR (KBr): 3450, 1530, 1487, 1454, 1417, 1314, 1179, 1076, 1046, 1006, 907, 869, 791, 736, 706, 665 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_9Br_2N$ $[M + H]^+$: 349.9175, found 349.9182.

*5-Bromo-2-(4-iodophenyl)-1H-indole (**4j**)*: White solid (79.7 mg, 67%), mp 222.3-223 °C. ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.79 (s, 1H), 7.83 (d, J = 8.5 Hz, 2H), 7.72 (s, 1H), 7.66 (d, J = 8.5 Hz, 2H), 7.35 (d, J = 8.5 Hz, 1H), 7.21 (dd, J_1 = 2.0 Hz, J_2 = 8.5 Hz, 1H), 6.92 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 138.1, 137.7, 135.9, 131.2, 130.4, 127.1, 124.3, 122.2, 113.3, 112.0, 98.8, 93.7. IR (KBr): 3430, 1533, 1460, 1447, 1420, 1318, 1271, 1172, 1056, 998, 907, 880, 824, 784, 736, 661 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_9BrIN$ $[M + H]^+$: 397.9036, found 397.9048.

*5-Bromo-2-(4-methoxyphenyl)-1H-indole (**4k**)*: Pale-yellow solid (57.0 mg, 63%), mp 224-225 °C (lit.[30] not reported). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.64 (s, 1H), 7.79 (d, J = 8.5 Hz, 2H), 7.66 (d, J = 2.0 Hz, 1H), 7.32 (d, J = 8.5 Hz, 1H), 7.16 (dd, J_1 = 2.0 Hz, J_2 = 8.5 Hz, 1H), 7.04 (d, J = 8.5 Hz, 2H), 6.75 (d, J = 2.0 Hz, 1H), 3.80 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 159.1, 139.3, 135.6, 130.7, 126.6, 124.2, 123.4, 121.7, 114.4, 112.9, 111.7, 96.9, 55.2.

*5-Bromo-2-(naphthalen-1-yl)-1H-indole (**4l**)*: Oil (74.7 mg, 77%). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.83 (s, 1H), 8.29-8.27 (m, 1H), 8.04-7.99 (m, 2H), 7.82-7.81 (m, 1H), 7.72-7.71 (m, 1H), 7.64-7.58 (m, 3H), 7.42 (d, J = 8.5 Hz, 1H), 7.27 (dd, J_1 = 2.0 Hz, J_2 = 8.5 Hz, 1H), 6.74 (d, J = 2.0 Hz, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 138.5,

135.8, 134.0, 131.1, 130.8, 130.7, 129.0, 128.9, 127.9, 127.3, 126.7, 126.0, 125.7, 124.3, 122.7, 113.8, 112.2, 102.5. IR (KBr): 3411, 1729, 1437, 1391, 1321, 1298, 1116, 1049, 902, 869, 804, 788, 781, 686, 665 cm^{-1}. HRMS (ESI) calcd for $C_{18}H_{12}BrN$ $[M + H]^+$: 322.0226, found 322.0223.

*5,7-Bibromo-2-phenyl-1H-indole (**4m**)*: White solid (82.1 mg, 78%), mp 163-164 °C. ^1H NMR (500 MHz, DMSO-d_6) δ 11.60 (s, 1H), 7.98 (d, J = 7.0 Hz, 2H), 7.76 (s, 1H), 7.49-7.46 (m, 3H), 7.38 (t, J = 7.5 Hz, 1H), 6.99 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 141.0, 134.6, 131.5, 131.0, 128.7, 128.3, 126.3, 125.9, 121.6, 111.7, 104.7, 100.2. IR (KBr): 3427, 2922, 2364, 1742, 1561, 1457, 1340, 1303, 1180, 1072, 897, 842, 759, 724, 680, 514, 484, 442 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_9Br_2N$ $[M + H]^+$: 349.9175, found 349.9175.

*5,7-Dibromo-2-(4-fluorophenyl)-1H-indole (**4n**)*: Pale-yellow solid (90.8 mg, 82%), mp 165-166 °C. ^1H NMR (500 MHz, DMSO-d_6) δ 11.64 (s, 1H), 8.04-8.02 (m, 2H), 7.75 (s, 1H), 7.46 (s, 1H), 7.32 (t, J = 8.5 Hz, 2H), 6.96 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 163.1, 161.1, 140.0, 134.6, 131.5, 128.5, 128.4, 127.7, 127.6, 125.9, 121.6, 115.7, 115.5, 111.7, 104.7, 100.1. IR (KBr): 3447, 2923, 1736, 1602, 1539, 1494, 1461, 1335, 1229, 1186, 1070, 828, 779, 711, 573, 430 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_8Br_2FN$ $[M + H]^+$: 367.9081, found 367.9081.

