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Access to Six- and Seven-Membered 1,7-Fused Indolines via Rh(III)-Catalyzed Redox-Neutral C7-Selective C−H Functionalization of Indolines with Alkynes and Alkenes

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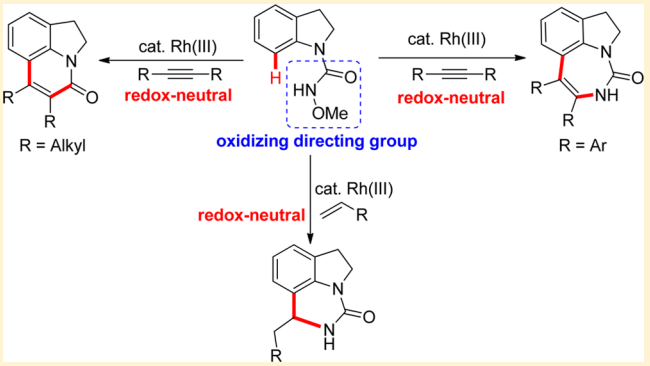
Supporting Information

ABSTRACT: We report herein a new strategy for the Rh(III)-catalyzed redox-neutral C7-selective C−H activation/annulation of indolines to rapidly access various privileged 1,7-fused indolines by utilizing an oxidizing−directing group. For example, a Rh(III)-catalyzed redox-neutral C7-selective C−H functionalization of indolines with arylalkynes is described to directly access 7-membered 1,7-fused indolines. Moreover, an unprecedented intramolecular addition of an alkenyl-Cp*Rh(III) species to a carbamoyl moiety occurred to give 1*H*-pyrroloquinolinones when employing alkyl alkynes. Additionally, an efficient Rh(III)-catalyzed redox-neutral C7-selective C−H activation/alkenylation/aza-Michael addition of indolines is also developed to give 6-membered 1,7-fused indolines. The advantages of these processes are as follows: (1) mild and simple reaction conditions; (2) no need for an external oxidant; (3) broad scope of substrates; and (4) valuable six- or seven-membered 1,7-fused indolines as products.



INTRODUCTION

The indoles and indolines have been a topic of substantial research interest due to their ubiquity in numerous natural bioactive products, marketed drugs, pharmaceutically important compounds, and other functional molecules.[1] Among them, 1,7-fused indoles and indolines are particularly noteworthy due to their prevalence in numerous natural bioactive products and pharmaceutically important compounds (Figure 1).[2] However, 1,7-fused indolines are typically formed via an intramolecular fashion. Moreover, the annulation precursors are normally not readily available and require multistep synthesis.[3] To date, only one intermolecular catalytic method is available to directly access 1,7-fused indoline core. However, this method requires the installation of 2 equiv of terminal alkynes, thus largely limiting the diversity of the products.[4] Therefore, the development of general synthetic methods for rapid preparation of 1,7-fused indolines and indoles would be highly desirable.

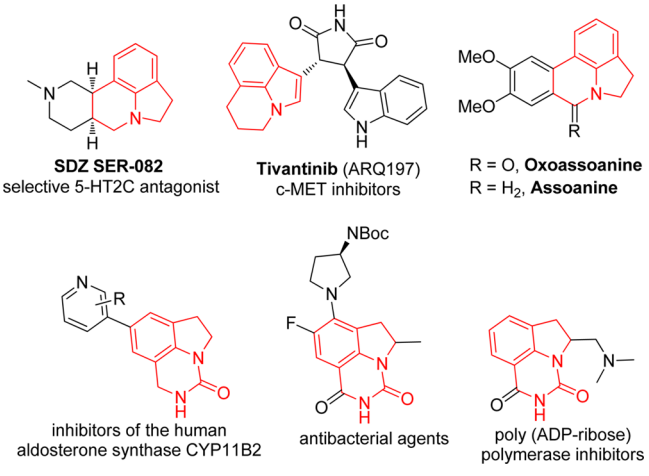


Figure 1. Selective bioactive compounds based on 1,7-fused indolines.

On the other hand, with the development of catalytic C−H functionalization, direct C−H bond functionalization of indoles and indolines should be one of the most effective and straightforward approaches to access substituted indoles and indolines.[5] Although several elegant approaches to transition-metal-catalyzed C2- or C3-H functionalization of indoles have been reported,[6,7] the indole C-7 C−H functionalization has very limited reports.[8] Recently, some examples of transition-metal-catalyzed chelation-assisted direct C7 C−H functionalization of indolines, such as arylation,[9] alkenylation,[10] alkylation,[11] amidation,[12] acylation,[13] and alkynylation,[14] have been disclosed by several groups and us (Scheme 1a). However, no 1,7-fused indolines could be accessed through these methods.

Recently, the Rh(III)-catalyzed redox-neutral functionalization of aryl C−H bond with alkynes and alkenes has proven to be a powerful method for the rapid assembly of various complex molecular structures under mild reaction conditions without the use of external oxidant by utilizing an oxidizing−directing

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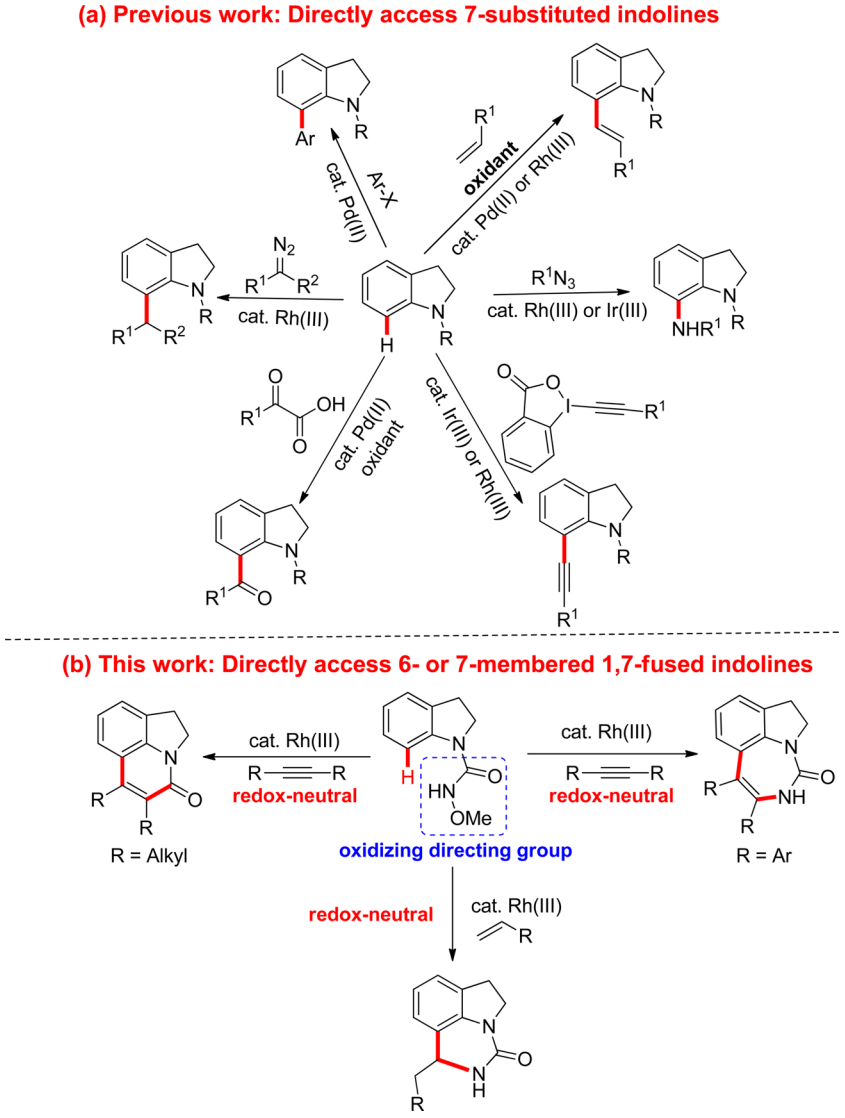
Scheme 1. C7-Selective C−H Functionalization of Indolines



group.[15] In this context, also with our continued interest in the Rh(III)-catalyzed C−H activation/annulation reaction,[16] we herein report the Rh(III)-catalyzed redox-neutral C7-selective C−H functionalization of indolines with alkynes and alkenes under mild reaction conditions via utilization of an oxidizing−directing group strategy (Scheme 1b). More significantly, this method can directly access various valuable six- or seven-membered 1,7-fused indolines.[2,17]

RESULTS AND DISCUSSION

We commenced our study with the coupling of *N*-methoxycarbamoyl-protected indoline (**1a**) and diphenylacetylene (**2a**) (Table 1). When $[Cp^*RhCl_2]_2$ (2.5 mol %)[18] was employed as catalyst together with CsOAc (50 mol %) as additive at 60 °C in MeCN, the desired annulation product **3a** was obtained in 15% yield (entry 1). Changing the OMe group (**1a**) to an *O*-pivaloyl group (**1a′**), did not give any desired product **3a** (entry 2). Various solvents were screened, and MeOH was proven to be optimal, affording **3a** in 35% yield (entry 4). A stoichiometric amount (200 mol %) of CsOAc gave an improved yield of **3a** (entry 5). Moreover, the reaction efficiency could be increased at higher temperature (80 °C), affording **3a** in 65% yield (entry 6). Finally, changing CsOAc to NaOAc gave a further improvement of yield (75%) (entry 7). In addition, a palladium catalyst system was found to be ineffective (entry 8).

With the optimized reaction conditions in hand, the substrate scope of indolines was investigated. As shown in Scheme 2, indolines containing both electron-donating (**3b−g**) and -withdrawing (**3h−j**) groups could proceed smoothly in this transformation to give the corresponding 7-membered 1,7-fused indolines in good to high yields. Moreover, substitutions at the C2 (**3b**), C3 (**3c,d**), C4 (**3e**), and C5 (**3f−j**) were all well tolerated. Of special importance, indolines bearing chloro (**3h**), bromo (**3i**) and ester (**3j**) functional groups were also compatible with this catalytic system, thus offering the opportunity for further transformations. The scope of the alkynes partners was also explored and diphenylacetylenes bearing both electron-donating and -withdrawing groups, coupled smoothly in good to high yields (**3k−n**). Notably, the use of alkyl aryl disubstituted alkynes gave a high regioselectivity, affording **3o** and **3p** as the single regioisomer.

Next, the dialkyl-substituted alkynes were explored under the standard reaction conditions. Surprisingly, in addition to the 7-membered product **5a′**, 1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]-quinolin-4-one **5a** was also isolated as the main product,

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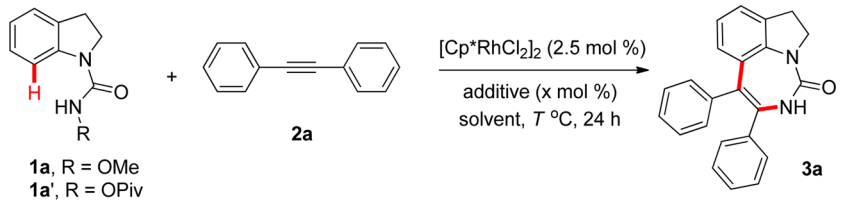
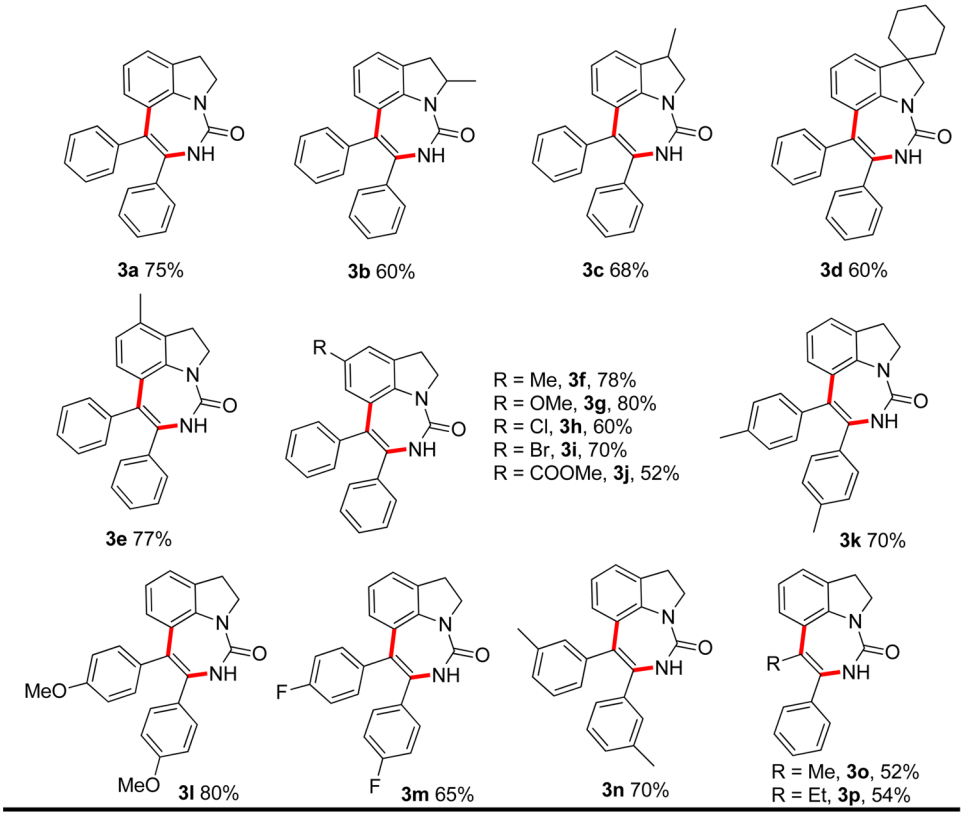
Table 1. Optimization of the Synthesis of Seven-Membered 1,7-Fused indolines[a]



entry	substrate	additive (x mol %)	solvent	T (°C)	yield[b] (%)
1	**1a**	CsOAc (50 mol %)	CH_3CN	60	15
2	**1a′**	CsOAc (50 mol %)	CH_3CN	60	0
3	**1a**	CsOAc (50 mol %)	DMF	60	5
4	**1a**	CsOAc (50 mol %)	MeOH	60	35
5	**1a**	CsOAc (200 mol %)	MeOH	60	55
6	**1a**	CsOAc (200 mol %)	MeOH	80	65
7	**1a**	NaOAc (200 mol %)	MeOH	80	75
8[c]	**1a**	CsOAc (200 mol %)	MeOH	80	<3

[a]Reaction conditions: **1a** (0.2 mmol), **2a** (0.4 mmol), $[Cp^*RhCl_2]_2$ (2.5 mol %), additive (x mol %) and solvent (2 mL) in a sealed tube at 80 °C for 24 h. [b]Yield of isolated product. [c]$Pd(OAc)_2$ was used as the catalyst.

