

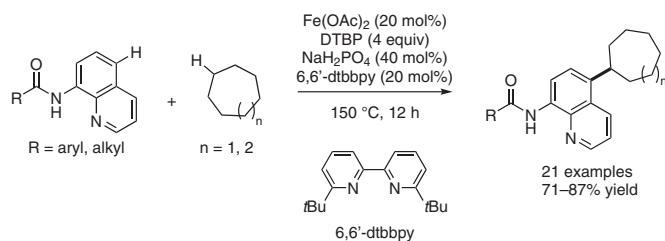
# Iron-Catalyzed Remote C–H Alkylation of 8-Amidoquinolines with Cycloalkanes

Wengang Xu<sup>a</sup> Mingbo Wu<sup>\*a</sup>Naohiko Yoshikai<sup>\*b</sup>

<sup>a</sup> College of New Energy, Institute of New Energy, State Key Laboratory of Heavy Oil Processing, China University of Petroleum (East China), Qingdao 266580, P. R. of China  
wumb@upc.edu.cn

<sup>b</sup> Division of Chemistry and Biological Chemistry, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371, Singapore  
nyoshikai@ntu.edu.sg

Published as part of the Special Topic  
*Bond Activation – in Honor of Prof. Shinji Murai*



Received: 20.11.2020

Accepted after revision: 15.12.2020

Published online: 15.12.2020

DOI: 10.1055/a-1337-5416; Art ID: ss-2020-f0595-st

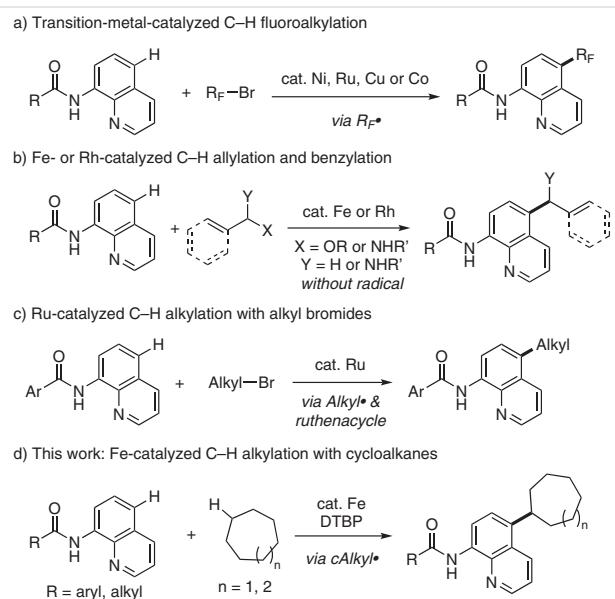
**Abstract** An iron-catalyzed, peroxide-mediated cross-dehydrogenative coupling between 8-amidoquinolines and cycloalkanes has been developed for the site-selective alkylation of the quinoline nucleus at the C5 position. The reaction tolerates various substituted *N*-(quinolin-8-yl)benzamides and *N*-(quinolin-8-yl)alkylamides, affording the corresponding C5-alkylation products in good yields. On the basis of control experiments, a reaction mechanism involving the addition of an alkyl radical to an iron-chelated intermediate is proposed.

**Key words** C–H functionalization, iron catalysis, quinolines, alkylation, radical reaction

The quinoline nucleus is widely present in pharmaceuticals and natural products.<sup>1</sup> Consequently, direct and site-selective C–H functionalization of this privileged heterocycle has attracted considerable attention as a strategy to rapidly access structurally diverse quinoline derivatives.<sup>2</sup> Among various C–H functionalization reactions of quinolines, those employing 8-amidoquinoline, which was originally popularized as an excellent *N,N*-bidentate directing group for chelation-assisted C–H functionalizations,<sup>3</sup> have been extensively explored for the site-selective installation of various functional groups into the otherwise less reactive C5 position of the quinoline nucleus. Thus, since the seminal work by Stahl and co-workers on copper-catalyzed C5-selective chlorination through a single-electron-transfer mechanism,<sup>4</sup> various methods for the C5-functionalization of 8-amidoquinolines with halogen,<sup>5</sup> oxygen,<sup>6</sup> sulfur (and selenium),<sup>7</sup> and nitrogen<sup>8</sup> groups have been developed.

8-Amidoquinolines have also allowed for the C5-selective functionalization with alkyl groups. The most extensively studied reaction of this type is metal-catalyzed fluoroalkylation with fluoroalkyl bromides via a radical mechanism (Scheme 1a).<sup>9</sup> Meanwhile, Zeng and co-workers

developed iron-catalyzed C5-allylation of 8-amidoquinolines with allyl alcohols, which likely operates by a non-radical mechanism (Scheme 1b).<sup>10</sup> This was followed by the development of analogous metal-catalyzed C5-functionalization reactions using amines,<sup>11</sup> benzylamines,<sup>12</sup> and benzyl acetates<sup>13</sup> as electrophiles. Recently, Jeganmohan and co-workers disclosed ruthenium-catalyzed C5–H alkylation of 8-amidoquinolines bearing an aryl group with alkyl bromides, which was proposed to involve the addition of an alkyl radical to a ruthenacycle intermediate formed by bidentate chelation-assisted aromatic C–H activation (Scheme 1c).<sup>5g,14</sup> Despite the above developments, C5-alkylation of 8-amidoquinolines with unfunctionalized



**Scheme 1** Development of transition-metal-catalyzed C5-alkylation of 8-amidoquinolines

alkanes via C(sp<sup>3</sup>)-H bond cleavage, which can be categorized as C-H/C-H coupling,<sup>15</sup> remains elusive. Herein, we report on such a transformation using cycloalkanes as alkyl sources promoted by an iron catalyst in combination with di-*tert*-butyl peroxide (DTBP; Scheme 1d). The reaction tolerates 8-amidoquinolines bearing various aryl and alkanoyl groups and is proposed to involve the addition of an alkyl radical to an iron-chelated intermediate.

The present study commenced with exploration of the reaction of *N*-(quinolin-8-yl)benzamide (**1a**) in cyclooctane as the solvent and the alkylation agent (Table 1). In light of the capability of Fe(II)/peroxide systems to generate alkoxy radical that can abstract hydrogen from aliphatic C-H bonds,<sup>15,16</sup> we initially performed the reaction in the presence of Fe(OAc)<sub>2</sub> (20 mol%) and DTBP (4 equiv), which afforded, after 12 hours at 150 °C, the alkylation product **2a** in 43% yield with exclusive C5-selectivity (entry 1). While the addition of inorganic or organic base (40 mol%) to this system had detrimental or negligible effect in most cases (entries 2–8), NaH<sub>2</sub>PO<sub>4</sub> was found to improve the yield of **2a** to 61% (entry 6). With NaH<sub>2</sub>PO<sub>4</sub> as the additive, we next explored ligand effects. While commercially available bipyri-

dine/phenanthroline-type ligands had only negative or negligible effect (entries 9–13), those bearing substituents near the nitrogen atoms were found to give marginally but consistently better results than 1,10-phenanthroline. Given this observation, we tested a bulkier ligand to find that 6,6'-di-*tert*-butyl-2,2'-bipyridine (6,6'-dtbbpy) improved the yield to 77% (isolated; entry 14).

