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Osaka University
Doctoral Dissertation

Studies on Nickel-Catalyzed C-H Bond Functionalization
Utilizing $N,N$-Bidentate Directing Assistance

Yoshinori Aihara

January 2016

Department of Applied Chemistry,
Graduate School of Engineering,
Osaka University
Preface and Acknowledgements

The findings presented in this thesis were carried out under the direction of Professor Naoto Chatani of the Department of Applied Chemistry, Faculty of Engineering, Osaka University between April 2010 and March 2016. The thesis is concerned with the development of the nickel(II)-catalyzed direct functionalization of aromatic and aliphatic C-H bonds utilizing an N,N-bidentate directing group.

This thesis would not be possible without help, advice, and support from many people and I would like to express my sincerest appreciation to all of them.

I would like to express my utmost gratitude to Professor Chatani for his guidance and suggestions throughout this work. His enthusiasm for chemistry has always motivated me. I also admire him for his wit and humor in daily life. He also arranged for me to be involved in research at The Scripps Research Institute in America for four months, and provided a financial support for this experience. I had one of the most exciting times in my life there.

I would also like to thank Dr. Yoshiya Fukumoto and Dr. Mamoru Tobisu for their instructive and expert advice based on their extensive backgrounds in chemistry.

I thank the secretaries in our laboratory, including Ms. Mayuko Nakamura, Ms. Yoshimi Shinomiya, and Ms. Junko Ohmagari for their kind assistance.

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I would like to express my special gratitude to the Chatani group members, who were involved in research on the nickel-catalyzed functionalization of C-H bonds utilizing bidentate directing groups, Dr. Luis Carlos Misal Castro, Mr. Hirotaka Shiota, Ms. Miki Iyanaga, Ms. Ayana Yokota, Mr. Teruhiko Kubo and Mr. Atsushi Obata.

Professor Chatani also allowed me to spend a period of time doing research in the USA. Professor Phil Baran at The Scripps Research Institute in La Jolla, USA, accepted me in his group as an exchange graduate student from September to December 2014. During my stay in Baran’s group, he and Mr. Yi Yang See supported my stay and taught me experimental
techniques about total synthesis. I also acknowledge Ms. Patrece, who provided me with lodging, and all member of Baran’s Group, especially Dr. Yoshihiro Ishihara, Mr. Hai Dao, Dr. Quentin Michaudel, Dr. Chung-Mao Pan, Dr. Bart Roman, Dr. Yuki Yabe Mr. Daisuke Ogasawara and Dr. Syuhei Kawamura. They taught me many things about the culture, food, and life of Americans.

I am grateful for and wish to acknowledge a JSPS Research Fellowship for Young Scientists.

Finally, I would like to express my deepest gratitude to my parents, Mr. Yoshihisa Aihara and Ms. Masayo Aihara, my brother, Mr. Yuki Aihara, my sister, Ms. Saki Aihara and my fiancée, Ms. Sanae Kotani.

Suita, Osaka

January 2016

Yoshinori Aihara
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General Introduction

The transition metal-catalyzed functionalization of C-H bonds has emerged as a powerful tool for the synthesis of organic molecules in recent years. From the point of view of economy of steps and its environmentally friendly nature, the direct functionalization of C-H bonds has been developed as an alternative method for conventional cross coupling reactions. Palladium, rhodium, and ruthenium are mainly used for functionalization of C-H bonds. On the other hand, there are only limited examples of the direct functionalization of C-H bonds using low-cost and more abundant metals, such as iron, copper, and nickel, but this area of research has attracted recent attention.

Focusing on C-H bond activation using a nickel complex, a pioneering example of activation of benzene C-H bond by chelation-assistant was achieved by utilizing a stoichiometric amount of a nickel complex and azobenzene (eq 1). Remarkably, this cyclometalation was published earlier than cyclometalation with palladium complex (eq 2), although cyclopalladation has been widely used method for C-H bonds actication. Cyclometalation via the cleavage of C-H bonds using nickel has been undeveloped even when a stoichiometric amount of nickel is used. Zargarian and co-workers recently reported on cyclometalation via the cleavage of benzene C-H bonds using a stoichiometric amount of a nickel complex prepared from phenol (eq 3).

Most of the known nickel-catalyzed transformations of C-H bonds are limited to acidic C-H bonds, such as activated C(sp²)-H bonds in azole, perfluorobenzene derivatives and
activated pyridine derivatives (Figure 1), although the use of nickel in cyclometalation has been reported (eq 1 and 3). The transformation of non-activated benzene or aliphatic C-H bonds with a nickel-catalyst represent undeveloped and challenging topics, due to the low-reactivity of nickel complexes.

**Figure 1.** Scope and Limitation of C-H bonds with Ni-catalyst

Incidentally, one of the methods for the regioselective functionalization of C-H bonds, which are ubiquitous in organic molecules, is the use of directing groups. Murai and co-workers reported on a pioneering concept of the use of a directing group for activating C-H bonds in 1993, the reaction of acetophenone and vinylsilane in the presence of a Ru-catalyst gave the ortho-alkylation product via the formation of a metallacycle intermediate generated by the activation of aromatic C-H bonds (eq 4).

Directing groups, especially ketones or sp² nitrogen-containing compounds, such as pyridine coordinated to a metal, can be used to selectively activate C-H bonds, and, after activation, the reaction proceeds via a metallacycle intermediate (Figure 2a). The driving force for the activation of inert C-H bonds in a directing group system is the formation of a metallacycle intermediate. Various types of directing groups for C-H functionalizations have been developed, since the appearance of Murai’s significant work. The transformation of C-H bonds using nickel-catalyst has been limited, even if conventional directing groups are used. The low interaction between the nickel(II) complex and directing group and the low affinity between nickel(II) and C-H bonds make the activation of C-H bonds with a nickel-catalyst difficult (Figure 2a).
Figure 2. Working Hypothesis: Ni-Catalyzed Activation of C-H Bonds

(a) Conventional Directing Group

(b) Bidentate Directing Group

In this study, I hypothesized that the use of a strong coordinating directing group and more stabilized metallacycle would provide sufficient driving force to permit inert C-H bonds to be activated when a low reactive nickel-catalyst was used. On the basis of this hypothesis, many experiments that were intended to increase the reactivity of nickel were carried out. The combination of a nickel(II) complex and a bidentate directing group which has two coordinating atoms within the directing group has the potential to activate inert C-H bonds because the bidentate directing group can strongly coordinate to nickel(II) complexes and stabilize the metallacycle by coordinating two atoms within the bidentate directing group (Figure 2b). The successful pioneering example of the bidentate directing group assisted functionalization of C−H bonds was reported by Daugulis, who discovered the Pd(II)-catalyzed arylation of C–H bonds in aliphatic amides that contain a picolinamide and 8-aminoquinoline moiety (eq 5 and 6). 8 The transformation of C–H bonds using bidentate directing groups and a palladium catalyst has grown in popularity since this seminal discovery by Daugulis. 9 The use of a bidentate directing group in conjunction with another transition metal catalyst in the transformation of C-H bonds had not still been developed before I started this study, except for our example of the direct Ru-catalyzed functionalization of C-H bonds utilizing a 2-aminopyridylmethylamine moiety as a bidentate directing group. 9
Based on this working hypothesis, the activation of C-H bonds using a nickel(II)-catalyst and a bidentate directing group were examined. This thesis includes various types of transformations of C-H bonds utilizing a nickel(II)-catalyst and a bidentate directing group. This thesis is composed of the following three chapters.

Chapter 1 discusses the nickel(II)-catalyzed direct alkylation of C(sp²)-H bonds containing an 8-aminoquinoline moiety as a bidentate directing group with an alkyl halide.

Chapter 2 deals with the nickel(II)-catalyzed direct arylation of aliphatic amide possessing a bidentate directing group with an aryl halide via cleavage of a C(sp³)-H bond.

Chapter 3 is concerned with the nickel(II)-catalyzed oxidative coupling of C(sp²)-H bond in benzanides and benzylic C-H bond in toluene derivatives using hetafluorosopropyl iodide as a mild oxidant. This reaction involves the catalytic cleavage of two different C-H bonds, C(sp²)-H and benzylic C-H bonds.

Finally, the findings are summarized in the conclusion section of the thesis.

References
(d) Daugulis, O.; Roane, J.; Tran, L. D. Acc. Chem. Res. 2015, 48, 1053.
Chapter 1

Nickel(II)-Catalyzed Direct Alkylation of C-H Bonds in Aromatic Amides Containing an 8-Aminoquinoline Moiety as the Directing Group

1.1 Introduction

Transition metal-catalyzed direct arylation of C-H bonds with aryl halides or aryl metal reagents has been developed and emerged as a powerful method for the construction of organic molecules. Compared to these arylation reactions, examples of the direct alkylation of C-H bonds with alkyl halide remain limited, because of the unfavorable of alkyl halides toward oxidative addition and the fact that the resulting alkyl metal complexes are susceptible to $\beta$-hydride elimination.\(^1\) Conventional approaches to the synthesis of alkylated arenes rely on Friedel-Crafts type reactions or S$_E$Ar type reactions, both of which have some limitations including i) only electron rich arenes were applicable ii) a low functional group tolerance, ii) low regioselectivities, and iii) a mixture of normal and branched products are often produced.\(^2\) Numerous efforts have been made to address these limitations, and transition metal-catalyzed direct alkylation with alkyl halides has emerged as an alternative method for the synthesis alkylated arenes. Due to those efforts, direct alkylation using alkyl halides as the alkylation reagent with Pd,\(^3\) Ru,\(^4\) Fe,\(^5\) and Co\(^6\) catalysts have been developed over the past few years, while a direct alkylation with nickel-catalyst has been undeveloped.

Our group has focused on the use of 2-aminopyridylmethylamine as a bidentate directing groups in a catalytic functionalization of C-H bonds, such as the Ru-catalyzed carbonylation of aliphatic C-H bond utilizing 2-aminopyridylmethylamine (eq 1),\(^7a\) and the Ru-catalyzed direct arylation of aromatic amides with aryl halides by taking advantage of 2-aminopyridylmethylamine and 8-aminoquinoline (eq 2).\(^7b\)
Chapter 1 describes the Ni(II)-catalyzed direct alkylation of aromatic amides with alkyl halides by taking advantage of N,N-bidentate directing chelation system. This reaction represents the first example of Ni-catalyzed direct alkylation of aromatic C-H bonds.

1.2. Results and Discussion

Motivated by previous our results and working hypothesis described in general introduction, various type of directing groups and additives were examined to find the new method for transformation of C-H bond with Ni(II)-catalyst. The arylation with aryl halide was examined as a preliminary experiment. The reaction of aromatic amide 1a containing an 8-aminoquinoline moiety and iodobenzene in the presence of Ni(OTf)$_2$ and sodium bicarbonate furnished direct ortho-arylation product 2a in excellent yield (Scheme 1). This result represented that the cleavage of non-activated aromatic C-H bonds with low reactive nickel-catalyst was achieved. Screening of directing groups were examined. The reaction with amide without quinoline nitrogen, N-methylated amide and corresponding ester were resulted in no reaction (Scheme 1). These results indicated that both of NH and quinolone nitrogen atoms are necessary for the transformation of C-H bond.

To expand the utility of the present chelation system, we examined the alkylation reaction using alkyl halides. When the amide 1a was reacted with butyl bromide under the arylation condition, the alkylation did not proceed (entry 1 in Table 1). However, the addition of PPh$_3$ increased the alkylation product 3a yield to 41% NMR yield, along with 54% of unreacted 1a being recovered (entry 2). The yield was strongly depended on the choice of the base, and the sodium carbonate was chosen as a best base (entry 3). The use of PCy$_3$ decreased 3a in 26% NMR yield (entry 6). The use of 2 equivalents of butyl bromide improved the yield of 3a in 88% isolated yield (entry 7).

Scheme 1. The Ni-Catalyzed Direct Arylation with Iodide Benzene$^a$

\[
\begin{align*}
\text{Ph} & \quad \text{Ni(OTf)$_2$ 5 mol\%} \\
& \quad \text{NaHCO$_3$ 2 equiv} \\
& \quad \text{toluene 1 mL} \\
& \quad 160 ^\circ C, 20 h
\end{align*}
\]

ineffective directing groups

$^a$Isolated yields.
Table 1. The Nickel-Catalyzed Butylation of 1a with Butyl Bromide

<table>
<thead>
<tr>
<th>entry</th>
<th>ligand</th>
<th>base</th>
<th>yields (3a/1a)(^a)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>none</td>
<td>NaHCO(_3)</td>
<td>0% / 101%</td>
</tr>
<tr>
<td>2</td>
<td>PPh(_3)</td>
<td>NaHCO(_3)</td>
<td>41% / 54%</td>
</tr>
<tr>
<td>3</td>
<td>PPh(_3)</td>
<td>Na(_2)CO(_3)</td>
<td>79% / 15%</td>
</tr>
<tr>
<td>4</td>
<td>PPh(_3)</td>
<td>Li(_2)CO(_3)</td>
<td>3% / 109%</td>
</tr>
<tr>
<td>5</td>
<td>PPh(_3)</td>
<td>K(_2)CO(_3)</td>
<td>0% / 90%</td>
</tr>
<tr>
<td>6</td>
<td>PCy(_3)</td>
<td>Na(_2)CO(_3)</td>
<td>26% / 63%</td>
</tr>
<tr>
<td>7(^b)</td>
<td>PPh(_3)</td>
<td>Na(_2)CO(_3)</td>
<td>91% (88%) / 0%</td>
</tr>
</tbody>
</table>

\(^a\) NMR yields. The number in parenthesis is the isolated yield of 2a. \(^b\) BuBr (0.6 mmol) was used.

With the optimized reaction conditions in hand, we examined the scope of the substrate. Table 2 shows the results for reactions of various aromatic amides with butyl bromide under the standard reaction conditions. A variety of functional groups were found to be tolerated and, even the iodide was survived, as in 3h. The reaction of meta-substituted substrates resulted in selective alkylation at the less hindered C-H bonds, irrespective of the electronic nature of the substituent. In general, electron-withdrawing groups tended to give butylation products in higher yields. The addition of NaI was found to improve the product yields in the reaction with electron donating substituents, as in 3b and 3c. The C-H bonds in heterocyclic compounds could be alkylated, as in 8, 9 and 10. This C-H bond alkylation reaction was applicable to \(\alpha,\beta\)-unsaturated amides. The cyclic amides, 11, 12, and 13 gave the butylation products in good yields.

Various of alkyl halides, such as benzyl, allyl and methyl halide, were also applicable to this reaction (Table 3). Octyl iodide and octyl bromide gave the octylation product 24 in high yield. While no reaction took place in the case of octyl chloride, the addition of sodium iodide (2 equivalents) dramatically improved the product 24 yield to 88% isolated yield, generating the alkyl iodide in situ. This effect of sodium iodide was also observed in the reaction with sterically demanding alkyl bromides or some functionalized alkyl bromides. The use of 2-methylpropyl bromide and cyclopentylmethyl bromide without addition of sodium iodide resulted in almost no reaction, but the yields of 19 and 20 were dramatically improved to 44% and 45% yields when sodium iodide was added. While the reaction with methyl iodide gave the methylation product 29 and N-methylated product, the combination of methyl tosylate and sodium iodide gave the only methylation product 29 in excellent yields. The reaction of a cyclopentyl bromide under optimized reaction conditions gave only a trace amount of the
alkylation product 30. After screening of the reaction conditions, using IMes\textsuperscript{Me} and PPh\textsubscript{3} as the ligand improved the product 30 yield to 51\%.

**Table 2.** The Ni-Catalyzed Butylation of C(sp\textsuperscript{2})-H Bonds\textsuperscript{a}

<table>
<thead>
<tr>
<th>R</th>
<th>Product</th>
<th>Yield (%)</th>
<th>Additional Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMe</td>
<td>3b</td>
<td>74% (89%)</td>
<td>NaI (0.6 mmol)</td>
</tr>
<tr>
<td>OCH\textsubscript{2}Ph</td>
<td>3c</td>
<td>72% (85%)</td>
<td>Run at 160 °C</td>
</tr>
<tr>
<td>OSiMe\textsubscript{2}Bu</td>
<td>3d</td>
<td>75%</td>
<td>BuI (0.6 mmol)</td>
</tr>
<tr>
<td>Me</td>
<td>3e</td>
<td>92%</td>
<td>BuBr (1.2 mmol)</td>
</tr>
<tr>
<td>Ph</td>
<td>3f</td>
<td>81%</td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>3g</td>
<td>92%\textsuperscript{a}</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>3h</td>
<td>68%\textsuperscript{a}</td>
<td></td>
</tr>
<tr>
<td>C(O)CH\textsubscript{3}</td>
<td>3i</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>CF\textsubscript{3}</td>
<td>3j</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>88%\textsuperscript{c, e}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>52%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>92%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>71%\textsuperscript{c}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>76%\textsuperscript{c, e}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>81%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>72%</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a} Reaction conditions: amide (0.3 mmol), BuBr (0.6 mmol), Ni(OTf)\textsubscript{2} (0.03 mmol), PPh\textsubscript{3} (0.06 mmol), Na\textsubscript{2}CO\textsubscript{3} (0.6 mmol) in toluene (1 mL) at 140 °C for 24 h. \textsuperscript{b} NaI (0.6 mmol) was used as an additive. \textsuperscript{c} Run at 160 °C. \textsuperscript{d} BuI (0.6 mmol) was used instead of BuBr. \textsuperscript{e} BuBr (1.2 mmol) was used.
Table 3. The Ni-Catalyzed Alkylation of C-H Bonds in Aromatic Amides

![Chemical structure](image)

| Reaction conditions: amide (0.3 mmol), Alkyl halide (0.6 mmol), Ni(OTf)₂ (0.03 mmol), PPh₃ (0.06 mmol), Na₂CO₃ (0.6 mmol) in toluene (1 mL) at 140 °C for 24 h. NaI (0.6 mmol) was used as an additive. IMesMe⁺HCl (0.06 mmol) and NaO'Bu (0.07 mmol) was added as a ligand.

Several mechanistic studies were carried out to gain mechanistic information. We anticipated that under the reaction conditions, the alkylation takes place via the addition of the C–H bond with the alkene, which may generate from an alkyl halide via dehydrobromination. However, when 1a was reacted with octane resulted in no reaction (eq 3). A quaternary phosphonium bromide is also another candidate for alkylating reagent. However, the corresponding butylation product 3a was obtained in only 5% yield (eq 4). These results indicate that the alkyl halide itself functions as a coupling partner.
The deuterated amide 1a-d7 was reacted with BuBr for 8 h under the standard reaction condition (Scheme 2). A significant amount of H/D exchange at the ortho C-D bond (the d-content decreased from >98% to 51% (49%H)) and N-H on the amide nitrogen in the recovered amide was observed. A significant amount of H/D exchange occurred, even in the absence of BuBr, indicating that the cleavage of C-H bonds occurs before the reaction with an alkyl halide. It was also found that the presence of PPh₃ had no effect on the H/D exchange reaction. These results indicate that the cleavage of C-H bonds is reversible and rapid step and not likely the rate determining step in the reaction.

Scheme 2. Deuterium labeling experiments

We next performed a competition experiment using a 1:1 mixture of 31a and 32a in a reaction with octyl bromide (Scheme 3). The findings indicate that 32a reacted to give 32b as the major product. This result indicates that the presence of an electronic withdrawing group on aromatic amides facilitates the reaction.
Scheme 3. Competition experiment

To confirm the alkyl radical species, which were generated single electron transfer from nickel complex to alkyl halides were involved this reaction. The addition of radical scavengers were examined. The reaction in the presence of radical scavengers, such as TEMPO (2 equivalents) and GALVINOXYL (2 equivalents), resulted in no reaction. The radical clock experiments were carried out to gain more information. The use of 6-bromohex-1-ene gave the mixture of products, and the unrearranged alkylation product 33 was the major product (Scheme 4). We next used cyclopropylmethyl bromide, since the cyclopropylmethyl radical is known to undergo ring-opening faster than the cyclization of the 5-hexenyl radical. The reaction with cyclopropylmethyl bromide gave a mixture of the unrearranged product 35 and the rearranged product 36 in a total isolated yield of 81% in favor of the unrearranged product (Scheme 4).
Scheme 4. Radical clock experiments

We next examined the effect of catalyst concentration on the ratio of products in the reaction of 1a with 6-bromohex-1-ene. If a radical chain mechanism were operative, then the 33/34 ratio would increase at higher catalyst concentrations because the radical would have less time to rearrange before reacting with another nickel. In contrast, if a radical chain were not involved, the 33/34 ratio would be expected to be unchanged as a function of catalyst concentration. The ratio was found to be constant, irrespective of the catalyst concentration used (Scheme 5), suggesting that the radical chain mechanism is not operative. These results shown in Scheme 4 and 5 suggest that free radical species are not involved in the reaction. The possibility that the key intermediate has a radical character, but that a radical species is not free, but instead remains in the coordination sphere in a nickel center and rearrangement from alkyl nickel complex cannot be excluded.
Scheme 5. Dependence of the ratio of 33 and 34 on the concentration of nickel

<table>
<thead>
<tr>
<th>X mol%</th>
<th>33</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mol%</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>10 mol%</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>15 mol%</td>
<td>19</td>
<td>1</td>
</tr>
</tbody>
</table>

The ratio of product was determined by $^1$H-NMR.

Scheme 6. Proposed reaction mechanism

The alkylation of C-H bonds proceeds through a mechanism as shown in Scheme 6. Amide A coordinates to NiX$_2$ followed by a ligand exchange, which is accelerated by sodium carbonate, to give the nickel complex B. Complex B then undergoes a reversible cyclometalation to give complex C via a concerted metalation deprotonation (CMD) mechanism, which is also accelerated by sodium carbonate. The oxidative addition of an alkyl halide to the complex C gives the nickel(IV) species D. Complex D undergoes a reductive
elimination to give E, which is then protonated to afford the alkylation product with the regeneration of the nickel(II) catalyst.

1.3 Conclusion
In summary, we have reported the development of a new catalytic system that takes advantage of chelation assistance by an 8-aminoquinoline moiety. This represents the first example of Ni(II)-catalyzed direct ortho-alkylation of benzamides and acrylamide derivatives with unactivated alkyl halides. Various groups, such as alkyl, allyl, benzyl, and methyl groups can be introduced at the ortho position. A variety of functional groups are tolerated in the reaction. The proposed mechanism involves a Ni(II)/Ni(IV) catalytic cycle, which is rare in nickel-catalyzed cross coupling reaction. The key intermediate appears to have a radical character, but the reaction probably does not proceed via a radical chain mechanism.

After this paper appeared, another groups have reported the Ni(II)-catalyzed direct alkylation with alkyl halides, such as the direct alkylation of C(sp³)-H bonds, alklylation with secondary alkyl halides, allyl halides and phosphates as alkylating reagents by utilizing the nickel(II)-catalyst and 8-aminoquinoline system.

1.4 Experimental Section

General Information.
¹H NMR and ¹³C NMR spectra were recorded on a JEOL ECS–400 spectrometer in CDCl₃ with tetramethylsilane as the internal standard. The data is reported as follows: chemical shift (δ) in ppm, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, br = broad peak, and m = multiplet), coupling constant (Hz), and integration. Infrared spectra (IR) were obtained using a Horiba FT–700 spectrometer. Absorption is reported in reciprocal centimeters (cm⁻¹) with the following relative intensities: s (strong), m (medium), or w (weak). Mass spectra were obtained on a Shimadzu GCMS–QP 2010 instrument. High resolution mass spectra (HRMS) were obtained using a JEOL JMS–DX303 spectrometer. Melting points were determined using a Yamato melting point apparatus. Column chromatography was performed with SiO₂ (Silicycle SilicaFlash F60 (230-400 mesh)). Some compounds were purified by LC–908 HPLC (GPC).

Materials.
Na₂CO₃ (CAS 497-19-8) was purchased from Nacalai Tesque, Inc. Iodobenzene (CAS 591-50-4), 1-bromobutane (CAS 109-65-9) and 8-Aminoquinoline (CAS 578-66-5), were purchased from Tokyo Kasei Kogyo Co., Ltd. PPh₃ (CAS 603-35-01) and toluene super dehydrated (CAS 68-12-2) was purchased from Wako Pure Chemicals.

Synthesis of Nickel(II) Trifluoromethanesulfonate.
To a clear green solution of Ni(OAc)\(_2\) (0.519 g, 2.95 mmol) in MeCN (40 mL) trifluoromethanesulfonic acid (1.33 g, 8.84 mmol) was added dropwise; the color changed the blue. The mixture was evaporated under reduced pressure until 10 mL, diethyl ether (80 mL) was added, this resulted in precipitation of blue powder. The suspension was decanted, and the residual powder washed diethyl ether and hexane, and dried in vacuum at 70 °C; the color changed light green powder. Ni(OTf)\(_2\) was obtained in 72% (0.754 g). HRMS Calcd for C\(_2\)F\(_6\)O\(_6\)S\(_2\)Ni: 355.8394; Found: 355.8401.

**Synthesis of the Starting Amides.**

All amides containing an 8-aminoquinoline were prepared by the reaction of the corresponding acid chlorides and 8-aminoquinoline. All starting amides were synthesize following general procedure. All spectrum data of starting amides are cited in original paper.\(^{15}\)

**General Procedure for the Preparation of Starting Amide.**

\[
\text{Cl} \quad \text{COOH} \quad \xrightarrow{(\text{COCl})_2, \text{DMF}} \quad \text{NH}_2 \\
\text{DCM, rt} \quad \text{NH} \\
\text{Et}_3 \text{N} \quad \xrightarrow{\text{DCM, rt}} \quad \text{Cl} \quad \text{N} \\
\text{Cl} \quad \text{N} \\
\text{Cl} \quad \text{N} \\
\text{Cl} \quad \text{N}
\]

To an oven-dried 100 mL three-necked flask, 3-bromobenzoic acid (2.3 g, 15 mmol), DMF (5 drops) and DCM (30 mL) were added under a N\(_2\) atmosphere. Oxalyl chloride (1.5 mL, 18 mmol, 1.2 equiv.) was added dropwise at 0 °C resulting in vigorous bubbling. The mixture was stirred for 3 h at room temperature, and the solvent was then removed \textit{in vacuo}. The resulting acid chloride was used immediately without further purification.

To another oven-dried 100 mL three-necked flask, 8-aminoquinoline (2.9 g, 20 mmol, 1.3 equiv.), Et\(_3\)N (4.1 mL, 30 mmol, 2 equiv.) and DCM (30 mL) were added. A solution of the acid chloride in DCM (10 mL) was added dropwise to the solution at 0 °C, and the solution was then warmed to room temperature. After stirring overnight, the reaction system was quenched with sat. aq. NaHCO\(_3\) (30 mL) and the organic layer was separated. The aqueous layer was extracted with DCM (2 x 15 mL). The combined organic layers were washed with 1 M HCl aq. (30 mL) and brine (30 mL), dried over MgSO\(_4\), filtered and evaporated \textit{in vacuo}. The resulting crude amide was purified by column chromatography on silica gel (eluant: hexane/EtOAc = 5/1) to afford the desired amide.

**General Procedure for Direct Arylation: Ni-Catalyzed Reaction of Amide 1a with PhI.**

To an oven-dried 5 mL screw-capped vial, in a glove box 2-methyl-N-(8-quinolinyl)benzamide 1a (79 mg, 0.3 mmol), iodobenzene (122 mg, 0.6 mmol), Ni(OTf)\(_2\) (5 mg, 0.015 mmol), NaHCO\(_3\) (50 mg, 0.6 mmol) and toluene (1 mL) were added. The mixture was stirred for 20 h at 160 °C followed by cooling. The mixture was
filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluent: hexane/EtOAc = 10/1) to afford the desired arylated product 2a (97 mg, 94%) as a colorless oil.

**General Procedure for Direct Alkylation: Ni-Catalyzed Alkylation of Amides 1a with BuBr**

To an oven-dried 5 mL screw-capped vial, in a glove box 2-methyl-N-(8-quinolinyl)benzamide 1a (79 mg, 0.3 mmol), 1-bromobutane (82 mg, 0.6 mmol), Ni(OTf)$_2$ (10.6 mg, 0.03 mmol), PPh$_3$ (15.6 mg, 0.06 mmol), Na$_2$CO$_3$ (64 mg, 0.6 mmol) and toluene (1 mL) were added. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluent: hexane/EtOAc = 20/1) to afford the desired alkylated product 3a (84 mg, 88%) as a colorless oil.

**3-Methyl-N-(quinolin-8-yl)-[1,1'-biphenyl]-2-carboxamide (2a) [CAS 1436849-34-1].**

![Structural formula of 3-Methyl-N-(quinolin-8-yl)-[1,1'-biphenyl]-2-carboxamide (2a)](image)

Rf 0.23 (hexane/EtOAc = 5/1). Colorless oil. $^1$H NMR (CDCl$_3$, 400 MHz) δ 2.53 (s, 3H), 7.08 (t, J = 8.0 Hz, 1H), 7.19-7.24 (m, 2H), 7.28-7.33 (m, 3H), 7.38-7.54 (m, 5H), 8.04 (d, J = 8.4 Hz, 1H), 8.59 (d, J = 4.0 Hz, 1H), 9.64 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.94, 116.54, 121.57, 121.79, 127.34, 127.37, 127.74, 127.86, 128.29, 128.75, 129.32, 129.61, 134.48, 135.94, 136.18, 136.96, 138.45, 139.77, 140.48, 148.08, 168.41;

**2-Butyl-6-methyl-N-(quinolin-8-yl)benzamide (3a).**

![Structural formula of 2-Butyl-6-methyl-N-(quinolin-8-yl)benzamide (3a)](image)

Rf 0.43 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 0.80 (t, J = 7.6 Hz, 3H), 1.25-1.34 (m, 2H), 1.64-1.70 (m, 2H), 2.43 (s, 3H), 2.71 (t, J = 8.0 Hz, 2H), 7.13 (dd, J = 12, 4.0 Hz, 2H), 7.28 (t, J = 7.6 Hz, 1H), 7.45 (dd, J = 8.0, 4.0 Hz, 1H), 7.56-7.64 (m, 2H), 8.19 (dd, J = 8.0, 1.6 Hz, 1H), 8.74 (dd, J = 4.0, 1.6 Hz, 1H), 8.99 (dd, J = 7.2, 1.6 Hz, 1H), 9.94 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 13.92, 20.94, 22.62, 32.66, 33.98, 116.65, 121.67, 121.69, 127.48, 128.00, 130.26, 134.78, 135.52, 136.42, 138.16, 138.51, 148.15, 168.69; IR (neat) 3347 w, 2954 w, 2864 w, 1675 m, 1518 s, 1481 s, 1423 m, 1384 m, 1325 m, 1262 m, 1126 w, 897 w, 826 m; MS m/z (relative intensity, %) 318 (M$^+$, 35), 176
(12), 175 (100), 174 (32), 146 (11), 145 (38), 144 (12), 105 (26); HRMS Calcd for C_{23}H_{18}N_{2}O: 318.1732; Found: 318.1733.

2-Butyl-5-methoxy-N-(quinolin-8-yl)benzamide (3b).

![Chemical Structure](image)

Rf 0.31 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.85 (t, J = 7.2 Hz, 3H), 1.28-1.38 (m, 2H), 1.61-1.69 (m, 2H), 2.84 (t, J = 8.0 Hz, 2H), 3.84 (s, 3H), 6.97 (dd, J = 8.0, 2.8 Hz, 1H), 7.17 (d, J = 2.8 Hz, 1H), 7.24 (d, J = 8.0 Hz, 1H), 7.45 (dd, J = 8.0, 4.0 Hz, 1H), 7.54-7.62 (m, 2H), 8.17 (dd, J = 8.0, 1.6 Hz, 1H), 8.77 (dd, J = 4.0, 1.2 Hz, 1H), 8.94 (d, J = 7.2 Hz, 1H), 10.15 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.90, 22.55, 32.24, 34.07, 55.45, 112.51, 115.98, 116.64, 121.64, 127.40, 127.96, 131.41, 133.08, 134.67, 136.32, 137.45, 138.52, 148.20, 157.51, 168.21; IR (neat) 3349 w, 2954 w, 2858 w, 1675 m, 1607 w; MS m/z (relative intensity, %) 335 (11), 334 (M$^+$, 45), 191 (25), 190 (37), 162 (17), 161 (100), 149 (22), 144 (19), 121 (27); HRMS Calcd for C$_{21}$H$_{22}$N$_{2}$O$_{2}$: 334.1681; Found: 334.1682.

