JOC The Journal of Organic Chemistry

Ruthenium-Catalyzed Ring-Opening Addition of Anilides to 7- Azabenzonorbornadienes: A Diastereoselective Route to Hydronaphthylamines

Qiangqiang Yan, Chunhua Xiong, Steven Chu, Zhanxiang Liu, and Yuhong Zhang

J. Org. Chem., **Just Accepted Manuscript** • DOI: 10.1021/acs.joc.8b00604 • Publication Date (Web): 18 Apr 2018

Just Accepted

ACS Publications

is published by the American Chemical Society. 1155 Sixteenth Street N.W., Washington, DC 20036

Ruthenium-Catalyzed Ring-Opening Addition of Anilides to 7-Azabenzonorbornadienes: A Diastereoselective Route to Hydronaphthylamines

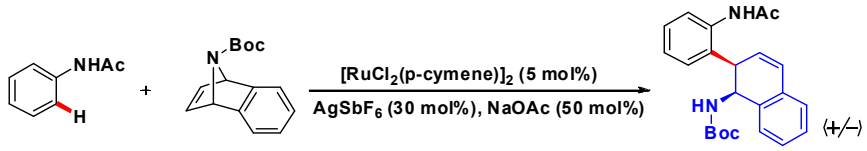
Qiangqiang Yan, [†] Chunhua Xiong, [‡] Steven Chu, [†] Zhanxiang Liu, [†] and Yuhong Zhang [*,†, §]

[†]Department of Chemistry, Zhejiang University, Hangzhou 310027, China.

[‡]Department of Applied Chemistry, Zhejiang Gongshang University, Hangzhou 310012, China.

[§]State Key Laboratory of Applied Organic Chemistry, Lanzhou University, Lanzhou 730000, China.

E-mail: *yhzhang@zju.edu.cn*



√ *Redox-Neutral Process* √ *Broad Substrate Scope* √ *High Efficiency* √ *Diastereoselectivity*

Abstract

Ruthenium(II)-catalyzed direct ring-opening reaction of 7-azabenzonorbornadienes with anilides via C-H activation to access hydronaphthylamines has been developed. The transformation proceeds with high stereoselectivity to give *cis*-configuration products under redox-neutral conditions.

Introduction

Hydronaphthylamines are ubiquitous structural motifs that widely exist in natural products, pharmaceuticals and biologically active molecules (Figure 1). [1] Over the past decades, significant advances have been made in the preparation of these important scaffolds.

Traditional methods to access hydronaphthylamines, such as Friedel-Crafts, Haworth and Leuckart-Wallach reactions, usually suffer from harsh reaction conditions, multiple steps, and narrow substrate scope. [2] In recent years, transition metal-catalyzed ring-opening reaction of azabicyclic alkenes with aryl halides, [3] amines, [4] phenols [5] and organometallic reagents [6] has been widely used as reliable approaches for the synthesis of hydronaphthylamines. However, the prefunctionalization of the substrates is usually inevitable in these transformations with the undesirable toxic waste. Consequently, the development of more facile and efficient routes to their preparation is highly desirable.

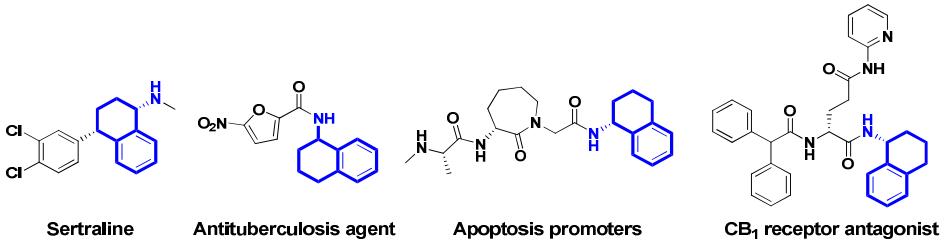
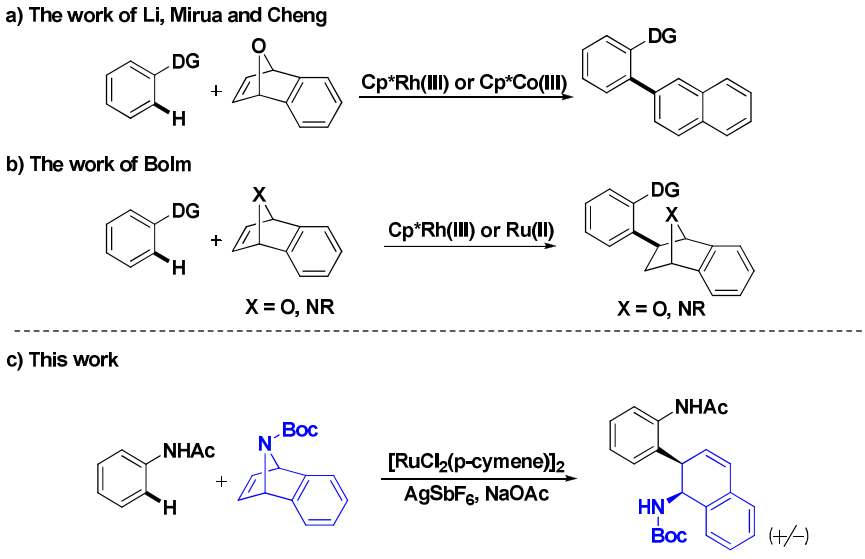


Figure 1 Representative biologically active molecules featuring hydronaphthylamines.

Transition-metal-catalyzed direct C-H functionalization reactions have emerged as an appealing and powerful tool owing to their high step- and atom-economy. [7] In particular, the ring-opening addition of a C-H bond to strained heterobicyclic alkenes for construction of complicated molecules represents an ideal and environmentally attractive strategy. [8] For instance, Li and coworkers reported rhodium(III)-catalyzed coupling reaction of 2-arylpyridines and strained 7-oxabenzonorbornadienes via C-H activation to afford *ortho*-naphthylated arenes under redox-neutral conditions, whereas the coupling reaction with similar 7-azabenzonorbornadienes only proceeded under oxidative conditions to furnish *cis*-fused dihydrocarbazoles. [9] Later, Miura and Satoh demonstrated the rhodium(III)-catalyzed direct coupling of arylphosphine oxides with heterobicyclic alkenes to

afford functionalized naphthalenes under redox-neutral conditions. [10] Recently, cobalt(III)-catalyzed direct C-H naphthylation of arenes with 7-oxabenzonorbornadienes was developed by Li and Cheng groups, independently (Scheme 1a). [11]Furthermore, selective alkylation reaction of arenes with heterobicyclic alkenes by Rh(III) or Ru(II)-catalysis has been described by Bolm groups (Scheme 1b). [12] Despite these significant advancements, the synthetic method to access hydronaphthylamines is still unprecedented. Herein, we disclose a ruthenium-catalyzed ring-opening reaction for the assembly of valuable hydronaphthylamines from anilides and 7-azabenzonornadiene (Scheme 1c). The reaction proceeded efficiently under redox-neutral conditions and displayed good functional group compatibility. Notably, the transformation exhibited high stereoselectivity to afford *cis*-configuration products. 7-Oxabenzonorbornadienes were compatible with the catalytic system to give functionalized naphthalenes under the modified reaction conditions.

Scheme 1. Metal-catalyzed C-H bond functionalization of oxa- and azabicyclic alkenes

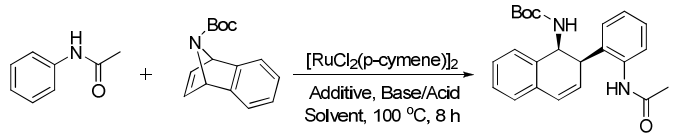


Results and discussion

We initially choose the acetanilide (**1a**) and 7-axabenzonorbornadiene (**2a**) as model

substrates to start our investigation. The reaction was performed in the presence of 5 mol % of $[RuCl_2(p\text{-cymene})]_2$ and 20 mol % of $AgSbF_6$ and PivOH in 1, 2-dichloroethane(DCE) at 100 ^oC under air atmosphere. Unfortunately, the desired ring-opening coupling product could be obtained in low yield (Table 1, entry 1). Other silver salts were screened and the results were inferior to that of $AgSbF_6$ (Table 1, entries 2-3). The yield of the reaction sharply increased to 62% when NaOAc was used as an additive (Table 1, entries 4-8). The solvent effect of the reaction was investigated by the employment of different solvents, and DCE exhibited the highest efficiency (Table 1, entries 9-12). To our delight, further optimization of the reaction conditions gave the ring opening product **3a** in 80% yield with 30 mol% $AgSbF_6$ and 50 mol% NaOAc (Table 1, entry 13). In addition, the amount of catalyst had a significant effect on the reaction efficiency and we found that $Cp^*Co(CO)I_2$ failed to promote the reaction, but $[Cp^*RhCl_2]_2$ catalyzed the reaction to give the same product in 36% yield (see Supporting Information). It should be emphasized that the reaction proceeded very efficiently under redox-neutral conditions.

Table 1. Optimization of the Reaction Conditions [a]



1a **2a** **3a**

Entry	Additive (mol %)	Base (mol %)	Solvent	Yield [b] (%)
1	$AgSbF_6$	PivOH	1, 2-Dichloroethane	26
2	$AgBF_4$	PivOH	1, 2-Dichloroethane	trace
3	$AgNTf_2$	PivOH	1, 2-Dichloroethane	10
4	$AgSbF_6$	HOAc	1, 2-Dichloroethane	16
5	$AgSbF_6$	$NaHCO_3$	1, 2-Dichloroethane	NR
6	$AgSbF_6$	LiOAc	1, 2-Dichloroethane	Trace
7	$AgSbF_6$	CsOAc	1, 2-Dichloroethane	Trace
8	$AgSbF_6$	NaOAc	1, 2-Dichloroethane	62

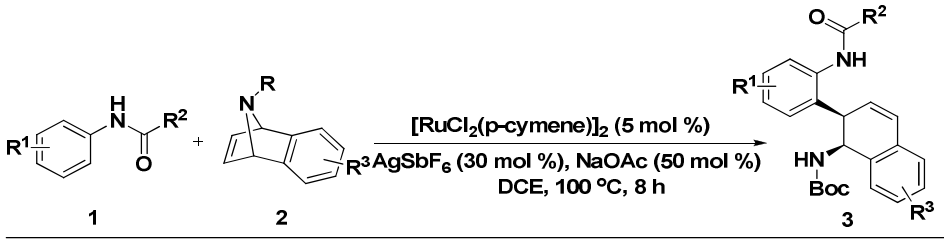
9	$AgSbF_6$	NaOAc	Toluene	36
10	$AgSbF_6$	NaOAc	CH_3CN	NR
11	$AgSbF_6$	NaOAc	DMF	Trace
12	$AgSbF_6$	NaOAc	2, 2, 2- Trifluoroethanol	NR
13	$AgSbF_6$	NaOAc	1, 2-Dichloroethane	80 [c]

[a] Reactions were carried out by using **1a** (0.2 mmol), **2a** (0.3 mmol), Cat. Ru (0. 01 mmol), additive (0.04 mmol), base/acid (0.04 mmol), solvent (1.0 mL), 100 °C, air, 8 h. [b] Isolated yield. [c] Cat. Ru (0. 01 mmol), additive (0.06 mmol), base/acid (0.1 mmol).

