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Iodine-Catalyzed Oxidative Cross-Coupling of Indoles and Azoles: Regioselective Synthesis of *N*-Linked 2-(Azol-1-yl)indole Derivatives

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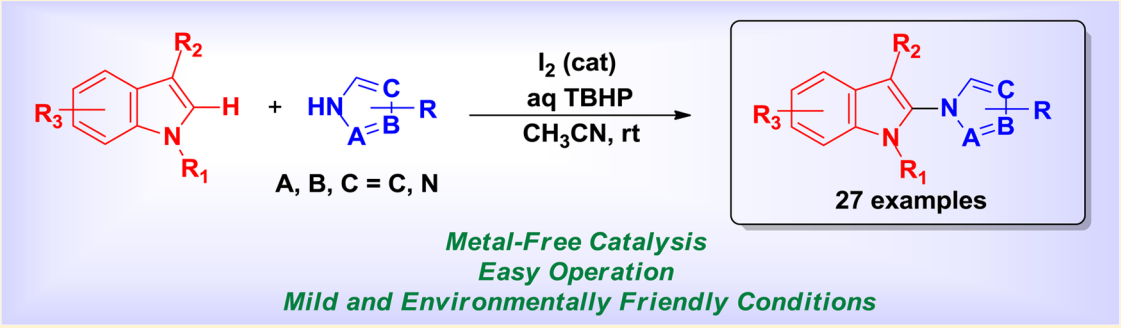
Supporting Information



ABSTRACT: A highly efficient iodine-catalyzed regioselective oxidative cross-coupling of an indole C−H bond and azole N−H bond is described. This metal-free reaction can be easily carried out at room temperature under mild and environmentally friendly conditions and provides a series of *N*-linked 2-(azol-1-yl)indole derivatives in moderate to excellence yields.

INTRODUCTION

Indoles are structural motifs prevalent in a number of biologically active natural products. They are employed widely in medicinal chemistry, pharmacological research, and material applications.[1] As a consequence of their importance, the development of efficient methodologies for the preparation and functionalization of various indole derivatives has been a subject of intense research efforts. Among many synthetic strategies available, direct C−H bond functionalization/C−C bond and C−N bond formations of indoles have received considerable attention.[2] Over the past decade, a number of studies have reported the synthesis of indoles via direct C−H bond functionalization/C−C bond construction approaches.[3] However, there are a few reports on a direct C−H bond functionalization/C−N bond formation of indole derivatives due to the lack of control over chemo- and regioselectivity in the reactions.[4]

2-(Azol-1-yl)indoles, *N*-substituted derivatives of indoles at the C-2 position, exhibit interesting pharmaceutical properties. This substituted indole moiety is present in some biologically active compounds, such as melatonin derivatives (with cardioprotective activity)[5] and celogentin and moroidin families of natural antimitotics (potent inhibitors for tubulin polymerization).[6] A general method for the synthesis of novel 2-(azol-1-yl)indoles is nucleophilic displacement on 2-halogenated indole derivatives bearing an electron-withdrawing group at the C-3 position (Scheme 1).[7] Another way to build up the 2-(azol-1-yl)indole core was reported by Poirier and Beaulieu using a thermal or microwave-mediated reaction of azoles and halogenated indoles.[8] A direct C−N bond formation of indole−azole linkage from nonactivated indole and azole was reported by Castle and co-workers.[9a] This method employed a stoichiometric amount of *N*-chlorosuccinimide (NCS) as the oxidant in the oxidative coupling reaction. The utility of this methodology was later demonstrated in the total synthesis of Celogentin C.[9b,c]

Recently, Huang and co-workers also reported an efficient protocol for the preparation of a series of 2-(azol-1-yl)indole derivatives from nonprefunctionalized indoles and azoles via iodine-mediated selective C−N bond formation in aqueous solution.[10] We envisioned that a catalytic version of this transformation should become feasible and provide an eco-friendly synthetic option because a number of recent studies have demonstrated the utility of iodine catalysis in oxidative coupling reactions.[11] The combination of catalytic amounts of iodine or iodide salts and readily available oxidants such as *tert*-butyl hydroperoxide (TBHP) or hydrogen peroxide (H_2O_2) has proven to be a versatile and powerful liaison for the successful carbon−carbon and carbon−heteroatom bond formation in many catalytic oxidative coupling methods.[12] Herein, we report regioselective C−N bond formation at the C-2 position of indoles with azoles via the I_2-catalyzed direct oxidative C−H and N−H coupling strategy. Our catalytic approach offers a facile synthesis of 2-(azol-1-yl)indole derivatives with several advantages, including metal-free regioselective catalysis, mild and environmentally benign

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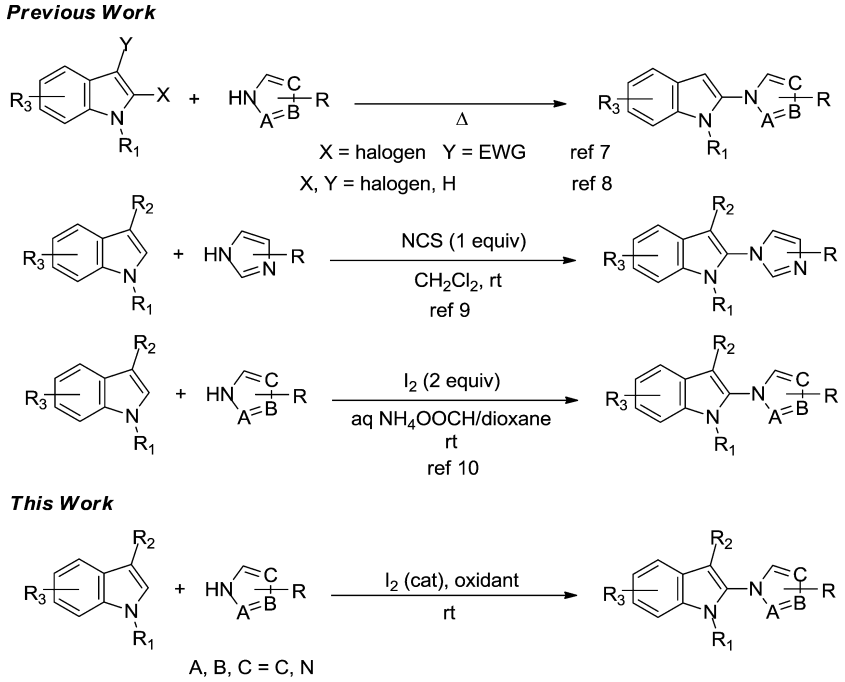
Scheme 1. Synthetic Strategies for *N*-linked 2-(Azol-1-yl)indoles

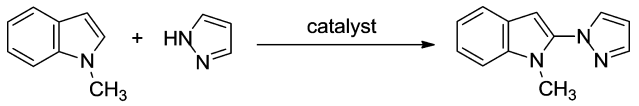


conditions, accommodation of a broad range of substrates, and avoiding the generation of toxic byproducts.

