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Substrate-Controlled Transformation of Azobenzenes to Indazoles and Indoles via Rh(III)-Catalysis

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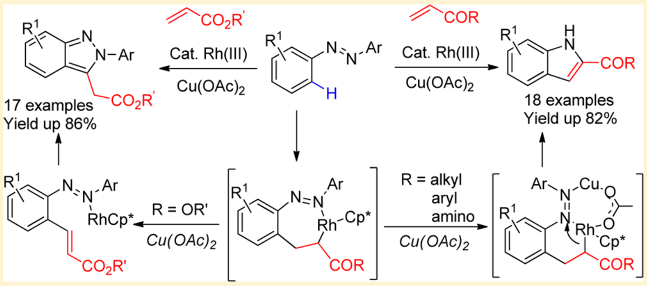
Supporting Information

ABSTRACT: Rh(III)-catalyzed substrate-controlled transformation of azobenzenes to indazoles and 2-acyl (NH) indoles is achieved via C−H functionalization. Generally, good functional groups tolerance, satisfying yields, and excellent regioselectivity are achieved in this reaction. Mechanistically, the reaction with acrylates undergoes *β*-hydride elimination, while the reaction with vinyl ketones or acrylamides undergoes nucleophilic addition. Copper acetate was supposed to play different roles in the *β*-hydride elimination to furnish indazoles and nucleophilic addition of C−Rh bond to deliver 2-acyl (NH) indoles.



INTRODUCTION

Indazoles and indoles represent two kinds of the most prevalent heterocycles in pharmaceuticals and biologically active molecules.[1] Consequently, numerous efforts have been devoted to construct these biologically important skeletal motifs. Traditionally, indazoles are formed by the condensation/cyclization of aryl ketone and hydrazine,[2] or by the cross-coupling/cyclization of *o*-halo phenylacetylene and hydrazine.[3] Indoles are prepared by Fisher,[4] Larock,[5] Buchwald,[6] and Hegadus[7] indole synthesis.

Recently, remarkable progress in transition-metal-catalyzed C−H bond functionalization has enabled the generation of indazoles and indoles via selective transformation of C−H bonds, which possesses gratifying atom- and step-economy. The synthesis of indazoles via C−H functionalization strategy mostly relies on the addition of C−H bond toward aldehydes, followed by the intramolecular cyclative capture of azo group. Within this method, rhodium,[8a−d] cobalt,[8e] and rhenium[8f] catalysts have been employed to give indazole products (Scheme 1, set A). The synthesis of indoles via C−H functionalization strategy often depends on intramolecular annulation of *N*-arylenamines or imines.[9] or intermolecular cyclization of anilines and alkynes under oxidative[10] or redox neutral[11] conditions (Scheme 1, set B). More recently, Glorius' group[12a] and Jana's group,[12b] respectively reported intermolecular oxidative cyclization of anilines and alkenes to deliver indole skeleton with substituent on the 1-position (Scheme 1, set C). To the best of our knowledge, no catalytic C−H annulation method has ever been established to selectively deliver 2-acyl (NH) indoles from simple starting materials. Herein, we would like to report a substrate-controlled transformation of azobenzenes to indazoles and indoles via rhodium-catalyzed C−H activation in the presence of Cu(OAc)$_2$. The reaction with acrylates afforded indazole skeleton (Scheme 1, part 1). The reaction with vinyl ketones or acrylamides afforded indole skeleton (Scheme 1, part 2).

RESULTS AND DISCUSSION

Optimization Studies. Initially, we treated azobenzene **1a** with methyl acrylate **2a** using [Cp*RhCl$_2$]$_2$ as a catalyst, Cu(OAc)$_2$ as an oxidant, 1,2-dichloroethane (DCE) as a solvent, at 90 °C under nitrogen atmosphere, product **3aa** was obtained in 71% yield (Table 1, entry 1). Encouragingly, the yield of the product was further improved to 90% by increasing the reaction temperature to 130 °C (entries 2−3). Reduction of the catalyst or oxidant resulted in slightly lower yields (entries 4−5). Solvent screening disclosed that DCE was the most efficient medium for this reaction (entries 6−9). No product was observed when either [Cp*RhCl$_2$]$_2$ or Cu(OAc)$_2$ was used alone (entries 10−11). Other catalysts, such as [(COD)RhCl]$_2$, [(*p*-cymene)RuCl$_2$]$_2$, RuCl$_2$(PPh$_3$)$_3$, [Cp*IrCl$_2$]$_2$, and Pd(OAc)$_2$, were proved to be of no activity for this transformation. Other oxidants, such as CuCl$_2$ and AgOAc, failed to improve the reaction yields (see SI). Therefore, entry 3 was chosen as the optimal reaction conditions for the indazole synthesis.

Substrates Scope and Limitations for Formation of Indazoles. Having arrived at the optimal conditions, we next explored a diverse set of azobenzenes **1** and alkenes **2**. The representative results are shown in Table 2. First, a series of acrylates **2a−e** were examined. The acrylates **2a−e** reacted with

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Scheme 1. Synthesis of Indazoles and Indoles via C−H Functionalization

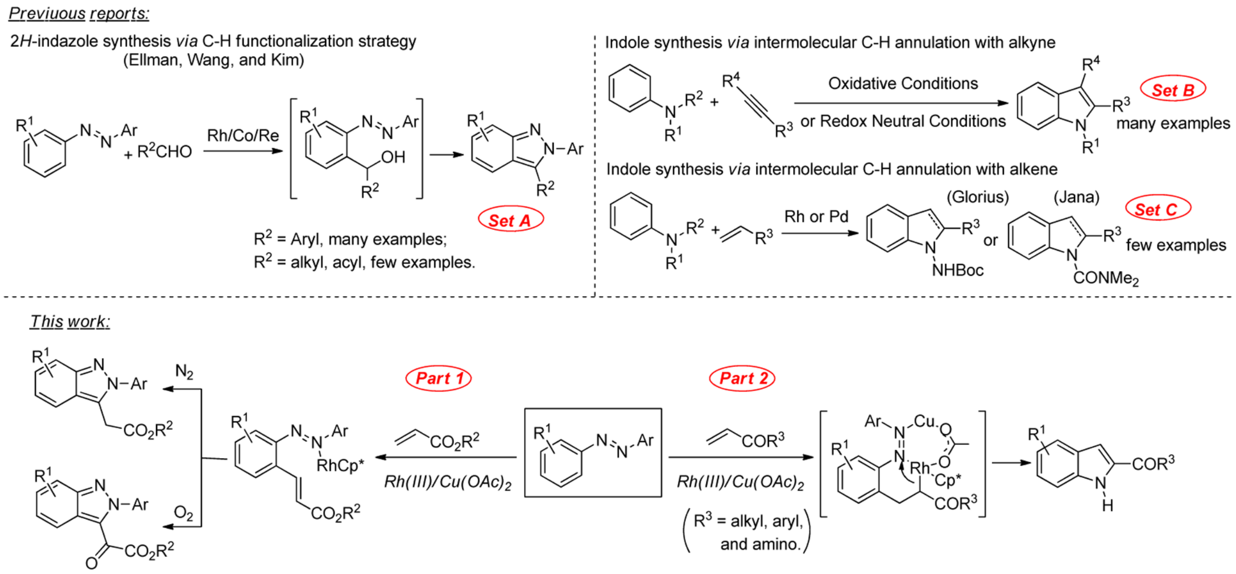
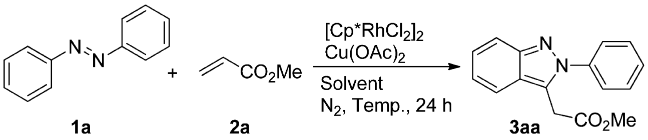


Table 1. Optimization of Reaction Conditions[a]



entry	$[Cp^*RhCl_2]_2$ (%)	$Cu(OAc)_2$ (equiv)	solvent	temp. (°C)	yield (%)[b]
1	5	2	DCE	90	71
2	5	2	DCE	110	84
3	5	2	DCE	130	90 (83[c])
4	2.5	2	DCE	130	81
5	5	1	DCE	130	85
6	5	2	toluene	130	n.r.
7	5	2	dioxane	130	n.r.
8	5	2	DMF	130	74
9	5	2	MeCN	130	64
10		2	DCE	130	n.r.
11	5		DCE	130	n.r.