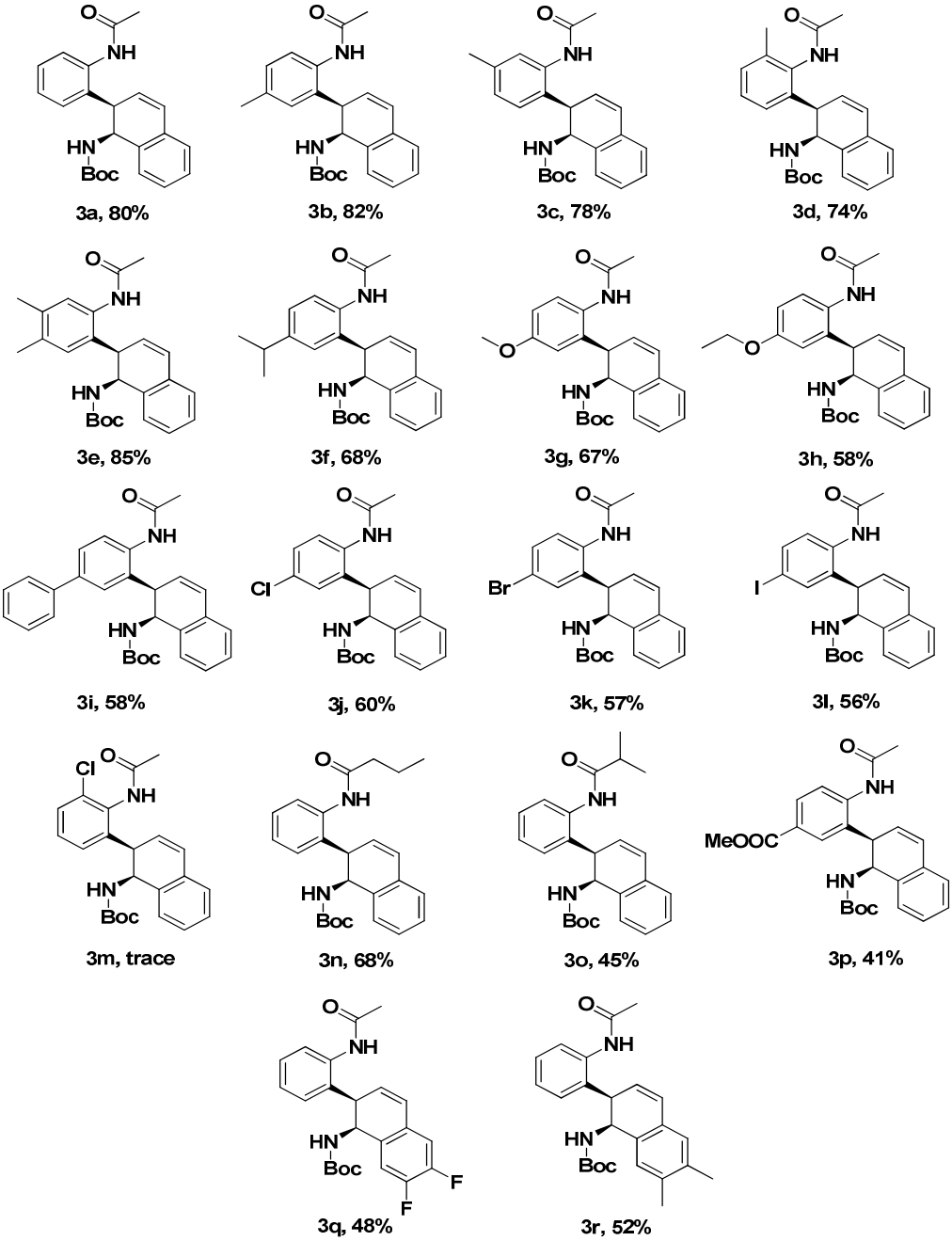
With the optimum reaction conditions in hand, we investigated the generality and limitation of the protocol with diverse 7-axabenzonorbornadienes (Scheme 2). We found that the reaction presented broad substrate scope, and a variety of electron-donating or electron-withdrawing groups were well-tolerated under the standard conditions (**3a-3l**). It was worth mentioning that the electronic factors of acetanilide had a distinct influence on the reaction. The similar reactivity of *para*- and *meta*- substituted anilides (**3b-3c**) was observed compared to the *ortho*-substituted one (**3d**), suggesting that steric hindrance exerted negligible influence on this transformation. In addition, anilides bearing a halogen atom (Cl, Br, or I) at *para* position of phenyl ring smoothly survived under the optimized conditions to deliver hydronaphthylamine products (**3j-3l**). Unfortunately, the *ortho*-chloro substituted anilides hampered the reactivity (**3m**). Other types of amides, including propyl or isopropyl amides, could be compatible with the reaction to afford the target product in moderate yield (**3n-3o**). It should be noted that the product **3o** was obtained in 45% yield along with the naphthylated product **5p** in 30% yield. The substrate bearing the strong electronwithdrawing

COOMe group could also be involved in the reaction to afford 3n in 41% isolated yield. Hydronaphthylamine product **3q** and **3r** were also isolated in moderate yields when substituted 7-axabenzonorbornadienes were used.

Scheme 2. Synthesis of hydronaphthylamines from diverse anilides [a,b]



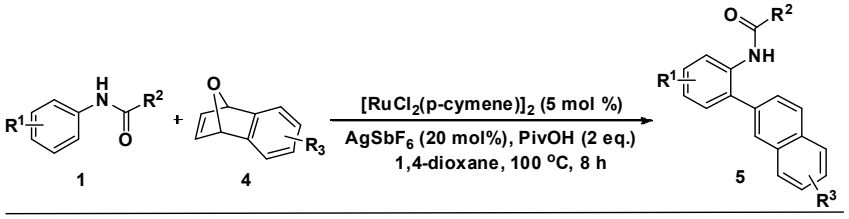
1 2 3

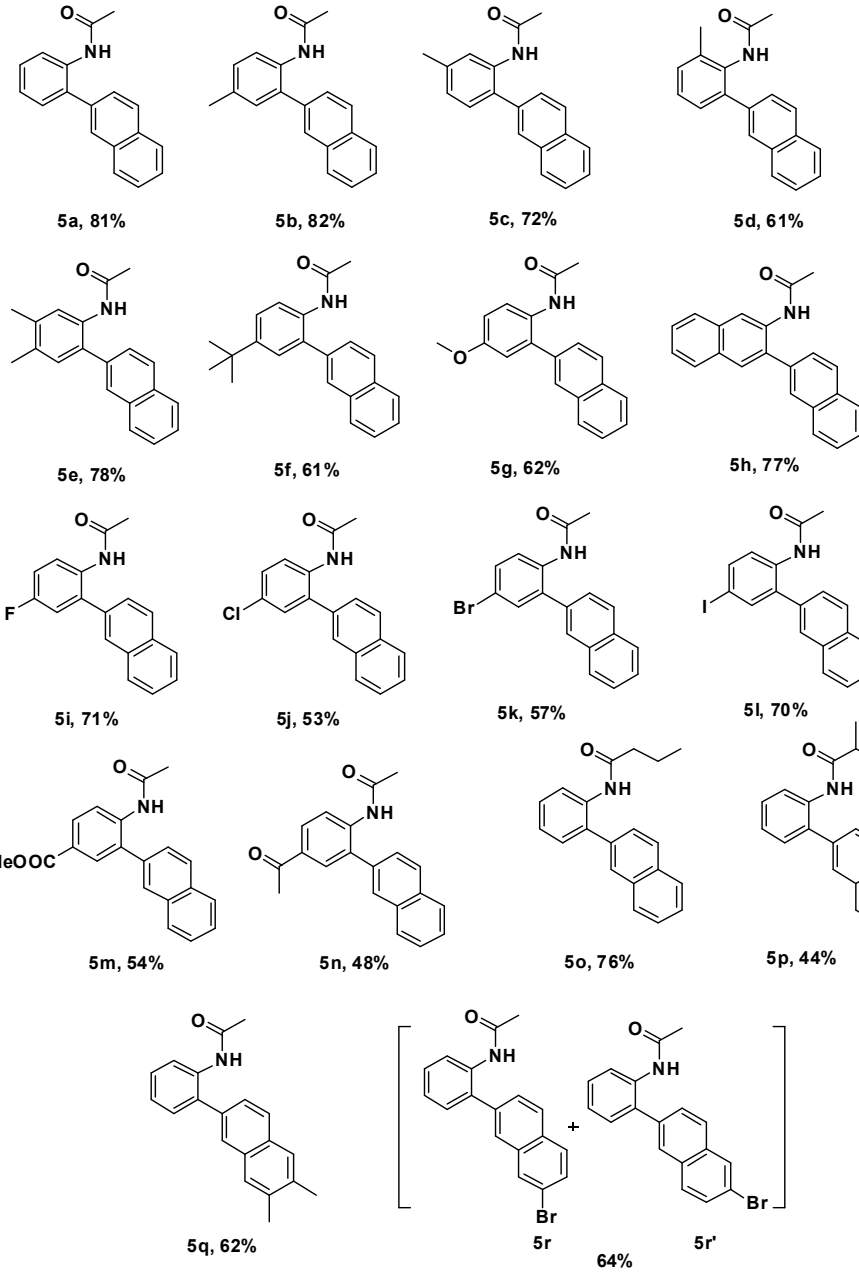


[a] Reaction conditions: **1** (0.2 mmol), **2** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (0.01 mmol), $AgSbF_6$ (0.06 mmol), NaOAc (0.1 mmol), DCE (1 mL), air, 100 °C, 8 h. [b] Isolated yields

With the development of dehydrative naphthylation reactions, we next extended the strained bicyclic alkenes to 7-oxabenzonorbornadienes (Schemec 3). For the reactions, the conditions are different from the ones in Scheme2. A wide variety of acetanilides bearing electron-donating (**5a–5h**) or electron-withdrawing (**5i–5n**) groups at different positions of the phenyl ring were subjected to the optimized conditions, and to our satisfaction, moderate to good yields of the desired naphthylation products were obtained in 48-82% yields, showing the good functional group compatibility. It was observed that the electron factors of acetanilide exerted an obvious effect on the reaction as demonstrated by the higher reactivity of electron-rich substrates. In case of the *meta* substituted substrates, the reaction occurred at the less hindered position, indicative of good regioselectivity (**5c**). The *ortho* substituted acetanilide had poor reactivity (**5d**), revealing that steric hindrance played effect on this transformation. The reaction showed good tolerance toward halogenated substituents, including Cl, Br and I groups, allows for further derivatization of the obtained products (**5j–5l**). It was noteworthy that the acetanilide attached with an acetyl group smoothly coupled with **4a** to afford the corresponding product **5n** in reasonable yield. Other types of amides, such as propyl or isopropyl amides, participated in the reaction successfully to access the relevant products (**5o–5p**) in acceptable yields. In addition, the heterobicyclic olefin substrate is not limited to **4a**, other substituted 7-oxabenzonorbornadienes were applicable under the standard conditions to give the desired compounds (**5q–5r**). Notably, the addition of **1a** onto unsymmetrically substituted 7-oxabicyclo alkene **4r** led to a mixture of regioisomers **5r** and **5r'** in 64% yield.

