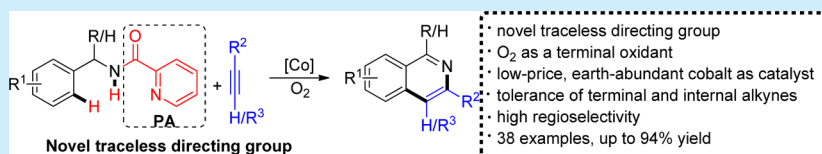


# Cobalt-Catalyzed Selective Synthesis of Isoquinolines Using Picolinamide as a Traceless Directing Group

Changsheng Kuai, Lianhui Wang, Bobin Li, Zhenhui Yang, and Xiuling Cui\*<sup>1</sup>

Engineering Research Center of Molecular Medicine of Ministry of Education, Key Laboratory of Fujian Molecular Medicine, Key Laboratory of Xiamen Marine and Gene Drugs, School of Biomedical Sciences, Huaqiao University, Xiamen 361021, P. R. China

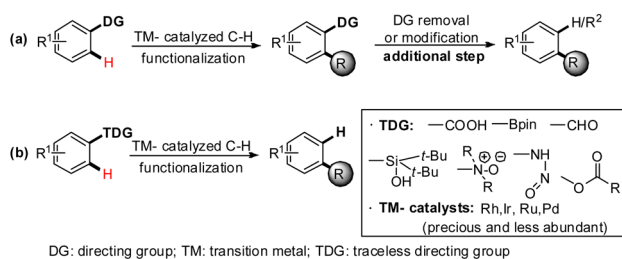
**S** Supporting Information



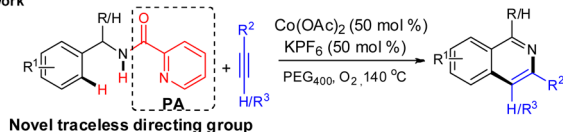
**ABSTRACT:** Picolinamide has first been employed as a traceless directing group for the cobalt-catalyzed oxidative annulation of benzylamides with alkynes to synthesize isoquinolines through C–H/N–H bonds activation. Oxygen is used as a terminal oxidant. This protocol exhibits good functional group tolerance and excellent regioselectivity. Both terminal and internal alkynes can be efficiently applied to this catalytic system as substrates.

Transition-metal-catalyzed functional group directed C–H functionalization has emerged as a powerful approach to construct C–C and C–X (X = heteroatom) bonds and represent a state-of-the-art method for the modification of organic molecules in terms of atom and step economy and regioselectivity.<sup>1</sup> In these reactions, the directing groups are essential for acceleration and regioselective control.<sup>2</sup> Nevertheless, this strategy suffers from multichemical steps including removal of directing groups which are not present in the target molecules (Scheme 1). Traceless directing groups, the removal

## Scheme 1. Directing Group Assisted Transition-Metal-Catalyzed C–H Functionalization



Our work



of which does not require additional steps, would be more attractive alternatives. However, the functional groups that can be employed as the traceless directing groups remain relatively rare.<sup>3</sup> Recently, carboxylic acid,<sup>4</sup> N-oxide,<sup>5</sup> silicon-tethered,<sup>6</sup> (pinacolato) boron (Bpin),<sup>7</sup> aldehyde,<sup>8</sup> N-nitroso,<sup>9</sup> and acetal<sup>10</sup> have been developed as elegant traceless directing groups for

the transition metal (such as Rh, Ir, Ru, and Pt) catalyzed direct C–H functionalization (Scheme 1). Picolinamide as a traceless directing group, in which C–N bond cleavage occurred in one step, remains unprecedented although it has been demonstrated as an effective directing group<sup>11</sup> for C–H functionalization. On the other hand, the isoquinoline framework is an important structural motif found in many natural products,<sup>12</sup> pharmaceuticals<sup>13</sup> and chiral ligands for asymmetric synthesis<sup>14</sup> as well as advanced functional materials.<sup>15</sup> Thus, developing an efficient method to construct such a structure has received considerable attention.<sup>16</sup> Herein we report a cheap and earth abundant cobalt-catalyzed oxidative annulation of benzylamides with alkynes to synthesize isoquinolines through C–H/N–H bond activation. This reaction employs oxygen as an oxidant and picolinamide as a traceless directing group, which exhibits good functional-group tolerance and excellent regioselectivity. Furthermore, both terminal and internal alkynes could be efficiently applied as substrates (Scheme 1).