[a]Conditions: **1a** (0.1 mmol), **2a** (0.12 mmol), $[Cp^*RhCl_2]_2$ (5 mol %), $Cu(OAc)_2$ (0.2 mmol), solvent (0.5 mL) under nitrogen atmosphere. [b]Yield determined by ^1H NMR. [c]Isolation yield.

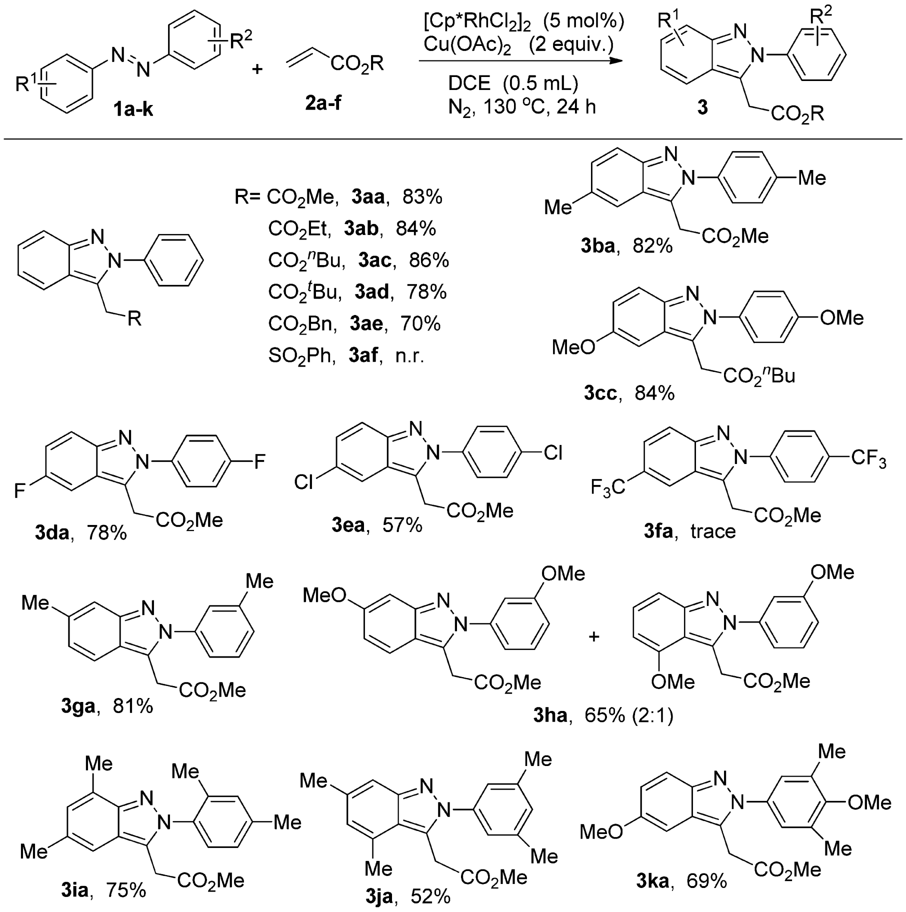
azobenzene **1a** to generate indazoles **3aa−3ae** in good yields, yet phenyl vinyl sulfone and dimethyl vinyl phosphonate failed to react with azobenzene **1a** under standard conditions. Then, a range of azobenzenes were conducted and results are summarized in Table 2. Electron-donating and electron-withdrawing substituents, such as Me, OMe, F, and Cl, on azobenzene led to the indazole products **3ba−3ea** in moderate to good yields, while the stronger electron-withdrawing group, such as CF_3, only give trace product detected by GC-MS **3fa**. Notably, crystals of **3da** was suitable for single crystal analysis, and its structure was fully characterized by X-ray diffraction analysis, which cleanly confirmed formation of the indazole backbone. We further extended the reaction using *meta*- or *ortho*-substituted azobenzenes, such as **1g−k**. With the *m*-methyl substituent afforded the desired indazole **3ga** exclusively at the less hindered site, while *m*-methoxyl substituent resulted in a mixture of two regio isomers in 65% combined yield with 2:1 ratio favoring functionalization at the less hindered position, such as **3ha**. It is also significant that the indazole products **3ia−3ja** can be obtained in good yields from disubstituted azobenzenes. When an unsymmetric azobenzene was employed, the reaction site satisfyingly focused on the less hindered position to give product **3ka** in 69% yield. When unsymmetric substrates, such as (*E*)-1-phenyl-2-(4-(trifluoromethyl)phenyl)diazene and (*E*)-methyl 4-(phenyldiazenyl)benzoate, were used, trace products were observed in both reactions. This may be due to the decrease of coordination ability of the azo group.

It was noteworthy that when the reaction was carried out under oxygen atmosphere, 3-acyl indazole product was yielded with the capture of molecular oxygen. Some representative results are shown in Table 3.

Scope and Limitations for Formation of Indoles. Further extension of this rhodium catalytic system toward vinyl ketone substrates led to fascinating 2-acyl (NH) indole products and the corresponding anilines were obtained as byproducts. Considering the volatility of vinyl ethyl ketone, two equivalents of vinyl ethyl ketone was used to enhance the yields. After optimization of the reaction conditions (see SI), this novel indole synthesis reaction was next explored with a diverse set of azobenzenes and vinyl ketones. The typical results are shown in Table 4. A broad range of synthetically useful functional groups, such as Me, OMe, F, Cl, and Br, on azobenzene were found to be compatible with this reaction, and gave the expected indole products in moderate to good yields. Notably, the tolerance of halides is particularly important thanks to their great capabilities of further transformation via a traditional cross-coupling reaction. Encouragingly, the stronger electron-withdrawing substituents, such as trifluoromethyl and methoxycarbonyl, are well tolerated in this reaction. Moreover, sterically hindered azobenzene **1j** also reacted smoothly to give indole product **5jg** in satisfying yield. Exclusive regioselectivity was also observed when unsymmetrically substituted azobenzenes, such as **1k**, **1l**, and **1n**, were employed in this approach.

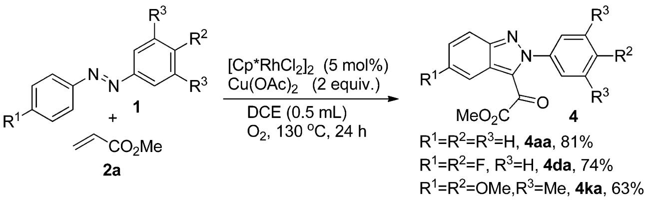
It was known that 2-aroyl indole derivatives were identified as a new class of potent tubulin-inhibitory and antimitotic agents.[13] Consequently, different kinds of vinyl aryl ketones were investigated under the standard conditions. The

Table 2. Scope of Indazoles Formation[a]



[a]Conditions: **1** (0.1 mmol), **2** (0.12 mmol), $[Cp^*RhCl_2]_2$ (5 mol%), $Cu(OAc)_2$ (0.2 mmol), DCE (0.5 mL), under nitrogen atmosphere. All yields are isolated yields.

Table 3. Capture of Molecular Oxygen in Indazole Formation[a]



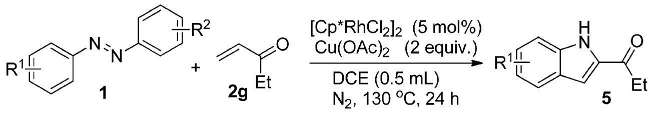
[a]Conditions: **1** (0.1 mmol), **2** (0.12 mmol), $[Cp^*RhCl_2]_2$ (5 mol%), $Cu(OAc)_2$ (0.2 mmol), DCE (0.5 mL), under oxygen atmosphere. All yields are isolated yields.