RESULTS AND DISCUSSION

We initiated this study by examining the oxidative C−H and N−H coupling reaction of 1-methylindole (**1a**) with pyrazole (**2a**) under various catalytic conditions; selected results are summarized in Table 1.[13] When the reaction of **1a** and **2a** was carried out in the presence of I_2 (20%), aq TBHP (1 equiv) in H_2O at room temperature, *N*-linkage at the C-2 position of indole (**3a**) was achieved in a promising 47% yield (Table 1, entry 1). Screening of solvents revealed that CH_3CN is the optimal solvent, in which the desired product **3a** can be generated in excellent yield (91%, entry 2). Dichloromethane (CH_2Cl_2) and 1,2-dichloroethane (DCE) are also viable solvents for this reaction (88−89%, entries 3 and 4). Other polar and nonpolar solvents are less effective (entries 5−10). Employing H_2O_2 as the oxidant gave lower yield of product (entry 11). Increasing the amount of TBHP led to a decrease in yield and caused unwanted side reactions, and incomplete conversion was observed when using less than 1 equiv of TBHP.[13] Further attempts to drive the reaction to completion by increasing temperature were unsuccessful; lower yield of product was found as temperature increased.[13] The combinations of TBHP with other forms of iodine/iodide (e.g., KI, TBAI, and NIS) showed much lower or no catalytic activity (entries 12−14, respectively). Additionally, no reaction was observed in the absence of I_2 (entry 15), and only 15% yield of product **3a** could be attained when the oxidant was omitted from the reaction (entry 16). These results indicated that both the I_2 catalyst and the TBHP oxidant play pivotal roles for this catalytic transformation.

Table 1. Optimization of Reaction Conditions[a]



entry	catalyst	oxidant	solvent	yield (%)[b]
1	I_2	TBHP	H_2O	47
2	**I_2**	**TBHP**	**CH_3CN**	**91**
3	I_2	TBHP	CH_2Cl_2	88
4	I_2	TBHP	DCE	89
5	I_2	TBHP	MeOH	63
6	I_2	TBHP	DMSO	13
7	I_2	TBHP	DMF	14
8	I_2	TBHP	THF	56
9	I_2	TBHP	1,4-dioxane	42
10	I_2	TBHP	toluene	41
11	I_2	H_2O_2	CH_3CN	54
12	KI	TBHP	CH_3CN	0
13	TBAI	TBHP	CH_3CN	0
14	NIS	TBHP	CH_3CN	5
15		TBHP	CH_3CN	0
16	I_2		CH_3CN	15

[a]Conditions: **1a** (0.5 mmol, 1 equiv), **2a** (1 mmol, 2 equiv), catalyst (0.1 mmol, 0.2 equiv), aq TBHP in water (0.5 mmol, 1 equiv), CH_3CN (2 mL), rt, 24 h. [b]GC yield.

Overall, the optimal conditions for I_2-catalyzed direct C−N bond coupling was established (Table 1, entry 2; 1 equiv of indole, 2 equiv of azole, 20 mol % of I_2, 1 equiv of aq TBHP, CH_3CN, rt, 24 h). This catalytic method employs readily available nonactivated substrates, avoids the use of excessive amounts of I_2 and TBHP oxidant, generates a minimal amount of waste, and can be conveniently carried out under mild conditions. Thus, our protocol offers good economic and environmental benefits and can be an alternative substitution for the stoichiometric I_2-mediated oxidative cross-coupling reaction or other previously reported methods.

We next explored the generality and functional group compatibility of this transformation under the established conditions. Reactions between many indole substrates and

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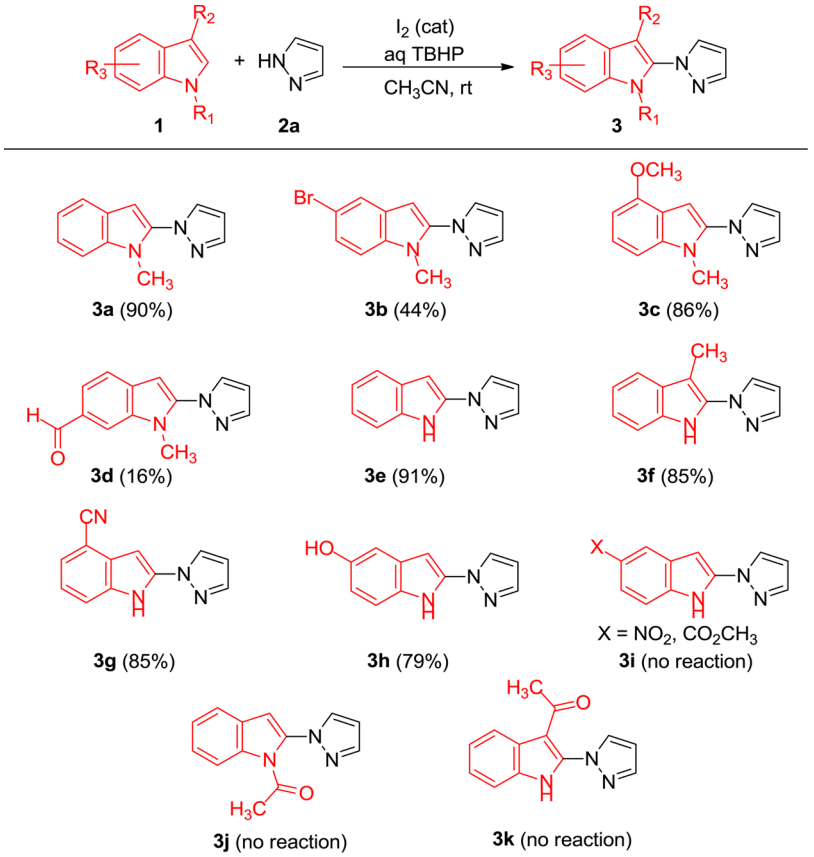
Table 2. Scope of Indoles[a]



[a]Conditions: indole (1 mmol, 1 equiv), **2a** (2 mmol, 2 equiv), I_2 (0.2 mmol, 0.2 equiv), aq TBHP (1 mmol, 1 equiv), CH_3CN (4 mL), rt, 24 h. In parenthesis: isolated yields after chromatography purification.

pyrazole **2a** were tested, and the results were summarized in Table 2 (**3a**–**3h**). The presence of halogen (bromo) at the C-5 position of 1-methylindole does not appear to interrupt the reaction. This 5-bromo-1-methylindole substrate gave the C–N coupling product **3b** in 44% isolated yield. Gratifyingly, the electron-rich 4-methoxyl-1-methylindole substrate reacted with pyrazole to provide product **3c** in decent yield. On the other hand, the presence of the electron poor formyl group at the C-6 position has a negative impact on the transformation; the corresponding product **3d** was obtained in considerably low yield (16%). Apart from 1-methylindole, we also examined the reaction scope of other free indole (N–H) substrates. To our delight, free N–H indole underwent smooth coupling with pyrazole (**2a**), affording product **3e** in excellent yield (91%). A self-coupling product between the C–H bond and the N–H bond of free indole was not observed. A reaction of 3-methylindole and pyrazole also furnished high yield of indole product **3f**. These outcomes from the successful formation of products **3e** and **3f** thus emphasized the usefulness of this catalytic method for regioselective C–N bond coupling at the C-2 position of indole.