Scheme 2. Rh(III)-Catalyzed Synthesis of Seven-Membered 1,7-Fused Indolines[a]



[a]Reactions conditions: 1 (0.20 mmol, 1.0 equiv), 2 (0.4 mmol, 2.0 equiv), [Cp*RhCl2]2 (2.5 mol %) and NaOAc (200 mol %) in MeOH (2.0 mL) for 24 h at 80 °C; isolated yields.

presumably due to an intramolecular nucleophilic addition of an alkenyl-Cp*Rh^{III} intermediate to carbamoyl group (eq 1).

Notably, to the best of our knowledge, the intramolecular addition of alkenyl-Cp*Rh^{III} species to the less electrophilic carbamoyl group is challenging and particularly rare.[19] Notably,

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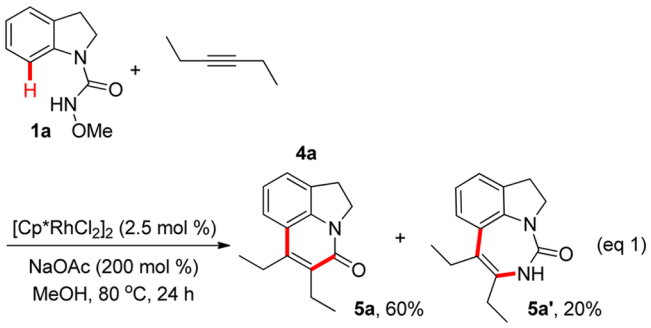


this pyrrolo[3,2,1-*ij*]quinolin-4-one framework is known to be a CYP11B1 inhibitor, a ligand for ORL-1 receptors, and to show fungicidal activity.[2h,20] This result encouraged us to further survey the scope of this addition reaction (Scheme 3).[21]

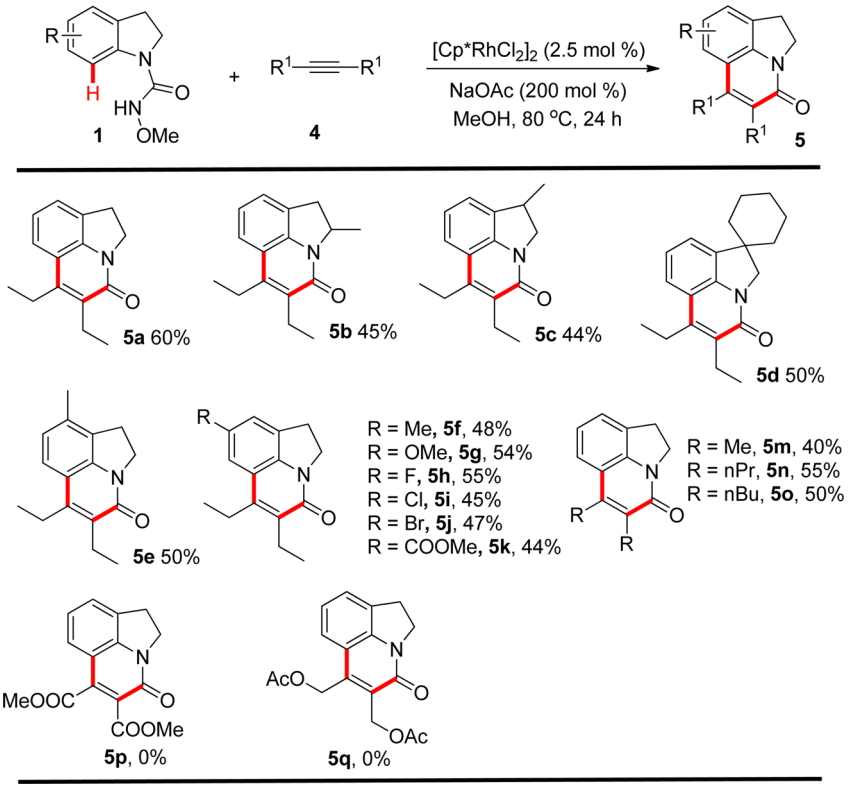
To our delight, a variety of electron-rich and -deficient indolines could be readily converted into 1,2,5,6-tetrahydropyrrolo[3,2,1-*ij*]-quinoline-4-ones (**5a**−**k**). Importantly, the reaction also showed good compatibility with a wide range of valuable functional groups such as methoxy (**5g**), fluoro (**5h**), chloro (**5i**), bromo (**5j**), and ester (**5k**) groups. Tolerance to the chloro, bromo, and ester functional groups was especially noteworthy since they have been frequently used as key intermediates for further synthetic transformations. Moreover, the position of the substituent on indole moiety showed no obvious influence on the reaction outcome. For example, substitutions at the C2 (**5b**), C3 (**5c**,**d**), C4 (**5e**), C5 (**5f**−**k**) positions were all well tolerated with the current catalytic system. Interestingly, the C6-methoxy-substituted indoline gave the 7-membered product **5l**′ as the sole product.[22] In addition, other dialkyl-substituted alkynes could also proceed smoothly in this transformation to give the corresponding products **5m**−**o**. Propargyl acetates and protected propargyl alcohols did not convert into the desired products (**5p**,**q**).

Since alkenes are also ideal coupling partners,[15c,m] the coupling of *N*-methoxycarbamoyl-protected indoline (**1a**) and acrylate (**6a**) was also investigated (Table 2). When $[Cp^*RhCl_2]_2$ (2.5 mol %) was employed as catalyst together with CsOAc (50 mol %) as additive at 50 °C in MeOH, the six-membered annulation product **7a** was obtained in 18% yield (entry 1). Interestingly, no seven-membered annulation product **7a**′ was observed. Changing of OMe (**1a**) to an *O*-pivaloyl group (**1a**′) did not give any desired product **7a** or **7a**′ (entry 2). Various solvents were tested, and DMF was proven to be optimal, affording **7a** in 78% yield (entry 6).

With the optimized reaction conditions in hand, the substrate scope of indolines was investigated (Scheme 4). As shown in Scheme 4, indolines containing both electron-donating (**7b**−**d**,**h**) and -withdrawing (**7e**−**g**) groups could proceed smoothly in this transformation to give the corresponding 1,7-fused indolines. Moreover, substitutions at the C4 (**7b**), C5 (**7c**−**g**), and even C6 positions (**7h**) were all well tolerated. Of special importance, indolines bearing chloro and bromo functional groups (**7e**,**f**), were also compatible with this catalytic system, thus offering the opportunity for further transformations.

The scope of the reaction with respect to the alkenes was also explored (Scheme 5). Satisfyingly, various acrylates such as ethyl (**7i**), butyl (**7j**), *tert*-butyl (**7k**), and benzyl acrylates (**7l**) smoothly coupled with **1a** to provide the corresponding 1,7-fused indolines in good yields. In addition to acrylates, phenyl

Scheme 3. Rh(III)-Catalyzed Synthesis of 1,2-Dihydro-4*H*- pyrrolo[3,2,1-*ij*]quinolin-4-ones[a]



[a]Reaction conditions: **1** (0.20 mmol, 1.0 equiv), **4** (0.4 mmol, 2.0 equiv), $[Cp^*RhCl_2]_2$ (2.5 mol %), and NaOAc (200 mol %) in MeOH (2.0 mL) for 24 h at 80 °C; isolated yields.

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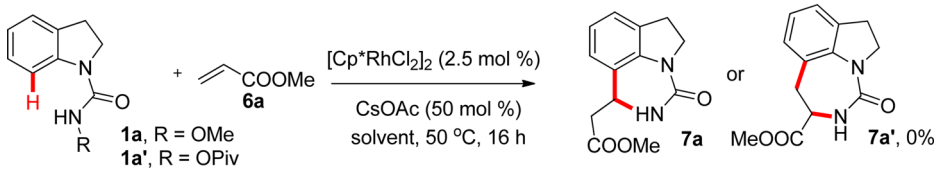
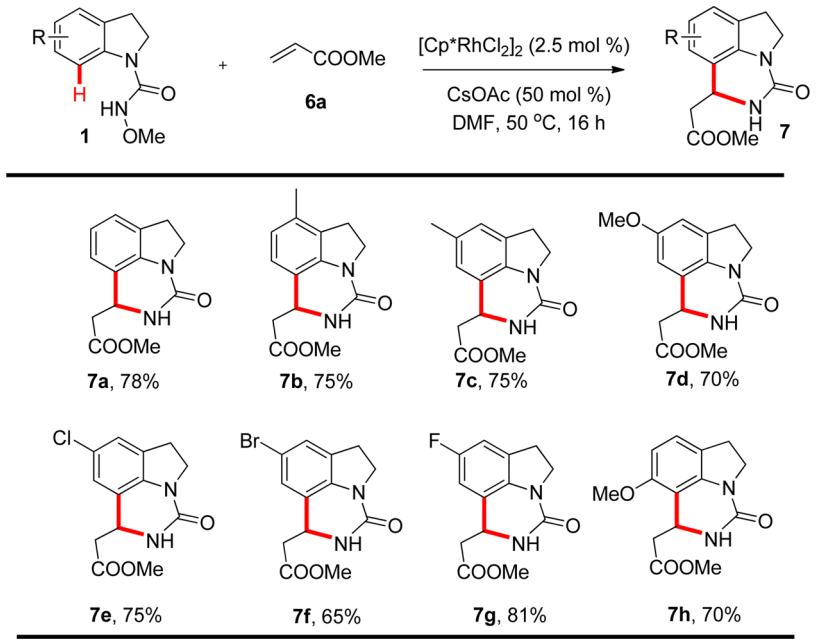
Table 2. Optimization of the Rh(III)-Catalyzed Annulation Reaction with Alkenes[a]



entry	substrate	solvent	yield[b] (%)
1	**1a**	MeOH	18
2	**1a′**	MeOH	0
3	**1a**	THF	30
4	**1a**	1,4-dioxane	20
5	**1a**	CH_3CN	45
6	**1a**	DMF	78

[a]Reaction conditions: **1a** (0.2 mmol), **6a** (0.4 mmol), $[Cp^*RhCl_2]_2$ (2.5 mol %), CsOAc (50 mol %), and solvent (2 mL) at 50 °C for 16 h. [b]Yield of isolated product **7a**.

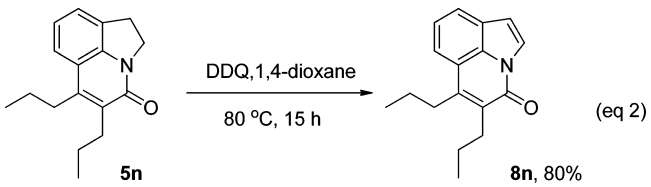
Scheme 4. Rh(III)-Catalyzed Redox-Neutral C7−H Functionalization of Various Indolines with Alkenes[a]



[a]Reaction conditions: **1** (0.2 mmol), **6a** (0.4 mmol), $[Cp^*RhCl_2]_2$ (2.5 mol %), CsOAc (50 mol %) and DMF (2 mL) at 50 °C for 16 h. Yield of isolated product.

vinyl sulfone was also a good coupling partner, giving the desired product **7m** in 48% yield. Alkenes containing other functional groups, such as nitrile (**7n**) and phosphonate (**7o**), were also tolerated.

The utility of this method was further highlighted by its successful conversion into 1,7-fused indoles with DDQ. For example, the product **5n** was easily oxidized to give a pyrroloquinolinone framework of **8n** (eq 2), which is prevalent



(eq 2)

in some biologically active indole based alkaloids[23] and whose derivatives are found to have some unusual photosensitizing properties.[24]

For a preliminary mechanistic study, H/D exchange experiments were performed. A significant H/D scrambling was observed in the C7-position of indoline when **1a** was reacted with the $[RhCp^*Cl_2]_2$ catalyst in CD_3OD in the absence of diphenylacetylene (**2a**) (eq 3). Moreover, in the presence of **2a**, a similar deuteration was also observed in the reisolated **1a** (eq 4). Together, these results indicate the reversibility of the C−H activation.

