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# Cobalt-Catalyzed Selective Functionalization of Aniline Derivatives with Hexafluoroisopropanol

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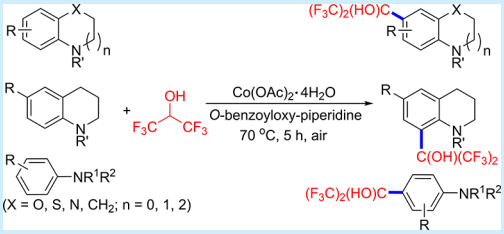
Supporting Information

**ABSTRACT:** A cobalt-catalyzed site-selective functionalization of aniline derivatives with hexafluoroisopropanol, which enables the synthesis of a wide array of fluoroalkylated anilines, a class of highly valuable building blocks for further preparation of fluorinated functional products, is reported. The developed transformation proceeds with operational simplicity, use of earth-abundant metal catalyst, broad substrate scope, good functional group tolerance, and mild reaction conditions.

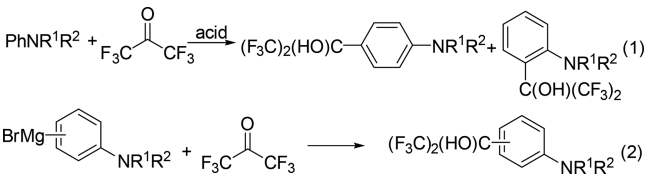





Selective introduction of fluorinated substituents into an organic molecule is of particular importance in synthetic chemistry, as it enables the electron distribution and the lipophilicity of the entire molecule to be altered and contributes to renewed applications in the fields of medicine, agrochemicals, and material science.[1] Among the various related transformations, the study on direct synthesis of hydroxyhexafluoroisopropyl (or bis(trifluoromethyl)carbinol) group containing products is relatively rare.[2] Nevertheless, such compounds exhibit diverse biological and therapeutic activities, and they have been applied for the treatment of hepatitis C, cancer, dyslipidemia, inflammation, and diabetes.[3] Moreover, they could be utilized for the preparation of polymer,[4] the development of ligands[5] and chemical sensors,[6] and the synthesis of spirosilanes.[7]

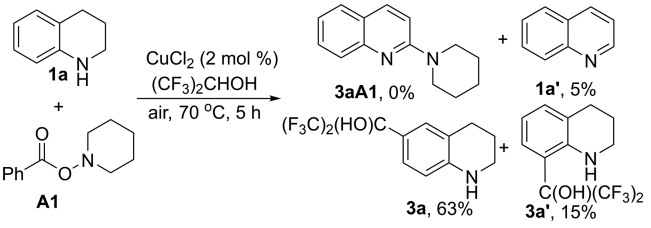
Anilines constitute a class of fundamental raw materials in chemical industry, for instance, for large-scale production of polymers and dyes. Moreover, they serve as highly useful building blocks for the preparation of bioactive molecules, pharmaceuticals, agrochemicals, dyes, and other functional products.[8] Because of the widespread applications, selective installation of a hydroxyhexafluoroisopropyl group on the aniline skeleton is of important significance, as it would pave the way for further elaboration of various fluorinated functional products. Despite the multidisciplinary impact of arylamino and hexafluoroisopropanol motifs, there are very limited strategies reported for the preparation of hydroxyhexafluoroisopropyl anilines, including the electrophilic substitution of anilines with hexafluoroacetone under acidic conditions (Scheme 1, eq 1)[9a,b] and the addition of organomagnesium to hexafluoroacetone (eq 2).[9c] However, these methods suffer from one or more limitations such as low regio- and chemoselectivity, poor substrate and functional group compatibility, the use of toxic[2a] and corrosive agents, and the need for pre-preparation of air- and moisture-sensitive agents. As such, the development of direct and selective methods for general synthesis of hydroxyhexafluoroisopropyl anilines from readily available feedstocks still remains a highly demanding goal.