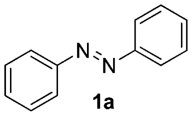
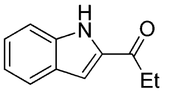
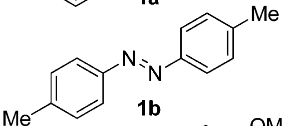
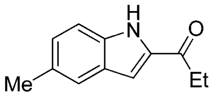
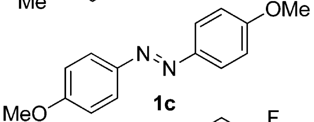
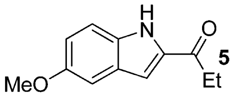
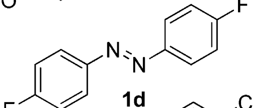
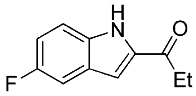
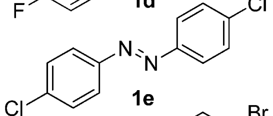
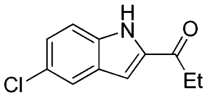
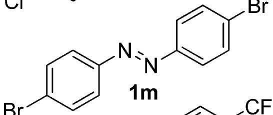
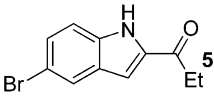
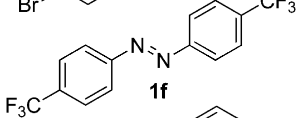
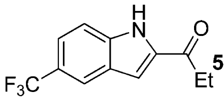
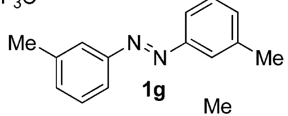
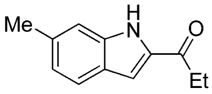
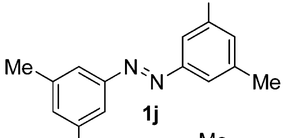
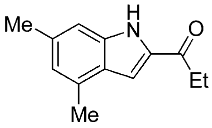
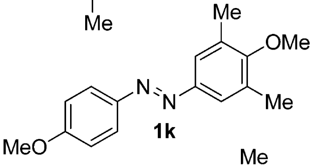
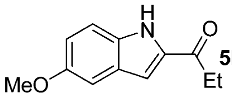
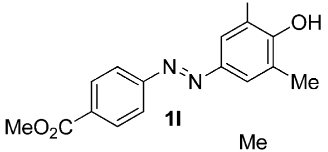
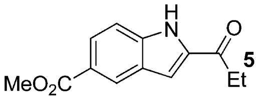
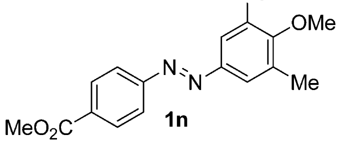
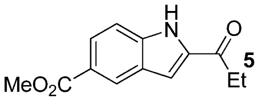
representative results are shown in Table 5. Both aryl and heteroaryl vinyl ketones can proceed smoothly to furnish biologically valuable 2-aroyl indoles in good yields, such as **5ah**, **5ai**, and **5aj**. Gratifyingly, antimitotic agent **5cl** can also be obtained in gram scale using this method. What is more, when *N*,*N*-dimethyl acrylamide was treated with azobenzenes under the standard conditions, the expected indole 2-carboxamides, such as **5ak**, **5fk**, and **5gk**, were obtained successfully. However, when chalcone **2m** was used, the reaction did not proceed and starting materials remained.

■ MECHANISTIC INVESTIGATION

To gain some insights of the reaction mechanism, additional experiments were performed. For indazole formation process, the olefinated azobenzene **6** was prepared (see SI) and treated with standard conditions to give a quantitative indazole **3aa**, indicating the olefinated azobenzene **6** is likely to be the key intermediate in the formation of indazole (Scheme 2a). For indole formation process, we first tried to prepare (*E*)-1-(2-((*E*)-phenyldiazenyl)phenyl)pent-1-en-3-one and it failed. So we prepared (*E*)-*N*,*N*-dimethyl-3-(2-((*E*)-phenyldiazenyl)-phenyl)-acrylamide **6′**. When the olefinated azobenzene **6′** was treated under the standard conditions and a quantitative yield of indazole **3ak** was obtained, revealing that the olefinated azobenzene **6′** was unlikely to be the intermediate for indole formation (Scheme 2b). To understand the role of $Cu(OAc)_2$ in the formation of indole, the model reaction was carried out without the addition of $Cu(OAc)_2$, no product was observed (Scheme 2c). Replacing $Cu(OAc)_2$ with KOAc also failed to give indole product, only trace amount of indazole **3ag** was detected by GC-MS (Scheme 2d). Moreover, the addition of catalytic amount of $Cu(OAc)_2$ led to 65% of olefin insertion product **7**, rather than the expected indole product **5ag** (Scheme 2e), indicating that stoichiometric amount of $Cu(OAc)_2$ is undoubtedly necessary for the indole formation. Furthermore, when compound **7** was treated under the standard conditions, the corresponding indole product **5ag** was generated in moderate yield (47%) (Scheme 2f), revealing that compound **7** is possibly to be the key intermediate in the indole formation process. In order to gain more insights of the mechanism of indole formation, a five-membered cyclo-

Table 4. Scope for the Formation of 2-Propionyl (NH) Indoles[a]

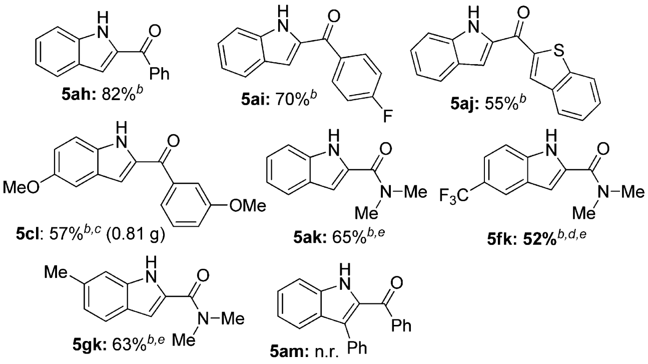


azobenzene	product		yield (%)[b]
 **1a**		**5ag**	76
 **1b**		**5bg**	80
 **1c**		**5cg**	73
 **1d**		**5dg**	71
 **1e**		**5eg**	51
 **1m**		**5mg**[c]	54
 **1f**		**5fg**[c]	73
 **1g**		**5gg**	81
 **1j**		**5jg**	72
 **1k**		**5kg**	67
 **1l**		**5lg**[c]	45
 **1n**		**5lg**[c]	50

[a]Conditions: **1** (0.1 mmol), **2** (0.2 mmol), [Cp*RhCl$_2$]$_2$ (5 mol%), Cu(OAc)$_2$ (0.2 mmol), DCE (0.5 mL), under nitrogen atmosphere. [b]Isolation yield. [c]AgSbF$_6$ (20 mol%) was added.

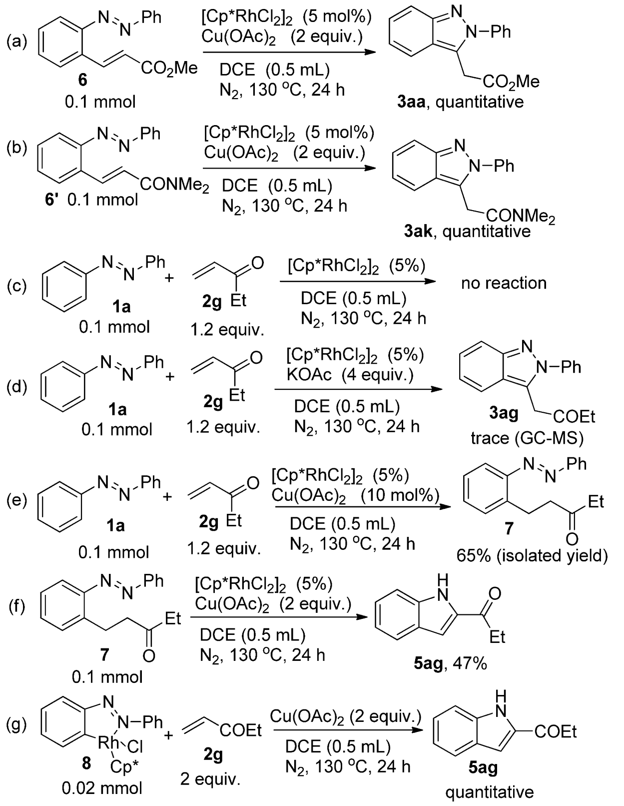
rhodium intermediate **8** was prepared (see SI) and treated with **2g** in the presence of two equivalents of Cu(OAc)$_2$, and the expected indole **5ag** was found to be the main product (Scheme 2g).