5-(Benzyloxy)-2-butyl-N-(quinolin-8-yl)benzamide (3c).

![Chemical Structure](image)

Rf 0.23 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.85 (t, J = 7.2 Hz, 3H), 1.28-1.38 (m, 2H), 1.61-1.69 (m, 2H), 2.84 (t, J = 7.6 Hz, 2H), 5.09 (s, 2H), 7.04 (dd, J = 8.8, 2.8 Hz, 1H), 7.23-7.27 (m, 2H), 7.30-7.53 (m, 6H), 8.16 (dd, J = 8.0, 1.6 Hz, 8.76 (dd, J = 4.0, 1.6 Hz, 1H), 8.94 (d, J = 7.2 Hz, 1H), 10.15 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.91, 22.56, 32.25, 34.04, 70.20, 113.51, 116.53, 116.77, 121.63, 121.77, 127.37, 127.54, 128.02, 128.59, 131.46, 133.47, 136.29, 136.70, 137.45, 138.52, 148.21, 156.72, 168.10; IR (neat) 3348 w, 2954 w, 2860 w, 1674 m, 1604 w, 1574 w, 1520 s, 1481 s, 1423 m, 1383 m, 1352 m, 1325 m, 1285 m, 1024 w, 825 m; MS m/z (relative intensity, %) 410 (M$^+$, 20), 319 (17), 267 (10), 266 (14), 237 (19), 144 (10), 91 (100); HRMS Calcd for C$_{27}$H$_{26}$N$_{2}$O$_{2}$: 410.1994; Found: 410.1994.

2-Butyl-5-((tert-butyldimethylsilyl)oxy)-N-(quinolin-8-yl)benzamide (3d).
Rf 0.54 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.25 (s, 6H), 0.86 (t, $J = 7.2$ Hz, 3H), 1.01 (s, 9H), 1.29-1.38 (m, 2H), 1.61-1.69 (m, 2H), 2.84 (t, $J = 8.0$ Hz, 2H), 6.90 (dd, $J = 8.0$, 2.8 Hz, 1H), 7.13 (d, $J = 2.8$ Hz, 1H), 7.18 (d, $J = 8.0$ Hz, 1H), 7.44 (dd, $J = 8.0$, 4.0 Hz, 1H), 7.53-7.61 (m, 2H), 2.84 (t, $J = 8.0$ Hz, 2H), 6.90 (dd, $J = 8.0$, 2.8 Hz, 1H), 7.13 (d, $J = 2.8$ Hz, 1H), 7.18 (d, $J = 8.0$ Hz, 1H), 7.44 (dd, $J = 8.0$, 4.0 Hz, 1H), 7.53-7.61 (m, 2H), 8.16 (dd, $J = 8.0$, 1.6 Hz, 1H), 8.77 (dd, $J = 4.0$, 1.6 Hz, 1H), 8.93 (d, $J = 6.4$ Hz, 1H), 10.17 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 4.44, 13.93, 18.17, 22.59, 25.66, 32.28, 34.03, 116.44, 118.70, 121.63, 121.68, 121.95, 127.94, 131.44, 134.02, 134.72, 136.28, 137.32, 138.55, 148.18, 153.49, 168.06; IR (neat) 3350 w, 2954 w, 2858 w, 1678 m, 1603 w, 1522 s, 1482 s, 1424 m, 1385 m, 1326 m, 1290 m, 973 m, 889 m, 837 s; MS m/z (relative intensity, %) 435 (21), 434 (M$^+$, 63), 292 (13), 291 (52), 262 (26), 261 (100), 249 (11), 234 (11), 233 (32), 215 (42), 205 (17), 174 (20), 171 (10), 165 (19), 163 (20), 144 (22), 73 (66); HRMS Calcd for C$_{23}$H$_{18}$N$_2$O: 434.2390; Found: 434.2388.

2-Butyl-5-methyl-N-(quinolin-8-yl)benzamide (3e).

Rf 0.40 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.85 (t, $J = 7.6$ Hz, 3H), 1.29-1.38 (m, 2H), 1.62-1.70 (m, 2H), 2.39 (s, 3H), 2.87 (t, $J = 7.6$ Hz, 2H), 7.20-7.25 (m, 2H), 7.44-7.47 (m, 2H), 7.54-7.62 (m, 2H), 8.18 (dd, $J = 7.6$, 1.6 Hz, 1H), 8.78 (dd, $J = 4.0$, 1.6 Hz, 1H), 8.95 (d, $J = 7.6$ Hz, 1H), 10.13 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.92, 20.94, 22.62, 32.67, 33.98, 116.65, 121.61, 121.69, 127.48, 127.83, 128.00, 130.26, 130.88, 134.78, 135.52, 136.42, 136.58, 138.16, 138.51, 148.15, 168.69; IR (neat) 3351 w, 2955 w, 2860 w, 1673 m, 1596 w, 1518 s, 1481 s, 1423 m, 1383 m, 1325 m, 1262 w, 824 m; MS m/z (relative intensity, %) 319 (13), 318 (M$^+$, 54), 175 (45), 174 (22), 146 (17), 145 (100), 144 (26), 133 (13), 105 (33); HRMS Calcd for C$_{21}$H$_{22}$N$_2$O: 318.1732; Found: 318.1734.

4-Butyl-N-(quinolin-8-yl)-[1,1'-biphenyl]-3-carboxamide (3f).
Rf 0.40 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.88 (t, J = 7.2 Hz, 3H), 1.34-1.43 (m, 2H), 1.69-1.76 (m, 2H), 2.94 (t, J = 7.6 Hz, 2H), 7.34-7.47 (m, 4H), 7.55-7.68 (m, 5H), 7.85 (d, J = 2.0 Hz, 1H), 8.17 (dd, J = 8.0, 1.6 Hz, 1H), 8.75 (dd, J = 4.0, 1.6 Hz, 1H), 8.98 (d, J = 7.2 Hz, 1H), 10.21 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.93, 22.66, 32.76, 33.87, 116.58, 121.17, 121.81, 125.86, 127.00, 127.40, 127.95, 128.70, 128.84, 130.08, 134.69, 136.31, 137.19, 138.53, 138.89, 140.21, 140.29, 148.25, 168.41; IR (neat) 3348 w, 2955 w, 2860 w, 1674 m, 1519 s, 1481 s, 1423 m, 1384 m, 1326 m, 1244 w, 825 m; MS m/z (relative intensity, %) 381 (16), 380 (M$^+$, 54), 237 (40), 236 (32), 208 (24), 207 (100), 165 (12), 178 (12), 167 (33), 166 (11), 165 (21), 152 (10), 144 (18); HRMS Calcd for C$_{26}$H$_{24}$N$_2$O: 380.1889; Found: 380.1890.

2-Butyl-5-chloro-N-(quinolin-8-yl)benzamide (3g).

Rf 0.37 (hexane/EtOAc = 5/1). White Solid. Mp = 79-80 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.86 (t, J = 7.6 Hz, 3H), 1.29-1.38 (m, 2H), 1.61-1.69 (m, 2H), 2.86 (t, J = 7.6 Hz, 1H), 7.27 (d, J = 8.0 Hz, 1H), 7.38 (dd, J = 8.0, 2.4 Hz, 1H), 7.47 (dd, J = 8.0, 4.4 Hz, 1H), 7.56-7.63 (m, 2H), 8.19 (dd, J = 8.0, 1.6 Hz, 1H), 8.79 (dd, J = 4.4, 1.6 Hz, 1H), 8.91 (dd, J = 7.6, 1.6 Hz, 1H), 10.13 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.87, 22.54, 32.51, 33.74, 116.72, 121.74, 122.07, 127.19, 127.37, 127.95, 130.14, 131.54, 131.75, 134.38, 136.42, 138.04, 138.43, 139.77, 148.31, 166.92; IR (neat) 3343 w, 2956 w, 2867 w, 1677 m, 1519 s, 1481 s, 1423 m, 1384 m, 1326 m, 1244 w, 825 m; MS m/z (relative intensity, %) 338 (17), 339 (12), 338 (M$^+$, 49), 311 (11), 309 (32), 195 (13), 167 (32), 166 (12), 165 (100), 153 (13), 144 (66), 142 (11), 130 (11), 125 (28), 116 (11), 89 (12); HRMS Calcd for C$_{20}$H$_{19}$ClN$_2$: 338.1186; Found: 338.1186.

2-Butyl-5-iodo-N-(quinolin-8-yl)benzamide (3h).

Rf 0.37 (hexane/EtOAc = 5/1). White Solid. Mp = 101 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.85 (t, J = 7.6 Hz, 3H), 1.28-1.38 (m, 2H), 1.61-1.69 (m, 2H), 2.83 (t, J = 7.6 Hz, 2H), 7.08 (d, J = 8.0 Hz, 1H), 7.47 (dd, J = 8.0, 4.0 Hz, 1H), 7.56-7.62 (m, 2H), 7.72 (dd, J = 8.0, 1.6 Hz, 1H), 7.93 (d, J = 1.2 Hz, 1H), 8.19 (dd, J = 8.0, 1.6 Hz, 1H), 8.79 (dd, J = 4.0, 1.6 Hz, 1H), 8.90 (dd, J = 7.6, 1.6 Hz, 1H), 10.10 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.86, 22.53, 32.66, 33.62, 90.43, 116.71, 121.73, 122.06, 127.35, 127.93, 132.21, 134.35, 135.75,
136.39, 138.40, 138.76, 140.82, 148.30, 166.62; IR (neat) 3342 w, 2955 w, 2865 w, 1675 m, 1521 s, 1483 s, 1423 m, 1384 m, 1326 m, 1259 m, 905 w, 825 m; MS m/z (relative intensity, %) 431 (17), 430 (M+, 78), 401 (29), 287 (17), 286 (13), 258 (12), 257 (100), 245 (10), 217 (13), 194 (11), 145 (11), 144 (63), 142 (15), 130 (15), 117 (14), 116 (22), 115 (10), 102 (10), 90 (18), 89 (14); HRMS Calcd for C20H19IN2O: 430.0542; Found: 430.0539.

5-Acetyl-2-butyl-N-(quinolin-8-yl)benzamide (3i).

Rf 0.11 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 88-90 °C. 1H NMR (CDCl3, 399.78 MHz) δ 0.87 (t, J = 7.6 Hz, 3H), 1.32-1.41 (m, 2H), 1.66-1.74 (m, 2H), 2.64 (s, 3H), 2.96 (t, J = 7.6 Hz, 2H), 7.43-7.48 (m, 2H), 7.57-7.64 (m, 2H), 8.01 (dd, J = 8.0, 1.6 Hz, 1H), 8.19 (dd, J = 8.0, 1.6 Hz, 1H), 8.23 (d, J = 2.0 Hz, 1H), 8.78 (dd, J = 4.0, 1.6 Hz, 1H), 8.93 (dd, J = 7.6, 1.6 Hz, 1H), 10.19 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) δ 13.83, 22.60, 26.60, 33.22, 33.52, 116.69, 121.73, 122.08, 127.33, 127.94, 129.76, 130.66, 134.39, 134.92, 136.37, 137.01, 138.44, 146.91, 148.31, 167.46, 197.10; IR (neat) 3346 w, 2956 w, 2867 w, 1677 s, 1600 w, 1521 s, 1482 m, 1424 m, 1385 w, 1326 m, 1226 m, 826 m; MS m/z (relative intensity, %) 347 (15), 346 (M+, 62), 317 (23), 203 (21), 174 (15), 173 (100), 145 (10), 144 (42); HRMS Calcd for C22H22N2O2: 346.1684; Found: 346.1684.

2-Butyl-N-(quinolin-8-yl)-5-(trifluoromethyl)benzamide (3j).

Rf 0.40 (hexane/EtOAc = 5/1). White Solid. Mp = 94-95 °C. 1H NMR (CDCl3, 399.78 MHz) 0.87 (t, J = 7.2 Hz, 3H), 1.29-1.40 (m, 2H), 1.68-1.74 (m, 2H), 2.95 (t, J = 7.6 Hz, 2H), 7.45-7.549 (m, 2H), 7.58-7.88 (m, 3H), 7.88 (s, 1H), 8.20 (dd, J = 8.0, 2.0 Hz, 1H), 8.79 (dd, J = 4.0, 1.6 Hz, 1H), 8.92 (dd, J = 7.2, 1.6 Hz, 1H), 10.17 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) δ 13.82, 22.59, 29.69, 33.01, 33.59, 116.86, 121.77, 122.21, 124.66 (d, J = 3.9 Hz), 123.89 (q, J = 271 Hz), 126.74 (d, J = 2.8 Hz), 127.38, 127.99, 128.68 (q, 33.4 Hz), 130.83, 134.31, 145.35, 148.37, 166.98; IR (neat) 3343 w, 2958 w, 2870 w, 1678 m, 1523 s, 1484 m, 1424 w, 1386 w, 1327 s, 1215 w, 1169 m, 1123 s, 1079 m, 826 m; MS m/z (relative intensity, %) 373 (14), 372 (M+, 64), 344 (11), 343 (54), 200 (16), 199 (94), 171 (12), 159 (22), 145 (14), 144 (100); HRMS Calcd for C21H10F3N2O: 372.1449; Found: 372.1452.

2,6-Dibutyl-4-methoxy-N-(quinolin-8-yl)benzamide (4).
Rf 0.34 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 0.81 (t, J = 7.6 Hz, 6H), 1.24-1.33 (m, 4H), 1.62-1.70 (m, 4H), 2.69 (t, J = 8.0 Hz, 4H), 3.88 (s, 3H), 6.68 (s, 2H), 7.43 (dd, J = 8.0, 4.0 Hz, 1H), 7.54-7.62 (m, 2H), 8.17 (dd, J = 8.0, 1.6 Hz, 1H), 8.72 (dd, J = 4.0, 1.6 Hz, 1H), 8.97 (dd, J = 8.0, 1.2 Hz, 1H), 9.90 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 13.82, 22.62, 33.39, 33.69, 55.17, 111.98, 116.57, 121.58, 121.70, 127.95, 130.59, 134.50, 136.24, 138.45, 141.37, 148.13, 159.73, 168.92; IR (neat) 3352 w, 2954 w, 1673 m, 1600 m, 1517 s, 1480 s, 1383 m, 1323 s, 1262 w, 1138 w, 826 m; MS m/z (relative intensity, %) 390 (M$^+$, 7), 249 (17), 248 (100); HRMS Calcd for C$_{25}$H$_{30}$N$_2$O$_2$: 390.2304; Found: 390.2307.

4-Butyl-2-methyl-3-(quinolin-8-ylcarbamoyl)phenyl acetate (5).

Rf 0.20 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 0.79 (t, J = 7.6 Hz, 3H), 1.24-1.33 (m, 2H), 1.61-1.69 (m, 2H), 2.24 (s, 3H), 2.34 (s, 3H), 2.69 (t, J = 8.0 Hz, 2H), 7.05 (d, J = 8.0 Hz, 1H), 7.17 (d, J = 7.2 Hz, 1H), 7.44 (dd, J = 8.0, 4.0 Hz, 1H), 7.56-7.63 (m, 2H), 8.17 (dd, J = 8.0, 1.6 Hz, 1H), 8.75 (dd, J = 4.0, 1.6 Hz, 1H), 8.97 (dd, J = 8.0, 1.6 Hz, 1H), 9.96 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 13.22, 13.79, 20.82, 22.55, 32.83, 33.65, 116.77, 121.70122, 126.63, 126.75, 127.30, 127.93, 134.22, 136.24, 137.25, 138.45, 139.06, 147.27, 148.31, 167.76, 169.44; IR (neat) 3346 w, 2956 w, 2867 w, 1763 w, 1675 m, 1598 w, 1519 s, 1482 s, 1424 m, 1384 m, 1325 m, 1262 w, 1204 w, 1138 w, 826 w; MS m/z (relative intensity, %) 377 (15), 376 (M$^+$, 60), 235 (15), 233 (100), 232 (52), 203 (43), 191 (54), 190 (29), 162 (10), 161 (36), 149 (14), 145 (10), 144 (29), 121 (25), 91 (11); HRMS Calcd for C$_{23}$H$_{19}$N$_2$O$_3$: 376.1787; Found: 376.1786.

2-Butyl-4,5-dimethoxy-N-(quinolin-8-yl)benzamide (6).

Rf 0.11 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 0.88 (t, J = 7.6 Hz, 3H), 1.32-1.40 (m, 2H), 1.67-1.74 (m, 2H), 2.89 (t, J = 8.0 Hz, 2H), 3.92 (s, 3H), 3.95 (s, 3H), 6.800 (s, 1H), 7.19 (s, 1H), 7.45 (dd, J = 8.0, 4.0 Hz, 1H), 7.53-7.62 (m, 2H), 8.17 (dd, 22
J = 8.0, 1.6 Hz, 1H), 8.78 (dd, J = 4.0, 1.6 Hz, 1H), 8.93 (dd, J = 7.6, 1.2 Hz, 1H), 10.16 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.26, 22.62, 32.95, 34.26, 55.90, 56.06, 110.85, 112.91, 116.37, 121.56, 121.57, 127.38, 127.92, 128.46, 134.60, 134.76, 136.38, 138.52, 146.77, 148.14, 150.29, 160.99; IR (neat) 3353 w, 2955 w, 1669 m, 1604 w, 1511 s, 1481 s, 1462 s, 1382 m, 1325 m, 1261 s, 1210 s, 1153 s, 824 m; MS m/z (relative intensity, %) 364 (M$^+$, 27), 222(14), 221 (100), 220 (25), 192 (12), 191 (65), 179 (15), 151 (13); HRMS Calcd for C$_{22}$H$_{24}$N$_2$O$_3$: 364.1787; Found: 364.1789.

2-Butyl-4-fluoro-6-methyl-N-(quinolin-8-yl)benzamide (7).

Rf 0.40 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.80 (t, J = 7.6 Hz, 3H), 1.24-1.33 (m, 2H), 1.61-1.69 (m, 2H), 2.42 (s, 3H), 2.71 (t, J = 7.6 Hz, 2H), 6.83 (t, J = 10.8 Hz, 2H), 7.45 (dd, J = 8.4, 4.0 Hz, 1H), 7.56-7.63 (m, 2H), 8.18 (dd, J = 8.4, 2.0 Hz, 1H), 8.74 (dd, J = 4.8, 2.0 Hz, 1H), 8.97 (dd, J = 8.0, 2.0 Hz, 1H), 9.91 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.78, 19.59, 22.46, 33.07, 33.39, 113.24 (d, J = 21 Hz), 114.44 (d, J = 21.0 Hz), 116.73 , 121.68, 122.02, 127.35, 127.96, 133.91 (d, J = 2.8 Hz), 134.23, 136.32, 13137.33 (d, J = 8.6 Hz), 138.42, 142.142.33 (d, J = 7.6 Hz), 148.28, 162.64 (d, J = 246 Hz), 168.11; IR (neat) 3343 w, 2955 w, 2866 w, 1761 m, 1676 m, 1519 s, 1481 s, 1424 m, 1384 m, 1200 s, 898 m, 827 m; MS m/z (relative intensity, %) 337 (10), 336 (M$^+$, 40), 194 (13), 193 (100), 192 (26), 164 (11), 163 (11), 144 (14), 137 (13), 123 (17); HRMS Calcd for C$_{21}$H$_{21}$FN$_2$O: 336.1638; Found: 336.1636.

2-Butyl-N-(quinolin-8-yl)-1-naphthamide (8).

Rf 0.34 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.82 (t, J = 7.6 Hz, 3H), 1.31-1.37 (m, 2H), 1.74-1.78 (m, 2H), 2.89 (t, J = 8.0 Hz, 2H), 7.38-7.49 (m, 4H), 7.58 (dd, J = 8.0, 1.6 Hz, 1H), 7.65 (t, J = 8.0 Hz, 1H), 7.83-7.88 (m, 2H), 7.98-8.00 (m, 1H), 8.16 (dd, J = 8.0, 2.0 Hz, 1H), 8.65 (dd, J = 4.0, 2.0 Hz, 1H9, 9.13 (d, J = 7.6 Hz, 1H), 10.13 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.87, 22.68, 33.60, 33.81, 116.81, 121.65, 122.02, 124.90, 125.56, 126.93, 127.41, 127.51, 127.92, 128.21, 130.27, 131.81, 133.91, 134.49, 136.26, 137.19, 138.44, 148.20, 168.41; IR (neat) 3343 w, 2954 m, 2862 m, 1672 s, 1596 w, 1517 s, 1481 s, 1423 m, 1383 m, 1325 m, 1257 w, 1212 w, 892 w, 823 m;
MS \textit{m/z} (relative intensity, \%) 354 (M$^+$, 34), 212 (17), 211 (100), 210 (35), 182 (13), 181 (42), 141 (42); HRMS Calcd for C$_{24}$H$_{22}$N$_2$O: 354.1732; Found: 354.1732.

2-butyl-9-methyl-N-(quinolin-8-yl)-9H-carbazole-3-carboxamide (9).

![Chemical Structure](image)

R$_f$ 0.29 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 69 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 0.91 (t, J = 7.2 Hz, 3H), 1.38-1.47 (m, 2H), 1.75-1.83 (m, 2H), 3.16 (t, J = 8.0 Hz, 2H), 3.87 (s, 3H), 7.33-7.30 (m, 2H), 7.40-7.56 (m, 4H), 7.63 (t, J = 7.6 Hz, 1H), 8.19 (d, J = 7.6 Hz, 1H), 8.18 (dd, J = 8.0, 2.0 Hz, 1H), 8.42 (s, 1H), 8.78 (dd, J = 4.0, 2.0 Hz, 1H), 9.01 (d, J = 7.6 Hz, 1H), 10.33 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 14.03, 22.79, 29.17, 34.12, 34.48, 108.63, 109.69, 116.43, 119.33, 120.06, 120.23, 120.34, 121.42, 121.57, 122.71, 125.81, 127.51, 127.98 (two overlapping peaks), 135.12, 136.39, 138.54, 140.12, 141.48, 142.34, 148.11, 169.25; IR (neat) 3356 w, 2954 w, 1667 m, 1600 m, 1517 s, 1478 s, 1382 m, 1324 s, 1252 s, 746 s; MS \textit{m/z} (relative intensity, \%) 407 (M$^+$, 15), 265 (20), 264 (100), 263 (24), 194 (17); HRMS Calcd for C$_{27}$H$_{25}$N$_2$O: 407.1998; Found: 407.1995.

2-Butyl-5-methyl-N-(quinolin-8-yl)thiophene-3-carboxamide (10).

![Chemical Structure](image)

Rf 0.51 (hexane/EtOAc = 5/1). White Solid. Mp = 54-55 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 0.95(t, J = 7.2 Hz, 3H), 1.41-1.50 (m, 2H), 1.72-1.79 (m, 2H), 2.50 (s, 3H), 3.23 (t, J = 7.2 Hz, 2H), 7.12 (s, 1H), 7.46-7.60 (m, 3H), 8.19 (dd, J = 8.4, 2.0 Hz, 1H), 8.84 (dd, J = 4.0, 2.0 Hz, 1H), 8.88 (dd, J = 7.6, 1.6 Hz, 1H), 1.031 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 113.90, 15.17, 22.49, 28.97, 34.02, 116.29, 121.28, 121.57, 124.48, 127.44, 127.95, 131.75, 134.80, 136.16, 136.32, 138.57, 148.11, 149.84, 162.67; IR (neat) 3360 w, 2954 w, 2859 w, 1666 m, 1522 s, 1484 s, 1424 m, 1383 m, 1327 m, 1245 w, 1165 w, 824 m; MS \textit{m/z} (relative intensity, \%) 325 (21), 324 (M$^+$, 91), 182 (16), 181 (98), 180 (92), 152 (11), 151 (100), 144 (16), 141 (10), 139 (54), 111 (15), 110 (14); HRMS Calcd for C$_{19}$H$_{20}$N$_2$OS: 324.1296; Found: 324.1297.

2-Butyl-N-(quinolin-8-yl)cyclohex-1-ene-carboxamide (11).
Rf 0.37 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.82 (t, J = 6.8 Hz, 3H), 1.21-1.30 (m, 2H), 1.67-1.75 (m, 4 H), 2.13-2.14 (m, 2H), 2.26 (t, J = 8.0, 2H), 2.43 (m, 2H), 7..45 (dd, J = 8.4, 4.0 Hz, 1H), 7.49-7.57 (m, 2H), 8.16 (dd, J = 8.0, 2.0 Hz, 1H), 8.80 (dd, J = 4.0, 2.0, 1H), 8.87 (d, J = 7.6 Hz, 1H), 9.83 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 13.98, 22.41, 22.80, 27.13, 28.95, 30.72, 34.88, 116.42, 121.31, 121.52, 127.44, 127.94, 129.92, 134.70, 136.29, 138.49, 139.81, 148.02, 170.46; IR (neat) 3326 w, 2930 m, 2870 w, 1738 w, 1666 m, 1597 m, 1520 s, 1483 s, 1423 m, 1382 m, 1261 m, 1114 m, 1087 w, 825 w; MS m/z (relative intensity, %) 308 (M$^+$, 33), 165 (55), 164 (24), 145 (13), 135 (32), 95 (24), 81 (18); HRMS Calcd for C$_{20}$H$_{24}$N$_2$O: 308.1889; Found: 308.1887.

2-Butyl-N-(quinolin-8-yl)cyclopent-1-enecarboxamide (12).

Rf 0.51 (hexane/EtOAc = 5/1). White Solid. Mp = 63-64 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.93 (t, J = 7.6 Hz, 3H), 1.36-1.45 (m, 2H), 1.51-1.59 (m, 2H), 1.96 (t, J = 7.6 Hz, 2H), 2.58 (t, J = 7.2 Hz, 2H), 2.72 (t, J = 8.0 Hz, 2H), 2.91 (t, J = 7.2 Hz, 2H), 7.44-7.57 (m, 3 H), 8.16 (dd, J = 8.0, 1.6 Hz, 1H), 8.80 (dd, J = 4.0, 1.6 Hz, 1H), 8.86 (dd, J = 18.0, 1.6 Hz, 1H), 10.02 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 14.07, 21.67, 22.95, 29.81, 30.41, 34.09, 37.99, 116.29, 121.09, 121.48, 127.46, 127.92, 129.98, 134.83, 136.28, 138.57, 148.03, 156.08, 165.28; IR (neat) 3357 w, 2954 w, 2858 w, 1739 w, 1665 m, 1520 s, 1483 s, 1423 m, 1382 m, 1325 m, 1259 w, 1202 w, 1123 w, 824 m; MS m/z (relative intensity, %) 294 (M$^+$, 29), 151 (48), 150 (13), 145 (12), 144 (100), 121 (14), 81 (12); HRMS Calcd for C$_{19}$H$_{22}$N$_2$O: 294.1732; Found: 294.1731.

6-Butyl-N-(quinolin-8-yl)-3,4-dihydro-2H-pyran-5-carboxamide (13).

Rf 0.49 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.90 (t, J = 7.6 Hz, 3H), 1.32-1.41 (m, 2H), 1.63-1.71 (m, 2H), 1.97 (f, J = 6.4 Hz, 2H), 2.56 (t, J = 6.4 Hz, 2H), 2.64 (t, J = 7.2 Hz, 2H), 4.08 (t, J = 5.2 Hz, 2H), 7.43-7.49 (m, 2H), 7.54 (t, J = 7.6 Hz,
1H), 8.15 (dd, J = 7.6, 1.2 Hz, 1H), 8.79 (dd, J = 4.0, 1.6 Hz, 1H), 8.83 (dd, J = 7.6, 1.2 Hz, 1H), 9.99 (brs, 1H); \(^{13}\)C NMR (CDCl\(_3\), 100.53 MHz) \(\delta\) 14.01, 21.92, 22.30, 22.68, 30.03, 32.71, 66.05, 105.14, 116.12, 120.85, 121.46, 127.51, 127.95, 135.08, 136.31, 138.63, 147.93, 163.15, 168.03; IR (neat) 3359 w, 2927 m, 2858 w, 1669 m, 1517 s, 1481 s, 1422 m, 1383 m, 1324 m, 1244 m, 1107 w, 899 w, 825 m; MS \(m/z\) (relative intensity, %) 310 (M\(^+\), 18), 168 (11), 167 (100), 166 (14), 85 (12); HRMS Calcd for C\(_{19}\)H\(_{22}\)N\(_2\)O\(_2\): 310.1681; Found: 310.1680.

2-Methyl-6-octyl-N-(quinolin-8-yl)benzamide (14).

![Methyl-6-octyl-N-(quinolin-8-yl)benzamide](image)

Rf 0.37 (hexane/EtOAc = 5/1). Colorless Oil. \(^1\)H NMR (CDCl\(_3\), 399.78 MHz) \(\delta\) 0.79 (t, J = 7.6 Hz, 3H), 1.09-1.18 (m, 8H), 1.22-1.29 (m, 2H), 1.63-1.71 (m, 2H), 2.43 (s, 3H), 2.71 (t, J = 7.6 Hz, 2H), 7.10-7.15 (m, 2H), 7.27 (t, J = 7.6 Hz, 1H), 7.43 (dd, J = 7.6, 4.0 Hz, 1H), 7.55-7.63 (m, 2H), 8.17 (dd, J = 7.6, 2.0 Hz, 1H), 8.72 (dd, J = 4.0, 2.0 Hz, 1H), 9.00 (dd, J = 7.6, 1.6 Hz, 1H), 9.93 (brs, 1H); \(^{13}\)C NMR (CDCl\(_3\), 100.53 MHz) \(\delta\) 14.04, 19.48, 22.52, 29.05, 29.26, 29.51, 31.67, 31.75, 33.42, 116.71, 121.61, 121.86, 126.74, 127.39, 127.66, 127.97, 128.93, 134.39, 134.47, 136.28, 137.72, 138.48, 139.51, 148.20, 168.89; IR (neat) 3348 w, 2924 w, 2854 w, 1677 m, 1518 s, 1481 s, 1423 m, 1384 m, 1325 m, 1244 m, 1107 w, 897 w, 825 m; MS \(m/z\) (relative intensity, %) 375 (12), 374 (M\(^+\), 42), 232 (16), 231 (100), 230 (34), 146 (20), 145 (71), 144 (29), 143 (13), 131 (14), 29 (105); HRMS Calcd for C\(_{25}\)H\(_{30}\)N\(_2\)O: 374.2358; Found: 374.2361.

2-Benzyl-6-methyl-N-(quinolin-8-yl)benzamide (15).

![2-Benzyl-6-methyl-N-(quinolin-8-yl)benzamide](image)

Rf 0.23 (hexane/EtOAc = 5/1). Colorless Oil. \(^1\)H NMR (CDCl\(_3\), 399.78 MHz) \(\delta\) 2.45 (s, 3H), 4.10 (s, 2H), 7.00 (t, J = 8.0 Hz, 1H), 7.05-7.11 (m, 3H), 7.13-7.17 (m, 3H), 7.26 (t, J = 7.6 Hz, 1H), 7.40 (dd, J = 8.0, 4.0 Hz, 1H), 7.53-7.61 (m, 2H), 8.14 (dd, J = 8.0, 1.6 Hz, 1H), 8.65 (dd, J = 4.0, 1.6 Hz, 1H), 8.96 (dd, J = 8.0, 1.6 Hz, 1H), 9.82 (brs, 1H); \(^{13}\)C NMR (CDCl\(_3\), 100.53 MHz) \(\delta\) 19.51, 39.10, 116.67, 121.55, 121.90, 125.88, 127.30, 127.56, 127.86, 128.25 (two overlapping peaks), 129.01, 129.09, 134.24, 134.66, 136.18, 137.83, 137.92, 138.39, 140.32, 148.10, 168.60; IR (neat) 2924 w, 1674 s, 1518 s, 1481 s, 1423 m, 1384 m, 1325 m, 1262 w, 1126 w, 897 w, 825 m; MS \(m/z\) (relative intensity, %) 352 (M\(^+\), 33), 209 (69), 208 (100), 194 (31), 166 (11), 165 (29); HRMS Calcd for C\(_{24}\)H\(_{20}\)N\(_2\)O: 352.1576; Found: 352.1574.
2-(4-Cyanobutyl)-6-methyl-N-(quinolin-8-yl)benzamide (16).