With the optimized conditions (Table 1, entry 14) in hand, we explored the scope for 8-amidoquinoline derivatives (Scheme 2). Various *N*-(quinolin-8-yl)benzamides containing electron-withdrawing (CF<sub>3</sub>, F, and Cl) or -donating (OMe and Me) groups on the aryl group at the *ortho*, *para*, or *meta* position afforded the corresponding C5-cyclooctylated products (**2b–2l**) in good yields (72–87%). The alkylation reactions of amide substrates bearing a 1- or 2-naphthyl group also proceeded smoothly to give the desired products (**2m** and **2n**) in 75% and 77% yield, respectively. For the reaction of *N*-(quinolin-8-yl)alkylamides, the use of KH<sub>2</sub>PO<sub>4</sub> instead of NaH<sub>2</sub>PO<sub>4</sub> proved to give slightly better

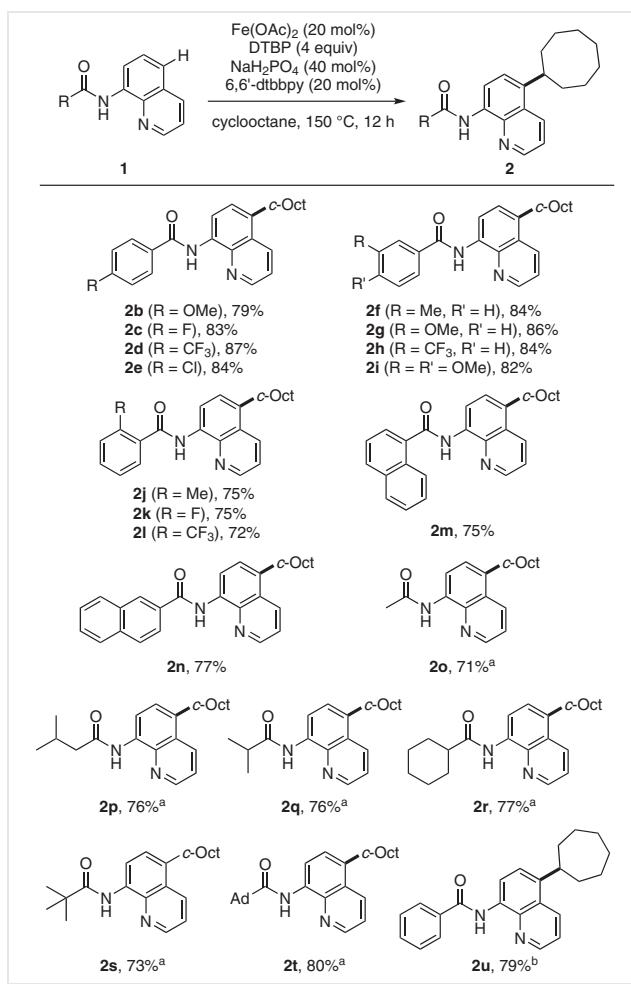
**Table 1** C5-Alkylation of 8-Amidoquinoline **1a** in Cyclooctane<sup>a</sup>

Entry	Additive	Ligand	Yield (%) <sup>b</sup>
1	–	–	43
2	Na <sub>2</sub> CO <sub>3</sub>	–	28
3	K <sub>3</sub> PO <sub>4</sub>	–	30
4	K <sub>2</sub> HPO <sub>4</sub>	–	41
5	KH <sub>2</sub> PO <sub>4</sub>	–	46
6	NaH <sub>2</sub> PO <sub>4</sub>	–	61
7	DABCO	–	39
8	DBU	–	31
9	NaH <sub>2</sub> PO <sub>4</sub>	1,10-phenanthroline	39
10	NaH <sub>2</sub> PO <sub>4</sub>	neocuproine	45
11	NaH <sub>2</sub> PO <sub>4</sub>	bathocuproine	54
12	NaH <sub>2</sub> PO <sub>4</sub>	6,6'-dmbpy	51
13	NaH <sub>2</sub> PO <sub>4</sub>	2,2'-biquinoline	57
14	NaH <sub>2</sub> PO <sub>4</sub>	6,6'-dtbbpy	77 <sup>c</sup>

<sup>a</sup> Reaction conditions: **1a** (0.10 mmol), Fe(OAc)<sub>2</sub> (20 mol%), DTBP (0.40 mmol), additive (40 mol%), ligand (20 mol%), cyclooctane (0.5 mL), 150 °C, 12 h. DABCO: 1,4-diazabicyclo[2.2.2]octane; DBU: 1,8-diazabicyclo-[5.4.0]undec-7-ene; 6,6'-dmbpy: 6,6'-dimethyl-2,2'-bipyridine; 6,6'-dtbbpy: 6,6'-di-*tert*-butyl-2,2'-bipyridine.

<sup>b</sup> Determined by GC using tridecane as an internal standard.

<sup>c</sup> Isolated yield.

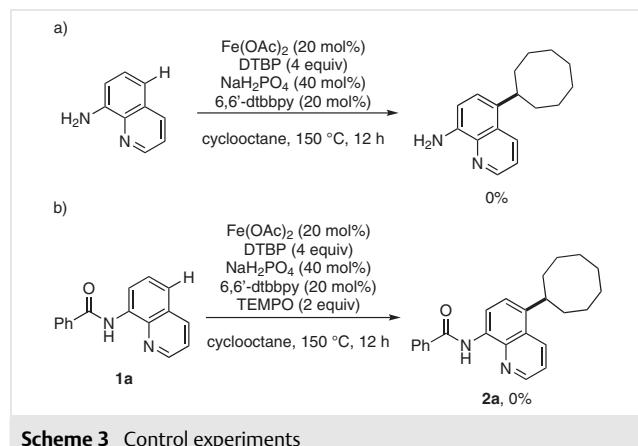


**Scheme 2** Substrate scope for the cyclooctylation of 8-amidoquinoline derivatives. <sup>a</sup> KH<sub>2</sub>PO<sub>4</sub> (40 mol%) was utilized instead of NaH<sub>2</sub>PO<sub>4</sub>.

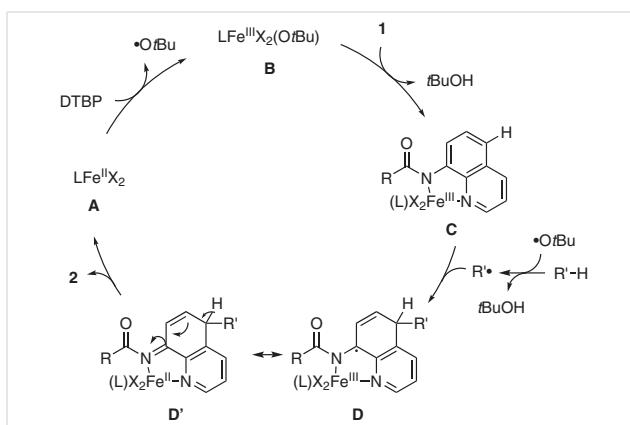
<sup>b</sup> Cycloheptane was used instead of cyclooctane.

yields. Thus, amides bearing various alkyl substituents, such as methyl, isobutyl, isopropyl, cyclohexyl, *tert*-butyl, and 1-adamantyl groups, afforded the corresponding C5-cyclooctylated products in good yields (**2o–2t**). The alkylation of **1a** also proceeded in cycloheptane to afford the C5-cycloheptylated product **2u** in 79% yield, whereas attempts at C5-cycloalkylation in cyclohexane or cyclopentane failed for unknown reasons. Note also that additional attempts to use aliphatic solvents such as THF and 1,4-dioxane as alkylating agents were futile under the present catalytic system.