Table 5. Scope for the Synthesis of 2-Acyl (NH) Indoles[a]

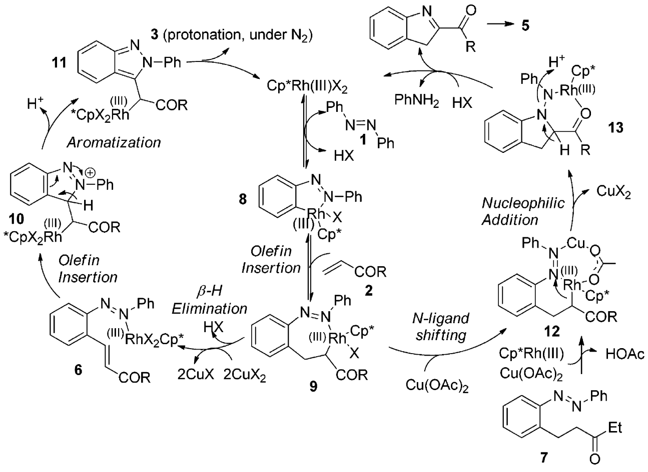


[a]Conditions: **1** (0.1 mmol), **2** (0.12 mmol), $[Cp^*RhCl_2]_2$ (5 mol%), $Cu(OAc)_2$ (0.2 mmol), DCE (0.5 mL), 130 °C for 24 h, under nitrogen atmosphere. [b]Isolation yield. [c]In 5 mmol scale. [d]$AgSbF_6$ (20 mol %) was added. [e]A little amount of corresponding indazole was detected as byproduct in GC-MS.

Scheme 2. Mechanistic Experiments



Scheme 3. Proposed Catalytic Cycles



Based on the preliminarily mechanistic experiments (see more details in SI) and reported literature,[12a] we proposed a mechanism as shown in Scheme 3. First, the C−H bond of azobenzene is activated by Rh(III) species to give a five-membered cyclo-rhodium species **8**, which is followed by alkene coordination and insertion to afford the seven-membered rhodacycle **9**. Following the insertion, if the substituent is an ester group (−COOR′), the *β*-hydride elimination occurred to give an olefined azobenzene, which subsequently undergoes insertion of C═C bond into Rh−N bond, and then aromatization to yield indazole. If the substituent is an acyl group (−COR″) or acylamino group ($-CONR_2'$), the weaker electron-withdrawing inductive effect of carbon, nitrogen (electronegativity: $CH_3 = 2.55$, $NH_2 = 3.12$, $OH = 3.55$)[14] possibly inhibited competitive *β*-hydride elimination, allowing the rearrangement of intermediate **9** to give more stable six-membered coordinately saturated Rh species **12** with the assistance of copper acetate. The C−Rh bond of intermediate **12** presumably undergoes nucleophilic addition toward N═N bond to afford intermediate **13**, which further undergoes N−N bond cleavage and aromatization to give free indole products. In this part, copper acetate possibly acts as Lewis acid to accelerate nucleophilic addition by coordinating with azo group, which is different from previous N-Boc strategy.[12a]

■ CONCLUSION

In summary, we reported a selective transformation of azobenzenes to indazoles and indoles via rhodium-catalyzed C−H functionalization. The reaction of azobenzene and acrylates provided a method for the construction of the indazole skeleton. The reaction of azobenzenes with vinyl ketones or acrylamides represented a novel and efficient route for synthesis of 2-acyl (NH) indoles from simple starting material. It was noteworthy that good functional groups tolerance, satisfying yields, and excellent regioselectivity were achieved in this reaction.

■ EXPERIMENTAL SECTION

General Information. Toluene, 1,2-dichloroethane, 1,4-dioxane, MeCN, and DMSO were fresh distilled. Unless otherwise indicated, all materials were obtained from commercial sources and used as received. ^1H NMR and ^{13}C NMR spectra were recorded by 400 MHz spectrometer using $CDCl_3$ or DMSO−D_6 as the solvent. The melting points were measured on X-4 digital melting point apparatus and were uncorrected. HRMS were obtained with ESI in positive or negative ion mode on IT-TOF instrument.

General Procedure for the Synthesis of azo Compounds (1b−1j, 1m). According to the literature,[15] the following azo compounds were prepared by this procedure: CuBr (34.4 mg, 0.24 mmol), pyridine (58.0 *μ*L, 0.72 mmol), and corresponding aniline (4 mmol) were mixed in toluene (20 mL). Under O_2 atmosphere, the reaction mixture was stirred vigorously at 60 °C for 24 h. After completion, the reaction mixture was cooled down to room temperature and concentrated under vacuum. Then, the residue was purified by flash chromatography on a short silica gel (eluent: petroleum ether) to afford the corresponding azo compounds.

General Procedure for the Synthesis of azo Compounds (1k, 1l, 1n). According to the literature,[16] the asymmetric azo compounds were prepared by this procedure: aqueous HCl solution (25 mL, 1M) was added to a round-bottom flask equipped with a stir bar. After cooling to 0 °C, the indicated aniline (10.0 mmol, 1.0 equiv) was added to the reaction mixture, and stirred for 10 min. Then, $NaNO_2$ (0.725 g, 10.5 mmol, 1.05 equiv) in water (35 mL) was added dropwise. The solution was stirred for additional 10 min and then was transferred into a round-bottom flask containing 1,3-dimethylphenol (1.22 g, 10.0 mmol, 1.0 equiv). At 0 °C, NaOH (0.400 g, 10.0 mmol, 1.0 equiv) in a mixture of water (100 mL) and ethanol (35 mL) was added via cannula. Red precipitate formed instantly, and the solution was stirred for 6 h at 0 °C. The mixture was filtered, and the red solid residue was purified by flash column chromatography with hexanes/ethyl acetate (9:1) to afford the azobenzene as a red powder.

The methylation of phenol was proceeded by the following procedure: the phenol-containing azo compound (752.6 mg, 2.94 mmol) was treated with K_2CO_3 (492 mg, 3.56 mmol). Under N_2, acetone (8.5 mL) was added to the reaction mixture, and the reaction mixture was stirred for 3 min. Then, MeI (500 μL, 8.03 mmol) was added to the reaction mixture, which was refluxed at 70 °C for 24 h. After completion, the reaction mixture was cooled to room temperature, and extracted with ethyl acetate for three times. After concentration under vacuum, the residue was purified by flash chromatography on a short silica gel (eluent: petroleum ether/ethyl acetate = 20:1) to afford the corresponding product.

General Procedure for the Synthesis of Vinyl Ketone Substrates (2h–2j, 2l). The vinyl ketone substrates were prepared according the literature:[17] to a solution of aldehyde (10 mmol) in dry THF (50 mL), vinyl magnesium bromide (10 mL, 1 equiv., 1 M in THF) was added dropwise at 0 °C. After stirring for 20 min, the reaction mixture was allowed to warm to room temperature, and stirred for additional 3 h. Then, the reaction was quenched by addition of saturated aqueous NH_4Cl and extracted with EtOAc for three times. The organic phase was washed with brine, dried over magnesium sulfate, filtered, and concentrated under reduced pressure to provide the respective allylic alcohol.

To a solution of the allylic alcohol (8 mmol) in CH_2Cl_2 (10 mL), iodobenzene diacetate (2.84 g, 1.1 equiv) and TEMPO (125 mg, 0.1 equiv) were added. The mixture was stirred at room temperature for 3 h. After completion, the reaction was quenched by saturated aqueous $Na_2S_2O_3$. The aqueous phase was extracted with CH_2Cl_2 for three times. The combined organic phases were washed with saturated aqueous $NaHCO_3$ and brine, dried over magnesium sulfate, filtered, and concentrated. Purification by column chromatography (silica, petrol ether/ethyl acetate = 20/1) afforded the corresponding vinyl ketone.

Preparation for Cyclorhodium Intermediate 8. A 25 mL sealed tube was charged with azobenzene (36.4 mg, 0.2 mmol), $[Cp^*RhCl_2]_2$ (60 mg, 0.1 mmol), and NaOAc (32.8 mg, 0.4 mmol). Under nitrogen atmosphere, DCE (1 mL) was added, then the tube was sealed. The mixture was allowed to stir at 130 °C for 24 h. After completion, the mixture was cooled to room temperature, and diluted with 1 mL CH_2Cl_2. The resulting mixture was filtered over a pad of Celite, and further washed with 5 mL CH_2Cl_2. The combined organic phase was concentrated and purified by column chromatography (silica, petrol ether/ethyl acetate = 3/1) to afforded the cyclo rhodium five member ring as a dark brown solid.

Preparation for Olefinated Azobenzene 6. A 25 mL sealed tube was charged with *o*-bromo aniline (0.86g, 5 mmol) and $PdCl_2(PPh_3)_2$ (175 mg, 5 mol %). Under N_2 atmosphere, methyl acrylate (0.55 mL, 6 mmol), and Et_3N (10 mL) were added, then the tube was sealed. The mixture was allowed to stir at 100 °C for 24 h. After completion, the mixture was cooled to room temperature, then H_2O (20 mL) was added and the mixture was extracted with EtOAc, dried by anhydrous Na_2SO_4. Evaporation of the solvent followed by purification by column chromatography (silica, petrol ether/ethyl acetate = 4/1) gave the olefinated aniline in 75% yield.