Scheme 3. Synthesis of naphthalene derivatives from diverse anilides [a,b]

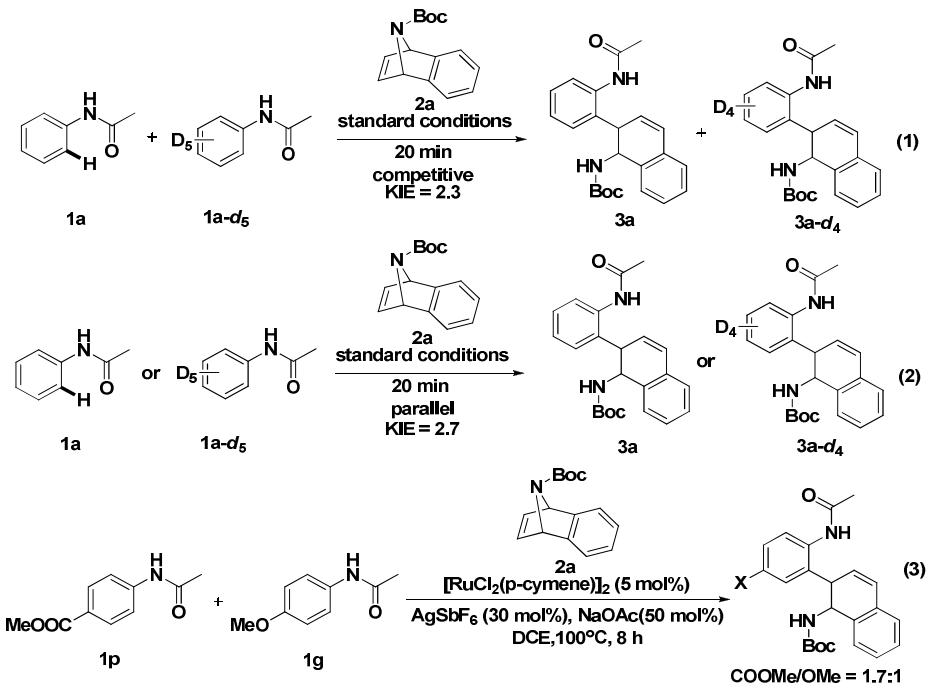




[a] Reaction conditions: **1** (0.2 mmol), **4** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (0.01 mmol), $AgSbF_6$ (0.04 mmol), PivOH (2 equiv), 1,4-dioxane (1 mL), air, 100 °C, 8 h. [b] Isolated yields.

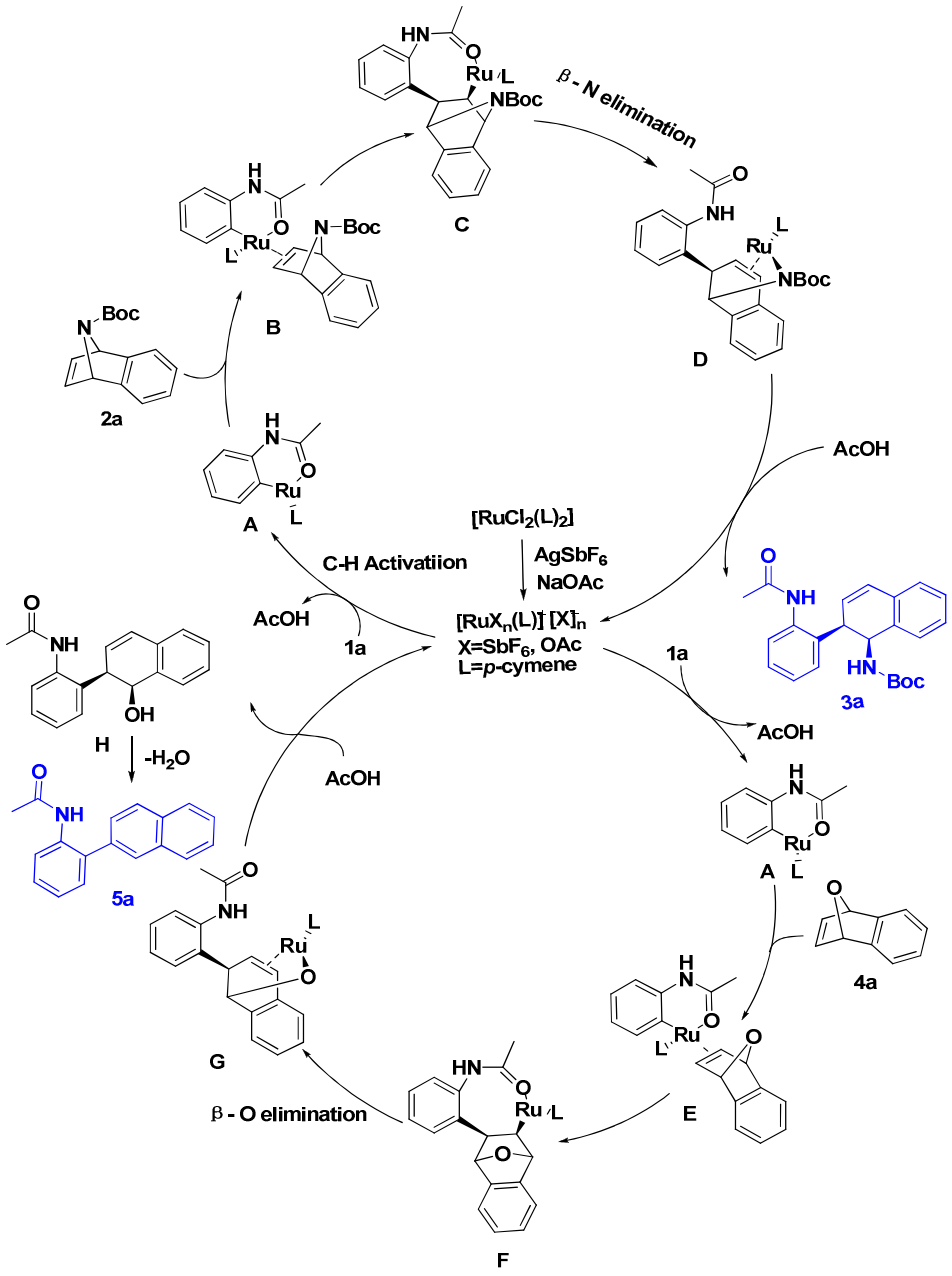
To gain insight into the reaction mechanism, a series of preliminary experiments were conducted as outlined in Scheme 4. The kinetic isotope effect (KIE) values of 2.3 were observed from the competitive reactions of **1a** and **1a-*d*$_5$** with **2a** at a low conversion [Scheme 4, Eq. (1)]. Moreover, a similar result was obtained from two parallel reactions [Scheme 4, Eq. (2)]. The above results indicated that the cleavage of C−H bond might be involved in the rate-determining step. Intermolecular competition experiment between **1p** and **1g** was carried out, and the more electron-deficient anilide reacted at a higher rate [Scheme 4, Eq. (3)], suggesting that the C−H activation probably occurs via a concerted metalation-deprotonation mechanism. [13]

Scheme 4. Mechanistic investigations



On the basis of previous reports [9-11,14] and the results of control experiments, a plausible catalytic cycle is proposed as shown in Scheme 5. Initially, the active cationic ruthenium complex is generated from ligand exchange with $AgSbF_6$ or NaOAc. The following directed C-H activation results in the formation of the six-membered ruthenacycle intermediate **A**. Then, the alkene π-bond in **2a** coordinates with ruthenacycle **A** and is subsequently inserted into the Ru-C bond of the resulting intermediate **B** to afford the eight-membered Ru(II) intermediate **C**. The subsequent β-N elimination leads to the ring-opening intermediate **D**. [9,15] Protonation of intermediate **D** in the presence of AcOH releases the corresponding product **3a** and regenerates the active ruthenium catalyst, which initiates the next catalytic cycle. In the case of the coupling of 7-oxabenzonorbornadiene, intermediate **F** undergoes β-oxygen elimination preferentially to give intermediate **G**. Protonolysis of the Ru-O bond by AcOH liberates the dihydronaphthol intermediate **H**, which is dehydrated to give the product **5a**.

Scheme 5. Plausible mechanism



Conclusion

In conclusion, we have developed the ruthenium-catalyzed ring-opening reaction of 7-azabenzonorbornadiene with anilides via C-H activation. The concerted-metalation-deprotonation and β-nitrogen elimination are supposed to be involved in the reaction processes. Attractive features of this system include redox-neutral conditions,

a broad substrate scope and good functional group tolerance, which provides an alternative avenue for the synthesis of hydronaphthylamines. Naphthlenes were obtained in high yields by the use of 7-oxabicyclic alkenes as the reaction partners.

Experiment Section

General Information. All reactions were performed under air atmosphere in a flame-dried reaction flask. The other materials and solvents were purchased from common commercial sources and used without additional purification, if there is no special version. Starting materials 7-oxa/azabenzonorbornadienes [9, 16] were synthesized according to literature procedures. ^{1}H NMR spectra were recorded at 400 MHz using TMS as internal standard, ^{13}C NMR spectra were recorded at 100 MHz using TMS as internal standard. The multiplicities are reported as follows: singlet (s), doublet (d), doublet of doublets (dd), multiplet (m), triplet (t) and broad resonances (br). Mass spectroscopy data of the products were collected on an HRMS-TOF instrument.

General Procedure for Ruthenium-Catalyzed Ring-Opening Addition of Anilides to 7-Azabenzonorbornadienes (3). To a flame-dried reaction flask, amides **1** (0.2 mmol), 7-axabenzonorbornadienes **2** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (6.1 mg, 0.01 mmol), $AgSbF_6$ (20.6 mg, 0.06 mmol), NaOAc (8.2 mg, 0.1 mmol) and DCE (1 mL) were added under air atmosphere. The mixture was stirred for 8 h at 100 °C. The mixture was then cooled to room temperature, diluted with EtOAc, filtered through a celite pad, and concentrated in vacuo. The residue was purified by flash column chromatography on silica gel (eluent: hexane/EtOAc = 5/1 with triethylamine), to afford the desired product **3**.