As an initial attempt, the reaction of benzylamide **1a** with toluene **2a** was chosen as a model reaction for optimization of the various reaction parameters (Table 1). First, the expected product **3a** was obtained in 33% isolated yield in the presence of Co(OAc)<sub>2</sub>·4H<sub>2</sub>O (20 mol %), KPF<sub>6</sub> (20 mol %), and O<sub>2</sub> as an oxidant in PEG-400 at 140 °C for 20 h (Table 1, entry 1). Among a variety of cobalt salts, Co(OAc)<sub>2</sub>·4H<sub>2</sub>O proved to give the optimal result (entries 1–4). Next, solvents, such as DMSO, 1,4-dioxane, and different molecular weight of PEG, were examined and provided inferior results (entries 5–8). Increasing the loading of KPF<sub>6</sub> from 20 to 50 mol % led to an increase in yield from 33% to 43% (entries 1, 9–11). When the amount of KPF<sub>6</sub> was increasing to 1 equiv, the yield of **3a** was slightly improved from 43% to 45% (entry 11). Increasing the

Received: March 10, 2017

Published: April 13, 2017

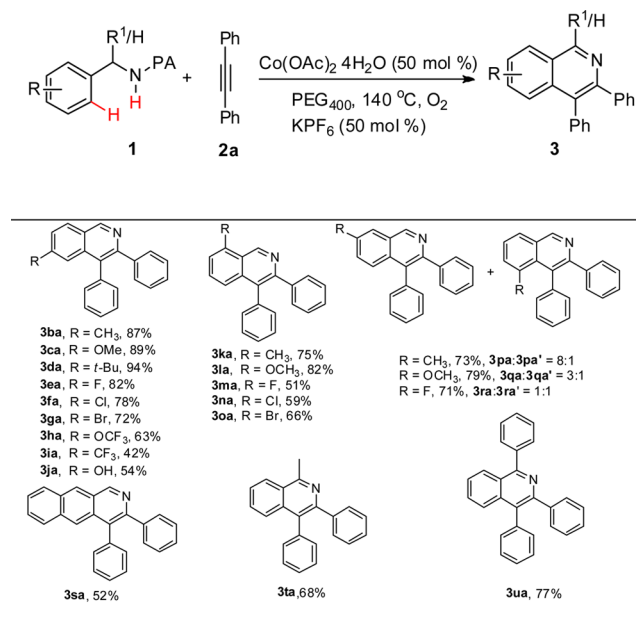
Table 1. Optimization of the Reaction Conditions<sup>a</sup>

entry	catalyst (mol %)	solvent	additive (mol %)	yield (%) <sup>b</sup>
1	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	PEG-400	KPF <sub>6</sub> (20)	28
2	Co(acac) <sub>2</sub> (20)	PEG-400	KPF <sub>6</sub> (20)	10
3	CoCl <sub>2</sub> (20)	PEG-400	KPF <sub>6</sub> (20)	15
4	CoSO <sub>4</sub> (20)	PEG-400	KPF <sub>6</sub> (20)	n.r.
5	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	DMSO	KPF <sub>6</sub> (20)	12
6	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	1,4-dioxane	KPF <sub>6</sub> (20)	n.r.
7	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	PEG-200	KPF <sub>6</sub> (20)	18
8	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	PEG-600	KPF <sub>6</sub> (20)	21
9	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	PEG-400	KPF <sub>6</sub> (30)	33
10	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	PEG-400	KPF <sub>6</sub> (40)	39
11	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (20)	PEG-400	KPF <sub>6</sub> (50)/ (100) <sup>c</sup>	43/45 <sup>c</sup>
12	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (30)	PEG-400	KPF <sub>6</sub> (50)	64
13	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (40)	PEG-400	KPF <sub>6</sub> (50)	72
14	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (50)	PEG-400	KPF <sub>6</sub> (50)	89
15	Co(OAc) <sub>2</sub> ·4H <sub>2</sub> O (60)	PEG-400	KPF <sub>6</sub> (50)	91