**Scheme 1. Existing Strategies**




As our sustained efforts toward the construction and functionalization of N-heterocycles,[10] we have recently reported an aerobic copper-catalyzed $\alpha$-amination of tetrahydronquinolines (THQs) with various amines.[10h] Interestingly, when the reaction of THQ **1a** with *O*-(benzoyloxy)piperidine (**A1**) as the aminating agent[11] was performed in hexafluoroisopropanol (HFIP) by using as $CuCl_2$ as a catalyst (Scheme 2), we observed that, instead of the anticipated $\alpha$-C−H

**Scheme 2. New Observation**

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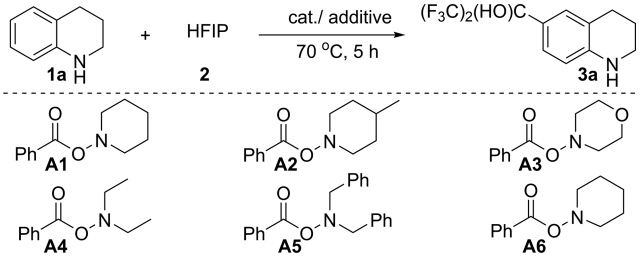
amination product **3aA1**, two hydroxyhexafluoroisopropyl products (**3a** and **3a′**), occurring at the sites *para* and *ortho* to the N atom of the THQ **1a**, were detected in 63% and 15% yields, respectively. Moreover, a noncoupling quinoline **1a′** was found in 5% yield. To the best of our knowledge, HFIP has emerged as a solvent of choice for different reactions,[12] whereas it has been scarcely utilized as a coupling agent for the functionalization of C−H bonds. In particular, the new observation on the formation products **3a** and **3a′** has spurred our interest, and we wished to develop a selective fluoroalkylation reaction. Through a thorough investigation, we report herein, for the first time, a cobalt-catalyzed direct and selective functionalization of aniline derivatives with HFIP.

Initially, we chose the reaction of substrate **1a** in HFIP (**2**) as a model system to screen an efficient catalyst system (Table 1). Gratifyingly, in the presence of catalytic amount of cobalt

**Table 1. Optimization of the Reaction Conditions**[a]



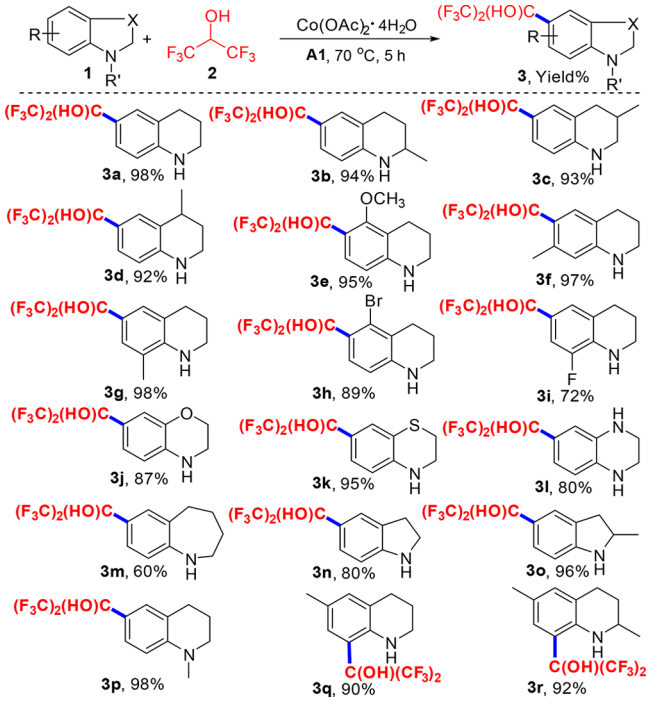

| entry | catalyst | additive | 3a, yield[b] (%) |
|---|---|---|---|
| 1 | $Co(OAc)_2{\cdot}4H_2O$ | A1 | 98 |
| 2 | $Co(OAc)_2{\cdot}4H_2O$ | A2 | 94 |
| 3 | $Co(OAc)_2{\cdot}4H_2O$ | A3 | trace |
| 4 | $Co(OAc)_2{\cdot}4H_2O$ | A4 | 34 |
| 5 | $Co(OAc)_2{\cdot}4H_2O$ | A5 | 34 |
| 6 | $Co(OAc)_2{\cdot}4H_2O$ | A6 | trace |
| 7 | $Co(OAc)_2{\cdot}4H_2O$ | (−, TBHP, $H_2O_2$) | − |
| 8 | − | A1 | 15 |
| 9 | $Co(OAc)_2{\cdot}4H_2O$ | A1 | 47[c] |
| 10 | $Co(OAc)_2{\cdot}4H_2O$ | A1 | 44[d] |

