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Article

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Iridium(III)-Catalyzed Tandem Annulation of Pyridine-Substituted Anilines and α-Cl Ketones for Accessing to 2-arylindoles

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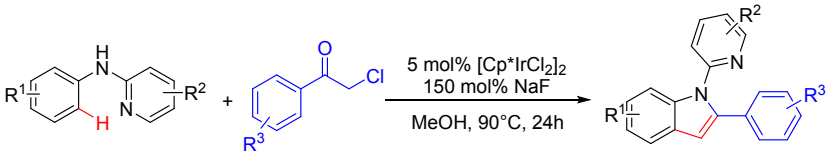


- versatile 2-arylindoles synthesis
- [3+2] annulation assisted by one sp^3 carbon
- high regioselectivity & broad substrate scope

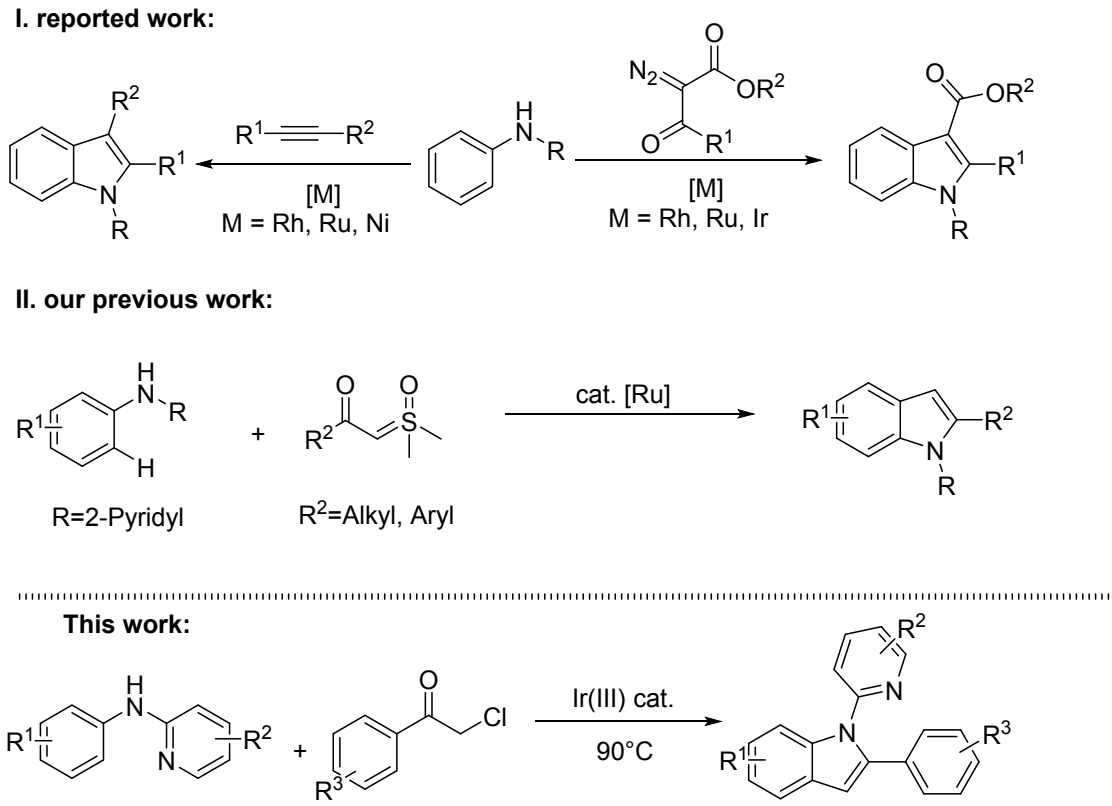
36 examples
Up to **98%** yield

ABSTRACT: A facile and expeditious protocol for the synthesis of 2-arylindoles compounds from readily available *N*-(2-pyridyl)anilines and commercially available α-Cl ketones through iridium-catalyzed C-H activation and cyclization is reported here. As a complementary approach to the conventional strategies for indole synthesis, the transformation exhibits powerful reactivity, tolerates a large number of functional groups and proceeds in good to excellent yields under mild conditions, providing a straightforward method to access structurally diverse and valuable indole scaffolds. Further, the reaction could be easily scaled up to gram scale.

INTRODUCTION

Indole derivatives represent one of long-standing target for synthetic chemists because they are prevalent in a variety of engrossing compounds, such as functional materials, pharmaceuticals and diverse bioactive natural products [1]. Consequently, a variety of synthetic methodologies have been developed for the synthesis of such scaffolds. In particular, the Fischer indole synthesis[2] and Larock's indole synthesis[3] represent valuable synthetic protocols. Other effective synthetic methods including Bischler synthesis[4], Sundberg synthesis[5], Bartoli synthesis[6], Fukuyama synthesis[7], etc. have been versatile tools for the construction of indole framework. Despite these great developments, these typical synthetic methods still face some disadvantages, such as poor selectivity towards reaction substrates, low functional group compatibility, and harsh conditions. Hence, designing simpler and more practical procedures for realizing indoles synthesis from general available substrates is highly desirable. Recently, directly synthesizing indoles based on transition-metal catalytic C-H bond activation has attracted much attention owing to its remarkable potential for receiving high regioselective and atom-economy[8]. This proposal takes advantage of the ubiquitous C-H bond in unactivated arenes as the direct source. For example, transition-metal-catalyzed C-H activation starting from aniline derivatives with alkynes[9] or diazo compounds[10] has been demonstrated (Scheme 1, eq I). In 2019, our group reported the Ru(II)-catalyzed construction of 2-arylindole from tandem C-H activation/annulation of *N*-(2-pyridyl)anilines with sulfoxonium

ylides[11] (Scheme 1, eq II). Subsequently, Wu and Cui group reported the similar work by using different catalysts, respectively[12]. Cui's group reported an efficient strategy for the synthesis of 2-arylindoles via palladium-catalyzed cyclization of anilines with vinyl azides as the coupling partner[13]. Liu's group described a Rh(III)-catalyzed C-H activation/annulation of hydrazines with sulfoxonium ylides as carbene precursors affording 1-aminoindole derivatives[14]. Besides, the construction of indole scaffolds based on transition-metal catalyzed C-H activation-annulation cascade has many reports[15]. Among them, sp-carbons, sp^2-carbons or metal carbenes precursors were critical coupling partners in these annulation reactions. To the best of our knowledge, sp^3-carbon synthons have been rarely reported for the construction of 2-arylindoles derivatives.



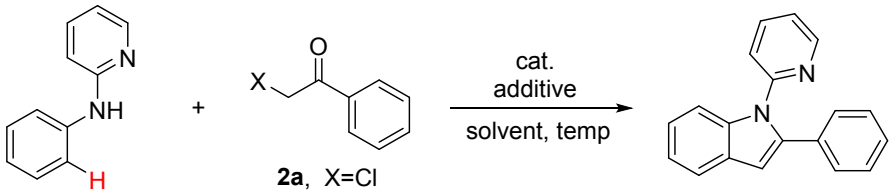
Scheme 1. Transition-Metal-Catalyzed Strategies for the Synthesis of Indoles from Anilines derivatives.

Very recently, α-Cl ketones have clearly emerged as versatile synthetic reagents in synthetic chemistry, among them, transformations involving transition-metal-catalyzed inert C-H activation/annulation with α-Cl ketones are especially appealing. In 2014, Glorius and co-workers developed a Rh(III)-catalyzed redox-neutral annulations to synthesize diverse *N*-heterocycles molecules using α-MsO/TsO/Cl substituted ketones as oxidized alkyne equivalents[16]. After that time, Li's group reported a similar synthetic strategy for isoquinolines via a Rh(III)-catalyzed C-H/N-H functionalization with α-Cl/MsO/TsO ketones[17]. In 2018, Liu's group developed a synthetic strategy to directly access to 3-acylindoles via Rh(III)-catalyzed C-H activation and [4+1] annulation of *N*-phenylamidines with readily accessible α-Cl ketones[18]. Thereafter, Wang and co-workers have developed a ruthenium(II)-catalyzed acylmethylation of (hetero)arenes coupling with α-Cl ketones/sulfoxonium ylides via C-H activation[19]. Despite these α-halo or pseudohaloketones functioned as the key synthons to construct these privileged scaffolds, achieving Ir(III)-catalyzed

C-H activation/annulation between anilines derivatives and α-Cl ketones is still an unexplored subject. Inspired by those pioneering studies and as continous interest on developing novel and efficient methods for synthesizing of heterocycles via CHA reactions(C-H bond activation)[20], herein we report sequential C-H activation of *N*-(2-pyridyl)anilines and coupling with α-Cl ketones, for highly efficient access to 2-arylindoles derivatives (Scheme 1, eq III), in which the α-Cl ketones function as the surrogates of alkynes, diazo compounds or sulfoxonium ylides compoounds.