The electronic effects of substitutents on indole substrates were also evaluated. The indole substrate bearing an electron-poor cyano group substituted at the C-4 position delivered product **3g** in very good yield. However, electronic variations in the C-5 position of indole substrates have a dramatic effect on the efficiency of the reaction. In the case of the electron-donating group (such as a hydroxyl group), good yield of product **3h** can be achieved (79% isolated yield). Conversely, no reaction was observed in the case of indole substrates bearing an electron-withdrawing substituent at C-5 position (nitro and methylcarboxylate groups; **3i**). In addition, 1- and 3-acetylindole do not react under optimal conditions, indicating that electronic effects from substituents on indole substrates play essential roles in this transformation.

The reactions between indoles and a variety of azoles were also examined under optimal conditions. As illustrated in Table 3, both 1-methylindole (**1a**) and N–H free indoles (indole and 3-methylindole) showed a tolerance toward many azole coupling partners, and the oxidative cross-coupling reactions can be achieved without any difficulties, allowing facile preparation of 2-(azol-1-yl)indoles in moderate to excellent yields. As anticipated, the reactions of these indole substrates and halogen-substituted pyrazoles (e.g., 4-bromopyrazole or 4-iodopyrazole) proceeded smoothly, affording the desired products **4a**$_1$, **4a**$_2$, **4b**$_1$, and **4b**$_2$ in reasonable to excellent quantities (54–91%). Notably, sterically hindered pyrazole (3,5-dimethylpyrazole) also gave products **4c**$_1$ and **4c**$_2$ in modest amounts. In the case of the imidazole coupling partner, the *N*-linked C-2 indole products **4d**$_1$ and **4d**$_2$ could be generated in excellent yields. It is noteworthy that reactions of indoles with 1,2,3-triazole and 1,2,4-triazole resulted in 2-(1-triazolyl)indole isomer exclusively, and the products **4e**$_1$, **4e**$_2$, **4e**$_3$, **4f**$_1$, **4f**$_2$, and **4f**$_3$ could be collected in good to excellent yields. Other regioisomers were not observed under our established coupling conditions. Benzimidazole and benzotriazole are also effective substrates for this direct C–H and N–H oxidative cross-coupling reaction (**4g**, **4f**$_1$, **4f**$_2$, and **4f**$_3$).

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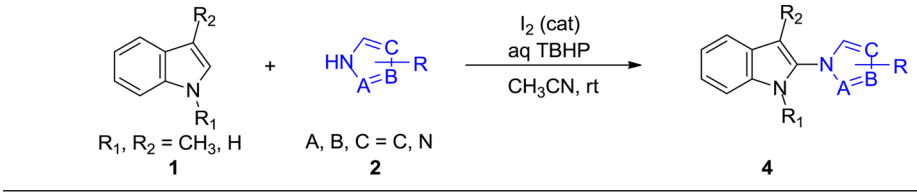
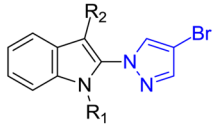
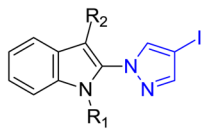
Table 3. Scope of Azoles[a]

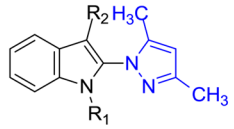




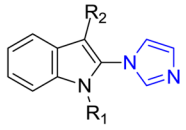
$R_1 = CH_3, R_2 = H$ **4a$_1$** (59%)
$R_1 = H, R_2 = CH_3$ **4a$_2$** (91%)



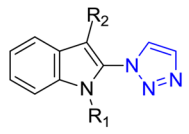
$R_1 = CH_3, R_2 = H$ **4b$_1$** (54%)
$R_1 = H, R_2 = CH_3$ **4b$_2$** (69%)



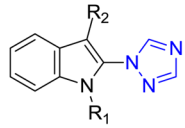
$R_1 = CH_3, R_2 = H$ **4c$_1$** (52%)
$R_1 = H, R_2 = CH_3$ **4c$_2$** (71%)



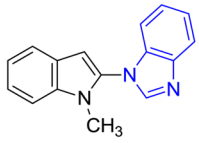
$R_1 = CH_3, R_2 = H$ **4d$_1$** (91%)
$R_1 = H, R_2 = CH_3$ **4d$_2$** (97%)



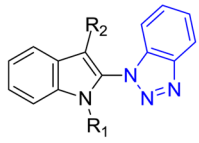
$R_1 = CH_3, R_2 = H$ **4e$_1$** (93%)
$R_1 = H, R_2 = CH_3$ **4e$_2$** (86%)
$R_1 = H, R_2 = H$ **4e$_3$** (53%)



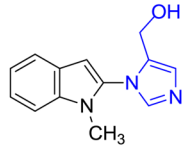
$R_1 = CH_3, R_2 = H$ **4f$_1$** (63%)
$R_1 = H, R_2 = CH_3$ **4f$_2$** (86%)
$R_1 = H, R_2 = H$ **4f$_3$** (65%)



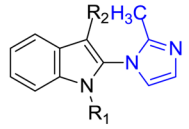
4g (78%)



$R_1 = CH_3, R_2 = H$ **4h$_1$** (92%)
$R_1 = H, R_2 = CH_3$ **4h$_2$** (95%)
$R_1 = H, R_2 = H$ **4h$_3$** (58%)



4i (50%)



$R_1 = CH_3, R_2 = H$ **4j$_1$** (trace)
$R_1 = H, R_2 = CH_3$ **4j$_2$** (trace)
$R_1 = H, R_2 = H$ **4j$_3$** (trace)

[a]Conditions: indole (1 mmol, 1 equiv), azole (2 mmol, 2 equiv), I_2 (0.2 mmol, 0.2 equiv), aq TBHP (1 mmol, 1 equiv), CH_3CN (4 mL), rt, 24 h. In parenthesis: isolated yields after chromatography purification.