***tert*-butyl (*1S,2R*)-2-(2-acetamidophenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3a)** Light brown solid; yield: 80% (60.5mg); m.p = 172-174 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.72 (s, 1H), 7.54 (d, J = 8.4 Hz, 1H), 7.30 (dd, J = 6.8, 2.4 Hz, 1H), 7.25-7.21 (m, 3H), 7.16 (d, J = 6.8 Hz, 1H), 7.10-7.04 (m, 2H), 6.68 (dd, J = 9.8, 1.4 Hz, 1H), 6.04 (dd, J = 9.8, 4.6 Hz, 1H), 5.29 (t, J = 6.4 Hz, 1H), 4.72 (d, J = 7.6 Hz, 1H), 4.25 (d, J = 7.8 Hz, 1H), 2.21 (s, 3H), 1.32 (s, 9H). ^{13}C NMR

(100MHz, $CDCl_3$) δ 169.3, 155.9, 135.9, 133.5, 132.9, 132.0, 129.8, 129.7, 128.3, 128.2, 128.0, 127.8, 126.8, 126.3, 126.2, 126.0, 80.0, 51.0, 39.6, 28.3, 23.9.HRMS (EI-TOF): Calculated for $C_{23}H_{26}N_2O_3$ $[M]^+$ 378.1943, Found 378.1946.

***tert*-butyl*(1S,2R)*-2-(2-acetamido-5-methylphenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3b)**

White solid; yield: 82% (64.3mg); m.p = 142-144 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.65 (s, 1H), 7.34 (d, J = 8.0 Hz, 1H), 7.28-7.23 (m, 3H), 7.15 (d, J = 6.8 Hz, 1H), 7.02 (d, J = 8.4 Hz, 1H), 6.91 (s, 1H), 6.66 (dd, J = 9.6, 1.8 Hz, 1H), 6.02 (dd, J = 9.6, 4.0 Hz, 1H) 5.25 (d, J = 8.0 Hz, 1H), 4.75 (d, J = 8.0 Hz, 1H), 4.21 (d, J = 8.0 Hz, 1H), 2.21 (s, 3H), 2.04 (s, 3H), 1.30 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.4, 155.6, 135.9, 133.6, 133.3, 132.7, 132.6, 130.6, 129.8, 128.5, 128.2, 128.1, 127.9, 126.7, 126.6, 126.3, 79.7, 50.7, 39.9, 28.2, 23.7, 21.1. HRMS (EI-TOF): Calculated for $C_{24}H_{28}N_2O_3$ $[M]^+$ 392.2100, Found 392.2108.

***tert*-butyl*(1S,2R)*-2-(2-acetamido-4-methylphenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3c)**

White solid; yield: 78% (61.2mg); m.p = 154-155 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.60 (s, 1H), 7.37 (s, 1H), 7.27-7.22 (m, 3H), 7.15 (d, J = 7.2 Hz, 1H), 6.94 (d, J = 8.0 Hz, 1H), 6.85 (d, J = 7.6 Hz, 1H), 6.66 (d, J = 9.6 Hz, 1H), 6.02 (dd, J = 9.4, 4.6 Hz, 1H), 5.29 (t, J = 8.8 Hz, 1H), 4.71 (d, J = 8.0 Hz, 1H), 4.19 (d, J = 8.0 Hz, 1H), 2.28 (s, 3H), 2.09 (s, 3H), 1.34 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.2, 155.9, 137.7, 135.7, 133.5, 132.9, 129.9, 129.6, 128.7, 128.3, 128.1, 127.9, 127.2, 126.9, 126.7, 125.9, 79.9, 51.1, 39.3, 28.3, 23.9, 21.0. HRMS (EI-TOF): Calculated for $C_{24}H_{28}N_2O_3$ $[M]^+$ 392.2100, Found 392.2106.

***tert*-butyl(*1S,2R*)-2-(2-acetamido-3-methylphenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3d)**

Light brown solid; yield: 74% (58.1mg); m.p = 105-106 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.55 (s, 1H), 7.25-7.19 (m, 3H), 7.11-7.06 (m, 3H), 6.99 (d, J = 6.0 Hz, 1H), 6.59 (dd, J = 9.6, 2.0 Hz, 1H), 6.01 (dd, J = 9.8, 3.0 Hz, 1H), 5.24 (t, J = 8.6 Hz, 1H), 4.74 (d, J = 8.8 Hz, 1H), 4.22 (d, J = 8.8 Hz, 1H), 2.19 (s, 3H), 2.11 (s, 3H), 1.22 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.4, 155.5, 136.4, 134.6, 133.7, 132.7, 130.4, 130.1, 129.5, 128.3, 128.0, 127.6, 127.5, 127.2, 126.9, 126.5, 79.5, 50.3, 40.5, 28.1, 23.0, 18.5. HRMS (EI-TOF): Calculated for $C_{24}H_{28}N_2O_3$ $[M]^+$ 392.2100, Found 392.2112.

***tert*-butyl(*1S,2R*)-2-(2-acetamido-4,5-dimethylphenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3e)**

White solid; yield: 85% (69.1mg); m.p = 140-141 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.49 (s,

1H), 7.29-7.23 (m, 4H), 7.15(d, *J* = 6.8 Hz, 1H), 6.84 (s, 1H), 6.66 (d, *J* = 9.6 Hz, 1H), 6.03 (dd, *J* = 9.8, 4.2 Hz, 1H), 5.25 (t, *J* = 7.8, 1H), 4.72 (d, *J* = 8.4 Hz, 1H), 4.16 (d, *J* = 8.2 Hz, 1H), 2.18 (s, 1H), 2.10 (s, 3H), 2.05 (s, 3H), 1.31 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.4, 155.8, 136.2, 134.8, 133.7, 133.4, 132.9, 130.9, 130.0, 129.8, 128.2, 128.1, 127.8, 127.7, 126.7, 126.2, 79.7, 50.8, 39.7, 28.2, 23.8,19.5. HRMS (EI-TOF): Calculated for $C_{25}H_{30}N_2O_3$ $[M]^+$ 406.2256, Found 406.2252.

***tert*-butyl(*1S,2R*)-2-(2-acetamido-5-isopropylphenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3f)**

Light brown solid; yield: 68% (57.1mg); m.p = 125-126 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.52 (s, 1H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.30-7.28 (m, 1H), 7.23 (d, *J* = 5.6 Hz, 2H), 7.16 (d, *J* = 7.2 Hz, 1H), 7.09 (dd, *J* = 8.2, 1.8 Hz, 1H), 6.91 (d, *J* = 1.6 Hz, 1H), 6.70 (dd, *J* = 9.6, 1.6 Hz, 1H), 6.07 (dd, *J* = 9.6, 4.4 Hz, 1H), 5.30 (d, *J* = 6.4 Hz, 1H), 4.70 (d, *J* = 8.4 Hz, 1H), 4.20 (d, *J* = 8.4 Hz, 1H), 2.77-2.72 (m,1H), 2.07 (s, 3H), 1.31 (s, 9H), 1.11 (d, *J* = 9.6 Hz, 3H), 1.09 (d, *J* = 9.2 Hz, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.4, 155.7, 146.8, 133.8, 133.5, 132.9, 132.2, 129.9, 128.3, 128.1, 127.9, 126.6, 126.5, 126.2, 125.9, 79.8, 50.8, 40.1, 33.6, 28.3, 24.1, 23.8, 23.6. HRMS (EI-TOF): Calculated for $C_{26}H_{32}N_2O_3$ $[M]^+$ 420.2413, Found 420.2418.

***tert*-butyl(*1S,2R*)-2-(2-acetamido-5-methoxyphenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3g)**

White solid; yield: 67% (54.7mg); m.p = 148-149 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.55 (s, 1H), 7.32 (d, *J* = 8.4 Hz, 1H), 7.29-7.22 (m, 3H), 7.14 (d, *J* = 6.8 Hz, 1H), 6.76 (dd, *J* = 8.6, 3.2 Hz, 1H), 6.68-6.64 (m, 2H), 6.03 (dd, *J* = 9.6, 4.0 Hz, 1H), 5.27 (t, *J* = 8.8 Hz, 1H), 4.74 (d, *J* = 8.8 Hz, 1H), 4.20 (d, *J* = 8.0 Hz, 1H), 3.63 (s, 3H), 2.09 (s, 3H), 1.32 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.7, 157.9, 155.7, 134.8, 133.5, 132.8, 129.8, 129.1, 128.7, 128.3, 128.2, 128.1, 126.7, 126.2, 115.1, 112.9, 79.9, 55.2, 50.9, 39.9, 28.2, 23.7. HRMS (EI-TOF): Calculated for $C_{24}H_{28}N_2O_4$ $[M]^+$ 408.2049, Found 408.2056.

***tert-butyl (1S,2R)*-2-(2-acetamido-5-ethoxyphenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3h)**

White solid; yield:52% (43.8mg); ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.50 (s, 1H), 7.31 (d, *J* = 9.2 Hz, 1H), 7.29-7.25 (m, 3H), 7.16 (d, *J* = 6.8 Hz, 1H), 6.75 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.68-6.65 (m, 2H), 6.04 (dd, *J* = 9.4, 3.8 Hz, 1H), 5.27 (t, *J* = 8.4 Hz, 1H), 4.74 (d, *J* = 9.2 Hz, 1H), 4.20 (d, *J* = 8.0 Hz, 1H), 3.92-3.86 (m, 2H), 2.10 (s, 3H), 1.33 (s, 9H), 1.29 (t, *J* = 4.8 Hz, 3H). ^{13}C NMR (100MHz, CDCl3) δ 169.6, 157.3, 155.7, 134.9, 133.5, 132.8, 129.8, 128.5, 128.4, 128.3, 128.2, 128.1, 126.7, 126.3, 115.6, 113.5, 79.9, 63.4, 50.8, 39.9, 28.2, 23.7,14.7. HRMS (EI-TOF): Calculated for $C_{25}H_{30}N_2O_4$ $[M]^+$ 422.2206, Found 422.2213.

***tert*-butyl(*1S,2R*)-2-(4-acetamidobiphenyl-3-yl)-1,2-dihydronaphthalen-1-ylcarbamate (3i)**

White solid; yield: 58% (52.7mg); m.p = 150-151 °C; ^{1}H NMR (400 MHz, CDC_{l3}, ppm) δ 7.66 (s, 1H), 7.62 (d, J = 8.4 Hz, 1H), 7.46 (d, J = 8.0 Hz, 1H), 7.37 (d, J = 4.0 Hz, 4H), 7.33-7.26 (m, 5H), 7.18 (d, J = 6.8 Hz, 1H), 6.70 (d, J = 9.6 Hz, 1H), 6.08 (dd, J = 9.6, 3.6 Hz, 1H), 5.33 (t, J = 7.6, 1H), 4.79 (d, J = 7.6 Hz, 1H), 4.29 (s, 1H), 2.13 (s, 3H), 1.27 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.3, 155.7, 140.5, 138.9, 135.2, 133.4, 132.8, 132.5, 129.7, 128.7, 128.4, 128.4, 128.3, 127.2, 127.0, 126.8, 126.6, 126.5, 126.4, 80.0, 50.9, 40.0, 28.2, 24.0. HRMS (EI-TOF): Calculated for $C_{29}H_{30}N_2O_3$ $[M]^+$ 454.2256, Found 454.2246.