[a]Reaction conditions: **1a** (0.25 mmol), additive (0.25 mmol), $Co(OAc)_2{\cdot}4H_2O$ (2 mol %), HFIP **2** (0.5 mL), 70 °C, under air, 5 h. [b]Isolated yield. [c]Catalyst loading: 1 mol %. [d]Additive loading: 0.5 equiv.

acetate and *O*-(benzoyloxy)piperidine (**A1**) as the additive, performing the reaction at 70 °C for 5 h gave product **3a** in almost quantitative yield (Table 1, entry 1:98%), and its structure was confirmed by X-ray diffraction (Figure S1 and Table S3). Then a series of *O*-benzoyl hydroxylamines were tested (**A2**−**A6**). The results showed that they were inferior to **A1** (entries 1−6). However, the absence of additive **A1** or catalyst, or the use of other common oxidants (e.g., TBHP and $H_2O_2$), led to no product formation or poor yield (entries 7 and 8), showing that the combination of **A1** and $Co(OAc)_2$ is critical to constitute an efficient catalyst system. Further, a decrease of catalyst or additive loading significantly diminished the product yield. Thus, the optimal conditions are as described in entry 1 (standard conditions).

With the availability of the optimal conditions, we then evaluated the substrate scope of the synthetic protocol. Initially, a variety of benzocyclic amines **1** (for their structures, see Scheme S1), a class of specific aniline derivatives, were tested. As shown in Scheme 3, all the reactions proceeded with

**Scheme 3. Variation of Benzocyclic Amines**[a]




[a]Standard conditions: **1** (0.25 mmol), **A1** (0.25 mmol), $Co(OAc)_2{\cdot}4H_2O$ (2 mol %), HFIP **2** (0.5 mL), 70 °C, under air, 5 h. Isolated yield.

smooth hydroxyhexafluoroisopropylation at the site *para* to the N atom of substrates **1** and furnished the desired products in good to excellent yields upon isolation (Scheme 3, **3a**−**i**). The electronic properties of the substituents on the aryl ring of THQs affected the product yields to some extent. In particular, THQs containing an electron-donating group afforded the products (**3b**−**g**) in relatively higher yields than those of with electron-deficient THQs (**3h**,**i**). This phenomenon is attributable to the fact that the electron-rich THQs enhance the electron density of the aryl ring and favor the coupling step. In addition to THQs, other types of secondary and tertiary benzocyclic amines, such as benzomorpholine (**1j**), benzothiazine (**1k**), 1,2,3,4-tetrahydroquinoxaline (**1l**), 2,3,4,5-tetrahydro-1*H*-benzo[*b*]azepine (**1m**), indolines (**1n** and **1o**), and *N*-methyl-1,2,3,4-tetrahydroquinoline (**1p**), were also amenable to the transformation, affording the desired products in satisfactory yields (**3j**−**p**). Intriguingly, THQs (**1q** and **1r**) substituted with a methyl group at position 6 resulted in 8-hydroxyhexafluoroisopropyl products **3q** and **3r** in excellent yields. It is important to note that, in all cases studied, no dehydrogenation on the cyclic amine motifs was found, showing that the reaction proceeds in a chemoselective manner. The retention of such structural units has the potential for further elaboration of functional frameworks.[10]

Next, we focused on the variation of aniline derivatives with different substitution patterns. As shown in Scheme 4, primary, secondary, and tertiary anilines (**4a**−**o**) were reacted with HFIP **2**, which generated the desired products in the moderate to good isolated yields (**5a**−**o**). Similar to the results described in Scheme 4, electron-rich anilines gave relatively higher yields (**5c**, **5k**, and **5m**) than those of electron-deficient ones (**5j**, **5l**, and **5n**). It is noteworthy that various functional groups, as shown in Schemes 3 and 4, were well tolerated, which offers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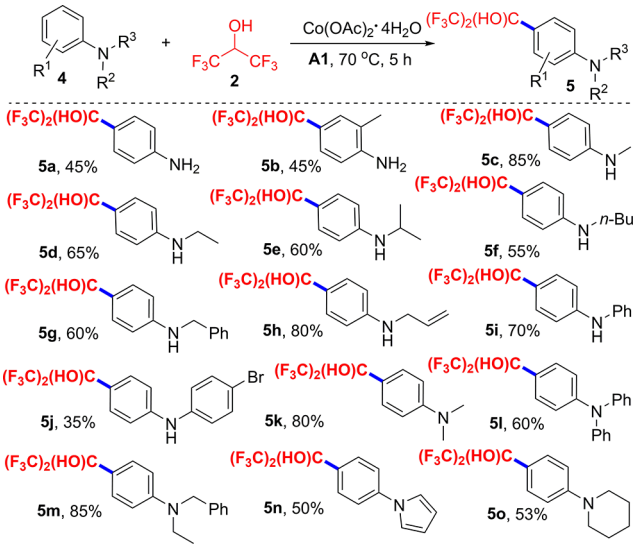
**Scheme 4. Variation of Aniline Derivatives**[a]