Interestingly, the azole substrate containing an oxidant-sensitive hydroxyl group is compatible with the reaction conditions. The C−N coupling product **4i** was formed selectively in one regioisomer without impacting the hydroxyl group, demonstrating the mild nature of our protocol. The regiochemistry of the isolated coupling product (**4i**) was confirmed by the two-dimensional NOESY spectrum (see the Supporting Information), which exhibits the through-space correlations between indole-hydrogen at the C-3 position and imidazole-CH_2OH at the C-5 position as well as an indole methyl (CH_3) group at the N-1 position and imidazole-hydrogen at the C-2 position.[13] Nonetheless, 2-methylimidazole is unable to couple with indoles under these conditions; only trace amounts of products **4j$_1$**, **4j$_2$**, and **4j$_3$** were detected by GCMS. These results suggested that the steric hindrance from the methyl group at the C-2 position of imidazole could interfere with product formation.

To gain insight into the reaction mechanism, a series of control experiments were conducted (Scheme 2). When a radical inhibitor was employed in the reaction of indole **1a** and azole **2a**, no inhibition was observed under optimal conditions (Scheme 2a). The product can be obtained in 60, 96, and 94% in the presence of TEMPO, BHT, and hydroquinone, respectively. Therefore, these results suggested that the reaction is not likely to involve a radical pathway. To provide further evidence regarding the role of iodine and TBHP, the reaction was carried out without the use of an oxidant. The yield of product **3a** was significantly reduced when subjecting 1 or 2 equiv of I_2 to this reaction (Scheme 2b), which implied that I_2 is not likely to be the catalytic active species. These results are different from that reported by Huang and co-workers (2012), who showed that a stoichiometric amount (1−2 equiv) of I_2 can be utilized to mediate the oxidative C−N coupling reaction in a saturated aqueous ammonium salt solution. Under our standard conditions, however, the I_2 precatalyst could likely be converted to another active intermediate prior to entering the catalytic cycle. In the absence of TBHP, excess I_2 would presumably directly react with the starting material and lead to unwanted side reactions.[13]

Although the combination of a catalytic amount of iodide anion (I^-) and TBHP oxidant was insufficient to elaborate successful formation of the *N*-linked indole product (Table 1, entries 12 and 13), the reaction of indole **1a** and pyrazole **2a** in the presence of catalytic HI (hydroiodic acid) and TBHP

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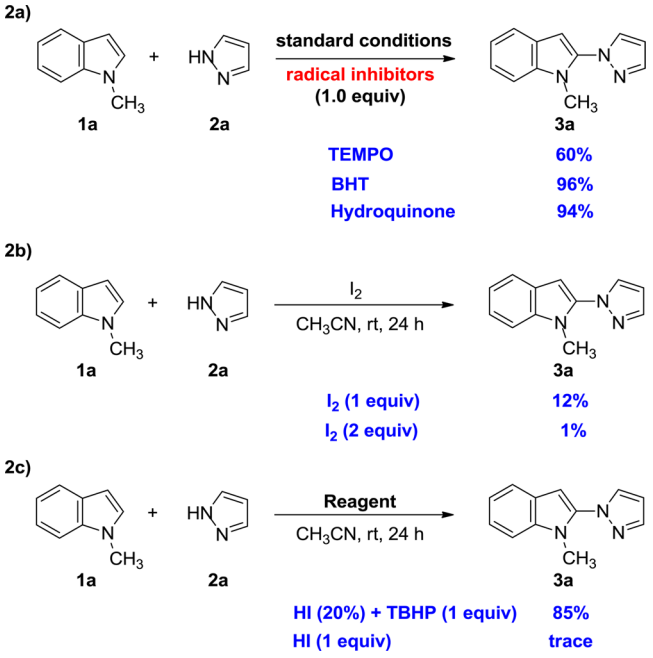
Scheme 2. Control Experiments



oxidant afforded product **3a** in 85% yield (Scheme 2c). This result implied that a catalytic amount of acid might be required for conversion of an iodide anion to an active species in this reaction. We also speculated that H^+ and I^- (HI) are possibly involved in the catalytic cycle. To verify whether HI could facilitate product formation, the reaction of **1a** and **2a** was treated with only a stoichiometric amount of HI. In this case, no product was obtained. This outcome underlined the necessity of TBHP oxidant to convert not only I_2, but also HI (iodide anion in acidic medium) to the active catalytic species in this transformation.

On the basis of the results described above and relevant literature,[9−12] a plausible mechanism for this transition-metal-free oxidative coupling is proposed using 1-methylindole **1a** and pyrazole **2a** as the model substrates. Under the optimal reaction conditions, the initial process could involve *in situ* iodination, giving an electrophilic iodine species ("I^+"), such as hypoiodous (HIO) or iodous acid (HIO_2).[11b,14,15] Then, nucleophilic attack of this "I^+" species by indole will generate either active iodonium ion **A** or 3-iodo iminium intermediate **B**.[4f,10] This intermediate can be trapped by a nucleophilic azole, leading to the formation of key intermediate **C**.[8,9a] Subsequent elimination of HI would furnish the corresponding 2-(azol-1-yl)indole product. Further oxidation of HI by TBHP would reproduce the "I^+" species to resume the catalytic cycle as depicted in Scheme 3.

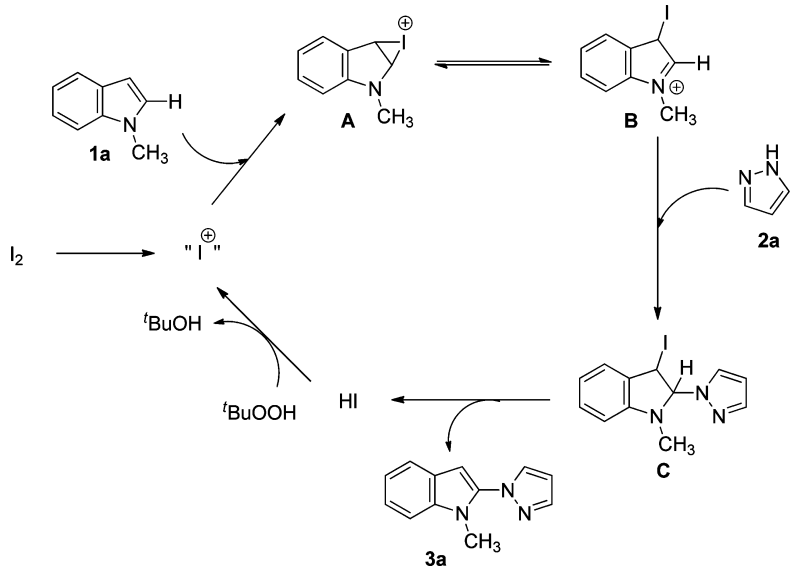
CONCLUSION

In summary, we have disclosed an expedient metal-free catalytic protocol for regio- and chemoselective C−N bond formation of indoles with azoles. This iodine-catalyzed oxidative coupling reaction can be carried out at room temperature under mild conditions with good scope using a ubiquitous and inexpensive catalytic combination. This catalytic transformation provides a convenient synthetic route with good economical and environmental advantages to access a series of *N*-linked 2-(azol-1-yl)indole derivatives, which have potential applications in medicinal chemistry. Mechanistic studies and further extension of this methodology to other substrates are currently under investigation.

