

Metal-free C–H Borylation and Hydroboration of Indoles

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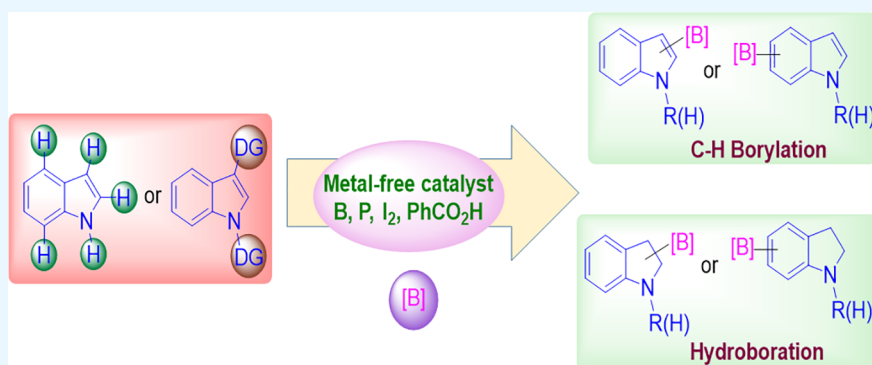
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ABSTRACT: The C–H borylation and hydroboration reactions have emerged as promising synthetic tools to construct organoboron compounds. Organoboron compounds of N-heterocycles, particularly indole derivatives, have found widespread application in a variety of fields. As a result, considerable advancement in the area of C–H borylation and hydroboration reactions of indoles was observed in the last few decades. Among the various synthetic methods applied, the metal-free approach has received special attention. This mini-review discusses the recent progress in the area of C–H borylation and hydroboration reactions of indoles under metal-free conditions, their scope, and brief mechanistic studies.

INTRODUCTION

The C–H bond activation is an emerging field in synthetic organic chemistry that has received considerable attention in the last few decades.¹ Of the various C–H functionalization methods developed in the literature,^{2a–c} C–H borylation has become one of the important methods since the resultant organoboron compounds are chief synthetic intermediates that can be applied in coupling reactions for the formation of C–X (X = C, heteroatoms) bonds³ and making pharmaceutically relevant drug molecules.⁴ The organoboron compounds contribute remarkably to the production of OLEDs, anion sensors, imaging, and electron-transport materials.⁵ Moreover, the triarylboranes have been extensively applied as a frustrated Lewis pair (FLP) system for the activation of small molecules⁶ and as catalysts in various organic transformations.⁷ Over the course of time, an impressive level of progress has been observed in transition metal catalysis with Ti, Co, Mn, Pd, Rh, Ir, etc. metals for the C–H borylation reactions.^{2a–c,g–i} Moreover, the metal-free approach has also gained a steady momentum of late⁸ due to its lower cost and environmental friendliness. Besides the advancement of C–H borylation reactions, the hydroboration reaction⁹ also resulted in the formation of several organoboron compounds which have been extensively applied to synthesize important pharmaceutical compounds and biomolecules.⁴ The hydroboration of unsaturated bonds, including alkene, alkyne,

and carbonyl compounds can be achieved with pinacolborane (HBpin),¹⁰ catechol borane (HBCat),¹¹ and Piers' borane (HB(C₆F₅)₂)¹² using metal and metal-free catalysts. Metal-based catalytic systems demonstrated better reactivity and product selectivity, whereas metal-free systems showed a slightly lower reactivity with selectivity comparable to that of the former. The metal-free catalysts are good alternatives and also overcome drawbacks associated with transition metal catalysts.

Of the various unsaturated compounds explored for the C–H borylation and hydroboration reactions, the N-heterocycles, especially the indole and indoline skeletons have shown promising applications in numerous pharmaceuticals, natural products, materials, and various biologically active compounds (Figure 1).¹³ As a consequence, synthetic chemists and chemical industries around the world have paid special attention to the development of suitable techniques for the C–H borylation and hydroboration of indoles. Among the various synthetic methods known in the literature, the metal-free approach is particularly

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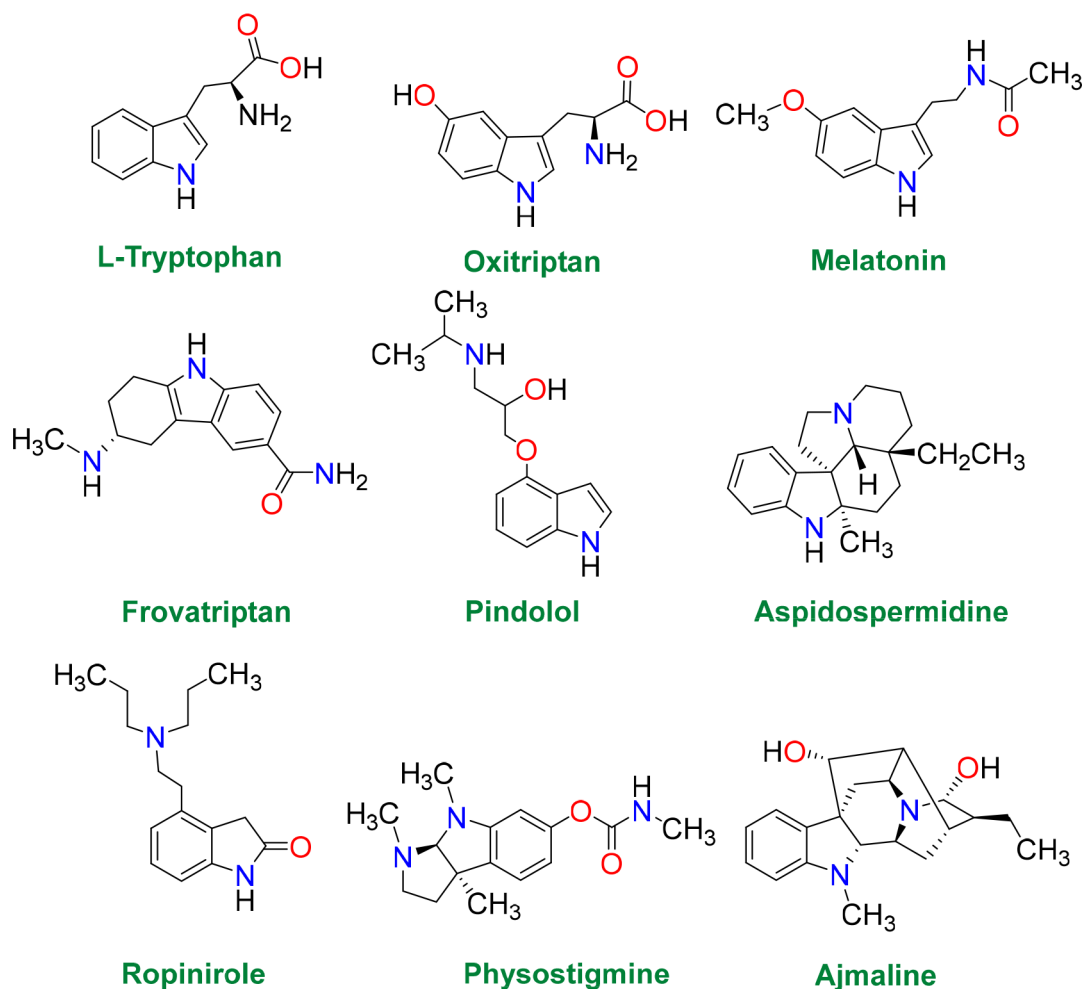
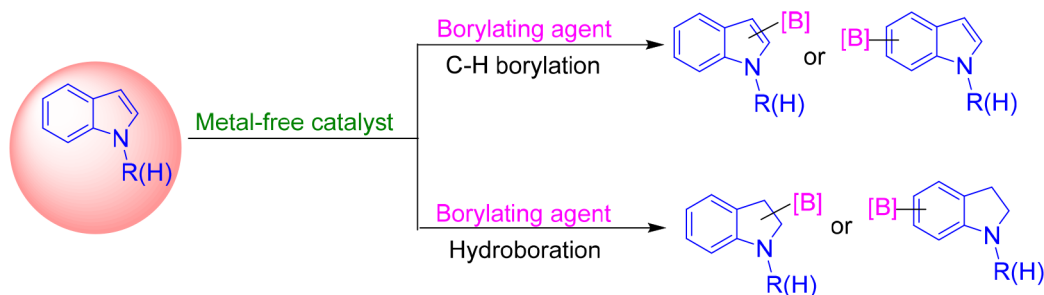


Figure 1. Value-added compounds with an indole and indoline core.

Scheme 1. General Schematic Diagram of C–H Borylation and Hydroboration Reaction of Indoles



attractive due to lower toxicity, cost-effectiveness, sustainability, and less chance of any metal contamination in the final product.^{9a,b}

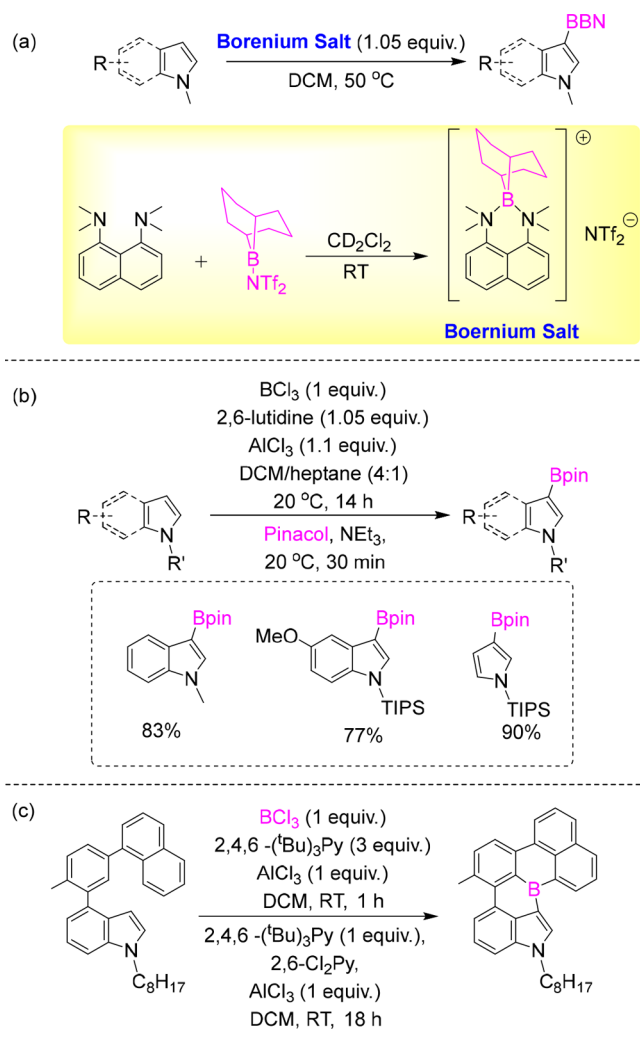
Recently, several excellent reviews have been published for the C–H borylation and hydroboration reactions of unsaturated compounds.^{9a,b,14} However, there is no report to date that accounts for the selective C–H borylation and hydroboration reactions of indoles via a metal-free pathway. This prompted us to write the present mini-review on the selective metal-free C–H borylation and hydroboration reactions of indoles to the corresponding borylated indoles and indoline derivatives (Scheme 1). This mini-review presents the recent advancement of the field with various interesting protocols, a selected substrate scope, and a brief discussion of the mechanism.