A preliminary mechanistic pathway is postulated for the Rh(III)-catalyzed redox-neutral functionalization of aryl C−H bond with alkynes and alkenes (Scheme 6). First, a Rh(III)-catalyzed reversible C-7 C−H bond cleavage occurs to give rhodacycle **A** upon proton abstraction. Insertion of alkyne to the carbon−rhodium bond of **A** affords the eight-membered rhodacycle **B**. When aryl alkynes were involved, reductive elimination occurs with the formation of intermediates **C** and a Rh(I) species. Oxidative addition of **C** releases the product **3** and regenerates the Rh(III) catalyst. If alkyl alkynes were involved, an

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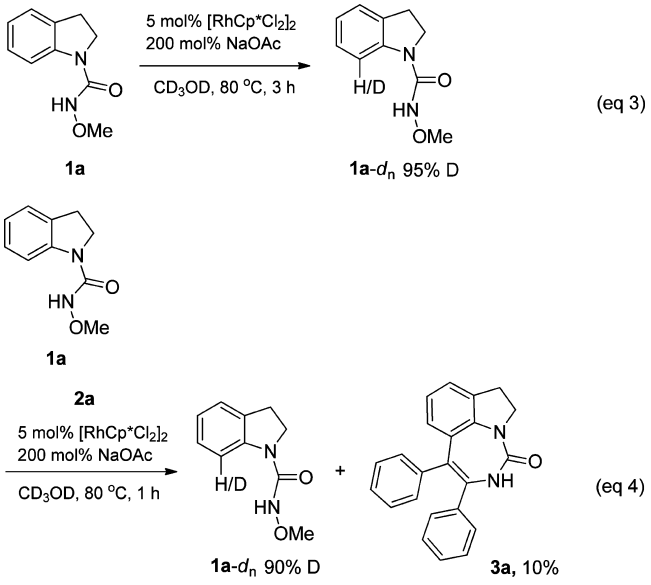


intramolecular nucleophilic addition followed by release of methoxyamine, occurred to give product **5** with the regeneration of Rh(III) catalyst.

Similarly, insertion of olefin to the carbon−rhodium bond of **A** affords the eight-membered rhodacycle **E**. This metallacycle might undergo a β-hydride elimination/N−O bond cleavage to provide the intermediate **F** and regenerate the Rh(III) catalyst. Finally, an intramolecular aza-Michael addition[25] occurs to give 1,7-fused indoline **7**.

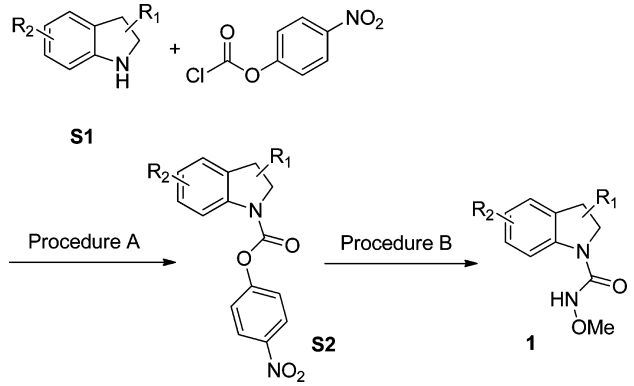
CONCLUSIONS

In summary, we have developed the first example of Rh(III)-catalyzed redox-neutral C7-selective C−H functionalization of indolines with alkynes and alkenes. In general, this mild method has enabled us to rapidly access valuable six- and seven-membered 1,7-fused indolines. Given the valuable structure of the products and lack of external oxidants, this method should be of synthetic utility.

EXPERIMENTAL SECTION

General Information. ^{1}H NMR (400 or 300 MHz) and ^{13}C NMR (125, 100 MHz) spectra were determined with $CDCl_3$ as solvent and tetramethylsilane (TMS) as internal standard. Chemical shifts were reported in ppm from internal TMS (δ). All coupling constants (J values) were reported in hertz (Hz). High-resolution mass spectra were recorded using the EI method with a double-focusing magnetic mass analyzer. Reactions were monitored by thin-layer chromatography or LC−MS analysis. Column chromatography (petroleum ether/ethyl acetate) was performed on silica gel (200−300 mesh).All of the reagents were used directly as obtained commercially unless otherwise noted.

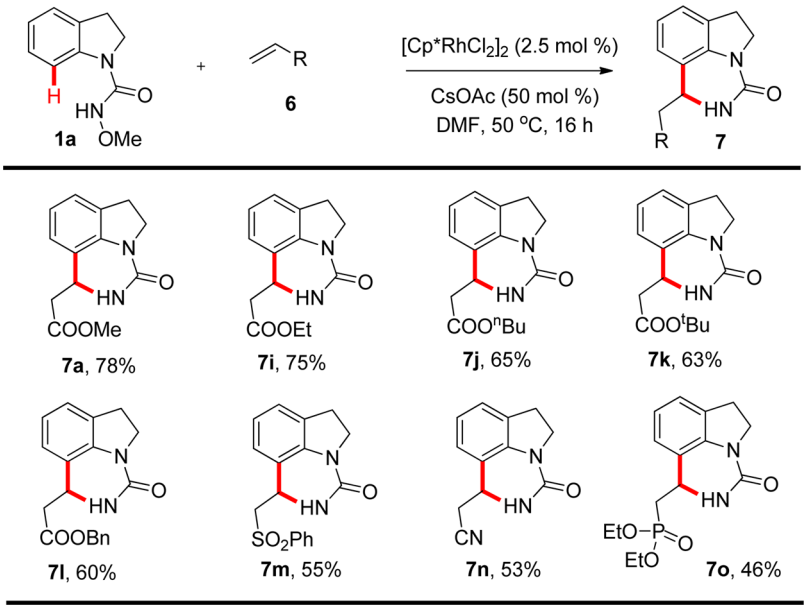
Typical Experimental Procedure for Synthesis of *N*-Methoxyindoline-1-carboxamide 1.



Procedure A. To a mixture of indoline **S1** (8.50 g, 43.1 mmol) and 4-nitrophenyl chloroformate (8.69 g, 43.1 mmol) in THF (120 mL) was added pyridine (3.50 mL, 43.1 mmol) at 0 °C. The mixture was stirred at room temperature under N_2 atmosphere for 3 h. The solid was collected and washed with AcOEt to give the title compound as a pale yellow solid (14.6 g, 94%), which was used for the next step without further purification.

Procedure B. To a solution of compound **S2** (2.84g, 10 mmol) and methoxylamine hydrochloride (4.18 g, 50 mmol) in pyridine (50 mL)

Scheme 5. Rh(III)-Catalyzed Redox-Neutral C7−H Functionalization of Indolines with Various Alkenes[a]



[a]Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), $[Cp^*RhCl_2]_2$ (2.5 mol %), CsOAc (50 mol %) and DMF (2 mL) at 50 °C for 16 h. Yield of isolated product.

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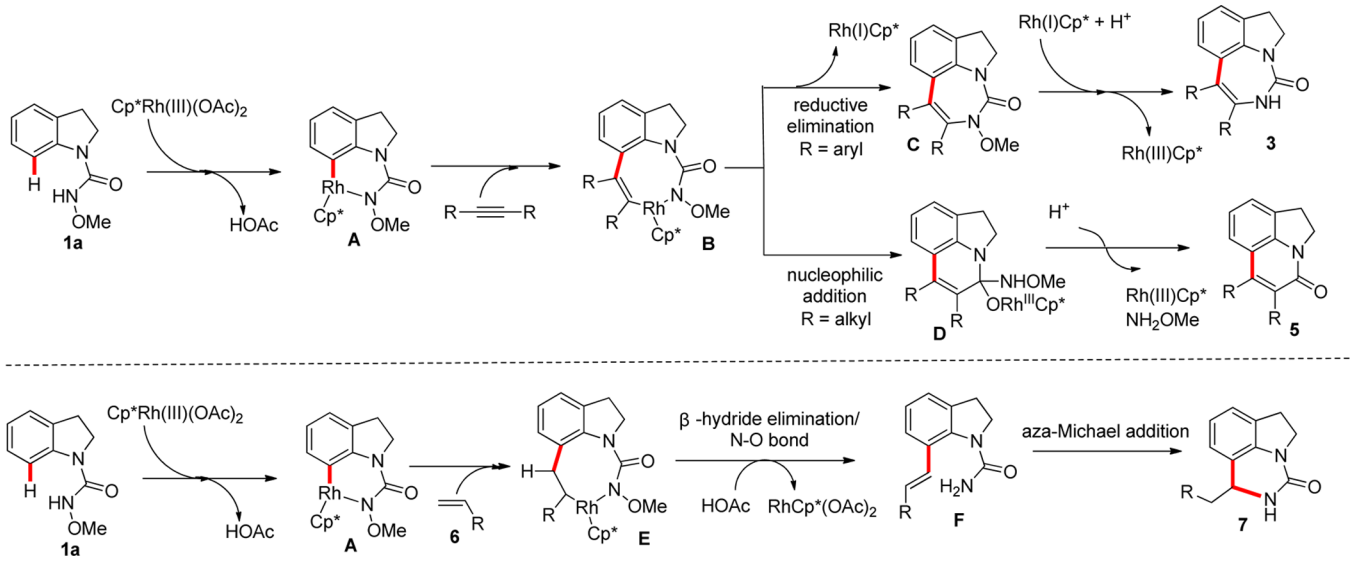
Scheme 6. Proposed Mechanism for the Rh(III)-Catalyzed Indoline C7−H Functionalization with Alkynes and Alkenes



was added DBU (7.5 mL, 50 mmol) at 0 °C. The reaction mixture was stirred overnight at 60 °C.The reaction mixture was cooled, diluted with water, and extracted with AcOEt. The organic layer was washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by silica gel column chromatography to give the title compound **1** as a colorless solid.

Compound ***1a:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 1.1 g, yield 60%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (d, J = 8.0 Hz, 1H), 7.69 (s, 1H), 7.18 (dd, J = 13.4, 7.2 Hz, 2H), 6.97 (t, J = 7.4 Hz, 1H), 3.88 (q, J = 8.1 Hz, 2H), 3.81 (s, 3H), 3.17 (t, J = 8.5 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 155.9, 142.4, 129.9, 127.1, 124.1, 122.1, 114.6, 63.9, 45.8, 27.6; HRMS (EI) calcd for $C_{10}H_{12}N_2O_2$ $[M]^+$ 192.0899, found 192.0895.

Compound ***1b:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1),1.1 g, yield 60%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, J = 8.0 Hz, 1H), 7.54 (s, 1H), 7.25−7.17 (m, 2H), 7.00 (t, J = 7.5 Hz, 1H), 4.46 (dd, J = 13.4, 6.7 Hz, 1H), 3.85 (s 3H), 3.40 (dd, J = 15.8, 9.2 Hz, 1H), 2.65 (d, J = 16.0 Hz, 1H), 1.33 (d, J = 6.4 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.0, 141.2, 130.1, 127.7, 125.4, 123.0, 115.4, 64.6, 55.1, 36.4, 20.8; HRMS (EI) calcd for $C_{11}H_{14}N_2O_2$ $[M]^+$ 206.1055, found 206.1051.

Compound ***1c:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 1.2 g, yield 60%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, J = 8.1 Hz, 1H), 7.53 (s, 1H), 7.25−7.14 (m, 2H), 7.01 (td, J = 7.4, 1.0 Hz, 1H), 4.07 (t, J = 9.2 Hz, 1H), 3.82 (s, 3H), 3.55−3.46 (m, 1H), 3.43 (dd, J = 9.2, 6.7 Hz, 1H), 1.36 (d, J = 6.8 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.2, 142.2, 135.6, 127.9, 123.5, 122.9, 115.2, 64.6, 54.5, 34.9, 20.3; HRMS (EI) calcd for $C_{11}H_{14}N_2O_2$ $[M]^+$ 206.1055, found 206.1048.

Compound ***1d:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 1.0 g, yield 50%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86 (d, J = 8.1 Hz, 1H), 7.52 (s, 1H), 7.23−7.09 (m, 2H), 6.99 (td, J = 7.4, 0.9 Hz, 1H), 3.82 (s, 3H), 3.68 (s, 2H), 1.85−1.51 (m, 7H), 1.35 (t, J = 10.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.3, 141.6, 139.7, 127.9, 122.9, 122.5, 115.1, 64.7, 56.8, 44.8, 37.3, 25.3, 23.0; HRMS (EI) calcd for $C_{15}H_{20}N_2O_2$ $[M]^+$ 260.1525, found 260.1547.

Compound ***1e:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 1.5 g, yield 55%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, J = 8.0 Hz, 1H), 7.45 (s, 1H), 7.13 (t, J = 7.8 Hz, 1H), 6.82 (d, J = 7.6 Hz, 1H), 3.92 (t, J = 8.5 Hz, 2H), 3.83 (s, 3H), 3.09 (t, J = 8.5 Hz, 2H), 2.24 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.3, 142.4, 134.2, 129.2, 127.8, 123.8, 112.6, 64.6, 46.4, 26.9, 18.6; HRMS (EI) calcd for $C_{11}H_{14}N_2O_2$ $[M]^+$ 206.1055, found 206.1053.

Compound ***1f:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 0.55 g, yield 55%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.73 (d, J = 8.7 Hz, 1H), 7.35 (s, 1H), 6.98 (d, J = 6.4 Hz, 2H), 3.86 (dd, J = 16.8, 8.1 Hz, 2H), 3.80 (s, 3H), 3.13 (t, J = 8.4 Hz, 2H), 2.29 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 156.2, 140.3, 132.4, 130.5, 128.1, 125.4, 114.8, 64.6, 46.6, 28.1, 20.9; HRMS (EI) calcd for $C_{11}H_{14}N_2O_2$ $[M]^+$ 206.1055, found 206.1046.