To gain insight into the mechanism of the present C5-alkylation, control experiments were performed. First, the reaction of 8-aminoquinoline under the standard conditions failed to give any products including the C5-cyclooctylated derivative (Scheme 3a), which indicated the importance of the chelation effect of the amide moiety for the activation of the quinoline ring. Second, the addition of 2 equivalents of TEMPO completely shut down the reaction of **1a** under the standard conditions (Scheme 3b), which suggested the involvement of radical species.



Based on the results of the control experiments and literature precedents,<sup>6b,16,17</sup> we propose a possible reaction mechanism as shown in Scheme 4. The Fe(II) precatalyst **A** would be first oxidized by DTBP to an Fe(III) species **B** with concomitant generation of *tert*-butoxy radical. Deprotonation of 8-amidoquinoline **1** by species **B** would form a chelate complex **C**. Meanwhile, *tert*-butoxy radical abstracts a hydrogen atom from the cycloalkane to generate an alkyl radical. The alkyl radical would then undergo addition to the C5 position of **C** to give radical species **D**, which could be alternatively represented as Fe(II) chelate intermediate **D'**. Deprotonation of the C5 position and protonation of the amide nitrogen, which might be assisted by the base, would furnish product **2** and regenerate species **A**.



**Scheme 4** Possible catalytic cycle

In summary, we have developed an iron-catalyzed C5-selective alkylation of 8-amidoquinolines using cycloalkane as the alkylating agent under oxidative conditions. 8-Amidoquinoline derivatives bearing a variety of aryl- and alkylamide moieties were tolerated, affording the desired alkylation products in moderate to good yields. The present study would hold a promise for further development of C5-alkylation of quinoline derivatives using a broader range of unactivated alkanes with the aid of different approaches of hydrogen atom abstraction/alkyl radical generation.

All reactions dealing with air- and moisture-sensitive compounds were carried out in oven-dried reaction vessels under nitrogen atmosphere. Analytical TLC was performed on Merck 60 F254 silica gel plates. Flash column chromatography was performed using 40–63 µm silica gel (Si 60, Merck). <sup>1</sup>H and <sup>13</sup>C NMR spectra were recorded on a JEOL ECA-400 or Bruker AV-400 (400 MHz) NMR spectrometer, and are reported in parts per million (ppm) downfield from an internal standard (tetramethylsilane, 0 ppm). GC analysis was performed on a Shimadzu GC-2010 system equipped with glass capillary column DB-5 (Agilent J&W, 0.25 mm i.d. × 30 m, 0.25 µm film thickness). High-resolution mass spectra (HRMS) were obtained with a Q-ToF Premier LC HR mass spectrometer. Melting points were determined using a capillary melting point apparatus and are uncorrected. Unless otherwise noted, commercial reagents were purchased from Aldrich, Alfa Aesar, and other commercial suppliers, and were used as received. 8-Amidoquinolines **1** were prepared according to a literature procedure.<sup>18</sup> 6,6'-Di-*tert*-butyl-2,2'-bipyridine was prepared according to the literature.<sup>19</sup>

#### Iron-Catalyzed C5-Alkylation of 8-Amidoquinolines with Cycloalkanes; General Procedure

In a Schlenk tube were placed 8-amidoquinoline **1** (0.1 mmol), Fe(OAc)<sub>2</sub> (5.2 mg, 0.02 mmol), 6,6'-di-*tert*-butyl-2,2'-bipyridine (5.4 mg, 0.02 mmol), and NaH<sub>2</sub>PO<sub>4</sub> [4.8 mg, 0.04 mmol; KH<sub>2</sub>PO<sub>4</sub> was used for *N*-(quinolin-8-yl)alkylamides] under nitrogen atmosphere. Di-*tert*-butyl peroxide (73 µL, 0.4 mmol) and cycloalkane (0.5 mL) were added, and the resulting solution was stirred at 150 °C for 12 h. The reaction mixture was allowed to cool to room temperature, and then filtered through a short pad of silica gel, which was washed with

*EtOAc* (5 mL). The filtrate was concentrated under reduced pressure. Silica gel chromatography (hexane/*EtOAc*, 5:1) of the crude product afforded the desired product **2**.

#### **N-(5-Cyclooctylquinolin-8-yl)benzamide (2a)**

Yellow oil; yield: 28 mg (77%);  $R_f$  = 0.64 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.77 (s, 1 H), 8.87 (d,  $J$  = 8.1 Hz, 1 H), 8.84 (dd,  $J$  = 4.1, 1.5 Hz, 1 H), 8.47 (dd,  $J$  = 8.7, 1.4 Hz, 1 H), 8.10–8.07 (m, 2 H), 7.58–7.47 (m, 5 H), 3.53–3.46 (m, 1 H), 1.96–1.83 (m, 6 H), 1.79–1.58 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 165.4, 147.6, 140.6, 139.3, 135.4, 132.5 (two signals overlapped), 131.8, 128.8, 127.4, 125.9, 124.3, 121.2, 116.6, 38.6, 34.2, 27.1, 26.6, 26.3.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{24}\text{H}_{27}\text{N}_2\text{O}$  [M + H] $^+$ : 359.2123; found: 359.2126.

#### **N-(5-Cyclooctylquinolin-8-yl)-4-methoxybenzamide (2b)**

Yellow oil; yield: 31 mg (79%);  $R_f$  = 0.50 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.70 (s, 1 H), 8.89–8.81 (m, 2 H), 8.46 (dd,  $J$  = 8.6, 1.5 Hz, 1 H), 8.13–8.00 (m, 2 H), 7.54–7.42 (m, 2 H), 7.08–6.98 (m, 2 H), 3.89 (s, 3 H), 3.53–3.45 (m, 1 H), 1.97–1.79 (m, 6 H), 1.77–1.60 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 165.0, 162.5, 147.5, 140.3, 139.3, 132.7, 132.5, 129.2, 127.8, 125.9, 124.4, 121.1, 116.4, 114.0, 55.5, 38.5, 34.2, 27.1, 26.6, 26.3.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{25}\text{H}_{29}\text{N}_2\text{O}_2$  [M + H] $^+$ : 389.2229; found: 389.2232.