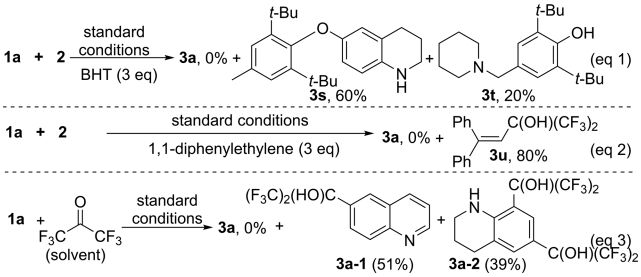



[a]Standard conditions: **4** (0.25 mmol), **A1** (0.25 mmol), $Co(OAc)_2 \cdot 4H_2O$ (2 mol %), HFIP **2** (0.5 mL), 70 °C, under air, 5 h. Isolated yield.

the potential for the construction of complex molecules via further chemical transformations.

To gain mechanistic insights into the reaction, we conducted several control experiments. As illustrated in Scheme 5, the

**Scheme 5. Control Experiments**




addition of 3 equiv of butylated hydroxytoluene (BHT) or 1,1-diphenylethylene (DPE) into the model reaction completely suppressed the formation product **3a** (eqs 1 and 2), whereas the products of BHT trapping THQ **1a** at position 6 (**3s**) and a piperidyl motif from additive **A1** (**3t**) were detected in 60% and 20% yields, respectively (eq 1), and DPE combined with a HFIP unit was produced in 80% yield. These two experiments show that the reaction involves piperidyl, tetrahydroquinolyl, and hydroxyhexafluoroisopropyl radicals. Further, the reaction of THQ **1a** and hexafluoroacetone yielded a mixture of 6-functionalized quinoline **3a-1** (51%) and 6,8-difunctionalized THQ **3a-2** (39%), but it failed to give even trace of product **3a** (eq 3). Thus, the reaction involving hexafluoroacetone as an intermediate can be ruled out.

To better understand the role of the additive, we analyzed the redox potentials of compounds **A1** and **A3**. As shown in Figure 1, in sharp contrast with the weak signal of **A3**, **A1** exhibits a significant redox potential and a larger surface area under the same conditions, which indicate that **A1** has stronger oxidizing capacity than that of **A3**, and compound **A3** is not an applicable oxidant for the reaction.

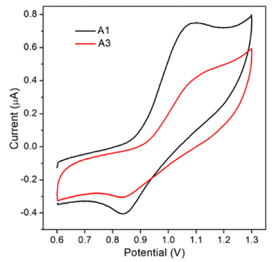
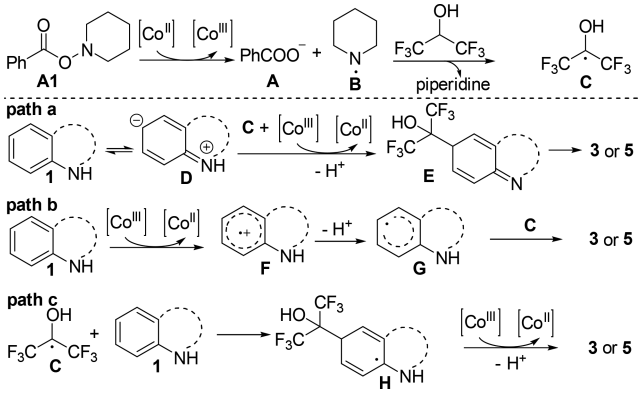