The olefinated aniline (654.4 mg, 3.7 mmol) was further treated with nitrosobenzene (399.4 mg, 3.7 mmol) in the presence of acetic acid (35 mL). The reaction was protected from light by wrapping with foil. The resulting mixture was then allowed to stir at room temperature for 48 h. After completion, the reaction mixture was extracted with petrol ether for 4–6 times to extract the desired olefinated azobenzene. Then, the extract was combined and washed with saturated aqueous Na_2CO_3, brine, dried over magnesium sulfate, filtered, and concentrated. Purification by column chromatography (silica, petrol ether/ethyl acetate = 30/1) afforded the desired olefinated azobenzene as yellow solid in 88% yield.

Preparation for Olefinated Azobenzene 6′. A 25 mL sealed tube was charged with *o*-bromo aniline (0.86 g, 5 mmol) and $PdCl_2(PPh_3)_2$ (175 mg, 5 mol %). Under N_2 atmosphere, *N*,*N*-dimethyl acrylamide (0.62 mL, 6 mmol) and Et_3N (10 mL) were added, then the tube was sealed. The mixture was allowed to stir at 100 °C for 24 h. After completion, the mixture was cooled to room temperature, then H_2O (20 mL) was added and the mixture was extracted with EtOAc, dried by anhydrous Na_2SO_4. Evaporation of the solvent followed by purification by column chromatography (silica, petrol ether/ethyl acetate = 1/1) gave the olefinated aniline in 46% yield.

The olefinated aniline (440 mg, 2.3 mmol) was further treated with nitrosobenzene (247 mg, 2.3 mmol) in the presence of acetic acid (35 mL). The reaction was protected from light by wrapping with foil. The resulting mixture was then allowed to stir at room temperature for 48 h. After completion, the reaction mixture was diluted with EtOAc (100 mL), and neutralized by adding saturated aqueous Na_2CO_3 slowly until no bubble was generated. Then, the resulting mixture was further extracted with EtOAc. The combined organic phase was washed with brine, dried over magnesium sulfate, filtered, and concentrated. Purification by column chromatography (silica, petrol ether/ethyl acetate = 1/1) afforded the desired olefinated azobenzene as yellow solid in 73% yield.

General Procedure for the Synthesis of 3-Alkyl Indazole Product 3. A 25 mL sealed tube was charged with azobenzene (0.1 mmol), $[Cp^*RhCl_2]_2$ (5 mol%, 3 mg), and $Cu(OAc)_2$ (2 equiv., 36.4 mg). Under nitrogen atmosphere, acrylate **2** (1.2 equiv) and DCE (0.5 mL) were added, then the tube was sealed. The mixture was allowed to stir at 130 °C for 24 h. After completion, the mixture was cooled to room temperature, then H_2O (5 mL) was added and the mixture was extracted with EtOAc (5 mL x 3), dried by anhydrous Na_2SO_4. Evaporation of the solvent followed by purification on TLC preparative plates (petroleum ether/ethyl acetate = 4/1) provided the corresponding 3-alkyl indazole product **3**.

General Procedure for the Synthesis of 3-Acyl Indazole Product 4. A 25 mL sealed tube was charged with azobenzene (0.1 mmol), $[Cp^*RhCl_2]_2$ (5 mol%, 3 mg), and $Cu(OAc)_2$ (2 equiv., 36.4 mg). Under oxygen atmosphere, acrylate **2** (1.2 equiv) and DCE (0.5 mL) were added, then the tube was sealed. The mixture was allowed to stir at 130 °C for 24 h. After completion, the mixture was cooled to room temperature, then H_2O (5 mL) was added and the mixture was extracted with EtOAc (5 mL x 3), dried by anhydrous Na_2SO_4. Evaporation of the solvent followed by purification on TLC preparative plates (petroleum ether/ethyl acetate = 4/1) provided the corresponding 3-acyl indazole product **4**.

General Procedure for the Synthesis of 3-Acyl Indole Product 5. A 25 mL sealed tube was charged with azobenzene (0.1 mmol), $[Cp^*RhCl_2]_2$ (5 mol%, 3 mg), and $Cu(OAc)_2$ (2 equiv., 36.4 mg). Under nitrogen atmosphere, vinyl ketones or acrylamides **2** (1.2 equiv) and DCE (0.5 mL) were added, then the tube was sealed. The mixture was allowed to stir at 130 °C for 24 h. After completion, the mixture was cooled to room temperature, then H_2O (5 mL) was added and the mixture was extracted with EtOAc (5 mL × 3), dried by anhydrous Na_2SO_4. Evaporation of the solvent followed by purification on TLC preparative plates (petroleum ether/ethyl acetate = 4/1) provided the corresponding 3-acyl indole product **5**.

*Methyl 2-(2-Phenyl-2H-indazol-3-yl) Acetate (**3aa**).* Yellow solid, 22.1 mg (83% yield), mp: 79–81 °C; ^1H NMR ($CDCl_3$, 400 MHz): δ 7.76 (d, J = 8.8 Hz, 1H), 7.66 (d, J = 8.6 Hz, 1H), 7.61–7.49 (m, 5H), 7.35 (ddd, J = 8.6, 6.5, 0.8 Hz, 1H), 7.14 (dd, J = 8.4, 6.6 Hz, 1H), 4.06 (s, 2H), 3.68 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.4, 148.7, 139.5, 129.4, 129.3, 128.2, 127.0, 126.3, 122.1, 122.0, 119.8, 118.0, 52.6, 31.5; GC-MS found for 266. HRMS calcd for $C_{16}H_{15}N_2O_2$ [M+H]$^+$, 267.1128; found, 267.1128.

*Ethyl 2-(2-Phenyl-2H-indazol-3-yl) Acetate (**3ab**).* Oil, 23.5 mg (84% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.75 (d, J = 8.7 Hz, 1H), 7.67 (d, J = 8.6 Hz, 1H), 7.63−7.59 (m, 2H), 7.57−7.49 (m, 3H), 7.35 (dd, J = 7.9, 7.2 Hz, 1H), 7.14 (dd, J = 8.4, 6.7 Hz, 1H), 4.14 (q, J = 7.2 Hz, 2H), 4.05 (s, 2H), 1.21 (t, J = 7.1 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.0, 148.8, 139.6, 129.4, 129.3, 128.4, 127.0, 126.3, 122.1, 122.0, 119.9, 118.0, 61.7, 31.8, 14.2; GC-MS found for 280. HRMS calcd for $C_{17}H_{17}N_2O_2$ [M+H]$^+$, 281.1285; found, 281.1281.

*Butyl 2-(2-Phenyl-2H-indazol-3-yl) Acetate (**3ac**).* Oil, 26.5 mg (86% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.75 (d, J = 8.8 Hz, 1H), 7.67 (d, J = 8.4 Hz, 1H), 7.63−7.60 (m, 2H), 7.57−7.50 (m, 3H), 7.34 (ddd, J = 8.7, 6.5, 0.8 Hz, 1H), 7.16−7.11 (m, 1H), 4.09 (t, J = 6.7 Hz, 2H), 4.05 (s, 2H), 1.59−1.51 (m, 2H), 1.28 (dq, J = 14.6, 7.4 Hz, 2H), 0.88 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.1, 148.8, 139.6, 129.42, 129.3, 128.4, 127.0, 126.3, 122.1, 122.0, 119.9, 118.0, 65.6, 31.8, 30.6, 19.1, 13.7; GC-MS found for 308. HRMS calcd for $C_{19}H_{21}N_2O_2$ [M+H]$^+$, 309.1598; found, 309.1592.

*tert-Butyl 2-(2-Phenyl-2H-indazol-3-yl) Acetate (**3ad**).*[18a] Oil, 24.0 mg (78% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.75 (d, J = 8.7 Hz, 1H), 7.71−7.68 (m, 1H), 7.65−7.62 (m, 2H), 7.57−7.49 (m, 3H), 7.34 (ddd, J = 8.7, 6.6, 1.0 Hz, 1H), 7.15−7.10 (m, 1H), 3.96 (s, 2H), 1.39 (s, 9H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 168.1, 148.8, 139.7, 129.3, 129.1, 128.9, 126.9, 126.3, 122.0, 121.9, 120.0, 117.9, 82.2, 33.1, 28.0; GC-MS found for 308.