EXPERIMENTAL SECTION

General Information. Unless otherwise specified, all experiments were carried out under air atmosphere. All reagents were obtained from commercial suppliers and used without further purification. Oven-dried glassware was used in all cases. Column chromatography was performed over silica gel (SiO_2; 60 Å silica gel, 70−230 Mesh). GC experiments were carried out with a GC-FID on a chromatograph equipped with an HP-1 polysiloxane column (24.5 m × 0.32 mm ID × 0.17 μm). ^{1}H and ^{13}C NMR spectra were recorded at 400 and 100 MHz in $CDCl_3$ or DMSO-d_6 solution. NMR chemical shifts are reported in ppm and were measured relative to $CHCl_3$ (7.24 ppm for ^{1}H and 77.00 ppm for ^{13}C) or DMSO (2.51 ppm for ^{1}H and 39.51 ppm for ^{13}C). IR spectra were recorded on an FT-IR spectrometer, and only partial data are listed. High resolution mass spectroscopy (HRMS) data were analyzed by a high-resolution micrOTOF

Scheme 3. Tentative Reaction Mechanism



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instrument with electrospray ionization (ESI). The structures of known compounds were corroborated by comparing their ^{1}H and ^{13}C NMR data with values from the literature.[9]

General Procedure for the Synthesis of Compounds 3a−3h and 4a−4i. A 20 mL oven-dried scintillation vial equipped with a magnetic stir bar was charged with a mixture of indole substrate (1.00 mmol, 1.00 equiv), azole (2.00 mmol, 2.00 equiv), iodine (I_2, 51 mg, 0.20 mmol, 0.20 equiv), TBHP in water (1.00 mmol, 1.00 equiv), and acetonitrile (CH_3CN) (4.00 mL). The vial was capped, and the reaction mixture was stirred at room temperature for 24 h. Upon completion, saturated $Na_2S_2O_3$ (5 mL) and distilled deionized H_2O (12 mL) was added, and the mixture was extracted with ethyl acetate (EtOAc) (2 × 25 mL). The combined organic layer was washed with saturated NaCl, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The crude product was purified by SiO_2 column chromatography to afford the desired *N*-linked 2-(azol-1-yl)indole product.

1-Methyl-2-(1H-pyrazol-1-yl)-1H-indole (**3a**).[10] Following the general procedure, the product was isolated as a white solid in 177.5 mg (90%) by column chromatography (4:1 hexanes/ethyl acetate). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81 (d, J = 1.2 Hz, 1H), 7.72 (d, J = 2.4 Hz, 1H), 7.62 (d, J = 8.0 Hz, 1H), 7.36−7.34 (m, 1H), 7.31−7.27 (m, 1H), 7.19−7.15 (m, 1H), 6.51 (s, 1H), 6.47 (t, J = 2.0 Hz, 1H), 3.67 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 141.8, 135.7, 132.4, 126.0, 122.6, 121.0, 120.4, 109.6, 106.8, 95.9, 29.9. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{12}H_{12}N_3$, 198.1026; found, 198.1031.

5-Bromo-1-methyl-2-(1H-pyrazol-1-yl)-1H-indole (**3b**).[10] Following the general procedure, the product was isolated as a white solid in 121.1 mg (44%) by column chromatography (6:1 hexanes/ethyl acetate). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80 (d, J = 1.6 Hz, 1H), 7.73−7.72 (m, 2H), 7.37−7.34 (m, 1H), 7.22−7.20 (m, 1H), 6.47 (t, J = 2.0 Hz, 1H), 6.44 (s, 1H), 3.67 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 142.1, 136.6, 134.4, 132.3, 127.7, 125.5, 123.4, 113.6, 111.2, 107.1, 95.2, 30.2. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{12}H_{11}BrN_3$, 276.0131; found, 276.0130.

4-Methoxy-1-methyl-2-(1H-pyrazol-1-yl)-1H-indole (**3c**). Following the general procedure, the product was isolated as a white solid in 194.6 mg (86%) by column chromatography (4:1 hexanes/ethyl acetate). Mp 82.3−83.0 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79 (d, J = 1.2 Hz, 1H), 7.71−7.70 (m, 1H), 7.23−7.19 (m, 1H), 6.97 (d, J = 8.0 Hz, 1H), 6.60−6.57 (m, 2H), 6.45−6.44 (m, 1H), 3.95 (s, 3H), 3.65 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 153.5, 141.8, 137.0, 134.3, 132.4, 123.4, 116.6, 106.7, 103.0, 100.2, 93.3, 55.4, 30.2. IR (neat, cm^{-1}): 3145, 2929, 2838, 1889, 1569, 1501, 1463, 1388, 1355, 1250, 1104, 929, 624. HRMS (ESI+, m/z): [M + Na]$^+$ calcd for $C_{13}H_{13}N_3NaO$, 250.0951; found, 250.0949.

1-Methyl-2-(1H-pyrazol-1-yl)-1H-indole-6-carbaldehyde (**3d**). Following the general procedure, the product was isolated as a white solid in 35.4 mg (16%) by column chromatography (4:1 hexanes/ethyl acetate). Mp 117.9−119.1 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 10.07 (s, 1H), 7.93 (s, 1H), 7.83 (d, J = 1.2 Hz, 1H), 7.78 (d, J = 2.0 Hz, 1H), 7.72−7.67 (m, 2H), 6.55 (d, J = 0.8 Hz, 1H), 6.51 (t, J = 2.0 Hz, 1H), 3.84 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 192.1, 142.4, 139.4, 135.5, 132.0, 131.4, 131.3, 121.9, 121.1, 112.2, 107.5, 95.7, 30.6. IR (neat, cm^{-1}): 3114, 2922, 1674, 1570, 1468, 1369, 1221, 930, 811, 756, 627. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{13}H_{12}N_3O$, 226.0980; found, 226.0975.

2-(1H-Pyrazol-1-yl)-1H-indole (**3e**).[10] Following the general procedure, the product was isolated as a brown solid in 166.7 mg (91%) by column chromatography (4:1 hexanes/ethyl acetate). ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.41 (br s, 1H), 7.95 (d, J = 2.4 Hz, 1H), 7.71 (d, J = 1.6 Hz, 1H), 7.56 (d, J = 8.0 Hz, 1H), 7.34 (d, J = 8.0 Hz, 1H), 7.19−7.10 (m, 2H), 6.48 (t, J = 2.0 Hz, 1H), 6.41−6.40 (m, 1H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 140.8, 135.5, 133.5, 127.8, 127.6, 122.0, 120.6, 120.3, 111.0, 108.0, 87.1. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{11}H_{10}N_3$, 184.0869; found, 184.0870.