1. C–H BORYLATION REACTIONS

In 1948, Hurd and co-workers¹⁵ reported the first C–H borylation of benzene with the highly reactive B_2H_6 , wherein the reaction mixture was heated in a stainless-steel bomb or in a sealed tube for 12 h at 100 °C which resulted in the formation of the phenylboronic acid after workup. Following this study, several research groups explored the C–H borylation reactions of (hetero)arenes with transition metal and metal-free catalytic systems.^{2a–c,8} Among them, the metal-free C–H borylation of N-heterocycles, especially, the indoles has shown promising advancement.

In general, the C–H borylation of indoles proceeds at the C3-position with the various electrophilic borylating agents. In addition to this, the C2-borylation of indoles has also been

Scheme 2. C–H Borylation of Indoles with (a) Borenium Salt, (b) BCl₃/2,6-Lutidine, and (c) BCl₃/2,4,6-(^tBu)₃Py



observed of late. Moreover, the borylation of indoles can be tuned with a suitable directing group to afford the borylated products in rather unusual positions, such as at C4- or C7.

1.1. C3-Borylation of Indoles. In 2011, Vedejs and co-workers¹⁶ reported a borenium salt-assisted C–H borylation of indoles at the C3-position. The reactive borylating reagent was synthesized in one step, as depicted in Scheme 2a. Soon after that, Ingleson's group disclosed the electrophilic C–H borylation of electron-rich indoles with the borenium cations derived from BCl₃/2,6-lutidine¹⁷ and BCl₃/2,4,6-(^tBu)₃Py¹⁸ (Scheme 2b,c).

Oestreich et al.¹⁹ in 2017 demonstrated an electrophilic C–H borylation of electron-rich indoles with catecholborane (CatBH) (Table 1). The study revealed that the catalytic reaction proceeds with the activation of the B–H bond of CatBH in the presence of B(C₆F₅)₃ through the formation of reactive boron electrophiles. The reaction took place at the electron-rich site of the indoles, resulting in the formation of the C3-borylated products in good yields. Typically, the reaction proceeds at an elevated temperature (120 °C) in toluene for 72 h in the presence of CatBH (4 equiv). Interestingly, when an alkene, such as norbornadiene (nbd), was added to the reaction mixture, a drastic change in the rate of the reaction was observed. Under such reaction conditions, the borylation resulted at room

Table 1. Selected Examples of C3-Borylation of Indoles with B(C₆F₅)₃ and HBCat

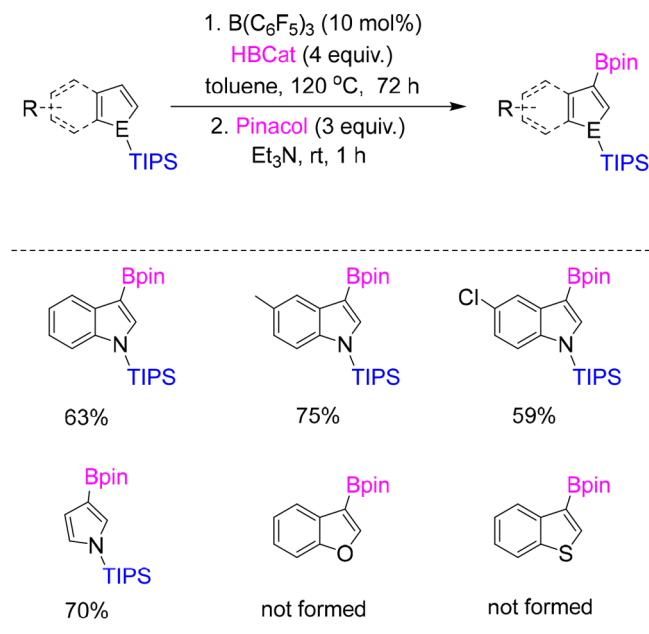
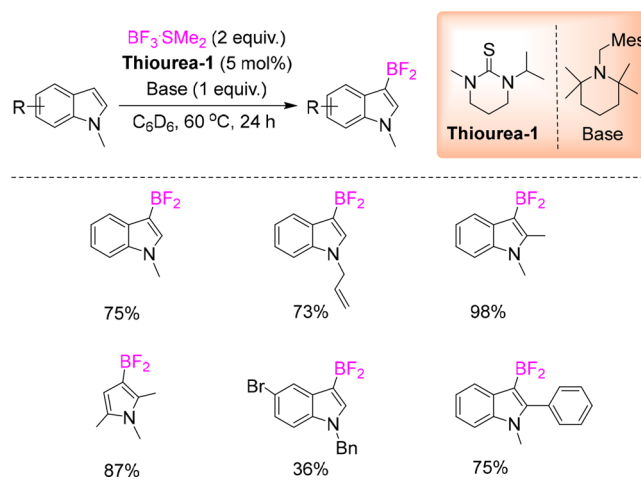


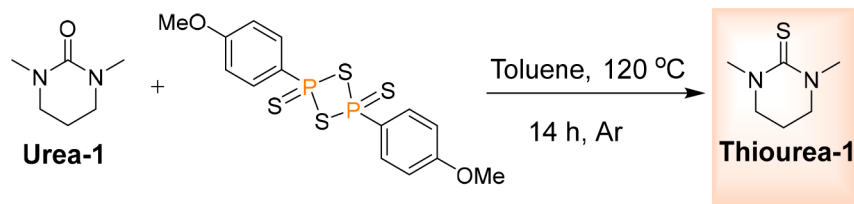
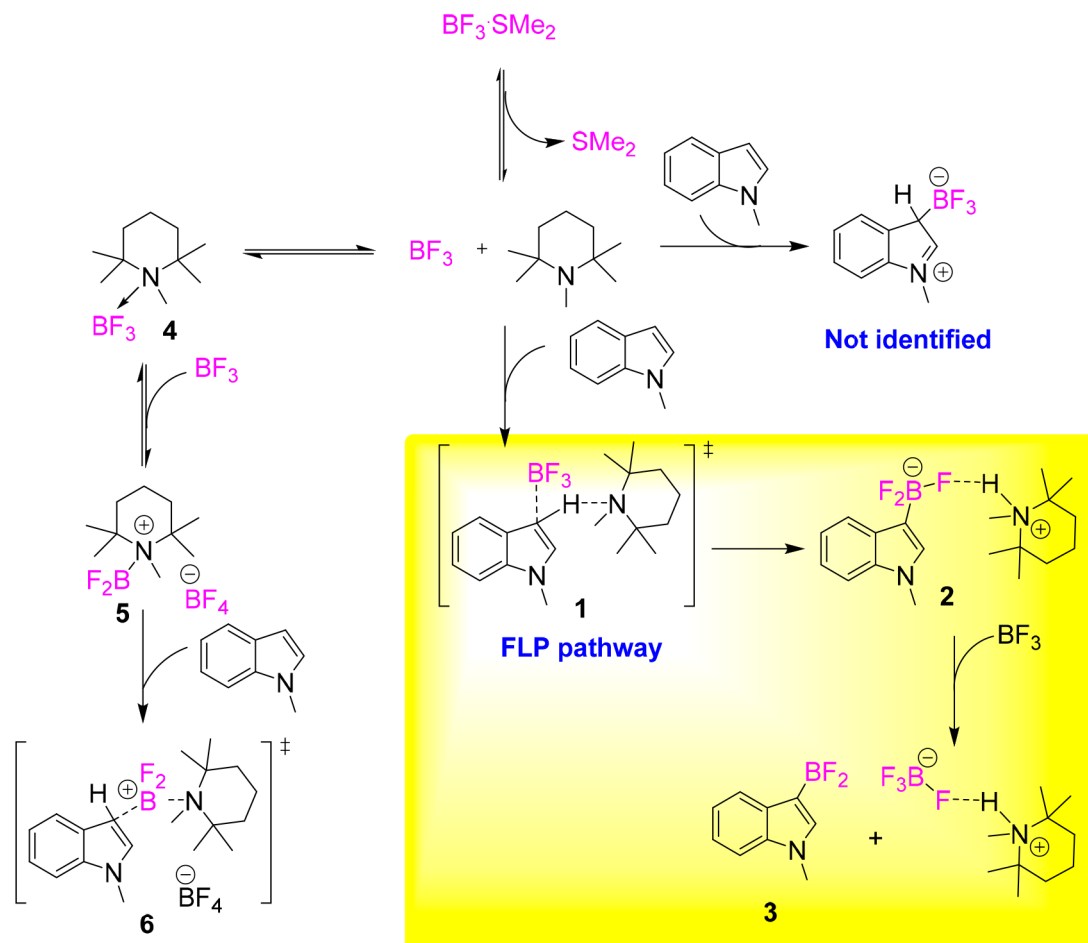
Table 2. C3-Borylation of Indole Using Thiourea-1 as a Catalyst and BF₃·SMe₂ as Borylating Agent



temperature with the reduced loading of CatBH (2 equiv). The acceleration in the rate of the reaction could be attributed to the fact that the generated byproduct H₂ was taken by the alkene, thus acting as a dihydrogen acceptor. Interestingly, when the reaction was performed with *N*-methyl indoles, the C5-borylated heterocycle was obtained in modest yield. Apart from indoles, the TIPS (triisopropylsilyl) protected pyrrole also provided the C3-borylated product in 70% yield. The formation of the C3-borylated product could be explained by the presence of the bulky TIPS group on the nitrogen center. Notably, under the reaction conditions, benzofuran and benzothiophene did not furnish the desired product.

Later, the group of Papai and Repo²⁰ described a C–H borylation of electron-rich *N*-heterocycles using BF₃·SMe₂ and piperidine in the presence of a catalytic amount of thiourea (Table 2). The thiourea derivative (Thiourea-1) was synthesized in a one-step reaction (Scheme 3). Under an argon

Scheme 3. Synthetic method of Thiourea-1

Scheme 4. Proposed Mechanistic Pathway of C3-Borylation Reaction of Indole with $\text{BF}_3 \cdot \text{SMe}_2$ 

atmosphere, the **Urea-1** (1 equiv) was treated with Lawesson's reagent (1.5 equiv) in dry toluene and the reaction mixture was refluxed for 14 h at 120 °C to afford **Thiourea-1** in 47% yield.

The study revealed that the combination of piperidine derivative as a base and thiourea derivative as a catalyst assisted the reaction smoothly. The obtained aryldifluoroboranes were further treated with Me_4NF to convert them to the corresponding air-stable tetramethylammonium organotrifluoroborates. The protocol exhibited good substrate scope tolerance, and the resulting C3-borylated indoles were obtained in good to excellent yields (Table 2).