***tert*-butyl(*1S,2R*)-2-(2-acetamido-5-chlorophenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3j)**

White solid; yield: 60% (49.4mg); m.p = 171-173 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.67 (s, 1H), 7.50 (d, J = 8.4 Hz, 1H), 7.33-7.25 (m, 3H), 7.19 (t, J = 7.2 Hz, 2H), 7.09 (d, J = 2.0 Hz, 1H), 6.70 (dd, J = 9.6, 1.2 Hz, 1H), 5.98 (dd, J = 9.6, 4.0 Hz, 1H), 5.24 (d, J = 8.0 Hz, 1H), 4.74 (d, J = 7.6 Hz, 1H), 4.23 (s, 1H), 2.10 (s, 3H), 1.31 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.2, 155.7, 134.7, 134.5, 132.9, 132.5, 131.5, 129.8, 128.8, 128.5, 128.5, 127.9, 127.5, 127.0, 126.5, 80.2, 50.6, 39.9, 28.2, 23.9. HRMS (EI-TOF): Calculated for $C_{23}H_{25}ClN_2O_3$ $[M]^+$ 412.1554, Found 412.1551.

***tert*-butyl(*1S,2R*)-2-(2-acetamido-5-bromophenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3k)**

White solid; yield: 57% (51.9mg); m.p = 183-184 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.66 (s, 1H), 7.44 (d, J = 7.6 Hz, 1H), 7.35(d, J = 7.6 Hz, 1H), 7.30-7.25 (m, 4H), 7.18 (d, J = 6.8 Hz, 1H), 6.70 (d, J = 9.2 Hz, 1H), 5.98 (dd, J = 9.2, 3.2 Hz, 1H), 5.23 (t, J = 7.6, 1H), 4.74 (d, J = 6.8 Hz, 1H), 4.22 (s, 1H), 2.09 (s, 3H), 1.31 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.2, 155.8, 135.3, 135.0, 132.9, 132.8, 132.5, 130.9, 128.8, 128.6, 128.5, 127.9, 127.1, 126.6, 119.5, 80.3, 50.6, 40.1, 28.3, 24.0. HRMS (EI-TOF): Calculated for $C_{23}H_{25}BrN_2O_3$ $[M]^+$ 456.1049, Found 456.1055.

***tert*-butyl(*1S,2R*)-2-(2-acetamido-5-iodophenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3l)**

White solid; yield: 56% (56.4mg); m.p = 170-172 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.66 (s, 1H), 7.47 (d, J = 6.8 Hz, 1H), 7.37 (s, 1H), 7.25-7.18 (m, 4H), 7.10 (d, J = 7.2 Hz, 1H), 6.62 (d, J = 9.6 Hz, 1H), 5.89 (dd, J = 9.6, 3.6 Hz, 1H), 5.13 (t, J = 8.2 Hz, 1H), 4.70 (d, J = 7.6 Hz, 1H), 4.11 (d, J = 7.8 Hz, 1H), 1.99 (s, 3H), 1.23 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.3, 155.6, 138.8, 136.8, 135.9, 135.3, 132.9, 132.9, 132.4, 128.8, 128.5, 128.1, 127.0, 126.7, 90.9, 80.2, 50.5, 40.1, 28.2, 23.9. HRMS (EI-TOF): Calculated for $C_{23}H_{25}IN_2O_3$ $[M]^+$ 504.0910, Found 504.0918.

***tert*-butyl (*1S,2R*)-2-(2-butyramidophenyl)-1,2-dihydronaphthalen-1-ylcarbamate(3n)**

White solid; yield: 68% (55.2mg); m.p = 154-155 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.63 (s, 1H), 7.57 (d, J = 7.6 Hz, 1H), 7.30-7.20 (m, 4H), 7.16 (d, J = 7.2 Hz, 1H), 7.09-7.03 (m, 2H), 6.68 (d, J = 9.2 Hz, 1H), 6.04 (dd, J = 9.8, 4.2 Hz, 1H), 5.32 (s, 1H), 4.69 (d, J = 6.8 Hz, 1H), 4.22 (s, 1H), 2.28 (t, J = 7.2 Hz, 2H), 1.79-1.70 (m, 2H), 1.33 (s, 9H), 0.99 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 172.0, 155.8, 135.9, 133.5, 132.9, 131.8, 129.8, 128.3, 128.1, 128.0, 127.8, 126.8, 126.3, 126.1, 126.0, 80.0, 51.1, 39.7, 39.2, 28.3, 19.2, 13.8. HRMS (EI-TOF): Calculated for $C_{25}H_{30}N_2O_3$ $[M]^+$ 406.2256, Found 406.2254.

***tert*-butyl*(1S,2R)*-2-(2-isobutyramidophenyl)-1,2-dihydronaphthalen-1-ylcarbamate (3o)**

White solid; yield: 45% (36.5mg); m.p = 166-167 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.65 (s, 1H), 7.58 (d, J = 6.0 Hz, 1H), 7.28 (t, J = 6.0 Hz, 1H), 7.24-7.19 (m, 3H), 7.16 (d, J = 6.0 Hz, 1H), 7.10-7.03 (m, 2H), 6.68 (d, J = 6.8 Hz, 1H), 6.05 (dd, J = 7.8, 3.4 Hz, 1H), 5.32 (s, 1H), 4.66 (s, 1H), 4.18 (s, 1H), 2.53-2.47 (m, 1H), 1.32 (s, 9H), 1.26 (t, J = 5.2 Hz, 6H). ^{13}C NMR (100MHz, $CDCl_3$) δ 175.8, 155.7, 135.9, 133.6, 132.9, 131.8, 129.8, 129.7, 128.3, 128.2, 128.1, 127.8, 126.7, 126.2, 126.1, 126.0, 80.0, 51.3, 39.8, 36.3, 28.2, 19.8, 19.6. HRMS (EI-TOF): Calculated for $C_{25}H_{30}N_2O_3$ $[M]^+$ 406.2256, Found 406.2255.

***methyl 4-acetamido-3-((1S,2R)-1-(tert-butoxycarbonylamino)-1,2-dihydronaphthalen-2-yl) benzoate* (3p)**

White solid; yield: 41% (35.7mg); m.p = 181-182 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.90-7.86 (m, 2H), 7.80 (s, 2H), 7.31-7.29 (m, 1H), 7.26-7.25 (d, J = 4.0 Hz, 2H), 7.20 (d, J = 7.2 Hz, 1H), 6.74 (d, J = 9.2 Hz, 1H), 6.01 (dd, J = 9.6, 4.0 Hz, 1H), 5.27 (t, J = 6.8 Hz, 1H), 4.73 (d, J = 6.8 Hz, 1H), 4.27 (s, 1H), 3.83 (s, 3H), 2.07 (s, 3H), 1.27 (s, 9H). ^{13}C NMR (100MHz, CDCl3) δ 168.9, 166.5, 155.7, 140.6, 133.1, 132.5, 131.7, 130.8, 129.2, 128.8, 128.6, 128.5, 127.1, 126.9, 126.3, 124.5, 80.1, 52.0, 50.8, 40.2, 20.2, 24.2. HRMS (EI-TOF): Calculated for $C_{25}H_{28}N_2O_5$ $[M]^+$ 436.1998, Found 436.1992.

***tert*-butyl *(1S,2R)*-2-(2-acetamidophenyl) -6,7-difluoro-1,2-dihydronaphthalen-1-ylcarbamate (3q)**

White solid; yield: 48% (39.7mg); m.p = 133-135 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.58 (s, 1H), 7.50 (d, J = 6.0 Hz, 1H), 7.24 (t, J = 6.0 Hz, 1H), 7.09-7.02 (m, 3H), 6.97 (t, J = 7.2 Hz, 1H), 6.57 (d, J = 7.6 Hz, 1H), 6.06 (dd, J = 7.2, 3.2 Hz, 1H), 5.27 (s, 1H), 4.62 (s, 1H), 4.20 (s, 1H), 2.14 (s, 3H), 1.34 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.2, 155.7, 150.8 (q, J_{C-F} = 3.4 Hz), 148.8 (q,

J_{C-F} = 4.0 Hz), 135.8, 131.4, 130.7, 130.4, 129.8(q, J_{C-F} = 3.5 Hz), 129.4, 128.2, 126.7, 126.5, 126.3, 115.6 (d, J_{C-F} = 15.2 Hz), 115.4 (d, J_{C-F} = 15.2 Hz), 80.4, 50.5, 38.7, 28.3, 23.9. HRMS (EI-TOF): Calculated for $C_{23}H_{24}F_2N_2O_3$ $[M]^+$ 414.1755, Found 414.1751.

***tert*-butyl *(1S,2R)*-2-(2-acetamidophenyl) -6,7-dimethyl-1,2-dihydronaphthalen-1-ylcarbamate (3r)**

White solid; yield: 52% (42.2mg); m.p = 126-128 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.67 (s, 1H), 7.56 (d, J = 8.0 Hz, 1H), 7.22 (t, J = 7.2 Hz, 1H), 7.11-7.03 (m, 2H), 6.99 (s, 1H), 6.94 (s, 1H), 6.61 (d, J = 9.2 Hz, 1H), 5.95 (dd, J = 5.4, 4.2 Hz, 1H), 5.23 (s, 1H), 4.65 (s, 1H), 4.22 (s, 1H), 2.25 (s, 3H), 2.24 (s, 3H), 2.09 (s, 3H), 1.33 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.1, 155.9, 136.7, 136.3, 136.0, 132.2, 130.7, 130.4, 129.9, 128.6, 128.2, 127.8, 127.7, 127.4, 126.1, 79.9, 50.8, 39.9, 28.3, 24.0, 19.8, 19.4. HRMS (EI-TOF): Calculated for $C_{25}H_{30}N_2O_3$ $[M]^+$ 406.2256, Found 406.2256.

General Procedure for Ruthenium-Catalyzed Ring-Opening Addition of Anilides to 7-oxabenzonorbornadienes (5). To a flame-dried reaction flask, amides **1** (0.2 mmol), 7-oxabenzonorbornadienes **4** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (6.1 mg, 0.01 mmol), $AgSbF_6$ (13.7 mg, 0.04 mmol), PivOH (40.8 mg, 0.4 mmol) and 1,4-dioxane (1 mL) were added under air atmosphere. The mixture was stirred for 8 h at 100 °C. The mixture was then cooled to room temperature, diluted with EtOAc, filtered through a celite pad, and concentrated in vacuo. The residue was purified by flash column chromatography on silica gel (eluent: hexane/EtOAc = 10/1), to afford the desired product **5**.

***N*-(2-(naphthalen-2-yl)phenyl)acetamide (5a)**

White solid; yield: 81% (42.3mg); m.p = 144-146 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.15 (d, J = 8.4 Hz, 1H), 7.70 (t, J = 7.6 Hz, 1H), 7.50 (d, J = 8.4 Hz, 1H), 7.40 (t, J = 7.6 Hz, 1H), 7.28-7.18 (m, 6H), 7.10-7.05 (m, 4H), 2.56 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, ppm) δ 157.8, 146.9, 146.8, 138.5, 136.7, 134.1, 130.1, 130.1, 129.3, 128.4, 127.9, 127.7, 127.3, 126.9, 126.7, 126.3, 125.9, 25.3. HRMS (EI-TOF): Calculated for $C_{18}H_{15}NO$ $[M]^+$ 261.1154, found : 261.1153.