RESULTS AND DISCUSSION

Table 1. Optimization of Reaction Conditions[a]



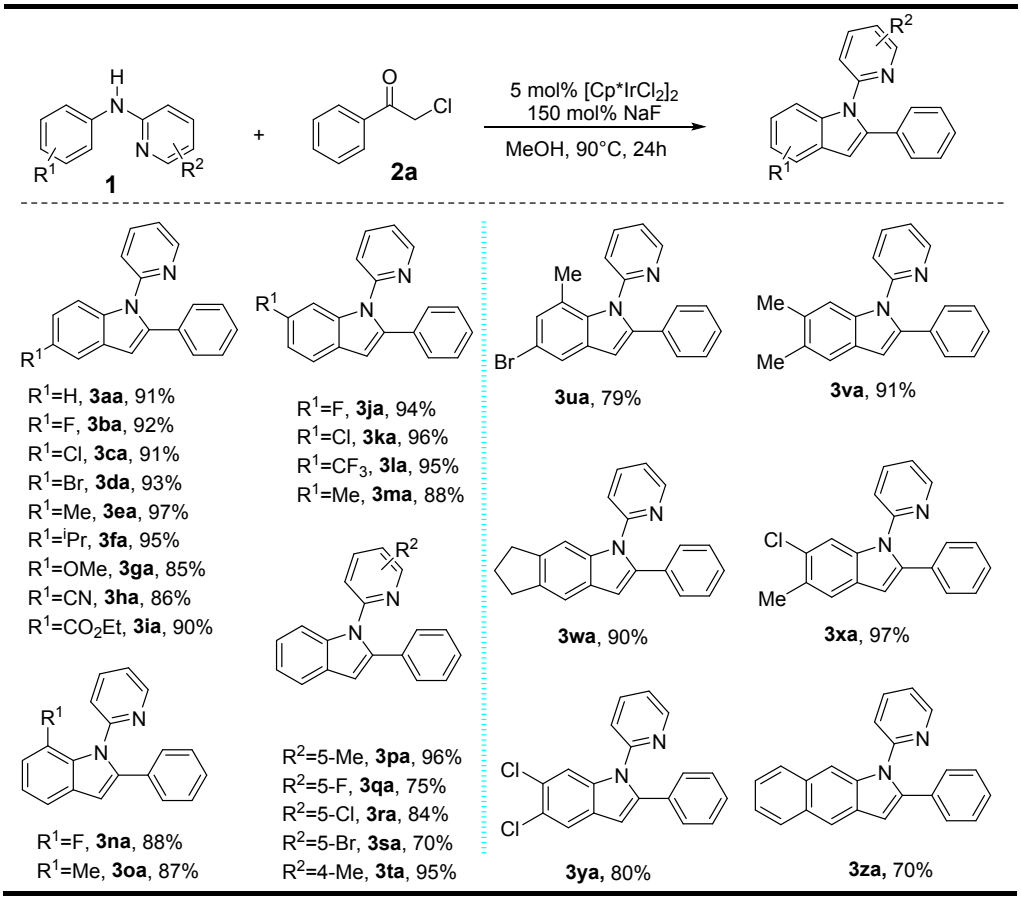
entry	catalyst	additive	solvent	X	Temp (°C)	yield[b]
1	$[IrCp^*Cl_2]_2$	NaOAc	MeOH	X=Cl	90	24
2	$[RhCp^*Cl_2]_2$	NaOAc	MeOH	X=Cl	90	15
3	$[Ru(p\text{-cymene})Cl_2]_2$	NaOAc	MeOH	X=Cl	90	0
4	$Cp^*Co(CO)I_2$	NaOAc	MeOH	X=Cl	90	0
5	$[IrCp^*Cl_2]_2$	$AgSbF_6$/NaOAc	MeOH	X=Cl	90	8
6	$[IrCp^*Cl_2]_2$	$AgBF_4$/NaOAc	MeOH	X=Cl	90	6
7	$[IrCp^*Cl_2]_2$	$AgNTf_2$/NaOAc	MeOH	X=Cl	90	13
8	$[IrCp^*Cl_2]_2$	AgOTf/NaOAc	MeOH	X=Cl	90	trace
9	$[IrCp^*Cl_2]_2$	KOAc	MeOH	X=Cl	90	10
10	$[IrCp^*Cl_2]_2$	$Zn(OAc)_2$	MeOH	X=Cl	90	67
11	$[IrCp^*Cl_2]_2$	$NaHCO_3$	MeOH	X=Cl	90	17
12	$[IrCp^*Cl_2]_2$	KH_2PO_4	MeOH	X=Cl	90	48
13	$[IrCp^*Cl_2]_2$	NaF	MeOH	X=Cl	90	91
14	$[IrCp^*Cl_2]_2$	KF	MeOH	X=Cl	90	69
15	$[IrCp^*Cl_2]_2$	Et_3N	MeOH	X=Cl	90	33
16	$[IrCp^*Cl_2]_2$	NaF	EtOH	X=Cl	90	28
17	$[IrCp^*Cl_2]_2$	NaF	CF_3CH_2OH	X=Cl	90	15
18	$[IrCp^*Cl_2]_2$	NaF	HFIP	X=Cl	90	37
19	$[IrCp^*Cl_2]_2$	NaF	DCE	X=Cl	90	0
20	$[IrCp^*Cl_2]_2$	NaF	$PhCF_3$	X=Cl	90	0
21	$[IrCp^*Cl_2]_2$	NaF	MeOH	X=Cl	100	89
22	$[IrCp^*Cl_2]_2$	NaF	MeOH	X=Cl	80	82
23	$[IrCp^*Cl_2]_2$	NaF	MeOH	X=Br	90	6
24	$[IrCp^*Cl_2]_2$	NaF	MeOH	X=OTs	90	79
25	$[IrCp^*Cl_2]_2$	NaF	MeOH	X=OMs	90	81

[a] Reaction conditions: **1a** (0.2 mmol), **2a** (0.26 mmol), catalyst (5 mol%), Ag salts (20 mol%), additive (1.5 equiv.) and a solvent (2.0 mL) at 90 °C in a pressure tube for 24 h, the vial was capped

prior to heating. [b] Isolated yields after column chromatography.

To establish the optimal conditions for this C-H activation/annulation protocol, the reaction of *N*-(2-pyridyl)anilines (**1a**) and α-Cl acetophenone(**2a**) was performed with different catalysts and solvents. As shown in Table 1, the treatment of **1a** (0.2 mmol) with **2a** (0.26 mmol, 1.3 equiv.) in the presence of $[IrCp^*Cl_2]_2$ (5 mol%) and NaOAc (1.5 equiv) in MeOH at 90 ℃ for 24 h gave the desired product 2-phenyl-1-(pyridin-2-yl)-1H-indole **3aa** in 24% yield (entry 1). The structure of **3aa** was confirmed by ^1H and ^{13}C NMR spectroscopy and high-resolution mass spectrometry. Subsequently, screening of transition-metal catalysts including $[RhCp^*Cl_2]_2$, $[Ru(p\text{-cymene})Cl_2]_2$ and $[Cp^*Co(CO)I_2]$ revealed that $[IrCp^*Cl_2]_2$ was the optimal choice (entries 1-4). The yield of the target product **3aa** decreased by using different silver salt as co-catalyst (entries 5-8). Based on these results, we further replaced NaOAc with other additives, including KOAc, $Zn(OAc)_2$, $NaHCO_3$, KH_2PO_4, NaF, KF and Et_3N (entries 9-15). Surprisingly, a better yield for this transformation was achieved in the presence of NaF. A further screening of the solvent revealed that MeOH was the optimized choice (entries 16-20). Moreover, we further screened the effect of the temperature, lower and raising the temperature led to inferior results (entries 21-22). Further exploration using different α-substituted acetophenones, such as α-Br ,α-OTs and α-OMs acetophenones (**2b-2d**), indicated that the new group was detrimental to the formation of the 2-arylindole scaffold (entries 23-25). Thus, the conditions in **entry 13** were adopted for subsequent studies.

Table 2. Scope of N-(2-pyridyl)anilines [a,b]

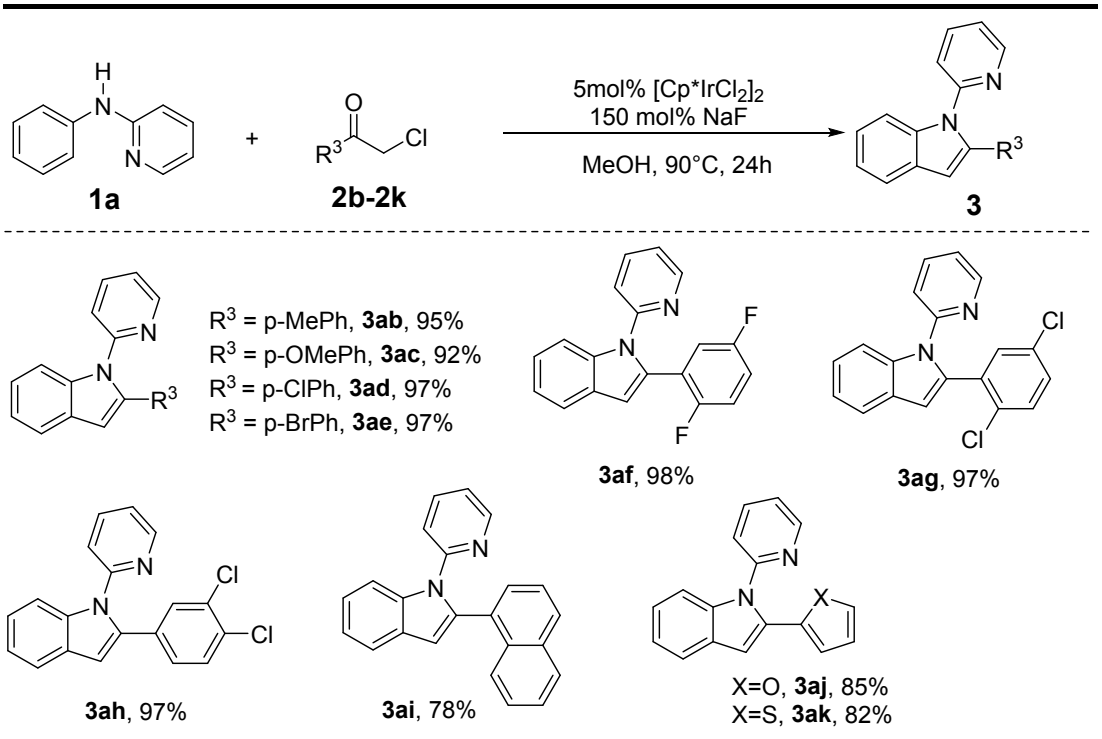


[a] Reaction conditions: **1a-1z** (0.2 mmol), **2a** (0.26 mmol), $[IrCp^*Cl_2]_2$ (5 mol%), NaF(1.5 equiv.) and MeOH (2.0 mL) at 90 ℃ for 24 h. [b] Isolated yields after column chromatography.