![Chemical structure of 2-(4-Cyanobutyl)-6-methyl-N-(quinolin-8-yl)benzamide](image)

Rf 0.09 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 1.61-1.68 (m, 2H), 1.80-1.88 (m, 2H), 2.25 (t, $J$ = 7.6 Hz, 2H), 2.44 (s, 3H), 2.76 (t, $J$ = 7.6 Hz, 2H), 7.13-7.16 (m, 2H), 7.29 (t, $J$ = 8.0 Hz, 1H), 7.46 (dd, $J$ = 8.0, 4.0 Hz, 1H), 7.57-7.64 (m, 2H), 8.19 (dd, $J$ = 8.0, 1.2 Hz, 1H), 8.75 (dd, $J$ = 4.4, 1.6 Hz, 1H), 8.97 (dd, $J$ = 7.6, 1.6 Hz, 1H), 9.93 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 16.88, 19.48, 24.93, 30.33, 32.36, 116.73, 119.60, 121.74, 122.10, 126.62, 127.35, 127.99, 128.19, 129.16, 134.16, 134.67, 136.37, 137.77, 137.84, 138.41, 148.37, 168.62; IR (neat) 3346 w, 2945 w, 2866 w, 1673 m, 1595 w, 1518 s, 1481 s, 1423 m, 1385 m, 1325 m, 1263 m, 1127 w, 897 w, 827 m; MS m/z (relative intensity, %) 343 (M$^+$, 35), 201 (13), 200 (100), 199 (16), 171 (48), 145 (17), 144 (16), 131 (19), 105 (11); HRMS Calcd for C$_{22}$H$_{21}$N$_3$O: 343.1685; Found: 343.1686.

2-(3-Methoxypropyl)-6-methyl-N-(quinolin-8-yl)benzamide (17).

![Chemical structure of 2-(3-Methoxypropyl)-6-methyl-N-(quinolin-8-yl)benzamide](image)

Rf 0.11 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 1.92-1.99 (m, 2H), 2.43 (s, 3H), 2.80 (t, $J$ = 8.0 Hz, 2H), 3.23 (s, 3H), 3.34 (t, $J$ = 6.4 Hz, 2H), 7.12-7.18 (m, 2H), 7.29 (t, $J$ = 8.0 Hz, 1H), 7.44 (dd, $J$ = 8.4, 4.0 Hz, 1H), 7.56-7.63 (m, 2H), 8.18 (dd, $J$ = 8.4, 1.6 Hz, 1H), 8.73 (dd, $J$ = 4.0, 1.6 Hz, 1H), 8.99 (dd, $J$ = 8.0, 1.6 Hz, 1H), 9.93 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 19.48, 29.83, 31.21, 58.29, 71.87 116.74, 121.64, 121.92, 126.87, 127.36, 127.91, 127.95, 129.02, 134.33, 134.54, 136.31, 137.82, 138.45, 138.60, 148.24, 168.73; IR (neat) 3347 w, 2923 w, 2869 w, 1675 m, 1595 w, 1518 s, 1480 s, 1423 m, 1385 m, 1325 m, 1263 w, 1117 m, 897 w, 826 m; MS m/z (relative intensity, %) 335, (10), 334 (M$^+$, 44), 190 (28), 145 (33), 144 (19), 132 (16), 131 (100), 117 (12), 105 (21), 61 (19); HRMS Calcd for C$_{21}$H$_{22}$N$_3$O$_2$: 334.1681; Found: 334.1684.

2-Allyl-6-methyl-N-(quinolin-8-yl)benzamide (18).
Rf 0.37 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 2.44 (s, 3H), 3.51 (d, $J = 6.8$ Hz, 2H), 4.97-5.04 (m, 2H), 5.94-6.04 (m, 1H), 7.15 (d, $J = 8.0$, 2H), 7.30 (t, $J = 7.2$ Hz, 1H), 7.44 (dd, $J = 8.4$, 4.0 Hz, 1H), 7.56-7.63 (m, 2H), 8.17 (d, $J = 8.4$ Hz, 1H), 8.73 (d, $J = 4.0$ Hz, 1H), 8.99 (d, $J = 7.2$ Hz, 1H), 9.95 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 19.49, 37.71, 116.22, 116.74, 121.64, 121.95, 121.01, 127.35, 127.95, 128.23, 129.12, 134.27, 134.71, 136.29, 136.62, 136.86, 137.70, 138.41, 148.21, 168.53; IR (neat) 3345 w, 2921 w, 1675 m, 1595 w, 1519 s, 1482 s, 1424 m, 1385 w, 1326 m, 1264 w, 1127 w, 902 w, 826 w; MS m/z (relative intensity, %) 303 (13), 302 (M$^+$, 59), 301 (28), 160 (10), 159 (89), 158 (100), 157 (11), 144 (41), 131 (47), 130 (13), 129 (18), 128 (12), 116 (32), 115 (30), 91 (26); HRMS Calcd for C$_{20}$H$_{18}$N$_2$O: 302.1419; Found: 302.1420.

2-Isobutyl-6-methyl-N-(quinolin-8-yl)benzamide (19).

Rf 0.37 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.87 (d, $J = 7.2$ Hz, 6H), 1.97-2.04 (m, 1H), 2.43 (s, 3H), 2.61 (d, $J = 7.2$ Hz, 2H), 7.12 (d, $J = 7.6$ Hz, 2H), 7.28 (t, $J = 87.6$ Hz, 1H), 7.45 (dd, $J = 8.0$, 4.0 , 1H), 7.56-7.64 (m, 2H), 8.18 (dd, $J = 8.0$, 1.6 Hz, 1H), 8.73 (dd, $J = 4.0$, 1.6 Hz, 1H), 8.99 (dd, $J = 7.6$, 1.6 Hz, 1H), 9.90 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 19.67, 22.68, 30.01, 31.07, 42.65, 116.82, 121.76, 121.98, 127.51, 127.54, 127.88, 128.11, 128.80, 134.52, 134.58, 136.41, 138.27, 138.43, 138.62, 148.37, 169.02; IR (neat) 3347 w, 2954 w, 2867 w, 1676 m, 1595 w, 1519 s, 1481 s, 1423m, 1384 m, 1325 m, 1263 w, 1126 w, 899 w, 826 w; MS m/z (relative intensity, %) 318 (M$^+$, 66), 176 (12), 175 (97), 174 (58), 159 (56), 158 (14), 157 (100), 145 (14), 144 (53), 132 (16), 131 (11), 129 (11), 116 (11), 105 (24), 104 (13), 103 (12), 91 (11); HRMS Calcd for C$_{21}$H$_{22}$N$_2$O: 318.1735; Found: 318.1732.

2-(cyclopentylmethyl)-6-methyl-N-(quinolin-8-yl)benzamide (20 and 34).
Rf 0.40 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 1.11-1.20 (m, 2H), 1.41-1.58 (m, 4H), 1.64-1.69 (m, 2H), 2.21 (se, J = 3.6 Hz, 1H), 2.43 (s, 3H), 2.73 (d, J = 7.6 Hz, 1H), 7.12 (d, J = 7.6 Hz, 1H), 7.16 (d, J = 8.0 Hz, 1H), 7.27 (t, J = 7.6 Hz, 1H), 7.44 (dd, J = 4.0, 2.0 Hz, 1H), 7.56-7.64 (m, 2H), 8.18 (dd, J = 8.0, 2.0 Hz, 1H), 8.73 (dd, J = 4.0, 1.6 Hz, 1H), 8.99 (dd, J = 7.6, 1.6 Hz, 1H), 9.92 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 19.54, 24.72, 32.59, 39.07, 41.60, 116.71, 121.64, 121.86, 127.08, 127.40, 127.65, 127.95, 128.75, 134.37, 134.42, 136.29, 137.88, 138.47, 138.86, 148.20, 168.93; IR (neat) 3347 w, 2949 m, 1676 m, 1520 s, 1482 s, 1424 m, 1326 m, 1126 w; MS m/z (relative intensity, %) 345 (11), 344 (M$^+$, 46), 201 (36), 200 (49), 184 (15), 200 (49), 184 (15), 183 (100), 182 (16), 168 (10), 159 (10), 157 (15), 155 (25), 149 (13), 145 (15), 144 (70), 143 (10), 142 (10), 132 (14), 129 (14), 129 (10), 105 (31), 104 (11); 144 (42); HRMS Calcd for C$_{23}$H$_{24}$N$_2$O$_2$: 344.1889; Found: 344.1891.

2-(2-(Benzyloxy)ethyl)-6-methyl-N-(quinolin-8-yl)benzamide (21).

Rf 0.20 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 2.44, 3.05 (t, J = 7.2 Hz, 2H), 3.74 (t, J = 7.2 Hz, 2H), 4.45 (s, 2H), 7.15-7.20 (m, 7H), 7.29 (t, J = 7.6 Hz, 1H), 7.44 (dd, J = 8.0, 4.0 Hz, 1H), 7.57-7.65 (m, 2H), 8.20 (dd, J = 8.4, 1.6 Hz, 1H), 8.69 (dd, J = 4.4, 1.6 Hz, 1H), 9.00 (dd, J = 7.6, 1.6 Hz, 1H), 10.05 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 19.53, 33.79, 70.97, 72.70, 116.87, 121.60, 121.98, 127.29, 127.37, 127.39, 127.98, 128.12, 128.31, 128.98, 134.35, 134.58, 135.50, 136.28, 138.28 (two overlapping peaks), 138.49, 148.19, 168.66; IR (neat) 3344 w, 2925 w, 2858 w, 1673 m, 1595 w, 1519 s, 1481 s, 1424 m, 1385 m, 1325 m, 1264 m, 1095 m, 898 w, 826 m; MS m/z (relative intensity, %) 396 (M$^+$, 7), 289 (11), 288 (7), 287 (17), 234 (13), 233 (14), 145 (12), 144 (38), 129 (12), 91 (100); HRMS Calcd for C$_{26}$H$_{24}$N$_2$O$_2$: 396.1836; Found: 396.1838.

2-Methyl-6-phenethyl-N-(quinolin-8-yl)benzamide (22).
Rf 0.29 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 2.45 (s, 3H), 2.96-3.05 (m, 4H), 7.05-7.09 (m, 1H), 7.12-7.16 (m, 4H), 7.28 (t, J = 8.0 Hz, 1H), 7.44 (dd, J = 8.0, 4.0 Hz, 1H), 7.56-7.65 (m, 2H), 8.18 (s, 1H), 8.72 (dd, J = 4.0, 1.6 Hz, 1H), 9.01 (dd, J = 8.0, 1.6 Hz, 1H), 9.95 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 19.53, 35.83, 38.14, 116.82, 121.66, 121.98, 125.78, 126.95, 127.42, 127.99, 128.09, 128.21, 128.37, 129.05, 134.30, 134.59, 136.36, 137.79, 138.42, 141.66, 148.26, 168.70; IR (neat) 3345 w, 3025 w, 2927 w, 1738 w, 1674 m, 1595 w, 1518 s, 1481 s, 1423 m, 1384 m, 1325 m, 1262 w, 1126 w, 897 w, 826 m; MS m/z (relative intensity, %) 366 (M$^+$, 17), 224 (10), 223 (61), 222 (46), 179 (12), 178 (13), 165 (12), 145 (37), 144 (100), 132 (81), 117 (27), 103 (11), 91 (20); HRMS Calcd for C$_{25}$H$_{22}$N$_2$O: 366.1732; Found: 366.1730.

2-Isopentyl-6-methyl-N-(quinolin-8-yl)benzamide (23).

Rf 0.26 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 0.77 (d, J = 6.4 Hz, 6H), 1.47-1.60 (m, 3H), 2.43 (s, 3H), 2.70 (t, J = 8.0 Hz, 2H), 7.10-7.15 (m, 2H), 7.27 (t, J = 7.6 Hz, 1H), 7.45 (dd, J = 8.4, 4.0 Hz, 1H), 7.56-7.64 (m, 2H), 8.18 (dd, J = 8.4, 1.6 Hz, 1H), 8.74 (dd, J = 4.4, 1.6 Hz, 1H), 8.99 (dd, J = 8.4, 1.6 Hz, 1H), 9.93 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 19.49, 22.33, 27.95, 31.39, 41.17, 116.79, 121.63, 121.87, 126.77, 127.44, 127.65, 128.98, 134.37, 134.55, 136.35, 137.69, 138.44, 139.73, 148.19, 168.87; IR (neat) 3348 w, 2953 w, 2868 w, 1677 m, 1595 w, 1519 s, 1481 s, 1424 m, 1385 m, 1325 m, 1263 w, 1216 w, 898 w, 826 w; MS m/z (relative intensity, %) 333 (13), 332 (M$^+$, 52), 289 (14), 189 (55), 188 (31), 171 (13), 147 (12), 146 (13), 145 (100), 144 (25), 132 (11), 131 (42), 105 (32), 59 (32); HRMS Calcd for C$_{22}$H$_{24}$N$_2$O: 332.1889; Found: 332.1890.

2-(But-3-en-1-yl)-6-methyl-N-(quinolin-8-yl)benzamide (24).
Rf 0.29 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 2.41-2.47 (m, 5H), 2.2.80-2.84 (m, 2H), 4.86-4.95 (m, 2H), 5.75-5.82 (m, 1H), 7.14 (t, J = 8.0 Hz, 2H), 7.27 (t, J = 8.0 Hz, 1H), 7.44 (dd, J = 8.0, 4.0 Hz, 1H), 7.56-7.63 (m, 2H), 8.17 (dd, J= 8.4, 16 Hz, 1H), 8.73 (dd, J = 4.0, 1.6 Hz, 1H), 8.99 (dd, J = 8.0, 1.6 Hz, 1H), 9.93 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 19.49, 32.87, 35.54, 115.05, 116.74, 121.65, 121.93, 126.80, 127.38, 127.93, 127.96, 128.96, 134.31, 134.50, 136.31, 137.82, 137.89, 138.38, 138.46, 148.24, 168.72; IR (neat) 3345 w, 2924 w, 1674 m, 1595 w, 1518 s, 1481 s, 1423 m, 1385 m, 1325 m, 1263 w, 1127 w, 899 w, 826 m; MS m/z (relative intensity, %) 316 (M$^+$, 32), 173 (67), 172 (58), 171 (17), 157 (18), 146 (10), 145 (82), 144 (100), 143 (10), 132 (11), 131 (14), 130 (21), 129 (19), 128 (15), 115 (1), 105 (18), 104 (11); HRMS Calcd for C$_{21}$H$_{20}$N$_2$O: 316.1576; Found: 316.1576.

2-Methyl-N-(quinolin-8-yl)-6-((triisopropylsilyl)hex-5-yn-1-yl)benzamide (25).

Rf 0.34 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) δ 0.95-1.17 (m, 21H), 1.49-1.57 (m, 2H), 1.79-1.86 (m, 2H), 2.19 (t, J = 7.2 Hz, 2H), 2.43 (s, 3H), 2.74 (t, J = 7.6 Hz, 2H), 7.11-7.16 (m, 2H), 7.28 (t, J = 7.6 Hz, 1H), 7.45 (dd, J = 8.0, 4.0 Hz, 1H), 7.56-7.64 (m, 2H), 8.19 (d, J = 7.6 Hz, 1H), 8.73 (d, J = 3.6 Hz, 1H), 8.98 (d, J = 7.6 Hz, 1H), 9.92 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) δ 111.20, 18.59, 19.50, 19.63, 28.65, 30.50, 32.71, 80.04, 108.90, 116.81, 121.66, 121.94, 126.58, 127.41, 127.80, 127.99, 129.00, 134.31, 134.48, 136.35, 137.74, 138.43, 138.94, 148.21, 168.80; IR (neat) 3349 w, 2941 w, 1679 m, 1520 s, 1482 s, 1463 m, 1424 m, 1385 m, 1325 m, 1263 w, 1126 w, 883 m, 826 m; MS m/z (relative intensity, %) 498 (M$^+$, 2), 457 (10), 456 (37), 455 (100); HRMS Calcd for C$_{32}$H$_{42}$N$_2$OSi: 498.3066; Found: 498.3062.

Methyl 5-(3-methyl-2-(quinolin-8-ylcarbamoyl)phenyl)pentanoate (26).
Rf 0.11 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) $\delta$ 1.60-1.76 (m, 4H), 2.24 (t, J = 7.6 Hz, 2H), 2.43 (s, 3H), 2.74 (t, J = 7.6 Hz, 2H), 3.56 (s, 3H), 7.13 (t, J = 7.2 Hz, 2H), 7.28 (t, J = 7.6 Hz, 1H), 7.45 (dd, J = 8.4, 4.0 Hz, 1H), 7.56-7.64 (m, 2H), 8.18 (dd, J = 8.4, 1.6 Hz, 1H), 8.92 (dd, J = 8.0, 1.6 Hz, 1H), 9.92 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) $\delta$ 19.47, 24.72, 31.00, 33.04, 33.78, 51.33, 116.75, 121.65, 121.95, 126.70, 127.37, 127.90, 127.97, 129.01, 134.28, 134.54, 136.31, 137.71, 138.45, 138.70, 148.26, 168.72, 173.95; IR (neat) 3347 w, 2948 w, 2864 w, 1734 m, 1675 m, 1595 w, 1518 s, 1481 s, 1424 m, 1384 m, 1325 m, 1262 m, 1127 m, 896 w, 827 m; MS m/z (relative intensity, %) 377 (19), 376 (M$^+$, 72), 245 (20), 234 (14), 233 (99), 232 (100), 201 (14), 200 (13), 173 (24), 163 (20), 159 (21), 158 (13), 157 (13), 155 (10), 146 (14), 145 (84), 144 (39), 143 (10), 119 (12), 117 (12), 116 (14), 115 (15), 105 (21), 91 (14); HRMS Calcd for C$_{23}$H$_{18}$N$_2$O: 376.1787; Found: 376.1789.

2-Methyl-6-(2-methylpropen-3-yl)-N-(quinolin-8-yl)benzamide (27).

Rf: 0.31 (hexane/EtOAc = 5/1). Yellow oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 1.63 (s, 3H), 2.43 (s, 3H), 3.44 (s, 2H), 4.65 (s, 1H), 4.76 (s, 1H), 7.13-7.15 (m, 2H), 7.26-7.62 (m, 4H), 8.17 (dd, J = 2.0, 8.4 Hz, 1H), 8.71 (dd, J = 2.0, 4.4 Hz, 1H), 8.97 (dd, J = 1.2, 7.2 Hz, 1H), 9.92 (s, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.66, 22.48, 41.67, 112.85, 116.83, 121.76, 122.01, 127.41, 127.51, 128.08, 128.38, 129.05, 134.49, 134.88, 136.32, 136.38, 138.24, 138.61, 144.62, 148.31, 168.72; IR (neat): 3345 w, 3066 w, 2969 w, 2916 w, 1737 w, 1674 s, 1595 w, 1578 w, 1517 s, 1481 s, 1423 m, 1384 m, 1325 s, 1263 m, 1170 w, 1126 m, 1088 w, 1071 w, 1042 w, 977 w, 894 m, 825 m, 790 m, 760 m, 685 m; MS m/z (relative intensity, %): 326 (M$^+$, 29), 315 (20), 173 (18), 172 (21), 157 (14), 145 (65), 144 (100), 130 (16), 129 (21), 128 (17), 115 (12), 105 (14); HRMS Calcd for C$_{18}$H$_{13}$F$_3$N$_2$O: 316.1576; Found: 316.1571.

2-methyl-N-(quinolin-8-yl)-6-(2,2,2-trifluoroethyl)benzamide (28).
R_{f} 0.37 (hexane/EtOAc = 5/1). White Solid. M_p = 148 °C. \(^1\)H NMR (CDCl\textsubscript{3}, 399.78 MHz) 2.48 (s, 2H), 3.59 (q, J = 10.8 Hz, 2H), 7.30 (t, J = 8.0 Hz, 2H), 7.37 (t, J = 8.0 Hz, 1H), 7.45 (dd, J = 8.4, 4.4 Hz, 1H), 7.58-7.64 (m, 2H), 8.18 (dd, J = 8.0, 2.0 Hz, 1H), 8.74 (dd, J = 4.4, 1.6 Hz, 1H), 8.97 (dd, J = 7.6, 1.6 Hz, 1H), 10.05 (brs, 1H); \(^{13}\)C NMR (CDCl\textsubscript{3}, 100.53 MHz) 19.78, 37.08 (q, J = 29.6 Hz), 116.82, 121.50, 121.73, 122.28, 125.64 (q, J = 275.5 Hz), 127.15 (d, J = 3 Hz), 127.27, 127.97, 128.25, 128.61, 129.01, 129.28, 130.37, 134.02, 135.15, 136.30, 137.15, 137.77, 138.42, 138.45, 139.05, 148.38, 167.64; IR (neat) 3343 w, 1671 m, 1520 s, 1483 s, 1326 m, 1260 m, 1134 m, 792 m; MS \(m/z\) (relative intensity, %) 344 (M\(^+\), 41), 202 (24), 201 (100), 200 (19), 181 (16), 144 (21), 123 (25); HRMS Calcd for C\textsubscript{19}H\textsubscript{15}F\textsubscript{3}N\textsubscript{2}O: 344.1136; Found: 344.1134.

2,6-Dimethyl-N-(quinolin-8-yl)benzamide (29).

R_{f} 0.37 (hexane/EtOAc = 5/1). White Solid. M_p = 125 °C. \(^1\)H NMR (CDCl\textsubscript{3}, 399.78 MHz) 2.44 (s, 6H), 7.12 (d, J = 7.2 Hz, 2H), 7.25 (t, J = 7.6 Hz, 1H), 7.45 (dd, J = 8.0, 4.4 Hz, 1H), 7.56-7.64 (m, 2H), 8.19 (d, J = 8.0 Hz, 1H), 8.74 (d, J = 4.0 Hz, 1H), 9.00 (d, J = 7.2 Hz, 1H), 9.95 (brs, 1H); \(^{13}\)C NMR (CDCl\textsubscript{3}, 100.53 MHz) 19.45, 116.82, 121.65, 121.94, 127.43, 127.89, 127.99, 128.95, 134.34, 134.53, 136.42, 137.99, 138.42, 148.21, 168.89; IR (neat) 3345 w, 1673 m, 1518 s, 1481 s, 1424 m, 1385 m, 1320 m, 1172 w; MS \(m/z\) (relative intensity, %): 276 (M\(^+\), 29), 259 (12), 133 (100), 132 (21), 105 (26); HRMS Calcd for C\textsubscript{18}H\textsubscript{16}N\textsubscript{2}O: 276.1263; Found: 276.1261.

2-cyclopentyl-N-(quinolin-8-yl)benzamide (30).

R_{f} 0.49 (hexane/EtOAc = 5/1). Colorless Oil. \(^1\)H NMR (CDCl\textsubscript{3}, 399.78 MHz) 1.62-1.82 (m, 6H), 2.14-2.22 (m, 2H), 3.48-3.54 (m, 1H), 7.27-7.31 (m, 1H), 7.43-7.47 (m, 3H), 7.54-7.63 (m, 3H), 8.18 (dd, J = 8.4, 1.2 Hz, 1H), 8.76 (dd, J = 4.0, 1.6 Hz, 1H), 8.97 (dd, J = 7.6, 1.6 Hz, 1H), 10.14 (brs, 1H); \(^{13}\)C NMR (CDCl\textsubscript{3}, 100.53 MHz) 25.85, 35.44, 41.95, 116.60, 121.63, 121.79, 125.71, 126.91, 126.93, 127.41, 127.96, 130.28, 134.68, 136.40, 137.17,
138.40, 144.83, 148.15, 168.91; IR (neat) 3347 w, 2952 w, 1672 m, 1519 s, 1482 s, 1424 m, 1385 m, 1326 m, 1260 w; MS m/z (relative intensity, %) 316 (M+, 41), 173 (29), 172 (100), 171 (17), 155 (41), 154 (16), 153 (14), 145 (16), 144 (92), 131 (15), 130 (18), 129 (33), 128 (15), 117 (10), 116 (12), 115 (19), 91 (15); HRMS Calcd for C21H20N2O: 316.1576; Found: 316.1576.

5-Methoxy-2-octyl-N-(quinolin-8-yl)benzamide (31b).

![Chemical structure of 5-Methoxy-2-octyl-N-(quinolin-8-yl)benzamide (31b).]

Rf 0.40 (hexane/EtOAc = 5/1). Colorless Oil. 1H NMR (CDCl3, 399.78 MHz) δ 0.80 (t, J = 7.2 Hz, 3H), 1.11-1.29 (m, 10H), 1.66 (t, J = 7.6 Hz, 2H), 2.83 (t, J = 7.6 Hz, 2H), 3.84 (s, 3H), 6.97 (dd, J = 8.0, 1.6 Hz, 1H), 7.17 (d, J = 2.4 Hz, 1H), 7.25 (d, J = 8.0 Hz, 1H), 7.45 (dd, J = 8.4, 4.4 Hz, 1H), 7.54-7.62 (m, 2H), 8.17 (dd, J = 8.0, 1.6 Hz, 1H), 8.76 (dd, J = 4.0, 1.6 Hz, 1H), 8.94 (dd, J = 7.6, 1.2 Hz, 1H), 10.15 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) δ 14.04, 22.55, 39.16, 29.34, 29.45, 31.77, 31.89, 32.47, 55.42, 112.45, 115.93, 116.52, 121.63, 121.76, 127.37, 127.76, 131.40, 133.08, 134.64, 136.29, 137.46, 138.51, 148.20, 157.48, 168.22; IR (neat) 3349 w, 2924 w, 2853 w, 1676 m, 1607 w, 1520 s, 1481 s, 1423 m, 1384 m, 1326 m, 1285 m, 1109 w, 1040 m, 824 m; MS m/z (relative intensity, %) 391 (14), 390 (M+, 50), 305 (10), 247 (15), 246 (35), 217 (15), 176 (11), 161 (100), 149 (23), 147 (13), 146 (12), 144 (34), 121 (30). HRMS Calcd for C25H30N2O2: 390.2307; Found: 390.2306.

2-Octyl-N-(quinolin-8-yl)-5-(trifluoromethyl)benzamide (32b).

![Chemical structure of 2-Octyl-N-(quinolin-8-yl)-5-(trifluoromethyl)benzamide (32b).]

Rf 0.51 (hexane/EtOAc = 5/1). Colorless Oil. 1H NMR (CDCl3, 399.78 MHz) δ 0.80 (t, J = 7.2 Hz, 3H), 1.11-1.35 (m, 10H), 1.67-1.74 (m, 2H), 2.94 (t, J = 8.0 Hz, 2H), 7.45-7.49 (m, 2H), 7.57-7.68 (m, 3H), 7.88 (s, 1H), 8.19 (dd, J = 8.0, 4.0, 1H), 8.78 (dd, J = 4.0, 1.6 Hz, 1H), 8.93 (dd, J = 7.6, 4.0 Hz, 1H), 10.17 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) δ 14.02, 22.54, 29.09, 29.25, 29.44, 31.45, 31.74, 33.28, 116.76, 121.76, 122.19, 123.88 (q, J = 271 Hz), 124.21 (d, J = 2.9 Hz), 126.71 (d, J = 3.8 Hz), 127.73, 127.95, 128.35 (q, J = 33Hz), 130.82, 134.28, 136.38, 137.23, 138.44, 145.35, 148.37, 166.97; IR (neat) 3344 w, 2924 w, 2855 w, 1678 m, 1522 s, 1483 s, 1424 m, 1385 m, 1326 s, 1258 m, 1169 m, 1125 s, 1080 w, 910 w, 826 m; MS m/z (relative intensity, %) 429 (11), 428 (M+, 41), 344 (11), 343 (52), 213 (11), 200 (12), 199 (59), 145 (13), 144 (100); HRMS Calcd for C25H27F3N2O: 428.2075; Found: 428.2073.
2-(hex-5-en-1-yl)-6-methyl-N-(quinolin-8-yl)benzamide (33).

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\begin{align*}
\text{R} & : 0.40 \text{ (hexane/EtOAc = 5/1). Colorless Oil.} \\
1^H \text{NMR (CDCl}_3, 399.78 \text{ MHz}) & : 1.37 (f, J = 7.6 \text{ Hz, 2H}), 1.66-1.73 (m, 2H), 1.96 (q, J = 7.6 \text{ Hz, 2H}), 2.43 (s, 3H), 2.72 (t, J = 8.0 \text{ Hz, 2H}), 4.78 (dd, J = 10.4, 1.6 \text{ Hz, 1H}), 4.86 (dd, J = 17.2, 1.6 \text{ Hz, 1H}), 5.62-5.72 (m, 1H), 7.13 (t, J = 8.0 \text{ Hz}), 7.28 (t, J = 7.6 \text{ Hz, 1H}), 7.45 (dd, J = 8.0, 4.0 \text{ Hz, 1H}), 7.56-7.64 (m, 2H), 8.19 (dd, J = 8.0, 1.2 \text{ Hz, 1H}), 8.74 (dd, J = 4.0, 1.2 \text{ Hz, 1H}) 9.00 (dd, J = 7.2, 1.6 \text{ Hz, 1H}), 9.93 (brs, 1H); \\
13^C \text{NMR (CDCl}_3, 100.53 \text{ MHz}) & : 19.50, 28.73, 31.09, 33.27, 33.48, 114.21, 116.80, 121.64, 121.92, 126.73, 127.44, 127.74, 127.99, 128.97, 134.34, 134.51, 136.39, 137.72, 138.41, 138.74, 139.24, 148.20, 168.87; \text{IR (neat) 3347 w, 1676 m, 1519 s, 1481 s, 1423 m, 1385 m, 1126 w; MS m/z (relative intensity, %) 344 (M^+ , 13), 201 (32), 200 (22), 159 (47), 145 (30), 144 (100), 131 (20), 130 (11), 116 (10), 105 (28); HRMS Calcd for C_{22}H_{22}N_2O_2: 344.1889; Found: 344.1890.}
\end{align*}
\]

2-(cyclopropylmethyl)-6-methyl-N-(quinolin-8-yl)benzamide (35).

\[
\begin{align*}
\text{R} & : 0.41 \text{ (hexane/EtOAc = 5/1). Colorless Oil.} \\
1^H \text{NMR (CDCl}_3, 399.78 \text{ MHz}) & : 0.18 (q, J = 5.2 \text{ Hz, 2H}), 0.47 (q, J = 5.6 \text{ Hz, 2H}), 1.03-1.09 (m, 1H), 2.44 (s, 3H), 2.67 (d, J = 6.8 \text{ Hz, 2H}), 7.15 (d, J = 8.4 \text{ Hz, 1H}), 7.29-7.34 (m, 2H), 7.44 (dd, J = 4.4, 2.4 \text{ Hz, 1H}), 7.56-7.63 (m, 2H), 8.17 (d, J = 8.0 \text{ Hz, 1H}), 8.73 (dd, J = 4.0, 1.6 \text{ Hz, 1H}), 9.00 (d, J = 6.8 \text{ Hz, 1H}), 9.96 (brs, 1H); \\
13^C \text{NMR (CDCl}_3, 100.53 \text{ MHz}) & : 4.95, 11.72, 19.49, 37.59, 116.77, 121.64, 126.51, 127.39, 127.92, 129.00, 134.31, 134.33, 136.34, 137.58, 138.39, 138.86, 148.20, 168.89; \text{IR (neat) 3346 w, 1676 m, 1520 s, 1482 s, 1424 m, 1385 m, 1126 w; MS m/z (relative intensity, %) 316 (M^+ , 21), 315 (11), 173 (17), 172 (37), 171 (15), 157 (14), 146 (11), 145 (89), 144 (100), 130 (19), 129 (21), 128 (17), 115 (17), 105 (15); HRMS Calcd for C_{21}H_{22}N_2O_2: 316.1576; Found: 316.1573.}
\end{align*}
\]

2-(but-3-en-1-yl)-6-methyl-N-(quinolin-8-yl)benzamide (36).
Rt 0.41 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.41-2.47 (m, 5H), 2.82 (t, J = 8.0 Hz, 2H), 5.74-5.84 (m, 1H), 7.14 (t, J = 8.4 Hz, 2H), 7.29 (t, J = 7.2 Hz, 1H), 7.45 (dd, J = 8.0, 4.0 Hz, 1H), 7.56-7.64 (m, 2H), 8.19 (dd, J = 8.4, 1.6 Hz, 1H), 8.74 (dd, J = 4.0, 2.0 Hz, 1H), 8.99 (dd, J = 7.2, 1.2 Hz, 1H), 9.94 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.52, 32.88, 35.56, 115.05, 116.90, 121.65, 121.97, 126.80, 127.46, 127.94, 128.01, 128.98, 134.27, 134.52, 136.48, 137.80, 137.92, 138.34, 138.39, 148.18, 168.77; IR (neat) 3346 w, 1675 m, 1519 s, 1481 s, 1424 m, 1385 m, 1325 m, 1263 w, 826 w; MS m/z (relative intensity, %) 316 (M$^+$, 32), 173 (64), 172 (56), 171 (18), 157 (19), 146 (11), 145 (86), 144 (100), 143 (11), 132 (12), 131 (14), 130 (22), 129 (22), 128 (18), 115 (14), 105 (21), 104 (11), 103 (11); HRMS Calcd for C$_{21}$H$_{20}$N$_2$O: 316.1576; Found: 316.1574.