#### **N-(5-Cyclooctylquinolin-8-yl)-4-fluorobenzamide (2c)**

Yellow solid; yield: 31 mg (83%); mp 87–88 °C;  $R_f$  = 0.65 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.71 (s, 1 H), 8.91–8.71 (m, 2 H), 8.47 (dd,  $J$  = 8.7, 1.5 Hz, 1 H), 8.11–8.06 (m, 2 H), 7.52–7.46 (m, 2 H), 7.24–7.19 (m, 2 H), 3.52–3.46 (m, 1 H), 1.95–1.76 (m, 6 H), 1.72–1.67 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 165.0 (d,  $^1J_{\text{C}-\text{F}}$  = 252.2 Hz), 164.3, 147.6, 140.8, 139.2, 132.6, 132.4, 131.6 (d,  $^4J_{\text{C}-\text{F}}$  = 3.0 Hz), 129.7 (d,  $^3J_{\text{C}-\text{F}}$  = 9.0 Hz), 125.9, 124.3, 121.2, 116.5, 115.9 (d,  $^2J_{\text{C}-\text{F}}$  = 21.9 Hz), 38.6, 34.2, 27.0, 26.6, 26.3.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{24}\text{H}_{26}\text{N}_2\text{OF}$  [M + H] $^+$ : 377.2029; found: 377.2027.

#### **N-(5-Cyclooctylquinolin-8-yl)-4-(trifluoromethyl)benzamide (2d)**

Yellow solid; yield: 37 mg (87%); mp 142–143 °C;  $R_f$  = 0.60 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.81 (s, 1 H), 8.87–8.81 (m, 2 H), 8.49 (dd,  $J$  = 8.6, 1.2 Hz, 1 H), 8.18 (d,  $J$  = 8.2 Hz, 2 H), 7.81 (d,  $J$  = 8.2 Hz, 2 H), 7.54–7.47 (m, 2 H), 3.55–3.46 (m, 1 H), 1.99–1.83 (m, 6 H), 1.79–1.62 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 164.0, 147.7, 141.2, 139.2, 138.7, 133.4 (q,  $^2J_{\text{C}-\text{F}}$  = 32.8 Hz), 132.6, 132.1, 127.8, 125.91 (q,  $^3J_{\text{C}-\text{F}}$  = 3.8 Hz), 125.90, 124.3, 123.8 (q,  $^1J_{\text{C}-\text{F}}$  = 272.6 Hz), 121.3, 116.8, 38.6, 34.2, 27.0, 26.6, 26.2.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{25}\text{H}_{26}\text{N}_2\text{OF}_3$  [M + H] $^+$ : 427.1997; found: 427.1999.

#### **4-Chloro-N-(5-cyclooctylquinolin-8-yl)benzamide (2e)**

Yellow solid; yield: 33 mg (84%); mp 110–111 °C;  $R_f$  = 0.62 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.73 (s, 1 H), 8.85–8.81 (m, 2 H), 8.47 (dd,  $J$  = 8.8, 1.5 Hz, 1 H), 8.04–7.99 (m, 2 H), 7.53–7.45 (m, 4 H), 3.52–3.46 (m, 1 H), 1.95–1.81 (m, 6 H), 1.79–1.56 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 164.2, 147.6, 140.9, 139.2, 138.0, 133.8, 132.6, 132.2, 129.1, 128.8, 125.9, 124.3, 121.2, 116.6, 38.6, 34.2, 27.0, 26.6, 26.2.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{24}\text{H}_{26}\text{N}_2\text{OCl}$  [M + H] $^+$ : 393.1734; found: 393.1729.

#### **N-(5-Cyclooctylquinolin-8-yl)-3-methylbenzamide (2f)**

Yellow oil; yield: 31 mg (84%);  $R_f$  = 0.67 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.73 (s, 1 H), 8.88–8.83 (m, 2 H), 8.47 (d,  $J$  = 7.7 Hz, 1 H), 7.89 (s, 1 H), 7.86 (d,  $J$  = 7.7 Hz, 1 H), 7.52–7.41 (m, 3 H), 7.38 (d,  $J$  = 7.6 Hz, 1 H), 3.53–3.46 (m, 1 H), 2.48 (s, 3 H), 1.97–1.80 (m, 6 H), 1.77–1.66 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 165.6, 147.6, 140.6, 139.3, 138.7, 135.4, 132.6, 132.52, 132.49, 128.7, 128.1, 125.9, 124.33, 124.27, 121.1, 116.6, 38.5, 34.2, 27.1, 26.6, 26.3, 21.6.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{25}\text{H}_{29}\text{N}_2\text{O}$  [M + H] $^+$ : 373.2280; found: 373.2284.

#### **N-(5-Cyclooctylquinolin-8-yl)-3-methoxybenzamide (2g)**

Yellow oil; yield: 33 mg (86%);  $R_f$  = 0.67 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.75 (s, 1 H), 8.87–8.82 (m, 2 H), 8.47 (dd,  $J$  = 8.6, 1.2 Hz, 1 H), 7.65–7.62 (m, 2 H), 7.52–7.42 (m, 3 H), 7.11 (dd,  $J$  = 8.1, 2.3 Hz, 1 H), 3.91 (s, 3 H), 3.53–3.46 (m, 1 H), 1.93–1.82 (m, 6 H), 1.78–1.62 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 165.2, 160.1, 147.6, 140.7, 139.3, 136.9, 132.5 (two signals overlapped), 129.8, 125.9, 124.3, 121.2, 119.2, 118.0, 116.5, 112.7, 55.6, 38.6, 34.2, 27.1, 26.6, 26.3.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{25}\text{H}_{29}\text{N}_2\text{O}_2$  [M + H] $^+$ : 389.2229; found: 389.2226.

#### **N-(5-Cyclooctylquinolin-8-yl)-3-(trifluoromethyl)benzamide (2h)**

Yellow solid; yield: 36 mg (84%); mp 80–81 °C;  $R_f$  = 0.65 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.80 (s, 1 H), 8.86–8.83 (m, 2 H), 8.49 (dd,  $J$  = 8.7, 1.4 Hz, 1 H), 8.35 (s, 1 H), 8.24 (d,  $J$  = 7.9 Hz, 1 H), 7.83 (d,  $J$  = 7.7 Hz, 1 H), 7.69 (t,  $J$  = 7.9 Hz, 1 H), 7.54–7.47 (m, 2 H), 3.54–3.47 (m, 1 H), 1.98–1.83 (m, 6 H), 1.78–1.64 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 163.8, 147.8, 141.2, 139.2, 136.3, 132.6, 132.1, 131.5 (q,  $^2J_{\text{C}-\text{F}}$  = 32.9 Hz), 130.3, 129.4, 128.3 (q,  $^3J_{\text{C}-\text{F}}$  = 3.4 Hz), 125.9, 124.6 (q,  $^3J_{\text{C}-\text{F}}$  = 3.6 Hz), 124.3, 123.9 (q,  $^1J_{\text{C}-\text{F}}$  = 272.6 Hz), 121.3, 116.8, 38.6, 34.2, 27.0, 26.6, 26.3.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{25}\text{H}_{26}\text{N}_2\text{OF}_3$  [M + H] $^+$ : 427.1997; found: 427.1999.