3-Methyl-2-(1H-pyrazol-1-yl)-1H-indole (**3f**).[10] Following the general procedure, the product was isolated as an off-white solid in 167.2 mg (85%) by column chromatography (4:1 hexanes/ethyl acetate). ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.33 (br s, 1H), 7.92 (d, J = 2.4 Hz, 1H), 7.75 (d, J = 1.5 Hz, 1H), 7.57 (d, J = 7.6 Hz, 1H), 7.30 (d, J = 8.0 Hz, 1H), 7.22−7.13 (m, 2H), 6.51 (t, J = 2.0 Hz, 1H), 2.42 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 140.6, 132.9, 131.4, 129.3, 128.6, 122.4, 119.9, 118.7, 110.9, 107.3, 98.1, 8.6. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{12}H_{12}N_3$, 198.1026; found, 198.1031.

2-(1H-Pyrazol-1-yl)-1H-indole-4-carbonitrile (**3g**). Following the general procedure, the product was isolated as a white solid in 177.0 mg (85%) by column chromatography (4:1 hexanes/ethyl acetate). Mp 203.6−203.9 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 10.10 (s, 1H), 8.02 (d, J = 2.4 Hz, 1H), 7.75 (d, J = 1.2 Hz, 1H), 7.51 (d, J = 7.6 Hz, 1H), 7.48−7.45 (m, 1H), 7.21−7.16 (m, 1H), 6.61 (d, J = 1.2 Hz, 1H), 6.56−6.55 (m, 1H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 141.7, 137.6, 132.9, 130.0, 127.8, 125.8, 121.6, 118.6, 115.5, 108.9, 102.6, 85.7. IR (neat, cm^{-1}): 3211, 3123, 2349, 2219, 2013, 1573, 1367, 1195, 1046, 772, 604. HRMS (ESI+, m/z): [M + Na]$^+$ calcd for $C_{12}H_8N_4Na$, 231.0641; found, 231.0646.

2-(1H-Pyrazol-1-yl)-1H-indol-5-ol (**3h**). Following the general procedure, the product was isolated as a pale-white solid in 158.1 mg (79%) by column chromatography (1:1 hexanes/ethyl acetate). Mp 188.3−189.8 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ 11.54 (br s, 1H), 8.80 (s, 1H), 8.35 (d, J = 2.4 Hz, 1H), 7.77 (d, J = 1.4 Hz, 1H), 7.17 (d, J = 8.8 Hz, 1H), 6.82 (d, J = 2.0 Hz, 1H), 6.61−6.59 (m, 1H), 6.56−6.55 (m, 1H), 6.41 (d, J = 1.2 Hz, 1H). ^{13}C{^{1}H} NMR (100 MHz, DMSO): δ 151.4, 140.9, 136.2, 128.5, 128.3, 128.2, 112.0, 111.3, 107.8, 104.1, 87.2. IR (neat, cm^{-1}): 3436, 3069, 2920, 1645, 1511, 1476, 1318, 1201, 1052, 792, 740, 641. HRMS (ESI+, m/z): [M + Na]$^+$ calcd for $C_{11}H_9N_3NaO$, 222.0638; found, 222.0640.

2-(4-Bromo-1H-pyrazol-1-yl)-1-methyl-1H-indole (**4a$_1$**). Following the general procedure, the product was isolated as a white solid in 163.6 mg (59%) by column chromatography (10:1 hexanes/ethyl acetate). Mp 131.1−131.9 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (s, 1H), 7.74 (s, 1H), 7.64 (d, J = 8.0 Hz, 1H), 7.37−7.30 (m, 2H), 7.22−7.18 (m, 1H), 6.52 (s, 1H), 3.67 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 142.4, 135.7, 134.7, 132.2, 125.8, 122.9, 121.1, 120.6, 109.7, 96.3, 94.9, 29.9. IR (neat, cm^{-1}): 3137, 2938, 1699, 1480, 1454, 1337, 953, 775,755, 609. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{12}H_{11}BrN_3$, 276.0131; found, 276.0134.

2-(4-Bromo-1H-pyrazol-1-yl)-3-methyl-1H-indole (**4a$_2$**). Following the general procedure, the product was isolated as a white solid in 250.6 mg (91%) by column chromatography (10:1 hexanes/ethyl acetate). Mp 71.0−71.5 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.83 (s, 1H), 7.91 (s, 1H), 7.68 (s, 1H), 7.56 (d, J = 8.0 Hz, 1H), 7.31 (d, J = 8.0 Hz, 1H), 7.23−7.20 (m, 1H), 7.18−7.14 (m, 1H), 2.40 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 141.2, 132.8, 130.6, 129.2, 128.4, 122.9, 120.2, 119.0, 110.9, 99.0, 95.4, 8.6. IR (neat, cm^{-1}): 3364, 3244, 3113, 2920, 1718, 1584, 1451, 1381, 950, 736, 576. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{12}H_{11}BrN_3$, 276.0131; found, 276.0138.

2-(4-Iodo-1H-pyrazol-1-yl)-1-methyl-1H-indole (**4b$_1$**). Following the general procedure, the product was isolated as an off-white solid in 173.6 mg (54%) by column chromatography (10:1 hexanes/ethyl acetate). Mp 156.3−157.5 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80 (s, 1H), 7.76 (s, 1H), 7.63 (d, J = 8.0 Hz, 1H), 7.36−7.29 (m, 2H), 7.20−7.16 (m, 1H), 6.51 (s, 1H), 3.66 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 146.8, 136.5, 135.7, 134.5, 125.8, 122.9, 121.1, 120.6, 109.7, 96.3, 58.2, 29.9. IR (neat, cm^{-1}): 3130, 2921, 2337, 1563, 1454, 1334, 1165, 953, 855, 776, 610. HRMS (ESI+, m/z): [M + Na]$^+$ calcd for $C_{12}H_{10}IN_3Na$, 345.9812; found, 345.9816.

2-(4-Iodo-1H-pyrazol-1-yl)-3-methyl-1H-indole (**4b$_2$**). Following the general procedure, the product was isolated as a white solid in 221.5 mg (69%) by column chromatography (10:1 hexanes/ethyl acetate). Mp 61.7−62.7 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.62 (s, 1H), 7.94 (s, 1H), 7.72 (s, 1H), 7.56 (d, J = 8.0 Hz, 1H), 7.32 (d, J = 8.0 Hz, 1H), 7.22−7.20 (m, 1H), 7.18−7.14 (m, 1H), 2.41 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 145.5, 133.4, 132.8, 130.5, 128.4, 122.9, 120.1, 119.0, 110.9, 99.0, 58.6, 8.7. IR (neat, cm^{-1}): 3277, 3139, 2917, 1714, 1595, 1505, 1452, 1019, 939, 737. HRMS (ESI+, m/z): [M + H]$^+$ calcd for $C_{12}H_{11}IN_3$, 323.9992; found, 323.9999.