<sup>a</sup>Reaction conditions: **1a** (0.25 mmol), **2a** (0.3 mmol), solvent (1.0 mL), 140 °C under O<sub>2</sub> (1 atm), 20 h. <sup>b</sup>Isolated yields. <sup>c</sup>1 equiv of KPF<sub>6</sub>.

catalyst loading from 20 to 50 mol % significantly enhanced this reaction (entries 1, 12–14), while further increasing the loading of the catalyst to 60 mol % could not obviously improve the reaction efficiency (entry 15).

With the optimized reaction conditions in hand, we first investigated the scope of benzylamides (Scheme 2). To our delight, a remarkably broad range of benzylamides was tolerated. Tolane **2a** could react efficiently with benzylamides **1** bearing both electron-donating and -withdrawing groups, delivering the targeted products **3** in moderate to excellent yields. Generally, benzylamides with electron-withdrawing groups gave lower yields than those with electron-donating groups. For instance, benzylamides with the electron-donating groups at the *para* position, such as Me–, MeO–, and *tert*-Bu– promoted this transformation smoothly. The desired products (**3ba**–**3da**) were obtained in excellent yields (87%–94%). Benzylamides substituted by electron-withdrawing groups, such as X– (Cl–, F–, Br–), CF<sub>3</sub>O–, and CF<sub>3</sub>– also reacted with **2a**, giving the corresponding products in 42–82% yields (**3ea**–**3ia**). *para*-Hydroxyl benzylamide also could react with **2a** and give the desired product in 54% yield (**3fa**). Next the *ortho*-substituted benzylamides had been investigated. The corresponding annulated products were given in moderate to good yields (**3ka**–**3oa**). The steric hindrance of *ortho*-substitution had no significant effect on the reaction efficiency. In the case of *meta*-substituted substrates (**3pa**–**3ra**), a regioisomeric

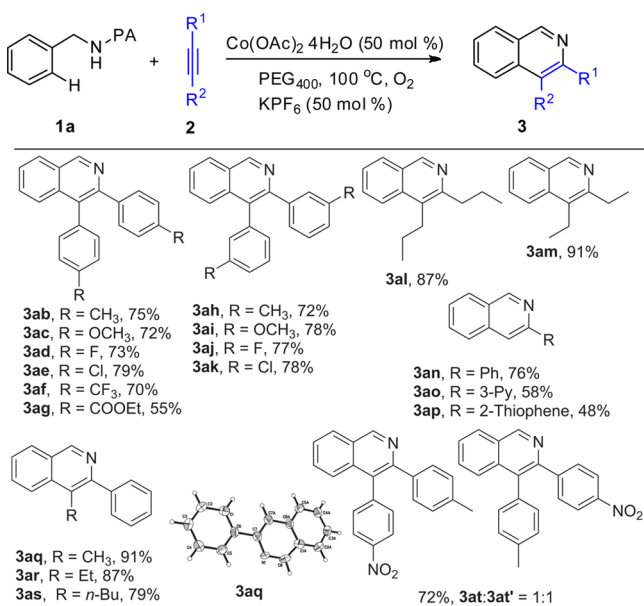
Scheme 2. Scope of the Benzylamides<sup>a</sup>