Compound ***1g:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 0.6 g, yield 58%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.78 (d, J = 8.5 Hz, 1H), 7.30 (s, 1H), 6.77−6.66 (m, 2H), 3.93−3.84 (m, 2H), 3.81−3.79 (m, 3H), 3.77 (s, 3H), 3.15 (t, J = 8.5 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.1, 155.8, 136.4, 131.9, 115.7, 112.1, 111.2, 64.6, 55.7, 46.6, 28.3; HRMS (EI) calcd for $C_{11}H_{14}N_2O_3$ $[M]^+$ 222.1004, found 222.1006.

Compound ***1h:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 0.7 g, yield 52%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (dd, J = 9.6, 4.7 Hz, 1H), 7.38 (s, 1H), 6.95−6.85 (m, 2H), 3.97−3.89 (m, 2H), 3.82 (s, 3H), 3.20 (t, J = 8.6 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 158.9 (d, J = 275.1), 156.1, 138.95, 132.0 (d, J = 19.8), 115.9 (d, J = 19.5), 113.8 (d, J = 54.6), 111.9 (d, J = 57.9), 64.6, 46.7, 28.1; HRMS (EI) calcd for $C_{10}H_{11}FN_2O_2$ $[M]^+$ 210.0805, found 210.0801.

Compound ***1i:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 0.6 g, yield 58%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.84 (d, J = 8.3 Hz, 1H), 7.38 (s, 1H), 7.14 (d, J = 8.8 Hz, 2H), 3.89 (t, J = 8.6 Hz, 2H), 3.80 (s, 3H), 3.16 (t, J = 8.5 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.1, 141.6, 132.1, 127.7, 127.6, 124.8, 116.2, 64.7, 46.6, 27.9; HRMS (EI) calcd for $C_{10}H_{11}ClN_2O_2$ $[M]^+$ 226.0509, found 226.0501.

Compound ***1j:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 0.7 g, yield 52%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (d, J = 8.4 Hz, 1H), 7.45 (s, 1H), 7.32−7.29 (m, 1H), 3.90 (t, J = 8.6 Hz, 2H), 3.82 (s, 3H), 3.19 (t, J = 8.6 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.1, 142.1, 132.5, 130.5, 127.6, 116.6, 115.1, 64.6, 46.5, 27.9; HRMS (EI) calcd for $C_{10}H_{11}BrN_2O_2$ $[M]^+$ 270.0004, found 270.0001.

Compound ***1k:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 0.7 g, yield 52%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02−7.91 (m, 2H), 7.85 (s, 1H), 7.46 (d, J = 10.1 Hz, 1H), 4.00−3.93 (m, 2H), 3.91 (s, 3H), 3.84 (d, J = 0.5 Hz, 3H), 3.25 (t, J = 8.6 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.9, 156.1, 147.1, 130.4, 130.3, 126.1, 125.9, 124.4, 115.8, 114.5, 64.6, 51.9, 46.8, 27.6; HRMS (EI) calcd for $C_{12}H_{14}N_2O_4$ $[M]^+$ 250.0954, found 250.0951.

Compound ***1l:*** column chromatography (CH_2Cl_2/CH_3OH = 30:1), 0.4 g, yield 50%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.59 (d, J = 2.1 Hz, 1H), 7.42 (s, 1H), 7.02 (d, J = 8.2 Hz, 1H), 6.51 (dd, J = 8.3, 2.3 Hz, 1H), 3.88 (t, J = 8.5 Hz, 2H), 3.80 (d, J = 2.7 Hz, 6H), 3.10 (t, J = 8.5 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.6, 156.2, 143.9, 124.8, 122.1, 108.8, 101.5, 64.7, 55.6, 47.2, 27.4; HRMS (EI) calcd for $C_{11}H_{14}N_2O_3$ $[M]^+$ 222.1004, found 222.1006.

General Procedure for the Synthesis of 3 (Taking 3a as an Example). $(RhCp^*Cl_2)_2$ (2.5 mol %), NaOAc (200 mol %), indoline **1a**

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(0.2 mmol), diphenylacetylene **2a** (0.4 mmol), and MeOH (2 mL, 0.1 M) were added to a sealed test tube under air. The reaction mixture was stirred at 80 °C for 24 h. The crude mixture was filtered through Celite and concentrated under reduced pressure. The residue was purified by flash column chromatography (PE:EA = 10:1) to give the desired product **3a**.

*Compound **3a**:* 50 mg, yield 75%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20−7.10 (m, 8H), 7.10−7.00 (m, 3H), 6.81 (t, J = 7.6 Hz, 1H), 6.54 (d, J = 7.9 Hz, 1H), 5.84 (s, 1H), 4.28 (t, J = 8.4 Hz, 2H), 3.07 (t, J = 8.4 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.5, 141.6, 139.7, 139.6, 136.5, 132.9, 131.7, 128.6, 128.4, 127.9, 127.7, 126.8, 124.5, 123.9, 123.6, 47.6, 27.6; HRMS (EI) calcd for $C_{23}H_{18}N_2O$ $[M]^+$ 338.1419, found 338.1417.

*Compound **3b**:* column chromatography (PE:EA = 10:1), 42 mg, yield 60%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23−7.07 (m, 8H), 7.08−6.98 (m, 3H), 6.82 (dd, J = 13.8, 6.2 Hz, 1H), 6.54 (d, J = 7.9 Hz, 1H), 5.82 (s, 1H), 5.11−4.93 (m, 1H), 3.40 (dd, J = 16.0, 9.5 Hz, 1H), 2.54 (dd, J = 16.1, 2.6 Hz, 1H), 1.39 (d, J = 6.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3, 140.5, 139.7, 139.7, 136.5, 131.8, 131.7, 128.6, 128.4, 128.1, 127.9, 126.8, 124.8, 123.8, 123.4, 55.1, 35.2, 22.1; HRMS (EI) calcd for $C_{24}H_{20}N_2O$ $[M]^+$ 352.1576, found 352.1577.

*Compound **3c**:* column chromatography (PE:EA = 10:1), 47 mg, yield 68%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19−7.10 (m, 8H), 7.08−6.99 (m, 3H), 6.85 (t, J = 7.6 Hz, 1H), 6.56 (d, J = 7.9 Hz, 1H), 5.88 (s, 1H), 4.49 (dd, J = 11.4, 9.0 Hz, 1H), 3.75 (dd, J = 11.5, 7.0 Hz, 1H), 3.44−3.32 (m, 1H), 1.35 (d, J = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.5, 141.1, 139.7, 139.5, 138.2, 136.5, 131.6, 128.6, 128.4, 127.9, 127.9, 127.6, 126.8, 124.0, 123.6, 123.3, 55.4, 34.4, 19.7; HRMS (EI) calcd for $C_{24}H_{20}N_2O$ $[M]^+$ 352.1576, found 352.1572.

*Compound **3d**:* column chromatography (PE:EA = 8:1), 48 mg, yield 60%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23−7.07 (m, 8H), 7.06−6.98 (m, 3H), 6.88−6.82 (m, 1H), 6.54 (dd, J = 7.9, 1.2 Hz, 1H), 5.84 (s, 1H), 4.10 (s, 2H), 1.74 (dd, J = 18.7, 12.4 Hz, 5H), 1.64−1.46 (m, 5H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.6, 142.4, 140.6, 139.8, 139.6, 136.6, 131.7, 128.6, 128.5, 127.9, 127.7, 126.8, 124.0, 123.6, 122.3, 57.6, 44.0, 36.8, 25.7, 23.2. HRMS (EI) calcd for $C_{28}H_{26}N_2O$ $[M]^+$ 406.2045, found 406.2041.

*Compound **3e**:* column chromatography (PE:EA = 10:1), 54 mg, yield 77%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23−7.08 (m, 8H), 7.03 (dd, J = 7.5, 2.0 Hz, 2H), 6.65 (d, J = 8.0 Hz, 1H), 6.46 (d, J = 8.0 Hz, 1H), 5.87 (s, 1H), 4.29 (t, J = 8.4 Hz, 2H), 2.97 (t, J = 8.4 Hz, 2H), 2.21 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.4, 141.3, 139.6, 135.5, 134.2, 131.5, 128.5, 128.3, 127.9, 127.8, 127.8, 126.6, 124.9, 124.8, 123.5, 47.3, 26.4, 18.6; HRMS (EI) calcd for $C_{24}H_{20}N_2O$ $[M]^+$ 352.1576, found 352.1574.

*Compound **3f**:* column chromatography (PE:EA = 10:1), 54 mg, yield 78%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23−7.09 (m, 8H), 7.09−6.99 (m, 2H), 6.90 (s, 1H), 6.36 (s, 1H), 5.88 (s, 1H), 4.26 (t, J = 8.3 Hz, 2H), 3.02 (t, J = 8.3 Hz, 2H), 2.12 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.6, 139.8, 139.5, 139.4, 136.5, 133.5, 133.1, 131.6, 128.6, 128.3, 128.1, 127.9, 127.8, 127.3, 126.7, 125.3, 123.6, 47.7, 27.6, 20.9; HRMS (EI) calcd for $C_{24}H_{20}N_2O$ $[M]^+$ 352.1576, found 352.1575.

*Compound **3g**:* column chromatography (PE:EA = 6:1), 58 mg, yield 80%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19−7.04 (m, 8H), 7.06−7.00 (m, 2H), 6.71−6.61 (m, 1H), 6.09 (d, J = 2.5 Hz, 1H), 5.84 (s, 1H), 4.31−4.22 (m, 2H), 3.58 (s, 3H), 3.03 (t, J = 8.3 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.4, 156.5, 139.7, 139.3, 136.9, 135.2, 134.3, 131.6, 128.6, 128.4, 128.3, 127.9, 126.8, 123.3, 113.1, 110.4, 55.7, 47.9, 28.1; HRMS (EI) calcd for $C_{24}H_{20}N_2O$ $[M]^+$ 368.1525, found 368.1517.

*Compound **3h**:* column chromatography (PE:EA = 10:1), 44 mg, yield 60%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 (dd, J = 9.2, 5.7 Hz, 8H), 7.01 (dd, J = 6.6, 4.1 Hz, 3H), 6.51 (s, 1H), 5.88 (s, 1H), 4.28 (t, J = 8.4 Hz, 2H), 3.05 (t, J = 8.4 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.1, 140.2, 139.5, 138.8, 137.5, 134.9, 131.6, 129.2, 128.9, 128.5, 128.2, 127.4, 127.2, 124.5, 122.6, 47.9, 27.6; HRMS (EI) calcd for $C_{23}H_{17}ClN_2O$ $[M]^+$ 372.1029, found 372.1024.

*Compound **3i**:* column chromatography (PE:EA = 10:1), 58 mg, yield 70%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.13 (ddd, J = 10.0, 8.5, 3.9 Hz, 9H), 7.00 (dd, J = 7.3, 2.1 Hz, 2H), 6.65 (s, 1H), 5.90 (s, 1H), 4.27 (t, J = 8.4 Hz, 2H), 3.05 (t, J = 8.4 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.1, 140.8, 139.4, 138.8, 137.6, 135.2, 131.5, 130.3, 129.4, 128.5, 128.2, 128.2, 127.3, 127.2, 122.5, 116.7, 47.8, 27.5; HRMS (EI) calcd for $C_{23}H_{17}BrN_2O$ $[M]^+$ 416.0524, found 416.0522.

*Compound **3j**:* column chromatography (PE:EA = 8:1), 41 mg, yield 52%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, J = 1.1 Hz, 1H), 7.28 (s, 1H), 7.21−7.08 (m, 8H), 7.01 (dd, J = 7.5, 1.9 Hz, 2H), 5.95 (s, 1H), 4.31 (t, J = 8.5 Hz, 2H), 3.76 (s, 3H), 3.09 (t, J = 8.5 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.6, 161.5, 145.7, 139.4, 138.9, 136.9, 133.3, 131.5, 130.3, 128.5, 128.5, 128.2, 128.1, 127.3, 127.1, 125.9, 125.6, 123.0, 52.1, 47.9, 27.1; HRMS (EI) calcd for $C_{25}H_{20}N_2O_3$ $[M]^+$ 396.1474, found 396.1481.

*Compound **3k**:* column chromatography (PE:EA = 10:1), 51 mg, yield 70%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.14−6.89 (m, 9H), 6.81 (t, J = 7.6 Hz, 1H), 6.56 (d, J = 7.9 Hz, 1H), 5.84 (s, 1H), 4.27 (t, J = 8.3 Hz, 2H), 3.06 (t, J = 8.3 Hz, 2H), 2.25 (d, J = 4.3 Hz, 6H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.9, 141.8, 137.6, 137.1, 136.7, 136.3, 136.3, 132.9, 131.5, 129.1, 128.7, 128.4, 128.1, 127.9, 124.3, 123.8, 123.4, 47.5, 27.7, 21.4, 21.3, 0.14; HRMS (EI) calcd for $C_{25}H_{22}N_2O$ $[M]^+$ 366.1732, found 366.1730.