***N*-(4-methyl-2-(naphthalen-2-yl)phenyl)acetamide (5b)**

Light brown solid; yield: 82% (45.1mg); m.p = 123-126 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.11 (d, J = 8.4 Hz, 1H), 7.94 (d, J = 8.4 Hz, 1H), 7.91-7.86 (m, 2H), 7.83 (s, 1H), 7.56-7.54 (m, 2H),

7.47 (dd, J = 9.4, 1.2 Hz, 1H), 7.21 (dd, J = 9.6, 1.2 Hz, 1H), 7.16 (s, 1H), 7.07 (s, 1H), 2.37 (s, 3H), 1.98 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.4, 135.8, 134.2, 133.5, 132.7, 132.4, 132.3, 130.8, 129.1, 128.7, 128.3, 128.0, 127.8, 127.1, 126.7, 126.5, 122.2, 24.5, 20.9. HRMS (EI-TOF): Calculated for $C_{19}H_{17}NO$ $[M]^+$ 275.1310, Found 275.1313.

***N*-(5-methyl-2-(naphthalen-2-yl)phenyl)acetamide (5c)**

Light brown solid; yield: 72% (39.6mg); m.p = 141-142 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.11 (s, 1H), 7.93 (d, J = 8.4 Hz, 1H), 7.92-7.85 (m, 2H), 7.82 (s, 1H), 7.55-7.53 (m, 2H), 7.46 (dd, J = 8.4, 1.2 Hz, 1H), 7.22 (d, J = 7.6 Hz, 1H), 7.13 (s, 1H), 7.03 (d, J = 7.6 Hz, 1H), 2.42 (s, 3H), 1.97 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.4, 138.6, 135.7, 134.6, 133.6, 132.6, 130.1, 129.5, 128.7, 128.3, 128.0, 127.8, 127.2, 126.7, 126.5, 125.4, 122.4, 24.6, 21.5. HRMS (EI-TOF): Calculated for $C_{19}H_{17}NO$ $[M]^+$ 275.1310, Found 275.1311.

***N*-(2-methyl-6-(naphthalen-2-yl)phenyl)acetamide (5d)**

Light brown solid; yield: 61% (33.5mg); m.p = 145-146 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.80-7.75 (m, 3H), 7.70 (s, 1H), 7.44-7.42 (m, 2H), 7.36 (dd, J = 8.4, 1.2 Hz, 1H), 7.21 (d, J = 5.2 Hz, 2H), 7.19 (t, J = 5.0 Hz, 1H), 6.61 (s, 1H), 2.25 (s, 3H), 1.88 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 169.7, 139.6, 137.3, 137.2, 133.6, 133.0, 132.7, 130.5, 128.3, 128.2, 128.0, 127.9, 127.8, 127.3, 126.6, 126.4, 23.3, 18.9. HRMS (EI-TOF): Calculated for $C_{19}H_{17}NO$ $[M]^+$ 275.1310, Found 275.1314.

***N*-(4,5-dimethyl-2-(naphthalen-2-yl)phenyl)acetamide (5e)**

Light brown solid; yield: 78% (45.1mg); m.p = 138-140 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.99 (s, 1H), 7.93 (d, J = 8.4 Hz, 1H), 7.90-7.86 (m, 2H), 7.82 (s, 1H), 7.55-7.53 (m, 2H), 7.47 (dd, J = 8.0, 1.2 Hz, 1H), 7.13 (s, 1H), 7.09 (s, 1H), 2.34 (s, 3H), 2.29 (s, 3H), 1.98 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.4, 137.0, 135.8, 133.6, 133.1, 132.6, 132.3, 131.3, 130.3, 128.6, 128.2, 128.0, 127.8, 127.3, 126.6, 126.4, 123.6, 24.5, 19.9, 19.3. HRMS (EI-TOF): Calculated for $C_{20}H_{19}NO$ $[M]^+$ 289.1467, Found 289.1461.

***N*-(4-tert-butyl-2-(naphthalen-2-yl)phenyl)acetamide (5f)**

Light brown solid; yield: 61% (38.7mg); m.p = 83-84 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.14 (d, J = 8.4 Hz, 1H), 7.95 (d, J = 8.4 Hz, 1H), 7.92-7.88 (m, 2H), 7.85 (s, 1H), 7.57-7.54 (m, 2H), 7.49 (dd, J = 9.2, 1.6 Hz, 1H), 7.43 (dd, J = 8.8, 2.4Hz, 1H), 7.33 (d, J = 2.4 Hz, 1H), 7.09 (s, 1H), 1.98 (s, 3H), 1.35 (s, 9H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.4, 147.6, 136.2, 133.6, 132.6, 132.2,

132.1, 128.7, 128.3, 128.0, 127.8, 127.2, 126.7, 126.5, 125.5, 121.9, 34.5, 31.4, 24.5. HRMS (EI-TOF): Calculated for $C_{22}H_{23}NO$ $[M]^+$ 317.1780, Found 317.1782.

6-fluoro-2-methyl-3,4-diphenylquinoline(5g)

Light brown solid; yield: 62% (36.1mg); m.p = 135-137 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.02 (d, J = 9.2 Hz, 1H), 7.93 (d, J = 8.8 Hz, 1H), 7.91-7.86 (m, 2H), 7.83 (s, 1H), 7.56-7.53 (m, 2H), 7.47 (dd, J = 8.4, 1.2 Hz, 1H), 6.98 (s, 1H), 6.93 (dd, J = 8.8, 3.2 Hz, 1H), 8.90 (d, J = 2.8 Hz, 1H), 3.82 (s, 1H), 7.96 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.5, 156.6, 135.7, 134.7, 133.5, 132.7, 128.6, 128.2, 128.0, 127.9, 127.8, 126.9, 126.7, 126.6, 124.5, 115.7, 113.6, 55.6, 24.3. HRMS (EI-TOF): Calculated for $C_{19}H_{17}NO_2$ $[M]^+$ 291.1259, Found 291.1256.

***N*-(2,2'-binaphthyl-3-yl)acetamide (5h)**

Light brown solid; yield: 77% (47.9mg); m.p = 148-150 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.85 (s, 1H), 7.98 (d, J = 8.4 Hz, 1H), 7.93-7.87 (m, 4H), 7.77 (d, J = 7.2 Hz, 2H), 7.58-7.54 (m, 3H), 7.50-7.41 (m, 2H), 7.32 (s, 1H), 2.01 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.4, 135.4, 133.6, 133.5, 132.8, 132.7, 132.1, 130.3, 129.5, 128.9, 128.7, 128.1, 127.9, 127.8, 127.5, 127.1, 126.9, 126.8, 126.6, 125.5, 118.3, 24.9. HRMS (EI-TOF): Calculated for $C_{22}H_{17}NO$ $[M]^+$ 311.1310, Found 311.1315.

***N*-(4-fluoro-2-(naphthalen-2-yl)phenyl)acetamide (5i)**

Light brown solid; yield: 71% (39.6mg); m.p = 147-149 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.07 (dd, J = 8.6, 5.4 Hz, 1H), 7.86 (d, J = 8.4 Hz, 1H), 7.83-7.78 (m, 2H), 7.74 (s, 1H), 7.49-7.46 (m, 2H), 7.36 (d, J = 8.0 Hz, 1H), 7.02-6.97 (m, 3H), 1.88 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.5, 159.3(d, J_{C-F} = 243.3 Hz), 134.7, 134.6, 133.5, 132.9, 130.8(d, $JC–F$ = 1.9 Hz), 128.9, 128.3, 128.1, 127.8, 126.9(d, J_{C-F} = 5.3 Hz), 126.6, 124.2(d, J_{C-F} = 7.8 Hz), 116.8(d, J_{C-F} = 22.1 Hz), 115.0(d, J_{C-F} = 21.9 Hz), 24.4. HRMS (EI-TOF): Calculated for $C_{18}H_{14}FNO$ $[M]^+$ 279.1059, Found 279.1056.

***N*-(4-chloro-2-(naphthalen-2-yl)phenyl)acetamide (5j)**

White solid; yield: 53% (31.3mg); m.p = 160-162 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.27 (d, J = 8.8 Hz, 1H), 7.97 (d, J = 8.4 Hz, 1H), 7.93-7.86 (m, 2H), 7.83 (s, 1H), 7.59-7.56 (m, 2H), 7.44 (dd, J = 8.4, 1.6 Hz, 1H), 7.36 (dd, J = 8.4, 2.6 Hz, 1H), 7.32 (d, J = 2.0 Hz, 1H), 7.14 (s, 1H), 1.98 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.3, 134.2, 133.6, 133.6, 133.5, 132.9, 130.0, 129.4, 129.1, 128.4, 128.1, 127.8, 127.0, 126.9, 126.5, 122.9, 24.6. HRMS (EI-TOF): Calculated for $C_{18}H_{14}ClNO$ $[M]^+$ 295.0764, Found 295.0767.

***N*-(4-bromo-2-(naphthalen-2-yl)phenyl)acetamide (5k)**

Light brown solid; yield: 57% (38.6mg); m.p = 158-160 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.23 (d, J = 8.8 Hz, 1H), 7.97 (d, J = 8.4 Hz, 1H), 7.93-7.87 (m, 2H), 7.83 (s, 1H), 7.59-7.56 (m, 2H), 7.52-7.47 (m, 2H), 7.44 (dd, J = 8.4, 1.2 Hz, 1H), 7.14 (s, 1H), 1.97 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.3, 134.1, 133.9, 133.5, 132.9, 132.8, 131.4, 129.1, 128.4, 128.1, 127.9, 127.0, 126.9, 126.5, 123.1, 117.0, 24.7. HRMS (EI-TOF): Calculated for $C_{18}H_{14}BrNO$ $[M]^+$ 339.0259, Found 339.0251.

***N*-(4-iodo-2-(naphthalen-2-yl)phenyl)acetamide (5l)**

Light brown solid; yield: 70% (54.1mg); m.p = 161-163 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.13 (d, J = 8.8 Hz, 1H), 7.97 (d, J = 8.0 Hz, 1H), 7.93-7.87 (m, 2H), 7.83 (s, 1H), 7.69 (dd, J = 8.6, 1.8 Hz, 1H), 7.67 (s, 1H), 7.59-7.57 (m, 2H), 7.44 (dd, J = 8.4, 1.2 Hz, 1H), 7.13 (s, 1H), 1.98 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.3, 138.7, 137.4, 134.9, 134.0, 133.9, 133.5, 132.9, 129.1, 128.4, 128.1, 127.9, 127.0, 126.9, 126.5, 123.2, 24.8. HRMS (EI-TOF): Calculated for $C_{18}H_{14}INO$ $[M]^+$ 387.0120, Found 387.0122.

methyl 4-acetamido-3-(naphthalen-2-yl)benzoate (5m)

Light brown solid; yield: 54% (34.4mg); m.p = 109-111 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.52 (d, J = 8.4 Hz, 1H), 8.07 (d, J = 8.6, 2.2 Hz, 1H), 8.02 (d, J = 2.0 Hz, 1H), 7.99 (d, J = 8.8 Hz, 1H), 7.95-7.89 (m, 2H), 7.87 (s, 1H), 7.61-7.57 (m, 2H), 7.48 (dd, J = 8.2, 1.8 Hz, 1H), 7.42 (s, 1H), 3.91 (s, 3H), 2.02 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.5, 166.6, 139.2, 134.4, 133.6, 132.9, 131.8, 131.2, 130.2 129.2, 128.6, 128.1, 127.8, 127.0, 126.9, 126.7, 125.5, 120.2, 52.1, 24.9. HRMS (EI-TOF): Calculated for $C_{20}H_{17}NO_3$ $[M]^+$ 319.1208, Found 319.1214.