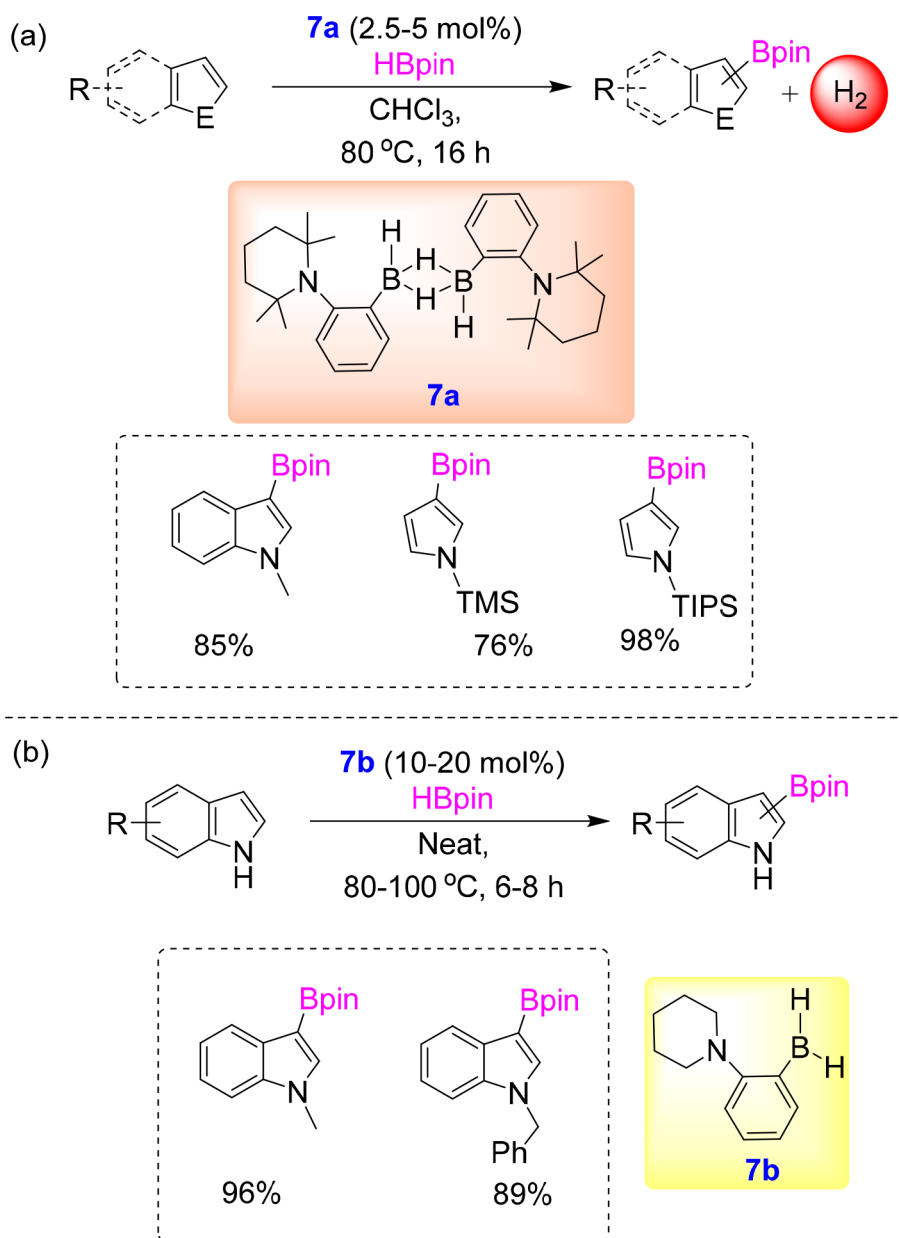
The computational study revealed that the reaction proceeds via the FLP-type mechanism (Scheme 4). Under the reaction conditions, indole, pyridine, and BF_3 generate a weakly bound transient complex that undergoes a concerted C–H activation via transition state 1, leading to the formation of intermediate 2. The intermediate 2 is stabilized by N–H...F hydrogen bonding interactions and undergoes the reaction with an additional BF_3 molecule to produce an intermediate- BF_3 adduct which

undergoes fluoride transfer and generated borylated product (3).

In the quest for the development of metal-free C–H borylation of heteroarenes, Fontaine et al. demonstrated an elegant approach with ambiphilic aminoboranes (7a and 7b) as a catalyst^{21,22} (Scheme 5). Remarkably, both reactions proceed with the borylation of a number of heteroarenes along with the indoles in good to excellent yields.

The same group recently demonstrated that 2-mercaptopyridine can catalyze the C–H borylation of indoles with 2-furylcatecholborane (2-FurylBCat)²³ (Table 3). The borylating reagent was synthesized from 2-furanylboronic acid and pyrocatechol. Initially, 2-furanylboronic acid was dissolved in toluene, and 1 equiv of pyrocatechol was added to it. Following this, the reaction flask was directly placed on the rotary evaporator, and the mixture was heated at 50 °C. After complete evaporation of the solvent, the desired compound was crystallized in hexane at –30 °C. Notably, among the various

Scheme 5. C3-Borylation of Indoles with Ambiphilic Aminoborane as a Catalyst



arylboronates screened for the isodesmic C–H borylation of indole, **2-FurylBCat** was found to produce the best outcome.

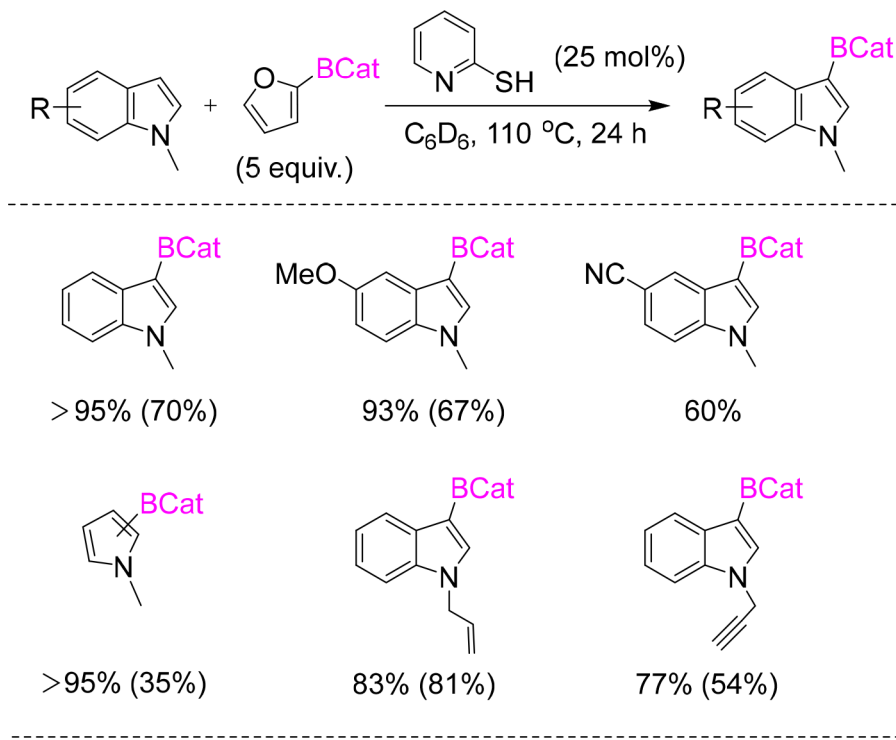
A detailed mechanistic study suggested that 2-mercaptopyridine functions as an ambiphilic reagent having both Brønsted acidic and Lewis basic sites (Scheme 6). At first, the coordination of 2-mercaptopyridine with the electrophilic boron atom of **2-FurylBCat** led to the formation of intermediate **8**. Subsequently, the liberation of furan from **8** generates the intermediate **9** or **9'** that behaves as a FLP type catalyst to activate the C–H bond of indole with the formation of intermediate **10**. Following this, the desired borylated product was formed via regeneration of the catalytic system.

In addition to the FLP catalysts and Lewis acidic systems, organonictogens have also shown promising activity for the C–H borylation of indoles. In 2021, Radosevich, Liu, and co-workers²⁴ introduced a nontrigonal phosphorus triamide (**11**) as a catalyst for the C–H borylation of electron-rich heteroarenes with HBpin (Table 4). The P(III) catalyst was

prepared upon treatment of PCl₃ with **11'** in Et₂O at –78 °C followed by the dropwise addition of NEt₃ in Et₂O (Scheme 7).

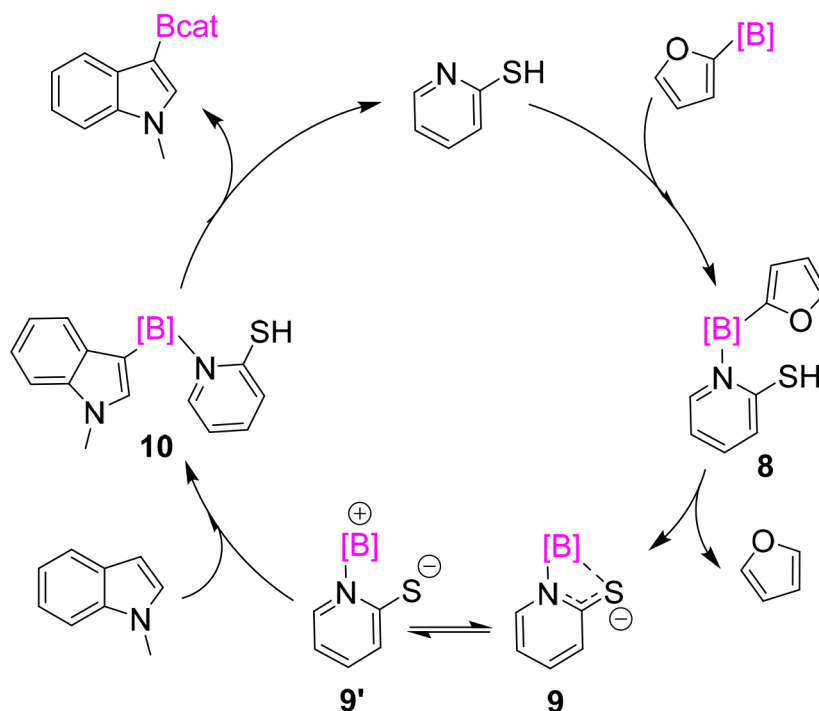
The strained organophosphorus catalyst exhibited good activity, and a diverse range of *N*-methylindoles was borylated in good to excellent yields. Interestingly, the reaction of *N*-alkyl indoles proceeds with the formation of a C3-borylated product. The pyrroles and thiophenes also undergo the reaction, resulting in the formation of the C2-borylated product under the optimized conditions.

On the basis of experimental and computational studies, the authors proposed the mechanism of the C–H borylation reaction with **11** (Scheme 8). Initially, catalyst **11** reacts with HBpin to form intermediate **12**, which is then oxidized to **13** in the presence of PhCHCl₂. The intermediate **13** undergoes a metathesis reaction with HBpin to furnish ClBpin with the concomitant regeneration of **12**. Subsequently, the electron-rich *N*-methylindole undergoes S_EAr borylation with electrophilic ClBpin to afford C3-borylated *N*-methylindoles.

Table 3. C3-Borylation of Indole Using 2-Mercaptopyridine as a Catalyst and 2-FurylBCat as Borylating Agent^a

^aYields were calculated by ¹H NMR spectroscopy; isolated yields are provided in parentheses.