#### **N-(5-Cyclooctylquinolin-8-yl)-3,4-dimethoxybenzamide (2i)**

Yellow oil; yield: 34 mg (82%);  $R_f$  = 0.41 (hexane/*EtOAc*, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.72 (s, 1 H), 8.85–8.82 (m, 2 H), 8.46 (dd,  $J$  = 8.8, 1.4 Hz, 1 H), 7.68–7.64 (m, 2 H), 7.51–7.46 (m, 2 H), 6.99 (d,  $J$  = 8.8 Hz, 1 H), 4.00 (s, 3 H), 3.97 (s, 3 H), 3.52–3.45 (m, 1 H), 1.95–1.83 (m, 6 H), 1.75–1.66 (m, 8 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 165.0, 152.0, 149.2, 147.5, 140.4, 139.3, 132.6, 132.5, 128.2, 125.9, 124.4, 121.1, 119.8, 116.3, 111.0, 110.5, 56.2, 56.1, 38.6, 34.2, 27.1, 26.6, 26.2.

HRMS (ESI): *m/z* calcd for C<sub>26</sub>H<sub>31</sub>N<sub>2</sub>O<sub>3</sub> [M + H]<sup>+</sup>: 419.2335; found: 419.2337.

### N-(5-Cyclooctylquinolin-8-yl)-2-methylbenzamide (2j)

Yellow oil; yield: 28 mg (75%); *R*<sub>f</sub> = 0.70 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 10.22 (s, 1 H), 8.87 (d, *J* = 8.1 Hz, 1 H), 8.76 (dd, *J* = 4.1, 1.5 Hz, 1 H), 8.46 (dd, *J* = 8.7, 1.5 Hz, 1 H), 7.67 (d, *J* = 7.5 Hz, 1 H), 7.50–7.46 (m, 2 H), 7.42–7.37 (m, 1 H), 7.32 (t, *J* = 7.3 Hz, 2 H), 3.53–3.46 (m, 1 H), 2.60 (s, 3 H), 1.96–1.83 (m, 6 H), 1.71–1.62 (m, 8 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 168.1, 147.6, 140.7, 139.1, 136.9, 136.7, 132.7, 132.4, 131.4, 130.2, 127.3, 126.0, 125.8, 124.2, 121.1, 116.5, 38.6, 34.2, 27.0, 26.6, 26.3, 20.3.

HRMS (ESI): *m/z* calcd for C<sub>25</sub>H<sub>29</sub>N<sub>2</sub>O [M + H]<sup>+</sup>: 373.2280; found: 373.2283.

### N-(5-Cyclooctylquinolin-8-yl)-2-fluorobenzamide (2k)

Yellow oil; yield: 28 mg (75%); *R*<sub>f</sub> = 0.67 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 11.16 (d, *J* = 12.0 Hz, 1 H), 8.90 (d, *J* = 8.1 Hz, 1 H), 8.86 (dd, *J* = 4.1, 1.4 Hz, 1 H), 8.47 (dd, *J* = 8.7, 1.4 Hz, 1 H), 8.22 (td, *J* = 7.8, 1.8 Hz, 1 H), 7.57–7.46 (m, 3 H), 7.35–7.31 (m, 1 H), 7.27–7.21 (m, 1 H), 3.53–3.47 (m, 1 H), 1.98–1.81 (m, 6 H), 1.76–1.68 (m, 8 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 161.5 (d, <sup>3</sup>*J*<sub>C-F</sub> = 3.2 Hz), 160.6 (d, <sup>1</sup>*J*<sub>C-F</sub> = 249.1 Hz), 147.8, 141.0, 139.3, 133.5, 132.7, 132.4, 132.1, 125.9, 124.9 (d, <sup>3</sup>*J*<sub>C-F</sub> = 3.4 Hz), 124.3, 122.4 (d, <sup>2</sup>*J*<sub>C-F</sub> = 11.7 Hz), 121.2, 117.3, 116.4 (d, <sup>2</sup>*J*<sub>C-F</sub> = 24.5 Hz), 38.7, 34.2, 27.1, 26.6, 26.3.

HRMS (ESI): *m/z* calcd for C<sub>24</sub>H<sub>26</sub>N<sub>2</sub>OF [M + H]<sup>+</sup>: 377.2029; found: 377.2027.

### N-(5-Cyclooctylquinolin-8-yl)-2-(trifluoromethyl)benzamide (2l)

Yellow solid; yield: 31 mg (72%); mp 189–190 °C; *R*<sub>f</sub> = 0.60 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 10.17 (s, 1 H), 8.85 (d, *J* = 8.1 Hz, 1 H), 8.74 (d, *J* = 4.0 Hz, 1 H), 8.46 (d, *J* = 8.2 Hz, 1 H), 7.79 (d, *J* = 7.8 Hz, 1 H), 7.75 (d, *J* = 7.4 Hz, 1 H), 7.68 (t, *J* = 7.4 Hz, 1 H), 7.61 (t, *J* = 7.6 Hz, 1 H), 7.50–7.45 (m, 2 H), 3.53–3.47 (m, 1 H), 1.96–1.83 (m, 6 H), 1.78–1.64 (m, 8 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 165.8, 147.6, 141.3, 139.0, 136.4, 132.5, 132.3, 132.2, 130.1, 128.6, 127.8 (q, <sup>2</sup>*J*<sub>C-F</sub> = 32.3 Hz), 126.7 (q, <sup>3</sup>*J*<sub>C-F</sub> = 4.7 Hz), 125.8, 124.2, 123.7 (q, <sup>1</sup>*J*<sub>C-F</sub> = 273.8 Hz), 121.2, 116.9, 38.6, 34.2, 27.0, 26.6, 26.3.

HRMS (ESI): *m/z* calcd for C<sub>25</sub>H<sub>26</sub>N<sub>2</sub>OF<sub>3</sub> [M + H]<sup>+</sup>: 427.1997; found: 427.1998.

### N-(5-Cyclooctylquinolin-8-yl)-1-naphthamide (2m)

Yellow solid; yield: 31 mg (75%); mp 91–92 °C; *R*<sub>f</sub> = 0.55 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 10.43 (s, 1 H), 8.98 (d, *J* = 8.1 Hz, 1 H), 8.73 (dd, *J* = 4.1, 1.6 Hz, 1 H), 8.55–8.51 (m, 1 H), 8.47 (dd, *J* = 8.7, 1.5 Hz, 1 H), 8.00 (d, *J* = 8.2 Hz, 1 H), 7.94–7.90 (m, 2 H), 7.60–7.51 (m, 4 H), 7.47 (dd, *J* = 8.6, 4.1 Hz, 1 H), 3.55–3.49 (m, 1 H), 1.98–1.85 (m, 6 H), 1.78–1.65 (m, 8 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 167.7, 147.6, 140.9, 139.1, 135.0, 134.0, 132.8, 132.5, 131.0, 130.5, 128.4, 127.3, 126.6, 125.9, 125.7, 125.6, 125.0, 124.3, 121.2, 116.7, 38.6, 34.2, 27.1, 26.6, 26.3.