We next carried out the reactions of α-Cl ketone **2a** with various *N*-(2-pyridyl)anilines (**1a-1z**)

to explore the generality of the current methodology (Table 2). Notably, the chelation-assisted C-H/N-H bond functionalization proved to be broadly applicable. Anilines substrates bearing electron-donating or electron-withdrawing substituents at the para-, meta- and ortho- positions of the phenyl ring all participated well, providing the corresponding annulated products (**3ba–3oa**) in good to excellent yields. To our delight, this transformation showed excellent regioselectivities. The completely regioselective coupling occurred at the less hindered position for meta-substituted substrates (**3ja-3ma**). The substituent on the pyridines ring of *N*-(substituted phenyl)-2-pyridin-amines showed minor steric effect on reaction activity, affording the products **3pa-3ta** in moderate to outstanding yields (70-96%). It is noteworthy that the halo-substituted (e.g., F, Cl, and Br) substrates performed well to afford the corresponding products in sensational yields, thus offering the opportunity for further transformations. Notably, several *N*-(2-pyridyl)anilines bearing two substitutes (**1u−1y**) in the phenyl ring have also been examined, affording the corresponding indoles (**3ua-3ya**) in moderate to good yields and high regioselectivity. When *N*-(naphthalen-2-yl)pyridine-2-amine (**1z**) was used in the reaction, the 3-position C-H bond with less steric hindrance was selectively functionalized to afford the corresponding product (**3za**) in 70% yield. When pyrimidine was used as a directing functional group, we couldn't get the desired product.

Table 3. Scope of α-Cl Ketones[a,b]



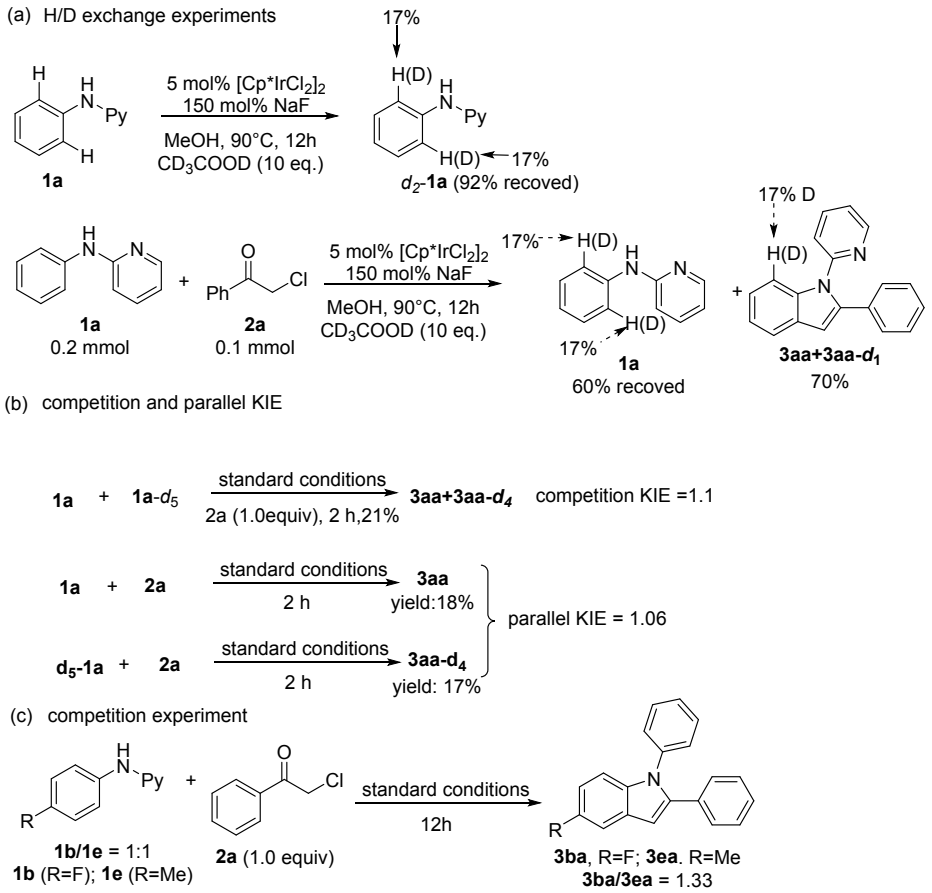
[a] Reaction conditions: **1a** (0.2 mmol), **2b-2k** (0.26 mmol), $[IrCp^*Cl_2]_2$ (5 mol%), NaF(1.5 equiv.) and MeOH (2.0 mL) at 90 ℃ for 24 h. [b] Isolated yields after column chromatography.

To further explore the scope of this transformation, more α-Cl ketones were investigated under the optimized conditions (Table 3). First, diverse monosubstituted α-Cl acetophenones (**2b−2e**) and disubstituted α-Cl acetophenones (**2f−2h**) were selected as the substrates for this reaction, furnishing the desired products **3ab-3ah** in good to excellent yields, in which electronic effects have no significant effect in this transformation. The reaction also showed good tolerance toward other ketones containing a naphthyl (**3ai**) with good yields. we were also pleased to find that

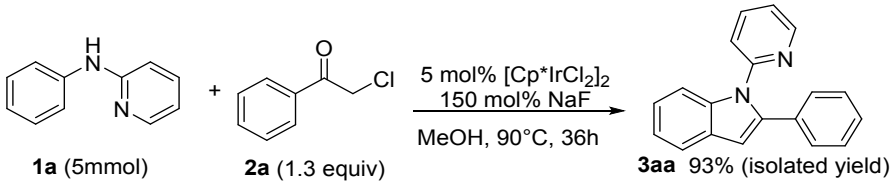
heteroaromatic ketone derivatives **2j-k** could also be employed in the transformation, affording the corresponding products **3aj-3ak** in moderate yields.

To better understand the reaction mechanism, several control experiments were carried out (Scheme 2). Initially, related H/D scrambling experiments with **1a** were implemented in the absence of α-Cl acetophenone **2a** or not, in which a slight H/D exchange took place and the deuterated product was observed (Scheme 2a). These outcomes clearly disclosed the fact that the ortho-metalation step process was reversible in this transformation. Subsequently, the kinetic isotope effect (KIE) experiment was implemented, and a deuterium competition experiment between substrate **1a** and **1a-*d*$_5$** illustrated a KIE of k_H/k_D = 1.1 (Scheme 2b, top). Moreover, the kinetic isotope effect of this reaction was measured on the basis of parallel experiments, and a KIE value of 1.06 was obtained (Scheme 2b, bottom). The results suggested that the cleavage of the C-H bond may not be included in the rate-determining step. An intermolecular competition reaction between *N*-(4-methylphenyl)pyridin-2-amine **1e** and *N*-(4-fluorophenyl)pyridin-2-amine **1b** with **2a** was performed in a one-pot fashion. The NMR yield of **3ba** was higher than that of **3ea**, indicating a higher reactivity for the electron-deficient substrate (Scheme 2c).

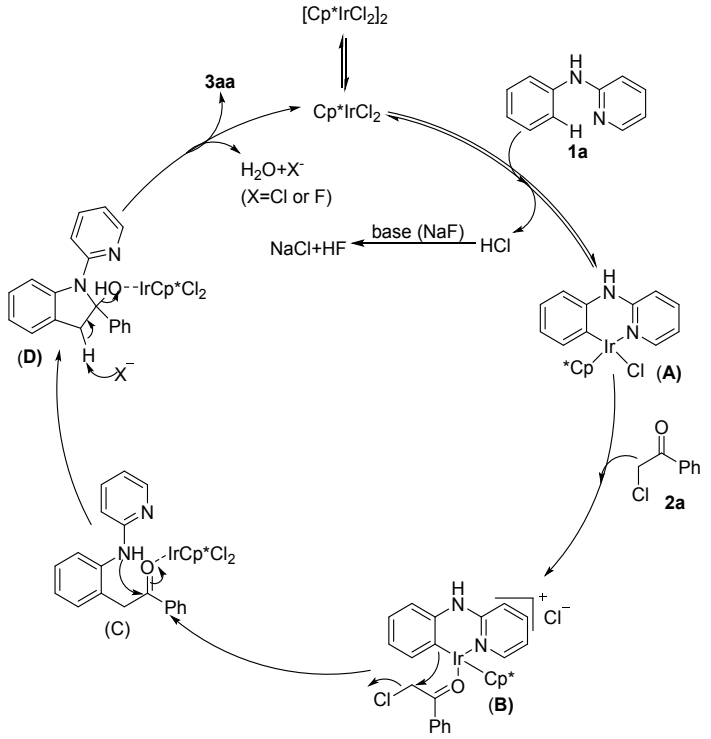
To evaluate the synthetic utility of this transformation, a gram-scale preparation of product **3aa** was carried out with a remarkable yield of 93% (Scheme 3).



Scheme 2. mechanism studies.



Scheme 3. Large-scale synthesis



Scheme 4. Proposed Reaction Mechanism.

According to these mechanistic investigations and the results of previous studies[15-17], a plausible reaction mechanism for the formation of 2-arylindoles was hypothesized (Scheme 4). Initially, the dimeric precursor $[Cp^*IrCl_2]_2$ was converted into $[Cp^*IrCl_2]$ as an active catalyst. Then, cyclometalation of the *N*-(2-pyridyl)anilines (**1a**) affords a six-membered iridacycle **A** via CMD (concerted metalation-deprotonation) process. Coordination of oxygen atom of α-Cl acetophenone (**2a**) gives a Ir(III) alkyl intermediate **B**, in which the nucleophilic C(aryl)-Ir species further attacks the methylene group of α-Cl acetophenone to produce α-aryl ketone species **C**. Intramolecular nucleophilic attack at the acyl group under the assistance of Cp*Ir(III) affords **D**, and subsequent dehydration eventually furnishes the final product **3aa**.

CONCLUSION

In summary, we have developed an unprecedented synthetic strategy to directly access practical 2-arylindoles via Ir(III)-catalyzed C-H activation and [3+2] annulation of *N*-(2-pyridyl)anilines with readily accessible α-Cl ketones. Also, the generality and practicability of this cyclization reaction was reflected by a broad scope of substrates with diverse functional groups, large-scale synthesis and good to excellent yields. Meanwhile, the discovery of α-Cl ketones as a coupling partner may promote the development of indole skeleton construction. We believe that this strategy will find its wide application in organic synthesis.