**Deuterium Labeling Experiments (Scheme 2).**

To an oven-dried 5 mL screw-capped vial in a glove box, 2-methyl-N-(8-quinolinyl)benzamide 1a-d$_7$ (79 mg, 0.3 mmol), 1-bromobutane (82 mg, 0.6 mmol), Ni(OTf)$_2$ (10.6 mg, 0.03 mmol), PPh$_3$ (15.6 mg, 0.06 mmol), Na$_2$CO$_3$ (64 mg, 0.6 mmol) and toluene (1 mL) were added. The mixture was stirred for 8 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The ratio of deuterium was determined by $^1$H-NMR.

**Competition Experiment (Scheme 3).**

To an oven-dried 5 mL screw-capped vial, N-(8-Quinolinyl)-3-(trifluoromethyl)benzamide 32a (158 mg, 0.5 mmol), 3-Methoxy-N-(quinolin-8-yl)benzamide 31a (139 mg, 0.5 mmol), 1-bromoocatane (79 mg, 0.4 mmol), Ni(OTf)$_2$ (7.1 mg, 0.02 mmol), PPh$_3$ (10 mg, 0.04 mmol), Na$_2$CO$_3$ (42 mg, 0.4 mmol) and toluene (1 mL) were added in a glove box. The mixture was stirred for 36 h at 160 °C followed by cooling. The mixture was filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluant: hexane/EtOAc= 20/1) to afford the desired alkylated product 32b (115 mg, 67% based on Oct-Br) as a colorless oil and alkylated product 31b (7 mg 5% based on Oct-Br) as a colorless oil. N-(8-Quinolinyl)-3-(trifluoromethyl)benzamide 32a and 3-Methoxy-N-(quinolin-8-yl)benzamide 31a was recovered 41% and 90%.

**Radical Trapping Experiment.**
To an oven-dried 5 mL screw-capped vial in a glove box, 2-methyl-N-(8-quinoliny)benzamide 1a-d7 (79 mg, 0.3 mmol), 1-bromobutane (82 mg, 0.6 mmol), TEMPO or GALVINOXYL (0.6 mmol), Ni(OTf)2 (10.6 mg, 0.03 mmol), PPh3 (15.6 mg, 0.06 mmol), Na2CO3 (64 mg, 0.6 mmol) and toluene (1 mL) were added. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The yield of product was determined by 1H-NMR.

Radical Clock Experiments (Scheme 4 and 5).

To an oven-dried 5 mL screw-capped vial in a glove box, 2-methyl-N-(8-quinoliny)benzamide 1a (79 mg, 0.3 mmol), 6-bromohex-1-ene (97 mg, 0.6 mmol) or (bromomethyl)cyclopropane (80 mg, 0.6 mmol), Ni(OTf)2 (10.6 mg, 0.03 mmol), PPh3 (15.6 mg, 0.06 mmol), Na2CO3 (64 mg, 0.6 mmol) and toluene (1 mL) were added. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The ratio of products was determined by 1H-NMR.

1.5 References and Notes


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Nickel(II)-Catalyzed Direct Arylation of C(sp\textsuperscript{3})-H Bonds in Aliphatic Amides via Bidentate-Chelation Assistance

2.1 Introduction

As described in general introduction and chapter 1, the transition metal-catalyzed functionalization of C(sp\textsuperscript{2})-H bonds has emerged as a powerful tool for the formation of C-C and C-heteroatom bonds in recent years.\textsuperscript{1} Compare to those functionalization of C(sp\textsuperscript{2})-H bonds, the functionalization of C(sp\textsuperscript{3})-H bonds has been limited and continues to be a challenging issue.\textsuperscript{2} However, most of the functionalization reactions of C(sp\textsuperscript{3})-H bonds reported so thus have involved the use of palladium complexes as catalysts. One of the method for the functionalization of C(sp\textsuperscript{3})-H bonds is the utilization of a bidentate directing group discovery by Daugulis,\textsuperscript{3} and various types of functionalization of C(sp\textsuperscript{3})-H bonds have been achieved using the bidentate-chelation system in conjunction with Pd(II) catalysts.\textsuperscript{4} Another method for functionalization of C(sp\textsuperscript{3})-H bond with Pd-catalyst is the use of electron deficient directing groups, which is reported by Yu.\textsuperscript{5} The Functionalization of C-H bonds using transition metal complexes other than palladium complexes have been limited.\textsuperscript{6} To the best of our knowledge, Ni-catalyzed transformation of C(sp\textsuperscript{3})-H bonds have been restricted to only one example, i.e., the Ni(0)-catalyzed cycloaddition of formamide with alkynes.\textsuperscript{7}

Chapter 2 deals the Ni(II)-catalyzed direct arylation of aliphatic amide containing an 8-aminoquinoline moiety with aryl iodides via a cleavage of C(sp\textsuperscript{3})-H bond. This reaction represents the first general method for functionalization of C(sp\textsuperscript{3})-H bond with nickel-catalyst.

2.2 Result and Discussion

The reaction of amide 1a (0.3 mmol) with 4-iodoanisole (0.6 mmol) in the presence of Ni(OTf)\textsubscript{2} (0.03 mmol) as a catalyst and Na\textsubscript{2}CO\textsubscript{3} (0.6 mmol) as a base in DMA (0.6 mL) at 140 °C for 24 h gave the β-arylation product 1b in 40% NMR yield along with the recovery of 44% of the unreacted 1a, and no evidence of any biarylated product or any other products produced by reaction at the methylene or γ-benzene C-H bonds was found (entry 1 in Table 1). The addition of benzoic acid as a ligand improved the yield of 1a to 70% (entry 2). Further investigation revealed that the addition of a sterically bulky carboxylic acid, such as 2,4,6-trimethylbenzoic acid (MesCOOH) or [1,1':3',1"-terphenyl]-2'-carboxylic acid (2,6-Ph\textsubscript{2}C\textsubscript{6}H\textsubscript{3}COOH), also improved the product yield (entries 3-7). The efficiency of the reaction was also significantly affected by the choice of the base used. Na\textsubscript{2}CO\textsubscript{3} was determined to be the best base for this reaction (entries 8-11). Among the solvents examined,
DMF was the solvent of choice. Curiously, not only a Ni(II) complex but also a Ni(0) complex showed a high catalytic activity, resulting in high yields of the $\beta$-arylation product (entries 15-17).

We next examined the effect of directing groups (Figure 1). The reaction did not proceed at all when the corresponding $N$-2-naphthylbenzamide 2 or the ester 3 was used. The use of other bidentate directing groups, such as 2-pyridinylmethylamine 4 or 2-(methylthio)aniline 5, also resulted in no reaction.

**Figure 1. Ineffective Directing Groups**
Table 1. Optimization of the Nickel-Catalyzed Direct Arylation of Aliphatic Amide 1a with 4-Iodoanisole

<table>
<thead>
<tr>
<th>entry</th>
<th>catalyst</th>
<th>ligand</th>
<th>base</th>
<th>solvent</th>
<th>yield (1b/1a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ni(OTf)₂</td>
<td>none</td>
<td>Na₂CO₃</td>
<td>DMA</td>
<td>40% / 44%</td>
</tr>
<tr>
<td>2</td>
<td>Ni(OTf)₂</td>
<td>PhCOOH</td>
<td>Na₂CO₃</td>
<td>DMA</td>
<td>70% / 22%</td>
</tr>
<tr>
<td>3</td>
<td>Ni(OTf)₂</td>
<td>2-PhC₆H₄COOH</td>
<td>Na₂CO₃</td>
<td>DMA</td>
<td>72% / 24%</td>
</tr>
<tr>
<td>4</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>Na₂CO₃</td>
<td>DMA</td>
<td>82% (78%) /17%</td>
</tr>
<tr>
<td>5</td>
<td>Ni(OTf)₂</td>
<td>2,6-Pr₂C₆H₄COOH</td>
<td>Na₂CO₃</td>
<td>DMA</td>
<td>74% / 23%</td>
</tr>
<tr>
<td>6</td>
<td>Ni(OTf)₂</td>
<td>2,6-PhC₆H₄COOH</td>
<td>Na₂CO₃</td>
<td>DMA</td>
<td>81% / 21%</td>
</tr>
<tr>
<td>7</td>
<td>Ni(OTf)₂</td>
<td>1-AdCOOH</td>
<td>Na₂CO₃</td>
<td>DMA</td>
<td>72% / 27%</td>
</tr>
<tr>
<td>8</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>Li₂CO₃</td>
<td>DMA</td>
<td>49% / 35%</td>
</tr>
<tr>
<td>9</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>NaHCO₃</td>
<td>DMA</td>
<td>14% / 72%</td>
</tr>
<tr>
<td>10</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>K₂CO₃</td>
<td>DMA</td>
<td>0% / 103%</td>
</tr>
<tr>
<td>11</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>NaOAc</td>
<td>DMA</td>
<td>0% / 105%</td>
</tr>
<tr>
<td>12</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>Na₂CO₃</td>
<td>DMF</td>
<td>88% (83%) /12%</td>
</tr>
<tr>
<td>13</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>Na₂CO₃</td>
<td>toluene</td>
<td>59% / 38%</td>
</tr>
<tr>
<td>14</td>
<td>Ni(OTf)₂</td>
<td>MesCOOH</td>
<td>Na₂CO₃</td>
<td>AcOH</td>
<td>0% / 99%</td>
</tr>
<tr>
<td>15</td>
<td>NiCl₂</td>
<td>MesCOOH</td>
<td>Na₂CO₃</td>
<td>DMF</td>
<td>81% / 10%</td>
</tr>
<tr>
<td>16</td>
<td>Ni(OAc)₂</td>
<td>MesCOOH</td>
<td>Na₂CO₃</td>
<td>DMF</td>
<td>81% / 10%</td>
</tr>
<tr>
<td>17</td>
<td>Ni(cod)₂</td>
<td>MesCOOH</td>
<td>Na₂CO₃</td>
<td>DMF</td>
<td>79% / 10%</td>
</tr>
</tbody>
</table>

a Reaction conditions: amide 1a (0.3 mmol), 4-iodoanisole (0.6 mmol), catalyst (0.03 mmol), ligand (0.06 mmol), base (0.6 mmol) in solvent (0.6 mL) at 140 °C for 24 h. b NMR yields. The number in parenthesis is the isolated yield.

Table 2 shows the scope of the substrates under the standard reaction conditions. Aliphatic amides possessing three substituents at the α-position reacted efficiently. The reactions proceeded exclusively at the methyl group in a highly regioselective manner, as in the cases of 6, 7, 8, and 9, and methylene and benzene C-H bonds were not arylated. Although the reaction of 1-methylcyclohexanecarboxamide 10a resulted in selective mono arylation only at the methyl group, 1-methylcycloheptanecarboxamide 11a gave a mixture of monoarylated
11b and biarylated products 11c, the latter involving the arylation at the cyclic methylene C-H bonds. When 1-phenylcyclobutanecarboxamide 12a and 1-phenylcyclopentanecarboxamide 13a were used, the cleavage of $\beta$-methylene C-H bonds was the predominant reaction and $\gamma$-benzenes C(sp$^2$)-H bonds reacted to a lesser extent. The structure of 12c was confirmed from X-ray crystallography, which show that the introduced aryl groups are located syn to the directing group. This also indicates the importance of the directing group. The presence of two substituents on the $\alpha$-carbon, as in 14a resulted in a low conversion and the arylation product 14b was obtained in 30% yield.

Phenyl bromides and triflates did not give arylation products (Table 3). The scope of aryl iodides with various substituents at the para position was examined using 1a as the substrate (Table 3). The results showed that common functional groups, including esters, iodide, bromides, chlorides and amines, were compatible in the present reaction. Electron rich aryl iodides tended to give the products in slightly higher yields than electron poor aryl iodides. Ortho-substituted aryl iodides resulted in no reaction. The heterocyclic aryl iodide, such as thiophene and indole gave the arylated product.

A gram scale reaction of 6a was successfully performed in a 30-mL two-necked flask under the 5 mol% of nickel catalyst (eq 1).
Table 2. The Nickel-Catalyzed Direct Arylation of Aliphatic Amides with 4-Iodoanisole\(^a\)

<table>
<thead>
<tr>
<th>Amide Structure</th>
<th>Yield (Isolated)</th>
<th>Recovery Yields</th>
</tr>
</thead>
<tbody>
<tr>
<td>6b</td>
<td>72% (10%)</td>
<td></td>
</tr>
<tr>
<td>7b</td>
<td>50% (32%)</td>
<td></td>
</tr>
<tr>
<td>8b</td>
<td>56% (31%)</td>
<td></td>
</tr>
<tr>
<td>9b</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>10b</td>
<td>61% (26%)</td>
<td></td>
</tr>
<tr>
<td>11b</td>
<td>41%</td>
<td></td>
</tr>
<tr>
<td>11c</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>12b</td>
<td>50%</td>
<td>12% (^b)</td>
</tr>
<tr>
<td>12c</td>
<td>33% (15%)</td>
<td>62% (0%) (^b)</td>
</tr>
<tr>
<td>13b</td>
<td>41%</td>
<td>42% (^b)</td>
</tr>
<tr>
<td>13c</td>
<td>8% (40%)</td>
<td>18% (14%) (^b)</td>
</tr>
<tr>
<td>14b</td>
<td>30% (40%)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Reaction conditions: amide (0.3 mmol), aryl iodides (0.6 mmol), Ni(OTf)\(_2\) (0.03 mmol), MesCOOH (0.06 mmol), Na\(_2\)CO\(_3\) (0.6 mmol) in DMF (0.6 mL) at 140 °C for 24 h. Isolated yields by column chromatography. The number in parenthesis is the yield of the recovered starting amide. \(^b\) [1,1’:3’,1”-terphenyl]-2’-carboxylic acid (2,6-Ph\(_2\)C\(_6\)H\(_3\)COOH) was used instead of MesCOOH and 4-iodoanisole (0.9 mol) was used.
**Table 3. Scope of Aryl Halides in Ni-Catalyzed Direct Arylation of C(sp³)-H Bonds**

<table>
<thead>
<tr>
<th>Aryl Halide</th>
<th>Product</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph-I 1c</td>
<td>R = p-CF₃ 1d</td>
<td>49% (22%)</td>
</tr>
<tr>
<td>Ph-Br</td>
<td>R = p-CO₂Me 1e</td>
<td>44% (19%)</td>
</tr>
<tr>
<td>Ph-OTf</td>
<td>R = p-I 1f</td>
<td>61% (trace)</td>
</tr>
<tr>
<td></td>
<td>R = p-Cl 1g</td>
<td>60% (12%)</td>
</tr>
<tr>
<td></td>
<td>R = p-Me 1h</td>
<td>76% (13%)</td>
</tr>
<tr>
<td></td>
<td>R = p-OMe 1i</td>
<td>83% (12%)</td>
</tr>
<tr>
<td></td>
<td>R = p-NH₂ 1j</td>
<td>68% (10%)</td>
</tr>
<tr>
<td></td>
<td>R = p-NMe₂ 1k</td>
<td>75% (12%)</td>
</tr>
<tr>
<td></td>
<td>o-Me 1l</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Reaction conditions:** amide (0.3 mmol), aryl iodides (0.6 mmol), Ni(OTf)₂ (0.03 mmol), MesCOOH (0.06 mmol), Na₂CO₃ (0.6 mmol) in DMF (0.6 mL) at 140 °C for 24 h. The number in parentheses is the yield of recovered starting amides. b NMR yields. c Purified by GPC.

To gain additional insights into the mechanism for the reaction, deuterium labeling experiments were carried out (Scheme 1). The deuterated amides 1a-d3 were reacted with 4-iodoanisole for 3h under standard conditions (Scheme 1). A significant amount of H/D exchange between the methyl C-D bond and N-H bond was detected. Thus, the D content in the recovered amide decreased from >99% to 76%, and the D content of the amide nitrogen increased from 0% to 23%. A significant amount of H/D exchange was observed, even in the absence of 4-iodoanisole. These results suggest that the cleavage of C-H bonds is rapid and reversible, and the cleavage of C-H bonds occurs before the reaction with the aryl iodide.
Scheme 1. Deuterium Labeling Experiments

\[
\begin{align*}
\text{Ni(cod)$_2$} & : 67\% \quad \text{(32\%)} \\
\text{Ni(OTf)$_2$} & : 65\% \quad \text{(36\%)}
\end{align*}
\]

Product distribution was examined in detail, in order to develop a better understanding of the difference between Ni(0) and Ni(II)-catalyzed reactions (Scheme 2). In the reaction of 1a with 1-butyl-4-iodobenzene in the presence of 30 mol\% Ni(cod)$_2$, the arylation product 1o was obtained in 67\% NMR yield with 32\% of the starting amide 1a being recovered. When Ni(0) was used, butylbenzene was produced in 86\% yield/Ni(0) and no biaryl derivative was formed. In sharp contrast, when Ni(OTf)$_2$ was used as the catalyst, neither butylbenzene nor biaryl were detected. The arylation product 1o was obtained in 65\% NMR yield with 36\% of the starting amide being recovered, along with the corresponding amount of 4-iodo-biphenyl. It is known that Ni(0) complexes react with Ar-X to give homocoupling products Ar-Ar with
the generation of a Ni(II) complex, however the results in Scheme 2 indicate that such a reaction did not take place. Instead, the results suggest that the Ni(0) complex was oxidized by 1-butyl-4-iodobenzene with the generation of butylbenzene. The source of hydrogen is probably the N-H bonds of the amide. The results of the above analyses indicate that the catalytic active species in this reaction is not Ni(0)-complex but rather, the Ni(II) complex.

Scheme 3. Deuterium Labeling Experiments with Ni(0)-Catalyst

To gain more information, deuterium labeling experiment using nickel(0)-catalyst was examined. The deuterated amides 1a-d3 were reacted with Ni(0)-catalyst for 3h under standard conditions (Scheme 3). As the result with Ni(II)-catalyst, the H/D exchange at methyl group was observed (Scheme 1). Contrast to the Ni(II)-catalyst, the H/D exchange did not take place in the case of the absence of 4-iodoanisole, suggesting that the presence of an aryl iodide is required for the cleavage of C-H bonds with Ni(0)-catalyst to take place. These results also indicate that Ni(0)-complex was not catalytic active species and Ni(0)-complex was oxidized by the aryl iodide to generate Ni(II)-complex.

A proposed mechanism for the reaction is shown in Scheme 4. Coordination of the amide to the Ni center followed by ligand exchange with the concomitant generation of HX gives the Ni complex 15, which undergoes reversible cyclometalation to give 16 probably via a concerted-metalation–deprotonation mechanism. The oxidative addition of iodobenzene gives the high-valent Ni(IV) complex 17 which is stabilized by the N,N-bidentate directing group. The Ni(IV) complex 17 underwent reductive elimination to give 18, which, on protonation, affords the desired arylation product with the regeneration of Ni(II). In the case of the Ni(0)-catalyst, the reaction of the Ni(0) complex and iodobenzene gives the aryl-nickel species, following protonation or ligand exchange with amide N-H and protonation to give the Ni(II) complex 15 with the generation of benzene. In order to gain additional insight into the mechanism, we performed some radical trapping experiments. The addition of
2,2,6,6-tetramethyl-1-piperidinoxyl (TEMPO) did not inhibit the reaction and the arylation product was obtained in moderate yield (53%). This suggests that a single electron transfer (SET) was not involved in this reaction.

Scheme 4. Proposed Mechanism

Not only aryl iodide but also diaryliodonium salt is applicable as an arylated reagent (eq 2). Although the addition of a sterically bulky carboxylic acid was required for the reaction with aryl iodides, the arylated product was obtained in the absence of a carboxylic acid. A Ni(II)/Ni(IV) cycle is also operable in this reaction.

2.3 Conclusion

In summary, we report on the first example of the nickel-catalyzed direct arylation of unactivated C(sp³)-H bonds in aliphatic amides having 8-aminoquinoline moiety as a bidentate directing group with aryl halides and diaryliodonium salts. Some mechanistic experiments revealed that the reaction proceeded via not Ni(0)/Ni(II) or Ni(I)/Ni(III) cycle but Ni(II)/Ni(IV) cycle, which is not common for nickel-catalyzed cross coupling reaction. After
published this paper, about 10 reports about the Ni(II)-catalyzed functionalization of C(sp³)-H bonds using a combination of nickel(II)-catalyst and bidentate directing group were reported by another researchers.¹²

2.4 Experimental Section

General Information.

¹H NMR and ¹³C NMR spectra were recorded on a JEOL ECS-400 spectrometer in CDCl₃ with tetramethylsilane as the internal standard. The data is reported as follows: chemical shift (δ) in ppm, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, br = broad peak, and m = multiplet), coupling constant (Hz), and integration. Infrared spectra (IR) were obtained using a Horiba FT-700 spectrometer. Absorption is reported in reciprocal centimeters (cm⁻¹) with the following relative intensities: s (strong), m (medium), or w (weak). Mass spectra were obtained on a Shimadzu GCMS-QP 2010 instrument. High resolution mass spectra (HRMS) were obtained using a JEOL JMS-DX303 spectrometer. Melting points were determined using a SRS MPA 100 instrument. Column chromatography was performed with SiO₂ (Silicycle SilicaFlash F60 (230-400 mesh)). Some compounds were purified by LC-908 HPLC (GPC). X-Ray crystallographic structure analysis performed on Rigaku R-AXIS RAPID imaging plate diffract meter with graphite monochromated Cu Kα radiation (λ= 1.54187 Å).

Materials.

Na₂CO₃ (CAS 497-19-8) was purchased from Nacalai Tesque, Inc. 4-Iodoanisole (CAS 696-62-8) and 8-Aminoquinoline (CAS 578-66-5), 2,4,6-Trimethylbenzoic Acid (CAS 480-63-7) and methyl 2-methylbenzoate (CAS 89-71-4 ) were purchased from Tokyo Kasei Kogyo Co., Ltd. N,N-dimethylformamide, super dehydrated (CAS 68-12-2) was purchased from Wako Pure Chemicals. Ni(OTf)₂ ( CAS 60871-84-3) was prepared by chapter 1 procedure.

Synthesis of the Starting Amides.

All amides bearing an 8-aminoquinoline moiety were prepared by the reaction of the corresponding acid chlorides with 8- aminoquinoline. 1-Phenylcyclobutanecarboxylic acid (SM for 12a) was synthesized by a literature procedure.¹³ 2-Phenyheptanoic acid (SM for 1a-d₃ ) was synthesized by a literature procedure.¹⁴ 1-Methyl-N-(quinolin-8-yl)cyclohexanecarboxamide 10a (CAS 1429896-59-2) and 2-methyl-2-phenyl-N-(quinolin-8-yl)propanamide 9a (CAS 1327475-16-0) were prepared by a literature procedure.¹⁵ All spectrum data of starting amides are cited in original paper.¹⁶

General Procedure for the Preparation of the Starting Carboxylic Acid.
A solution of n-buthyllithium in hexane (1.6M, 15 mL, 24 mmol) was added dropwise to a solution of diisopropylamine (2.4 g, 24 mmol) in 30 mL of THF at -78 °C. The solution was stirred for 1h and a solution of methyl 2-phenylpropanoate (3.3 g, 20 mmol) in 10 mL of THF was added dropwise to the LDA solution. The solution was stirred for 1h at -78 °C and 1-bromopentane (6.0 g, 40 mmol) was added dropwise to the solution. The solution was stirred for 1 h at -78 °C and then 4h at r.t. The reaction mixture was quenched with water and the organic layer was separated. The aqueous layer was extracted with ether (2 x 15 mL). The combined organic layers were washed with brine (30 mL), dried over MgSO₄, filtered and evaporated in vacuo to give the desired methyl 2-methyl-2-phenylheptanoate (4.5 g, 96%).

The ester was hydrolyzed in 30 mL of 4N NaOH aq. and MeOH at 100 °C for 1 day. After cooling the solution, the aqueous layer was extracted with DCM (2 x 15 mL). The aqueous layer was acidified with aqueous HCl and the aqueous layer was extracted with DCM (2 x 15 mL) and brine (30 mL), dried over MgSO₄, filtered and evaporated in vacuo to give the desired carboxylic acid (2.9 g, 70%).

2-Butyl-2-methylhexanoic acid (SM for 7a) was synthesized by the reaction of methyl 2-butylnhexanoate with methyl iodide. 2-Benzyl-2-methylbutanoic acid (SM for 8a) was synthesized by the reaction of methyl 2-methyl-3-phenylpropanoate with ethyl iodide. 1-Methylcycloheptanecarboxylic acid (SM for 11a) was synthesized by the reaction of methyl cycloheptanecarboxylate with methyl iodide. 2-Cyclohexylpropanoic acid (SM for 14a) was synthesized by the reaction of methyl 2-cyclohexylacetate with methyl iodide. 2-methyl-d₃-2-phenylheptanoic acid (SM for 1a-d₃) was synthesized by the reaction of methyl 2-phenylheptanoate with methyl iodide-d₃.

**General Procedure for the Preparation of Starting Amide.**

To an oven-dried 100 mL three-necked flask, 2-methyl-2-phenylheptanoic acid (3.3 g, 15 mmol), DMF (5 drops) and DCM (30 mL) were added under a N₂ atmosphere. Oxalyl chloride (1.5 mL, 18 mmol, 1.2 equiv.) was added dropwise at 0 °C resulting in vigorous bubbling. The mixture was stirred for 3 h at room temperature, and the solvent was then
removed in vacuo. The resulting acid chloride was used immediately without further purification. To another oven-dried 100 mL three-necked flask, 8-aminoquinoline (2.9 g, 20 mmol, 1.3 equiv.), Et₃N (4.1 mL, 30 mmol, 2 equiv.) and DCM (30 mL) were added. A solution of the acid chloride in DCM (10 mL) was added dropwise to the solution at 0 °C, and the solution was then warmed to room temperature. After stirring overnight, the reaction system was quenched with sat. aq. NaHCO₃ (30 mL) and the organic layer was separated. The aqueous layer was extracted with DCM (2 x 15 mL). The combined organic layers were washed with 1 M HCl aq. (30 mL) and brine (30 mL), dried over MgSO₄, filtered and evaporated in vacuo. The resulting crude amide was purified by column chromatography on silica gel (eluant: hexane/EtOAc = 5/1) to afford the desired amide as a white solid (4.6 g, 90%).

General Procedure for Direct Arylation: Ni-Catalyzed Arylation of Amides 1a with 4-iodoanisole.

To an oven-dried 5 mL screw-capped vial, in a glove box 2-methyl-2-phenyl-N-(quinolin-8-yl)heptanamide 1a (104 mg, 0.3 mmol), 4-iodoanisole (140 mg, 0.6 mmol), Ni(OTf)₂ (10.6 mg, 0.03 mmol), MesCOOH (9.8 mg, 0.06 mmol), Na₂CO₃ (64 mg, 0.6 mmol) and DMF (0.6 mL) were added. The mixture was stirred for 24 h at 140 °C followed by cooling. 30 mL of water was added to the reaction mixture and the aqueous layer was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with and brine (20 mL), dried over MgSO₄, filtered and evaporated in vacuo. The residue was purified by column chromatography on silica gel (eluent: hexane/EtOAc= 20/1) to afford the desired arylated product 1b (112 mg, 83%) as a white solid.

2-(4-methoxybenzyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1b).

Rf 0.34 (hexane/EtOAc = 5/1). White Solid. Mp = 144 °C. ¹H NMR (CDCl₃, 399.78 MHz) 0.83 (t, J = 6.4 Hz, 3H), 1.26-1.55 (m, 6H), 2.01 (t, J = 8.0, 2H), 3.35 (d, J = 14.0 Hz, 1H), 3.51 (d, J = 13.6 Hz, 1H), 3.72 (s, 3H), 6.64 (s, 4H), 7.25-7.36 (m, 6H), 7.46 (d, J = 8.0, 1H), 7.54 (t, J = 8.4 Hz, 1H), 8.08 (d, J = 16.0 Hz, 1H), 8.69 (dd, J = 4.0, 1.2 Hz, 1H), 8.78 (d, J = 7.6 Hz, 1H), 9.80 (brs, 1H); ¹³C NMR (CDCl₃, 100.53 MHz) 14.03, 22.42, 24.06, 32.31, 33.99, 40.79, 55.05, 56.60, 113.00, 116.02, 21.012, 121.40, 126.96, 127.32, 127.66, 127.84, 128.39, 129.30, 131.24, 134.65, 138.62, 142.99, 148.11, 158.01, 174.67; IR (neat) 3343 w, 2934 w, 1712 m, 1683 m, 1522 s, 1424 m, 1325 m, 1247 m, 1036 w, 825 m, 754 m; MS m/z
(relative intensity, %) 452 (M⁺, 23), 264 (26), 167 (67), 144 (34), 119 (100), 13 (13); HRMS Calcd for C₃₀H₃₂N₂O₂: 452.2464; Found: 452.2469.

3-(4-methoxyphenyl)-2,2-diphenyl-N-(quinolin-8-yl)propanamide (6b).

Rᶠ 0.20 (hexane/EtOAc = 5/1). White Solid. Mp =164 °C. ¹H NMR (CDCl₃, 399.78 MHz) 3.68 (s, 3H), 3.85 (s, 2H), 6.56 (d, J = 8.8 Hz, 2H), 6.73 (d, J = 8.8 Hz, 2H), 7.54-7.32 (m, 7H), 7.36-7.38 (m, 4H), 7.42 (d, J = 8.0 Hz, 1H), 7.50 (t, J = 8.0 Hz, 1H), 8.04 (d, J = 8.4 Hz, 1H), 8.52 (dd, J = 4.0, 1.2 Hz, 1H), 8.78 (dd, J = 8.0, 1.2 Hz, 1H), 10.23 (brs, 1H); ¹³C NMR (CDCl₃, 100.53 MHz) 43.59, 55.02, 64.45, 112.75, 115.98, 121.29, 121.40, 126.97, 127.24, 127.78, 128.02, 129.70, 129.79, 132.15, 134.65, 135.96, 138.66, 142.35, 148.07, 157.88, 172.18; IR (neat) 3330 w, 1679 m, 1512 s, 1484 m, 1384 m, 1326 m, 1250 m, 1178 w, 1036 w, 825 m, 753 s, 700 m; MS m/z (relative intensity, %) 458 (M⁺, 12), 337 (29), 265 (10), 264 (51), 171 (40), 165 (13), 144 (17), 121 (100); HRMS Calcd for C₃₁H₂₆N₂O₂: 458.1994; Found: 458.1995.

2-butyl-2-(4-methoxybenzyl)-N-(quinolin-8-yl)hexanamide (7b).