<sup>a</sup>Reaction conditions: **1a** (0.25 mmol), **2a** (0.3 mmol), Co(OAc)<sub>2</sub>·4H<sub>2</sub>O (0.125 mmol), KPF<sub>6</sub> (0.125 mmol), PEG-400 (1.0 mL), 140 °C under O<sub>2</sub> (1 atm), 20 h.

mixture was obtained in good yields (71%–79%). Higher regioselectivity (**3pa:3pa'** = 8:1) was provided for *meta*-methyl benzylamide than *meta*-F benzylamide (**3ra:3ra'** = 1:1) perhaps due to the steric hindrance. When 2-naphthamide was used as the substrate, **3sa** could be isolated in 52% yield. Importantly,  $\alpha$ -substituted substrates, such as  $\alpha$ -methyl and phenyl benzylamines, proceeded smoothly with tolane, allowing facile access to 1,3,4-trisubstituted isoquinolines **3ta** and **3ua** in good yields.

Subsequently, we investigated the scope of alkynes (Scheme 3). The annulative coupling between **1a** and various symmetric diarylacetylenes bearing electron-donating (CH<sub>3</sub>–, CH<sub>3</sub>O–) or electron-withdrawing (F–, Cl–, CF<sub>3</sub>–, EtOOC–) groups at the *para* or *meta* position afforded the corresponding products in 55–79% yields (**3ab**–**3ak**). However, no desired product was obtained for *ortho*-substituted tolanes, such as CH<sub>3</sub>–, CH<sub>3</sub>O– groups, probably due to the steric effect. The reaction of dialkyl-substituted alkynes also reacted smoothly, affording the corresponding product in 87–91% yield (**3al**, **3am**). To our surprised, the terminal arynes (**2n**–**2p**) displayed good reactivity as well with high regioselectivity (**3an**–**3ao**). Unsymmetrical internal alkynes with one phenyl group such as 1-phenyl-1-propyne (**2q**), 1-phenyl-1-butyne (**2r**), and 1-phenyl-1-hexyne (**2s**) also efficiently gave products (**3aq**–**3as**) in good yields with excellent regioselectivity. The configuration of **3aq** was confirmed by single-crystal X-ray diffraction. Unsymmetrical internal aryl alkynes with two aryl groups, such as methyl-4-((4-nitrophenyl)ethynyl)benzene, were tested as substrate, giving a regioisomeric mixture (**3at:3at'** = 1:1) in 72% total yield.

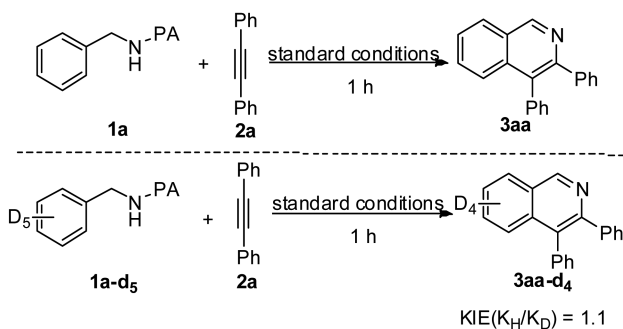
To gain insights into the reaction mechanism, deuterium-labeling experiments were conducted (Scheme 4). Two parallel reactions of **1a** and **1a-d<sub>5</sub>** were conducted under the standard reaction conditions and were terminated after 30 min. The KIE (KH/KD) is 1.1, indicating that C–H bond activation might not be involved as the rate-determining step. Furthermore, a

Scheme 3. Scope of Symmetrical and Unsymmetrical Alkynes<sup>a</sup>

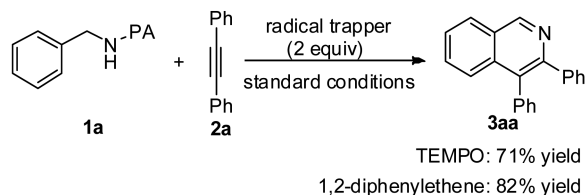
<sup>a</sup>Reaction conditions: **1a** (0.25 mmol), **2a** (0.3 mmol),  $\text{Co}(\text{OAc})_2 \cdot 4\text{H}_2\text{O}$  (0.125 mmol),  $\text{KPF}_6$  (0.125 mmol), PEG-400 (1.0 mL), 140 °C under  $\text{O}_2$  (1 atm), 20 h.