*Compound **3l**:* column chromatography (PE:EA = 7:1), 63 mg, yield 80%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06 (t, J = 7.2 Hz, 3H), 6.93 (d, J = 8.6 Hz, 2H), 6.81 (t, J = 7.6 Hz, 1H), 6.72−6.65 (m, 4H), 6.57 (d, J = 7.8 Hz, 1H), 5.83 (s, 1H), 4.26 (t, J = 8.4 Hz, 2H), 3.74 (d, J = 2.3 Hz, 6H), 3.05 (t, J = 8.3 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.9, 158.9, 158.2, 141.7, 136.1, 132.8, 132.7, 132.5, 132.1, 129.9, 128.1, 127.9, 124.3, 123.8, 123.1, 113.7, 113.4, 55.3, 55.2, 47.5, 27.7; HRMS (EI) calcd for $C_{25}H_{22}N_2O_3$ $[M]^+$ 398.1630, found 398.1628.

*Compound **3m**:* column chromatography (PE:EA = 10:1), 48 mg, yield 65%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16−7.03 (m, 3H), 6.97 (dd, J = 8.5, 5.6 Hz, 2H), 6.92−6.74 (m, 5H), 6.50 (d, J = 7.8 Hz, 1H), 5.88 (s, 1H), 4.26 (t, J = 8.4 Hz, 2H), 3.06 (t, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.1 (d, J = 34.4 Hz), 162.2, 160.6 (d, J = 32.5 Hz), 141.5, 135.7, 135.6 (d, J = 3.5 Hz), 135.3 (d, J = 3.3 Hz), 133.2 (d, J = 8.3 Hz), 133.1, 130.5 (d, J = 8.1 Hz), 127.8, 127.3, 124.7, 123.9, 122.9, 115.7, 115.5, 115.3, 115.0, 47.6, 27.6; HRMS (EI) calcd for $C_{23}H_{16}F_2N_2O$ $[M]^+$ 374.1231, found 374.1228.

*Compound **3n**:* column chromatography (PE:EA = 10:1), 51 mg, yield 70%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.10−6.98 (m, 4H), 6.93 (dd, J = 11.6, 7.1 Hz, 3H), 6.83 (dd, J = 17.3, 9.8 Hz, 3H), 6.58 (d, J = 7.9 Hz, 1H), 5.86 (s, 1H), 4.27 (t, J = 8.4 Hz, 2H), 3.06 (t, J = 8.4 Hz, 2H), 2.20 (d, J = 6.4 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.7, 141.7, 139.6, 139.5, 137.9, 137.4, 136.5, 132.9, 132.2, 129.1, 128.7, 128.6, 128.1, 128.0, 127.9, 127.7, 127.5, 125.8, 124.4, 123.8, 123.5, 47.5, 27.7, 21.4; HRMS (EI) calcd for $C_{25}H_{22}N_2O$ $[M]^+$ 366.1732, found 366.1731.

*Compound **3o**:* column chromatography (PE:EA = 12:1), 28 mg, yield 52%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46−7.33 (m, 5H), 7.14−7.09 (m, 2H), 7.03 (t, J = 7.5 Hz, 1H), 5.58 (s, 1H), 4.31−4.16 (m, 2H), 3.03 (t, J = 8.3 Hz, 2H), 1.98 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.6, 142.3, 139.6, 135.2, 132.9, 129.2, 128.8, 128.6, 125.4, 124.3, 124.2, 116.8, 47.3, 27.8, 19.0; HRMS (EI) calcd for $C_{18}H_{16}N_2O$ $[M]^+$ 276.1263, found 276.1255.

*Compound **3p**:* column chromatography (PE:EA = 12:1), 31 mg, yield 54%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.46−7.28 (m, 5H), 7.13 (t, J = 8.0 Hz, 2H), 7.03 (t, J = 7.5 Hz, 1H), 5.51 (s, 1H), 4.24 (t, J = 8.2 Hz, 2H), 3.03 (t, J = 8.3 Hz, 2H), 2.43 (q, J = 7.4 Hz, 2H), 0.83 (t, J = 7.4 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.8, 143.4, 139.5, 135.2, 133.2, 128.8, 128.8, 128.4, 126.7, 125.0, 124.1, 123.5, 47.1, 27.8, 24.3, 14.1; HRMS (EI) calcd for $C_{19}H_{18}N_2O$ $[M]^+$ 290.1419, found 290.1412.

General Procedure for the Synthesis of 5 and 6 (taking 5a and 5a′ as an Example). $(RhCp^*Cl_2)_2$ (2.5 mol %), NaOAc (200 mol %), indoline **1a** (0.2 mmol), 3-hexyne **4a** (0.4 mmol), and MeOH (2 mL, 0.1 M) were added to a test tube under air. The reaction mixture was stirred at 80 °C for 24 h. The crude mixture was filtered through Celite and concentrated under reduced pressure. The residue was purified by flash column chromatography (PE:EA = 15:1) to give the compound

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5a′. Subsequently, the major product was further eluted with PE/EA (3:1) to provide the pure compound **5a**.

*Compound **5a**:* column chromatography (PE:EA = 3:1), 27 mg, yield 60%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (dd, J = 8.1, 0.8 Hz, 1H), 7.28−7.24 (m, 1H), 7.13 (dd, J = 8.0, 7.2 Hz, 1H), 4.42 (dd, J = 8.7, 7.6 Hz, 2H), 3.44−3.32 (m, 2H), 2.88 (q, J = 7.6 Hz, 2H), 2.75 (q, J = 7.5 Hz, 2H), 1.26 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.1, 146.2, 141.0, 133.9, 130.8, 123.8, 122.9, 120.9, 118.1, 47.0, 27.2, 21.7, 20.5, 14.4, 14.1; HRMS (EI) calcd for $C_{15}H_{17}NO$ $[M]^+$ 227.1310, found 227.1308.

*Compound **5a′**:* column chromatography (PE:EA = 15:1), 10 mg, yield 20%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06 (dd, J = 10.1, 4.1 Hz, 2H), 6.98 (t, J = 7.5 Hz, 1H), 5.31 (s, 1H), 4.21−4.13 (m, 2H), 2.99 (t, J = 8.3 Hz, 2H), 2.45 (q, J = 7.5 Hz, 2H), 2.26 (q, J = 7.5 Hz, 2H), 1.19 (t, J = 7.5 Hz, 3H), 1.07 (t, J = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 143.2, 136.9, 133.0, 128.1, 124.5, 124.1, 123.6, 121.6, 47.1, 27.9, 27.9, 24.3, 15.1, 12.7; HRMS (EI) calcd for $C_{15}H_{18}N_2O$ $[M]^+$ 242.1419, found 242.1417.

*Compound **5b**:* column chromatography (PE:EA = 3:1), 21 mg, yield 45%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48−7.44 (m, 1H), 7.24 (d, J = 1.0 Hz, 1H), 7.14 (dd, J = 8.0, 7.2 Hz, 1H), 5.10−4.98 (m, 1H), 3.59 (dd, J = 16.6, 9.4 Hz, 1H), 2.95 (dd, J = 16.6, 3.7 Hz, 1H), 2.88 (q, J = 7.6 Hz, 2H), 2.75 (qd, J = 7.5, 3.3 Hz, 2H), 1.60 (d, J = 6.4 Hz, 3H), 1.27 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.9, 145.9, 140.4, 134.5, 129.4, 123.9, 122.9, 121.0, 117.9, 56.7, 36.4, 21.7, 20.8, 20.5, 14.4, 14.1; HRMS (EI) calcd for $C_{16}H_{19}NO$ $[M]^+$ 241.1467, found 241.1465.

*Compound **5c**:* column chromatography (PE:EA = 3:1), 21 mg, yield 44%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, J = 8.0 Hz, 1H), 7.25 (d, J = 5.7 Hz, 1H), 7.16 (t, J = 7.6 Hz, 1H), 4.59 (dd, J = 12.6, 9.4 Hz, 1H), 3.97 (dd, J = 12.6, 5.5 Hz, 1H), 3.74 (dd, J = 15.5, 6.7 Hz, 1H), 2.89 (q, J = 7.6 Hz, 2H), 2.76 (q, J = 7.4 Hz, 2H), 1.44 (d, J = 7.0 Hz, 3H), 1.26 (t, J = 7.6 Hz, 3H), 1.18 (t, J = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.0, 146.2, 140.4, 136.0, 134.0, 123.0, 122.9, 121.2, 117.9, 54.9, 34.8, 21.8, 20.9, 20.5, 14.5, 14.1; HRMS (EI) calcd for $C_{16}H_{19}NO$ $[M]^+$ 241.1467, found 241.1464.

*Compound **5d**:* column chromatography (PE:EA = 5:1), 29 mg, yield 50%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, J = 7.9 Hz, 1H), 7.23 (d, J = 7.1 Hz, 1H), 7.17 (t, J = 7.6 Hz, 1H), 4.24 (s, 2H), 2.89 (q, J = 7.6 Hz, 2H), 2.76 (q, J = 7.4 Hz, 2H), 1.85−1.31 (m, 10H), 1.28 (d, J = 7.6 Hz, 3H), 1.18 (t, J = 7.4 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.0, 146.2, 140.0, 139.8, 133.9, 122.9, 121.9, 121.3, 118.0, 57.8, 45.7, 37.9, 25.4, 23.1, 21.8, 20.5, 14.5, 14.1; HRMS (EI) calcd for $C_{20}H_{25}NO$ $[M]^+$ 295.1936, found 295.1934.

*Compound **5e**:* column chromatography (PE:EA = 3:1), 24 mg, yield 50%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 (d, J = 8.2 Hz, 1H), 6.96 (d, J = 8.2 Hz, 1H), 4.46−4.37 (m, 2H), 3.32−3.22 (m, 2H), 2.86 (q, J = 7.6 Hz, 2H), 2.74 (q, J = 7.4 Hz, 2H), 2.34 (s, 3H), 1.24 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.4 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.3, 146.2, 140.9, 134.0, 132.6, 128.9, 124.6, 121.1, 115.9, 47.4, 26.3, 21.7, 20.4, 18.6, 14.5, 14.1; HRMS (EI) calcd for $C_{16}H_{19}NO$ $[M]^+$ 241.1467, found 241.1462.

*Compound **5f**:* column chromatography (PE:EA = 3:1), 23 mg, yield 48%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (s, 1H), 7.11 (s, 1H), 4.53−4.33 (m, 2H), 3.34 (t, J = 8.0 Hz, 2H), 2.86 (q, J = 7.6 Hz, 2H), 2.75 (q, J = 7.5 Hz, 2H), 2.44 (s, 3H), 1.25 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.9, 145.9, 139.2, 133.8, 132.6, 130.9, 125.3, 120.6, 117.7, 47.1, 27.2, 21.9, 21.7, 20.5, 14.5, 14.1; HRMS (EI) calcd for $C_{16}H_{19}NO$ $[M]^+$ 241.1467, found 241.1463.

*Compound **5g**:* column chromatography (PE:EA = 2:1), 28 mg, yield 54%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.94 (s, 1H), 6.87 (s, 1H), 4.50−4.33 (m, 2H), 3.85 (s, 3H), 3.35 (t, J = 8.0 Hz, 2H), 2.85 (q, J = 7.6 Hz, 2H), 2.75 (q, J = 7.5 Hz, 2H), 1.25 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.4 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.5, 156.6, 145.5, 135.9, 134.4, 132.2, 117.9, 113.5, 103.3, 56.3, 47.2, 27.3, 21.8, 20.6, 14.2, 14.1; HRMS (EI) calcd for $C_{16}H_{19}NO_2$ $[M]^+$ 257.1416, found 257.1412.

*Compound **5h**:* column chromatography (PE:EA = 3:1), 27 mg, yield 55%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.11 (d, J = 10.4 Hz, 1H), 7.03 (d, J = 8.2 Hz, 1H), 4.50−4.36 (m, 2H), 3.38 (t, J = 8.0 Hz, 2H), 2.82 (q, J = 7.6 Hz, 2H), 2.74 (q, J = 7.5 Hz, 2H), 1.24 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.6 (d, J = 15.4 Hz), 158.4, 145.4 (d, J = 3.4 Hz), 137.4, 135.1, 132.5 (d, J = 9.2 Hz), 117.9 (d, J = 9.1 Hz), 112.8 (d, J = 26.7 Hz), 106.3 (d, J = 24.8 Hz), 47.3, 27.2, 21.9, 20.6, 14.2, 13.9; HRMS (EI) calcd for $C_{15}H_{16}FNO$ $[M]^+$ 245.1216, found 245.1212.

*Compound **5i**:* column chromatography (PE:EA = 3:1), 23 mg, yield 45%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (s, 1H), 7.23 (s, 1H), 4.55−4.33 (m, 2H), 3.37 (t, J = 8.0 Hz, 2H), 2.83 (q, J = 7.6 Hz, 2H), 2.74 (q, J = 7.5 Hz, 2H), 1.25 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.7, 145.2, 139.7, 135.2, 132.5, 128.3, 124.4, 120.7, 118.5, 47.2, 27.1, 21.7, 20.6, 14.4, 13.9; HRMS (EI) calcd for $C_{15}H_{16}ClNO$ $[M]^+$ 261.0920, found 261.0917.

*Compound **5j**:* column chromatography (PE:EA = 3:1), 28 mg, yield 47%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60−7.55 (m, 1H), 7.36 (dd, J = 2.8, 1.3 Hz, 1H), 4.42 (dd, J = 8.7, 7.5 Hz, 2H), 3.37 (t, J = 8.1 Hz, 2H), 2.83 (q, J = 7.6 Hz, 2H), 2.74 (q, J = 7.5 Hz, 2H), 1.24 (t, J = 7.6 Hz, 3H), 1.16 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.7, 145.1, 139.9, 135.2, 132.8, 127.0, 123.7, 119.1, 115.6, 47.1, 27.1, 21.7, 20.6, 14.4, 13.9; HRMS (EI) calcd for $C_{15}H_{16}BrNO$ $[M]^+$ 305.0415, found 305.0408.