HRMS (ESI): *m/z* calcd for C<sub>28</sub>H<sub>29</sub>N<sub>2</sub>O [M + H]<sup>+</sup>: 409.2280; found: 409.2281.

### N-(5-Cyclooctylquinolin-8-yl)-2-naphthamide (2n)

Yellow solid; yield: 31 mg (77%); mp 104–105 °C; *R*<sub>f</sub> = 0.60 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 10.92 (s, 1 H), 8.92 (d, *J* = 8.1 Hz, 1 H), 8.88 (dd, *J* = 4.1, 1.4 Hz, 1 H), 8.60 (s, 1 H), 8.49 (dd, *J* = 8.6, 1.3 Hz, 1 H), 8.14 (dd, *J* = 8.6, 1.8 Hz, 1 H), 8.05 (dd, *J* = 6.3, 2.9 Hz, 1 H), 8.00 (d, *J* = 8.6 Hz, 1 H), 7.95–7.90 (m, 1 H), 7.62–7.56 (m, 2 H), 7.54–7.49 (m, 2 H), 3.54–3.48 (m, 1 H), 2.01–1.81 (m, 6 H), 1.78–1.66 (m, 8 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 165.5, 147.6, 140.7, 139.3, 135.0, 132.9, 132.7, 132.6, 132.5, 129.3, 128.7, 128.0, 127.87, 127.85, 126.8, 125.9, 124.4, 123.9, 121.2, 116.6, 38.6, 34.2, 27.1, 26.6, 26.3.

HRMS (ESI): *m/z* calcd for C<sub>28</sub>H<sub>29</sub>N<sub>2</sub>O [M + H]<sup>+</sup>: 409.2280; found: 409.2279.

### N-(5-Cyclooctylquinolin-8-yl)acetamide (2o)

Yellow oil; yield: 21 mg (71%); *R*<sub>f</sub> = 0.70 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 9.78 (s, 1 H), 8.78 (dd, *J* = 4.1, 1.5 Hz, 1 H), 8.67 (d, *J* = 8.1 Hz, 1 H), 8.44 (dd, *J* = 8.6, 1.4 Hz, 1 H), 7.47 (dd, *J* = 8.6, 4.1 Hz, 1 H), 7.41 (d, *J* = 8.1 Hz, 1 H), 3.49–3.43 (m, 1 H), 2.33 (s, 3 H), 1.92–1.80 (m, 6 H), 1.76–1.61 (m, 8 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 168.7, 147.4, 140.3, 138.8, 132.5, 132.4, 125.8, 124.2, 121.0, 116.4, 38.4, 34.2, 27.0, 26.6, 26.2, 25.2.

HRMS (ESI): *m/z* calcd for C<sub>19</sub>H<sub>25</sub>N<sub>2</sub>O [M + H]<sup>+</sup>: 297.1967; found: 297.1969.

### N-(5-Cyclooctylquinolin-8-yl)-3-methylbutanamide (2p)

Yellow oil; yield: 26 mg (76%); *R*<sub>f</sub> = 0.72 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 9.79 (s, 1 H), 8.79 (dd, *J* = 4.2, 1.5 Hz, 1 H), 8.72 (d, *J* = 8.1 Hz, 1 H), 8.44 (dd, *J* = 8.7, 1.4 Hz, 1 H), 7.47 (dd, *J* = 8.6, 4.1 Hz, 1 H), 7.41 (d, *J* = 8.1 Hz, 1 H), 3.49–3.43 (m, 1 H), 2.42 (d, *J* = 7.1 Hz, 2 H), 2.36–2.27 (m, 1 H), 1.94–1.78 (m, 6 H), 1.76–1.62 (m, 8 H), 1.06 (d, *J* = 6.6 Hz, 6 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 171.2, 147.4, 140.2, 138.8, 132.5, 132.4, 125.8, 124.3, 121.0, 116.4, 47.7, 38.6, 34.2, 27.1, 26.6, 26.4, 26.2, 22.6.

HRMS (ESI): *m/z* calcd for C<sub>22</sub>H<sub>31</sub>N<sub>2</sub>O [M + H]<sup>+</sup>: 339.2436; found: 339.2435.

### N-(5-Cyclooctylquinolin-8-yl)isobutyramide (2q)

Yellow oil; yield: 25 mg (76%); *R*<sub>f</sub> = 0.72 (hexane/EtOAc, 2:1).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 9.91 (s, 1 H), 8.79 (dd, *J* = 4.1, 1.4 Hz, 1 H), 8.71 (d, *J* = 8.0 Hz, 1 H), 8.47–8.42 (m, 1 H), 7.47 (dd, *J* = 8.6, 4.1 Hz, 1 H), 7.42 (dd, *J* = 7.9, 3.4 Hz, 1 H), 3.48–3.43 (m, 1 H), 2.80–2.70 (m, 1 H), 1.93–1.80 (m, 6 H), 1.75–1.67 (m, 8 H), 1.34 (d, *J* = 6.8 Hz, 6 H).

<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>): δ = 175.7, 147.4, 140.2, 139.0, 132.5, 132.4, 125.8, 124.3, 121.0, 116.4, 38.5, 37.2, 34.2, 27.1, 26.6, 26.2, 19.8.

HRMS (ESI): *m/z* calcd for C<sub>21</sub>H<sub>29</sub>N<sub>2</sub>O [M + H]<sup>+</sup>: 325.2280; found: 325.2283.

**N-(5-Cyclooctylquinolin-8-yl)cyclohexanecarboxamide (2r)**

Yellow oil; yield: 28 mg (77%);  $R_f$  = 0.72 (hexane/EtOAc, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 9.89 (s, 1 H), 8.79 (dd,  $J$  = 4.1, 1.3 Hz, 1 H), 8.71 (d,  $J$  = 8.1 Hz, 1 H), 8.44 (d,  $J$  = 8.6 Hz, 1 H), 7.47 (dd,  $J$  = 8.6, 4.1 Hz, 1 H), 7.41 (d,  $J$  = 8.1 Hz, 1 H), 3.49–3.43 (m, 1 H), 2.50–2.42 (m, 1 H), 2.10–2.06 (m, 2 H), 1.94–1.80 (m, 8 H), 1.77–1.64 (m, 10 H), 1.45–1.25 (m, 4 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 174.8, 147.4, 140.1, 139.0, 132.6, 132.4, 125.8, 124.3, 121.0, 116.4, 47.0, 38.5, 34.2, 29.9, 27.1, 26.6, 26.2, 25.9 (two signals overlapped).

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{24}\text{H}_{33}\text{N}_2\text{O}$  [M + H] $^+$ : 365.2593; found: 365.2594.