*5,7-Dibromo-2-(4-methoxyphenyl)-1H-indole (**4o**)*: White solid (80.0 mg, 70%), mp 188.5-189 °C. ^1H NMR (500 MHz, DMSO-d_6) δ 11.51 (s, 1H), 7.92 (d, J = 8.5 Hz, 2H), 7.71 (d, J = 1.5 Hz, 1H), 7.42 (d, J = 1.5 Hz, 1H), 7.04 (d, J = 8.5 Hz, 2H), 6.87 (d, J = 1.5 Hz, 1H), 3.82 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 159.4, 141.2, 134.4, 131.8,

127.7, 125.3, 123.6, 121.2, 114.1, 111.6, 104.5, 98.8, 55.2. IR (KBr): 3411, 1606, 1543, 1497, 1459, 1279, 1253, 1245, 1179, 1027, 940, 870, 850, 822, 774, 734, 710, 665 cm^{-1}. HRMS (ESI) calcd for $C_{15}H_{11}Br_2NO$ $[M + H]^+$: 379.9280, found 379.9296.

*5-Iodo-2-phenyl-1H-indole (**4p**)*: White solid (66.4 mg, 69%), mp 237-238 °C. ^1H NMR (500 MHz, DMSO-d_6) δ 11.72 (s, 1H), 7.89 (s,1H), 7.85 (d, J = 8.5 Hz, 2H), 7.47 (t, J = 8.0 Hz, 2H), 7.36-7.32 (m, 2H), 7.26 (d, J = 8.0 Hz, 1H), 6.86 (s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 138.7, 136.1, 131.6, 131.4, 129.4, 128.9, 128.3, 127.8, 125.2, 113.7, 97.9, 83.0. IR (KBr): 3432, 2922, 2809, 2318, 1451, 1388, 796, 761, 505 cm^{-1}. HRMS (ESI) calcd for $C_{14}H_{10}IN$ $[M + H]^+$: 319.9931, found 319.9935.

*2-(4-Fluorophenyl)-5-iodo-1H-indole (**4q**)*: White solid (65.9 mg, 65%), mp 186-187 °C (lit.[31] 174-175 °C). ^1H NMR (500 MHz, DMSO-d_6) δ 11.72 (s, 1H), 7.90-7.88 (m, 3H), 7.36-7.33 (m, 3H), 7.25 (d, J = 8.5 Hz, 1H), 6.84 (m, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 162.7, 160.8, 137.7, 136.1, 131.4, 129.4, 128.3, 127.3, 127.2, 116.0, 115.8, 113.7, 97.9, 83.1.

*5-Iodo-2-(4-methoxyphenyl)-1H-indole (**4r**)*: White solid (63.4 mg, 60%), mp 195-196 °C (lit.[32] not reported). ^1H NMR (500 MHz, DMSO-d_6) δ 11.60 (s, 1H), 7.84 (s, 1H), 7.77 (d, J = 8.5 Hz, 2H), 7.31 (d, J = 8.5 Hz, 1H), 7.22 (d, J = 8.5 Hz, 1H), 7.03 (d, J = 8.5 Hz, 2H), 6.71 (s, 1H), 3.80 (s, 3H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 159.1, 138.8, 135.9, 131.6, 128.9, 127.9, 126.6, 124.2, 114.4, 113.5, 96.5, 82.9, 55.2.

*2,5-Diphenyl-1H-indole (**5**)*: White solid (57.8 mg, 71%), mp 191-192 °C (lit.[33] 192-193 °C). ^1H NMR (500 MHz, DMSO-d_6) δ 11.60 (s, 1H), 7.88 (d, J = 7.5 Hz, 2H), 7.80 (s, 1H), 7.68 (d, J = 7.5 Hz, 2H), 7.49-7.40 (m, 6H), 7.35-7.29 (m, 2H), 6.97 (s, 1H);

^{13}C NMR (125 MHz, DMSO-d_6) δ 141.8, 138.4, 136.8, 132.1, 131.9, 129.2, 128.9, 128.7, 127.5, 126.6, 126.2, 125.0, 121.0, 118.0, 111.7, 99.1.

*N-(2-(2-oxo-2-phenylethyl)phenyl)acetamide (**6**)*: Pale-red solid, mp 99-100 °C (lit.[19] not reported). ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.35 (s, 1H), 8.01 (d, *J* = 7.5 Hz, 2H), 7.65 (t, *J* = 7.5 Hz, 1H), 7.54 (t, *J* = 7.5 Hz, 1H), 7.42 (d, *J* = 8.0 Hz, 1H), 7.23 (t, *J* = 7.5 Hz, 2H), 7.13 (t, *J* = 7.5 Hz, 2H),4.40 (s, 2H), 1.92 (s, 3H); ^{13}C NMR (125MHz, DMSO-d_6) δ 197.4, 168.2, 136.8, 136.7, 133.1, 131.2, 129.8, 128.6, 128.1, 126.9, 125.4, 125.0, 41.3, 23.1.

ASSOCIATED CONTENT

Supporting Information

^{1}H and ^{13}C NMR spectra for all products. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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