EXPERIMENTAL SECTION

General information.

Unless otherwise mentioned, all materials were commercially available and used without further purification. *N*-(2-pyridyl)anilines **1a-1z**[21] are known compounds and synthesized according to previous reported methods. The α-Cl ketones **2a-2k** were commercially available. The solvent used

in the experiment is commercially available without further purification or drying. The reaction set up under air and performed in a pressure tube (capacity: 15.0 mL) with oil bath. Flash Chromatography was performed with silica gel (200-300 mesh). Proton-1 nuclear magnetic resonance (^{1}H NMR) data were acquired at 400 MHz on a Bruker Ascend 400(400 MHz) spectrometer, and chemical shifts are reported in delta (δ) units, in parts per million (ppm) downfield from tetramethylsilane. Resonance patterns are reported with the notations s (singlet), d (doublet), t (triplet), q (quartet), and m (multiplet). In addition, the notation br is used to indicate a broad signal. Coupling constants (J) are reported in hertz (Hz). Carbon-13 nuclear magnetic resonance (^{13}C NMR) data were acquired at 100 MHz on a Bruker Ascend 400 spectrometer, chemical shifts are reported in ppm relative to the center line of a triplet at 77.0 ppm for $CDCl_3$. HRMS data obtained using a Q-TOF instrument equipped with an ESI source.

General procedure for the synthesis of starting materials N-(2-pyridyl)anilines [21]

To an oven-dried flask charged with aniline (977.8 mg, 10.5 mmol, 150 mol %), 2-chloropyrimidine (801.7 mg, 7.0 mmol, 100 mol %) and acetic acid (7 mL) in 1,4-dioxane (19 mL) was added. The reaction mixture was stirred at 110 ℃ for 24 h and monitored by TLC. Upon completion, the mixture was extracted with CH_2Cl_2 (3 × 20 mL) and washed with brine. The organic layer was dried over Mg_2SO_4 and concentrated in vacuo. The residue was purified by flash column chromatography (n-hexanes/EtOAc; silica gel) to give *N*-phenylpyrimidin-2-amine **1a** (990.6 mg) in 82% yield.

General procedure for the synthesis of pyridinyl arylamines 1a-1z[21]

To an oven-dried flask charged with aniline (1.4 g, 15 mmol, 100 mol %), 2-bromopyridine (2.4 g, 15 mmol, 100 mol %) was added. The reaction mixture was stirred at 160℃ for 7 h and monitored by TLC. Upon completion, saturated $NaHCO_3$ was added and the mixture was extracted with EtOAc (3 × 15 mL). The combined organic phase was washed with brine and dried over Mg_2SO_4. The solid was filtered off and the filtrate was evaporated in vacuum. The crude product was purified by flash column chromatography (n-hexanes/EtOAc; silica gel) to give *N*-phenylpyridin-2-amine **1a** (2.44 g) in 95% yield.

General procedure for the synthesis of d_5-1a[22]

To an oven-dried flask charged with 2-bromopyridine (79 mg, 0.5 mmol), aniline-d_5 (60 mg, 0.6 mmol) and potassium tert-butoxide (112 mg, 1 mmol), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol) and (±)-BINAP (15.55 mg, 0.025 mmol) were added and the reaction vessel was flushed with N_2 . Dry toluene (2 mL) was added to the mixture through the septum. The reaction mixture was stirred at 120℃ for 6 h and monitored by TLC. Upon completion, water was added and the mixture was extracted with EtOAc (3 × 10 mL). The combined organic phase was washed with brine and dried over Na_2SO_4. The organic layer was evaporated in vacuum and the crude product was purified by flash column chromatography (Petroleum ether /EtOAc = 6:1; silica gel) to give ***d*$_5$-1a**.

General procedure for the synthesis of products 3.

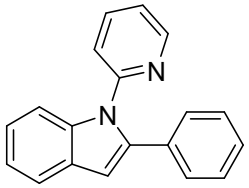
A pressure tube was charged with $[IrCp^*Cl_2]_2$ (8mg, 5mol%), NaF(13mg, 1.5equiv), N-(2-pyridyl) anilines (**1**, 0.2 mmol), and α-Cl acetophenone (**2**, 0.26 mmol), MeOH (2 mL) was then added and the mixture was stirred at 90℃ for 24h. Then the solvent was evaporated and the crude product was purified by column chromatography (silica gel) using PE/EA as the eluent to afford the desired compound **3**.

Representative procedure for synthesis of α-tosyloxyacetophenones/α-OMs acetophenone [23]

To a solution of iodosobenzene (660 mg, 3.0 mmol) and *p*-toluenesulfonic acid monohydrate (567 mg, 3.0 mmol) or methanesulfonic acid (289mg, 3.0 mmol) in acetonitrile (15 ml), was added the

acetophenone (2.0 mmol) and the reaction mixture was refluxed for 5 h. After the solution had cooled to ambient temperature, the solvent was removed under vacuum, the unpurified product was dissolved in CH_2Cl_2 (50 ml) and washed with $NaHCO_3$(50 ml), water (50 ml), and then brine (50 ml). The product was purified by recrystallization from a toluene-hexane mixture.

Characterization data for the all products.

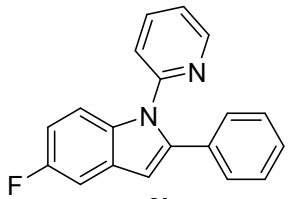


3aa

2-phenyl-1-(pyridin-2-yl)-1H-indole(3aa)

White solid (49.1 mg, 91%), M.p. 132-134 ℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.64 – 8.58 (m, 1H), 7.66 (dd, *J* = 11.5, 4.6 Hz, 2H), 7.57 (td, *J* = 7.7, 1.7 Hz, 1H), 7.29 –7.16 (m, 8H), 6.87 (d, *J* = 8.0 Hz, 1H), 6.80 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 152.0 (s), 149.1 (s), 139.9 (s), 138.4 (s), 137.6 (s), 132.6 (s), 128.6 (s), 128.2 (s), 127.3 (s), 122.9 (s), 121.9 (s), 121.5 (s), 121.3 (s), 120.5 (s), 111.4(s), 105.5 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{15}N_2$ 271.1230; Found: 271.1231.

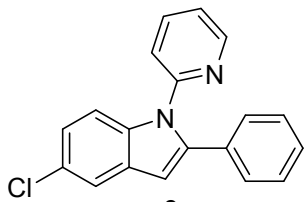


3ba

5-fluoro-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ba)

Coloress liquid (53.0 mg, 92%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ =8.63 (dd, *J* = 4.9, 1.2 Hz, 1H), 7.66 – 7.56 (m, 2H), 7.33 – 7.19 (m, 7H), 6.95 (td, *J* = 9.1, 2.5 Hz, 1H), 6.83 (d, *J* = 8.1 Hz, 1H), 6.75 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ =159.9 (s), 157.5 (s), 151.8 (s), 149.1 (s), 141.4 (s), 137.8 (s), 134.9 (s), 132.3 (s), 129.1 (d, J_{CF} = 10.3 Hz), 128.7 (s), 128.3 (s), 127.7 (s), 121.8 (d, J_{CF} = 16.9 Hz), 112.4 (d, J_{CF} = 9.4 Hz), 111.0 (d, J_{CF} = 25.8 Hz), 105.4 (d, J_{CF} = 11.2 Hz), 105.3 (d, J_{CF} = 8.0 Hz).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}FN_2$ 289.1136; Found: 289.1137.

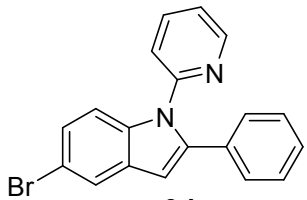


3ca

5-chloro-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ca)

Yellowish liquid (55.3 mg, 91%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.62 (dd, *J* = 4.8, 1.2 Hz, 1H), 7.63 – 7.56 (m, 3H), 7.29 – 7.20 (m, 6H), 7.16 (dd, *J* = 8.7, 2.1 Hz, 1H), 6.83 (d, *J* = 8.0 Hz, 1H), 6.72 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.6 (s), 149.2 (s), 141.2 (s), 137.8 (s), 136.8 (s), 132.1 (s), 129.7 (s), 128.7 (s), 128.3 (s), 127.7(s), 126.7 (s), 123.1 (s), 121.9 (s), 121.8 (s), 119.8 (s), 112.7 (s), 104.8 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}ClN_2$ 305.0840; Found: 305.0842.

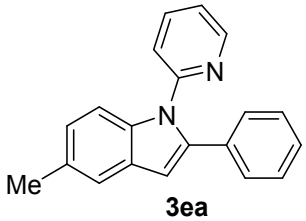


3da

5-bromo-2-phenyl-1-(pyridin-2-yl)-1H-indole(3da)

Yellowish liquid (64.7 mg, 93%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ =8.62 (dd, *J* = 4.6, 1.4 Hz, 1H), 7.77 (d, *J* = 1.8 Hz, 1H), 7.58 (ddd, *J* = 14.8, 10.3, 5.3 Hz, 2H), 7.30 – 7.22 (m, 7H), 6.83 (d, *J* = 8.0 Hz, 1H), 6.71 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ =151.6 (s), 149.2 (s), 141.0 (s), 137.8 (s), 137.1 (s), 132.0 (s), 130.3 (s), 128.7 (s), 128.3 (s), 127.7 (s), 125.6 (s), 122.9 (s), 121.9 (s), 121.9 (s), 114.4 (s), 113.1 (s), 104.7 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}BrN_2$ 349.0335; Found: 349.0336.

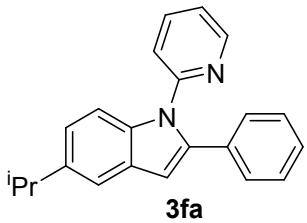


3ea

5-methyl-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ea)

Colorless liquid (55.0 mg, 97%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.64 – 8.59 (m, 1H), 7.58 (ddd, *J* = 7.9, 4.5, 2.0 Hz, 2H), 7.44 (s, 1H), 7.30 – 7.22 (m, 5H), 7.18 (ddd, *J* = 7.4, 4.9, 0.9 Hz, 1H), 7.04 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.86 (d, *J* = 8.0 Hz, 1H), 6.72 (s, 1H), 2.45 (s, 3H).