*Compound **5k**:* column chromatography (PE:EA = 2:1), 25 mg, yield 44%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.93 (s, 1H), 4.50−4.38 (m, 2H), 3.94 (s, 3H), 3.40 (t, J = 8.1 Hz, 2H), 2.92 (q, J = 7.6 Hz, 2H), 2.75 (q, J = 7.4 Hz, 2H), 1.27 (t, J = 7.6 Hz, 3H), 1.17 (t, J = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 161.2, 146.4, 144.3, 134.7, 131.1, 124.9, 124.7, 124.4, 117.1, 52.4, 47.4, 26.9, 21.7, 20.5, 14.6, 13.9; HRMS (EI) calcd for $C_{17}H_{19}NO_3$ $[M]^+$ 285.1365, found 285.1363.

*Compound **5l′***. Column chromatography (PE:EA = 10:1), 27 mg, yield 35%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.02 (d, J = 8.1 Hz, 1H), 6.54 (d, J = 8.1 Hz, 1H), 5.28 (s, 1H), 4.20 (brs, 2H), 3.81 (s, 3H), 2.93 (t, J = 7.8 Hz, 2H), 2.53 (d, J = 6.3 Hz, 2H), 2.30 (s, 2H), 1.18 (t, J = 7.5 Hz, 3H), 0.92 (t, J = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 156.1, 146.6, 137.8, 125.2, 123.6, 123.6, 117.4, 106.5, 55.8, 47.6, 27.4, 27.3, 23.4, 14.8, 12.7; HRMS (EI) calcd for $C_{16}H_{20}N_2O_2$ $[M]^+$ 272.1525, found 272.1521.

*Compound **5m**:* column chromatography (PE:EA = 3:1), 16 mg, yield 40%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (d, J = 8.1 Hz, 1H), 7.29−7.24 (m, 1H), 7.17−7.10 (m, 1H), 4.48−4.33 (m, 2H), 3.38 (t, J = 8.1 Hz, 2H), 2.40 (s, 3H), 2.25 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.2, 140.7, 140.4, 130.5, 128.6, 123.8, 122.8, 120.8, 118.9, 46.9, 27.2, 14.8, 13.2; HRMS (EI) calcd for $C_{13}H_{13}NO$ $[M]^+$ 199.0997, found 199.0994.

*Compound **5n**:* column chromatography (PE:EA = 3:1), 26 mg, yield 55%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, J = 7.4 Hz, 1H), 7.31−7.22 (m, 1H), 7.13 (dd, J = 8.0, 7.2 Hz, 1H), 4.46−4.37 (m, 2H), 3.39 (t, J = 8.1 Hz, 2H), 2.86−2.79 (m, 2H), 2.77−2.64 (m, 2H), 1.69−1.51 (m, 4H), 0.99 (t, J = 7.2 Hz, 3H), 0.95 (t, J = 7.2 Hz, 3H),; ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.2, 144.9, 141.0, 133.1, 130.8, 123.8, 122.8, 121.2, 118.4, 46.9, 30.8, 29.5, 27.3, 23.4, 22.9, 14.7, 14.7; HRMS (EI) calcd for $C_{17}H_{21}NO$ $[M]^+$ 255.1623, found 255.1618.

*Compound **5o**:* column chromatography (PE:EA = 3:1), 28 mg, yield 50%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (dd, J = 8.1, 0.7 Hz, 1H), 7.28−7.25 (m, 1H), 7.13 (dd, J = 8.0, 7.2 Hz, 1H), 4.47−4.32 (m, 2H), 3.38 (t, J = 8.1 Hz, 2H), 2.88−2.78 (m, 2H), 2.78−2.66 (m, 2H), 1.64−1.39 (m, 8H), 0.97 (dt, J = 12.3, 7.2 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.2, 145.1, 140.9, 133.0, 130.8, 123.8, 122.9, 121.1, 118.4, 46.9, 32.2, 31.8, 28.5, 27.3, 27.2, 23.4, 23.3, 14.2, 14.1; HRMS (EI) calcd for $C_{19}H_{25}NO$ $[M]^+$ 283.1936, found 283.1931.

General Procedure for the Synthesis of 7 (Taking 7a). $(RhCp^*Cl_2)_2$ (2.5 mol %), CsOAc (50 mol %), indoline **1a** (0.2 mmol), methyl acrylate **6a** (0.4 mmol), and DMF (2 mL, 0.1 M) were added to a test tube under air. The reaction mixture was stirred at 50 °C for 16 h. The crude mixture was filtered through Celite and concentrated under reduced pressure. The residue was purified by flash column chromatography to give the desired product **7a**. The structure was established via NOE studies (see the Supporting Information).

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Compound ***7a:*** column chromatography (PE:acetone = 2:1), 38 mg, yield 78%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08 (dd, J = 7.9, 5.7 Hz, 1H), 6.92−6.83 (m, 2H), 5.59 (s, 1H), 5.06 (ddd, J = 8.8, 4.6, 2.5 Hz, 1H), 4.04−3.95 (m, 2H), 3.72 (s, 3H), 3.17 (t, J = 8.6 Hz, 2H), 2.85−2.67 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.5, 153.4, 140.6, 128.7, 124.5, 122.8, 122.8, 116.8, 52.1, 51.3, 45.8, 42.9, 28.0; HRMS (EI) calcd for $C_{13}H_{14}N_2O_3$ $[M]^+$ 246.1004, found 246.1001.

Compound ***7b.*** Column chromatography (PE:acetone =2:1), 39 mg, yield 76% (dr = 2.5:1), amorphous solid. The indicated compounds were separated from the reaction crude mixture by flash column chromatography on silica gel. The two compounds are having the same R_f values, and they were obtained as an inseparable mixture with a ratio of 2.5:1. The following ^{1}H NMR data are not complete due to overlapping of some of the peaks. Major product: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06−6.84 (m, Ar−H, 3H), 5.47 (s, 1H, N−H), 5.12 (d, J = 9.9 Hz, 1H), 4.55 (m, 1H), 3.74 (s, 3H), 3.38 (m, 1H), 2.77−2.69 (m, 3H), 1.44 (d, J = 6.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.7, 152.7, 139.9, 127.5, 124.7, 122.7, 122.5, 116.6, 55.8, 52.2, 51.0, 42.3, 36.9, 20.9, Minor product: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06−6.84 (m, 3H), 5.43 (s, 1H, N−H), 5.01 (dt, J = 10.0, 3.2 Hz, 1H), 4.55 (m, 1H), 3.72 (s, 3H), 3.38 (m, 1H), 2.91−2.85 (m, 3H), 1.51 (d, J = 6.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.5, 153.6, 140.4, 127.6, 124.4, 122.9, 122.8, 116.9, 55.3, 52.1, 51.3, 43.1, 37.1, 22.0; HRMS (EI) calcd for $C_{14}H_{16}N_2O_3$ $[M]^+$ 260.1161, found 260.1162.

Compound ***7c.*** Column chromatography (PE:acetone = 2:1), 37 mg, yield 72% (dr = 1:1), amorphous solid. The indicated compounds were separated from the reaction crude mixture by flash column chromatography on silica gel. The two compounds are having the same R_f values and they were obtained as an inseparable mixture with a ratio of 1:1: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.07−6.87 (m, Ar−H, 3H), 5.53 (s, 1H, N−H), 5.07 (m, 1H), 4.17 (m, 1H), 3.73 (s, 3H), 3.53 (m, 2H), 2.75 (m, 2H), 1.36 (d, J = 6.4 Hz, 3H); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.07−6.87 (m, Ar−H, 3H), 5.53 (s, 1H, N−H), 5.07 (m, 1H), 4.17 (m, 1H), 3.72 (s, 3H), 3.53 (m, 2H), 2.75 (m, 2H), 1.36 (d, J = 6.4 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.6 (171.5), 153.5 (153.2), 140.2 (139.9), 133.9 (133.7), 123.5 (123.4), 122.9, 116.8, 54.1 (53.8), 52.1 (52.1), 51.4 (51.3), 43.1 (42.9), 35.6 (35.5), 20.9 (19.8); HRMS (EI) calcd for $C_{14}H_{16}N_2O_3$ $[M]^+$ 260.1161, found 260.1158.

Compound ***7d:*** column chromatography (PE:acetone = 2:1), 39 mg, yield 75%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.79 (d, J = 7.8 Hz, 1H), 6.71 (d, J = 7.8 Hz, 1H), 5.44 (s, 1H), 5.05 (t, J = 5.6 Hz, 1H), 4.02 (m, 2H), 3.73 (s, 3H), 3.10 (t, J = 8.5 Hz, 2H), 2.22 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.6, 153.4, 140.3, 134.6, 127.5, 123.8, 123.0, 114.3, 52.2, 51.3, 45.8, 43.1, 27.1, 18.4; HRMS (EI) calcd for $C_{14}H_{16}N_2O_3$ $[M]^+$ 260.1161, found 260.1155.

Compound ***7e:*** column chromatography (PE:acetone = 2:1), 39 mg, yield 75%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.91 (s, 1H), 6.68 (s, 1H), 5.42 (s, 1H), 5.17−4.91 (m, 1H), 4.10−3.87 (m, 2H), 3.73 (s, 3H), 3.14 (t, J = 8.5 Hz, 2H), 2.85−2.64 (m, 2H), 2.28 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.6, 153.4, 138.4, 132.6, 128.8, 125.3, 123.1, 116.5, 52.2, 51.4, 45.9, 43.0, 28.1, 21.3; HRMS (EI) calcd for $C_{14}H_{16}N_2O_3$ $[M]^+$ 260.1161, found 260.1157.

Compound ***7f:*** column chromatography (PE:acetone = 1:1), 38 mg, yield 70%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.70 (s, 1H), 6.44 (s, 1H), 5.36 (s, 1H), 5.12−4.88 (m, 1H), 4.06−3.96 (m, 2H), 3.75 (s, 3H), 3.74 (s, 3H), 3.16 (t, J = 8.5 Hz, 2H), 2.82−2.54 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.5, 156.6, 153.4, 134.4, 129.9, 117.1, 111.3, 108.3, 56.2, 52.2, 51.5, 46.1, 42.9, 28.3; HRMS (EI) calcd for $C_{14}H_{16}N_2O_4$ $[M]^+$ 276.1110, found 276.1108.

Compound ***7g:*** column chromatography (PE/acetone = 2:1), 42 mg, yield 75%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06 (s, 1H), 6.88 (s, 1H), 5.49 (s, 1H), 5.13−4.98 (m, 1H), 4.15−3.93 (m, 2H), 3.74 (s, 3H), 3.17 (t, J = 8.6 Hz, 2H), 2.75 (qd, J = 17.1, 6.8 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.3, 153.0, 139.5, 130.5, 127.7, 125.0, 123.0, 117.8, 52.3, 51.1, 46.2, 42.8, 27.9; HRMS (EI) calcd for $C_{13}H_{13}ClN_2O_3$ $[M]^+$ 280.0615, found 280.0612.

Compound ***7h:*** column chromatography (PE:acetone =2:1), 42 mg, yield 65%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (s, 1H), 7.02 (s, 1H), 5.48 (s, 1H), 5.12−4.88 (m, 1H), 3.99 (m, 2H), 3.74 (s, 3H), 3.18 (t, J = 8.6 Hz, 2H), 2.75 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.3, 152.9, 139.9, 130.9, 127.8, 125.8, 118.3, 114.8, 52.3, 50.9, 46.1, 42.8, 27.9; HRMS (EI) calcd for $C_{13}H_{13}BrN_2O_3$ $[M]^+$ 324.0110, found 324.0112.

Compound ***7i:*** column chromatography (PE:acetone = 2:1), 42 mg, yield 81%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.82 (d, J = 8.0 Hz, 1H), 6.61 (d, J = 8.9 Hz, 1H), 5.46 (s, 1H), 5.02 (d, J = 9.5 Hz, 1H), 4.04 (t, J = 8.6 Hz, 2H), 3.73 (s, 3H), 3.17 (t, J = 8.5 Hz, 2H), 2.74 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.3, 159.4 (d, J = 238.6 Hz), 153.2, 136.8, 130.3 (d, J = 8.7 Hz), 117.2 (d, J = 8.5 Hz), 112.3 (d, J = 24.8 Hz), 109.7 (d, J = 25.5 Hz), 52.3, 51.2, 46.2, 42.7, 28.1; HRMS (EI) calcd for $C_{13}H_{13}FN_2O_3$ $[M]^+$ 264.0910, found 264.0911.

Compound ***7j:*** column chromatography (PE:acetone = 1:1), 38 mg, yield 70%, amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.01 (d, J = 8.1 Hz, 1H), 6.38 (d, J = 8.2 Hz, 1H), 5.47 (s, 1H), 5.11 (d, J = 10.7 Hz, 1H), 4.09−3.94 (m, 2H), 3.79 (s, 3H), 3.73 (s, 3H), 3.11 (t, J = 8.4 Hz, 2H), 2.96−2.83 (m, 1H), 2.64 (dd, J = 17.3, 10.7 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.2, 154.9, 153.3, 142.0, 124.9, 120.8, 105.1, 104.2, 55.8, 52.1, 48.6, 46.6, 41.2, 27.3; HRMS (EI) calcd for $C_{14}H_{16}N_2O_4$ $[M]^+$ 276.1110, found 276.1106.