Rᶠ 0.31 (hexane/EtOAc = 5/1). Pale Brown Solid. Mp =97-98 °C. ¹H NMR (CDCl₃, 399.78 MHz) 0.92 (t, J = 6.8 Hz, 6H), 1.32-1.38 (m, 8H), 1.59-1.80 (m, 4H), 3.01 (s, 2H), 3.69 (s, 3H), 6.70 (d, J = 8.8 Hz, 2H), 7.05 (d, J = 8.4 Hz, 2H), 7.42 (dd, J = 8.4, 4.0, 1H), 7.48-7.57 (m, 2H), 8.14 (dd, J = 8.4, 1.6 Hz, 1H), 8.74 (dd, J = 4.4, 1.6 Hz, 1H), 8.82 (dd, J = 8.0, 1.6 Hz, 1H), 10.15 (brs, 1H); ¹³C NMR (CDCl₃, 100.53 MHz) 14.05, 23.24, 26.25, 34.27, 40.18, 51.64, 55.04, 113.35, 116.23, 11.12, 121.45, 127.44, 127.87, 129.80, 130.92, 134.45, 136.16, 138.75, 148.11, 157.98, 175.39; IR (neat) 3361 w, 2931 w, 1672 m, 1524 s, 1466 m, 1423 m, 1384 m, 1325 m, 1249 m, 1178 w, 1038 w, 825 m, 792 m; MS m/z (relative intensity, %) 418 (M⁺, 23), 361 (10), 297 (10), 246 (14), 217 (31), 171 (47), 145 (10), 144 (67), 121 (100); HRMS Calcd for C₂₇H₅₄N₂O₂: 418.2620; Found: 418.2617.

2-benzyl-2-(4-methoxybenzyl)-N-(quinolin-8-yl)butanamide (8b).
Rf 0.29 (hexane/EtOAc = 5/1). Pale Brown Solid. Mp = 97-98 °C. 1H NMR (CDCl3, 399.78 MHz) 1.18 (t, J = 7.2 Hz, 3H), 1.75 (q, J = 7.2 Hz, 2H), 2.95 (dd, J = 20.8, 13.6 Hz, 2H), 3.29 (dd, J = 25.6, 14.0 Hz, 2H), 3.64 (s, 3H), 6.66 (d, J = 8.0 Hz, 2H), 7.07-7.21 (m, 7H), 7.36 (dd, J = 8.4, 4.0 Hz, 1H), 7.47 (d, J = 8.4 Hz, 1H), 7.55 (t, J = 8.0 Hz, 1H), 8.09 (d, J = 8.4 Hz, 1H), 8.60 (dd, J = 4.0, 1.2 Hz, 1H), 8.86 (dd, J = 8.0, 1.2 Hz, 1H), 9.95 (broad s, 1H); 13C NMR (CDCl3, 100.53 MHz) 8.68, 23.84, 41.54, 53.25, 55.00, 113.37, 116.25, 121.36, 126.24, 127.34, 127.75, 128.00, 129.50, 130.11, 131.03, 134.21, 136.02, 137.69, 138.62, 147.96, 158.00, 174.57; IR (neat) 3366 w, 2931 w, 1679 m, 1525 s, 1325 w, 1245 m, 1179 w, 1036 w, 826 w; MS m/z (relative intensity, %) 424 (M+, 8), 334 (14), 333 (60), 190 (12), 189 (100), 171 (31), 144 (25), 121 (73) 91 (26); HRMS Calcd for C28H28N2O2: 424.2151; Found: 424.2145

3-(4-methoxyphenyl)-2-methyl-2-phenyl-N-(quinolin-8-yl)propanamide (9b).

Rf 0.23 (hexane/EtOAc = 5/1). White Solid. Mp = 136 °C. 1H NMR (CDCl3, 399.78 MHz) 1.68 (s, 3H), 3.34 (d, J = 13.6 Hz, 2H), 3.56 (d, J = 13.6 Hz, 1H), 3.71 (s, 3H), 6.66 (d, J = 8.8 Hz, 2H), 6.79 (d, J = 8.8 Hz, 2H), 7.27-7.38 (m, 4H), 7.43-7.45 (m, 3H), 7.52 (t, J = 8.4 Hz, 1H), 8.06 (dd, J = 4.0, 1.6 Hz, 1H), 8.57 (dd, J = 4.0, 1.6 Hz, 1H), 8.80 (d, J = 8.0 Hz, 1H), 9.89 (broad s, 1H); 13C NMR (CDCl3, 100.53 MHz) 22.80, 44.34, 52.89, 55.05, 113.06, 116.00, 121.24, 121.40, 127.08, 127.22, 127.79, 128.53, 129.47, 131.53, 134.60, 136.04, 138.58, 143.16, 148.09, 158.05, 175.12; IR (neat) 3351 w, 1679 w, 1525 s, 1484 m, 1384 m, 1326 m, 1245 m, 1034 w, 824 m, 755 m; MS m/z (relative intensity, %) 396 (M+, 9), 171 (40), 144 (23), 121 (100), 103 (16); HRMS Calcd for C26H24N2O2: 396.1838; Found: 396.1838.

2-(4-methoxybenzyl)-3-(4-methoxyphenyl)-2-phenyl-N-(quinolin-8-yl)propanamide (9c).
Rf 0.11 (hexane/EtOAc = 5/1). White Solid. Mp =157 °C. \( ^1\)H NMR (CDCl\(_3\), 399.78 MHz) 3.43 (q, J = 10.8 Hz, 4H), 3.69 (s, 6H), 6.64 (d, J = 8.8 Hz, 4H), 6.87 (d, J = 8.8 Hz, 4H), 7.27-7.37 (m, 6H), 7.44 (d, J = 8.4 Hz, 1H), 7.52 (t, J = 8.4 Hz, 1H), 8.06 (dd, J = 8.0, 1.2 Hz, 1H), 8.52 (dd, J = 4.0, 1.2 Hz, 1H), 8.73 (d, J = 7.2 Hz, 1H), 9.87 (brs, 1H); \( ^{13}\)C NMR (CDCl\(_3\), 100.53 MHz) 40.93, 55.01, 58.20, 113.12, 116.04, 121.15, 121.36, 127.16, 127.30, 127.78, 128.15, 128.38, 129.11, 131.55, 134.44, 135.94, 138.53, 142.40, 148.06, 158.03, 173.84; IR (neat) 3338 w, 1685 m, 1610 w, 1512 s, 1484 m, 1325 w, 1248 m, 1179 m, 1035 m, 824 m, 754 m; MS m/z (relative intensity, %) 502 (M\(^+\), 2), 382 (19), 381 (69), 264 (13), 237 (50), 209 (17), 171 (46), 144 (10), 121 (100); HRMS Calcd for C\(_{33}\)H\(_{30}\)N\(_2\)O\(_3\): 502.2249; Found: 502.2256.

1-(4-methoxybenzyl)-N-(quinolin-8-yl)cyclohexanecarboxamide (10b).

Rf 0.31 (hexane/EtOAc = 5/1). Colorless oil. \( ^1\)H NMR (CDCl\(_3\), 399.78 MHz) 1.32-1.75 (m, 8H), 2.22-2.25 (m, 2H), 2.90 (s, 2H), 3.61 (s, 3H), 6.61 (d, J = 8.4 Hz, 2H), 7.01 (d, J = 8.4 Hz, 2H), 7.40 (dd, J = 8.4, 4.0 Hz, 1H), 7.47 (dd, J = 8.0, 4.0, 1H), 7.54 (t, J = 8.4 Hz, 1H), 8.12 (dd, J = 8.4, 2.0 Hz, 1H), 8.69 (dd, J = 4.0, 2.0 Hz, 1H), 8.80 (dd, J = 8.0, 1.6 Hz, 1H), 10.01 (brs, 1H); \( ^{13}\)C NMR (CDCl\(_3\), 100.53 MHz) 23.11, 25.92, 34.12, 46.40, 49.61, 54.99, 113.20, 116.22, 121.09, 121.36, 127.39, 127.81, 129.13, 130.99, 134.47, 136.09, 138.70, 148.02, 158.08, 174.69; IR (neat) 3359 w, 2928 w, 1672 m, 1512 s, 1468 m, 1324 m, 1245 s, 1178 m, 1035 m, 792 m, 753 s; MS m/z (relative intensity, %) 374 (M\(^+\), 17), 253 (14), 202 (13), 171 (44), 145 (10), 144 (68), 121 (100), 109 (10); HRMS Calcd for C\(_{24}\)H\(_{26}\)N\(_2\)O\(_2\): 374.1990; Found: 374.1994.

1-(4-methoxybenzyl)-N-(quinolin-8-yl)cycloheptanecarboxamide (11b).
R_f 0.34 (hexane/EtOAc = 5/1). Pale yellow oil. ^1^H NMR (CDCl$_3$, 399.78 MHz) 1.58-1.78 (m, 10 H), 2.22-2.28 (m, 2H), 2.93 (s, 2H), 3.63 (s, 3H), 6.63 (d, J = 8.8 Hz, 2H), 7.03 (d, J = 8.4 Hz, 2H), 7.41 (dd, J = 8.4, 4.0 Hz, 1H), 7.48 (dd, J = 8.4, 1.6 Hz, 1H), 7.54 (t, J = 8.0 Hz, 1H), 8.13 (dd, J = 8.0, 1.6 Hz, 1H), 8.71 (dd, J = 4.0, 1.6 Hz, 1H), 8.82 (dd, J = 8.0, 1.2 Hz, 1H), 10.02 (brs, 1 H); \(^{13}\)C NMR (CDCl$_3$, 100.53 MHz) 23.46, 30.02, 36.10, 46.90, 52.45, 55.00, 113.23, 116.18, 121.08, 121.39, 127.43, 127.83, 129.71, 131.01, 134.59, 136.13, 138.69, 148.03, 158.05, 175.87; IR (neat) 3359 w, 2924 w, 1672 m, 1523 s, 1465 m, 1324 m, 1246 s, 1178 m, 1036 m, 753 s; MS m/z (relative intensity, %) 388 (M$^+$, 26), 267 (20), 216 (14), 171 (56), 145 (13), 144 (93), 121 (100); HRMS Calcd for C$_{25}$H$_{28}$N$_2$O$_2$: 388.2152; Found: 388.2152.

1-(4-methoxybenzyl)-2-(4-methoxyphenyl)-N-(quinolin-8-yl)cycloheptanecarboxamide (11c).

R_f 0.23 (hexane/EtOAc = 5/1). White Solid. Mp = 79-80 °C. \(^1^H\) NMR (CDCl$_3$, 399.78 MHz) 1.44-1.68 (m, 5H), 1.92-1.95 (m, 3H), 2.31-2.49 (m, 3H), 2.79 (t, J = 10.0 Hz, 1H), 2.98 (d, J = 13.6 Hz, 1H), 3.11 (d, J = 14.0 Hz, 1H), 3.64 (s, 3H), 3.82 (s, 3H), 6.60 (d, J = 8.0 Hz, 1H), 6.86 (d, J = 8.4 Hz, 1H), 6.99 (d, J = 8.4 Hz, 1H), 7.16 (d, J = 8.4 Hz, 1H), 7.41 (dd, J = 8.0, 4.0 Hz, 1H), 7.48-7.56 (m, 2H), 8.13 (d, J = 8.4 Hz, 1H), 8.72 (d, J = 4.4 Hz, 1H), 8.80 (d, J = 7.2 Hz, 1H), 10.12 (brs, 1 H); \(^{13}\)C NMR (CDCl$_3$, 100.53 MHz) 23.76, 31.07, 35.74, 40.07, 40.74, 43.83, 45.85, 51.88, 55.02, 55.25, 113.37, 113.80, 116.26, 121.19, 121.45, 127.42 (two overlapping peaks), 127.85, 129.50, 131.01, 134.56, 136.18, 142.01, 148.14, 157.58, 158.07, 175.92; IR (neat) 3358 w, 2924 w, 1670 m, 1611 m, 1511 s, 1484 m, 1325 m, 1245 s, 1178 m, 1035 m, 824 m, 752 s; MS m/z (relative intensity, %) 495 (18), 494 (M$^+$, 43), 373 (18), 172 (10), 171 (68), 145 (11), 144 (63), 122 (10), 121 (100); HRMS Calcd for C$_{32}$H$_{34}$N$_2$O$_3$: 494.2569; Found: 494.2568.

2-(4-methoxyphenyl)-1-phenyl-N-(quinolin-8-yl)cyclobutanecarboxamide (12b).
2,4-bis(4-methoxyphenyl)-1-phenyl-N-(quinolin-8-yl)cyclobutanecarboxamide (12c).

R_f 0.20 (hexane/EtOAc = 5/1). White Solid. Mp =87 °C. ¹H NMR (CDCl₃, 399.78 MHz) 2.72 (q, 8.0 Hz, 1H), 3.49 (q, J = 10.4 Hz, 1H), 3.69 (s, 6H), 4.09 (dd, J = 10.8, 8.0 Hz, 1H), 6.78 (d, J = 8.8 Hz, 4H), 7.20 (dd, J = 8.0, 4.0 Hz, 1H), 7.27-7.34 (m, 2H), 7.43-7.48 (m, 5H), 7.34 (t, J = 7.6 Hz, 2H), 7.68 (d, J = 8.4 Hz, 2H), 7.92 (dd, J = 8.0, 1.6 Hz, 1H), 8.31 (dd, J = 4.4, 1.6 Hz, 1H), 8.44 (dd, J = 7.6, 1.6 Hz, 1H), 9.38 (brs, 1H); ¹³C NMR (CDCl₃, 100.53 MHz) 30.83, 47.16, 55.11, 67.56, 113.38, 115.90, 120.87, 121.01, 127.06, 127.32, 127.45, 129.08, 129.57, 132.57, 134.32, 135.64, 138.51, 145.12, 147.58, 158.14, 169.56; IR (neat) 3318 w, 1674 m, 1610 w, 1512 s, 1483 m, 1326 w, 1248 s, 1178 m, 1035 m, 852 m, 755 m; MS m/z (relative intensity, %) 514 (M⁺, 9), 381 (12), 380 (41), 525 (12), 251 (67), 238 (17), 237 (100), 210 (14), 209 (80), 171 (13), 165 (14), 144 (21); HRMS Calcd for C₁₉H₁₆N₂O₃: 514.2256; Found: 514.2253.

2-(4-methoxyphenyl)-1-phenyl-N-(quinolin-8-yl)cyclopentanecarboxamide (13b).
2,5-bis(4-methoxyphenyl)-1-phenyl-N-(quinolin-8-yl)cyclopentanecarboxamide (13c).

R<sub>f</sub> 0.23 (hexane/EtOAc = 5/1). White Solid. Mp = 130 °C. <sup>1</sup>H NMR (CDCl<sub>3</sub>, 399.78 MHz) 1.74-1.81 (m, 1H), 2.14-2.33 (m, 4H), 3.40-3.11 (m, 1H), 3.53 (s, 3H), 3.92 (t, J = 8.0 Hz, 2H), 7.97 (dd, J = 8.0, 1.6 Hz, 1H), 8.39 (dd, J = 4.4, 1.6 Hz, 1H), 8.56 (dd, J = 8.0, 1.6 Hz, 1H), 9.35 (brs, 1H); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100.53 MHz) 22.42, 33.28, 38.24, 52.76, 54.90, 64.91, 113.25, 115.63, 120.87, 121.10, 126.89, 127.10, 127.51, 128.63, 129.92, 134.07, 134.49, 138.40, 144.08, 147.65, 157.92, 173.31; IR (neat) 3326 w, 2952 w, 1672 m, 1520 s, 1484 s, 1384 m, 1247 s, 1180 m, 1035 m, 826 m; MS m/z (relative intensity, %) 423 (13), 422 (M<sup>+</sup>, 40), 276 (20), 275 (100), 257 (16), 250 (26), 172 (10), 171 (70), 147 (12), 145 (10), 144 (76), 117 (18), 103 (30), 91 (10); HRMS Calcd for C<sub>28</sub>H<sub>26</sub>N<sub>2</sub>O<sub>2</sub>: 422.1994; Found: 422.1992.

2-cyclohexyl-3-(4-methoxyphenyl)-N-(quinolin-8-yl)propanamide (14b).

R<sub>f</sub> 0.23 (hexane/EtOAc = 5/1). White Solid. Mp = 130 °C. <sup>1</sup>H NMR (CDCl<sub>3</sub>, 399.78 MHz) 2.31-2.38 (m, 2H), 2.81-2.86 (m, 2H), 3.57 (s, 6H), 3.74-3.78 (m, 2H), 6.57 (d, J = 8.8 Hz, 4H), 7.16 (dd, J = 8.4, 4.0 Hz, 1H), 7.23 (d, J = 8.4 Hz, 4H), 7.26-7.33 (m, 5H), 7.37 (dd, J = 8.0, 1.6 Hz, 1H), 7.95 (dd, J = 8.0, 1.6 Hz, 1H), 8.16 (dd, J = 4.0, 1.6 Hz, 1H), 8.76 (dd, J = 7.2, 1.6 Hz, 1H), 9.15 (brs, 1H); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100.53 MHz) 30.71, 54.94, 56.84, 69.23, 113.02, 115.78, 120.93, 120.98, 127.03, 127.11, 127.50, 127.96, 129.26, 130.79, 132.30, 134.53, 135.44, 138.46, 140.53, 147.51, 158.08, 171.52; IR (neat) 3325 w, 2933 w, 1672 m, 1513 s, 1483 m, 1246 s, 1179 m, 1036 m, 826 m; MS m/z (relative intensity, %) 529 (12), 528 (M<sup>+</sup>, 28), 395 (10), 394 (34), 381 (29), 356 (12), 250 (16), 238 (17), 237 (94), 223 (14), 210 (12), 209 (58), 171 (33), 145 (14), 144 (100), 121 (15), 115 (10) 91 (10); HRMS Calcd for C<sub>35</sub>H<sub>32</sub>N<sub>2</sub>O<sub>3</sub>: 528.2413; Found: 528.2414.
Rf 0.23 (hexane/EtOAc = 5/1). Pale wellow oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 1.34-1.31 (m, 5H), 1.64-1.87 (m, 5H), 2.04 (d, J = 8.4 Hz, 1H), 2.46-2.52 (m, 1H), 2.92-3.04 m, 2H), 3.62 (s, 3H), 6.69 (d, J = 8.4 Hz, 2H), 7.15 (d, J = 8.4 Hz, 2H), 7.36 (dd, J = 8.4, 4.0 Hz, 1H), 7.41-7.50 (m, 2H), 8.07 (dd, J = 8.4, 1.2 Hz, 1H), 8.70 (dd, J = 4.0, 2.0 Hz, 1H), 8.76 (d, J = 8.0 Hz, 1H), 9.53 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 26.33 (t, J = 5.7 Hz), 30.89, 31.05, 35.09, 40.63, 54.99, 58.02, 113.67, 116.28, 121.18, 121.36, 127.25, 127.74, 129.73, 132.26, 134.19, 136.11, 138.19, 147.90, 155.73, 173.34; IR (neat) 2925 w, 1683 m, 1523 s, 1484 m, 1324 m, 1246 m, 1037 w, 825 w; MS m/z (relative intensity, %) 388 (M$^+$, 29), 306 (15), 305 (49), 171 (30), 161 (56), 145 (16), 144 (100), 121 (54); HRMS Calcd for C$_{25}$H$_{28}$N$_2$O$_2$: 388.2151; Found: 388.2153.

2-phenyl-N-(quinolin-8-yl)-2-(4-(trifluoromethyl)benzyl)heptanamide (1d).

Rf 0.51 (hexane/EtOAc = 5/1). Pale Brown Solid. Mp =136 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 0.83 (t, J = 6.8 Hz, 3H), 1.27-1.57 (m, 6H), 1.94-2.07 (m, 2H), 3.45 (d, J = 13.6 Hz, 1H), 3.59 (d, J = 14.0 Hz, 1H), 6.79 (d, J = 7.6 Hz, 2H), 7.27-7.36 (m, 8H), 7.46 (d, J = 8.4 Hz, 1H), 7.54 (t, J = 8.4 Hz, 1H), 8.08 (dd, J = 8.0, 1.6 Hz, 1H), 8.56 (dd, J = 4.0, 1.6 Hz, 1H), 8.77 (d, J = 7.6 Hz, 1H), 9.79 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 14.11, 22.50, 24.23, 32.35, 34.27, 41.83, 56.63, 116.16, 120.33, 121.43, 121.58, 124.40 (q, J = 270 Hz), 124.52 (d, J = 3.8 Hz), 127.41 (d, J = 3.8 Hz), 127.72, 127.96, 128.69, 130.73, 134.59, 136.16, 138.69, 141.89, 142.37, 148.27, 147.23; IR (neat) 3340 w, 2934 w, 1682 m, 1523 s, 1485 m, 1324 m, 1163 m, 1119 s, 1067 m, 825 m, 700 m; MS m/z (relative intensity, %) 490 (M$^+$, 6), 172 (12), 171 (100), 144 (16); HRMS Calcd for C$_{30}$H$_{29}$N$_2$O: 490.2232; Found: 490.2228.

Methyl 4-(2-phenyl-2-(quinolin-8-ylcarbamoyl)heptyl)benzoate (1e).
R_f 0.26 (hexane/EtOAc = 5/1). Off white solid. Tmp =122 °C. ^1H NMR (CDCl3, 399.78 MHz)
0.83 (t, J = 7.6 Hz, 3H), 1.26-1.60 (m, 6H), 1.93-2.03 (m, 2H), 3.43 (d, J = 14.0 Hz, 1H), 3.60 (d, J = 13.2 Hz, 1H), 3.86 (s, 3H), 6.76 (d, J = 8.4 Hz, 2H), 7.28-7.36 (m, 6H), 7.47 (d, J = 8.4 Hz, 1H), 7.54 (t, J = 8.0 Hz, 1H), 7.76 (d, J = 8.4 Hz, 2H), 8.09 (d, J = 8.4 Hz, 1H), 8.56 (dd, J = 4.4, 1.2 Hz, 1H), 8.78 (d, J = 8.0 Hz, 1H), 9.79 (brs, 1H); ^13C NMR (CDCl3, 100.53 MHz)
14.02, 22.39, 24.09, 32.24, 34.08, 41.84, 51.94, 56.54, 116.05, 121.28, 121.44, 127.26, 127.30,
127.57, 127.84, 128.10, 128.53, 130.39, 134.49, 136.05, 138.56, 142.37, 143.20, 148.14,
167.14, 174.20; IR (neat) 3341 w, 2951 w, 1719 s, 1682 m, 1522 s, 1484 m, 1325 m, 1278 s,
1183 w, 1108 m, 754 m; MS m/z (relative intensity, %) 480 (M^+ +, 5), 172 (11), 171 (100), 144
(16); HRMS Calcd for C_{31}H_{32}N_{2}O_{3}: 480.2413; Found: 480.2414.

2-(4-Iodobenzyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1f).

R_f 0.51 (hexane/EtOAc = 5/1). Off white solid. Tmp =121 °C. ^1H NMR (CDCl3, 399.78 MHz)
0.82 (t, J = 6.8 Hz, 3H), 1.25-1.54 (m, 6H), 1.93-2.05 (m, 2H), 3.33 (d, J = 13.6 Hz, 1H), 3.48 (d, J = 13.6 Hz, 1H), 6.43 (d, J = 8.4 Hz, 2H), 7.26-7.35 (m, 6H), 7.39 (d, J = 8.4 Hz, 2H), 7.44 (d, J = 8.4 Hz, 1H), 7.53 (t, J = 8.4 Hz, 1H), 8.06 (dd, J = 8.4, 1.6 Hz, 1H), 8.56 (dd, J = 4.0, 1.6 Hz, 1H), 8.77 (d, J = 8.0 Hz, 1H), 9.78 (brs, 1H); ^13C NMR (CDCl3, 100.53 MHz)
14.01, 22.38, 24.07, 32.24, 34.03, 41.33, 56.40, 91.84, 116.01, 121.24, 121.42, 127.19, 127.26,
127.60, 127.81, 128.51, 132.36, 134.48, 136.01, 136.60, 137.11, 138.55, 142.42, 148.13,
174.23; IR (neat) 3334 w, 2933 w, 1739 s, 1673 s, 1524 s, 1485 s, 1378 m, 1326 m, 1216 m,
822 m, 792 m; MS m/z (relative intensity, %) 548 (M^+ +, 15), 172 (12), 171 (100), 144
(24); HRMS Calcd for C_{29}H_{28}N_{2}O_{3}: 548.1325; Found: 548.1323.

2-(4-Chlorobenzyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1g).

R_f 0.51 (hexane/EtOAc = 5/1). White Solid. Tmp =109 °C. ^1H NMR (CDCl3, 399.78 MHz)
0.82 (t, J = 6.8 z, 3H), 1.26-1.55 (m, 6H), 1.94-2.07 (m, 2H), 3.36 (d, J = 13.6 Hz, 1H), 3.52 (d, J = 13.6 Hz, 1H), 6.62 (d, J = 8.4 Hz, 2H), 7.04 (d, J = 8.8 Hz, 2H), 7.25-7.35 (m, 6H), 7.45 (dd, J = 8.4, 1.2 Hz, 1H), 7.53 (t, J = 7.6 Hz, 1H), 8.07 (dd, J = 8.4, 1.2 Hz, 1H), 8.56 (dd, J = 4.4, 1.2 Hz, 1H), 8.77 (d, J = 8.0 Hz, 1H), 9.79 (brs, 1H); ^13C NMR (CDCl3, 100.53 MHz)
14.01, 22.38, 24.06, 32.24, 34.03, 41.15, 56.45, 116.02, 121.24, 121.42, 127.18, 127.27, 127.60, 127.68, 127.81, 131.61, 132.07, 134.49, 135.91, 136.01, 138.55, 142.46, 148.12, 174.26; IR (neat) 3342 w, 2932 w, 1683 m, 1522 s, 1485 m, 1326 m, 824 m, 754 m; MS m/z (relative intensity, %) 456 (M^+7),172 (12), 171 (100), 144 (20); HRMS Calcd for C_{29}H_{29}ClN_{2}O: 456.1968; Found: 456.1970.

2-(4-methylbenzyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1h).

R_f 0.51 (hexane/EtOAc = 5/1). White Solid. Mp =101 °C. ^1H NMR (CDCl\textsubscript{3}, 399.78 MHz) 0.82 (t, J = 7.2 Hz, 3H), 1.26-1.55 (m, 6H), 2.302 (t, J = 8.4 Hz, 2H), 2.23 (s, 3H), 3.36 (d, J = 13.2 Hz, 1H), 3.54 (d, J = 13.6 Hz, 1H), 6.61 (d, J = 8.0 Hz, 2H), 6.89 (d, J = 8.0 Hz, 2H), 7.26-7.33 (m, 6H), 7.43 (d, J = 8.4 Hz, 1H), 7.52 (t, J = 8.0 Hz, 1H), 8.04 (dd, J = 8.0, 1.2 Hz, 1H), 8.55 (dd, J = 4.0, 1.2 Hz, 1H), 8.79 (dd, J = 8.0, 1.2 Hz, 1H), 9.81 (brs, 1H); ^13C NMR (CDCl\textsubscript{3}, 100.53 MHz) 14.02, 20.98, 22.41, 24.05, 32.27, 33.92, 41.14, 56.49, 115.97, 121.09, 121.36, 126.94, 127.29, 127.60, 127.80, 128.31, 128.37, 130.17, 134.13, 134.63, 135.62, 135.97, 138.57, 143.01, 148.06, 174.63; IR (neat) 3342 w, 2932 w, 1638 m, 1521 s, 1484 m, 1383 m, 1325 m, 791 m, 753 m; MS m/z (relative intensity, %) 436 (M^+17), 172 (12), 171 (100), 144 (34), 105 (24), 91 (11); HRMS Calcd for C_{30}H_{32}N_{2}O: 436.2513; Found: 436.2515.

2-(4-aminobenzyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1j).

R_f 0.22 (hexane/EtOAc = 5/1). Pale yellow Solid. Mp =121 °C. ^1H NMR (CDCl\textsubscript{3}, 399.78 MHz) 0.82 (t, J = 7.2 Hz, 3H), 1.25-1.45 (m, 6H), 1.99-2.04 (m, 2H), 3.29 (d, J = 13.6 Hz, 1H), 3.45-3.49 (m, 3H), 6.42 (d, J = 7.6 Hz, 2H), 6.51 (d, J = 8.4 Hz, 2H), 7.23-7.34 (m, 6H), 7.44 (dd, J = 8.4, 1.6 Hz, 1H), 7.52 (t, J = 8.4 Hz, 1H), 8.07 (dd, J = 8.0, 1.6 Hz, 1H), 8.57 (dd, J = 4.0, 1.6 Hz, 1H), 8.78 (dd, J = 8.0, 1.6 Hz, 1H), 9.80 (brs, 1H); ^13C NMR (CDCl\textsubscript{3}, 100.53 MHz) 14.04, 24.21, 24.03, 32.30, 33.89, 40.77, 56.59, 114.56, 115.96, 121.05, 121.37, 126.85, 127.15, 127.30, 127.65, 127.81, 128.32, 131.07, 134.66, 135.98, 138.58, 143.15, 144.49, 148.08, 174.80; IR (neat) 3352 w, 2931 w, 1638 m, 1622 w, 1521 s, 1484 m, 1326 m, 826 w, 755 m; MS m/z (relative intensity, %) 437 (M^+, 6), 332 (18), 171 (11), 144 (28), 106 (100); HRMS Calcd for C_{29}H_{31}N_{3}O: 437.2467; Found: 437.2465.
2-(4-(dimethylamino)benzyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1k).

Rf 0.29 (hexane/EtOAc = 5/1). Pale yellow Solid. Mp =125 °C. 1H NMR (CDCl3, 399.78 MHz) 0.82 (t, J = 6.8 Hz, 3H), 1.26-1.51 (m, 6H), 2.02 (t, J = 8.4 Hz, 1H), 2.84 (s, 6H), 3.32 (d, J = 13.6 Hz, 1H), 3.50 (d, J = 14.0 Hz, 1H), 6.49 (d, J = 8.4 Hz, 2H), 6.60 (d, J = 8.4 Hz, 2H), 7.24-7.36 (m, 6H), 7.43 (dd, J = 8.0, 1.2 Hz, 1H), 7.52 (t, J = 8.4 Hz, 1H), 8.06 (dd, J = 8.0, 1.2 Hz, 1H), 8.56 (dd, J = 4.4, 1.2 Hz, 1H), 8.79 (dd, J = 7.6, 1.2 Hz, 1H), 9.81 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) 14.20, 22.58, 24.20, 32.47, 34.07, 40.78, 56.79, 112.23, 116.09, 121.16, 121.50, 126.95, 127.45, 127.80, 127.96, 128.46, 131.11, 134.85, 136.11, 138.74, 143.44, 148.21, 149.13, 175.01; IR (neat) 3343 w, 2931 w, 1682 m, 1614 w, 1520 s, 1483 m, 1326 m, 791 m, 751 s, 699 m; MS m/z (relative intensity, %) 465 (M+ 4), 135 (10), 134 (100); HRMS Calcd for C31H35N3O: 465.2780; Found: 465.2778.

2-((1H-indol-5-yl)methyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1m).

Rf 0.11 (hexane/EtOAc = 5/1). Off white Solid. Mp =90 °C. 1H NMR (CDCl3, 399.78 MHz) 0.82 (t, J = 7.2 Hz, 3H), 1.26-1.61 (m, 6H), 1.99-2.11 (m, 2H), 3.50 (d, J = 14.0 Hz, 1H), 3.69 (d, J = 14.0 Hz, 1H), 6.34 (t, J = 2.0 Hz, 1H), 6.49 (dd, J = 4.4, 1.2 Hz, 1H), 7.05 (t, J = 4.4 Hz, 3H), 7.23-7.33 (m, 6H), 7.43 (dd, J = 8.8, 1.2 Hz, 1H), 7.52 (t, J = 8.0 Hz, 1H), 8.05 (dd, J = 8.0, 1.6 Hz, 1H), 8.11 (brs, 1H), 8.55 (dd, J = 4.0, 1.6 Hz, 1H), 8.81 (dd, J = 7.6, 1.2 Hz, 1H), 9.85 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) 14.21, 22.55, 24.23, 32.45, 34.78, 41.78, 56.99, 102.33, 110.16, 116.15, 121.53, 122.32, 124.15, 124.82, 126.99, 127.46, 127.66, 127.88, 127.97, 128.38, 128.47, 134.72, 134.85, 136.13, 138.77, 143.51, 148.24, 175.23; IR (neat) 3343 w, 2935 w, 1671 m, 1522 s, 1484 m, 1423 m, 1326 m, 825 w, 753 s; MS m/z (relative intensity, %) 461 (M+ 13), 273 (18), 171 (20), 144 (18), 131 (11), 130 (100); HRMS Calcd for C31H33N3O: 461.2471; Found: 461.2471.