Scheme 6. Proposed Mechanistic Pathway of C3-Borylation Reaction of Indole Using 2-FurylBCat as Borylating Agent

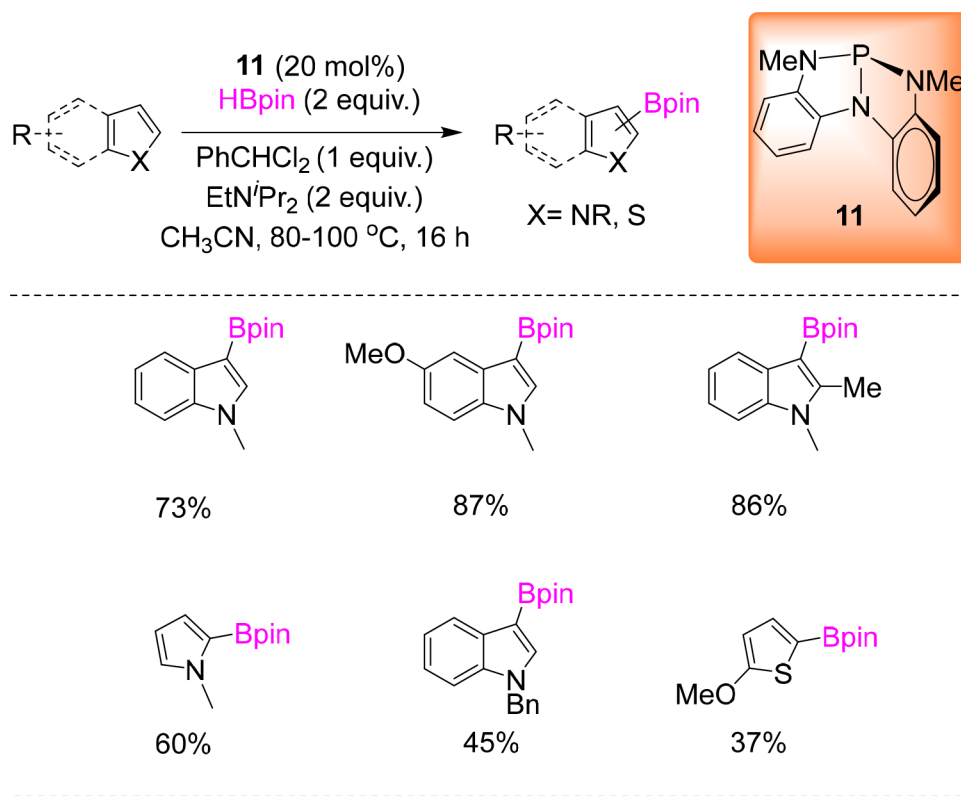
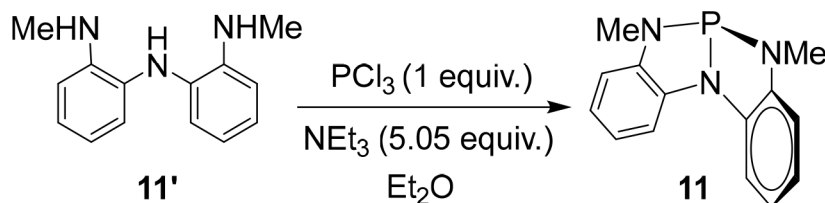


1.2. C2-Borylation of Indoles. The C2-borylation of indole is quite uncommon. Despite this, several studies have been published of late that show that the transformation can be achieved by suitable application of borylating agent/catalytic systems.

In 2017, Ingleson and his colleagues²⁵ demonstrated an elegant approach for the selective borylation of indoles at the

C2-position (Table 5). In this study, N-heterocyclic carbene borane (**14**) was employed as a borylating agent in the presence of molecular iodine in a catalytic amount. Notably, the C2-H borylation of indoles proceeds with the liberation of H₂ gas as a byproduct at 130 °C.

The reaction is proposed to proceed with the initial formation of adduct **15** upon reaction between **14** and HI (Scheme 9).

Table 4. C3-Borylation of Indole Using **11** as a Catalyst and HBpin as Borylating AgentScheme 7. Synthetic Method of **11**

Subsequently, the electrophilic boron adduct **15** undergoes nucleophilic attack at the C3-position to afford **16**. Next, the boron migration from the C3-position to the C2-position leads to the formation of intermediate **17**, which undergoes the aromatization to provide the thermodynamically stable C2-borylated *N*-methylindole (**18**).

Soon after this study, Zhang et al.²⁶ demonstrated a C2–H borylation of electron-rich indoles with B₂pin₂ in the presence of a catalytic amount of BF₃·OEt₂ (Table 6). The reaction proceeds in *n*-octane/THF solution at 140 °C for 16 h to furnish the substituted C2-borylated *N*-alkylated indoles in good yields.

Based on the previous studies, the postulated mechanism is depicted in Scheme 10. The *N*-alkylated indole initially forms intermediate **7** upon the electrophilic attack by BF₃ on the C3-position. Next, the reaction of **7** with B₂pin₂ resulted in the formation of intermediate **19**. Subsequently, the elimination of BF₃ and deprotonation of **21** led to the formation of the desired C2-borylated desired product.

Very recently, the same group²⁷ put forward a simple benzoic acid-promoted C2- borylation of indole with HBpin (Table 7). Notably, the transformation is postulated to proceed via the in situ formation of BH₃-related borane species from HBpin in the presence of indole or benzoic acid. The reaction proceeds inside

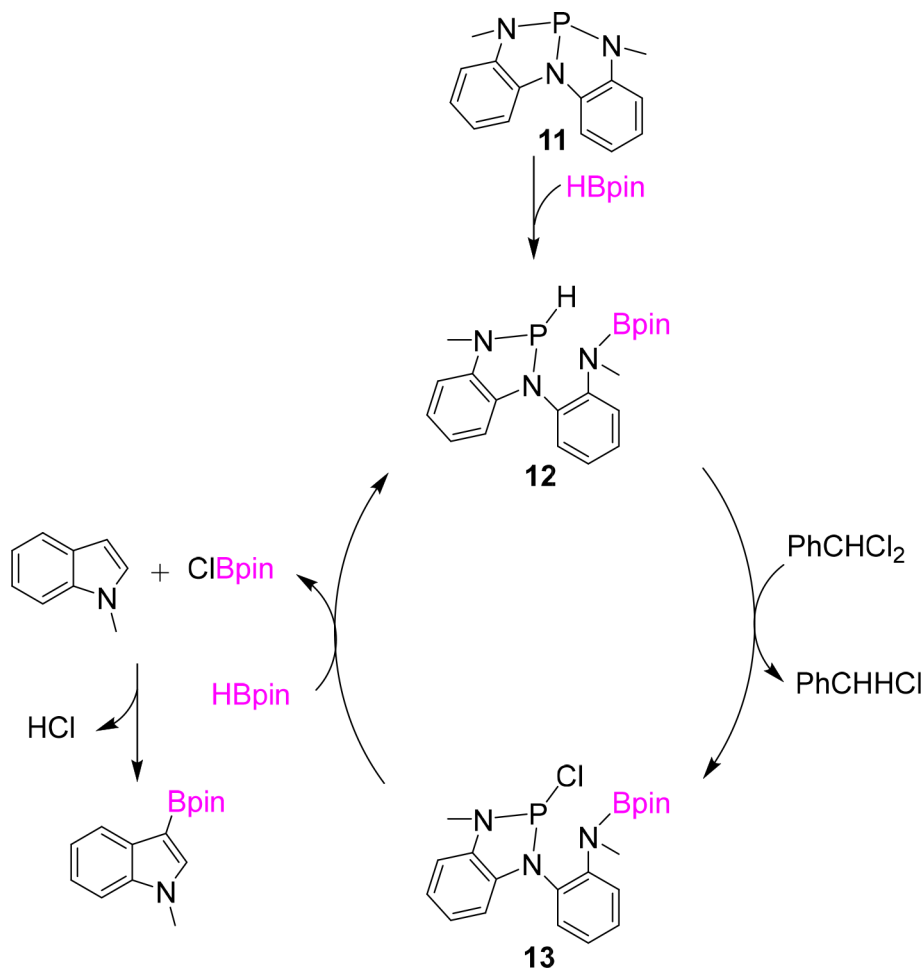
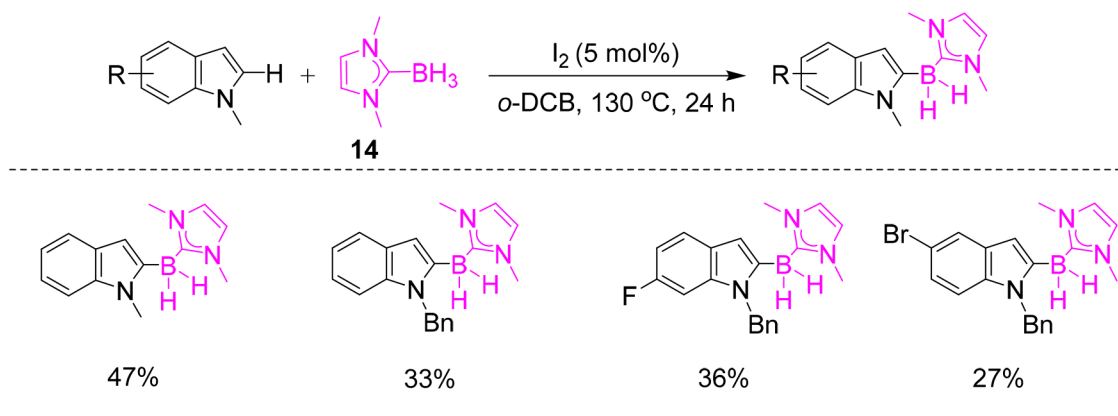
the Schlenk-type sealed tube in a heating module at elevated temperature (180 °C) in hexane with PhCOOH (10 mol %) for 16 h. A wide range of electron-donating and electron-withdrawing substituents on the indoles underwent smooth C2-borylation under the optimized reaction conditions.

A plausible mechanism of this protocol involves the initial formation of the borane species BH₃·L (Scheme 11). Following this, the reaction of the borane adduct with the indole affords **22**, which undergoes transborylation to generate the C2-borylated indole as the final product.

1.3. C4- and C7-Borylation of Indoles. One important strategy in synthetic chemistry is to functionalize the unusual positions of organic compounds by the introduction of suitable auxiliary groups that directs the incoming reagents to occupy such positions.^{8c} This will ensure the C–H activated products in unfamiliar positions that could be explored for pharmaceuticals applications.⁴ A progressive advancement in the C–H functionalization of indoles has been made in the recent past for the synthesis of C4- and C7-borylated products.