Scheme 4. Mechanistic Studies

(a) KIE by independent experiment



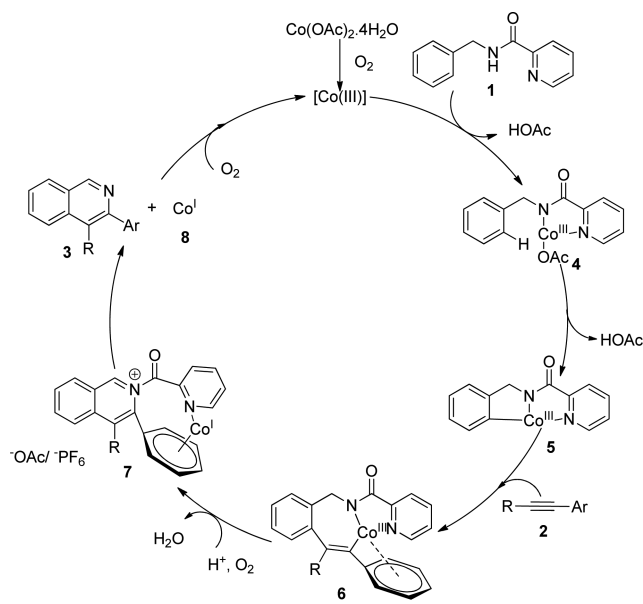
(b) Radical trapping experiment



radical trapping experiment carried out using TEMPO and 1,2-diphenylethene under standard reaction conditions. The reaction was not obviously inhibited, which suggested that the radical process could be ruled out.

In accordance with the mechanistic studies and literature,<sup>17</sup> a plausible reaction mechanism is depicted in Scheme 5. The reaction is initiated by Co(III) species generated *in situ* by the aid of oxygen from Co(II) species. Then coordination of the benzylamide **1** with the cobalt center followed by ligand exchange with the concomitant generation of HOAc gives the intermediate **4**, which undergoes reversible cyclometalation to give the intermediate **5** probably via a concerted metalation–

Scheme 5. Plausible Reaction Mechanism



deprotonation (CMD) mechanism. Then, coordination and insertion of intermediate **5** with alkyne **2** gives a seven-membered intermediate **6**, which undergoes reductive elimination and dehydrogenation with the aid of oxygen to afford isoquinolinium salt **7**. Then the C–N bond cleavage gives isoquinoline product **3** and the Co(I) species **8**, which was subsequently oxidized by oxygen into the active Co(III) species for the next catalytic cycle.

In summary, we developed a cobalt-catalyzed annulation of benzylamides with alkynes to synthesize isoquinolines by using picolinamide as a traceless directing group. This protocol features a wide substrate scope: not only internal aryl/aliphatic alkynes but also terminal alkynes can efficiently be applied in this reaction which show good tolerance to functional groups and excellent regioselectivity. Furthermore, oxygen was used as the sole oxidant instead of a metal oxidant.

## ■ ASSOCIATED CONTENT

### Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.orglett.7b00702.

Experimental details and procedures (PDF)

Crystallographic information for compound **3aa** (CIF)

Crystallographic information for compound **3aq** (CIF)

## ■ AUTHOR INFORMATION

### Corresponding Author

\*E-mail: cuixl@hqu.edu.cn.

### ORCID

Xiuling Cui: 0000-0001-5759-766X

### Notes

The authors declare no competing financial interest.

## ■ ACKNOWLEDGMENTS

This research was supported by NSF of China (Nos 21572072 and 21602064), Xia-men Southern Oceanographic Center

(15PYY052SF01), Science and Technology Bureau of Xiamen City (3502Z20150054), and Huaqiao University.