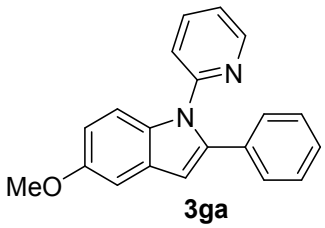
^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ =152.2 (s), 149.1 (s), 139.9 (s), 137.6 (s), 136.9 (s), 132.8 (s), 130.6 (s), 128.9 (s), 128.6 (s), 128.2 (s), 127.2 (s), 124.5 (s), 121.8 (s), 121.3 (s), 120.2 (s), 111.2 (s), 105.3 (s). **HRMS** (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2$ 285.1386; Found: 285.1387.



3fa

5-isopropyl-2-phenyl-1-(pyridin-2-yl)-1H-indole(3fa)

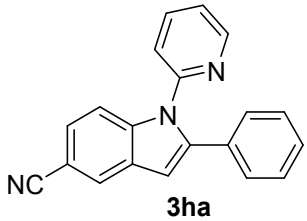
Yellowish liquid (59.2 mg, 95%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.60 (dd, *J* = 4.7, 1.4 Hz, 1H), 7.57 (ddd, *J* = 10.9, 9.7, 5.2 Hz, 2H), 7.49 (s, 1H), 7.27 – 7.20 (m, 5H), 7.16 (ddd, *J* = 7.4, 4.9, 0.7 Hz, 1H), 7.10 (d, *J* = 8.6 Hz, 1H), 6.84 (d, *J* = 8.0 Hz, 1H), 6.74 (s, 1H), 3.01 (dt, *J* = 13.8, 6.9 Hz, 1H), 1.30 (d, *J* = 6.9 Hz, 6H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 152.2 (s), 149.1 (s), 142.1 (s), 140.0 (s), 137.6 (s), 137.1 (s), 132.8 (s), 128.7 (s), 128.6 (s), 128.2 (s), 127.2 (s), 122.2 (s), 121.7 (s), 121.3 (s), 117.4 (s), 111.3 (s), 105.5 (s), 34.1 (s), 24.5 (s).
HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{22}H_{21}N_2$ 313.1699; Found: 313.1697.



3ga

5-methoxy-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ga)

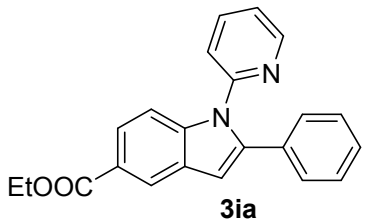
White solid (51.0 mg, 85%), M.p. 91-92℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ =8.61 (d, *J* = 4.5 Hz, 1H), 7.65 – 7.54 (m, 2H), 7.25 (d, *J* = 7.2 Hz, 5H), 7.21 – 7.16 (m, 1H), 7.12 (d, *J* = 1.6 Hz, 1H), 6.91 – 6.80 (m, 2H), 6.73 (s, 1H), 3.87 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 155.2 (s), 152.1 (s), 149.0 (s), 140.3 (s), 137.6 (s), 133.7 (s), 132.7 (s), 129.2 (s), 128.6 (s), 128.2 (s), 127.3 (s), 121.7 (s), 121.3 (s), 112.8 (s), 112.4 (s), 105.5 (s), 102.2 (s), 55.7 (s).
HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2O$ 301.1336; Found: 301.1337.



3ha

2-phenyl-1-(pyridin-2-yl)-1H-indole-5-carbonitrile（3ha）

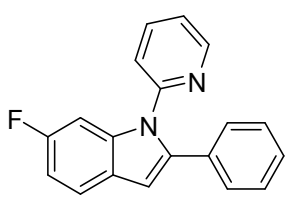
White solid (44.5 mg, 86%), M.p. 185-187 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ= 8.69 – 8.64 (m, 1H), 8.00 (d, *J* = 0.8 Hz, 1H), 7.72 – 7.61 (m, 2H), 7.48 – 7.42 (m, 1H), 7.33 – 7.28 (m, 4H), 7.28 – 7.23 (m, 2H), 6.88 (d, *J* = 7.9 Hz, 1H), 6.83 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.0 (s), 149.4 (s), 142.3 (s), 139.8 (s), 138.1 (s), 131.5 (s), 128.8 (s), 128.5 (s), 128.4 (s), 128.2 (s), 125.8 (s), 125.7 (s), 122.5 (s), 122.1 (s), 120.4 (s), 112.5 (s), 105.2 (s), 104.4 (s). **HRMS** (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{14}N_3$ 260.1182; Found: 260.1185.



3ia

ethyl 2-phenyl-1-(pyridin-2-yl)-1H-indole-5-carboxylate（3ia）

Colorless liquid (61.3 mg, 90%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.67 – 8.62 (m, 1H), 8.43 (d, *J* = 1.5 Hz, 1H), 7.93 (dd, *J* = 8.7, 1.7 Hz, 1H), 7.63 (dd, *J* = 12.3, 5.1 Hz, 2H), 7.29 – 7.23 (m, 6H), 6.90 (d, *J* = 7.9 Hz, 1H), 6.86 (s, 1H), 4.41 (q, *J* = 7.1 Hz, 2H), 1.43 (t, *J* = 7.1 Hz, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 167.4 (s), 151.5 (s), 149.3 (s), 141.3 (s), 140.8 (s), 137.9 (s), 132.1 (s), 128.7 (s), 128.3 (s), 128.2 (s), 127.7 (s), 124.2 (s), 123.6 (s), 123.2 (s), 122.1 (s), 122.0 (s), 111.1 (s), 106.1 (s), 60.6 (s), 14.4 (s).
HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{22}H_{19}N_2O_2$ 342.1368; Found: 342.1370.



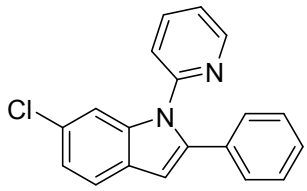
3ja

6-fluoro-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ja)

Colorless liquid (54.1 mg, 94%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ =8.63 (ddd, *J* = 4.9, 1.9, 0.7 Hz, 1H), 7.61 (td, *J* = 7.8, 2.0 Hz, 1H), 7.43 (d, *J* = 8.3 Hz, 1H), 7.29 – 7.21 (m, 6H), 7.12 (td, *J* = 8.1, 5.3 Hz, 1H), 6.90 – 6.83 (m, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 157.3 (s), 154.8 (s), 151.7 (s),

149.2 (s), 140.7 (d, J_{CF} = 10.6 Hz), 139.9 (s), 137.8 (s), 132.1 (s), 128.7 (s), 128.3 (s), 127.7 (s), 123.3 (d, J_{CF} = 7.6 Hz), 122.0 (d, J_{CF} = 2.6 Hz), 117.7 (d, J_{CF} = 22.6 Hz), 107.6 (d, J_{CF} = 3.6 Hz), 106.1 (d, J_{CF} = 18.7 Hz), 100.9 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}FN_2$ 289.1136; Found: 289.1139.

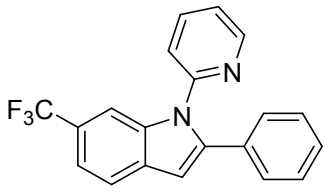


3ka

6-chloro-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ka)

Yellowish liquid (58.3 mg, 96%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.64 (ddd, *J* = 5.0, 1.8, 0.7 Hz, 1H), 7.70 (s, 1H), 7.60 (td, *J* = 7.7, 1.9 Hz, 1H), 7.55 (d, *J* = 8.4 Hz, 1H), 7.27 – 7.21 (m, 6H), 7.18 – 7.14 (m, 1H), 6.85 – 6.82 (m, 1H), 6.75 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.6 (s), 149.2 (s), 140.6 (s), 138.7 (s), 137.8 (s), 132.2 (s), 128.8 (s), 128.6 (s), 128.3 (s), 127.6 (s), 127.2 (s), 121.9 (s), 121.9 (s), 121.8 (s), 121.3 (s), 111.7 (s), 105.3 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}ClN_2$ 305.0840; Found: 305.0843.

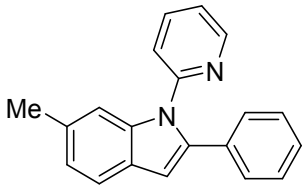


3la

2-phenyl-1-(pyridin-2-yl)-6-(trifluoromethyl)-1H-indole(3la)

Yellowish liquid (64.2 mg, 95%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.63 (ddd, *J* = 4.9, 1.8, 0.7 Hz, 1H), 7.92 (d, *J* = 0.6 Hz, 1H), 7.69 (d, *J* = 8.3 Hz, 1H), 7.59 (td, *J* = 7.8, 1.9 Hz, 1H), 7.40 (dd, *J* = 8.3, 1.1 Hz, 1H), 7.27 – 7.19 (m, 6H), 6.82 (d, *J* = 8.0 Hz, 1H), 6.79 (d, *J* = 0.4 Hz, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.3 (s), 149.4 (s), 142.5 (s), 138.0 (s), 137.3 (s), 131.9 (s), 131.0 (s), 128.8 (s), 128.4 (s), 128.0 (s), 126.4 (s), 124.7 (q, *J* = 31.8 Hz), 123.7 (s), 122.1 (d, *J* = 19.7 Hz), 120.8 (s), 117.9 (q, *J* = 3.5 Hz), 109.2 (q, *J* = 4.5 Hz), 105.2 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{14}F_3N_2$ 339.1104; Found: 339.1106.



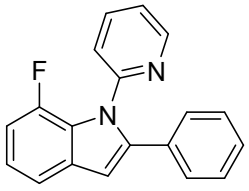
3ma

6-methyl-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ma)

White solid (50.0 mg, 88%), M.p. 147-149 ℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.64 (ddd, *J* = 4.9, 1.9, 0.7 Hz, 1H), 7.61-7.52 (m, 2H), 7.48 (d, *J* = 0.6 Hz, 1H), 7.26-7.18 (m, 6H), 7.03 (dd, *J* = 8.0, 0.9 Hz, 1H), 6.87-6.83 (m, 1H), 6.75 (d, *J* = 0.6 Hz, 1H), 2.44 (s, 3H).