2-Phenyl-N-(quinolin-8-yl)-2-(thiophen-2-ylmethyl)heptanamide (1n).
Rf 0.51 (hexane/EtOAc = 5/1). Colorless oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 0.82 (t, J = 6.8 Hz, 3H), 1.27-1.59 (m, 6H), 2.06-2.18 (m, 2H), 3.64 (d, J = 14.8 Hz, 1H), 3.83 (d, J = 15.2 Hz, 1H), 6.45 (d, J = 3.2 Hz, 1H), 6.79 (t, J = 4.0 Hz, 1H), 7.01 (d, J = 5.2 Hz, 1H), 7.25-7.54 (m, 8H), 8.07 (d, J = 7.2 Hz, 1H), 8.57 (d, J = 7.6 Hz, 1H), 9.82 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 14.05, 22.39, 23.99, 32.12, 34.12, 36.00, 56.13, 116.03, 121.21, 121.41, 123.93, 126.12, 127.00, 127.25, 127.51, 127.80, 128.60, 134.53, 136.03, 138.55, 139.07, 142.43, 148.11, 174.10; IR (neat) 3342 w, 2931 w, 1681 m, 1523 s, 1484 s, 1384 m, 1326 m, 791 m; MS m/z (relative intensity, %) 429 (12), 428 (M$^+$, 38), 357 (14), 331 (20), 172 (13), 171 (100), 145 (11), 144 (59), 117 (13), 97 (19), 91 (11); HRMS Calcd for C$_{27}$H$_{28}$N$_2$OS: 428.1922; Found: 428.1924.

2-(4-Butylbenzyl)-2-phenyl-N-(quinolin-8-yl)heptanamide (1o).

Deuterium Labeling Experiment (Scheme. 1 and 3).

To an oven-dried 5 mL screw-capped vial, in a glove box 2-methyl-2-phenyl-N-(quinolin-8-yl)heptanamide 1a-d$_3$ (104 mg, 0.3 mmol), 4-iodoanisole (140 mg, 0.6 mmol), Ni(OTf)$_2$ (10.6 mg, 0.03 mmol) or Ni(cod)$_2$ (6.5 mg, 0.03 mmol),
MesCOOH (9.8 mg, 0.06 mmol), Na₂CO₃ (64 mg, 0.6 mmol) and DMF (0.6 mL) were added. The mixture was stirred for 3 h at 140 °C followed by cooling. 30 mL of water was added to the reaction mixture and the aqueous layer was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with and brine (20 mL), dried over MgSO₄, filtered and evaporated in vacuo. The residue was purified by column chromatography on silica gel (elucent: hexane/EtOAc= 20/1) to afford the desired arylated product. The ratio of deuterium was determined by ¹H-NMR.

**Product Distribution (Scheme 2).**

To an oven-dried 5 mL screw-capped vial, in a glove box 2-methyl-2-phenyl-N-(quinolin-8-yl)heptanamide 1a (104 mg, 0.3 mmol), 1-butyl-4-iodobenzene (156 mg, 0.6 mmol), Ni(OTf)₂ (10.6 mg, 0.03 mmol) or Ni(cod)₂ (6.5 mg, 0.03 mmol), MesCOOH (29 mg, 0.18 mmol), Na₂CO₃ (64 mg, 0.6 mmol) and DMF (0.6 mL) were added. The mixture was stirred for 24 h at 140 °C followed by cooling. The yields of butylbenzene, 1-butyl-4-iodobenzene, and 4,4'-dibutyl-1,1'-biphenyl were determined by GC. After determined GC yields, 30 mL of water was added to the reaction mixture and the aqueous layer was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with and brine (20 mL), dried over MgSO₄, filtered and evaporated in vacuo. The yield of product 1o was determined by ¹H-NMR.

**Radical Trapping Experiment.**

To an oven-dried 5 mL screw-capped vial, in a glove box 2-methyl-2-phenyl-N-(quinolin-8-yl)heptanamide 1a (52 mg, 0.15 mmol), 4-idoanisole (70 mg, 0.3 mmol), TEMPO (47 mg, 0.3 mmol), Ni(OTf)₂ (5.3 mg, 0.015 mmol), MesCOOH (4.8 mg, 0.03 mmol), Na₂CO₃ (32 mg, 0.3 mmol) and DMF (0.6 mL) were added. The mixture was stirred for 24 h at 140 °C followed by cooling. 30 mL of water was added to the reaction mixture and the aqueous layer was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with and brine (20 mL), dried over MgSO₄, filtered and evaporated in vacuo. The yield of product 1b was determined by ¹H-NMR.

**General Procesure for Direct Arylation: Ni-Catalyzed Arylation of Amides with Diaryliodonium salt (eq 1).**

To an oven-dried 5 mL screw-capped vial, in a glove box 2,2-diphenyl-N-(quinolin-8-yl)propanamide 6a (106 mg, 0.3 mmol), 4-methoxyphenyl(mesityl)iodonium trifluoromethanesulfonate (181 mg, 0.36 mmol), Ni(OTf)₂ (10.6 mg, 0.03 mmol), Na₂CO₃ (64 mg, 0.6 mmol) and 4-methyltetrahydropyrrane (1 mL) were added. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The residue was
purified by column chromatography on silica gel (eluent: hexane/EtOAc = 10/1) to afford the desired arylated product 6b (99 mg, 72%) as a white solid.

2.5 References and Notes


(8) The energy difference of cyclometalated complexes between the cleavage of methyl C-H bond and of methylene C-H bond are calculated by B3LYP/SDD (Ni)/6-31G* (C, H, O, N). Although the complex of activated methyl C-H bond is 4.6 kJ/mol more stable in six-membered ring, the complex of activated methlene C-H bond is 13.9 kJ/mol more stable in seven-membered ring.


Ni(II)-Catalyzed Oxidative Coupling between C(sp²)−H in Benzamides and C(sp³)−H in Toluene Derivatives

3.1 Introduction

The direct functionalization of C-H bonds has been developed, and most of them were divided into the reaction of C-H bonds and C-X bonds, such as halogen and organometallic reagents, as dealt in Chapter 1 and 2 (Figure 1). In contrast, oxidative coupling between C-H bonds and C-H bonds is an ideal and environmentally attractive strategy because the reaction does not require functionalized compounds for coupling and stoichiometric amounts of halogenated and organometallic byproducts are not generated (Figure 1). In a pioneering study, Fagnou reported on such a reaction: the Pd-catalyzed reaction of indole derivatives with benzene derivatives gave the arylation products. Following this pioneering example, a number of reactions involving oxidative C-H/C-H coupling have been reported. However, most of these examples involve the coupling of C(sp²)-H/C(sp²)-H bonds. The oxidative coupling of C(sp²)-H/C(sp³)-H bonds represent the next targeted reaction (Figure 1). To the best of our knowledge, only one example of the oxidative coupling between C(sp²)-H bonds and C(sp³)-H bonds is available.

**Figure 1.** Oxidative Cross Coupling of C-H/C-H bond.

In fact, Li reported on the Ru(II)-catalyzed oxidative coupling between C(sp²)-H bonds in 2-arylpyridines and with C(sp³)-H bonds in cycloalkanes, as the solvent, in the presence of a strong oxidant, such as di-tert-butyl peroxide(eq 1). The role of di-tert-butyl peroxide is used to generate radical species from the cycloalkanes. The scope of cycloalkane is quite narrow, only cyclohexane, cycloheptane and cyclooctane were applicable, and functional group compatibility is low, due to the use a strong oxidant. The oxidative coupling of C(sp²)-H/C(sp³)-H bonds without the use of such strong oxidants and the high functional groups compatibility continues to be a challenging issue in the field of organic synthesis.
In this chapter, we report here on the Ni(II)-catalyzed oxidative coupling between ortho C-H bonds in aromatic amides and benzylic C-H bonds in toluene derivatives. Various functionalized benzyl groups can be introduced by using mild oxidant.

### 3.2 Results and discussion

Based on the result from chapter 1, we hypothesize that use of alkyl radical which is generated from alkane by hydrogen atom transfer instead of alkyl halide achieves oxidative coupling. Inspired by Fu work: tert-alkyl radical act as a hydrogen atom abstraction reagent in Ni-catalyzed cross coupling reaction. Various alkyl halides were examined as alkyl radical sources, but all efforts were in vain. However, the benzylation of ortho C-H bonds proceeded, when t-C₃F₇I was used as an alkyl halide. The reaction of amide 1a (0.3 mmol) with t-C₃F₇I (0.6 mmol) in the presence of Ni(OTf)₂ (0.03 mmol) as the catalyst, Na₂CO₃ (0.6 mmol) as the base and PPh₃ (0.03 mmol) as the ligand in toluene (1 mL) at 140 °C for 24 h gave the benzylation product 2a in 91% isolated yield (Table 1, entry 1). The reaction also produced 2a in 75% NMR yield in the absence of PPh₃ (entry 2). While the presence of PPh₃ as a ligand was not crucial for the reaction to proceed, PPh₃ was added because the product yields were consistently higher than the yields in the absence of PPh₃. Other perfluoroalkyl or aryl iodides, such as n-C₆F₁₃I, C₆F₅I, and CF₃CH₂I, or C₆Br₆ were not effective (entries 3-6). The reaction was also dependent on the base used in the reaction. Among the bases screened, carbonates were found to be effective. The nature of the cation portion is also important (entries 7-11). A 1.2 equivalent of t-C₃F₇I (0.36 mmol, 1.2 equivalents to the amide 1a) did not affect the product yield (entries 1 vs 12).

**Figure 2.** The effect of directing groups

Raction conditions: amide (0.3 mmol), Ni(OTf)₂ (10 mol%), PPh₃ (10 mol%), Na₂CO₃ (0.6 mmol), t-C₃F₇I (0.36 mmol) in toluene (1 mL) at 140 °C for 24 h. Isolated yield.
To examine the effect of 5-substituent at a quinolone moiety, the screening of directing groups were conducted (Figure 2). The reaction of non-substituent at 5-position gave the mixture of benzylation product 2b in 54% yield and heptafluoroisopropylation at 5-position 3 in 33% yield. The use of chlorine group instead of methoxy group increase the benzylation product 2c in 94% yield. We choose an 8-amino-5-chloro-quinoline moiety as a suitable directing group.

Table 1. Optimization of reaction conditions

<table>
<thead>
<tr>
<th>entry</th>
<th>oxidant</th>
<th>ligand</th>
<th>base</th>
<th>yields&lt;sup&gt;b&lt;/sup&gt; (2a / 1a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[C₃F₇]l</td>
<td>PPh₃</td>
<td>Na₂CO₃</td>
<td>94% (91%) / trace</td>
</tr>
<tr>
<td>2</td>
<td>[C₃F₇]l</td>
<td>–</td>
<td>Na₂CO₃</td>
<td>75% / 13%</td>
</tr>
<tr>
<td>3</td>
<td>C₆F₁₃l</td>
<td>PPh₃</td>
<td>Na₂CO₃</td>
<td>30% / 40%</td>
</tr>
<tr>
<td>4</td>
<td>C₆F₅l</td>
<td>PPh₃</td>
<td>Na₂CO₃</td>
<td>0% / 60%</td>
</tr>
<tr>
<td>5</td>
<td>CF₃CH₂l</td>
<td>PPh₃</td>
<td>Na₂CO₃</td>
<td>39% / 0%</td>
</tr>
<tr>
<td>6</td>
<td>C₆Br₆</td>
<td>PPh₃</td>
<td>Na₂CO₃</td>
<td>0% / 90%</td>
</tr>
<tr>
<td>7</td>
<td>[C₃F₇]l</td>
<td>PPh₃</td>
<td>Cs₂CO₃</td>
<td>73% / 13%</td>
</tr>
<tr>
<td>8</td>
<td>[C₃F₇]l</td>
<td>PPh₃</td>
<td>K₂CO₃</td>
<td>10% / 73%</td>
</tr>
<tr>
<td>9</td>
<td>[C₃F₇]l</td>
<td>PPh₃</td>
<td>NaHCO₃</td>
<td>59% / 37%</td>
</tr>
<tr>
<td>10</td>
<td>[C₃F₇]l</td>
<td>PPh₃</td>
<td>Li₂CO₃</td>
<td>0% / 63%</td>
</tr>
<tr>
<td>11</td>
<td>[C₃F₇]l</td>
<td>PPh₃</td>
<td>NaOAc</td>
<td>21% / 63%</td>
</tr>
<tr>
<td>12&lt;sup&gt;c&lt;/sup&gt;</td>
<td>[C₃F₇]l</td>
<td>PPh₃</td>
<td>Na₂CO₃</td>
<td>94% (91%) / trace</td>
</tr>
</tbody>
</table>

<sup>a</sup>Raction conditions: 1a (0.3 mmol), Ni(OTf)₂ (10 mol%), PPh₃ (10mol%), Na₂CO₃ (0.6 mmol), oxidant (0.6 mmol) in toluene (1 mL) at 140 °C for 24 h. <sup>b</sup>NMR yields. The Number in parentheses is the isolated yield. <sup>c</sup>[C₃F₇]l (0.36 mmol) was used.

With the optimized reaction conditions in hand, the reaction of various benzamides in toluene as the solvent was examined (Table 2). A wide variety of functional groups on benzamides are tolerated in the reaction. The less hindered C-H bonds were exclusively activated to give benzylation products, 4-8, 11, and 15 in the reaction of meta-substituted aromatic amides. In the case of a meta-fluoro substrate and a benzamide, di-benzylation
products 12 and 13 were obtained in high yields by using 3 equivalents of $^1$C$_3$F$_7$I. In all cases, no coupling between the ortho C-H bonds in benzamides and C(sp$^2$)-H bonds in toluene was observed.

Table 2. The Ni(II)-catalyzed ortho-benzylation of benzamides in toluene$^a$

<table>
<thead>
<tr>
<th>R</th>
<th>Product</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Me</td>
<td>4</td>
<td>84%</td>
</tr>
<tr>
<td>OMe</td>
<td>5</td>
<td>91%</td>
</tr>
<tr>
<td>Cl</td>
<td>6</td>
<td>76%</td>
</tr>
<tr>
<td>CF$_3$</td>
<td>7</td>
<td>90%</td>
</tr>
<tr>
<td>COMe</td>
<td>8</td>
<td>78%</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>82%$^b, c$</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>82%$^c$</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>81%$^d$</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>49%</td>
</tr>
</tbody>
</table>

$^a$Reactions were conducted on a 0.3 mmol scale. Reported yields are isolated yields. $^b$Run at 160 °C. $^c$C$_3$F$_7$I (0.9 mmol) was used. $^d$Reaction was conducted on a 0.15 mmol scale and 15 mol% catalyst was used.

In order to develop a more useful reaction in organic synthesis, we examined the reaction with functionalized toluene derivatives in unreactive solvent. When 5 equivalents of toluene in 0.7 mL of tert-buthylbenzene as the solvent were used under standard reaction condition, 2c was obtained in 62% yield. The yield increased to 84% isolated yield when 10 equivalents of toluene were used. The results for the reaction of 1c with various toluene derivatives in tert-buthylbenzene as a solvent were shown in Table 3. Various functional groups, even
bromides, iodides and protected amine are tolerated under the current catalytic system. The presence of substituents at the ortho position had no effect on the efficiency of the reaction, as in 24, 25, 26, 29 and 31.

Table 3. The scope of toluene derivatives in oxidative coupling with benzamides

| R = H 2c | 84% (94)b |
| R = Me 17 | 69% |
| R = CF3 18 | 65%b |
| R = Cl 19 | 85% |
| R = Me 20 | 89% |
| OMe 21 | 61% |

| R | 87%b |
| R = NHAc 23 | 74% |
| R = I 24 | 52% |
| Me 25 | 84%b |
| OMe 26 | 78%b |

| 27 | 95%a |
| 28 | 42% |

| 29 | 32%b |
| F-Br |  |

| 30 | 91%b |
| F-Br |  |

| 31 | 92%b |
| Cl |  |

a Reactions were conducted on a 0.3 mmol scale. Reported yields are isolated yields. b Toluene derivatives (1.0 mL) were used as the solvent.

To gain insights into the reaction mechanism, deuterium-labeling experiments were performed. When the deuterated benzamide 1c-d7 was reacted under standard reaction conditions for 4 h to recover the 1c-d7, 2c was obtained in 52% isolated yield, along with 41% of 1c-d7 being recovered, in which H/D exchange was observed between only at the ortho C-H bond and the NH bond. The D-content at the ortho C-H bond was decreased to 0.48D (eq 2). Even without a 1C3F7I, the H/D exchange was also observed in recovered stirring amide. These results clearly indicate that activation of aromatic C-H bond in benzamides is reversible under the reaction conditions, and 1C3F7I is not involved in activation of aromatic C-H bond step.
When toluene-\(d_8\) was used instead of toluene, the reaction was slower than the reaction in toluene. Furthermore, no H atom was detected in the benzyl moiety in the product and no deuterium atom was incorporated into the recovered 1c, indicating the cleavage of benzylic C-H bond is irreversible step (eq 3).

To collect additional information regarding the reaction mechanism, the reaction of 1c in a 1:1 mixture of toluene and toluene-\(d_8\) was carried out (eq 4). In the \(^1\)H-NMR spectrum of the product, 1.52H was observed in the benzylic position, indicating that the reaction in toluene is 3.2 times faster when toluene-\(d_8\) is used (1.52/0.48).

The most important issue to be addressed is what the real benzylation reagent is and how it is generated. A reaction of \(^1\)C\(_3\)F\(_7\)I and toluene at 140 °C for 24 h resulted in no reaction (Scheme 1). But the in the presence of Na\(_2\)CO\(_3\) gave the benzyl iodide in 21% NMR yield. The addition of Ni(OTf)\(_2\) and Na\(_2\)CO\(_3\) furnished benzyl iodide in 39% NMR yield. Although benzyl iodide was formed only in 39% yield, catalytic C-H benzylation proceeded smoothly as shown in Table 2. These results suggest that benzyl iodide is formed to some extent under the reaction conditions, but that it does not contribute to the benzylation as the major path. To gain the more information about formation of benzyl iodide, the addition of TEMPO as a radical scavenger was examined. The inhibition effect of TEMPO indicated the benzyl radical or perfluoroalkyl radical were intermediate for this reaction.
On the basis of these results and previous reports, a plausible reaction mechanism is proposed in Scheme 2. The coordination of amide A to the nickel(II) center gives the nickel(II) complex B with the generation of HX, which is trapped by Na$_2$CO$_3$. The C-H bonds in complex B then undergo reversible cleavage via a concerted metalation deprotonation (CMD) mechanism to give nickelacycle C. The reaction of the complex C with a benzyl radical, which is generated by the base-promoted SET of R$^f$I followed by the abstraction of a hydrogen from toluene, generates a benzyl radical and R$^f$-H. The reaction of the complex C with the benzyl radical affords the Ni(III) species D, from which the reductive elimination and protonation occurs to give the final product with the generation of Ni(I) complex. The reaction of Ni(I) with R$^f$I regenerates the Ni(II) complex with the generation of an R$^f$ radical, which undergoes H-atom abstraction from toluene gives the benzyl radical and R$^f$-H. In fact, the formation of R$^f$-H was confirmed by $^{19}$F NMR spectra of the reaction mixtures. A mechanism involving the oxidative addition of benzyl iodide to complex C cannot be excluded as the alternative mechanism, since we also observed the formation of benzyl iodide. However, this mechanism is not the major route for the present benzylation because the benzylation of C-H bonds proceeded smoothly even when the generation of benzyl iodides was not efficient.

Another alternative mechanism involves the oxidative addition of Rf-I to complex C to give complex G, which reacts with toluene to afford the complex H. The step from the complex G to H would be expected to proceed via a radical mechanism because the oxidative addition of $^1$C$_3$F$_7$I to transition metal complexes and the abstraction of a H-atom radical by a $^1$C$_3$F$_7$ radical are known.

As shown in Table 1, $^6$C$_8$F$_{13}$I was less reactive, although $^1$C$_3$H$_7$I showed a high activity. It is known that secondary perfluoroalkyl radical undergoes the abstraction of H-atom faster than a primary perfluoroalkyl radical. If perfluoroalkyl anion is involved in the reaction, perfluoroalkene would be generated by $\beta$-fluoro elimination. However, no perfluoroalkene
was detected. Furthermore, the addition of TEMPO completely quenched the reaction. These results suggest that the reaction involves the formation of a $^{1}C_{3}F_{7}$ radical and benzyl radical.

**Scheme 2. Reaction mechanism**

After published this reaction, Fu and co-workers performed computational studies of this reaction mechanism (Scheme 3). The left catalytic cycle is our proposed mechanism. The reaction of nickel(II) and an amide gives a metallacycle C. A metallacycle C reacts with a benzyl radical to give the product. In contrast to our mechanism, DFT calculations indicate that an iodine atom transfer between alkyl iodide and complex C occurs, to give alkyl radical and Ni(III) intermediate I. The reaction of complex I and a benzyl radical gives the Ni(IV) complex H, which undergoes reductive elimination and protonation to give the final product. This catalytic cycle, including the iodine atom transfer and the formation of a Ni(IV) intermediate H, is more feasible based on DFT calculations.
3.3 Conclusions

In summary, we report on a unique strategy that enables oxidative coupling between C(sp²)-H and C(sp³)-H bonds via a Ni(II)-catalyzed reaction of benzamides with toluene derivatives. The presence of C₃H₇I is essential for the reaction to proceed. The role of C₃H₇ radical is to generate a benzyl radical via the abstraction of a H-atom from toluene derivatives, and high functional group compatibility was achieved by using a C₃H₇I as a mild oxidant. This reaction system is applicable to oxidative coupling of two C(sp³)-H bonds. The reaction of aliphatic amide and toluene in the presence of C₃H₇I, 1-AdCOOH as a ligand and Pd(OAc)₂ gave the β-benzylation product in good yield (eq 5). The addition of carboxylic acid is necessary to increase the product yields. The reaction in the presence of nickel-catalyst resulted in no reaction.

The reaction of aromatic amide containing an 8-amino-5-Chloroquinoline and iodine in the presence of nickel(II)-catalyst gave the ortho-iodination product (eq 6). This reaction represents the first example of direct iodination of C-H bonds with nickel-catalyst. In contrast, the reaction of aliphatic amide and iodine didn’t furnish the corresponding iodination products but the β-lactams (eq 7). The synthesis of β-lactams via cleavage of C(sp³)-H bonds with
nickel-catalyst was reported by using TEMPO as a oxidant.\textsuperscript{15} The reaction with 5-methoxy directing group were ineffective, indicating that the role of chloro group at 5 position is not only to prevent the substitution reaction at 5-position but also to facilitate the reaction.

![Chemical Structures](image)

\[ \text{1c (0.15 mmol)} + \text{I}_2 + \text{Ni(OTf)}_2 (10\text{ mol}\%), \text{Na}_2\text{CO}_3 (2\text{ equiv}), \text{toluene (0.7 mL)}, 120^\circ\text{C, 24 h} \rightarrow \text{34 (76\%)} \]

\[ \text{35 (0.15 mmol)} + \text{I}_2 + \text{Ni(OTf)}_2 (10\text{ mol}\%), \text{Ag}_2\text{CO}_3 (25\text{ mol}\%), \text{Na}_2\text{CO}_3 (2\text{ equiv}), \text{DMF (0.5 mL)}, 140^\circ\text{C, 24 h} \rightarrow \text{36 (91\%)} \]

### 3.4 Experimental Section

#### General Information.

\textsuperscript{1}H NMR and \textsuperscript{13}C NMR spectra were recorded on a JEOL ECS-400 spectrometer in CDCl\textsubscript{3} with tetramethylsilane as the internal standard. Data are reported as follows: chemical shift in ppm, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, bs = broad singlet, and m = multiplet), coupling constant (Hz), and integration. Infrared spectra (IR) were obtained using a JASCO FT/IR-4000; absorptions are reported in reciprocal centimeters with the following relative intensities: s (strong), m (medium), or w (weak). Mass spectra were obtained using Shimadzu GCMS-QP 2014 and Shimadzu GCMS-QP 5000 instruments instrument with ionization voltages of 70 eV. High resolution mass spectra (HRMS) were obtained on a JEOL JMS-700 instrument. Analytical gas chromatography (GC) was carried out on Shimadzu GC-14B, Shimadzu GC-2014 and Shimadzu GC-8A gas chromatographs, equipped with a flame ionization detector. Melting points were determined using a Stanford Research Systems apparatus. Column chromatography was performed with SiO\textsubscript{2} (Silicycle SiliaFlash F60 (230-400 mesh)). Some compounds were purified by LC-908 HPLC (GPC).

#### Materials.

Na\textsubscript{2}CO\textsubscript{3} (CAS 497-19-8) was purchased from Nacalai Tesque, Inc. Heptafluoroisopropyl iodide (CAS 677-69-0) and 8-Aminoquinoline (CAS 578-66-5), were purchased from Tokyo Kasei Kogyo Co., Ltd. Ni(OTf)\textsubscript{2} (CAS 60871-84-3) was prepared by chapter 1 procedure. Toluene, super dehydrated (CAS 68-12-2) and PPh\textsubscript{3} (CAS 603-35-0) was purchased from Wako Pure Chemicals. 5-methoxyquinolin-8-amine (CAS 30465-68-0) was prepared by following procedure.\textsuperscript{16}
Synthesis of the Starting Amides.

All amides containing an 8-aminoquinoline were prepared by the reaction of the corresponding acid chlorides and 8-aminoquinoline. All starting amides were synthesized following general procedure. All spectrum data of starting amides are cited in original paper.\textsuperscript{17}

**General Procedure for the Preparation of 8-amino-5-chloroquinoline.**

\begin{center}
\begin{tabular}{c}
\chem{\text{NO}_2} & \text{glycerol} & \text{NaI, H}_2\text{SO}_4} \\
\text{Cl} & 150 \degree \text{C} & \\
\text{Cl} & \text{Fe, AcOH} & 65 \degree \text{C} \\
& & \\
\text{NH}_2 & & \\
\end{tabular}
\end{center}

Glycerol (57 mL, 782.5 mmol, 2.7 equiv) was added to an oven-dried 300 mL of three-necked flask and heated at 160 \degree \text{C} for 1 h, then cooled to 110 \degree \text{C}. 5-Chloro-2-nitroaniline (50 g, 290 mmol, 1 equiv) and NaI (850 mg, 6 mmol, 0.02 equiv) were added, and the mixture was heated to 150 \degree \text{C} with vigorous stirring. Conc. H\textsubscript{2}SO\textsubscript{4} (35.5 mL, 666.5 mmol, 2.3 equiv) was added dropwise, and the reaction was heated at 150 \degree \text{C} for 1 h, and then the reaction was cooled to rt. The reaction was diluted with 200 mL of water and 200 mL of DCM, and filtered through a celite pad. The filtrate was extracted with DCM(3x). The combined organic layer was washed with brine and dried by anhydrous Na\textsubscript{2}SO\textsubscript{4}, and concentrated in vacuo to give 5-chloro-8-nitroquinoline (36.4 g, 175 mmol, 60\%) which was used for next step without purification.

5-Chloro-8-nitroquinoline (13.8 g, 66 mmol) was dissolved in 180 mL of acetic acid, and the iron powder (25 g, 455 mmol) was added to the solution. The mixture was heated to 65 \degree \text{C} for 2 h under nitrogen. The reaction was filtered through a celite pad, and washed with ethyl acetate. The filtrate was concentrated in vacuo. The resulting brown gum was dissolved in 200 mL of DCM, and basified by 4N NaOH aq. until pH 10, and the solution was filtered through a celite pad, and filtrate was extracted with DCM (3x). The combined organic layer was washed with brine and dried by anhydrous Na\textsubscript{2}SO\textsubscript{4}, and concentrated in vacuo to give 5-chloroquinolin-8-amine (10.2 g, 57 mmol, 87\%).

**General Procedure for the Preparation of Starting Amide.**

\begin{center}
\begin{tabular}{c}
\chem{\text{MeO}} & \chem{\text{COOH}} & (\text{COCl})\textsubscript{2}, \text{DMF} \\
& & DCM, rt \\
\text{Cl} & & NE\textsubscript{3} \\
& & DCM, rt \\
\chem{\text{MeO}} & \text{N} & \\
\text{Cl} & & \\
\end{tabular}
\end{center}
To an oven-dried 100 mL three-necked flask, 3-methoxybenzoic acid (1.5 g, 10 mmol), DMF (5 drops) and DCM (20 mL) were added under a N₂ atmosphere. Oxalyl chloride (1.0 mL, 12 mmol, 1.2 equiv.) was added dropwise at 0 °C resulting in vigorous bubbling. The mixture was stirred for 3 h at room temperature, and the solvent was then removed in vacuo. The resulting acid chloride was used immediately without further purification. To a solution of acid chloride in DCM(30 mL), the solution of 8-amino-5-chloroquinoline (2.1 g, 12 mmol, 1.2 equiv.), Et₃N (2.5 mL, 24 mmol, 2 equiv.) in DCM (15 mL) were added dropwise to the solution at 0 °C, and the solution was then warmed to room temperature. After stirring overnight, the reaction system was quenched with sat. aq. NaHCO₃ (30 mL) and the organic layer was separated. The aqueous layer was extracted with DCM (2 x 15 mL). The combined organic layers were washed with 1 M HCl aq. (30 mL) and brine (30 mL), dried over MgSO₄, filtered and evaporated in vacuo. The resulting crude amide was purified by column chromatography on silica gel (eluant: hexane/DCM = 3/1) to afford the desired amide as a white solid (2.3 g, 74%).

**General Procedure for Direct Benzylation: Ni-Catalyzed Dehydrogenative Cross Coupling of Amides 1c with Toluene**

To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)-2-methylbenzamide 1c (89 mg, 0.3 mmol), heptafluoroisopropyl iodide (107 mg, 0.36 mmol), Ni(OTf)₂ (10.6 mg, 0.03 mmol), PPh₃ (7.8 mg, 0.03 mmol), Na₂CO₃ (64 mg, 0.6 mmol) and toluene (1 mL) were added in a glove box. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluant: hexane/EtOAc= 20/1) to afford the desired alkylated product 2c (108 mg, 94%) as a light yellow solid.

**General Procedure for Direct Benzylation: Ni-Catalyzed Dehydrogenative Cross Coupling of Amides 1c with arene**

To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)-2-methylbenzamide 1c (89 mg, 0.3 mmol), heptafluoroisopropyl iodide (107 mg, 0.36 mmol), Ni(OTf)₂ (10.6 mg, 0.03 mmol), PPh₃ (7.8 mg, 0.03 mmol), Na₂CO₃ (64 mg, 0.6 mmol), toluene (276 mg, 3.0 mmol) and tert-buthylbenzene (0.7 mL) were added in a glove box. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluent: hexane/EtOAc= 20/1) to afford the desired alkylated product 2c (97 mg, 84%) as a light yellow solid.