In 2019, Houk, Shi, and co-workers²⁸ came up with an excellent strategy for the formation of C4- and C7-borylated indoles with only BBr₃ as the reagent under mild conditions (Table 8). The reaction proceeds at room temperature in DCM

Scheme 8. Proposed Mechanistic Pathway of C3-Borylation of Indole

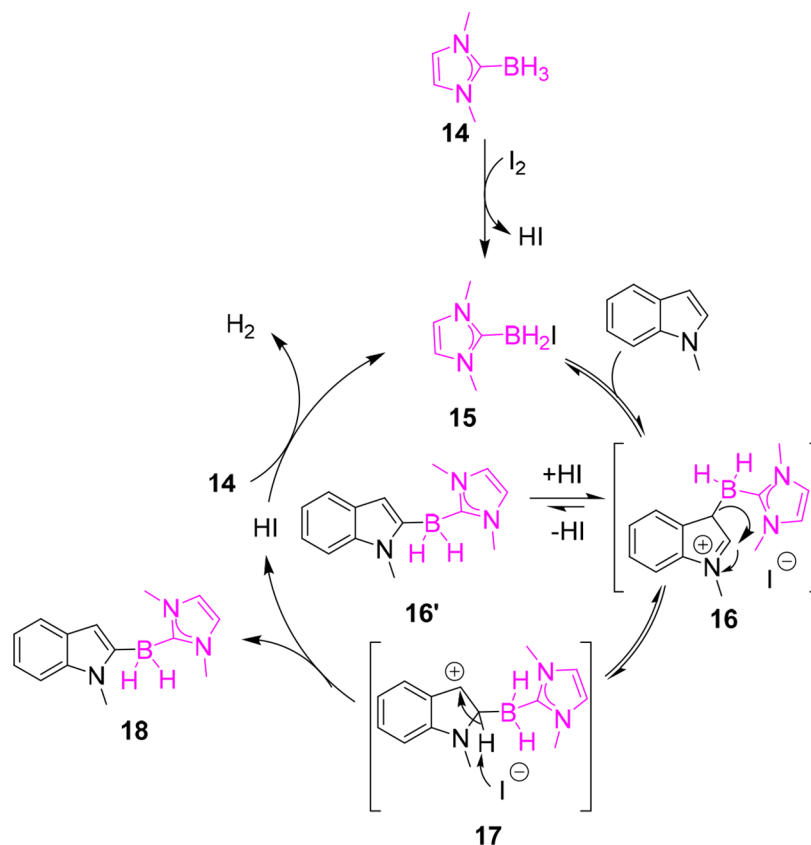
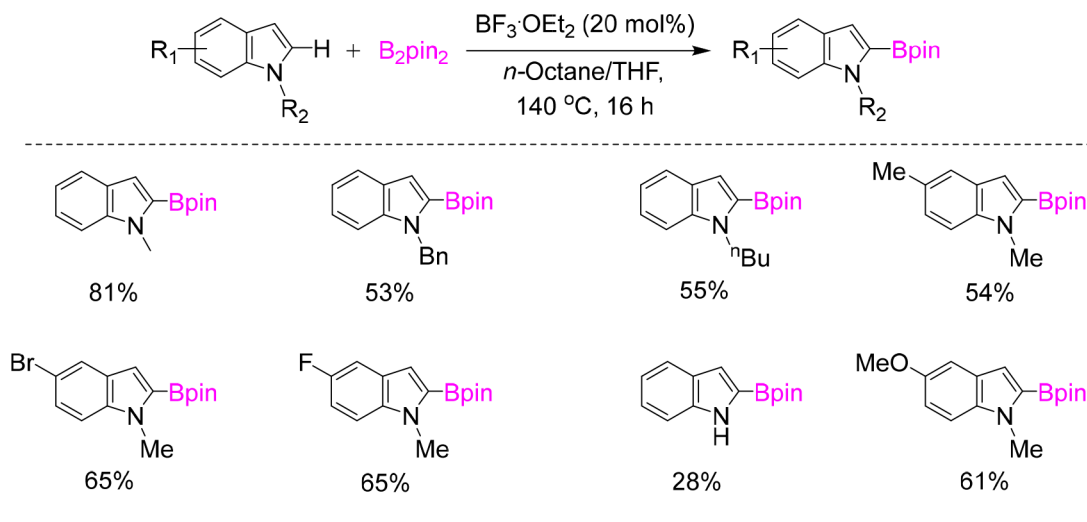
Table 5. C–H Borylation of Indole Using I₂ as a Catalyst and 14 as a Borylating Agent

and requires only 1 h. Initially, the reaction between the N-pivaloyl indole and BBr_3 led to the formation of an intermediate with dibromoborane substitution at the C7-position (INT1). The formation of INT1 was confirmed through X-ray crystallography analysis, which upon further treatment with pyridine and pinacol at low temperature afforded the C7-Bpin substituted final product. Notably, both electron-donating and electron-withdrawing groups were found to be compatible under the reaction conditions furnishing good to excellent yield of the desired product. Remarkably, when the pivaloyl group was

introduced at the C3-position of the starting indole, the corresponding C4-substituted products resulted. A detailed mechanistic study was performed to understand the reaction pathway of the present protocol.

At the same time, Ingleson's group²⁹ independently reported the N-acyl directed C–H borylation of indoles with BBr_3 (Table 9). The electrophilic borylation proceeds with the formation of a C7-borylated product as the major one. Additionally, the C2-borylation of the substrate was observed under the reaction conditions, albeit in a lower yield. After the reaction, heating the

Scheme 9. Proposed Mechanistic Pathway of C2-Borylation of Indole Using 14 as Borylating Agent

Table 6. C2-Borylation of Indoles Using $\text{BF}_3 \cdot \text{OEt}_2$ as a Catalyst and B_2pin_2 as Borylating Agent

C7-borylated product in MeOH for 16 h at 60 °C resulted in the removal of the N-substitution on the indole ring.

2. HYDROBORATION REACTIONS

In 1980, Itsuno et al.³⁰ first reported the reduction of aromatic ketones with chiral alkoxy-amineborane. Later, Corey and co-workers developed the CBS (Corey–Bakshi–Shibata catalyst) process.³¹ Following these studies, many transition-metal-catalyzed and metal-free approaches for hydroboration reactions have been developed. Recently, Crudden's group^{10a} disclosed that the borenium salt catalyzed the hydroboration reaction of

imines. Similar to that for the various unsaturated functional groups, a notable advancement in the metal-free hydroboration of indoles has been observed of late. Importantly, despite the unfavorable kinetics and thermodynamics of the dearomatization of the heterocyclic ring involved during the hydroboration of indoles, a number of protocols have been developed.

Fontaine and co-workers³² disclosed a dearomative hydroboration of N-sulfonyl indoles in the presence of HBpin and a catalytic amount of 1,1-piperidyl(H)-2- $\text{BF}_3 \cdot \text{C}_6\text{H}_4$ (**23**) (Table 10). The fluoroborate salt (**23**) acts as a precatalyst which has been synthesized via a three-step process as outlined in Scheme

Scheme 10. Proposed Mechanistic Pathway of C2-Borylation of Indole

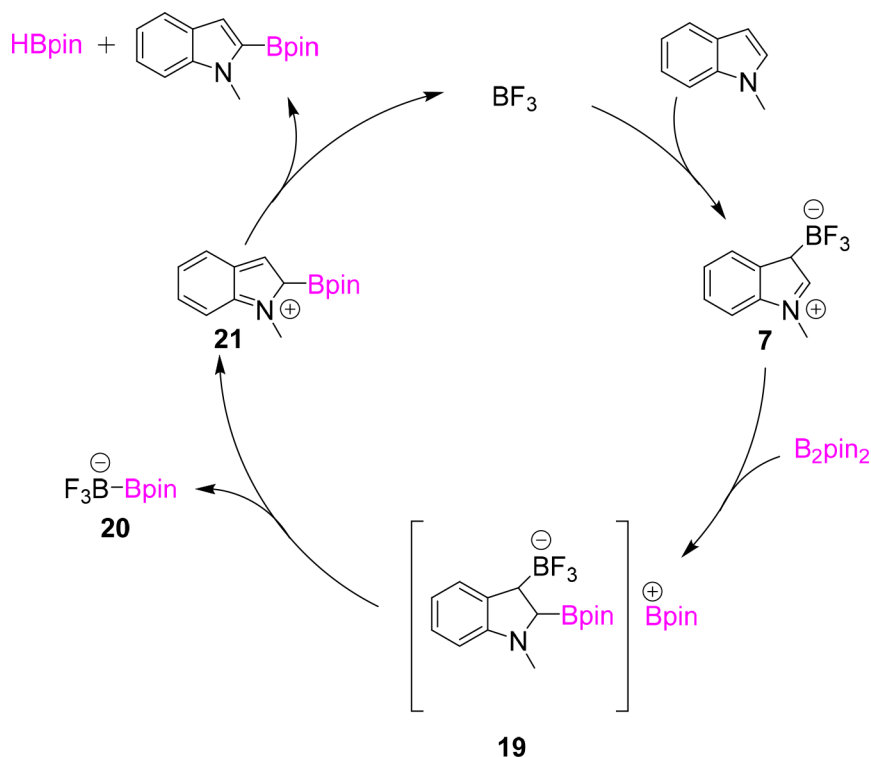
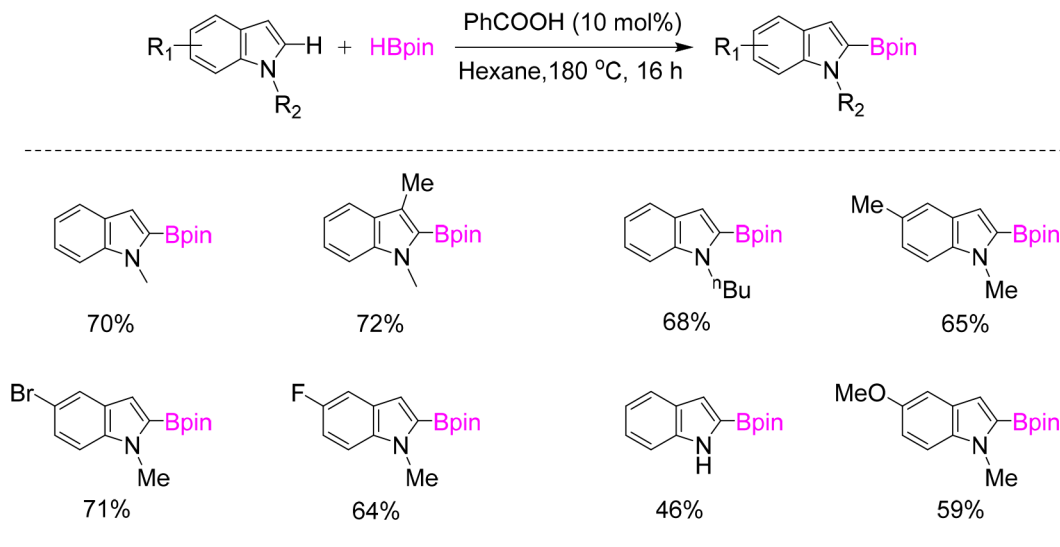


Table 7. C–H Borylation of Indole Using PhCOOH as a Catalyst and HBpin as a Borylating Agent



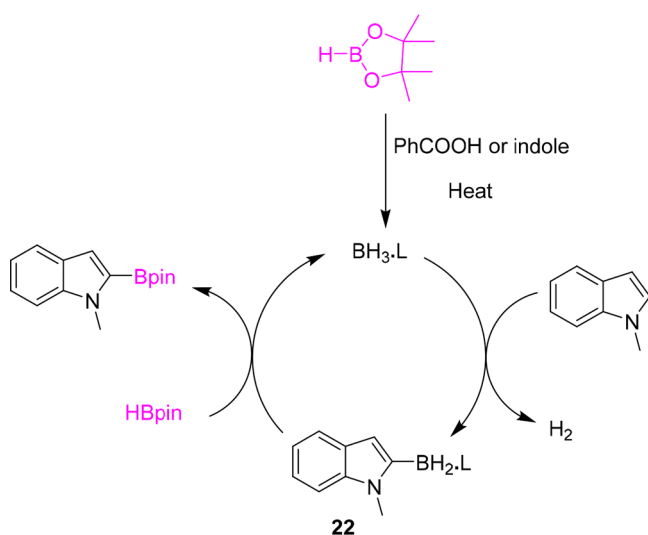
12. Initially, treatment of 2-bromoaniline with 1,5-dibromopentane and diisopropylethylamine at 140 °C for 48 h resulted in the formation of **23''**. Treatment of **23''** with *n*-BuLi/ $B(OMe)_3$ and KHF_2/HCl afforded **23**.