^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ =152.2 (s), 149.1 (s), 139.3 (s), 138.9 (s), 137.6 (s), 132.9 (s), 132.8 (s), 128.5 (s), 128.2 (s), 127.1 (s), 126.5 (s), 123.0 (s), 122.0 (s), 121.4 (s), 120.1 (s), 111.3 (s), 105.5 (s), 21.9 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2$ 285.1386; Found: 285.1388.

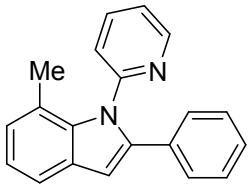


3na

7-fluoro-2-phenyl-1-(pyridin-2-yl)-1H-indole(3na)

Colorless liquid (50.6 mg, 88%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.52 (dd, *J* = 4.6, 1.9 Hz, 1H), 7.66 (td, *J* = 7.7, 2.0 Hz, 1H), 7.42 (d, *J* = 7.8 Hz, 1H), 7.27-7.19 (m, 7H), 7.06 (ddd, *J* = 9.8, 6.9, 4.4 Hz, 1H), 6.91-6.84 (m, 1H), 6.78 (d, *J* = 2.3 Hz, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.6 (d, *J* = 118.8 Hz), 148.7 (s), 148.5 (s), 141.9 (s), 137.5 (s), 132.1 (d, *J* = 4.5 Hz), 132.0 (s), 128.8 (s), 128.1 (s), 127.6 (s), 126.1 (d, *J* = 9.0 Hz), 123.2 (d, *J* = 2.9 Hz), 122.8 (s), 120.9 (d, *J* = 6.6 Hz), 116.3 (d, *J* = 3.4 Hz), 108.5 (d, *J* = 18.2 Hz), 104.8 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}FN_2$ 289.1136; Found: 289.1141.

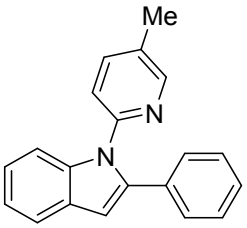


3oa

7-methyl-2-phenyl-1-(pyridin-2-yl)-1H-indole（3oa）

Colorless liquid (49.4 mg, 87%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.67 – 8.61 (m, 1H), 7.60 (td, *J* = 7.7, 2.0 Hz, 1H), 7.54 (d, *J* = 7.8 Hz, 1H), 7.30 (ddd, *J* = 7.5, 4.9, 0.9 Hz, 1H), 7.25 (dd, *J* = 6.5, 3.2 Hz, 2H), 7.22-7.18 (m, 3H), 7.10-

7.04 (m, 2H), 6.94 (d, J = 7.2 Hz, 1H), 6.74 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 153.6 (s), 148.6 (s), 141.6 (s), 137.5 (s), 137.3 (s), 132.7 (s), 129.2 (s), 129.0 (s), 128.0 (s), 127.3 (s), 125.3 (s), 125.1 (s), 123.3 (s), 121.8 (s), 120.8 (s), 118.6 (s), 104.2 (s), 19.4 (s). **HRMS** (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2$ 285.1386; Found: 285.1389.

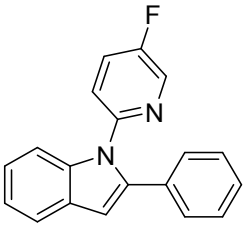


3pa

1-(5-methylpyridin-2-yl)-2-phenyl-1H-indole(3pa)

Yellowish liquid (54.5 mg, 96%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.44 (dd, J = 1.7, 0.7 Hz, 1H), 7.67 – 7.58 (m, 2H), 7.41 (ddd, J = 8.1, 2.4, 0.5 Hz, 1H), 7.29 – 7.22 (m, 5H), 7.21 – 7.15 (m, 2H), 6.79 (dd, J = 4.3, 3.7 Hz, 2H), 2.35 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ =149.7 (s), 149.3 (s), 140.0 (s), 138.6 (s), 138.3 (s), 132.7 (s), 131.3 (s), 128.7 (s), 128.6 (s), 128.2 (s), 127.3 (s), 122.8 (s), 121.4 (s), 121.1 (s), 120.4 (s), 111.4 (s), 105.0 (s), 17.9 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2$ 285.1386; Found: 285.1385.

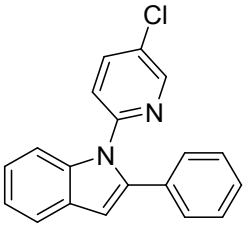


3qa

1-(5-fluoropyridin-2-yl)-2-phenyl-1H-indole(3qa)

Yellowish liquid (43.2 mg, 75%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.48 (d, J = 3.0 Hz, 1H), 7.69 – 7.64 (m, 1H), 7.59 (d, J = 7.8 Hz, 1H), 7.34 (ddd, J = 8.7, 7.6, 3.0 Hz, 1H), 7.28 – 7.24 (m, 5H), 7.24 – 7.19 (m, 2H), 6.88 (dd, J = 8.8, 3.9 Hz, 1H), 6.80 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 157.7 (d, J = 255.8 Hz), 148.1 (s), 140.0 (s), 138.5 (s), 137.0 (d, J = 25.3 Hz), 132.4 (s), 128.7 (s), 128.6 (s), 128.4 (s), 127.5 (s), 124.8 (d, J = 20.0 Hz), 123.1 (s), 122.9 (d, J = 4.8 Hz), 121.4 (s), 120.6 (s), 111.2 (s), 105.5 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}FN_2$ 289.1136; Found: 289.1138.

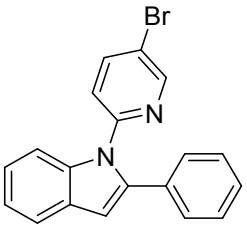


3ra

1-(5-chloropyridin-2-yl)-2-phenyl-1H-indole(3ra)

Colorless liquid (51.0 mg, 84%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.57 (d, J = 2.6 Hz, 1H), 7.70 – 7.63 (m, 2H), 7.57 – 7.52 (m, 1H), 7.31 – 7.25 (m, 5H), 7.24 – 7.20 (m, 2H), 6.78 (d, J = 9.1 Hz, 2H).
^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ= 150.3 (s), 147.8 (s), 139.8 (s), 138.3 (s), 137.4 (s), 132.4 (s), 129.4 (s), 128.7 (s), 128.7 (s), 128.4 (s), 127.6 (s), 123.2 (s), 122.4 (s), 121.6 (s), 120.6 (s), 111.5 (s), 106.1 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}ClN_2$ 305.0840; Found: 305.0843.

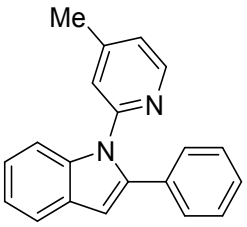


3sa

1-(5-bromopyridin-2-yl)-2-phenyl-1H-indole(3sa)

Yellowish liquid (48.7 mg, 70%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.68 (d, J = 2.5 Hz, 1H), 7.67 (ddd, J = 12.8, 7.4, 2.7 Hz, 3H), 7.32 – 7.25 (m, 5H), 7.24 – 7.19 (m, 2H), 6.80 (s, 1H), 6.73 (d, J = 8.6 Hz, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 150.7 (s), 150.1 (s), 140.2 (s), 139.7 (s), 138.2 (s), 132.4 (s), 128.8 (s), 128.7 (s), 128.4 (s), 127.6 (s), 123.2 (s), 122.9 (s), 121.6 (s), 120.6 (s), 117.7 (s), 111.5 (s), 106.3 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}BrN_2$ 349.0335; Found: 349.0334.

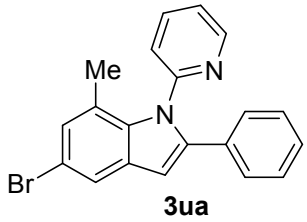


3ta

1-(4-methylpyridin-2-yl)-2-phenyl-1H-indole(3ta)

Yellowish liquid (54.0 mg, 95%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ =8.45 (d, J = 5.1 Hz, 1H), 7.68 – 7.60 (m, 2H), 7.26 (dtd, J = 9.5, 7.1, 5.0 Hz, 5H), 7.22 – 7.17 (m, 2H), 7.03 (d, J = 4.5 Hz, 1H), 6.77 (d, J = 17.9 Hz, 2H), 2.22 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ =152.0 (s), 149.2 (s), 148.7 (s), 140.0 (s), 138.5 (s), 132.7 (s), 128.6 (s), 128.2 (s), 127.3 (s), 126.1 (s), 122.8 (s), 122.8 (s), 122.6 (s), 121.1 (s), 120.5 (s), 111.4 (s), 105.2 (s), 20.8 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2$ 285.1386; Found: 285.1389.

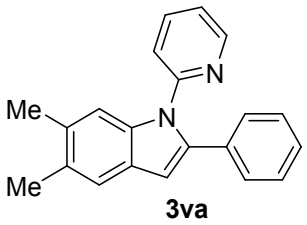


3ua

5-bromo-7-methyl-2-phenyl-1-(pyridin-2-yl)-1H-indole（3ua）

Yellowish liquid (57.1 mg, 79%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.63 (dd, *J* = 4.7, 1.0 Hz, 1H), 7.67 – 7.58 (m, 2H), 7.31 (dd, *J* = 6.9, 5.4 Hz, 1H), 7.25 – 7.18 (m, 5H), 7.04 (d, *J* = 7.7 Hz, 2H), 6.66 (s, 1H), 1.85 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 152.9 (s), 148.7 (s), 142.7 (s), 137.5 (s), 136.2 (s), 132.1 (s), 130.5 (s), 129.1 (s), 128.0 (s), 127.6 (s), 127.6 (s), 124.9 (s), 123.7 (s), 123.6 (s), 120.9 (s), 113.7 (s), 103.4 (s), 19.1 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{16}BrN_2$ 363.0492; Found: 363.0496.