**Spectroscopic Data for Products**

2-benzyl-N-(5-methoxyquinolin-8-yl)-6-methylbenzamide (2a).
Rf 0.17 (hexane/EtOAc = 5/1). Light Yellow Solid. Mp = 149 °C. 1H NMR (CDCl3, 399.78 MHz) 2.45 (s, 3H), 4.02 (s, 3H), 4.10 (s, 2H), 6.89 (d, J = 8.4 Hz, 1H), 7.00-7.18 (m, 7H), 7.25 (t, J = 8.0 Hz, 1H), 7.41 (dd, J = 8.0, 4.0 Hz, 1H), 8.58 (dd, J = 8.4, 1.6 Hz, 1H), 8.67 (dd, J = 4.0, 1.6 Hz, 1H), 8.88 (d, J = 8.4 Hz, 1H), 9.59 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) 19.53, 39.08, 55.81, 104.20, 116.96, 120.37, 120.66, 125.87, 127.49, 127.67, 128.18, 128.25, 128.97, 129.04, 131.19, 134.71, 137.85, 138.08, 139.08, 140.43, 148.52, 150.56, 168.16; IR (neat) 3351 w, 1664 m, 1594 w, 1521 s, 1490 s, 1396 m, 1325 w, 1260 m, 1148 m, 1090 m, 903 m; MS m/z (relative intensity, %) 383 (13), 382 (M^+, 45), 292 (11), 210 (11), 209 (77), 208 (100), 194 (37), 174 (35), 166 (13), 165 (31), 159 (18), 119 (22), 91 (12); HRMS Calcd for C25H22N2O2: 382.1681; Found: 382.1684.

2-Benzyl-6-methyl-N-(quinolin-8-yl)benzamide (2b).

Rf 0.23 (hexane/EtOAc = 5/1). 1H NMR (CDCl3, 399.78 MHz) 2.45 (s, 3H), 4.10 (s, 2H), 7.00 (t, J = 8.0 Hz, 1H), 7.05-7.11 (m, 3H), 7.13-7.17 (m, 3H), 7.26 (t, J = 7.6 Hz, 1H), 7.40 (dd, J = 8.0, 4.0 Hz, 1H), 7.53-7.61 (m, 2H), 8.14 (dd, J = 8.0, 1.6 Hz, 1H), 8.65 (dd, J = 4.0, 1.6 Hz, 1H), 8.96 (dd, J = 8.0, 1.6 Hz, 1H), 9.82 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) 19.51, 39.10, 116.67, 121.55, 121.90, 125.88, 127.30, 127.56, 127.86, 128.25 (overlapping peaks), 129.01, 129.09, 134.24, 134.66, 136.18, 137.83, 137.92, 138.39, 140.32, 148.10, 168.60; HRMS Calcd for C24H20N2O: 352.1576; Found: 352.1574.

2-benzyl-6-methyl-N-(5-(perfluoropropan-2-yl)quinolin-8-yl)benzamide (3).

Rf 0.46 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 88 °C. 1H NMR (CDCl3, 399.78 MHz) 2.44(s, 3H), 4.09 (s, 2H), 6.95 (t, J = 7.2 Hz, 1H), 7.04-7.18 (m, 6H), 7.29 (t, J = 7.6 Hz, 1H),
7.51 (dd, J = 7.6, 4.0 Hz, 1H), 7.87 (d, J = 8.8 Hz, 1H), 8.68 (dd, J = 4.0, 1.2 Hz, 1H), 8.77 (d, J = 8.4 Hz, 1H), 9.00 (dd, J = 7.6 Hz, 1H), 10.04 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.48, 39.18, 114.54, 115.44 (d, J = 19.1 Hz), 119.55 (d, J = 27.8 Hz), 122.32 (d, J = 27.6 Hz), 122.46, 125.90, 126.66, 127.79, 128.24, 128.38, 128.92, 129.35, 1134.19 (d, J = 21.0 Hz); 134.64, 137.49, 137.53, 137.79, 138.40, 140.15, 148.11, 169.02; IR (neat) 3336 w, 1712 s, 1517 m, 1359 m, 1266 m, 1220 s, 1096 m, 975 m, 888 m; MS m/z (relative intensity, %) 520 (M$^+$, 11), 210 (13), 209 (85), 208 (100), 194 (29), 166 (11), 165 (28), 119 (19), 91 (10); HRMS Calcd for C$_{27}$H$_{19}$F$_7$N$_2$O: 520.1386; Found: 520.1390.

2-benzyl-$N$-(5-chloroquinolin-8-yl)-6-methylbenzamide (2c and 9).

R$_f$ 0.43 (hexane/EtOAc = 5/1). Light Yellow Solid. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.43 (s, 3H), 4.09 (s, 2H), 6.98 (t, J = 7.2 Hz, 1H), 7.05-7.17 (m, 6H), 7.28 (t, J = 7.6 Hz, 1H), 7.54 (dd, J = 8.4, 4.0 Hz, 1H), 7.66 (d, J = 8.8 Hz, 1H), 8.56 (dd, J = 8.0, 1.6 Hz, 1H), 8.68 (dd, J = 4.0, 1.6 Hz, 1H), 8.90 (d, J = 8.4 Hz, 1H), 9.73 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.51, 39.17, 116.64, 122.27, 124.70, 125.87, 125.90, 127.71, 127.26, 128.26, 128.33, 128.93, 129.23, 1331.32, 133.45, 134.69, 137.71, 137.79, 138.88, 140.26, 148.53, 168.62; IR (neat) 3342 w, 1673 m, 1626 w, 1595 w, 1518 s, 1425 s, 1422 s, 1264 m, 1158 m; MS m/z (relative intensity, %) 386 (M$^+$, 17), 210 (15), 209 (100), 208 (93), 194 (35), 166 (13), 165 (32); HRMS Calcd for C$_{24}$H$_{19}$ClN$_2$O: 386.1186; Found: 386.1189.

2-benzyl-$N$-(5-chloroquinolin-8-yl)-5-methylbenzamide (4).

R$_f$ 0.40 (hexane/EtOAc = 5/1). White Solid. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.40 (s, 3H), 4.25 (s, 2H), 7.04-7.08 (m, 1H), 7.13-7.24 (m, 6H), 7.46 (s, 1H), 7.55 (dd, J = 8.4, 4.0 Hz, 1H), 7.65 (d, J = 8.8 Hz, 1H), 8.57 (dd, J = 8.0, 1.6 Hz, 1H), 8.55 (dd, J = 4.0, 1.6 Hz, 1H), 8.85 (d, J = 8.8 Hz, 1H), 10.02 (brs); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 20.98, 38.44, 116.60, 122.28, 124.52, 125.87, 127.23, 127.77, 128.30, 129.01, 131.02, 131.21, 133.44, 133.85, 136.23, 136.52, 138.96, 140.84, 148.76, 168.36; IR (neat) 3349 w, 1675 m, 1515 s, 1475 s, 1383 m, 1319 m, 1207 w, 950 m; MS m/z (relative intensity, %) 386 (M$^+$, 17), 209
(49), 208 (100), 194 (28), 178 (10), 165 (29); HRMS Calcd for C_{24}H_{19}ClN_{2}O: 386.1186; Found: 386.1187

**2-benzyl-N-(5-chloroquinolin-8-yl)-5-methoxybenzamide (5).**

![Chemical Structure](image)

R_{f} 0.26 (hexane/EtOAc = 5/1). White Solid. Mp = 102 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 3.85 (s, 3H), 4.23 (s, 2H), 6.96 (dd, J = 8.0, 2.8 Hz, 1H), 7.04-7.08 (m, 1H), 7.13-7.20 (m, 6H), 7.54 (dd, J = 8.8, 4.8 Hz, 1H), 7.64 (d, J = 8.0 Hz, 1H), 8.56 (dd, J = 8.4, 1.6 Hz, 1H), 8.73 (dd, J = 4.0, 1.6 Hz, 1H), 8.83 (d, J = 8.4 Hz, 1H), 10.03 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 38.03, 55.47, 112.66, 116.02, 116.53, 122.30, 124.61, 125.86, 127.15, 128.29, 128.93, 131.37, 132.26, 133.34, 133.73, 137.46, 138.96, 140.96, 148.61, 157.89, 167.87; IR (neat) 3347 w, 1675 m, 1605 w, 1516 s, 1475 s, 1319 m, 1219 m, 1038 m, 948 m; MS m/z (relative intensity, %) 402 (M$^+$, 18), 225 (36), 224 (100), 194 (10), 181 (12), 165 (12); HRMS Calcd for C$_{24}$H$_{19}$ClN$_2$O$_2$: 402.1135; Found: 402.1133.

**2-benzyl-5-chloro-N-(5-chloroquinolin-8-yl)benzamide (6).**

![Chemical Structure](image)

R_{f} 0.40 (hexane/EtOAc = 5/1). White Solid. Mp = 162 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 4.25 (s, 2H), 7.05 (q, J = 4.0 Hz, 1H), 7.16-7.21 (m, 5H), 7.38 (dd, J = 8.4, 2.4 Hz, 1H), 7.56 (dd, J = 8.4, 4.4 Hz, 1H), 7.62-7.64 (m, 2H), 8.57 (dd, J = 8.8, 1.2 Hz, 1H), 8.75 (4.4, 1.2 Hz, 1H), 8.81 (d, J = 7.6 Hz, 1H), 10.00 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 38.26, 116.63, 122.39, 124.93, 125.87, 126.17, 127.10, 127.14, 128.43, 129.01, 130.45, 132.23, 132.46, 133.38, 133.47, 137.96, 138.17, 138.92, 139.97, 148.74, 166.60; IR (neat) 3340 w, 1676 m, 1516 s, 1475 s, 1384 m, 13119 m, 1254 w, 941 m, 837 m; MS m/z (relative intensity, %) 408 (27), 407 (10), 406 (M$^+$, 33), 230 (34), 229 (22), 228 (100), 195 (10), 194 (69), 193 (83), 180 (20), 179 (24), 178 (60), 166 (19), 165 (90), 164 (20), 163 (20); HRMS Calcd for C$_{23}$H$_{16}$Cl$_2$N$_2$O: 406.0640; Found: 406.0642.

**2-benzyl-N-(5-chloroquinolin-8-yl)-5-(trifluoromethyl)benzamide (7).**
Rf 0.37 (hexane/EtOAc = 5/1). White Solid. Mp = 176 °C. \( ^1 \)H NMR (CDCl\(_3\), 399.78 MHz) 4.33 (s, 2H), 7.06-7.12 (m, 1H), 7.17-7.12 (m, 4H), 7.39 (d, J = 8.4, 1H), 7.57 (dd, J = 8.8, 4.0 Hz, 1H), 7.64-7.67 (m, 2H), 7.90 (s, 1H), 8.58 (d, J = 8.8 Hz, 1H), 8.76 (d, J = 4.0 Hz, 1H), 8.82 (d, J = 8.8 Hz, 1H), 10.04 (brs, 1H); \( ^{13} \)C NMR (CDCl\(_3\), 100.53 MHz) 38.78, 116.70, 122.37 (q, J = 270 Hz), 122.42, 124.14 (d, J = 3.8 Hz), 125.08, 125.87, 126.36, 127.03, 127.08, 128.53, 129.05 (q, J = 65.8 Hz), 129.08, 131.55, 133.38, 137.17, 138.89, 139.39, 143.70, 148.78, 166.64; IR (neat) 3341 w, 1678 m, 1518 s, 1477 s, 1385 m, 133 s, 1253 m, 1171 m, 1123 s, 944 m; MS m/z (relative intensity, %) 442 (10), 440 (M\(^+\), 31), 379 (12), 263 (30), 262 (100), 194 (32), 180 (16), 179 (10), 178 (51), 166 (11), 165 (47), 164 (11), 163 (11); HRMS Calcd for C\(_{24}\)H\(_{16}\)ClF\(_3\)N\(_2\)O: 440.0903; Found: 440.0901.

5-acetyl-2-benzyl-N-(5-chloroquinolin-8-yl)benzamide (8).

Rf 0.31 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 155 °C. \( ^1 \)H NMR (CDCl\(_3\), 399.78 MHz) 2.63 (s, 3H), 4.34 (s, 2H), 7.07-7.10 (m, 2H), 7.15-7.18 (m, 4H), 7.37 (d, J = 8.0 Hz, 1H), 7.56 (dd, J = 8.0, 4.0 Hz, 1H), 7.65 (d, J = 8.8 Hz, 1H), 7.98 (dd, J = 8.0, 2.0 Hz, 1H), 8.24 (d, J = 8.4 Hz, 1H), 8.57 (dd, J = 8.4, 1.6 Hz, 1H), 8.75 (d, J = 4.4, 1.6 Hz, 1H), 8.83 (d, J = 8.4 Hz, 1H), 10.07 (brs, 1H); \( ^{13} \)C NMR (CDCl\(_3\), 100.53 MHz) 26.62, 38.93, 116.64, 122.39, 124.94, 125.87, 126.28, 127.09, 128.48, 129.09, 130.36, 131.36, 133.37, 133.50, 135.30, 136.98, 138.91, 139.53, 145.10, 148.73, 167.20, 196.95; IR (neat) 3342 w, 1677 s, 1598 w, 1517 s, 1476 s, 1385 m, 1319 m, 1255 m, 942 m; MS m/z (relative intensity, %) 416 (17), 415 (14), 414 (M\(^+\), 47), 237 (29), 236 (100), 221 (40), 195 (24), 194 (35), 193 (11), 180 (16), 179 (17), 178 (48), 165 (37); HRMS Calcd for C\(_{25}\)H\(_{19}\)ClN\(_2\)O: 414.1135; Found: 414.1138.

4-benzyl-3-((5-chloroquinolin-8-yl)carbamoyl)-2-methylphenyl acetate (10).
Rf 0.11 (hexane/EtOAc = 5/1). White Solid. Mp = 169 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 12.25 (s, 3H), 2.34 (s, 3H), 4.06 (s, 2H), 6.68-7.14 (m, 7H), 7.54 (dd, J = 8.0, 4.0 Hz, 1H), 7.65 (d, J = 8.4 Hz, 1H), 8.56 (d, J = 8.0 Hz, 1H), 8.71 (dd, J = 4.0, 1.2 Hz, 1H), 8.89 (d, J = 8.0 Hz, 1H), 9.78 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 13.31, 20.83, 38.82, 116.65, 122.34, 122.92, 124.91, 125.83, 126.03, 127.05 (overlapping peaks), 128.31, 128.70, 128.99, 133.24, 133.30, 135.60, 138.88, 139.04, 139.77, 147.73, 148.66, 167.49, 169.35; IR (neat) 3340 w, 1675 m, 1590 w, 1514 s, 1476 s, 1384 m, 1319 m, 1218 w, 939 m; MS m/z (relative intensity, %) 444 (M$^+$, 16), 267 (26), 266 (17), 226 (11), 225 (71), 224 (100), 223 (10), 210 (24), 181 (19), 179 (10), 178 (12), 165 (11), 152 (10); HRMS Calcd for C$_{26}$H$_{21}$ClN$_2$O$_3$: 444.1241; Found: 444.1245.

2-benzyl-$N$-(5-chloroquinolin-8-yl)-4,5-dimethoxybenzamide (11).

![Chemical Structure](image1)

Rf 0.60 (hexane/EtOAc = 1/1). Yellow Solid. Mp = 60 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 3.85 (s, 3H), 3.94 (s, 3H), 4.29 (s, 2H), 6.73 (s, 1H), 7.11-7.23 (m, 6H), 7.54 (dd, J = 8.0, 4.0 Hz, 1H), 7.63 (d, J = 8.8 Hz, 1H), 8.56 (d, J = 8.8 Hz, 1H), 8.71 (d, J = 4.0, 1H), 8.82 (d, J = 8.4 Hz, 1H), 10.07 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 38.48, 55.88, 56.09, 110.65, 113.69, 116.40, 122.22, 124.36, 125.82, 125.94, 127.14, 128.33, 128.60, 128.77, 132.54, 133.29, 133.83, 138.74, 140.82, 147.19, 148.54, 150.53, 167.66; IR (neat) 3348 w, 1671 m, 1604 w, 1511 s, 1476 s, 1382 m, 1318 m, 1262 s, 1210 s, 1034 m, 397 m; MS m/z (relative intensity, %) 432 (M$^+$, 12), 256 (11), 255 (70), 254 (100), 224 (20), 165 (10); HRMS Calcd for C$_{25}$H$_{21}$ClN$_2$O$_3$: 432.1241; Found: 432.1239.

2,6-dibenzyl-$N$-(5-chloroquinolin-8-yl)-3-fluorobenzamide (12).

![Chemical Structure](image2)

Rf 0.37 (hexane/EtOAc = 5/1). White Solid. Mp = 102 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 4.05 (s, 2H), 4.11 (s, 2H), 6.92-6.95 (m, 1H), 6.98-7.03 (m, 3H), 7.08-7.16 (m, 8H), 7.49 (dd, J = 8.8, 4.4 Hz, 1H), 7.63 (d, J = 8.4 Hz, 1H), 8.52-8.55 (m, 2H), 8.84 (dd, J = 8.0, 2.4 Hz, 1H), 9.56 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 32.53, 38.60, 116.28, 116.51, 122.18, 124.88, 125.05, 125.22, 125.68, 125.91, 126.07, 127.01, 128.18, 128.35, 128.43, 128.91, 129.97 (d, J = 8.6 Hz), 133.06 (d, J = 3.8 Hz), 133.76 (d, J = 3.8 Hz), 138.69, 139.21, 139.26,
139.85, 148.41, 159.69 (d, J = 245 Hz), 166.79 (d, J = 2.8 Hz); IR (neat) 3333 w, 1676 m, 1515 s, 1475 s, 1384 m, 1319 m, 1265 m, 935 m, 724 s; MS m/z (relative intensity, %) 482 (13), 481 (12), 480 (M+, 36), 317 (16), 303 (19), 302 (68), 301 (13), 226 (17), 225 (100), 224 (57), 212 (20), 197 (10), 196 (23), 183 (18), 179 (10), 178 (16), 91 (22); HRMS Calcd for C$_{30}$H$_{22}$ClFN$_2$O: 480.1405; Found: 480.1407.

2,6-dibenzyl-N-(5-chloroquinolin-8-yl)benzamide (13).

![Structure of 2,6-dibenzyl-N-(5-chloroquinolin-8-yl)benzamide (13).]

R$_f$ 0.43 (hexane/EtOAc = 5/1). White Solid. Mp = 171 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 4.09 (s, 4H), 6.98 (t, J = 7.6 Hz, 1H), 7.06-7.15 (m, 10H), 7.27 (t, J = 7.6 Hz, 1H), 7.45 (dd, J = 8.0, 4.0 Hz, 1H), 7.61 (d, J = 8.8 Hz, 1H), 8.49 (dd, J = 8.4, 1.6 Hz, 1H), 8.57 (dd, J = 4.0, 1.2 Hz, 1H), 8.86 (d, J = 8.0 Hz, 1H), 9.63 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 39.13, 116.44, 122.14, 124.62, 125.67, 125.92, 127.02, 128.13, 128.25, 128.94, 129.31, 133.04, 133.30, 137.55, 137.90, 138.75, 140.06, 148.37, 168.27; IR (neat) 3339 w, 1674 m, 1514 s, 1384 m, 1319 m, 1260 w, 939 m; MS m/z (relative intensity, %) 462 (M+, 18), 285 (29), 284 (74), 283 (11), 208 (17), 207 (100), 206 (30), 179 (18), 178 (31), 165 (15), 91 (28); HRMS Calcd for C$_{30}$H$_{22}$ClFN$_2$O: 462.1499; Found: 462.1504.

2-benzyl-N-(5-chloroquinolin-8-yl)-1-naphthamide (14).

![Structure of 2-benzyl-N-(5-chloroquinolin-8-yl)-1-naphthamide (14).]

R$_f$ 0.34 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 192 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 4.26 (s, 2H), 7.05 (t, J = 7.2 Hz, 1H), 7.14 (t, J = 7.6 Hz, 1H), 7.22 (d, J = 7.2 Hz, 2H), 7.37 (d, J = 7.8 Hz, 1H), 7.47-7.51 (m, 3H), 7.69 (d, J = 8.4 Hz, 1H), 7.83-7.87 (m, 2H), 8.00 (dd, J = 8.4, 4.0 Hz, 1H), 8.55 (dd, J = 8.8, 4.4 Hz, 1H), 8.61 (dd, J = 4.4, 1.6 Hz, 1H), 9.05 (d, J = 8.0 Hz, 1H), 10.05 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 39.42, 116.76, 122.31, 124.91, 125.90, 125.98, 126.10, 127.17, 127.20, 1127.96, 128.04, 128.39, 129.00, 129.58, 130.15, 131.99, 133.28, 133.54, 134.18, 135.36, 138.87, 140.14, 148.57, 168.21; IR (neat) 3339 w, 1674 m, 1515 s, 1476 s, 1386 w, 1318 m, 1215 w, 937 w; MS m/z (relative intensity, %) 422 (M+, 10), 246 (18), 245 (100), 244 (93), 227 (17), 226 (10), 216 (11), 215 (34), 202 (14); HRMS Calcd for C$_{27}$H$_{19}$ClN$_2$O: 422.1186; Found: 422.1185.
(8R,9S,13S,14S)-2-benzyl-N-(5-chloroquinolin-8-yl)-13-methyl-17-oxo-7,8,9,11,12,13,14,15,16,17-decahydro-6H-cyclopenta[a]phenanthrene-3-carboxamide (15).

Rf 0.31 (hexane/EtOAc = 2/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 0.92 (s, 3H), 1.44-1.68 (m, 6H), 1.95-2.55 (m, 7H), 2.97 (dd, J = 9.6, 3.6 Hz, 2H), 4.26 (q, J = 15.6 Hz, 2H), 7.06 (t, J = 6.8 Hz, 1H), 7.13-7.22 (m, 5H), 7.40 (s, 1H), 7.54 (dd, J = 8.8, 4.0, 1H), 7.63 (dd, J = 8.8 Hz, 1H), 8.56 (dd, J = 8.4, 1.6 Hz, 1H), 8.73 (dd, J = 4.4, 1.6 Hz, 1H), 8.83 (d, J = 8.0 Hz, 1H), 10.01 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 13.81, 21.55, 25.57, 26.32, 28.95, 31.46, 35.80, 37.95, 38.74, 44.44, 47.89, 50.41, 116.43, 122.26, 124.41, 125.85, 127.19, 127.86, 128.26, 128.30, 128.80, 133.31, 133.92, 134.25, 134.79, 136.78, 139.01, 140.92, 142.26, 148.55, 168.19, 220.73; IR (neat) 3351 w, 2930 w, 1737 m, 1674 m, 1517 s, 1476 m, 1383 m, 1319 m, 938 w; MS m/z (relative intensity, %) 548 (M$^+$, 14), 372 (12), 371 (53), 370 (100), 368 (14), 207 (26); HRMS Calcd for C$_{35}$H$_{33}$ClN$_2$O$_2$: 548.2231; Found: 548.2228.

2-benzyl-N-(5-chloroquinolin-8-yl)cyclohex-1-ene carboxamide (16).

Rf 0.09 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 1.63-1.76 (m, 4H), 2.01-2.04 (m, 2H), 2.51-2.52 (m, 2H), 3.64 (s, 2H), 7.16-7.21 (m, 1H), 7.24-7.31 (m, 4H), 7.54 (dd, J = 8.0, 4.0 Hz, 1H), 7.60 (d, J = 8.4 Hz, 1H), 8.54 (dd, J = 8.0, 1.6 Hz, 1H), 8.76 dd, J = 4.4, 1.6 Hz, 1H), 8.81 (d, J = 8.4 Hz, 1H), 9.93 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 22.21, 22.23, 27.33, 28.77, 40.69, 116.52, 122.24, 124.23, 125.87, 126.01, 127.21, 128.33, 128.85, 131.26, 133.36, 133.76, 138.51, 138.93, 139.38, 148.47, 170.00; IR (neat) 3356 w, 2931 w, 1672 m, 1516 s, 1477 s, 1384 m, 1319 m, 939 w; MS m/z (relative intensity, %) 376 (M$^+$, 12), 199 (55), 198 (100), 178 (30), 157 (25), 129 (10), 91 (17); HRMS Calcd for C$_{23}$H$_{21}$ClN$_2$O: 376.1342; Found: 376.1341.

methyl 4-(2-((5-chloroquinolin-8-yl)carbamoyl)-3-methylbenzyl)benzoate (17).
Rf 0.14 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 173 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.43 (s, 3H), 3.79 (s, 3H), 4.12 (s, 2H), 7.10-7.20 (m, 4H), 7.31 (t, J = 8.0 Hz, 1H), 7.50 (dd, J = 8.8, 4.4 Hz, 1H), 7.63-7.66 (m, 3H), 8.54 (dd, J = 8.4, 1.6 Hz, 1H), 8.62 (dd, J = 4.0, 1.6 Hz, 1H), 8.85 (d, J = 8.8 Hz, 1H), 9.58 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.44, 39.38, 51.81, 116.53, 122.19, 124.78, 125.79, 127.08, 127.69, 127.88, 128.70, 128.84, 129.32, 129.54, 133.23, 133.28, 134.86, 136.86, 137.81, 138.66, 145.73, 148.50, 166.66, 168.38; IR (neat) 3341 w, 1718 m, 1676 m, 1514 s, 1476 s, 1319 m, 1278 m, 1108 m, 938 m, 753 m; MS m/z (relative intensity, %) 446 (14), 445 (12), 444 (37), 268 (16), 267 (88), 266 (100), 235 (13), 223 (14), 208 (57), 207 (67), 193 (13), 192 (19), 179 (27), 178 (30), 165 (30); HRMS Calcd for C$_{26}$H$_{21}$ClN$_2$O$_3$: 444.1241; Found: 444.1240.

$N$-(5-chloroquinolin-8-yl)-2-methyl-6-(4-(trifluoromethyl)benzyl)benzamide (18).

Rf 0.26 (hexane/EtOAc = 5/1). White Solid. Mp = 119 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 3.43 (s, 3H), 4.13 (s, 2H), 7.13 (d, J = 7.6 Hz, 1H), 7.19-7.26 (m, 5H), 7.33 (d, J = 8.0 Hz, 1H), 7.53 (dd, J = 8.4, 4.0 Hz, 1H), 7.65 (d, J = 8.4 Hz, 1H), 8.56 (dd, J = 8.8, 2.0 Hz, 1H), 8.62 (dd, J = 4.0, 1.6 Hz, 1H), 8.87 (d, J = 8.8 Hz, 1H), 9.59 (bns, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.47, 39.18, 116.55, 122.37, 124.03 (q, J = 271 Hz), 124.91, 125.12 (d, J = 3.8 Hz), 125.87, 127.10, 127.89, 128.15 (q, J = 32.4 Hz), 128.82, 129.06, 129.40, 133.18, 133.40, 135.02, 136.65, 137.82, 138.61, 144.44, 148.57, 168.37; IR (neat) 3342 w, 1718 m, 1678 m, 1516 s, 1477 s, 1385 m, 1323 s, 1186 m, 1121 m, 1066 m; MS m/z (relative intensity, %) 454 (M$^+$, 21), 278 (16), 277 (100), 276 (86), 262 (18), 208 (11), 165 (20); HRMS Calcd for C$_{25}$H$_{18}$ClF$_3$N$_2$O: 454.1060; Found: 454.1057.

2-(4-chlorobenzyl)-$N$-(5-chloroquinolin-8-yl)-6-methylbenzamide (19).
**N-(5-chloroquinolin-8-yl)-2-methyl-6-(4-methylbenzyl)benzamide (20).**

Rf 0.34 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 139 °C. ¹H NMR (CDCl₃, 399.78 MHz) 2.08 (s, 3H), 2.43 (s, 3H), 4.04 (s, 2H), 6.84 (d, J = 7.6 Hz, 1H), 7.00 (d, J = 8.0 Hz, 1H), 7.08 (d, J = 8.8 Hz, 1H), 7.14 (d, J = 8.8 Hz, 1H), 7.27 (t, J = 8.0 Hz, 1H), 7.52 (dd, J = 8.0, 4.0 Hz, 1H), 7.65 (d, J = 8.0 Hz, 1H), 8.55 (dd, J = 8.8, 1.2 Hz, 1H), 8.67 (dd, J = 4.0, 1.2 Hz, 1H), 8.90 (d, J = 8.0 Hz, 1H), 9.68 (brs, 1H); ¹³C NMR (CDCl₃, 100.53 MHz) 19.45, 20.79, 38.79, 116.57, 122.18, 124.60, 125.82, 127.15, 127.66, 128.21, 128.76, 128.92, 129.16, 133.25, 133.51, 134.61, 135.30, 137.21, 137.68, 138.07, 138.82, 148.43, 168.64; IR (neat) 3343 w, 1677 m, 1513 s, 1476 s, 1383 m, 1319 m, 938 m, 786 m; MS m/z (relative intensity, %) 400 (M⁺, 12), 224 (11), 223 (76), 222 (100), 208 (32), 179 (12), 178 (11), 165 (14); HRMS Calcd for C₂₅H₂₁ClN₂O: 400.1342; Found: 400.1341.

**N-(5-chloroquinolin-8-yl)-2-(4-methoxybenzyl)-6-methylbenzamide (21).**
Rf 0.20 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.42 (s, 3H), 3.56 (s, 3H), 4.02 (s, 2H), 6.56 (d, J = 8.4 Hz, 1H), 7.02 (d, J = 8.0 Hz, 2H), 7.09 (d, J = 7.6 Hz, 1H), 7.14 (d, J = 7.6 Hz, 1H), 7.28 (t, J = 7.6 Hz, 1H), 7.53 (dd, J = 8.4, 4.0 Hz, 1H), 7.65 (d, J = 8.8 Hz, 1H); 8.56 (dd, J = 8.8, 1.2 Hz, 1H), 8.67 (dd, J = 4.0, 1.2 Hz, 1H), 8.90 (d, J = 8.4 Hz, 1H), 9.06 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.44, 38.39, 54.91, 113.56, 116.53, 122.23, 124.60, 125.81, 127.13, 127.64, 128.25, 129.17, 129.78, 132.39, 133.20, 133.51, 134.67, 137.65, 138.21, 138.83, 148.49, 157.68, 168.66; IR (neat) 3343 w, 1677 m, 1512 s, 1477 s, 1384 m, 1247 m, 1037 w, 939 m; MS m/z (relative intensity, %) 416 (M$^+$, 9), 239 (47), 238 (100), 224 (14); HRMS Calcd for C$_{25}$H$_{21}$ClN$_2$O$_2$: 416.1292; Found: 416.1293.

$N$-(5-chloroquinolin-8-yl)-2-methyl-6-(3-methylbenzyl)benzamide (22).

Rf 0.40 (hexane/EtOAc = 5/1). Colorless Oil. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.01 (s, 3H), 2.43 (s, 3H), 4.04 (s, 2H), 6.73 (d, J = 6.8 Hz, 1H), 6.91-6.97 (m, 3H), 7.10 (d, J = 7.2 Hz, 1H), 7.14 (d, J = 8.0 Hz, 1H), 7.27 (t, J = 7.6 Hz, 1H), 7.51 (dd, J = 8.0, 4.0 Hz, 1H), 7.64 (d, J = 8.4 Hz, 1H), 8.54 (dd, J = 8.4, 1.6 Hz, 1H), 8.65 (dd, J = 4.4, 1.6 Hz, 1H), 8.91 (d, J = 8.4 Hz, 1H), 9.67 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.44, 21.05, 39.17, 116.49, 122.22, 124.60, 125.81, 125.90, 126.59, 127.10, 127.73, 128.12, 128.25, 129.66, 133.16, 133.51, 134.61, 137.73, 137.93, 138.90, 140.15, 148.46, 168.61; IR (neat) 3343 w, 1677 m, 1512 s, 1476 s, 1383 m, 1319 m, 938 m; MS m/z (relative intensity, %) 400 (M$^+$, 17), 224 (15), 223 (95), 222 (100), 208 (37), 179 (16), 178 (13), 165 (18); HRMS Calcd for C$_{25}$H$_{21}$ClN$_2$O: 400.1342; Found: 400.1341.