2-(3,5-Dimethyl-1H-pyrazol-1-yl)-1-methyl-1H-indole (**4c$_1$**). Following the general procedure, the product was isolated as a yellow solid in 116.3 mg (52%) by column chromatography (9:1 hexanes/ethyl acetate). Mp 45.7−46.3 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63

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(d, J = 8.0 Hz, 1H), 7.34−7.26 (m, 2H), 7.18−7.14 (m, 1H), 6.51 (d, J = 0.8 Hz, 1H), 6.01 (s, 1H), 3.48 (s, 3H), 2.31 (s, 3H), 2.16 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 150.1, 142.7, 135.5, 133.6, 126.1, 122.5, 121.1, 120.1, 109.5, 106.0, 98.4, 29.2, 13.6, 11.4. IR (neat, cm^{-1}): 3053, 2924, 2349, 1563, 1451, 1393, 1345, 1314, 1119, 1030, 783, 730, 656. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{14}H_{16}N_3$, 226.1344; found, 226.1342.

*2-(3,5-Dimethyl-1H-pyrazol-1-yl)-3-methyl-1H-indole (**4c$_2$**).* Following the general procedure, the product was isolated as a white solid in 159.7 mg (71%) by column chromatography (9:1 hexanes/ethyl acetate). Mp 173.9−174.9 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 8.48 (s, 1H), 7.57 (d, J = 7.6 Hz, 1H), 7.30−7.28 (m, 1H), 7.22−7.20 (m, 1H), 7.16−7.12 (m, 1H), 5.97 (s, 1H), 2.26 (s, 3H) 2.18−2.17 (m, 6H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 150.3, 142.4, 133.7, 129.3, 127.7, 123.0, 119.7, 119.3, 111.0, 106.1, 105.9, 13.6, 11.2, 8.5. IR (neat, cm^{-1}): 3057, 2917, 2349, 1629, 1452, 1300, 1131, 1037, 778, 735. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{14}H_{16}N_3$, 226.1344; found, 226.1354.

*2-(1H-Imidazol-1-yl)-1-methyl-1H-indole (**4d$_1$**).*[10] Following the general procedure, the product was isolated as a yellow solid in 179.2 mg (91%) by column chromatography (1:4 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 7.69 (s, 1H), 7.63 (d, J = 8.0 Hz, 1H), 7.35−7.29 (m, 2H), 7.25−7.24 (m, 1H), 7.21−7.17 (m, 1H), 7.14 (s, 1H), 6.53 (s, 1H), 3.52 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 138.7, 135.6, 132.1, 130.0, 125.9, 123.0, 121.3, 121.1, 120.8, 109.7, 97.8, 29.2. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{12}H_{12}N_3$, 198.1026; found, 198.1031.

*2-(1H-Imidazol-1-yl)-3-methyl-1H-indole (**4d$_2$**).*[8] Following the general procedure, the product was isolated as a white solid in 191.3 mg (97%) by column chromatography (1:4 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 11.14 (s, 1H), 7.69 (s, 1H), 7.62 (d, J = 8.0 Hz, 1H), 7.42 (d, J = 8.0 Hz, 1H), 7.30−7.25 (m, 2H), 7.23−7.19 (m, 1H), 7.15 (s, 1H), 2.29 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 137.3, 133.7, 128.5, 127.8, 127.7, 122.8, 120.7, 119.8, 119.0, 111.2, 103.3, 7.9. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{12}H_{12}N_3$, 198.1026; found, 198.1040.

*1-Methyl-2-(1H-1,2,3-triazol-1-yl)-1H-indole (**4e$_1$**).*[10] Following the general procedure, the product was isolated as a yellow solid in 184.3 mg (93%) by column chromatography (2:1 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 7.87 (dd, J = 5.2, 0.8 Hz, 2H), 7.65 (d, J = 8.0 Hz, 1H), 7.39−7.32 (m, 2H), 7.22−7.18 (m, 1H), 6.62 (s, 1H), 3.66 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 135.9, 133.5, 131.4, 126.5, 125.7, 123.4, 121.3, 120.8, 109.9, 97.3, 30.0. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{11}H_{11}N_4$, 199.0978; found, 199.0984.

*3-Methyl-2-(1H-1,2,3-triazol-1-yl)-1H-indole (**4e$_2$**).*[8] Following the general procedure, the product was isolated as a white solid in 170.6 mg (86%) by column chromatography (2:1 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 9.03 (s, 1H), 8.04 (d, J = 1.0 Hz, 1H), 7.88 (d, J = 1.0 Hz, 1H), 7.60 (d, J = 8.0 Hz, 1H), 7.40 (d, J = 8.0 Hz, 1H), 7.30−7.26 (m, 1H), 7.21−7.17 (m, 1H), 2.40 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 134.1, 133.4, 127.9, 127.5, 123.7, 123.5, 120.4, 119.4, 111.3, 101.7, 8.5. IR (neat, cm^{-1}): 3170, 2917, 2349, 1626, 1504, 1417, 1231, 1027, 766, 742. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{11}H_{11}N_4$, 199.0978; found, 199.0992.

*2-(1H-1,2,3-Triazol-1-yl)-1H-indole (**4e$_3$**).*[10] Following the general procedure, the product was isolated as a white solid in 96.9 mg (53%) by column chromatography (2:1 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 9.35 (s, 1H), 8.06 (s, 1H), 7.85 (s, 1H), 7.62 (d, J = 8.0 Hz, 1H), 7.44 (d, J = 8.0 Hz, 1H), 7.29−7.25 (m, 1H), 7.19−7.16 (m, 1H), 6.58−6.57 (m, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 134.5, 133.8, 131.4, 127.0, 123.5, 121.7, 121.2, 121.0, 111.4, 90.5. HRMS (ESI+, m/z): $[M + Na]^+$ calcd for $C_{10}H_8N_4Na$, 207.0641; found, 207.0650.

*1-Methyl-2-(1H-1,2,4-triazol-1-yl)-1H-indole (**4f$_1$**).*[10] Following the general procedure, the product was isolated as a yellow solid in 124.9 mg (63%) by column chromatography (1:2 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 8.38 (s, 1H), 8.19 (s, 1H), 7.65 (d, J = 8.0 Hz, 1H), 7.38−7.31 (m, 2H), 7.22−7.18 (m, 1H), 6.61 (s, 1H), 3.66 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 153.2, 145.5, 136.0 131.2, 125.6, 123.4, 121.4, 120.8, 109.8, 97.5, 29.9. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{11}H_{11}N_4$, 199.0978; found, 199.0986.