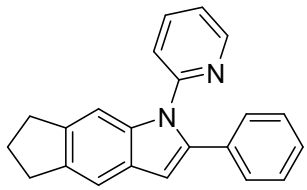


3va

5,6-dimethyl-2-phenyl-1-(pyridin-2-yl)-1H-indole（3va）

White solid (54.2 mg, 91%), m.p.160-163℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.65 – 8.59 (m, 1H), 7.60 – 7.54 (m, 1H), 7.47 (s, 1H), 7.41 (s, 1H), 7.26 – 7.23 (m, 4H), 7.22 (dd, *J* = 5.2, 3.4 Hz, 1H), 7.17 (ddd, *J* = 7.4, 4.9, 1.0 Hz, 1H), 6.84 (d, *J* = 7.9 Hz, 1H), 6.69 (s, 1H), 2.35 (s, 3H), 2.34 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 152.4 (s), 149.0 (s), 139.1 (s), 137.6 (s), 132.9 (s), 132.1 (s), 129.9 (s), 128.5 (s), 128.2 (s), 127.0 (s), 127.0 (s), 121.8 (s), 121.2 (s), 120.6 (s), 111.8 (s), 105.3 (s), 20.6 (s), 20.0 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{21}H_{19}N_2$ 299.1543; Found: 299.1544.

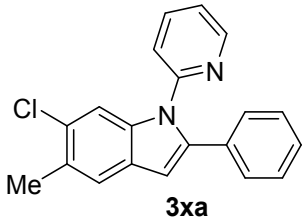


3wa

2-phenyl-1-(pyridin-2-yl)-1,5,6,7-tetrahydrocyclopenta[f]indole（3wa）

Colorless liquid (55.8 mg, 90%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.65 – 8.61 (m, 1H), 7.58 (td, *J* = 7.8, 2.0 Hz, 1H), 7.53 (s, 1H), 7.46 (s, 1H), 7.25 (dt, *J* = 5.6, 3.1 Hz, 4H), 7.23 – 7.16 (m, 2H), 6.85 (d, *J* = 7.9 Hz, 1H), 6.72 (s, 1H), 2.97 (q, *J* = 7.4 Hz, 4H), 2.10 (dq, *J* = 14.6, 7.3 Hz, 2H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 152.4 (s), 149.0 (s), 140.2 (s), 139.2 (s), 138.2 (s), 137.8 (s), 137.6 (s), 133.0 (s), 128.5 (s), 128.2 (s), 127.8 (s), 127.0 (s), 121.9 (s), 121.3 (s), 115.3 (s), 106.9 (s), 105.5 (s), 33.0 (s), 32.4 (s), 26.5 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{22}H_{19}N_2$ 311.1543; Found: 311.1549.

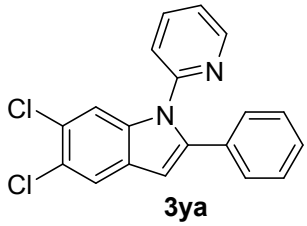


3xa

6-chloro-5-methyl-2-phenyl-1-(pyridin-2-yl)-1H-indole(3xa)

Yellowish liquid (61.6 mg, 97%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.64 (dd, *J* = 4.8, 1.1 Hz, 1H), 7.74 (s, 1H), 7.61 (td, *J* = 7.8, 1.9 Hz, 1H), 7.49 (d, *J* = 4.7 Hz, 1H), 7.28 – 7.21 (m, 6H), 6.83 (d, *J* = 8.1 Hz, 1H), 6.70 (s, 1H), 2.47 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.8 (s), 149.2 (s), 140.5 (s), 137.8 (s), 137.4 (s), 132.4 (s), 129.6 (s), 128.8 (s), 128.7 (s), 128.6 (s), 128.3 (s), 127.6 (s), 127.5 (s), 121.6 (s), 121.6 (s), 112.0 (s), 105.0 (s), 20.3 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{16}ClN_2$ 319.0997; Found: 319.0999.



3ya

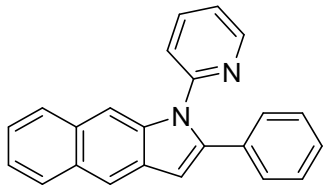
5,6-dichloro-2-phenyl-1-(pyridin-2-yl)-1H-indole(3ya)

Yellowish liquid (54.0 mg, 80%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.68-

8.61 (m, 1H), 7.83 (s, 1H), 7.71 (s, 1H), 7.61 (td, *J* = 7.8, 1.9 Hz, 1H), 7.31-7.22 (m, 6H), 6.81 (d, *J* = 8.1 Hz, 1H), 6.69 (s, 1H).

^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ =151.3 (s), 149.3 (s), 141.7 (s), 137.9 (s), 137.1 (s), 131.7 (s), 128.7 (s), 128.4 (s), 128.2 (s), 128.0 (s), 126.6 (s), 125.1 (s), 122.1 (s), 121.7 (s), 121.3 (s), 113.3 (s), 104.6 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{13}Cl_2N_2$ 339.0451; Found: 339.0450.



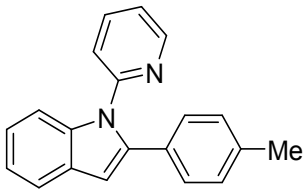
3za

2-phenyl-1-(pyridin-2-yl)-1H-benzo[f]indole(3za)

Yellow solid (44.8 mg, 70%), M.p. 167-169℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 8.68 (dt, *J* = 5.6, 2.8 Hz, 1H), 8.14 (d, *J* = 22.4 Hz, 2H), 7.96 – 7.84 (m, 2H), 7.64 – 7.59 (m, 1H), 7.37 – 7.32 (m, 4H), 7.29 (dd, *J* = 5.1, 1.9 Hz, 3H), 7.23 – 7.20 (m, 1H), 6.96 – 6.89 (m, 2H).

^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ = 152.3 (s), 149.1 (s), 143.5 (s), 138.9 (s), 137.8 (s), 132.4 (s), 131.0 (s), 130.0 (s), 129.8 (s), 128.6 (s), 128.3 (s), 128.3 (s), 127.9 (s), 127.8 (s), 123.9 (s), 123.2 (s), 121.8 (s), 121.3 (s), 118.0 (s), 107.2 (s), 105.5 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{23}H_{17}N_2$ 321.1386; Found: 321.1387.

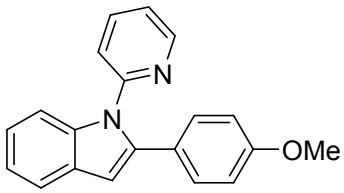


3ab

1-(pyridin-2-yl)-2-(p-tolyl)-1H-indole(3ab)

Yellowish liquid (54.0 mg, 95%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.66-8.61 (m, 1H), 7.69-7.58 (m, 3H), 7.19 (ddd, *J* = 12.2, 9.7, 6.6 Hz, 5H), 7.07 (d, *J* = 8.1 Hz, 2H), 6.88 (d, *J* = 8.0 Hz, 1H), 6.77 (s, 1H), 2.32 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ =152.1 (s), 149.1 (s), 140.0 (s), 138.4 (s), 137.7 (s), 137.2 (s), 129.7 (s), 129.0 (s), 128.7 (s), 128.6 (s), 122.8 (s), 122.0 (s), 121.5 (s), 121.2 (s), 120.4 (s), 111.4 (s), 105.1 (s), 21.1 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2$ 285.1386; Found: 285.1387.

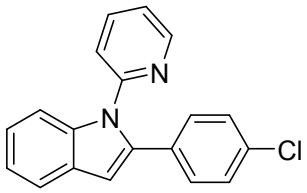


3ac

2-(4-methoxyphenyl)-1-(pyridin-2-yl)-1H-indole（3ac）

Colorless liquid (55.2 mg, 92%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 8.64-8.58 (m, 1H), 7.69-7.61 (m, 2H), 7.58 (td, *J* = 7.8, 1.9 Hz, 1H), 7.22-7.13 (m, 5H), 6.86 (d, *J* = 8.0 Hz, 1H), 6.79 (d, *J* = 8.6 Hz, 2H), 6.72 (s, 1H), 3.75 (s, 3H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ = 159.0 (s), 152.0 (s), 149.0 (s), 139.8 (s), 138.2 (s), 137.7 (s), 129.9 (s), 128.7 (s), 125.1 (s), 122.6 (s), 122.0 (s), 121.5 (s), 121.2 (s), 120.2 (s), 113.7 (s), 111.3 (s), 104.6 (s), 55.1 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{20}H_{17}N_2O$ 301.1336; Found: 301.1340.



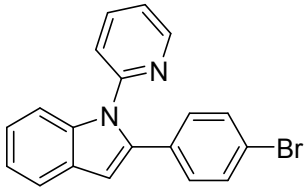
3ad

2-(4-chlorophenyl)-1-(pyridin-2-yl)-1H-indole(3ad)

White solid (59.0 mg, 97%), m.p. 110-113℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ =8.64-8.59 (m, 1H), 7.64 (dd, *J* = 10.8, 4.8 Hz, 3H), 7.21 (dt, *J* = 16.4, 7.3 Hz, 7H), 6.92 (d, *J* = 8.0 Hz, 1H), 6.79 (s, 1H).

^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ =151.7 (s), 149.3 (s), 138.7 (s), 138.5 (s), 137.9 (s), 133.3 (s), 131.1 (s), 129.8 (s), 128.5 (s), 123.2 (s), 121.9 (s), 121.8 (s), 121.4 (s), 120.6 (s), 111.4 (s), 105.8 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}ClN_2$ 305.0740; Found: 305.0743.