## REFERENCES

- (1) For recent selected reviews of C–H functionalization, see: (a) Li, B.; Dixneuf, P. H. *Chem. Soc. Rev.* **2013**, *42*, 5744. (b) Rouquet, G.; Chatani, N. *Angew. Chem., Int. Ed.* **2013**, *52*, 11726. (c) Wencel-Delord, J.; Glorius, F. *Nat. Chem.* **2013**, *5*, 369. (d) De Sarkar, S.; Liu, W.; Kozhushkov, S. I.; Ackermann, L. *Adv. Synth. Catal.* **2014**, *356*, 1461. (e) Miura, M.; Satoh, T.; Hirano, K. *Bull. Chem. Soc. Jpn.* **2014**, *87*, 751. (f) Wu, Y.; Wang, J.; Mao, F.; Kwong, F. Y. *Chem. - Asian J.* **2014**, *9*, 26. (g) Ackermann, L. *Acc. Chem. Res.* **2014**, *47*, 281. (h) Zhang, F.; Spring, D. R. *Chem. Soc. Rev.* **2014**, *43*, 6906. (i) Topczewski, J. J.; Sanford, M. S. *Chem. Sci.* **2015**, *6*, 70. (j) Hirano, K.; Miura, M. *Chem. Lett.* **2015**, *44*, 868. (k) Song, G.; Li, X. *Acc. Chem. Res.* **2015**, *48*, 1007. (l) Rit, R. K.; Yadav, R.; Ghosh, K.; Sahoo, A. K. *Tetrahedron* **2015**, *71*, 4450. (m) Qiu, G.; Wu, J. *Org. Chem. Front.* **2015**, *2*, 169. (n) Crisenza, G. E. M.; Bower, J. F. *Chem. Lett.* **2016**, *45*, 2. (o) Hartwig, J. F. *J. Am. Chem. Soc.* **2016**, *138*, 2. (p) Jiao, J.; Murakami, K.; Itami, K. *ACS Catal.* **2016**, *6*, 610. (q) Minami, Y.; Hiyama, T. *Acc. Chem. Res.* **2016**, *49*, 67.
- (2) (a) Davies, H. M. L.; Morton, D. J. *Org. Chem.* **2016**, *81*, 343. (b) Rousseau, G.; Breit, B. *Angew. Chem., Int. Ed.* **2011**, *50*, 2450; *Angew. Chem.* **2011**, *123*, 2498.
- (3) Zhang, F.; Spring, D. R. *Chem. Soc. Rev.* **2014**, *43*, 6906.
- (4) (a) Cornella, J.; Righi, M.; Larrosa, I. *Angew. Chem., Int. Ed.* **2011**, *50*, 9429. (b) Luo, J.; Preciado, S.; Larrosa, I. *J. Am. Chem. Soc.* **2014**, *136*, 4109. (c) Quan, Y.; Xie, Z. *J. Am. Chem. Soc.* **2014**, *136*, 15513. (d) Shi, X.; Liu, K.; Fan, J.; Dong, X.; Wei, J.; Li, C. *Chem. - Eur. J.* **2015**, *21*, 1900. (e) Zhang, Y.; Zhao, H.; Zhang, M.; Su, W. *Angew. Chem., Int. Ed.* **2015**, *54*, 3817. (f) Qin, X.; Sun, D.; You, Q.; Cheng, Y.; Lan, J.; You, J. *Org. Lett.* **2015**, *17*, 1762. (g) Lyu, H.; Quan, Y.; Xie, Z. *Angew. Chem., Int. Ed.* **2015**, *54*, 10623.