**N-(5-Cyclooctylquinolin-8-yl)pivalamide (2s)**

Yellow oil; yield: 25 mg (73%);  $R_f$  = 0.73 (hexane/EtOAc, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.28 (s, 1 H), 8.80 (d,  $J$  = 3.5 Hz, 1 H), 8.72 (d,  $J$  = 8.1 Hz, 1 H), 8.43 (d,  $J$  = 8.5 Hz, 1 H), 7.46 (dd,  $J$  = 8.6, 4.2 Hz, 1 H), 7.41 (d,  $J$  = 8.1 Hz, 1 H), 3.49–3.42 (m, 1 H), 1.92–1.80 (m, 6 H), 1.74–1.65 (m, 8 H), 1.42 (s, 9 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 177.1, 147.5, 140.1, 139.3, 132.6, 132.4, 125.8, 124.3, 121.0, 116.2, 40.3, 38.3, 34.2, 27.8, 27.0, 26.5, 26.2.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{22}\text{H}_{31}\text{N}_2\text{O}$  [M + H] $^+$ : 339.2436; found: 339.2440.

**N-(5-Cyclooctylquinolin-8-yl)adamantane-1-carboxamide (2t)**

Yellow oil; yield: 33 mg (80%);  $R_f$  = 0.80 (hexane/EtOAc, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.23 (s, 1 H), 8.81 (d,  $J$  = 4.1 Hz, 1 H), 8.74 (d,  $J$  = 8.1 Hz, 1 H), 8.43 (d,  $J$  = 8.6 Hz, 1 H), 7.46 (dd,  $J$  = 8.6, 4.1 Hz, 1 H), 7.41 (d,  $J$  = 8.1 Hz, 1 H), 3.49–3.42 (m, 1 H), 2.15–2.09 (m, 8 H), 1.94–1.78 (m, 13 H), 1.75–1.65 (m, 8 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 176.7, 147.5, 140.0, 139.4, 132.6, 132.4, 125.8, 124.3, 121.0, 116.3, 42.3, 39.4, 38.8, 36.6, 34.2, 28.4, 27.1, 26.6, 26.2.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{28}\text{H}_{37}\text{N}_2\text{O}$  [M + H] $^+$ : 417.2906; found: 417.2908.

**N-(5-Cycloheptylquinolin-8-yl)benzamide (2u)**

Yellow solid; yield: 27 mg (79%); mp 91–92 °C;  $R_f$  = 0.80 (hexane/EtOAc, 2:1).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 10.76 (s, 1 H), 8.86 (d,  $J$  = 8.1 Hz, 1 H), 8.84 (dd,  $J$  = 4.1, 1.6 Hz, 1 H), 8.46 (dd,  $J$  = 8.6, 1.6 Hz, 1 H), 8.10–8.06 (m, 2 H), 7.58–7.53 (m, 3 H), 7.52–7.47 (m, 2 H), 3.44–3.32 (m, 1 H), 2.05–2.01 (m, 2 H), 1.93–1.85 (m, 2 H), 1.83–1.76 (m, 4 H), 1.72–1.65 (m, 4 H).

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 165.4, 147.6, 140.3, 139.2, 135.4, 132.5, 132.4, 131.8, 128.8, 127.4, 125.9, 123.8, 121.2, 116.6, 40.6, 36.5, 27.9, 27.6.

HRMS (ESI):  $m/z$  calcd for  $\text{C}_{23}\text{H}_{25}\text{N}_2\text{O}$  [M + H] $^+$ : 345.1967; found: 345.1969.

**Funding Information**

This work was supported by the Singapore Ministry of Education Academic Research Fund Tier 2 (MOE2016-T2-2-043 to N.Y.) and Tier 1 (RG114/18 to N.Y.), the Fundamental Research Funds for China University of Petroleum (China East) (Grant No. 27RA2014007 to W.X.).

and the China Postdoctoral Science Foundation (Grant No. 31CZ2019010, 05FW2014001 to W.X.).

**Supporting Information**

Supporting information for this article is available online at <https://doi.org/10.1055/a-1337-5416>.

**References**

- (a) Michael, J. P. *Nat. Prod. Rep.* **2008**, *25*, 166. (b) Solomon, V. R.; Lee, H. *Curr. Med. Chem.* **2011**, *18*, 1488. (c) Colomb, J.; Becker, G.; Fieux, S.; Zimmer, L.; Billard, T. *J. Med. Chem.* **2014**, *57*, 3884.
- (a) Iwai, T.; Sawamura, M. *ACS Catal.* **2015**, *5*, 5031. (b) Khan, B.; Dutta, H. S.; Koley, D. *Asian J. Org. Chem.* **2018**, *7*, 1270. (c) Xu, Z.; Yang, X.; Yin, S.-F.; Qiu, R. *Top. Curr. Chem.* **2020**, *378*, 42.
- Daugulis, O.; Roane, J.; Tran, L. D. *Acc. Chem. Res.* **2015**, *48*, 1053.
- Suess, A. M.; Ertem, M. Z.; Cramer, C. J.; Stahl, S. S. *J. Am. Chem. Soc.* **2013**, *135*, 9797.
- Selected examples: (a) Guo, H.; Chen, M.; Jiang, P.; Chen, J.; Pan, L.; Wang, M.; Xie, C.; Zhang, Y. *Tetrahedron* **2015**, *71*, 70. (b) Zhang, S.; Ullah, A.; Yamamoto, Y.; Almansour, A. I.; Arumugam, N.; Kumar, R. S.; Bao, M. *ChemistrySelect* **2017**, *2*, 3414. (c) Ding, J.; Zhang, Y.; Li, J. *Org. Chem. Front.* **2017**, *4*, 1528. (d) Qiao, H.; Sun, S.; Yang, F.; Zhu, Y.; Kang, J.; Wu, Y.; Wu, Y. *Adv. Synth. Catal.* **2017**, *359*, 1976. (e) Du, Y.; Liu, Y.; Wan, J.-P. *J. Org. Chem.* **2018**, *83*, 3403. (f) Motati, D. R.; Uredi, D.; Watkins, E. B. *Chem. Sci.* **2018**, *9*, 1782. (g) Mariappan, A.; Das, K. M.; Jegannmohan, M. *Org. Biomol. Chem.* **2018**, *16*, 3419.
- (a) Shen, C.; Yang, M.; Xu, J.; Chen, C.; Zheng, K.; Shen, J.; Zhang, P. *RSC Adv.* **2017**, *7*, 49436. (b) Vinayak, B.; Navyasree, P.; Chandrasekharan, M. *Org. Biomol. Chem.* **2017**, *15*, 9200. (c) Xia, C.; Wang, K.; Xu, J.; Shen, C.; Sun, D.; Li, H.; Wang, G.; Zhang, P. *Org. Biomol. Chem.* **2017**, *15*, 531.
- Selected examples: (a) Liang, H.-W.; Jiang, K.; Ding, W.; Yuang, Y.; Shuai, L.; Chen, Y.-C.; Wei, Y. *Chem. Commun.* **2015**, *51*, 16928. (b) Zhu, L.; Qiu, R.; Cao, X.; Xiao, S.; Xu, X.; Au, C.-T.; Yin, S.-F. *Org. Lett.* **2015**, *17*, 5528. (c) Qiao, H.; Sun, S.; Yang, F.; Zhu, Y.; Zhu, W.; Dong, Y.; Wu, Y.; Kong, X.; Jiang, L.; Wu, Y. *Org. Lett.* **2015**, *17*, 6086. (d) Wang, K.; Wang, G.; Duan, G.; Xia, C. *RSC Adv.* **2017**, *7*, 51313. (e) Sahoo, H.; Mandal, A.; Selvakumar, J.; Baidya, M. *Eur. J. Org. Chem.* **2016**, *4321*. (f) Wei, J.; Jiang, J.; Xiao, X.; Lin, D.; Deng, Y.; Ke, Z.; Jiang, H.; Zeng, W. *J. Org. Chem.* **2016**, *81*, 946. (g) Chen, G.; Zhang, X.; Zeng, Z.; Peng, W.; Liang, Q.; Liu, J. *ChemistrySelect* **2017**, *2*, 1979. (h) Bai, P.; Sun, S.; Li, Z.; Qiao, H.; Su, X.; Yang, F.; Wu, Y.; Wu, Y. *J. Org. Chem.* **2017**, *82*, 12119. (i) Xia, H.; An, Y.; Zeng, X.; Wu, J. *Org. Chem. Front.* **2018**, *5*, 366. (j) Liu, X.; Zhang, H.; Yang, F.; Wang, B. *Org. Biomol. Chem.* **2019**, *17*, 7564. (k) Kumar, V.; Banert, K.; Ray, D.; Saha, B. *Org. Biomol. Chem.* **2019**, *17*, 10245.
- Selected examples: (a) Dou, Y.; Xie, Z.; Sun, Z.; Fang, H.; Shen, C.; Zhang, P.; Zhu, Q. *ChemCatChem* **2016**, *8*, 3570. (b) Whiteoak, C. J.; Planas, O.; Company, A.; Ribas, X. *Adv. Synth. Catal.* **2016**, *358*, 1679. (c) Zhu, X.; Qiao, L.; Ye, P.; Ying, B.; Xu, J.; Shen, C.; Zhang, P. *RSC Adv.* **2016**, *6*, 89979. (d) Sahoo, H.; Reddy, M. K.; Ramakrishna, I.; Baidya, M. *Chem. Eur. J.* **2016**, *22*, 1592. (e) He, Y.; Zhao, N.; Qiu, L.; Zhang, X.; Fan, X. *Org. Lett.* **2016**, *18*, 6054. (f) Yin, Y.; Xie, J.; Huang, F.-Q.; Qi, L.-W.; Zhang, B. *Adv. Synth. Catal.* **2017**, *359*, 1037. (g) Xia, H.; An, Y.; Zeng, X.; Wu, J. *Chem. Commun.* **2017**, *53*, 12548. (h) Yi, H.; Chen, H.; Bian, C.; Tang, Z.;