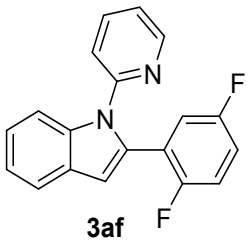
3ae

2-(4-bromophenyl)-1-(pyridin-2-yl)-1H-indole(3ae)

White solid (67.5 mg, 97%), m.p.125-127℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.61 (dd, *J* = 4.8, 1.4 Hz, 1H), 7.65 (td, *J* = 7.8, 1.6 Hz, 3H), 7.42-7.36 (m, 2H), 7.25-7.17 (m, 3H), 7.14-7.08 (m, 2H), 6.92 (d, *J* = 8.0 Hz, 1H), 6.79 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.7 (s), 149.3 (s),

138.6 (s), 138.5 (s), 137.9 (s), 131.6 (s), 131.4 (s), 130.0 (s), 128.5 (s), 123.2 (s), 121.8 (s), 121.8 (s), 121.5 (s), 121.4 (s), 120.6 (s), 111.4 (s), 105.9 (s).

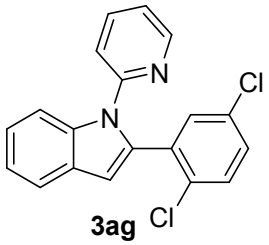
HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{14}BrN_2$ 349.0335; Found: 349.0336.



3af

2-(2,5-difluorophenyl)-1-(pyridin-2-yl)-1H-indole(3af)

White solid (60.0 mg, 98%), m.p. 140-143℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.56-8.51 (m, 1H), 7.73-7.65 (m, 3H), 7.28-7.24 (m, 1H), 7.23-7.18 (m, 2H), 7.08 (d, J = 8.0 Hz, 1H), 7.06-7.01 (m, 1H), 6.95-6.90 (m, 2H), 6.87 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ = 159.5 (s), 156.8 (d, J = 48.2 Hz), 154.2 (s), 151.6 (s), 149.2 (s), 137.9 (d, J_{CF} = 1.9 Hz), 132.6 (s), 128.3 (s), 123.6 (s), 122.4 (dd, J_{CF} = 17.1, 8.8 Hz), 121.6 (s), 121.4 (s), 120.9 (s), 120.3 (s), 117.5 (dd, J_{CF} = 24.8, 3.5 Hz), 116.7 (dd, J_{CF} = 25.1, 8.9 Hz), 115.8 (dd, J_{CF} = 24.0, 8.5 Hz), 111.3 (s), 107.9 (d, J_{CF} = 2.4 Hz). **HRMS** (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{13}F_2N_2$ 307.1042; Found: 307.1045.

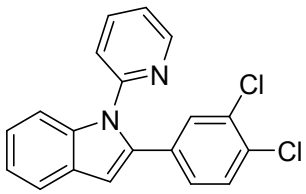


3ag

2-(2,5-dichlorophenyl)-1-(pyridin-2-yl)-1H-indole(3ag)

Colorless liquid (65.5 mg, 97%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.52 – 8.47 (m, 1H), 7.76 (d, J = 8.2 Hz, 1H), 7.67 (d, J = 7.4 Hz, 1H), 7.60 (td, J = 7.8, 1.9 Hz, 1H), 7.35 (d, J = 2.0 Hz, 1H), 7.30 – 7.26 (m, 1H), 7.26 – 7.22 (m, 1H), 7.22 – 7.16 (m, 2H), 7.16 – 7.11 (m, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.4 (s), 149.0 (s), 137.7 (s), 137.2 (s), 135.2 (s), 134.5 (s), 134.4 (s), 133.2 (s), 130.9 (s), 129.5 (s), 128.2 (s), 126.9 (s), 123.4 (s), 121.4 (s), 121.3 (s), 120.8 (s), 120.2 (s), 111.6 (s), 107.6 (s).

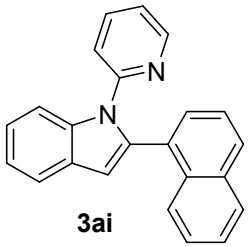
HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{13}Cl_2N_2$ 339.0451; Found: 339.0456.



3ah

2-(3,4-dichlorophenyl)-1-(pyridin-2-yl)-1H-indole(3ah)

Yellowish liquid (65.5 mg, 97%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.61 (dd, J = 4.8, 1.7 Hz, 1H), 7.74 – 7.64 (m, 2H), 7.61 (d, J = 8.0 Hz, 1H), 7.42 (d, J = 2.0 Hz, 1H), 7.31 – 7.18 (m, 4H), 7.02 – 6.96 (m, 2H), 6.82 (s, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ= 151.4 (s), 149.5 (s), 138.6 (s), 138.1 (s), 137.3 (s), 132.7 (s), 132.4 (s), 131.4 (s), 130.1 (s), 130.1 (s), 128.3 (s), 127.6 (s), 123.6 (s), 122.0 (s), 121.7 (s), 121.6 (s), 120.8 (s), 111.3 (s), 106.4 (s). **HRMS** (ESI) m/z: $(M + H)^+$ Calcd for $C_{19}H_{13}Cl_2N_2$ 339.0451; Found: 339.0454.



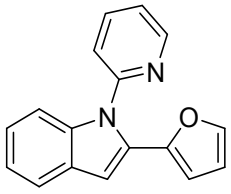
3ai

2-(naphthalen-1-yl)-1-(pyridin-2-yl)-1H-indole(3ai)

Colourless oil (49.9 mg, 78%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.51 (dd, J = 4.9, 1.2 Hz, 1H), 8.01 (d, J = 8.4 Hz, 1H), 7.87 (d, J = 8.2 Hz, 1H), 7.81 (d, J = 7.9 Hz, 2H), 7.72 (dd, J = 7.0, 1.2 Hz, 1H), 7.46 – 7.38 (m, 3H), 7.37 – 7.31 (m, 1H), 7.31 – 7.26 (m, 2H), 7.24 (dd, J = 6.6, 1.6 Hz, 1H), 6.99 (ddd, J = 7.4, 4.9, 0.8 Hz, 1H), 6.86 (s, 1H), 6.64 (d, J = 8.1 Hz, 1H).

^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ= 151.8 (s), 148.7 (s), 137.6 (s), 137.5 (s), 137.4 (s), 133.4 (s), 132.1 (s), 130.6 (s), 128.9 (s), 128.6 (s), 128.5 (s), 128.0 (s), 126.4 (s), 125.9 (s), 125.9 (s), 125.0 (s), 123.0 (s), 121.3 (s), 121.0 (s), 120.5 (s), 120.5 (s), 111.9 (s), 107.5 (s).

HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{23}H_{17}N_2$ 321.1386; Found: 321.1389.

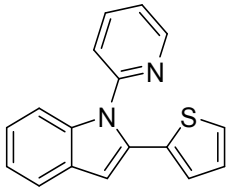


3aj

2-(furan-2-yl)-1-(pyridin-2-yl)-1H-indole(3aj)

Brown solid (44.2 mg, 85%), m.p. 123-125℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ= 8.66 (dd, J = 4.9, 1.2 Hz, 1H), 7.80 (td, J = 7.8, 1.9 Hz, 1H), 7.65 (dd, J = 6.1, 2.6 Hz, 1H), 7.43-7.39 (m, 1H), 7.37-7.31 (m, 2H), 7.25-7.22 (m, 1H), 7.21-7.15 (m, 2H), 6.96 (s, 1H), 6.32 (dd, J = 3.3, 1.8 Hz, 1H), 5.95 (d, J = 3.4 Hz, 1H).

^{13}C{1H}NMR (101 MHz, $CDCl_3$) δ= 151.7 (s), 149.3 (s), 146.8 (s), 142.1 (s), 138.4 (s), 138.1 (s), 130.5 (s), 128.3 (s), 123.1 (s), 122.5 (s), 121.9 (s), 121.2 (s), 120.7 (s), 111.1 (s), 110.9 (s), 108.1 (s), 104.0 (s).
HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{17}H_{13}N_2O$ 261.1023; Found: 261.1025.



3ak

1-(pyridin-2-yl)-2-(thiophen-2-yl)-1H-indole(3ak)
White solid (45.2 mg, 82%), m.p. 133-136℃. **^{1}H NMR** (400 MHz, $CDCl_3$) δ =8.66 (dd, *J* = 4.9, 1.2 Hz, 1H), 7.72 (td, *J* = 7.8, 1.9 Hz, 1H), 7.63 (dd, *J* = 6.3, 2.3 Hz, 1H), 7.49 – 7.45 (m, 1H), 7.29 (ddd, *J* = 7.4, 4.9, 0.8 Hz, 1H), 7.23 – 7.15 (m, 3H), 7.11 (d, *J* = 8.0 Hz, 1H), 6.91 (dd, *J* = 5.1, 3.6 Hz, 1H), 6.85 (s, 1H), 6.74 (dd, *J* = 3.6, 1.0 Hz, 1H). **^{13}C{1H}NMR** (101 MHz, $CDCl_3$) δ =151.5 (s), 149.3 (s), 138.5 (s), 137.9 (s), 134.2 (s), 133.2 (s), 128.3 (s), 127.2 (s), 126.5 (s), 125.7 (s), 123.1 (s), 122.4 (s), 122.3 (s), 121.3 (s), 120.5 (s), 111.1 (s), 105.5 (s).
HRMS (ESI) m/z: $(M + H)^+$ Calcd for $C_{17}H_{13}N_2S$ 277.0794; Found: 277.0795.

Gram-Scale Reaction Experiment.
A mixture of *N*-(2-pyridyl)anilines **1a** (0.85g, 5.0mmol, 1.0equiv), α-Cl acetophenone **2a** (1.001 g, 6.5 mmol, 1.3equiv), $[Cp^*IrCl_2]_2$ (0.199g, 0.25 mmol, 5mol%), NaF (0.315g, 7.5 mmol, 1.5equiv) was taken in a dry round-bottomed flask under air atmosphere. To the mixture, MeOH (40 mL) was added via a syringe and the closed reaction mixture was allowed to stir at 90℃ for 36 h monitored with TLC. After completion of the reaction, the solvent was removed under reduced pressure and then the crude reaction mixture was purified by flash silica gel column chromatography (petroleum ether/EtOAc = 10:1) to afford the desired product **3aa** (1.26g, 93%).

ASSOCIATED CONTENT

Supporting Information
The Supporting Information is available free of charge on the ACS Publications website.
Control Experiments
^{1}H and **^{13}C NMR** spectra for all products (PDF).

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Notes
The authors declare no competing financial interest.

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