*Benzyl 2-(2-Phenyl-2H-indazol-3-yl) Acetate (**3ae**).* Oil, 23.9 mg (70% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.75 (d, J = 8.7 Hz, 1H), 7.64 (d, J = 8.6 Hz, 1H), 7.56−7.53 (m, 2H), 7.48 (dd, J = 4.1, 2.6 Hz, 3H), 7.37−7.30 (m, 4H), 7.27−7.22 (m, 2H), 7.14−7.09 (m, 1H), 5.12 (s, 3H), 4.09 (s, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 168.8, 148.8 139.5, 135.3, 129.4, 129.3, 128.7, 128.6, 128.5, 128.2, 127.0, 126.3, 122.2, 122.1, 119.8, 118.0, 67.4, 31.8; GC-MS found for 342. HRMS calcd for $C_{22}H_{19}N_2O_2$ [M+H]$^+$, 343.1441; found, 343.1443.

*Methyl 2-(5-Methyl-2-(p-tolyl)-2H-indazol-3-yl) Acetate (**3ba**).* Yellow solid, 24.1 mg (82% yield), mp: 147−149 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.65 (d, J = 8.9 Hz, 1H), 7.44 (d, J = 8.2 Hz, 2H), 7.37 (s, 1H), 7.32 (d, J = 8.1 Hz, 2H), 7.18 (d, J = 8.8 Hz, 1H), 4.00 (s, 2H), 3.68 (s, 3H), 2.45 (s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.7, 147.6, 139.3, 137.1, 131.4, 129.9, 129.8, 127.2, 126.0, 122.1, 117.7, 117.6, 52.6, 31.4, 22.0, 21.4; GC-MS found for 294. HRMS calcd for $C_{18}H_{19}N_2O_2$ [M+H]$^+$, 295.1441; found, 295.1439.

*Butyl 2-(5-Methoxy-2-(4-methoxyphenyl)-2H-indazol-3-yl) Acetate (**3cc**).* Oil, 30.9 mg (84% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.63 (d, J = 9.4 Hz, 1H), 7.49 (d, J = 8.9 Hz, 2H), 7.06−7.00 (m, 3H), 6.83 (d, J = 2.2 Hz, 1H), 4.09 (t, J = 6.7 Hz, 2H), 3.95 (s, 2H), 3.88 (s, 3H), 3.86 (s, 3H), 1.60−1.52 (m, 2H), 1.29 (dt, J = 14.3, 7.2 Hz, 2H), 0.88 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.3, 160.0, 155.3, 145.4, 132.7, 127.5, 127.3, 121.9, 121.7, 119.3, 114.4, 95.9, 65.5, 55.7, 55.5, 31.8, 30.7, 19.2, 13.8; GC-MS found for 368. HRMS calcd for $C_{21}H_{25}N_2O_4$ [M+H]$^+$, 369.1809; found, 369.1810.

*Methyl 2-(5-Fluoro-2-(4-fluorophenyl)-2H-indazol-3-yl) Acetate (**3da**).* Yellow solid, 23.6 mg (78% yield), mp: 128−130 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.73 (dd, J = 9.3, 4.6 Hz, 1H), 7.62−7.57 (m, 2H), 7.29−7.23 (m, 3H), 7.17 (td, J = 9.2, 2.4 Hz, 1H), 3.99 (s, 2H), 3.73 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.2, 162.9 (d, J = 250.1 Hz), 158.6 (d, J = 241.4 Hz), 146.2, 135.5, 128.5 (d, J = 8.8 Hz), 128.1 (d, J = 8.7 Hz), 121.3 (d, J = 11.5 Hz), 120.1 (d, J = 9.8 Hz), 118.9 (d, J = 29.1 Hz), 116.5 (d, J = 23.0 Hz), 102.3 (d, J = 24.4 Hz), 52.8, 31.4; GC-MS found for 302. HRMS calcd for $C_{16}H_{13}F_2N_2O_2$ [M+H]$^+$, 303.0940; found, 303.0940.

*Methyl 2-(5-Chloro-2-(4-chlorophenyl)-2H-indazol-3-yl) Acetate (**3ea**).* Yellow solid, 19.0 mg (57% yield), mp: 178−180 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.68 (d, J = 9.2 Hz, 1H), 7.63 (d, J = 1.6 Hz, 1H), 7.54 (d, J = 1.6 Hz, 4H), 7.30−7.27 (m, 1H), 3.99 (s, 2H), 3.72 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.1, 147.3, 137.8, 135.7, 129.8, 128.7, 128.1, 128.1, 127.5, 122.5, 119.6, 118.5, 52.9, 31.4; GC-MS found for 334. HRMS calcd for $C_{16}H_{13}Cl_2N_2O_2$ [M+H]$^+$, 335.0349; found, 335.0349.

*Methyl 2-(6-Methyl-2-(m-tolyl)-2H-indazol-3-yl) Acetate (**3ga**).* Oil, 23.8 mg (81% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.54 (d, J = 8.6 Hz, 1H), 7.49 (d, J = 0.7 Hz, 1H), 7.40 (t, J = 7.6 Hz, 2H), 7.35 (d, J = 8.0 Hz, 1H), 7.29 (d, J = 7.5 Hz, 1H), 6.97 (dd, J = 8.6, 0.9 Hz, 1H), 4.02 (s, 2H), 3.68 (s, 3H), 2.47 (s, 3H), 2.44 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.5, 149.3, 139.6, 139.5, 136.8, 129.9, 129.1, 127.9, 126.9, 125.0, 123.1, 120.4, 119.3, 116.2, 52.6, 31.6, 22.4, 21.4; GC-MS found for 294. HRMS calcd for $C_{18}H_{19}N_2O_2$ [M+H]$^+$, 295.1441; found, 295.1440.

*Methyl 2-(2-(2,4-Dimethylphenyl)-5,7-dimethyl-2H-indazol-3-yl) Acetate (**3ia**).* Oil, 24.1 mg (75% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.23 (s, 1H), 7.20 (d, J = 7.9 Hz, 1H), 7.17 (s, 1H), 7.11 (d, J = 7.9 Hz, 1H), 6.96 (s, 1H), 3.81 (s, 2H), 3.62 (s, 3H), 2.61 (s, 3H), 2.42 (s, 3H), 2.40 (s, 3H), 1.97 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.4, 147.9, 139.9, 135.9, 131.8, 131.6, 128.7, 128.1, 127.7, 127.6, 127.2, 121.0, 115.2, 52.4, 31.1, 22.0, 21.4, 17.2, 17.2; GC-MS found for 322. HRMS calcd for $C_{20}H_{23}N_2O_2$ [M+H]$^+$, 323.1754; found, 323.1755.

*Methyl 2-(2-(3,5-Dimethylphenyl)-4,6-dimethyl-2H-indazol-3-yl) Acetate (**3ja**).* Yellow solid, 16.7 mg (52% yield), mp: 94−96 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.31 (s, 1H), 7.11 (s, 3H), 6.69 (s, 1H), 4.11 (s, 2H), 3.70 (s, 3H), 2.57 (s, 3H), 2.40 (s, 3H), 2.38 (s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 170.3, 149.7, 139.4, 139.2, 136.7, 130.9, 130.1, 128.4, 125.4, 124.2, 120.1, 114.1, 52.6, 32.6, 22.2, 21.4, 19.6; GC-MS found for 322. HRMS calcd for $C_{20}H_{23}N_2O_2$ [M+H]$^+$, 323.1754; found, 323.1753.

*Methyl 2-(5-Methoxy-2-(4-methoxy-3,5-dimethylphenyl)-2H-indazol-3-yl) Acetate (**3ka**).* Oil, 24.4 mg (69% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.62 (d, J = 9.3 Hz, 1H), 7.20 (s, 2H), 7.03 (dd, J = 9.3, 2.3 Hz, 1H), 6.81 (d, J = 2.1 Hz, 1H), 3.99 (s, 2H), 3.86 (s, 3H), 3.77 (s, 3H), 3.70 (s, 3H), 2.34 (s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 169.7, 157.5, 155.3, 145.4, 135.0, 132.2, 126.8, 126.4, 121.8, 121.7, 119.4, 95.8, 60.0, 55.6, 52.6, 31.6, 16.3; GC-MS found for 354. HRMS calcd for $C_{20}H_{23}N_2O_4$ [M+H]$^+$, 355.1652; found, 355.1651.