Compound ***7k:*** column chromatography (PE:acetone = 2:1), 39 mg, yield 75%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.12−7.04 (m, 1H), 6.93−6.84 (m, 2H), 5.47 (s, 1H), 5.12−5.00 (m, 1H), 4.19 (q, J = 7.1 Hz, 2H), 4.01 (t, J = 8.8 Hz, 2H), 3.18 (t, J = 8.6 Hz, 2H), 2.85−2.66 (m, 2H), 1.27 (t, J = 7.2 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.1, 153.4, 140.6, 128.8, 124.5, 122.8, 116.9, 61.2, 51.4, 45.9, 43.2, 28.1, 14.3; HRMS (EI) calcd for $C_{14}H_{16}N_2O_3$ $[M]^+$ 260.1161, found 260.1158.

Compound ***7l:*** column chromatography (PE:acetone = 2:1), 37 mg, yield 65%, amorphous solid; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.08 (m, 1H), 6.90 (m, 2H), 5.44 (s, 1H), 5.07 (m, 1H), 4.13 (t, J = 6.7 Hz, 2H), 4.02 (t, J = 8.4 Hz, 2H), 3.19 (t, J = 8.6 Hz, 2H), 2.85−2.67 (m, 2H), 1.61 (m, 2H), 1.36 (m, 2H), 0.93 (t, J = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.3, 153.4, 140.7, 128.8, 124.5, 122.8, 116.9, 65.2, 51.4, 45.9, 43.2, 30.7, 28.1, 19.2, 13.8; HRMS (EI) calcd for $C_{16}H_{20}N_2O_3$ $[M]^+$ 288.1474, found 288.1471.

Compound ***7m:*** column chromatography (PE:acetone = 2:1), 36 mg, yield 63%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16−7.00 (m, 1H), 6.91 (m, 2H), 5.48 (s, 1H), 5.14−4.98 (m, 1H), 4.11−3.98 (m, 2H), 3.20 (t, J = 8.5 Hz, 2H), 2.77−2.64 (m, 2H), 1.49 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.5, 153.5, 140.7, 128.7, 124.4, 122.9, 122.8, 117.1, 81.9, 51.5, 45.8, 44.2, 28.3, 28.1; HRMS (EI) calcd for $C_{16}H_{20}N_2O_3$ $[M]^+$ 288.1474, found 288.1469.

Compound ***7n:*** column chromatography (PE:acetone = 2:1), 38 mg, yield 60%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44−7.33 (m, 5H), 7.11 (m, 1H), 6.95−6.83 (m, 2H), 5.57 (s, 1H), 5.24−5.14 (m, 2H), 5.11 (m, 1H), 4.03 (t, J = 8.6 Hz, 2H), 3.20 (t, J = 8.5 Hz, 2H), 2.95−2.72 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.9, 153.4, 140.6, 135.4, 128.8, 128.6, 128.6, 124.5, 122.9, 122.8, 116.8, 67.0, 51.4, 45.9, 43.2, 28.1; HRMS (EI) calcd for $C_{19}H_{18}N_2O_3$ $[M]^+$ 322.1317, found 322.1313.

Compound ***7o:*** column chromatography (PE:acetone = 2:1), 36 mg, yield 55%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 7.6 Hz, 2H), 7.72 (t, J = 7.3 Hz, 1H), 7.63 (t, J = 7.5 Hz, 2H), 7.10 (d, J = 7.4 Hz, 1H), 6.89 (t, J = 7.5 Hz, 1H), 6.83 (d, J = 7.6 Hz, 1H), 5.83 (s, 1H), 5.34 (d, J = 9.5 Hz, 1H), 4.03 (t, J = 8.5 Hz, 2H), 3.72−3.49 (m, 1H), 3.39 (d, J = 14.0 Hz, 1H), 3.18 (t, J = 8.5 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 152.5, 140.7, 139.1, 134.3, 129.7, 128.9, 127.9, 124.9, 123.0, 122.6, 114.8, 63.2, 49.8, 45.8, 27.9; HRMS (EI) calcd for $C_{17}H_{16}N_2O_3S$ $[M]^+$ 328.0882, found 328.0880.

Compound ***7p:*** column chromatography (PE:acetone = 2:1), 22 mg, yield 53%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16 (d, J = 7.2 Hz, 1H), 7.02 (d, J = 7.6 Hz, 1H), 6.96 (t, J = 7.5 Hz, 1H), 5.69 (s, 1H), 4.98 (td, J = 6.1, 2.9 Hz, 1H), 4.21−3.91 (m, 2H), 3.22 (t, J = 8.5 Hz, 2H), 2.75 (d, J = 6.1 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 153.0, 140.4, 129.2, 125.4, 123.4, 123.2, 116.6, 115.1, 51.8, 46.0, 28.2, 28.1; HRMS (EI) calcd for $C_{12}H_{11}N_3O$ $[M]^+$ 213.0902, found 213.0897.

Compound ***7q:*** column chromatography (PE:EA = 4:1), 29 mg, yield 46%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.09 (t, J = 4.1 Hz, 1H), 6.91 (t, J = 6.2 Hz, 2H), 5.64 (s, 1H), 5.03 (dd, J = 13.7, 8.2 Hz, 1H), 4.27−4.08 (m, 4H), 4.08−3.95 (m, 2H), 3.18 (t, J = 8.6 Hz, 2H), 2.23 (m, 2H), 1.37 (td, J = 7.1, 2.0 Hz, 6H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 153.2, 140.6, 128.8,

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124.6, 122.9, 122.6, 117.8 (d, J = 17.5 Hz), 62.3 (dd, J = 15.6, 6.5 Hz), 50.3 (d, J = 5.0 Hz), 45.9, 35.6 (d, J = 136.4 Hz), 28.1, 16.6 (dd, J = 5.6, 2.7 Hz); HRMS (EI) calcd for $C_{15}H_{21}N_2O_4P$ $[M]^+$ 324.1239, found 324.1237.

General Procedure for the Oxidation of indoline. To a solution of **5n** (0.2 mmol) in 1,4-dioxane (2 mL) was added DDQ (0.4 mmol). The mixture was stirred at 80 °C for 15 h. The crude mixture was filtered through Celite and concentrated under reduced pressure. The residue was purified by flash column (PE:EA = 10:1) to give the desired product **8n**: 40 mg, yield 80%, amorphous solid; 1H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, J = 3.6 Hz, 1H), 7.75 (d, J = 7.6 Hz, 1H), 7.66 (d, J = 7.7 Hz, 1H), 7.41 (t, J = 7.7 Hz, 1H), 6.83 (d, J = 3.6 Hz, 1H), 2.97−2.88 (m, 2H), 2.78−2.70 (m, 2H), 1.79−1.68 (m, 2H), 1.63 (ddd, J = 13.0, 9.0, 4.9 Hz, 2H), 1.09 (dt, J = 22.0, 7.4 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.8, 147.2, 132.9, 131.4, 127.9, 123.9, 123.8, 123.8, 121.5, 118.3, 110.4, 30.9, 29.5, 24.5, 22.9, 14.8, 14.6; HRMS (EI) calcd for $C_{17}H_{19}NO$ $[M]^+$ 253.1467, found 253.1465.

■ ASSOCIATED CONTENT

Supporting Information

Table S1; ^{1}H and ^{13}C NMR spectra of all synthesized compounds. The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.5b00684.

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Notes

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■ REFERENCES

(1) (a) Sundberg, R. J. *Indoles*; Academic Press: San Diego, 1996. (b) Somei, M.; Yamada, F. *Nat. Prod. Rep.* **2005**, *22*, 73. (c) Kawasaki, T.; Higuchi, K. *Nat. Prod. Rep.* **2005**, *22*, 761. (d) Kochanowska-Karamyan, A. J.; Hamann, M. T. *Chem. Rev.* **2010**, *110*, 4489.

(2) For 1,7-fused indoles, see: (a) Nozulak, J.; Kalkman, H. O.; Floersheim, P.; Hoyer, D.; Schoeffter, P.; Buerki, H. R. *J. Med. Chem.* **1995**, *38*, 28. (b) Munshi, N.; Jeay, S.; Li, Y.; Chen, C. R.; France, D. S.; Ashwell, M. A.; Hill, J.; Moussa, M. M.; Leggett, D. S.; Li, C. J. *Mol. Cancer Ther.* **2010**, *9*, 1544. (c) Parnes, J. S.; Carter, D. S.; Kurz, L. J.; Flippin, L. A. *J. Org. Chem.* **1994**, *59*, 3497. (d) Hutchings, R. H.; Meyers, A. I. *J. Org. Chem.* **1996**, *61*, 1004. (e) Padwa, A.; Dimitroff, M.; Waterson, A. G.; Wu, T. *J. Org. Chem.* **1998**, *63*, 3986. (f) Harayama, T.; Hori, A.; Abe, H.; Takeuchi, Y. *Tetrahedron* **2004**, *60*, 1611. (g) Torres, J. C.; Pinto, A. C.; Garden, S. J. *Tetrahedron* **2004**, *60*, 9889. (h) Yin, L.; Lucas, S.; Kazmaier, F. U.; Hu, Q.; Hartmann, R. W. *J. Med. Chem.* **2012**, *55*, 6629. (i) Hartmann, R.; Heim, W.; Lucas, R. S. *PCT Int. Appl.* WO 2009/135651 A1. (j) Ellsworth, E. L.; Showalter, H. D. H.; Powell, S. A.; Sanchez, J. P.; Kerschen, J. A.; Stier, M. A.; Tran, T. P. *PCT Int. Appl.* WO 2002/102793 A2. (k) Masumoto, S.; Kitano, M.; Ohashi, N. *PCT Int. Appl.* WO 2001/079206 A1.

(3) In previous methods for preparation of 1,7-fused indoles, the annulation precursors normally are not readily available or require multistep synthesis. (a) Dobbs, A. P.; Jones, K.; Veal, K. T. *Tetrahedron Lett.* **1997**, *38*, 5379. (b) Miki, Y.; Shirokoshi, H.; Matsushita, K. *Tetrahedron Lett.* **1999**, *40*, 4347. (c) Smith, A. B., III; Kurti, L.; Davulcu, A. H.; Cho, Y. S.; Ohmoto, K. *J. Org. Chem.* **2007**, *72*, 4611. (d) Black, D. S.; Keller, P. A.; Kumar, N. *Tetrahedron* **1992**, *48*, 7601. (e) Black, D. S.; Kumar, N.; Mitchell, P. S. R. *J. Org. Chem.* **2002**, *67*, 2464.

(4) Yi, C. S.; Yun, S. Y.; Guzei, L. A. *J. Am. Chem. Soc.* **2005**, *127*, 5782.

(5) Selected reviews on C−H activation: (a) *C−H Activation*": *Topics in Current Chemistry*; Yu, J. Q., Shi, Z. J., Eds.; Springer: Heidelberg, 2010. (b) Cho, S. H.; Kim, J.; Kwak, Y. J.; Chang, S. *Chem. Soc. Rev.* **2011**, *40*, 5068. (c) Wencel-Delord, J.; Drçge, T.; Liu, F.; Glorius, F. *Chem. Soc. Rev.* **2011**, *40*, 4740. (d) Ackermann, L. *Chem. Rev.* **2011**, *111*, 1315.

(6) For selected reviews, see: (a) Seregin, I.; Gevorgyan, V. *Chem. Soc. Rev.* **2007**, *36*, 1173. (b) Joucla, L.; Djakovitch, L. *Adv. Synth. Catal.* **2009**, *351*, 673. (c) Beck, E. M.; Gaunt, M. J. *Top. Curr. Chem.* **2010**, *292*, 85. (d) Cacchi, S.; Fabrizi, G. *Chem. Rev.* **2011**, *111*, PR215. (e) Broggini, G.; Beccalli, E. M.; Fasana, A.; Gazzola, S. *Beilstein J. Org. Chem.* **2012**, *8*, 1730.