N-*(4-acetyl-2-(naphthalen-2-yl)phenyl)acetamide* (5n)

Light brown solid; yield: 48% (29.1mg); m.p = 134-135 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.55 (d, J = 8.4 Hz, 1H), 8.00 (dd, J = 8.6, 3.8 Hz, 2H), 7.95-7.89 (m, 3H), 7.87 (s, 1H), 7.61-7.58 (m, 2H), 7.47 (dd, J = 8.4, 1.6 Hz, 2H), 7.43 (s, 1H), 2.60 (s, 3H), 2.02 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 197.1, 168.5, 139.4, 134.4, 133.6, 132.9, 132.7, 131.3, 130.5 129.3, 129.3, 128.6, 128.1, 127.9, 127.0, 126.9, 126.6, 120.2, 26.5, 24.9. HRMS (EI-TOF): Calculated for $C_{20}H_{17}NO_2$ $[M]^+$ 303.1259, Found 303.1254.

***N*-(2-(naphthalen-2-yl)phenyl)butyramide (5o)**

Light brown solid; yield: 76% (43.9mg); m.p = 98-99 °C;^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.33 (d,

J = 8.4 Hz, 1H), 7.95 (d, *J* = 8.4 Hz, 1H), 7.92-7.89 (m, 1H), 7.88-7.86 (m, 1H), 7.85 (s, 1H), 7.57-7.53 (m, 2H), 7.48 (dd, *J* = 8.4,1.6 Hz, 1H), 7.40 (td, *J* = 8.8, 1.2 Hz, 1H), 7.33 (d, *J* = 7.6 Hz, 1H), 7.23-7.19 (m, 2H), 2.13 (t, 7.6 Hz, 2H), 1.63-1.57 (m, 2H), 0.89 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 171.4, 135.6, 134.9, 133.5, 132.7, 132.1, 130.3, 128.8, 128.6, 128.4, 128.0, 127.8, 127.1, 126.8, 126.6, 124.4, 121.8, 39.7, 18.9, 13.7. HRMS (EI-TOF): Calculated for $C_{20}H_{19}NO$ $[M]^+$ 289.1467, Found 289.1469.

***N*-(2-(naphthalen-2-yl)phenyl)isobutyramide (5p)**

Light brown solid; yield: 44% (25.4mg); m.p = 142-143 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.35 (d, *J* = 6.8 Hz, 1H), 7.96 (d, *J* = 6.8 Hz, 1H), 7.93-7.90 (m, 1H), 7.88-7.87 (m, 1H), 7.86 (s, 1H), 7.58-7.54 (m, 2H), 7.49 (dd, *J* = 6.8, 1.2 Hz, 1H), 7.41 (dt, *J* = 6.6, 1.2 Hz, 1H), 7.34 (d, *J* = 6.0 Hz, 1H), 7.24-7.19 (m, 2H), 2.32-2.61(m, 1H), 1.09 (s, 3H), 1.08(s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 175.0, 135.6, 135.0, 133.5, 132.7, 132.1, 130.2, 128.8, 128.6, 128.4, 128.0, 127.8, 127.2, 126.8, 126.6, 124.3, 121.6, 36.7, 19.4. HRMS (EI-TOF): Calculated for $C_{20}H_{19}NO$ $[M]^+$ 289.1467, Found 289.1469.

***N*-(2-(6,7-dimethylnaphthalen-2-yl)phenyl)acetamide (5q)**

Light brown solid; yield: 62% (35.8mg); m.p = 143-144 °C; ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.31 (d, *J* = 6.4 Hz, 1H), 7.83 (d, *J* = 6.8 Hz, 1H), 7.72 (s, 1H), 7.66 (s, 1H), 7.62 (s, 1H), 7.40-7.35 (m, 2H), 7.32 (d, *J* = 5.6 Hz, 1H), 7.21-7.18 (m, 2H), 2.47 (s, 3H), 2.46 (s, 3H), 1.97 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.3, 136.7, 136.5, 134.9, 134.6, 132.5, 132.3, 131.6, 130.2, 128.4, 127.8, 127.5, 127.3, 127.2, 126.2, 124.3, 121.5, 24.7, 20.3. HRMS (EI-TOF): Calculated for $C_{20}H_{19}NO$ $[M]^+$ 289.1467, Found 289.1461.

***N*-(2-(7-bromonaphthalen-2-yl)phenyl)acetamide (5r)** yield = 22 %

***N*-(2-(6-bromonaphthalen-2-yl)phenyl)acetamide (5r')** yield = 42 %

Light brown solid; yield: 64% (43.4mg); ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.25 (d, *J* = 8.0 Hz, 1H), 8.07 (s, 0.3H), 8.03 (d, *J* = 1.2 Hz, 0.7H), 7.92 (d, *J* = 8.0 Hz, 0.7H), 7.86 (d, *J* = 8.4 Hz, 0.4H), 7.80 (d, *J* = 10.4 Hz, 0.7H), 7.77 (s, 0.4H), 7.76-7.74 (m, 1H), 7.62 (dd, *J* = 8.8, 1.6 Hz, 1H), 7.52-7.49 (m, 1H), 7.42 (t, *J* = 7.8 Hz, 1H), 7.32 (d, *J* = 7.6 Hz, 1H), 7.23 (t, *J* = 7.4 Hz, 1H), 7.10 (s, 1H), 2.00 (s, 2H), 1.99 (s, 1H). ^{13}C NMR (100MHz, $CDCl_3$) δ 168.4, 136.8, 136.1, 134.8, 134.6, 133.7, 132.0, 131.9, 131.9, 131.1, 130.3, 130.2, 130.0, 130.0, 129.9, 129.7, 129.5, 128.8, 128.7, 128.3, 128.1, 127.9, 127.5, 127.3, 124.7, 122.2, 120.8, 120.6, 24.6. HRMS (EI-TOF): Calculated for

$C_{18}H_{14}BrNO$ $[M]^+$ 339.0259, Found 339.0257.

Procedure of Deuterium Labeling Experiment (Scheme 4, eq 1-2).

Scheme 4, Eq(1) To a flame-dried reaction flask was added substrate **1a** (0.1 mmol) and **1a-*d*$_5$** (0.1 mmol), **2a** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (6.1 mg, 0.01 mmol), $AgSbF_6$ (20.6 mg, 0.06 mmol), NaOAc (8.2 mg, 0.1 mmol) and DCE (1 mL). The mixture was stirred for 20 min at 100 °C under air atmosphere. The mixture was then cooled to room temperature, diluted with EtOAc, filtered through a celite pad, and concentrated in vacuo. The residue was purified by flash column chromatography on silica gel (eluent: hexane/EtOAc = 5/1 with triethylamine), to afford the desired product（yield = 33%）. The ratio of product **3a**/**3a-*d*$_4$** was analyzed by ^{1}H NMR (400MHz, $CDCl_3$).

Scheme 4, Eq(2) To a flame-dried reaction flask was added substrate **1a** (0.2 mmol), **2a** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (6.1 mg, 0.01 mmol), $AgSbF_6$ (20.6 mg, 0.06 mmol), NaOAc (8.2 mg, 0.1 mmol) and DCE (1 mL). The mixture was stirred for 20 min at 100 °C under air atmosphere. The mixture was then cooled to room temperature, diluted with EtOAc, filtered through a celite pad, and concentrated in vacuo. The residue was purified by flash column chromatography on silica gel (eluent: hexane/EtOAc = 5/1 with triethylamine), to afford the desired product **3a**（yield = 28.3%）.

To a flame-dried reaction flask was added substrate **1a-*d*$_5$** (0.2 mmol), **2a** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (6.1 mg, 0.01 mmol), $AgSbF_6$ (20.6 mg, 0.06 mmol), NaOAc (8.2 mg, 0.1 mmol) and DCE (1 mL). The mixture was stirred for 20 min at 100 °C under air atmosphere. The mixture was then cooled to room temperature, diluted with EtOAc, filtered through a celite pad, and concentrated in vacuo. The residue was purified by flash column chromatography on silica gel (eluent: hexane/EtOAc = 5/1 with triethylamine), to afford the desired product **3a-*d*$_4$**（yield = 10.3%）.

Procedure of Competitive Experiment (Scheme 4, eq 3). To a flame-dried reaction flask was added substrate **1n** (0.1 mmol) and **1g** (0.1 mmol), **2a** (0.3 mmol), $[RuCl_2(p\text{-cymene})]_2$ (6.1 mg, 0.01 mmol), $AgSbF_6$ (20.6 mg, 0.06 mmol), NaOAc (8.2 mg, 0.1 mmol) and DCE (1 mL). The mixture was stirred for 8 h at 100 °C under air atmosphere. The mixture was then cooled to room temperature, diluted with EtOAc, filtered through a celite pad, and concentrated in vacuo. The residue was purified by flash column chromatography on silica gel (eluent: hexane/EtOAc = 5/1), to afford the separated products **5n**（yield = 52.7%）and **5g**（yield = 30.5%）. The ratio of product **5n/5g** was determined on the basis of isolated yield by flash column chromatography on silica gel.

Supporting Information availability statement

Details for experiments conditions, copies of ^1H and ^{13}C NMR spectra for all isolated compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

Author Information

Corresponding Author

*Email: yhzhang@zju.edu.cn

Acknowledgments

Funding from National Basic Research Program of China (21472165, 21672186) and Important Project of Zhejiang Province (2017C03049) are highly acknowledged. As a summer intern at Zhejiang University, the co-author Steven Chu is from JSerra Catholic High School in the USA.

References

(1) (a) Sterling, J.; Herzig, Y.; Goren, T. Novel Dual Inhibitors of AChE and MAO Derived from Hydroxy Aminoindan and Phenethylamine as Potential Treatment for Alzheimer's Disease. *J. Med. Chem.* **2002**, *45*, 5260-5279. (b) Tangallapally, R. P.; Yendapally, R.; Lee, R. E.; Hevener, K.; Jones, V. C.; Lenaerts, A. J. M.; McNeil, M. R.; Wang, Y.; Franzblau, S.; Lee, R. E. Synthesis and Evaluation of Nitrofuranylamides as Novel Antituberculosis Agents. *J. Med. Chem.* **2004**, *47*, 5276-5283.