- Singh, A. K.; Qi, X.; Yur, X.; Lan, Y.; Lee, J.-F.; Lei, A. *Chem. Commun.* **2017**, 53, 6736. (i) Khan, B.; Khan, A. A.; Bora, D.; Verma, D.; Koley, D. *ChemistrySelect* **2017**, 2, 260.
- (9) Selected examples: (a) Chen, H.; Li, P.; Wang, M.; Wang, L. *Org. Lett.* **2016**, 18, 4794. (b) Kuninobu, Y.; Nishi, M.; Kanai, M. *Org. Biomol. Chem.* **2016**, 14, 8092. (c) Jin, L.-K.; Lu, G.-P.; Cai, C. *Org. Chem. Front.* **2016**, 3, 1309. (d) Han, S.; Liang, A.; Ren, X.; Gao, X.; Li, J.; Zou, D.; Wu, Y.; Wu, Y. *Tetrahedron Lett.* **2017**, 58, 4859. (e) Chen, C.; Zeng, R.; Zhang, J.; Zhao, Y. *Eur. J. Org. Chem.* **2017**, 6947. (f) Suo, J.-F.; Zhao, X.-M.; Zhang, K.-X.; Zhou, S.-L.; Niu, J.-L.; Song, M.-P. *Synthesis* **2017**, 49, 3916. (g) Mondal, S.; Hajra, A. *Org. Biomol. Chem.* **2018**, 16, 2846. (h) Jin, C.; Zhu, R.; Sun, B.; Zhang, L.; Zhuang, X.; Yu, C. *Asian J. Org. Chem.* **2019**, 8, 2213.
- (10) Cong, X.; Zeng, X. *Org. Lett.* **2014**, 16, 3716.
- (11) Reddy, M. D.; Fronczek, F. R.; Watkins, E. B. *Org. Lett.* **2016**, 18, 5620.
- (12) Cui, M.; Liu, J.-H.; Lu, X.-Y.; Lu, X.; Zhang, Z.-Q.; Xiao, B.; Fu, Y. *Tetrahedron Lett.* **2017**, 58, 1912.
- (13) Niu, T.-J.; Xu, J.-D.; Ren, B.-Z.; Liu, J.-H.; Hu, G.-Q. *Chemistry-Select* **2019**, 4, 4682.
- (14) See also: Ramesh, B.; Jeganmohan, M. *Org. Lett.* **2017**, 19, 6000.
- (15) (a) Li, C.-J. *Acc. Chem. Res.* **2009**, 42, 335. (b) Ashenhurst, J. A. *Chem. Soc. Rev.* **2010**, 39, 540. (c) Yeung, C. S.; Dong, V. M. *Chem. Rev.* **2011**, 111, 1215. (d) Liu, C.; Zhang, H.; Shi, W.; Lei, A. *Chem. Rev.* **2011**, 111, 1780. (e) Girard, S. A.; Knauber, T.; Li, C.-J. *Angew. Chem. Int. Ed.* **2014**, 53, 74. (f) Liu, C.; Yuan, J.; Gao, M.; Tang, S.; Li, W.; Shi, R.; Lei, A. *Chem. Rev.* **2015**, 115, 12138. (g) Kozlowski, M. C. *Acc. Chem. Res.* **2017**, 50, 638. (h) Huang, C. Y.; Kang, H.; Li, J.; Li, C. J. *J. Org. Chem.* **2019**, 84, 12705.
- (16) Selected examples: (a) Li, Z.; Cao, L.; Li, C.-J. *Angew. Chem. Int. Ed.* **2007**, 46, 6505. (b) Zhang, Y.; Li, C.-J. *Eur. J. Org. Chem.* **2007**, 4654. (c) Tanaka, T.; Hashiguchi, K.; Tanaka, T.; Yazaki, R.; Ohshima, T. *ACS Catal.* **2018**, 8, 8430.
- (17) (a) Huang, C.-Y.; Li, J.; Liu, W.; Li, C.-J. *Chem. Sci.* **2019**, 10, 5018. (b) Tian, H.; Yang, H.; Tian, C.; An, G.; Li, G. *Org. Lett.* **2020**, 22, 7709.
- (18) (a) Grigorjeva, L.; Daugulis, O. *Org. Lett.* **2014**, 16, 4688. (b) Deb, A.; Bag, S.; Kancherla, R.; Maiti, D. *J. Am. Chem. Soc.* **2014**, 136, 13602.
- (19) Hintermann, L.; Xiao, L.; Labonne, A. *Angew. Chem. Int. Ed.* **2008**, 47, 8246.