- (5) (a) Huang, X.; Huang, J.; Du, C.; Zhang, X.; Song, F.; You, J. *Angew. Chem., Int. Ed.* **2013**, *52*, 12970. (b) Sharma, U.; Park, Y.; Chang, S. *J. Org. Chem.* **2014**, *79*, 9899. (c) Barsu, N.; Sen, M.; Premkumar, J. R.; Sundararaju, B. *Chem. Commun.* **2016**, *52*, 1338. (d) Li, B.; Xu, H.; Wang, H.; Wang, B. *ACS Catal.* **2016**, *6*, 3856. (e) Wu, J.; Cui, X.; Chen, L.; Jiang, G.; Wu, Y. *J. Am. Chem. Soc.* **2009**, *131*, 13888. (f) Guimond, N.; Gorelsky, S. I.; Fagnou, K. *J. Am. Chem. Soc.* **2011**, *133*, 6449. (g) Sen, M.; Kalsi, D.; Sundararaju, B. *Chem. - Eur. J.* **2015**, *21*, 15529.
- (6) (a) Chernyak, N.; Dudnik, A. S.; Huang, C.; Gevorgyan, V. *J. Am. Chem. Soc.* **2010**, *132*, 8270. (b) Huang, C.; Chattopadhyay, B.; Gevorgyan, V. *J. Am. Chem. Soc.* **2011**, *133*, 12406. (c) Gulevich, A. V.; Melkonyan, F. S.; Sarkar, D.; Gevorgyan, V. *J. Am. Chem. Soc.* **2012**, *134*, 5528.
- (7) Preshlock, S. M.; Plattner, D. L.; Maligres, P. E.; Krska, S. W.; Maleczka, R. E., Jr; Smith, M. R., III *Angew. Chem., Int. Ed.* **2013**, *52*, 12915.
- (8) Liu, X.; Li, X.; Liu, H.; Guo, Q.; Lan, J.; Wang, R.; You. *Org. Lett.* **2015**, *17*, 2936.
- (9) (a) Wang, J.; Wang, M.; Chen, K.; Zha, S.; Song, C.; Zhu, J. *Org. Lett.* **2016**, *18*, 1178. (b) Zhou, S.; Wang, M.; Wang, L.; Chen, K.; Wang, J.; Song, C.; Zhu, J. *Org. Lett.* **2016**, *18*, 5632. (c) Wang, C.; Huang, Y. *Org. Lett.* **2013**, *15*, 5294.
- (10) Hua, Y.; Asgari, P.; Avullala, T.; Jeon, J. *J. Am. Chem. Soc.* **2016**, *138*, 7982.
- (11) For selected examples, see: (a) Zhao, Y.; Chen, G. *Org. Lett.* **2011**, *13*, 4850. (b) He, G.; Zhao, Y.; Zhang, S.; Lu, C.; Chen, G. *J. Am. Chem. Soc.* **2012**, *134*, 3. (c) Nadres, E. T.; Daugulis, O. *J. Am. Chem. Soc.* **2012**, *134*, 7. (d) Huang, L.; Sun, X.; Li, Q.; Qi, C. *J. Org. Chem.* **2014**, *79*, 6720. (e) Zhang, Y.; Zhao, H.; Wang, H.; Wei, J.; Shi, Z. *Angew. Chem., Int. Ed.* **2015**, *54*, 13686. (f) Wang, H.; Tong, H.; He, G.; Chen, G. *Angew. Chem., Int. Ed.* **2016**, *55*, 15387. (g) Li, Z.; Sun, S.; Qiao, H.; Yang, F.; Zhu, Y.; Kang, J.; Wu, Y.; Wu, Y. *Org. Lett.* **2016**, *18*, 4594.
- (12) (a) Bentley, K. W. *Nat. Prod. Rep.* **2006**, *23*, 444. (b) Chrzanowska, M.; Rozwadowska, M. D. *Chem. Rev.* **2004**, *104*, 3341. (c) Bentley, K. W. *Nat. Prod. Rep.* **1992**, *9*, 365.