The bench-stable fluoroborate salt (**23**) exhibited good activity for the dearomative hydroboration of *N*-sulfonyl indoles in the presence of HBpin. The resultant C3-borylated indolines were obtained in excellent yields, having various electron-rich and electron-poor substrates. The study revealed that, 2-methyl-*N*-sulfonylindoles undergoes the reaction in stereoselective manner to furnish the reduced borylated product in *trans* fashion between the existing Me group and the newly incorporated Bpin group (highlighted in Table 10).

A combined experimental and computational study for the dearomative hydroboration reaction is outlined in Scheme 13. Initially, the reaction between **23** and excess HBpin lead to the formation of the dimeric borane **24** with the elimination of FBpin and H_2 gas. Next, the in situ transformation of the dimeric borane compound (**24**) to the monomeric active catalyst **25** takes place. Then, compound **25** undergoes the reaction with the *N*-sulfonyl indoles in a *cis* fashion across the H–B bond to form intermediate **27** through transition state **26**. Following this, the reaction between **27** and HBpin led to the formation of the desired dearomative C3-borylated indolines.

Later, the same group explored the hydroboration of *N*–H indoles with catalytic amount of $BH_3 \cdot SMe_2$ and stoichiometric

Scheme 11. Proposed Mechanistic Pathway of C2-Borylation of Indole



amount of HBpin in CDCl_3 at 60°C for 2–16 h³³ (Table 11). Interestingly, the reaction proceeds with the formation of the corresponding indolines with various electronically different substituents in good to excellent yields with an N-Bpin bond. A detailed experimental and computational study was performed to understand the mechanism of the present protocol. The study

showed that the reaction proceeds with the generation and consumption of the H_2 gas via the FLP-type mechanism.

Initially, the reaction between $\text{BH}_3\cdot\text{SMe}_2$ and indole produced an intermediate N-BH₂ indoline (28) that can exist in equilibrium with the dimer 28' (Scheme 14). Intermediate 28 can advance via two possible catalytic cycles to afford the N-Bpin indoline. In cycle A, intermediate 28 undergoes metathesis with HBpin to furnish the desired product. On the other hand, in cycle B, intermediate 28 initially disproportionate to form the diamineborane intermediate (29) which subsequently reacts with HBpin to give the final product. Interestingly, the DFT calculation suggests the latter cycle is more favorable over the previous one.

Very recently, Ingleson et al.³⁴ demonstrated an excellent protocol for the borylation-directed borylation strategy wherein the reactivity of pyrazole-derived electrophiles (30 and 31) were explored to transform N-H-indoles to C7-borylated-indolines (Table 12). The boron derivatives (30 and 31) were synthesized from pyrazole via a two-step process (Scheme 15). Initially, the reaction of $\text{BH}_3\cdot\text{SMe}_2$ with pyrazole in DCM resulted in the formation of 30, which upon treatment with NHTf_2 afforded 31. The structure of 31 was confirmed through single-crystal X-ray diffraction analysis.

The hydroboration reaction is proposed to proceed via Scheme 16. At the outset, treatment of 30 and 31 in equimolar amounts resulted in the formation of reactive mono- NTf_2 intermediate 32 (Scheme 16). Following this, the reaction of 32 with unprotected indole furnished 33 through hydro-

Table 8. Directing-Group-Assisted C–H Borylation of Indole Using BBr_3

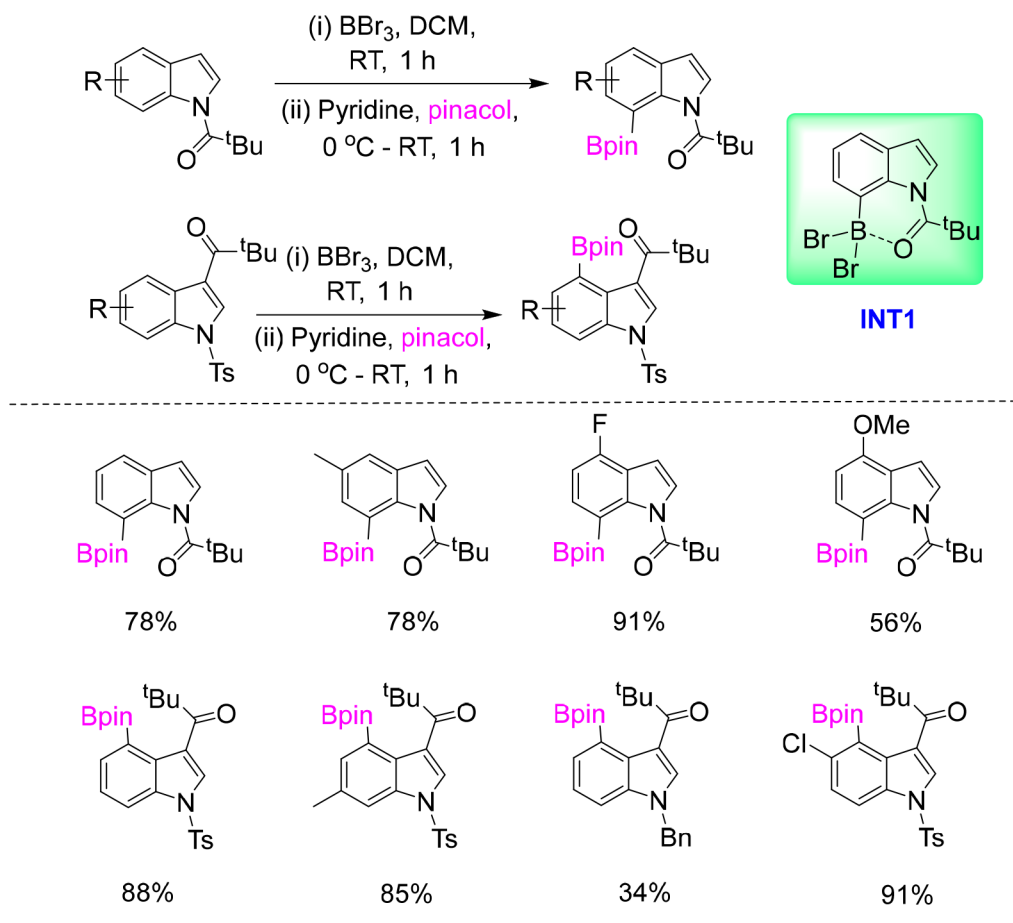


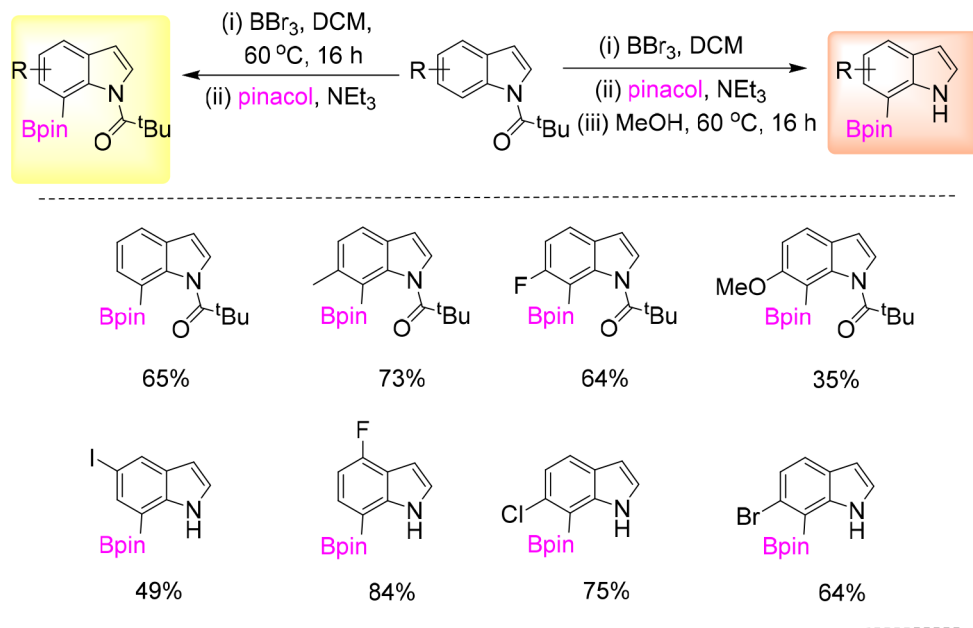
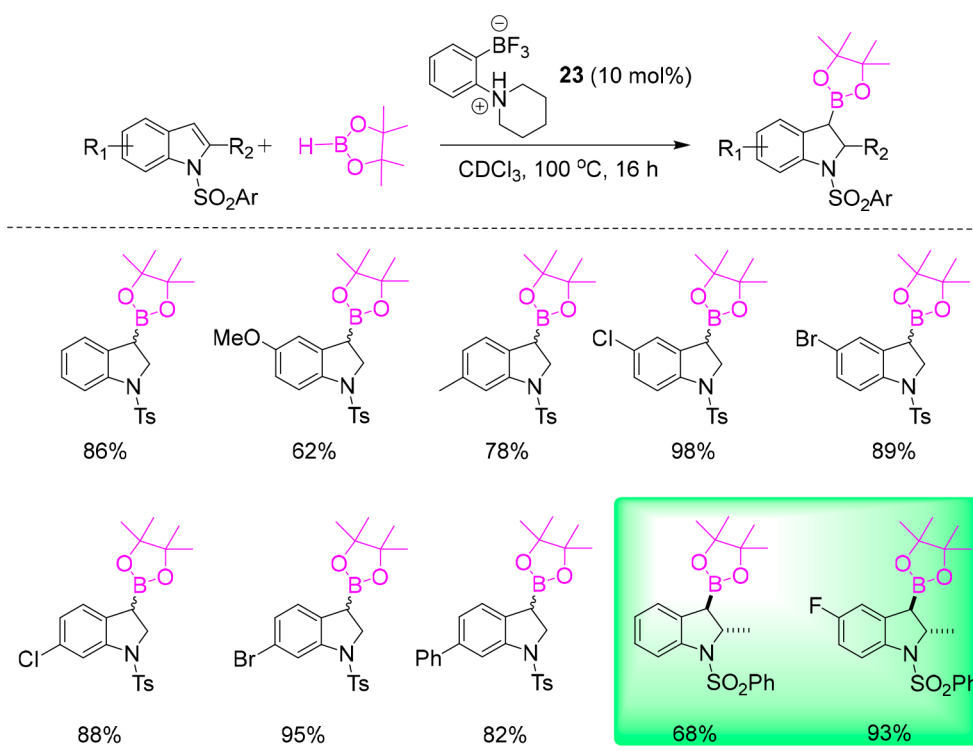
Table 9. Directing-Group-Assisted C–H Borylation of Indole Using BBr₃

Table 10. Hydroboration of Indoles Using HBpin as the Borylating Agent



boration/C3-protoboration. Subsequently, the intramolecular C–H borylation gave **34** which after workup resulted in the formation of the C7-borylated indoline.