(2) (a) Haworth, R. D. Syntheses of alkylphenanthrenes. Part I. 1-, 2-, 3-, and 4-Methylphenanthrenes. *J. Chem. Soc.* **1932**, 1125-1133. (b) Moore, M. L. The Leuckart Reaction. *Org. React.* **1949**, *5*, 301-330. (c) Hulin, B.; Koreeda, M. A Convenient, Mild Method for the Cyclization of 3- and 4-Arylalkanoic Acids via their Trifluoromethanesulfonic Anhydride Derivatives. *J. Org. Chem.* **1984**, *49*, 207-209. (d) Mallory, F. B.; Luzik Jr, E. D.; Mallory, C. W.; Carroll, P. J. Nuclear Spin-spin Coupling via Nonbonded Interactions. 7. Effects of Molecular Structure on Nitrogen-fluorine Coupling. *J. Org. Chem.* **1992**, *57*, 366-370. (e) Wempe, M. F.; Grunwell, J. R. The Transannular Rearrangement of 5-Cyclodecynone. *J. Org. Chem.* **1995**, *60*, 2714-2720. (f) Colyer, J. T.; Andersen, N. G.; Tedrow, J. S.; Soukup, T. S.; Faul, M. M. Reversal of Diastereofacial Selectivity in Hydride Reductions of N-tert-Butanesulfinyl Imines. *J. Org. Chem.* **2006**, *71*, 6859-6862.

(3) (a) Feng, C.-C.; Nandi, M.; Sambaiah, T.; Cheng, C.-H. Nickel-Catalyzed Highly Stereoselective Ring Opening of 7-Oxa- and Azanorbornenes with Organic Halides. *J. Org. Chem.* **1999**, *64*, 3538-3543. (b) Rayabarapu, D. K.; Shukla, P.; Cheng, C.-H. Cyclization of Oxa-Bicyclic Alkenes with β-Iodo-(Z)-propenoates and o-Iodobenzoate Catalyzed by Nickel Complexes: A Simple

Efficient Route to Annulated Coumarins. *Org. Lett.* **2003**, *5*, 4903-4906.

(4) (a) Lautens, M.; Fagnou, K.; Taylor, M. Rhodium-Catalyzed Asymmetric Ring Opening of Oxabicyclic Alkenes with Phenols. *Org. Lett.* **2000**, *2*, 1677-1679. (b) Cho, Y.-H.; Zunic, V.; Senboku, H.; Olsen, M.; Lautens, M. Rhodium-Catalyzed Ring-Opening Reactions of N-Boc-Azabenzonorbornadienes with Amine Nucleophiles. *J. Am. Chem. Soc.* **2006**, *128,* 6837-6846. (c) Lu, Z.; Wang, J.; Han, B; Li, S.; Zhou, Y.; Fan, B. Palladium−Catalyzed Asymmetric Ring Opening Reaction of Azabenzonorbornadienes with Aromatic Amines. *Adv. Synth. Catal.* **2015**, *357*, 3121-3125.

(5) Yang, F.; Chen, J.; Xu, J.; Ma, F.; Zhou, Y.; Shinde, M. V.; Fan, B. Palladium/Lewis Acid Co-catalyzed Divergent Asymmetric Ring-Opening Reactions of Azabenzonorbornadienes with Alcohols. *Org. Lett.* **2016**, *18*, 4832-4835.

(6) (a) Lautens, M.; Dockendorff, C. Palladium(II) Catalyst Systems for the Addition of Boronic Acids to Bicyclic Alkenes: New Scope and Reactivity. *Org. Lett.* **2003**, *5*, 3695-3698. (b) Arrayas, R. G.; Cabrera, S.; Carretero, J. C. Copper-Catalyzed Anti-Stereocontrolled Ring-Opening of Azabicyclic Alkenes with Grignard Reagents. *Org. Lett.* **2005**, *7*, 219-221. (c) Ogura, T.; Yoshida, K.; Yanagisawa, Akira.; Imamoto, T. Optically Active Dinuclear Palladium Complexes Containing a Pd-Pd Bond: Preparation and Enantioinduction Ability in Asymmetric Ring-Opening Reactions. *Org. Lett.* **2009**, *11*, 2245-2248. (d) Zhang, W.; Chen, J.; Zeng, G.; Yang, F.; Xu, J.; Sun, W.; Shinde, M. V.; Fan, B. Asymmetric Ring-Opening Reactions of Aza- and Oxa-bicyclic Alkenes with Boronic Acids Using a Palladium/Zinc Co-catalytic System. *J. Org. Chem.* **2017**, *82*, 2641-2647.

(7) For reviews on natural product synthesis by C-H activation, see: (a) Colby, D. A.; Tsai, A. S.; Bergman, R. G.; Ellman, J. A. Rhodium Catalyzed Chelation-Assisted C-H Bond Functionalization

Reactions. *Acc. Chem. Res.* **2012**, *45*, 814-825. (b) Ackermann, L. Carboxylate-Assisted Ruthenium-Catalyzed Alkyne Annulations by C-H/Het–H Bond Functionalizations. *Acc. Chem. Res.* **2014**, *47*, 281-295. For selected reports on ortho functionalization of anilides: (c) Boele, M. D. K.; van Strijdonck, G. P. F.; de Vries, A. H. M.; Kamer, P. C. J.; de Vries, J. G.; van Leeuwen, P. W. N. M. Selective Pd-Catalyzed Oxidative Coupling of Anilides with Olefins through C-H Bond Activation at Room Temperature. *J. Am. Chem. Soc.* **2002**, *124*, 1586-1587. (d) Ackermann, L.; Vicente, R.; Althammer, A. Assisted Ruthenium-Catalyzed C-H Bond Activation: Carboxylic Acids as Cocatalysts for Generally Applicable Direct Arylations in Apolar Solvents. *Org. Lett.* **2008**, *10*, 2299-2302. (e) Patureau, F. W.; Glorius, F. Rh Catalyzed Olefination and Vinylation of Unactivated Acetanilides. *J. Am. Chem. Soc.* **2010**, *132*, 9982-9983. (f) Ackermann, L.; Wang, L.; Wolfram. R.; Lygin, A. V. Ruthenium-Catalyzed Oxidative C-H Alkenylations of Anilides and Benzamides in Water. *Org. Lett.* **2012**, *14*, 728-731.

(8) Wang, F.; Yu, S.; Li, X. Transition Metal-Catalysed Couplings between Arenes and Strained or Reactive Rings: Combination of C-H Activation and Ring Scission. *Chem. Soc. Rev.* **2016**, *45*, 6462-6477.

(9) Qi, Z.; Li, X. Rhodium(III)−Catalyzed Coupling of Arenes with 7−Oxa/Azabenzonorbornadienes by C-H Activation. *Angew. Chem. Int. Ed.* **2013**, *52*, 8995-9000.

(10) Unoh, Y.; Satoh, T.; Hirano, K.; Miura, M. Rhodium(III)-Catalyzed Direct Coupling of Arylphosphine Derivatives with Heterobicyclic Alkenes: A Concise Route to Biarylphosphines and Dibenzophosphole Derivatives. *ACS Catal.* **2015**, *5*, 6634-6639.

(11) (a) Kong, L.; Yu, S.; Tang, G.; Wang, H.; Zhou, X.; Li, X. Cobalt(III)-Catalyzed C-C Coupling of Arenes with 7-Oxabenzonorbornadiene and 2-Vinyloxirane via C-H Activation. *Org. Lett.* **2016**,

18, 3802-3805. (b) Muralirajan, K.; Prakash S.; Cheng, C.-H. Cobalt−Catalyzed Mild Ring−Opening Addition of Arenes C-H Bond to 7−Oxabicyclic Alkenes. *Adv. Synth. Catal.* **2017**, *359*, 513-518.

(12) (a) Dong, W.; Parthasarathy, K.; Cheng, Y.; Pan, F.; Bolm, C. Hydroarylations of Heterobicyclic Alkenes through Rhodium-Catalyzed Directed C-H Functionalizations of S-Aryl Sulfoximines. *Chem. Eur. J.* **2014**, *20*, 15732-15736. (b) Cheng, H.; Dong, W.; Dannenberg, C. A.; Dong, S.; Guo, Q.; Bolm, C. Ruthenium-Catalyzed Hydroarylations of Oxa- and Azabicyclic Alkenes. *ACS. Catal.* **2015**, *5*, 2770-2773.

(13) Gorelsky, S. I.; Lapointe, D.; Fagnou, Keith. Analysis of the Concerted Metalation-Deprotonation Mechanism in Palladium-Catalyzed Direct Arylation Across a Broad Range of Aromatic Substrates. *J. Am. Chem. Soc.* **2008**, *130,* 10848-10849.

(14) (a) Ackermann, L.; Vicente, R.; Potukuchi, H. K.; Pirovano, V. Mechanistic Insight into Direct Arylations with Ruthenium(II) Carboxylate Catalysts. *Org. Lett.* **2010,** *12*, 5032-5035. (b) Flegeau, E. F.; Bruneau, C.; Dixneuf, P. H.; Jutand, A. Autocatalysis for C-H Bond Activation by Ruthenium(II) Complexes in Catalytic Arylation of Functional Arenes. *J. Am. Chem. Soc.* **2011**, *133*, 10161-10170. (c) Ackermann, L. Carboxylate-Assisted Transition-Metal-Catalyzed C-H Bond Functionalizations: Mechanism and Scope. *Chem. Rev.* **2011**, *111*, 1315-1345. (d) Sarkar, S. D.; Liu, W.; Kozhushkov, S. I.; Ackermann, L. Weakly Coordinating Directing Groups for Ruthenium(II) ‐ Catalyzed C-H Activation. *Adv. Synth. Catal.* **2014**, *356*, 1461-1479. (e) Lanke, V.; Bettadapur, K. R.; Prabhu, K. R. Site-Selective Addition of Maleimide to Indole at the C-2 Position: Ru(II)-Catalyzed C–H Activation. *Org. Lett.* **2015**, *17*, 4662-4664.

(15) Zhang, Y.; Wu, Q.; Cui, S. Rh(III)-Catalyzed C-H Activation-Desymmetrization of Diazabicycles with Arenes: Facile Synthesis of Functionalized Cyclopentenes. *Chem. Sci.* **2014**, *5*,

297-302.

(16) (a) Otani, Y.; Nagae, O.; Naruse, Y.; Inagaki, S.; Ohno, M.; Yamaguchi, K.; Yamamoto, G.; Uchiyama, M.; Ohwada, T. An Evaluation of Amide Group Planarity in 7-Azabicyclo[2.2.1]heptane Amides. Low Amide Bond Rotation Barrier in Solution. *J. Am. Chem. Soc.* **2003**, *125*, 15191-15199. (b) McManus, H. A.; Fleming, M. J.; Lautens, M. Enantioselective Total Synthesis of (+)−Homochelidonine by a PdII−Catalyzed Asymmetric Ring−Opening Reaction of a meso−Azabicyclic Alkene with an Aryl Boronic Acid. *Angew. Chem. Int. Ed.* **2007**, *46*, 433-436. (c) Gandeepan, P.; Rajamalli, P.; Cheng, C.-H. Diastereoselective [3+2] Annulation of Aromatic/Vinylic Amides with Bicyclic Alkenes through Cobalt−Catalyzed C-H Activation and Intramolecular Nucleophilic Addition. *Angew. Chem. Int. Ed.* **2016**, *55*, 4308-4311.