(7) For selected examples, see: (a) Grimster, N. P.; Gauntlett, C.; Godfrey, C. R. A.; Gaunt, M. J. *Angew. Chem., Int. Ed.* **2005**, *44*, 3125. (b) Capito, E.; Brown, J. M.; Ricci, A. *Chem. Commun.* **2005**, *14*, 1854. (c) Maehara, A.; Tsurugi, H.; Satoh, T.; Miura, M. *Org. Lett.* **2008**, *10*, 1159. (d) Garcia-Rubia, A.; Gomez-Arrayas, R.; Carretero, J. C. *Angew. Chem., Int. Ed.* **2009**, *48*, 6511. (e) Lanke, V.; Prabhu, K. R. *Org. Lett.* **2013**, *15*, 2818. (f) Wang, X.; Lane, B. S.; Sames, D. *J. Am. Chem. Soc.* **2005**, *127*, 4996. (g) Deprez, N. R.; Kalyani, D.; Krause, A.; Sanford, M. S. *J. Am. Chem. Soc.* **2006**, *128*, 4972. (h) Toure, B. B. B.; Lane, S.; Sames, D. *Org. Lett.* **2006**, *8*, 1979. (i) Stuart, D. R.; Villemure, E.; Fagnou, K. *J. Am. Chem. Soc.* **2007**, *129*, 12072. (j) Yang, S.-D.; Sun, C.-L.; Fang, Z.; Li, B.-J.; Li, Y.-Z.; Shi, Z.-J. *Angew. Chem., Int. Ed.* **2008**, *47*, 1473. (k) Jiao, L.; Bach, T. *J. Am. Chem. Soc.* **2011**, *133*, 12990. (l) Zhou, B.; Yang, Y.-X.; Li, Y.-C. *Chem. Commun.* **2012**, *48*, 5163. (m) Pan, S.; Ryu, N.; Shibata, T. *J. Am. Chem. Soc.* **2012**, *134*, 17474. (n) Jiao, L.; Herdtweck, E.; Bach, T. *J. Am. Chem. Soc.* **2012**, *134*, 14563. (o) Zhou, B.; Yang, Y.-X.; Lin, S.; Li, Y.-C. *Adv. Synth. Catal.* **2013**, *355*, 360. (p) Ding, Z.; Yoshikai, N. *Angew. Chem.* **2012**, *124*, 4776; *Angew. Chem., Int. Ed.* **2012**, *51*, 4698. (q) Kanyiva, K. S.; Nakao, Y.; Hiyama, T. *Heterocycles* **2007**, *72*, 677. (r) Schipper, D. J.; Hutchinson, M.; Fagnou, K. *J. Am. Chem. Soc.* **2010**, *132*, 6910. (s) Shi, J.-J.; Zhou, B.; Yang, Y.-X.; Li, Y.-C. *Org. Biomol. Chem.* **2012**, *10*, 8953. (t) Yang, L.; Zhang, G.; Huang, H. *Adv. Synth. Catal.* **2014**, *356*, 1509. (u) Liang, L.; Fu, S.; Lin, D.; Zhang, X.-Q.; Deng, Y.; Jiang, H.; Zeng, W. *J. Org. Chem.* **2014**, *79*, 9472. (v) Li, B.; Ma, J.; Xie, W.; Song, H.; Xu, S.; Wang, B. *Chem.—Eur. J.* **2013**, *19*, 11863.

(8) (a) Masters, N. F.; Mathews, N.; Nechvatal, G.; Widdowson, D. A. *Tetrahedron* **1989**, *45*, 5955. (b) Black, D. St.C.; Bowyer, M. C.; Catalano, M. M.; Ivory, A. J.; Keller, P. A.; Kumar, N.; Nugent, S. J. *Tetrahedron* **1994**, *50*, 10497. (c) Fukuda, T.; Ryoichi, M.; Iwao, M. *Tetrahedron* **1999**, *55*, 9151. (d) Hartung, C. G.; Fecher, A.; Chapell, B.; Snieckus, V. *Org. Lett.* **2003**, *5*, 1899. (e) Paul, S.; Chotana, G. A.; Holmes, D.; Reichle, R. C.; Maleczka, R. E.; Smith, M. R. *J. Am. Chem. Soc.* **2006**, *128*, 15552. (f) Robbins, D. W.; Boebel, T. A.; Hartwig, J. F. *J. Am. Chem. Soc.* **2010**, *132*, 4068.

(9) (a) Jiao, L.-Y.; Smirnov, P.; Oestreich, M. *Org. Lett.* **2014**, *16*, 6020. (b) Jiao, L.; Oestreich, M. *Chem.—Eur. J.* **2013**, *19*, 10845. (c) Nishikata, T.; Abela, A. R.; Huang, S.; Lipshutz, B. H. *J. Am. Chem. Soc.* **2010**, *132*, 4978. (d) Kalyani, D.; Deprez, N. R.; Desai, L. V.; Sanford, M. S. *J. Am. Chem. Soc.* **2005**, *127*, 7330. (e) Shi, Z.; Li, B.; Wan, X.; Cheng, J.; Fang, Z.; Cao, B.; Qin, C.; Wang, Y. *Angew. Chem., Int. Ed.* **2007**, *46*, 5554.

(10) (a) Urones, B.; Arrayás, R. G.; Carretero, J. C. *Org. Lett.* **2013**, *15*, 1120. (b) Jiao, L.; Oestreich, M. *Org. Lett.* **2013**, *15*, 5374. (c) Song, Z.; Samanta, R.; Antonchick, A. P. *Org. Lett.* **2013**, *15*, 5662. (d) Pan, S.; Wakaki, T.; Ryu, N.; Shibata, T. *Chem.—Asian J.* **2014**, *9*, 1257.

(11) (a) Pan, S.; Ryu, N.; Shibata, T. *Adv. Synth. Catal.* **2014**, *356*, 929. (b) Neufeldt, S. R.; Seigerman, C. K.; Sanford, M. *Org. Lett.* **2013**, *15*, 2302. (c) Ai, W.; Yang, X.-Y.; Wu, Y.-X.; Wang, X.; Li, Y.-C.; Yang, Y.-X.; Zhou, B. *Chem.—Eur. J.* **2014**, *20*, 17653.

(12) (a) Shin, K.; Chang, S. *J. Org. Chem.* **2014**, *79*, 12197. (b) Pan, C.; Abdukader, A.; Han, J.; Cheng, Y.; Zhu, C. *Chem.—Eur. J.* **2014**, *20*, 3606. (c) Hou, W.; Yang, Y.-X.; Ai, W.; Wu, Y.-X.; Wang, X.; Zhou, B.; Li, Y.-C. *Eur. J. Org. Chem.* **2015**, 395.

(13) Kim, M.; Mishra, N. K.; Park, J.; Han, S.; Shin, Y.; Sharma, S.; Lee, Y.; Lee, E.-K.; Kwak, J. H.; Kim, I. S. *Chem. Commun.* **2014**, *50*, 14249.

(14) (a) Wu, Y.-X.; Yang, Y.-X.; Zhou, B.; Li, Y.-C. *J. Org. Chem.* **2015**, *80*, 1946. (b) Yang, X.-F.; Hu, X.-H.; Feng, C.; Loh, T.-P. *Chem. Commun.* **2015**, *51*, 2532.

DOI: 10.1021/acs.joc.5b00684
J. Org. Chem. 2015, 80, 6238−6249

(15) For oxidizing directing groups used in rhodium-catalyzed C−H functionalization, see: (a) Guimond, N.; Gouliaras, C.; Fagnou, K. *J. Am. Chem. Soc.* **2010**, *132*, 6908. (b) Guimond, N.; Gorelsky, S. I.; Fagnou, K. *J. Am. Chem. Soc.* **2011**, *133*, 6449. (c) Rakshit, S.; Grohmann, C.; Besset, T.; Glorius, F. *J. Am. Chem. Soc.* **2011**, *133*, 2350. (d) Wang, H.; Glorius, F. *Angew. Chem., Int. Ed.* **2012**, *51*, 7318. (e) Too, P. C.; Wang, Y.-F.; Chiba, S. *Org. Lett.* **2010**, *12*, 5688. (f) Too, P. C.; Chua, S. H.; Wong, S. H.; Chiba, S. *J. Org. Chem.* **2011**, *76*, 6159. (g) Zhang, X.; Chen, D.; Zhao, M.; Zhao, J.; Jia, A.; Li, X. *Adv. Synth. Catal.* **2011**, *353*, 719. (h) Hyster, T. K.; Rovis, T. *Chem. Commun.* **2011**, *47*, 11846. (i) Xu, X.; Liu, Y.; Park, C.-M. *Angew. Chem., Int. Ed.* **2012**, *51*, 9372. (j) Hyster, T. K.; Kn, L.; Ward, T. R.; Rovis, T. *Science* **2012**, *338*, 500. (k) Ye, B.; Cramer, N. *Science* **2012**, *338*, 504. (l) Wang, H.; Grohmann, C.; Nimphius, C.; Glorius, F. *J. Am. Chem. Soc.* **2012**, *134*, 19592. (m) Neely, J. M.; Rovis, T. *J. Am. Chem. Soc.* **2013**, *135*, 66. (n) Hyster, T. K.; Ruhl, K. E.; Rovis, T. *J. Am. Chem. Soc.* **2013**, *135*, 5364. (o) Cui, S.; Zhang, Y.; Wu, Q. *Chem. Sci.* **2013**, *4*, 3421. For oxidizing directing groups used in ruthenium-catalyzed C−H functionalization, see: (p) Li, B.; Feng, H.; Xu, S.; Wang, B. *Chem.—Eur. J.* **2011**, *17*, 12573. (q) Ackermann, L.; Fenner, S. *Org. Lett.* **2011**, *13*, 6548. (r) Kornhaa, C.; Li, J.; Ackermann, L. *J. Org. Chem.* **2012**, *77*, 9190. (s) Chinnagolla, R.; Pimparkar, K. S.; Jeganmohan, M. *Org. Lett.* **2012**, *14*, 3032.

(16) Selected recent examples: (a) Zhou, B.; Hou, W.; Yang, Y.-X.; Li, Y.-C. *Chem.—Eur. J.* **2013**, *19*, 4701. (b) Hou, W.; Zhou, B.; Yang, Y.-X.; Feng, H.-J.; Li, Y.-C. *Org. Lett.* **2013**, *15*, 1814. (c) Du, J.-J.; Zhou, B.; Yang, Y.-X.; Li, Y.-C. *Chem.—Asian J.* **2013**, *8*, 1386. (d) Zhou, B.; Yang, Y.-X.; Tang, H.-Y.; Du, J.-J.; Feng, H.-J.; Li, Y.-C. *Org. Lett.* **2014**, *16*, 3900. (e) Zhou, B.; Du, J.-J.; Yang, Y.-X.; Li, Y.-C. *Chem.—Eur. J.* **2014**, *20*, 12768.

(17) During the preparation of our manuscript, Loh reported the beautiful example of C7-selective C−H functionalization of indolines with alkynes to form pyrroloquinolinones; see: Yang, X.-F.; Hu, X.-H.; Loh, T.-P. *Org. Lett.* **2015**, *17*, 1481.

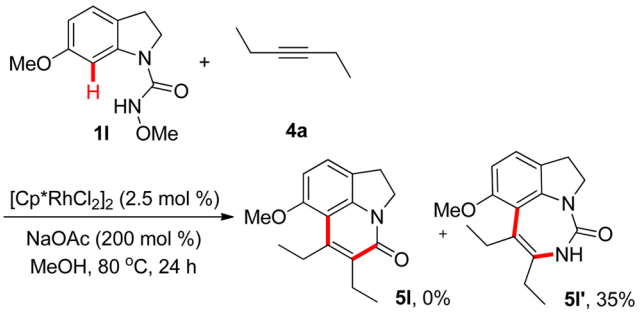
(18) For reviews on Rh(III) catalyzed C−H activation, see: (a) Colby, D. A.; Bergman, R. G.; Ellman, J. A. *Chem. Rev.* **2010**, *110*, 624. (b) Satoh, T.; Miura, M. *Chem.—Eur. J.* **2010**, *16*, 11212. (c) Colby, D. A.; Tsai, A. S.; Bergman, R. G.; Ellman, J. A. *Acc. Chem. Res.* **2012**, *45*, 814. (d) Song, G.; Wang, F.; Li, X. *Chem. Soc. Rev.* **2012**, *41*, 3651. (e) Patureau, F. W.; Wencel-Delord, J.; Glorius, F. *Aldrichimica Acta* **2012**, *45*, 31. (f) Kuhl, N.; Schroder, N.; Glorius, F. *Adv. Synth. Catal.* **2014**, *356*, 1443. (g) Song, G.; Li, X. *Acc. Chem. Res.* **2015**, *48*, 1007.

(19) For the Cp*Rh^{III}-catalyzed alkenylation/annulation sequence via C−N bond cleavage of amide, only one example was reported: (a) Li, B.-J.; Wang, H.-Y.; Zhu, Q.-L.; Shi, Z.-J. *Angew. Chem., Int. Ed.* **2012**, *51*, 3948. For Cp*Co-catalyzed C−N bond cleavage, see: (b) Ikemoto, H.; Yoshino, T.; Sakata, K.; Matsunaga, S.; Kanai, M. *J. Am. Chem. Soc.* **2014**, *136*, 5424.

(20) (a) Kappe, C. O.; Kappe, T. *J. Heterocycl. Chem.* **1989**, *26*, 1555. (b) Ito, F.; Koike, H.; Morita, A. WO 2003064425 A1.

(21) We attempted to obtain **5a** or **5a′** selectively; however, no better result was obtained. For details, see Table S1 in the Supporting Information.

(22) Compound **5l′** was obtained as the sole product.



(23) (a) De, S.; Ghosh, S.; Bhunia, S.; Sheikh, J. A.; Bisai, A. *Org. Lett.* **2012**, *14*, 4466. (b) Robbins, D. W.; Boebel, T. A.; Hartwig, J. F. *J. Am. Chem. Soc.* **2010**, *132*, 4068.

(24) (a) Baccichetti, F.; Marzano, C.; Carlassare, F.; Guiotto, A.; Bordin, F. *J. Photochem. Photobiol., B* **1997**, *40*, 299. (b) Vedaldi, D.; Frank, S.; Pozzan, A.; Miolo, G.; Dall'Acqua, F.; Caffieri, S.; Rodighiero, P.; Guiotto, A. *Farmaco* **1994**, *49*, 615. (c) Rodighiero, P.; Chilin, A.; Manzini, P.; Castellin, A.; Guiotto, A.; Bordin, F.; Carlassare, F.; Marzano, C.; Baccichetti, F. *Farmaco* **1994**, *49*, 607.

(25) (a) Lu, Y.; Wang, H.-W.; Spangler, J. E.; Chen, K.; Cui, P.-P.; Zhao, Y.; Sun, W.-Y.; Yu, J.-Q. *Chem. Sci.* **2015**, *6*, 1923. (b) Wang, F.; Song, G.; Li, X. *Org. Lett.* **2010**, *12*, 5430.

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