3. APPLICATIONS OF THE BORYLATED PRODUCTS

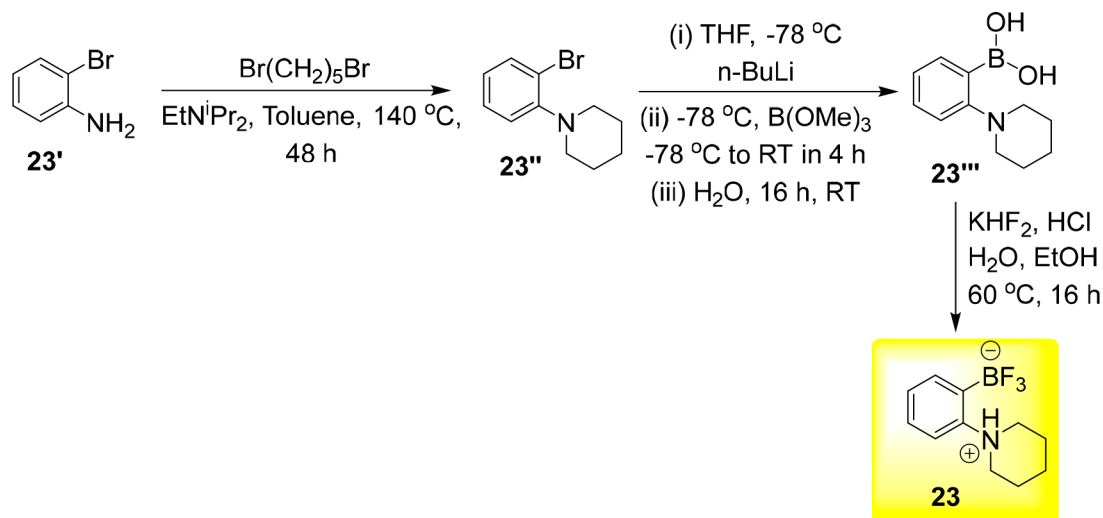
The borylated indoles and indolines can be transformed into several value-added products.¹⁴ Herein, we have shown only a few of them with C7-Bpin indole. Notably, various organic transformations, such as Suzuki–Miyaura coupling and other coupling reactions can be performed with these organoboron

compounds to synthesize a plethora of C7-functionalized indoles (Scheme 17).³⁵ Likewise, the organoboron substituents at other positions of the indoles can be transformed into various useful functional groups.

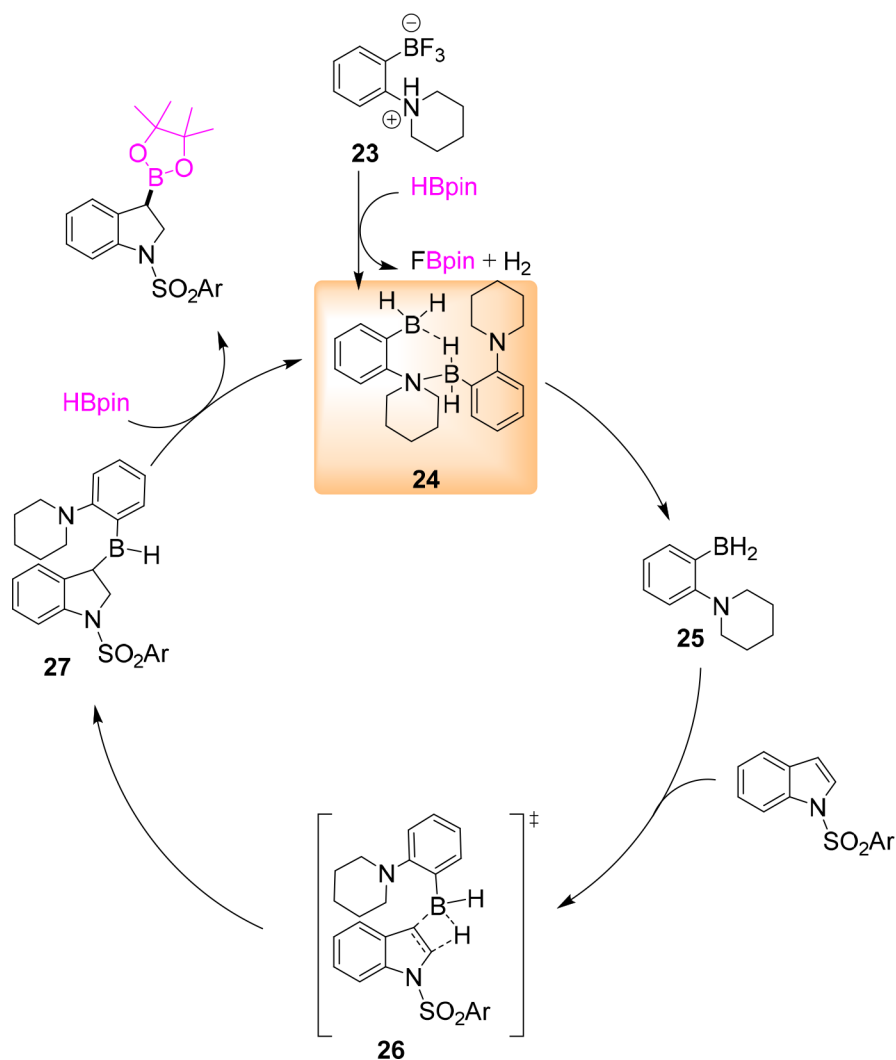
CONCLUSION AND FUTURE OUTLOOK

As seen in this mini-review, significant advancement has been achieved in C–H borylation and hydroboration reactions of indoles with metal-free catalytic systems. Substantial progress has been made with metal-free catalytic systems that exhibit

Scheme 12. Synthesis of Precatalyst 23



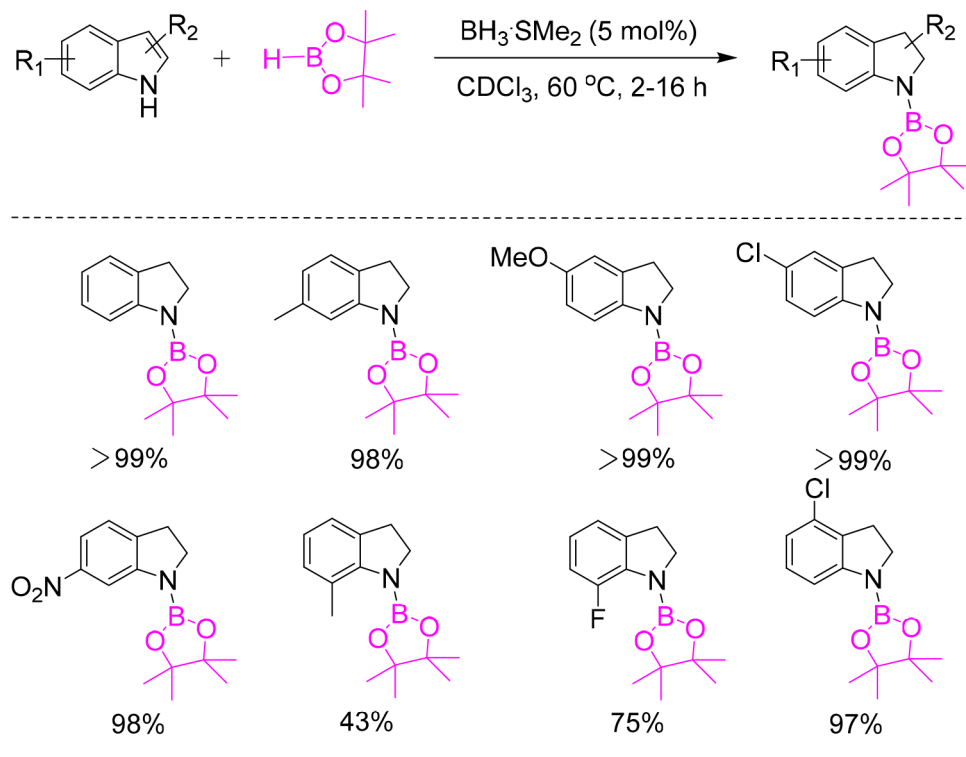
Scheme 13. Plausible Mechanistic Pathway for Hydroboration of Indole



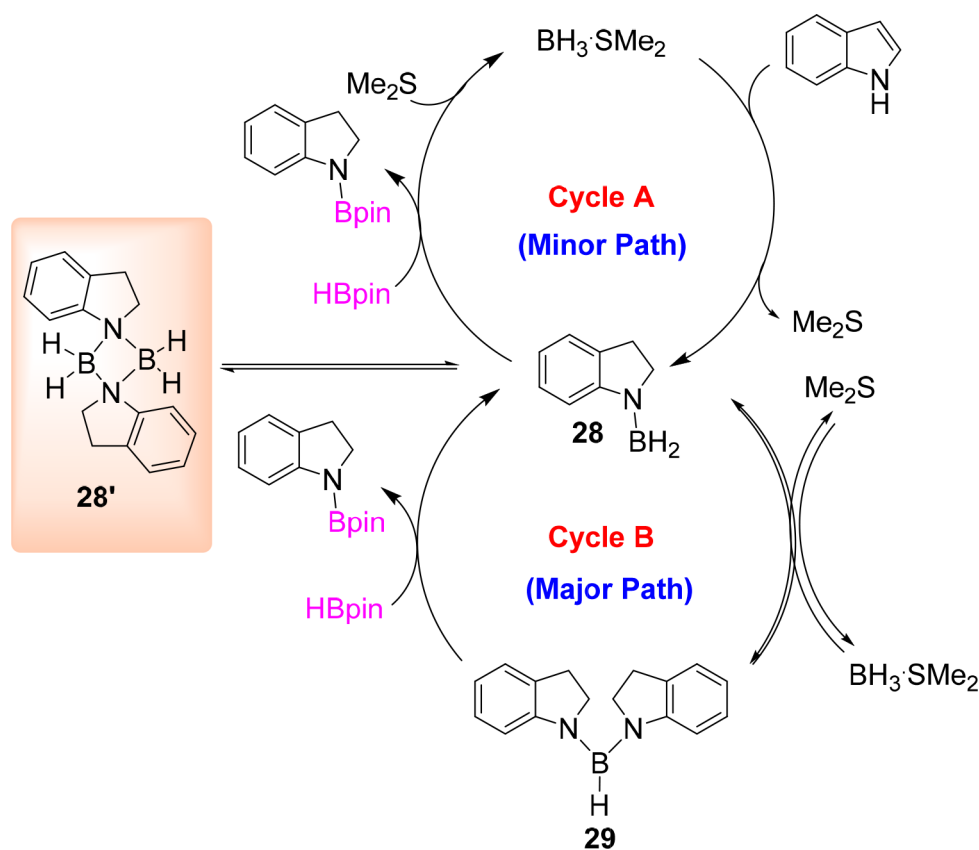
catalytic activity similar to that of transition metal systems. In this context, various electrophilic borylating agents were developed that resulted in the formation of borylated products at the electron-rich C3-sites of indoles. Moreover, the C2-

borylation of indoles has been achieved by suitable design of the catalytic systems/borylating agent. Intriguingly, a notable evolution has also been obtained by the introduction of the directing group on the indole nitrogen atom. With the