**Figure 1.** Representative cyclic voltammogram of **A1** and **A3** measured in HFIP with 0.1 M $TBAPF_6$ at 25 °C.

On the basis of the above findings, three possible reaction pathways are depicted in Scheme 6. Initially, the single-

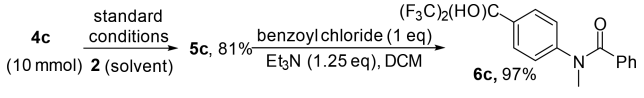
**Scheme 6. Plausible Reaction Pathways**




electron transfer from $[Co^{II}]$ to **A1** forms the $[Co^{III}]$ species, $PhCOO^-$ (**A**), and piperidyl radical **B**. Then the interaction between **B** and HFIP gives radical **C** along with elimination of piperidine. In path a, the electron-deficient radical **C** is trapped by electron-rich aniline **1** at the sterically less hindered *para*-site (see the zwitterionic form **D**),[10d] which then gives intermediate **E** via single-electron oxidation (SEO) by $[Co^{III}]$- and $PhCOO^-$-assisted deprotonation. Finally, the tautomerization of **E** generates product **3** or **5**. In path b, direct SEO of aniline **1** followed by deprotonation and radical–radical coupling between **G** and **C** would give rise to the desired product. Alternatively, direct addition of **C** to aniline on the aryl ring followed by SEO and elimination of proton also rationalizes the product formation (path c). It is noteworthy that when the site *para* to the N-atom of aniline **1** is blocked, the fluoroalkylation occurs at the *o*-position.

Finally, we were interested in demonstrating the utility of the developed chemistry. The reaction of substrate **4c** was scaled up to 10 mmol under the standard conditions, which still gave product **5c** in good isolated yield. Further, the treatment of compound **5c** with benzoyl chloride in dichloromethane (DCM) by using $NEt_3$ as a base resulted in the N-acylated product **6c**, a potent inhibitor of hepatitis C virus,[8b] in excellent yield (Scheme 7).

**Scheme 7. Synthetic Utility of the Developed Chemistry**



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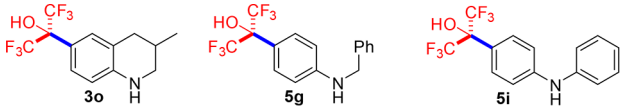
Furthermore, we evaluated the in vitro cytotoxicity of all the obtained products by the methylthiazoltetrazolium (MTT) assay on the human hepatoma carcinoma cell (HepG-2), human cervical cancer cell (Hela), human lung carcinoma cell (A549), and human skin fibroblasts (HSF) cell lines. The detailed results are listed in Scheme 8 and Table S2.

**Scheme 8. Anticancer Activity of Compounds 3o, 5g, and 5i**




$IC_{50}$ = 11.36 μM (Hela) $IC_{50}$ = 6.718 μM (HepG-2) $IC_{50}$ = 3.96 μM (A549) $IC_{50}$ = 11.731 μM (HepG-2)

Gratifyingly, compounds **5i** ($IC_{50}$ = 11.731 $\mu$M) and **5g** ($IC_{50}$ = 6.718 $\mu$M) exhibit potent inhibitory activities against HepG-2 cell lines, product **5i** ($IC_{50}$ = 3.96 $\mu$M) shows high inhibitory efficiency in A549 cell lines, and compound **3o** ($IC_{50}$ = 11.36 $\mu$M) is a powerful cytotoxic agent against these cell lines except for HepG-2 (Scheme 8). This study has demonstrated the potential of hydroxyhexafluoroisopropyl anilines in the discovery of new potent anticancer agents.

In summary, we have developed a new cobalt-catalyzed selective functionalization of aniline derivatives with hexafluoroisopropanol, which enables to access a wide array of fluoroalkylated anilines, a class of highly valuable building blocks for further preparation of fluorinated functional products. The catalytic transformation proceeds with good functional group and substrate compability, high regio and chemoselectivity, mild conditions, and operational simplicity, which offers the potential for the discovery of functional molecules such as new anticancer agents and sheds new light on further introduction of other fluoroalkyl groups into electron-rich organic systems via a radical-coupling strategy.

## ■ ASSOCIATED CONTENT

### Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.orglett.8b03666.

Experimental details, NMR spectra, and single-crystal X-ray diffraction data of **3a** (PDF)

### Accession Codes

CCDC 1875943 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif, or by emailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033.