*3-Methyl-2-(1H-1,2,4-triazol-1-yl)-1H-indole (**4f$_2$**).* Following the general procedure, the product was isolated as a white solid in 169.9 mg (86%) by column chromatography (1:1 hexanes/ethyl acetate). Mp 125.2−125.5 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 8.96 (s, 1H), 8.52 (s, 1H), 8.14 (s, 1H), 7.59 (d, J = 8.0 Hz, 1H), 7.34 (d, J = 8.0 Hz, 1H), 7.28−7.25 (m, 1H), 7.23−7.16 (m, 1H), 2.39 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 152.1, 142.8, 133.3, 128.0, 127.5, 123.5, 120.4, 119.3, 111.1, 101.6, 8.5. IR (neat, cm^{-1}): 3117, 2916, 1721, 1509, 1334, 1144, 983, 962, 729, 666. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{11}H_{11}N_4$, 199.0978; found, 199.0988.

*2-(1H-1,2,4-Triazol-1-yl)-1H-indole (**4f$_3$**).*[10] Following the general procedure, the product was isolated as a white solid in 119.8 mg (65%) by column chromatography (1:1 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 9.29 (s, 1H), 8.61 (s, 1H) 8.12 (s, 1H), 7.61 (d, J = 8.0 Hz, 1H), 7.38 (dd, J = 8.0, 0.8 Hz, 1H), 7.26−7.22 (m, 1H), 7.19−7.15 (m, 1H), 6.58 (d, J = 1.6 Hz, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 152.2, 141.4, 133.6, 131.3, 127.2, 123.1, 121.1, 120.9, 111.3, 90.0. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{10}H_9N_4$, 185.0822; found, 185.0824.

*1-(1-Methyl-1H-indol-2-yl)-1H-benzo[d]imidazole (**4g**).* Following the general procedure, the product was isolated as a white solid in 193.4 mg (78%) by column chromatography (1:2 hexanes/ethyl acetate). Mp 144.4−145.1 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 7.98 (s, 1H), 7.87−7.85 (m, 1H), 7.64 (d, J = 8.0 Hz, 1H), 7.36−7.26 (m, 4H), 7.22−7.16 (m, 2H), 6.60 (s, 1H), 3.43 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 143.6, 143.2, 135.9, 135.4, 130.3, 126.2, 124.3, 123.2, 123.1, 121.2, 120.7, 120.6, 110.5, 109.8, 99.1, 29.4. IR (neat, cm^{-1}); 3113, 2923, 1581, 1454, 1399, 1220, 751, 733, 659. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{16}H_{14}N_3$, 248.1188; found, 248.1180.

*1-(1-Methyl-1H-indol-2-yl)-1H-benzo[d][1,2,3]triazole (**4h$_1$**).* Following the general procedure, the product was isolated as a pale-yellow solid in 227.7 mg (92%) by column chromatography (4:1 hexanes/ethyl acetate). Mp 158.0−158.7 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 7.99 (d, J = 8.0 Hz, 1H), 7.53 (d, J = 8.0 Hz, 1H), 7.40−7.36 (m, 2H), 7.30−7.26 (m, 2H), 7.21−7.17 (m, 1H), 7.07−7.03 (m, 1H), 6.58 (s, 1H), 3.46 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 145.4, 136.0, 134.7, 130.2, 128.9, 126.1, 124.7, 123.4, 121.4, 120.8, 120.2, 110.2, 109.9, 98.2, 29.9. IR (neat, cm^{-1}): 3053, 2930, 1561, 1451, 1318, 1286, 1035, 788, 744, 651. HRMS (ESI+, m/z): $[M + Na]^+$ calcd for $C_{15}H_{12}N_4Na$, 271.0954; found, 271.0963.

*1-(3-Methyl-1H-indol-2-yl)-1H-benzo[d][1,2,3]triazole (**4h$_2$**).* Following the general procedure, the product was isolated as a yellow gel, 235.9 mg (95%) by column chromatography (4:1 hexanes/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): δ 8.49 (s, 1H), 8.14 (d, J = 8.0 Hz, 1H), 7.68 (d, J = 8.0 Hz, 1H), 7.58−7.54 (m, 1H), 7.51−7.48 (m, 1H), 7.47−7.42 (m, 2H), 7.34 (td, J = 8.0, 1.2 Hz, 1H), 7.26−7.22 (m, 1H), 2.27 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 145.4, 134.3, 133.9, 128.7, 127.9, 125.8, 124.6, 123.9, 120.4, 120.3, 119.7, 111.3, 110.3, 106.8, 8.60. IR (neat, cm^{-1}): 3209, 2919, 1920, 1722, 1452, 1278, 1048, 1004, 782, 739. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{15}H_{13}N_4$, 249.1135; found, 249.1149.

*1-(1H-Indol-2-yl)-1H-benzo[d][1,2,3]triazole (**4h$_3$**).* Following the general procedure, the product was isolated as a white solid in 135.3 mg (58%) by column chromatography (4:1 hexanes/ethyl acetate). Mp 166.1−166.3 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 9.57 (s, 1H), 8.14 (d, J = 8.4 Hz, 1H), 7.89 (d, J = 8.4 Hz, 1H), 7.70−7.68 (m, 1H), 7.64−7.60 (m, 1H), 7.51−7.44 (m, 2H), 7.31−7.26 (m, 1H), 7.22−7.18 (m, 1H), 6.78 (d, J = 1.6 Hz, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 146.2, 133.7, 131.4, 131.2, 129.0, 127.4, 125.0, 123.2, 121.0, 120.9, 120.4, 111.3, 110.8, 91.0. IR (neat, cm^{-1}): 3363, 1561, 1445, 1296, 1061, 766, 748, 738, 648, 548. HRMS (ESI+, m/z): $[M + Na]^+$ calcd for $C_{14}H_{10}N_4Na$, 257.0803; found, 257.0815.

*(1-(1-Methyl-1H-indol-2-yl)-1H-imidazol-5-yl)methanol (**4i**).* Following the general procedure, the product was isolated as a white solid in 113.6 mg (50%) by column chromatography (1:9 methanol/ethyl acetate). Mp 156.0−157.2 °C. ^1H NMR (400 MHz, $CDCl_3$): δ 7.63 (d, J = 8.0 Hz, 1H), 7.47 (s, 1H), 7.34−7.28 (m, 2H), 7.18−7.14 (m,

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1H), 7.06 (s, 1H), 6.58 (s, 1H), 4.44 (s, 2H), 3.42 (s, 3H), 3.02 (br s, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 139.7, 135.7, 133.7, 129.8, 128.5, 125.9, 123.2, 121.2, 120.7, 109.8, 99.8, 53.5, 29.1. IR (neat, cm^{-1}): 3770, 3591, 3140, 2783, 1670, 1562, 1562, 1467, 1098, 1030, 926, 752, 661. HRMS (ESI+, m/z): $[M + H]^+$ calcd for $C_{13}H_{14}N_3O$, 228.1131; found, 228.1130.

■ ASSOCIATED CONTENT

Supporting Information

^1H and ^{13}C spectra and spectral data. 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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(13) See Supporting Information for more details.

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