- (13) (a) Pike, V. W.; Halldin, C.; Crouzel, C.; Barré, L.; Nutt, D.; Osman, J. S.; Shah, F. D.; Turton, R.; Waters, S. L. *Nucl. Med. Biol.* **1993**, *20*, 503. (b) Giri, P.; Kumar, G. S. *Mini-Rev. Med. Chem.* **2010**, *10*, 568.
- (14) (a) Lim, C. W.; Tissot, O.; Mattison, A.; Hooper, M. W.; Brown, J. M.; Cowley, A. R.; Hulmes, D. I.; Blacker, A. *Org. Process Res. Dev.* **2003**, *7*, 379.
- (15) (a) Tsuboyama, A.; Iwawaki, H.; Furugori, M.; Mukaide, T.; Kamatani, J.; Igawa, S.; Moriyama, T.; Miura, S.; Takiguchi, T.; Okada, S.; Hoshino, M.; Ueno, K. *J. Am. Chem. Soc.* **2003**, *125*, 12971. (b) Fang, K.-H.; Wu, L.-L.; Huang, Y.-T.; Yang, C.-H.; Sun, I.-W. *Inorg. Chim. Acta* **2006**, *359*, 441. (c) Liu, S.-J.; Zhao, Q.; Chen, R.-F.; Deng, Y.; Fan, Q.-L.; Li, F.-Y.; Wang, L.-H.; Huang, C.-H.; Huang, W. *Chem. - Eur. J.* **2006**, *12*, 4351. (d) Zhao, Q.; Liu, S.; Shi, M.; Wang, C.; Yu, M.; Li, L.; Li, F.; Yi, T.; Huang, C. *Inorg. Chem.* **2006**, *45*, 6152. (e) Shin, I.-S.; Kim, J. I.; Kwon, T.-H.; Hong, J.-I.; Lee, J.-K.; Kim, H. J. *Phys. Chem. C* **2007**, *111*, 2280. (f) Park, G. Y.; Kim, Y.; Ha, Y. *Mol. Cryst. Liq. Cryst.* **2006**, *462*, 179.
- (16) (a) Morimoto, K.; Hirano, K.; Satoh, T.; Miura, M. *Chem. Lett.* **2011**, *40*, 600. (b) Gupta, S.; Han, J.; Kim, Y.; Lee, S. W.; Rhee, Y.; Park, J. *J. Org. Chem.* **2014**, *79*, 9094. (c) Kumar, S.; Saunthwal, R. K.; Aggarwal, T.; Reddy Kotla, S. K.; Verma, A. K. *Org. Biomol. Chem.* **2016**, *14*, 9063.
- (17) (a) Lapointe, D.; Fagnou, K. *Chem. Lett.* **2010**, *39*, 1118. (b) Grigorjeva, L.; Daugulis, O. *Angew. Chem., Int. Ed.* **2014**, *53*, 10209. (c) Zhang, J.; Chen, H.; Lin, C.; Liu, Z.; Wang, C.; Zhang, Y. *J. Am. Chem. Soc.* **2015**, *137*, 12990. (d) Wu, X.; Yang, K.; Zhao, Y.; Sun, H.; Li, G.; Ge, H. *Nat. Commun.* **2015**, *6*, 6462. (e) Maity, S.; Kancharla, R.; Dhawa, U.; Hoque, E.; Pimparkar, S.; Maiti, D. *ACS Catal.* **2016**, *6*, 5493. (f) Gandeepan, P.; Rajamalli, P.; Cheng, C.-H. *Angew. Chem.* **2016**, *128*, 4380. (g) Zou, F.; Chen, X.; Hao, W. *Tetrahedron* **2017**, *73*, 758. (h) Zhu, X.; Su, J.; Du, C.; Wang, Z.; Ren, C.; Niu, J.; Song, M.-P. *Org. Lett.* **2017**, *19*, 596. (i) Wang, F.; Wang, Q.; Bao, M.; Li, X. *Chin. J. Catal.* **2016**, *37*, 1423.