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### Notes

The authors declare no competing financial interest.

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## ■ REFERENCES

(1) For selected reviews, see: (a) Zhou, Y.; Wang, J.; Gu, Z.; Wang, S.; Zhu, W.; Aceña, J. L.; Soloshonok, V. A.; Izawa, K.; Liu, H. *Chem. Rev.* **2016**, *116*, 422. (b) Vitale, A.; Bongiovanni, R.; Ameduri, B. *Chem. Rev.* **2015**, *115*, 8835. (c) Mishra, S.; Daniele, S. *Chem. Rev.* **2015**, *115*, 8379. (d) Wang, J.; Sánchez-Roselló, M.; Aceña, J. L.; del Pozo, C.; Sorochinsky, A. E.; Fustero, S.; Soloshonok, V. A.; Liu, H. *Chem. Rev.* **2014**, *114*, 2432. (e) Purser, S.; Moore, P. R.; Swallow, S.; Gouverneur, V. *Chem. Soc. Rev.* **2008**, *37*, 320. (f) Purser, S.; Moore, P. R.; Swallow, S.; Gouverneur, V. *Chem. Soc. Rev.* **2008**, *37*, 320.

(2) (a) Domino, K.; Veryser, C.; Wahlqvist, B. A.; Gaardbo, C.; Neumann, K. T.; Daasbjerg, K.; De Borggraeve, W. M.; Skrydstrup, T. *Angew. Chem., Int. Ed.* **2018**, *57*, 6858. (b) Xu, Z.-B.; Hang, Z. J.; Chai, L.; Liu, Z.-Q. *Org. Lett.* **2016**, *18*, 4662.

(3) (a) Li, L.; Liu, J.; Zhu, L.; Cutler, S.; Hasegawa, H.; Shan, B.; Medina, J. C. *Bioorg. Med. Chem. Lett.* **2006**, *16*, 1638. (b) Kumar, N.; Solt, L. A.; Conkright, J. J.; Wang, Y.; Istrate, M. A.; Busby, S. A.; Garcia-Ordonez, R. D.; Burris, T. P.; Griffin, P. R. *Mol. Pharmacol.* **2010**, *77*, 228. (c) Wang, Y.; Kumar, N.; Nuhant, P.; Cameron, M. D.; Istrate, M. A.; Roush, W. R.; Griffin, P. R.; Burris, T. P. *ACS Chem. Biol.* **2010**, *5*, 1029. (d) Bourbeau, M. P.; Ashton, K. S.; Yan, J.; St. Jean, D. J., Jr *J. Org. Chem.* **2014**, *79*, 3684. (e) Li, Y.; Xia, G.; Guo, Q.; Wu, L.; Chen, S.; Yang, Z.; Wang, W.; Zhang, Z.-Y.; Zhou, X.; Jiang, Z.-X. *MedChemComm* **2016**, *7*, 1672. (f) Peng, Q.; Yuan, Y.; Zhang, H.; Bo, S.; Li, Y.; Chen, S.; Yang, Z.; Zhou, X.; Jiang, Z.-X. *Org. Biomol. Chem.* **2017**, *15*, 6441.

(4) (a) Cassidy, P. E.; Aminabhavi, T. M.; Reddy, V. S.; Fitch, J. W., III *Eur. Polym. J.* **1995**, *31*, 353. (b) Fitch, J. W.; Bucio, E.; Martinez, L.; Macossay, J.; Venumbaka, S. R.; Dean, N.; Stoakley, D.; Cassidy, P. E. *Polymer* **2003**, *44*, 6431. (c) Miyasaka, M.; Koike, N.; Fujiwara, Y.; Kudo, H.; Nishikubo, T. *Polym. J.* **2011**, *43*, 325.

(5) (a) Morikawa, S.; Michigami, K.; Amii, H. *Org. Lett.* **2010**, *12*, 2520. (b) O'Reilly, M. E.; Ghiviriga, I.; Abboud, K. A.; Veige, A. S. *J. Am. Chem. Soc.* **2012**, *134*, 11185. (c) Ratjen, L.; van Gemmeren, M.; Pesciaioli, F.; List, B. *Angew. Chem., Int. Ed.* **2014**, *53*, 8765.