2-(3-acetamidobenzyl)-$N$-(5-chloroquinolin-8-yl)-6-methylbenzamide (23).
Rf 0.23 (hexane/EtOAc = 1/1). White Solid. Mp = 212 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 1.97 (s, 3H), 2.41 (s, 3H), 4.00 (s, 2H), 6.82 (d, J = 8.0, 1H), 6.95-6.99 (m, 2H), 7.08 (d, J = 8.4 Hz, 1H), 7.14 (d, J = 6.8 Hz, 1H), 7.24-7.33 (m, 2H), 7.51 (dd, J = 8.0, 4.0 Hz, 1H), 7.62 (d, J = 8.0 Hz, 1H), 8.53 (dd, J = 8.4, 1.6 Hz, 1H), 8.65 (dd, J = 4.0, 1.6 Hz, 1H), 8.87 (d, J = 8.0 Hz, 1H), 9.651 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.40, 24.30, 39.16, 116.45, 117.45, 119.83, 122.39, 124.48, 124.75, 125.80, 126.99, 127.80, 128.42, 129.28, 130.56, 133.11, 133.38, 134.65, 137.41, 137.59, 137.96, 138.81, 140.94, 148.66, 168.11, 168.66; IR (neat) 3361w, 3291w, 1676m, 1657m, 1517 s, 1478 s, 1369 m, 1306 m, 1263 m, 941 m; MS m/z (relative intensity, %) 443 (M$^+$, 16), 225 (16), 224 (100), 223 (84), 180 (11), 178 (13); HRMS Calcd for C$_{26}$H$_{22}$ClN$_3$O: 443.1401; Found: 443.1404.

$N$-(5-chloroquinolin-8-yl)-2-(2-iodobenzyl)-6-methylbenzamide (24).

Rf 0.34 (hexane/EtOAc = 5/1). Light Yellow Solid. Mp = 148 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.46 (s, 3H), 4.21 (s, 2H), 6.79-6.87 (m, 2H), 7.15-7.27 (m, 4H), 7.54 (dd, J = 8.0, 4.0 Hz, 1H), 7.65 (d, J = 8.0, 1H), 7.69 (d, J = 8.0 Hz, 1H), 8.56 (dd, J = 8.0, 1.6 Hz, 1H), 8.71 (dd, J = 4.0, 1.6 Hz, 1H), 8.91 (d, J = 8.4 Hz, 1H); 9.91 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.55, 43.94, 101.36, 116.79, 122.30, 124.78, 125.92, 127.04, 127.19, 128.00, 128.36, 128.52, 129.27, 130.70, 133.39, 133.46, 134.73, 136.39, 137.80, 138.93, 139.38, 142.80, 147.58, 168.46; IR (neat) 3340 w, 1676 m, 1514 s, 1476 s, 1384 m, 1319 m, 939 m, 750 m; MS m/z (relative intensity, %) 514 (10), 512 (28), 335 (36), 209 (18), 208 (100), 207 (96), 193 (10), 179 (14), 178 (25), 165 (26); HRMS Calcd for C$_{26}$H$_{18}$ClN$_2$O$_2$: 512.0152; Found: 512.0149.

$N$-(5-chloroquinolin-8-yl)-2-methyl-6-(2-methylbenzyl)benzamide (25).

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R_f 0.40 (hexane/EtOAc = 5/1). Colorless Oil.  ^1^H NMR (CDCl\textsubscript{3}, 399.78 MHz) 2.36 (s, 3H), 2.60 (s, 3H), 4.09 (s, 2H), 6.85 (d, J = 7.6 Hz, 1H), 6.97-7.02 (m, 2H), 7.06-7.07 (m, 2H), 7.15 (d, J = 7.2 Hz, 1H), 7.23 (t, J = 7.6 Hz, 1H), 7.52 (dd, J = 8.4, 4.0 Hz, 1H), 7.64 (d, J = 8.8 Hz, 1H), 8.54 (dd, J = 8.4, 1.6 Hz, 1H), 8.71 (dd, J = 4.4, 1.6 Hz, 1H), 8.90 (d, J = 8.4 Hz, 1H), 9.81 (brs, 1H); ^1^C NMR (CDCl\textsubscript{3}, 100.53 MHz) 19.47, 19.64, 36.39, 116.57, 122.27, 124.70, 125.86, 126.30, 126.87, 127.10, 128.12, 129.06, 130.06, 133.24, 133.49, 134.60, 136.57, 137.16, 137.74, 138.02, 148.60, 168.63; IR (neat) 3345 w, 1678 m, 1515 s, 1476 s, 1384 m, 1319 m, 939 m; MS m/z (relative intensity, %) 400 (M\textsuperscript{+}, 17), 224 (15), 223 (98), 222 (100), 208 (37), 179 (13), 178 (14), 165 (16); HRMS Calcd for C\textsubscript{25}H\textsubscript{21}ClN\textsubscript{2}O: 400.1342; Found: 400.1340.

N-(5-chloroquinolin-8-yl)-2-(2-methoxybenzyl)-6-methylbenzamide (26).

R_f 0.23 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 138 °C. Yellow Solid. Mp = 138 °C. ^1^H NMR (CDCl\textsubscript{3}, 399.78 MHz) 2.43 (s, 3H), 3.57 (s, 3H), 4.09 (s, 2H), 6.63 (d, J = 7.6 Hz, 1H), 6.77 (td, J = 7.2, 0.8 Hz, 1H), 7.02-7.12 (m, 4H), 7.23 (t, J = 7.6 Hz, 1H), 7.49 (dd, J = 8.4, 4.4 Hz, 1H), 7.63 (d, J = 8.8 Hz, 1H), 8.52 (dd, J = 8.4, 1.6 Hz, 1H), 8.67 (dd, J = 4.0, 2.0 Hz, 1H), 8.93 (d, J = 8.8 Hz, 1H), 9.82 (brs, 1H); ^1^C NMR (CDCl\textsubscript{3}, 100.53 MHz) 19.47, 32.88, 55.03, 110.03, 116.51, 120.30, 122.20, 124.47, 125.78, 127.09, 127.32, 128.08, 128.98, 130.52, 133.14, 133.66, 134.44, 137.65, 137.68, 138.92, 148.48, 157.04, 168.75; IR (neat) 3344 w, 1677 m, 1590 w, 1514 s, 1476 s, 1383 m, 1319 m, 1245 m, 939 m, 753 m; MS m/z (relative intensity, %) 416 (M\textsuperscript{+}, 15), 240 (15), 239 (88), 238 (100), 224 (21), 223 (1), 208 (10), 195 (11); HRMS Calcd for C\textsubscript{25}H\textsubscript{21}ClN\textsubscript{2}O: 416.1292; Found: 416.1288.

N-(5-chloroquinolin-8-yl)-2-(3,5-dimethylbenzyl)-6-methylbenzamide (27).
Rf 0.43 (hexane/EtOAc = 5/1). White Solid. Mp = 143 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 1.97 (s, 6H), 2.42 (s, 3H), 3.99 (s, 2H), 6.47 (s, 1H), 6.70 (s, 2H), 7.14 (t, J = 9.2 Hz, 2H), 7.28 (t, J = 8.0 Hz, 1H), 7.52 (dd, J = 8.0, 4.0 Hz, 1H), 7.65 (d, J = 8.0 Hz, 1H), 8.55 (dd, J = 8.4, 1.6 Hz, 1H), 8.65 (dd, J = 4.4, 1.6 Hz, 1H), 8.91 (d, J = 8.4 Hz, 1H), 9.61 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.42, 20.94, 39.18, 116.45, 122.20, 124.53, 125.79, 126.69, 127.11, 127.42, 127.78, 128.20, 129.13, 133.18, 133.53, 134.56, 137.60, 137.75, 138.07, 138.84, 141.08, 148.31, 168.67; IR (neat) 3343 w, 2977 m, 1513 s, 1476 s, 1382 m, 1319 m, 938 m, 754 m; MS m/z (relative intensity, %) 414 (M$^+$, 16), 238 (14), 237 (82), 222 (34), 221 (11), 179 (20), 178 (12); HRMS Calcd for C$_{26}$H$_{23}$ClN$_2$O: 414.1499; Found: 414.1498.

$N$-(5-chloroquinolin-8-yl)-2-methyl-6-(naphthalen-1-ylmethyl)benzamide (28).

Rf 0.26 (hexane/EtOAc = 5/1). White Solid. Mp = 79 °C. $^1$H NMR (CDCl$_3$, 399.78 MHz) 2.47 (s, 3H), 4.55 (s, 2H), 6.88 (d, J = 6.8 Hz, 1H), 7.14-7.21 (m, 2H), 7.28-7.36 (m, 4H), 7.52 (dd, J = 8.8, 4.0 Hz, 1H), 7.59-7.62 (m, 2H), 7.67-7.69 (m, 1H), 7.94-7.67 (m, 1H), 8.53 (dd, J = 8.4, 1.6 Hz, 1H), 8.69 (dd, J = 4.0, 1.6 Hz, 1H), 8.88 (d, J = 8.4 Hz, 1H), 9.85 (brs, 1H); $^{13}$C NMR (CDCl$_3$, 100.53 MHz) 19.52, 35.99, 116.69, 122.25, 124.16, 124.74, 125.39 (overlapping peaks), 125.85, 125.92, 127.06, 127.10, 127.16, 127.64, 128.33 (overlapping peaks), 129.23, 131.94, 133.31, 133.40, 133.74, 134.65, 135.77, 137.38, 137.59, 138.86, 148.56, 168.72; IR (neat) 3342 w, 1676 m, 1616 s, 1577 s, 1373 s, 1379 m, 1383 m, 1485 m, 1687 m; MS m/z (relative intensity, %) 436 (16), 259 (54), 258 (100), 244 (17), 215 (30), 178 (15); HRMS Calcd for C$_{28}$H$_{21}$ClN$_2$O: 436.1342; Found: 436.1340

2-(2-bromo-5-fluorobenzyl)-N-(5-chloroquinolin-8-yl)-6-methylbenzamide (29).
Rf 0.40 (hexane/EtOAc = 5/1). White Solid. Mp = 125 °C.  
\(^1\)H NMR (CDCl\(_3\), 399.78 MHz) 
2.46 (s, 3H), 4.18 (s, 2H), 6.66 (td, J = 8.0, 2.8 Hz, 1H), 6.89 (dd, J = 9.6, 2.8 Hz, 1H), 6.97 (d, J = 7.6 Hz, 1H), 7.21 (d, J = 8.0 Hz, 1H), 7.28-7.32 (m, 2H), 7.53 (dd, J = 8.4, 4.4 Hz, 1H), 7.64 (d, J = 8.0 Hz, 1H), 8.56 (dd, J = 8.4, 1.6 Hz, 1H), 8.71 (dd, J = 4.0, 1.6 Hz, 1H), 8.88 (d, J = 8.4 Hz, 1H), 9.81 (brs, 1H); \(^{13}\)C NMR (CDCl\(_3\), 100.53 MHz) 19.54, 39.21, 115.95 (d, J = 21.9 Hz), 116.67, 118.11 (d, J = 22.9 Hz), 118.78 (d, J = 0.29 Hz), 122.34, 124.85, 125.87, 127.15, 127.33, 128.89, 129.42, 133.32, 133.61 (d, J = 0.85 Hz), 134.98, 134.46, 137.91, 138.96, 148.61, 161.99 (d, J = 245.1 Hz), 168.24; IR (neat) 3339 w, 1674 m, 1514 s, 1475 s, 1384 m, 1319 m, 1218 m, 1029 w, 938 m, 751 s; MS m/z (relative intensity, %) 484 (20), 482 (M\(^+\), 15), 307 (40), 305 (41), 305 (41), 305 (41), 307 (40), 307 (41), 307 (41), 226 (44), 225 (100), 197 (10), 196 (11), 183 (41), 178 (11); HRMS Calcd for C\(_{24}\)H\(_{17}\)BrClFN\(_2\)O: 482.0197; Found: 482.0193.

2-(3-bromo-5-fluorobenzyl)-N-(5-chloroquinolin-8-yl)-6-methylbenzamide (30).

Rf 0.40 (hexane/EtOAc = 5/1). Yellow Solid. Mp = 160 °C.  
\(^1\)H NMR (CDCl\(_3\), 399.78 MHz) 
2.44 (s, 3H), 4.01 (s, 2H), 6.71 (d, J = 8.0 Hz, 1H), 6.77 (d, J = 9.6 Hz, 1H), 7.02 (s, 1H), 7.11 (d, J = 7.2 Hz, 1H), 7.20 (d, J = 7.6 Hz, 1H), 7.32 (t, J = 7.6 Hz, 1H), 7.53 (dd, J = 8.0, 4.0 Hz, 1H), 7.65 (d, J = 8.8 Hz, 1H), 8.55 (d, J = 8.0 Hz, 1H), 8.68 (d, J = 4.0 Hz, 1H), 8.86 (d, J = 8.4 Hz, 1H), 9.60 (brs, 1H); \(^{13}\)C NMR (CDCl\(_3\), 100.53 MHz) 19.45, 38.84, 114.74 (d, J = 21.0 Hz), 116.56, 116.57 (d, J = 23.8 Hz), 122.23 (d, J = 10.5 Hz), 122.34, 124.95, 125.90, 127.11, 127.67 (d, J = 2.9 Hz), 127.83, 129.00, 129.44, 133.15, 133.28, 135.03, 136.11, 137.82, 138.82, 144.43 (d, J = 7.7 Hz), 148.59, 162.41 (d, J = 248.8 Hz), 168.18; IR (neat) 3338 w, 1674 m, 1578 m, 1514 s, 1476 m, 1439 m, 1384 m, 1319 m, 1259 w, 938 w, 729 s; MS m/z (relative intensity, %) 486 (12), 485 (12), 484 (45), 483 (10), 482 (M\(^+\), 33), 308 (15), 307 (97), 306 (89), 305 (99), 304 (77), 227 (33), 226 (58), 225 (41), 199 (19), 197 (29), 196 (26), 184 (18), 183 (100), 181 (11), 180 (14), 179 (25), 178 (39), 164 (15), 163 (14); HRMS Calcd for C\(_{24}\)H\(_{17}\)BrClFN\(_2\)O: 482.0197; Found: 482.0199.
2-(3-chloro-4-methylbenzyl)-N-(5-chloroquinolin-8-yl)-6-methylbenzamide (31a) and 2-(2-chloro-4-methylbenzyl)-N-(5-chloroquinolin-8-yl)-6-methylbenzamide (31b).

\[
\begin{align*}
\text{Rf} & \ 0.40 \ (\text{hexane/EtOAc} = 5/1). \ \text{White Solid.} \ \text{Mp} & \ 179 \ ^\circ \text{C.} \\
\text{H NMR (CDCl}_3, & \ 399.78 \ \text{MHz}) \ \delta & \ 1.99 (\text{s, } 3\text{H}), 2.15 (\text{d, } J = 7.6 \ \text{Hz}, 3\text{H}), 2.42 (\text{s, } 3\text{H}), 2.44 (\text{s, } 3\text{H}), 4.00 (\text{s, } 2\text{H}), 4.17 (\text{d, } J = 7.6 \ \text{Hz}, 1\text{H}), 7.00-7.06 (\text{d, } J = 7.6 \ \text{Hz}, 1\text{H}), 7.10-7.18 (\text{d, } J = 7.6 \ \text{Hz}, 1\text{H}), 7.50-7.54 (\text{d, } J = 8.8 \ \text{Hz}, 1\text{H}), 8.53-8.56 (\text{d, } J = 4.4, 1.6 \ \text{Hz}, 1\text{H}), 8.71 (\text{d, } J = 4.0, 1.6 \ \text{Hz}, 1\text{H}), 8.87 (\text{d, } J = 4.4, 1.6 \ \text{Hz}, 1\text{H}), 8.91 (\text{d, } J = 8.4 \ \text{Hz}, 1\text{H}), 9.59 (\text{s, } 1\text{H}), 9.84 (\text{s, } 1\text{H}); \\
\text{C NMR (CDCl}_3, & \ 100.53 \ \text{MHz}) \ \delta & \ 19.27, 19.41, 19.48, 20.57, 36.09, 38.63, 116.49, 116.65, 122.18, 122.24, 124.67, 125.80, 125.85, 127.13, 127.56, 127.78, 128.36, 128.57, 129.17, 129.26, 130.27, 131.11, 133.21, 133.29, 133.30, 133.50, 133.80, 134.06, 134.56, 134.61, 134.79, 136.56, 137.19, 137.59, 137.71, 137.76, 138.74, 138.90, 139.58, 148.43, 148.52; \ \text{IR (neat)} \\
& \ 3341 \ \text{w}, 1676 \ \text{m}, 1514 \ \text{s}, 1476 \ \text{s}, 1383 \ \text{m}, 1319 \ \text{m}, 1049 \ \text{w}, 938 \ \text{m}; \ \text{MS m/z} (\text{relative intensity, } \%) & \ 436 (16), 434 (M^+), 259 (27), 258 (82), 256 (100), 242 (12), 222 (58), 221 (58), 179 (37), 178 (26); \ \text{HRMS Calcd for C}_{25}\text{H}_{20}\text{Cl}_{2}\text{N}_{2}O: 434.0953; \ \text{Found: 434.0954.}
\end{align*}
\]

\[\text{N-(5-methoxyquinolin-8-yl)-3-methyl-4-phenylbutanamide (33).} \]

\[
\begin{align*}
\text{Rf} & \ 0.31 \ (\text{hexane/EtOAc} = 3/1). \ \text{White Solid.} \ \text{Mp} & \ 66 \ ^\circ \text{C.} \ \text{H NMR (CDCl}_3, & \ 399.78 \ \text{MHz}) \ \delta & \ 1.04 (\text{d, } J = 6.0 \ \text{Hz}, 3\text{H}), 2.34 (\text{dd, } J = 14.0, 7.2 \ \text{Hz}, 1\text{H}), 2.43-2.66 (\text{m, } 3\text{H}), 2.78 (\text{dd, } J = 13.6, 6.0 \ \text{Hz}, 1\text{H}), 3.98 (\text{s, } 3\text{H}), 6.83 (\text{d, } J = 8.8 \ \text{Hz}, 1\text{H}), 7.11-7.35 (\text{m, } 5\text{H}), 7.44 (\text{q, } J = 4.3 \ \text{Hz}, 1\text{H}), 8.57 (\text{dd, } J = 8.5, 1.6 \ \text{Hz}, 1\text{H}), 8.71 (\text{d, } J = 8.7 \ \text{Hz}, 1\text{H}), 8.81 (\text{dd, } J = 4.0, 1.2 \ \text{Hz}, 1\text{H}), 9.54 (\text{b, } 1\text{H}); \\
\text{C NMR (CDCl}_3, & \ 100.53 \ \text{MHz}) \ \delta & \ 19.56, 32.68, 43.05, 44.95, 55.72, 104.28, 116.50, 120.36, 120.66, 125.92, 127.89, 128.21, 129.29, 131.22, 138.98, 140.35, 148.54,
\end{align*}
\]
150.11, 170.60; IR (neat) 3362 w, 3011 w, 1734 w, 1672 w, 1596 w, 1525 m, 1493 m; MS m/z (relative intensity, %) 334 (M+, 30), 216 (70), 201 (12), 175 (14), 174 (100), 159 (77), 91 (16); HRMS Calcd for C21H22N2O2: 334.1681; Found: 334.1684.

N-(5-chloroquinolin-8-yl)-2-iodo-6-methylbenzamide (34).

Rf 0.43 (hexane/EtOAc = 5/1). White Solid. Mp = 210 °C. 1H NMR (CDCl3, 399.78 MHz) δ 2.46 (s, 3H), 7.05 (t, J = 8.0 Hz, 1H), 7.25 (d, J = 7.2 Hz, 1H), 7.57 (dd, J = 8.4, 4.0 Hz, 1H), 7.69 (d, J = 8.4 Hz, 1H), 7.73 (d, J = 8.0 Hz, 1H), 8.59 (dd, J = 8.4, 1.6 Hz, 1H), 8.81 (dd, J = 4.0, 1.6 Hz, 1H), 8.91 (d, J = 8.4 Hz, 1H), 9.88 (brs, 1H); 13C NMR (CDCl3, 100.53 MHz) δ 20.13, 92.85, 116.94, 122.43, 125.08, 126.02, 127.19, 130.08, 130.67, 133.37, 133.41, 136.61, 136.79, 139.07, 142.92, 148.83, 168.13; IR (neat) 330 w, 1725 w, 1672 m, 1581 m, 1517 s, 1476 s, 1381 m, 1266 m; MS m/z (relative intensity, %) 424 (10), 422 (M+, 30), 245 (100), 90 (18); HRMS Calcd for C17H12ClIN2O: 421.9683; Found: 421.9687.

1-(5-chloroquinolin-8-yl)-3,3-dimethylazetidin-2-one (36).

Rf 0.26 (hexane/EtOAc = 5/1). White Solid. Mp = 155 °C. 1H NMR (CDCl3, 399.78 MHz) δ 1.45 (s, 6H), 4.33 (s, 2H), 7.49 (dd, J = 8.4, 4.0 Hz, 1H), 7.56 (d, J = 8.8 Hz, 1H), 8.45 (d, J = 8.4 Hz, 1H), 8.53 (dd, J = 8.8, 6.0 Hz, 1H), 8.84 (dd, J = 4.0, 1.6 Hz, 1H); 13C NMR (CDCl3, 100.53 MHz) δ 21.44, 51.62, 60.79, 119.08, 121.89, 124.99, 126.58, 126.75, 132.75, 134.48, 140.82, 148.80, 173.71; IR (neat) 2966 w, 1739 s, 1502 m, 1466 m, 1399 m, 1350 m, 1140 m; MS m/z (relative intensity, %) 260 (M+, 21), 232 (18), 217 (12), 206 (32), 205 (13), 204 (100), 189 (17), 165 (11), 163 (33); HRMS Calcd for C14H13ClN2O: 260.0716; Found: 260.0716.

Deuterium Labeling Experiments (eq 2).

To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)-2-methylbenzamide 1c-d7 (90 mg, 0.3 mmol), heptafluoroisopropyl iodide (107 mg, 0.36 mmol), Ni(OTf)2 (10.6 mg, 0.03 mmol), PPh3 (7.8 mg, 0.03 mmol), Na2CO3 (64 mg, 0.6 mmol) and toluene (1 mL) were added in a glove box. The mixture was stirred for 4 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The ratio of deuterium was determined by 1H-NMR.
Deuterium Labeling Experiments (eq 3).
To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)-2-methylbenzamide 1c (89 mg, 0.3 mmol), heptafluoroisopropyl iodide (107 mg, 0.36 mmol), Ni(OTf)$_2$ (10.6 mg, 0.03 mmol), PPh$_3$ (7.8 mg, 0.03 mmol), Na$_2$CO$_3$ (64 mg, 0.6 mmol) and toluene-d$_8$ (1 mL) were added in a glove box. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The ratio of deuterium was determined by $^1$H-NMR.

Deuterium Labeling Experiments (eq 4).
To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)-2-methylbenzamide 1c (89 mg, 0.3 mmol), heptafluoroisopropyl iodide (107 mg, 0.36 mmol), Ni(OTf)$_2$ (10.6 mg, 0.03 mmol), PPh$_3$ (7.8 mg, 0.03 mmol), Na$_2$CO$_3$ (64 mg, 0.6 mmol) and toluene (0.5 mL) / toluene-d$_8$ (0.5 mL) were added in a glove box. The mixture was stirred for 4 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The ratio of deuterium was determined by $^1$H-NMR.

Observation of C$_3$F$_7$H.
To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)-2-methylbenzamide 1c (89 mg, 0.3 mmol), heptafluoroisopropyl iodide (177 mg, 0.60 mmol), Ni(OTf)$_2$ (10.6 mg, 0.03 mmol), PPh$_3$ (7.8 mg, 0.03 mmol), Na$_2$CO$_3$ (64 mg, 0.6 mmol) and toluene (1 mL) were added in a glove box. The mixture was stirred for 4 h at 140 °C. The resulting mixture was cooled at -78 °C, and transferred to sealed NMR tube. The formation of C$_3$F$_7$H was determined by $^{19}$F-NMR.

General Procedure for Direct Benzylation: Pd-Catalyzed Dehydrogenative Cross Coupling of Amides 32 with Toluene (eq 5).
To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)butyramide 32 (75 mg, 0.3 mmol), heptafluoroisopropyl iodide (178 mg, 0.60 mmol), Pd(OAc)$_2$ (6.7 mg, 0.03 mmol), 1-AdCOOH (10.8 mg, 0.06 mmol), K$_2$CO$_3$ (124 mg, 0.9 mmol) and toluene (1 mL) were added in a glove box. The mixture was stirred for 48 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluent: hexane/EtOAc= 2/1) to afford the desired alkylated product 33 (78 mg, 77%) as a white solid.

General Procedure for Direct Iodination of Aromatic C-H Bonds (eq 6).
To an oven-dried 5 mL screw-capped vial, N-(5-chloroquinolin-8-yl)-2-methylbenzamide (45 mg, 0.15 mmol), iodine (76 mg, 0.3 mmol), Ni(OTf)$_2$ (5.3 mg, 0.015 mmol), Na$_2$CO$_3$ (32 mg, 0.3 mmol) and toluene (0.7 mL) were added in a glove box. The mixture was stirred for
24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluent: hexane/EtOAc= 20/1) to afford the desired alkylated product 2c (48 mg, 76%) as a white solid.

**General Procedure for the formation of β-Lactams (eq 7).**

To a 5 mL two necked flask equipped with condenser, N-(5-chloroquinolin-8-yl)pivalamide (39 mg, 0.15 mmol), iodine (76 mg, 0.3 mmol), Ni(OTf)$_2$ (5.3 mg, 0.015 mmol), Ag$_2$CO$_3$ (10 mg, 0.0375 mmol), Na$_2$CO$_3$ (32 mg, 0.3 mmol) and DMF (0.5 mL) were added in a glove box. The mixture was stirred for 24 h at 140 °C followed by cooling. The resulting mixture was filtered through a celite pad and concentrated in vacuo. The residue was purified by column chromatography on silica gel (eluent: hexane/EtOAc= 20/1) to afford the desired β-lactam (35 mg, 91%) as a white solid.

### 3.5 References and Notes

7. The formation of Rf–H was confirmed by $^{19}$F NMR spectra of the reaction mixtures.

Conclusion

Although the Ni-catalyzed functionalization of C-H bonds has been limited to acidic C-H bonds, such as azole derivatives, perfluorobenzene and activated pyridine derivatives, these studies revealed that a combination of a nickel(II)-catalyst and an N,N-bidentate directing group permit inert C-H bonds to be functionalized.

Chapter 1 discusses the nickel(II)-catalyzed direct alkylation of C(sp²)-H bonds containing an 8-aminoquinoline moiety as a bidentate directing group with an alkyl halide. The driving force for C-H bond cleavage with a low active nickel-catalyst is the formation of metallacycle intermediate stabilized by an N,N-bidentate directing group. Deuterium labeling experiments indicated that the cleavage of the C-H bond is not likely the rate determining step. This reaction proceeded via a Ni(II)/Ni(IV) cycle, which is unusual in Ni-catalyzed cross coupling reactions.

Chapter 2 deals with the direct arylation of aliphatic amides with aryl halides via the cleavage of C(sp³)-H bonds by utilizing a combination of a nickel(II)-catalyst and an N,N-bidentate directing group. The C-H bond cleavage step proceeded rapidly and reversibly, even when a more inert C(sp³)-H bond was used. Diaryliodonium salts instead of aryl halides could be used for arylation reagents.

Chapter 3 is concerned with the nickel(II)-catalyzed oxidative coupling of C(sp²)-H bonds benzamides and benzylic C-H bonds in toluene derivatives using the hetafluoroisopropyl iodide as a mild oxidant. This reaction involves the catalytic cleavage of two different C-H bonds, C(sp²)-H and benzylic C-H bonds. A high functional group compatibility was achieved when 4C₃H₇I was used as a mild oxidant.

In this study, a combination of a nickel(II)-catalyst and an N,N-bidentate directing group has the potential to allow various functional groups to be introduced in benzene ring, such as aryl, alkyl, methyl and iodo groups, and benzyl moieties via oxidative coupling. Not only C(sp²)-H bonds but also more inert C(sp³)-H bonds could be functionalized by using this chelation system. Aryl groups were introduced by using aryl halides and diaryliodonium salts as arylation reagents, and β-lactams were prepared via the cleavage of C(sp³)-H bonds.
Key to these successes derives from the nature of the N,N-bidentate directing group. The N,N-bidentate directing group efficiently and strongly coordinates to the nickel(II) complex by the formation of a N-Ni covalent bond with the amide N-H, and the subsequent C-H bond activation step was facilitated by the formation of a stabilized metallacycle. In chapter 1 and 2, a mechanism is proposed for the Ni(II)/Ni(IV) cycle. A high valent Ni(IV) intermediate generated after the reaction with the aryl or alkyl halide was probably stabilized by the C, N, N pincer type ligand or a non-innocent ligand which is derived from the 8-amonoquinoline moiety.

These studies can be expected to provide new methodology for use in the functionalization of C-H bonds and to the development of a new field of high valent Ni(IV) chemistry. In fact, more than 30 papers concerning C-H bond functionalization reactions utilizing a nickel(II)-catalyst and an N,N-bidentate directing group have been reported since we published the first report of the Ni(II)-catalyzed direct alkylation of aromatic C-H bonds containing a N,N-bidentate directing group in 2013.
List of Publications

(1) Nickel-Catalyzed Direct Alkylation of C-H Bonds in Benzamides and Acrylamides with Functionalized Alkyl Halides via Bidentate-Chelation Assistance
   Yoshinori Aihara, and Naoto Chatani

(2) Nickel-Catalyzed Direct Arylation of C(sp^3)-H Bonds in Aliphatic Amides via Bidentate-Chelation Assistance
   Yoshinori Aihara, and Naoto Chatani

(3) Ni(II)-Catalyzed Oxidative Coupling between C(sp^2)-H in Benzamides and C(sp^3)-H in Toluene Derivatives
   Yoshinori Aihara, Mamoru Tobisu, Yoshiya Fukumoto, and Naoto Chatani

(4) The Nickel(II)-Catalyzed Direct Benzylation, Allylation, Alkylation, and Methylation of C-H Bonds in Aromatic Amides Containing an 8-Aminoquinoline Moiety as the Directing Group
   Yoshinori Aihara, Jendrik Wuelbern, and Naoto Chatani
Supplementary List of Publications

(1) Nickel-Catalyzed Chelation-Assisted Transformations Involving the ortho C-H Bond Activation: The Regioselective Oxidative Cycloaddition of Aromatic Amides to Alkynes

Hirotaka Shiota, Yusuke Ano, Yoshinori Aihara, Yoshiya Fukumoto, and Naoto Chatani


(2) Ruthenium-Catalyzed Direct Arylation of C-H Bonds in Aromatic Amides containing a Bidentate Directing Group: Significant Electronic Effects on Arylation

Yoshinori Aihara, and Naoto Chatani


(3) The Ru(II)-Catalyzed Chelation-Assisted Arylation of C-H Bonds with Diaryliodonium Salts

Jordan Sun Ho, Luis C. Misal Castro, Yoshinori Aihara, Mamoru Tobisu, and Naoto Chatani


(4) Direct Arylation of C(sp³)-H Bonds in Aliphatic Amides with Diaryliodonium Salts in the presence of a Nickel Catalyst

Miki Iyanaga, Yoshinori Aihara, and Naoto Chatani


(5) Nickel(II)-Catalyzed Direct Arylation of C-H Bonds in Aromatic Amides Containing an 8-Aminoquinoline Moiety as a Directing Group

Ayana Yokota, Yoshinori Aihara, and Naoto Chatani

(6) Pd(II)-Catalyzed Chelation-Assisted Cross Dehydrogenative Coupling between Unactivated C(sp³)-H Bonds in Aliphatic Amides and Benzylic C-H Bonds in Toluene Derivatives
Teruhiko Kubo, Yoshinori Aihara, and Naoto Chatani
Chem. Lett. 2015, 44, 1365.

(7) Scalable C-H Oxidation with Copper: Synthesis of Polyoxypregnanes
Yi Yang See, Aaron T. Herrmann, Yoshinori Aihara, and Phil S. Baran

(8) Chelation-Assisted Nickel-Catalyzed Oxidative Annulation via Double C-H Activation/Alkyne Insertion Reaction
Luis C. Misal Castro, Atsushi Obata, Yoshinori Aihara, and Naoto Chatani

(9) Nickel-Catalyzed Iodination of Aromatic Amide and Formation of β-Lactam via Cleavage of C(sp³)-H Bond
Yoshinori Aihara, and Naoto Chatani
in preparation.