*Methyl 2-oxo-2-(2-Phenyl-2H-indazol-3-yl) Acetate (**4aa**).* Oil, 22.6 mg (81% yield); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.11 (dd, J = 7.7, 1.7 Hz, 1H), 7.93 (d, J = 7.9 Hz, 1H), 7.56 (s, 5H), 7.51−7.43 (m, 2H), 3.53 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 175.9, 162.9, 148.9, 140.2, 130.0, 129.5, 129.5, 127.9, 127.5, 126.2, 125.5, 120.8, 119.1, 52.9; GC-MS found for 280. HRMS calcd for $C_{16}H_{13}N_2O_3$ [M+H]$^+$, 281.0921; found, 281.0919.

*Methyl 2-(5-Fluoro-2-(4-fluorophenyl)-2H-indazol-3-yl)-2-oxoacetate (**4da**).* Yellow solid, 23.4 mg (74% yield), mp: 129−131 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.90 (dd, J = 9.4, 4.7 Hz, 1H), 7.68 (dd, J = 8.9, 2.3 Hz, 1H), 7.53 (dd, J = 8.9, 4.6 Hz, 2H), 7.31−7.22 (m, 3H), 3.65 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 175.3, 163.3 (d, J = 251.5 Hz), 162.9, 162.1 (d, J = 248.4 Hz), 146.2, 136.3, 129.9 (d, J = 8.2 Hz), 128.1 (d, J = 8.8 Hz), 125.7 (d, J = 12.7 Hz), 121.5 (d, J = 10.1 Hz), 119.6 (d, J = 28.8 Hz), 116.5 (d, J = 23.2 Hz), 104.4 (d, J = 26.3 Hz), 53.2; GC-MS found for 316. HRMS calcd for $C_{16}H_{11}F_2N_2O_3$ [M+H]$^+$, 317.0732; found, 317.0732.

*Methyl 2-(5-Methoxy-2-(4-methoxy-3,5-dimethylphenyl)-2H-indazol-3-yl)-2-oxoacetate (**4ka**).* Yellow solid, 23.1 mg (63% yield), mp: 97−99 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.78 (d, J = 9.3 Hz, 1H), 7.41 (d, J = 2.3 Hz, 1H), 7.20 (s, 2H), 7.13 (dd, J = 9.3, 2.4 Hz, 1H), 3.93 (s, 3H), 3.77 (s, 3H), 3.47 (s, 3H), 2.36 (s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 176.4, 163.3, 159.9, 158.1, 145.3, 135.6, 132.5, 129.0, 127.0, 126.2, 122.7, 120.4, 97.7, 60.0, 55.9, 52.5, 16.2; GC-MS found for 368. HRMS calcd for $C_{20}H_{21}N_2O_5$ [M+H]$^+$, 369.1445; found, 369.1444.

*1-(1H-Indol-2-yl)propan-1-one (**5ag**).*[18b] Yellow solid, 13.1 mg (76% yield), mp: 152−154 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.28 (s, 1H), 7.71 (d, J = 8.1 Hz, 1H), 7.45 (d, J = 8.3 Hz, 1H), 7.35 (t, J = 7.6 Hz, 1H), 7.21 (d, J = 1.7 Hz, 1H), 7.16 (t, J = 7.5 Hz, 1H), 3.01 (q, J = 7.4 Hz, 2H), 1.29 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.2, 137.3, 135.1, 127.7, 126.3, 123.1, 121.0, 112.3, 109.0, 31.6, 8.9; GC-MS found for 173.

*1-(5-Methyl-1H-indol-2-yl)propan-1-one (**5bg**).* Yellow solid, 14.9 mg (80% yield), mp: 174−176 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.12 (s, 1H), 7.47 (s, 1H), 7.33 (d, J = 8.4 Hz, 1H), 7.17 (dd, J = 8.5, 1.0 Hz, 1H), 7.12 (d, J = 1.4 Hz, 1H), 2.99 (q, J = 7.4 Hz, 2H), 2.44 (s, 3H), 1.28 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.1, 135.7, 135.1, 130.3, 128.3, 128.0, 122.3, 112.0, 108.5, 31.6, 21.6, 8.9; GC-MS found for 187. HRMS calcd for $C_{12}H_{14}NO$ $[M+H]^+$, 188.1070; found, 188.1069.

1-(5-Methoxy-1H-indol-2-yl)propan-1-one (***5cg***).[18c] Yellow solid, 14.8 mg (73% yield), mp: 166−168 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.31 (s, 1H), 7.34 (d, J = 9.0 Hz, 1H), 7.12 (s, 1H), 7.08 (d, J = 1.7 Hz, 1H), 7.02 (dd, J = 9.0, 2.3 Hz, 1H), 3.85 (s, 3H), 2.99 (q, J = 7.4 Hz, 2H), 1.28 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.0, 154.8, 135.5, 132.8, 128.0, 118.1, 113.3, 108.6, 102.8, 55.8, 31.6, 8.9; GC-MS found for 203. HRMS calcd for $C_{12}H_{14}NO_2$ $[M+H]^+$, 204.1019; found, 204.1019.

1-(5-Fluoro-1H-indol-2-yl)propan-1-one (***5dg***). Yellow solid, 13.6 mg (71% yield), mp: 182−184 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.37 (s, 1H), 7.39 (dd, J = 9.0, 4.3 Hz, 1H), 7.34 (dd, J = 9.1, 2.3 Hz, 1H), 7.16 (d, J = 1.9 Hz, 1H), 7.11 (td, J = 9.1, 2.4 Hz, 1H), 3.00 (q, J = 7.4 Hz, 2H), 1.29 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.1, 158.3 (d, J = 236.9 Hz), 136.4, 133.9, 127.9, 115.5 (d, J = 27.2 Hz), 113.3 (d, J = 9.6 Hz), 108.7 (d, J = 5.0 Hz), 107.2 (d, J = 23.1 Hz), 31.7, 8.8; GC-MS found for 191. HRMS calcd for $C_{11}H_{11}FNO$ $[M+H]^+$, 192.0819; found, 192.0821.

1-(5-Chloro-1H-indol-2-yl)propan-1-one (***5eg***). Yellow solid, 10.5 mg (51% yield), mp: 195−197 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.29 (s, 1H), 7.68 (d, J = 1.6 Hz, 1H), 7.37 (d, J = 8.8 Hz, 1H), 7.29 (dd, J = 8.8, 1.9 Hz, 1H), 7.13 (d, J = 1.7 Hz, 1H), 3.00 (q, J = 7.4 Hz, 2H), 1.28 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.1, 136.1, 135.5, 128.6, 126.8, 126.6, 122.2, 113.5, 108.1, 31.7, 8.7; GC-MS found for 207. HRMS calcd for $C_{11}H_9ClNO$ $[M-H]^-$, 206.0378; found, 206.0377.

1-(5-Bromo-1H-indol-2-yl)propan-1-one (***5 mg***). Yellow solid, 13.6 mg (54% yield), mp: 193−195 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.28 (s, 1H), 7.84 (s, 1H), 7.42 (dd, J = 8.7, 1.8 Hz, 1H), 7.33 (d, J = 8.7 Hz, 1H), 7.12 (d, J = 1.0 Hz, 1H), 3.00 (q, J = 7.4 Hz, 2H), 1.28 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.1, 135.9, 135.8, 129.3, 129.2, 125.4, 114.1, 113.9, 108.0, 31.7, 8.7; GC-MS found for 251, 253. HRMS calcd for $C_{11}H_9BrNO$ $[M-H]^-$, 249.9873; found, 249.9872.

1-(5-(Trifluoromethyl)-1H-indol-2-yl)propan-1-one (***5fg***). White solid, 17.5 mg (73% yield), mp: 167−169 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.92 (s, 1H), 8.02 (s, 1H), 7.57 (s, 2H), 7.29 (d, J = 0.9 Hz, 1H), 3.06 (q, J = 7.3 Hz, 2H), 1.32 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.4, 138.5, 136.4, 126.8, 125.0 (q, J = 271.5 Hz), 123.5 (q, J = 32.3 Hz), 122.7 (q, J = 3.0 Hz), 121.0 (q, J = 4.4 Hz), 113.0, 109.6, 31.8, 8.7; GC-MS found for 241. HRMS calcd for $C_{12}H_9F_3NO$ $[M-H]^-$, 240.0642; found, 240.0644.