(6) (a) Kong, L.; Wang, J.; Fu, X.; Zhong, Y.; Meng, F.; Luo, T.; Liu, J. *Carbon* **2010**, *48*, 1262. (b) Kong, L.; Wang, J.; Luo, T.; Meng, F.; Chen, X.; Li, M.; Liu, J. *Analyst* **2010**, *135*, 368.

(7) (a) Lenormand, H.; Corcé, V.; Sorin, G.; Chhun, C.; Chamoreau, L.-M.; Krim, L.; Zins, E.-L.; Goddard, J.-P.; Fensterbank, L. *J. Org. Chem.* **2015**, *80*, 3280. (b) Perozzi, E. F.; Martin, J. *J. Am. Chem. Soc.* **1979**, *101*, 1591.

(8) (a) Mintzer, M. A.; Simanek, E. E. *Chem. Rev.* **2009**, *109*, 259. (b) Birch, A. M.; Groombridge, S.; Law, R.; Leach, A. G.; Mee, C. D.; Schramm, C. *J. Med. Chem.* **2012**, *55*, 3923. (c) Hutchby, M. *Novel Synthetic Chemistry of Ureas and Amides*; Springer: Berlin, 2012.

(9) (a) Zelenin, A.; Chkanikov, N.; Umnov, A.; Kolomiets, A.; Fokin, A. *Bull. Acad. Sci. USSR, Div. Chem. Sci.* **1986**, *35*, 1890. (b) Matsuno, K.; Ueda, Y.; Fukuda, M.; Onoda, K.; Waki, M.; Ikeda, M.; Kato, N.; Miyachi, H. *Bioorg. Med. Chem. Lett.* **2014**, *24*, 4276. (c) Satou, M.; Kakizawa, T. WO2014133048A1, 2014.

(10) (a) Chen, X.-W.; Zhao, H.; Chen, C.-L.; Jiang, H.-F.; Zhang, M. *Angew. Chem., Int. Ed.* **2017**, *56*, 14232. (b) Xie, F.; Chen, Q.-H.; Xie, R.; Jiang, H.-F.; Zhang, M. *ACS Catal.* **2018**, *8*, 5869. (c) Liang, T.; Tan, Z.; Zhao, H.; Chen, X.; Jiang, H.; Zhang, M. *ACS Catal.* **2018**, *8*, 2242. (d) Chen, X.; Zhao, H.; Chen, C.; Jiang, H.; Zhang, M. *Chem. Commun.* **2018**, *54*, 9087. (e) Chen, X.; Zhao, H.; Chen, C.; Jiang, H.;



DOI: 10.1021/acs.orglett.8b03666
*Org. Lett.* XXXX, XXX, XXX−XXX

Zhang, M. *Org. Lett.* **2018**, *20*, 1171. (f) Tan, Z.; Jiang, H.; Zhang, M. *Org. Lett.* **2016**, *18*, 3174. (g) Xie, F.; Xie, R.; Zhang, J.-X.; Jiang, H.-F.; Du, L.; Zhang, M. *ACS Catal.* **2017**, *7*, 4780. (h) Liang, Y.; Jiang, H.; Tan, Z.; Zhang, M. *Chem. Commun.* **2018**, *54*, 10096.

(11) Zhao, H.; Chen, X.-W.; Jiang, H.-F.; Zhang, M. *Org. Chem. Front.* **2018**, *5*, 539.

(12) For selected examples, see: (a) Hollóczki, O.; Berkessel, A.; Mars, J.; Mezger, M.; Wiebe, A.; Waldvogel, S. R.; Kirchner, B. *ACS Catal.* **2017**, *7*, 1846. (b) Berkessel, A.; Kramer, J.; Mummy, F.; Neudorfl, J. M.; Haag, R. *Angew. Chem., Int. Ed.* **2013**, *52*, 739. (c) Broese, T.; Francke, R. *Org. Lett.* **2016**, *18*, 5896. (d) Richmond, E.; Yi, J.; Vuković, V. D.; Sajadi, F.; Rowley, C. N.; Moran, J. *Chem. Sci.* **2018**, *9*, 6411. (e) Imada, Y.; Rockl, J. L.; Wiebe, A.; Gieshoff, T.; Schollmeyer, D.; Chiba, K.; Franke, R.; Waldvogel, S. R. *Angew. Chem., Int. Ed.* **2018**, *57*, 12136.



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