Table 11. Hydroboration of Indoles Using HBpin as a Borylating Agent



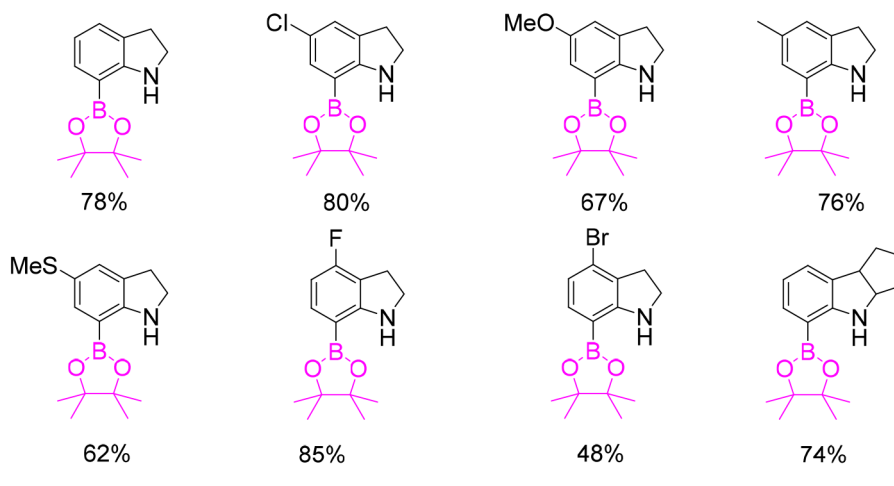
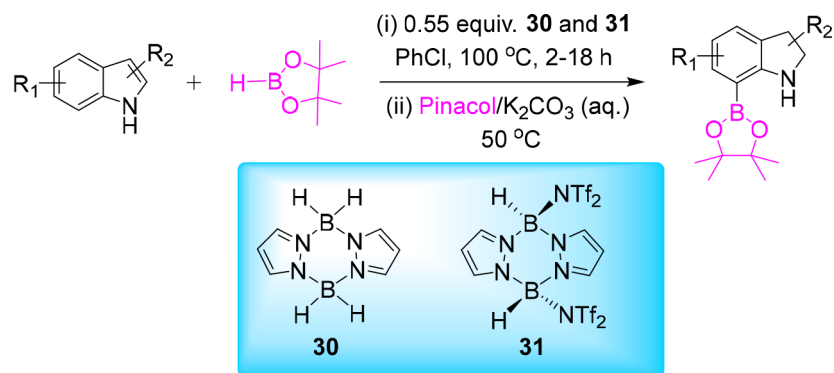
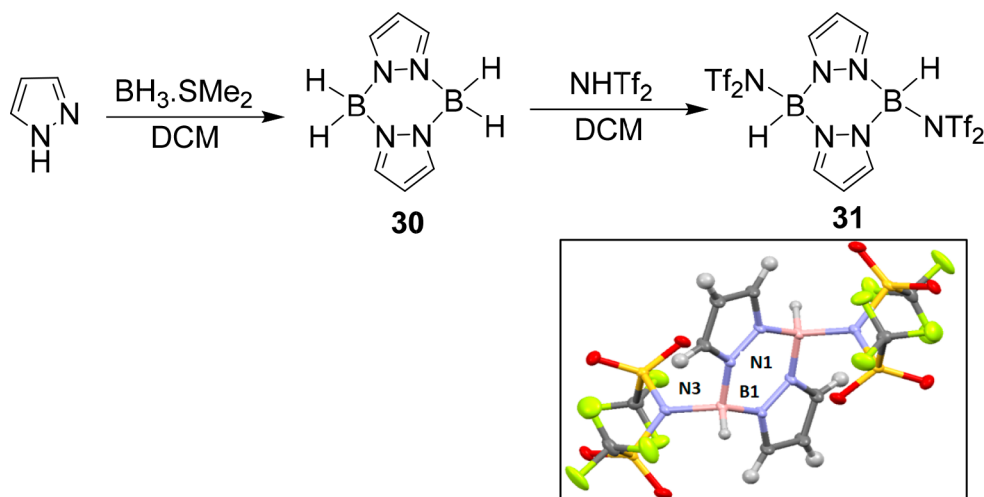
Scheme 14. Plausible Mechanistic Pathway for Hydroboration of Indole



introduction of acyl functional groups on the indole, borylation was achieved at the unusual C4- and C7-positions. Apart from the C–H borylation reaction, the field of metal-free hydro-

boration of indoles leading to the formation of the dearomatized borylated products has also shown steady progress.

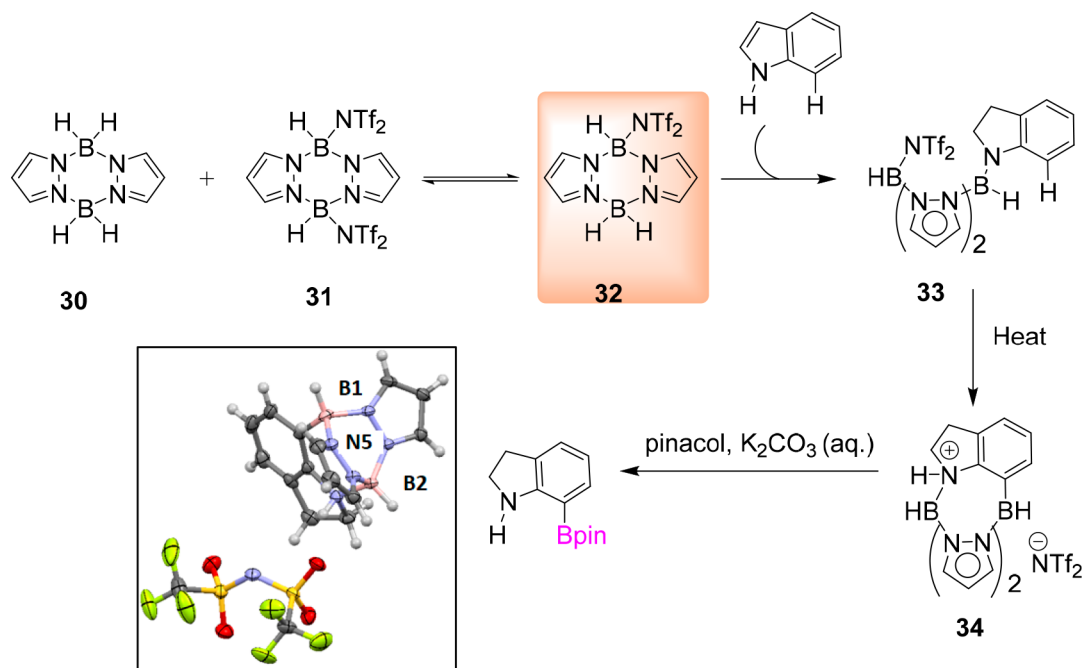
Table 12. C7-Hydroboration of Indoles Using HBpin as the Borylating Agent

Scheme 15. Synthesis of **30** and **31** (X-ray Structure of **31** in the Inset)

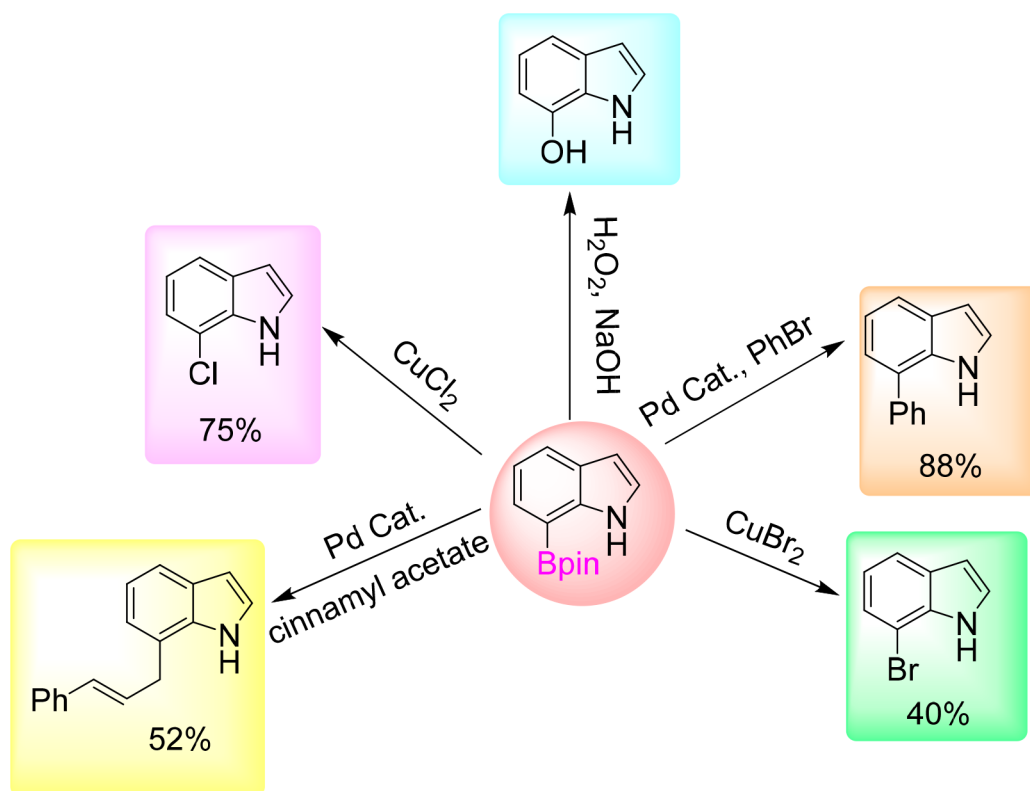
Importantly, despite the recent development of C–H borylation and hydroboration reactions of indoles with metal-free catalytic systems, their widespread application is yet to be explored at full capacity. In terms of future development, the catalytic systems that can be employed at low temperatures with greater functional group compatibility and a higher turnover number (TON) will be preferable. Moreover, most of the metal-free borylation and hydroboration reactions were accomplished with reactive boron electrophiles. As a result of that, controlling the regioselectivity of C–H functionalization has become a key

issue. Apart from this, carrying out the reaction under relatively mild conditions in green solvents, such as water, will be attractive in the future. Additionally, the advancement of chiral metal-free systems for enantioselective catalysis will be another avenue for the C–H borylation and hydroboration reactions that need special attention. We hope that this review will stimulate more such studies in this intriguing area of chemistry and lead to new and exciting discoveries in days to come.

Scheme 16. Plausible Mechanistic Pathway for C7-Hydroboration of Indoles (X-ray Structure of 34 in the Inset)



Scheme 17. Functionalization of 7-Borylated Indole



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Notes

The authors declare no competing financial interest.

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