1-(6-Methyl-1H-indol-2-yl)propan-1-one (***5gg***). Yellow solid, 15.1 mg (81% yield), mp: 141−143 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.13 (s, 1H), 7.58 (d, J = 8.2 Hz, 1H), 7.22 (s, 1H), 7.16 (s, 1H), 6.99 (d, J = 8.2 Hz, 1H), 2.98 (q, J = 7.4 Hz, 2H), 2.47 (s, 3H), 1.28 (t, J = 7.5 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.0, 137.9, 136.7, 134.7, 125.6, 123.2, 122.7, 111.9, 109.1, 31.5, 22.2, 9.0; GC-MS found for 187. HRMS calcd for $C_{12}H_{14}NO$ $[M+H]^+$, 188.1070; found, 188.1069.

1-(4,6-Dimethyl-1H-indol-2-yl)propan-1-one (***5jg***). Yellow solid, 14.5 mg (72% yield), mp: 171−173 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.15 (s, 1H), 7.19 (d, J = 1.1 Hz, 1H), 7.05 (s, 1H), 6.79 (s, 1H), 3.00 (q, J = 7.4 Hz, 2H), 2.54 (s, 3H), 2.43 (s, 3H), 1.29 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.9, 137.8, 136.9, 134.2, 132.3, 125.9, 123.2, 109.4, 107.8, 31.4, 22.2, 18.7, 9.1; GC-MS found for 201. HRMS calcd for $C_{13}H_{16}NO$ $[M+H]^+$, 202.1226; found, 202.1226.

Methyl 2-Propionyl-1H-indole-5-carboxylate (***5lg***). Yellow solid, 10.3 mg (45% yield), mp: 212−214 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.39 (s, 1H), 8.49 (s, 1H), 8.03 (dd, J = 8.7, 1.6 Hz, 1H), 7.46 (d, J = 8.7 Hz, 1H), 7.29−7.27 (m, 1H), 3.94 (s, 3H), 3.02 (q, J = 7.3 Hz, 2H), 1.29 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.0, 167.7, 139.5, 136.3, 127.3, 127.1, 126.4, 123.3, 112.1, 110.0, 52.2, 31.7, 8.7; GC-MS found for 231. HRMS calcd for $C_{13}H_{14}NO_3$ $[M+H]^+$, 232.0968; found, 232.0965.

(1H-Indol-2-yl) (phenyl)methanone (***5ah***).[18d] Yellow solid, 18.1 mg (82% yield), mp: 150−152 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.52 (s, 1H), 8.01 (dd, J = 5.2, 3.4 Hz, 2H), 7.75−7.71 (m, 1H), 7.66−7.61 (m, 1H), 7.57−7.48 (m, 3H), 7.39 (ddd, J = 8.2, 7.1, 1.0 Hz, 1H), 7.20−7.16 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 187.4, 138.1, 137.7, 134.5, 132.5, 129.4, 128.6, 127.9, 126.7, 123.4, 121.2, 113.0, 112.4; GC-MS found for 221. HRMS calcd for $C_{15}H_{12}NO$ $[M+H]^+$, 222.0913; found, 222.0916.

(4-Fluorophenyl)(1H-indol-2-yl)methanone (***5ai***).[18b,d] Yellow solid, 16.7 mg (70% yield), mp: 181−183 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.47 (s, 1H), 8.08−8.02 (m, 2H), 7.73 (d, J = 8.2 Hz, 1H), 7.53−7.46 (m, 1H), 7.42−7.37 (m, 1H), 7.25−7.14 (m, 4H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 185.8, 165.5 (d, J = 253.8 Hz), 137.7, 134.4 (d, J = 2.9 Hz), 134.2, 131.9 (d, J = 8.9 Hz), 127.8, 126.8, 123.4, 121.3, 115.8 (d, J = 21.8 Hz), 112.8, 112.3; GC-MS found for 239.

Benzo[b]thiophen-2-yl(1H-indol-2-yl)methanone (***5aj***). Yellow solid, 18.0 mg (65% yield), mp: 258−260 °C; ^{1}H NMR (DMSO−D_6, 400 MHz): δ 12.05 (s, 1H), 8.58 (s, 1H), 8.11 (t, J = 7.5 Hz, 2H), 7.78 (d, J = 8.1 Hz, 1H), 7.67 (d, J = 1.6 Hz, 1H), 7.59−7.49 (m, 3H), 7.37−7.31 (m, 1H), 7.17−7.11 (m, 1H); ^{13}C NMR (DMSO−D_6, 100 MHz): δ 178.6, 142.1, 141.1, 139.3, 138.1, 133.7, 130.8, 127.6, 127.2, 126.5, 126.0, 125.3, 122.9, 120.6, 112.8, 110.9; GC-MS found for 277. HRMS calcd for $C_{17}H_{12}NOS$ $[M+H]^+$, 278.0634; found, 278.0635.

N,N-Dimethyl-1H-indole-2-carboxamide (***5ak***).[18e] White solid, 12.2 mg (65% yield), mp: 185−187 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.64 (s, 1H), 7.67 (d, J = 8.1 Hz, 1H), 7.45 (d, J = 8.3 Hz, 1H), 7.28 (dd, J = 12.8, 4.8 Hz, 1H), 7.13 (t, J = 7.5 Hz, 1H), 6.86 (d, J = 2.0 Hz, 1H), 3.45 (s, 3H), 3.22 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.3, 135.6, 129.8, 127.9, 124.5, 122.1, 120.5, 111.9, 106.0; GC-MS found for 188. HRMS calcd for $C_{11}H_{11}N_2O$ $[M-H]^-$, 187.0877; found, 187.0879.

N,N-Dimethyl-5-(trifluoromethyl)-1H-indole-2-carboxamide (***5fk***). Yellow solid, 13.3 mg (52% yield), mp: 224−226 °C; ^{1}H NMR (DMSO−D_6, 400 MHz): δ 11.98 (s, 1H), 8.03 (s, 1H), 7.61 (d, J = 8.7 Hz, 1H), 7.47 (dd, J = 8.7, 1.6 Hz, 1H), 7.03 (d, J = 1.6 Hz, 1H), 3.31 (s, 3H), 3.06 (s, 3H); ^{13}C NMR (DMSO−D_6, 100 MHz): δ 162.3, 137.2, 132.5, 126.4, 125.5 (q, J = 271.2 Hz), 120.6 (q, J = 31.2 Hz), 119.5 (q, J = 9.5 Hz), 119.5 (q, J = 10.5 Hz), 113.0, 105.7; GC-MS found for 256. HRMS calcd for $C_{12}H_{12}F_3N_2O$ $[M+H]^+$, 257.0896; found, 257.0896.

N,N,6-Trimethyl-1H-indole-2-carboxamide (***5gk***).[18f] Yellow solid, 12.7 mg (63% yield), mp: 206−208 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.44 (s, 1H), 7.54 (d, J = 8.2 Hz, 1H), 7.23 (s, 1H), 6.97 (d, J = 7.9 Hz, 1H), 6.81 (s, 1H), 3.33 (s, 6H), 2.47 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 136.1, 134.7, 129.2, 125.8, 122.6, 121.7, 111.6, 106.0, 22.1; GC-MS found for 202. HRMS calcd for $C_{12}H_{15}N_2O$ $[M+H]^+$, 203.1179; found, 203.1177.

(5-Methoxy-1H-indol-2-yl)(3-methoxyphenyl)methanone (***5cl***).[18g] Yellow solid, 810 mg (57% yield), mp: 146−148 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.41 (s, 1H), 7.59 (d, J = 7.6 Hz, 1H), 7.51−7.49 (m, 1H), 7.44 (t, J = 7.9 Hz, 1H), 7.38 (d, J = 8.8 Hz, 1H), 7.16 (dd, J = 8.2, 2.1 Hz, 1H), 7.11−7.04 (m, 3H), 3.89 (s, 3H), 3.85 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 186.9, 159.8, 155.0, 139.5, 134.9, 133.2, 129.6, 128.2, 122.0, 118.8, 118.6, 113.9, 113.3, 112.5, 102.9, 55.8, 55.6; GC-MS found for 281. HRMS calcd for $C_{17}H_{14}NO_3$ $[M-H]^-$, 280.0979; found, 280.0978.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.6b02548.

Procedure for preparation of starting materials, optimization conditions, mechanistic experiments, and spectra for all compounds (PDF)

X-ray crystallographic data for compound **3da** (CIF)

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Notes

The authors declare no competing financial interest.

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