Taylor & Francis
Taylor & Francis Group

Synthetic Communications

An International Journal for Rapid Communication of Synthetic Organic Chemistry

ISSN: 0039-7911 (Print) 1532-2432 (Online) Journal homepage: http://www.tandfonline.com/loi/lsyc20

p-Toluenesulfonic acid-promoted autocatalytic hydrolyzation of 1-tosyl-1,2,3-triazoles

Haohao Dong, Dongdong Zhang, Renjie Fang, Qingyang Du, Zhuoya Dong, Hao Wei, Min Shi & Feijun Wang

To cite this article: Haohao Dong, Dongdong Zhang, Renjie Fang, Qingyang Du, Zhuoya Dong, Hao Wei, Min Shi & Feijun Wang (2018): p-Toluenesulfonic acid-promoted autocatalytic hydrolyzation of 1-tosyl-1,2,3-triazoles, Synthetic Communications, DOI: 10.1080/00397911.2018.1440316

To link to this article: https://doi.org/10.1080/00397911.2018.1440316

SYNTHETIC COMMUNICATIONS®
https://doi.org/10.1080/00397911.2018.1440316

Taylor & Francis
Taylor & Francis Group

p-Toluenesulfonic acid-promoted autocatalytic hydrolyzation of 1-tosyl-1,2,3-triazoles

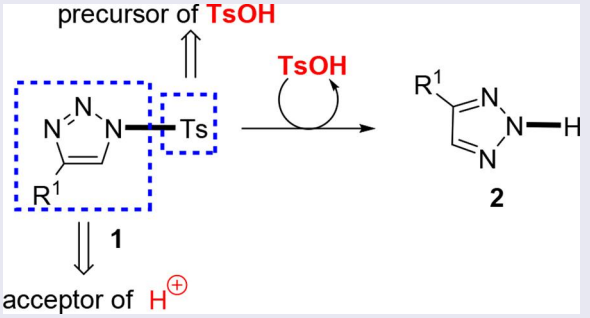
Haohao Dong[a], Dongdong Zhang[a], Renjie Fang[a], Qingyang Du[a], Zhuoya Dong[a], Hao Wei[b], Min Shi[a,c], and Feijun Wang[a]

[a]Key Laboratory for Advanced Materials, School of Chemistry & Molecular Engineering, East China University of Science and Technology, Shanghai, P. R. China; [b]Key Laboratory for Thin Film and Microfabrication Technology of Ministry of Education, School of Electronic Information and Electrical Engineering, Shanghai Jiao Tong University, Shanghai, P. R. China; [c]State Key Laboratory of Organometallic Chemistry, Chinese Academy of Sciences, Shanghai Institute of Organic Chemistry, Shanghai, P. R. China

ABSTRACT

The first example of autocatalytic hydrolyzation of 4-aryl-1-tosyl-1,2,3-triazoles induced by *p*-toluenesulfonic acid was reported, providing an effective and metal-free synthetic approach to deliver a broad range of new 4-aryl-2*H*-1,2,3-triazoles in good yields. The kinetic profile of this hydrolyzation suggested that this reaction has exponential autocatalytic behavior.

GRAPHICAL ABSTRACT



ARTICLE HISTORY
Received 3 December 2017

KEYWORDS
1,2,3-Triazoles; autocatalytic hydrolyzation; brønsted acid

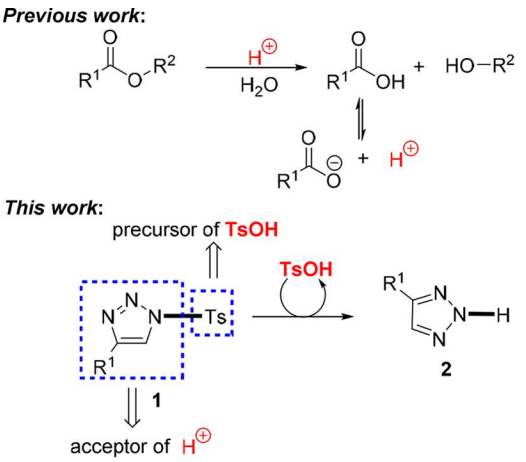
Introduction

Autocatalysis is widely presented in nature and is central to containment-based, metabolic, and genetic theories on the origins of life.[1] Consequently, the development of autocatalytic processes is a prominent objective in chemical research.[2] Many reported autocatalytic processes are primarily based on template-directed self-replication[3] under the presence of template triggers such as oligonucleotides,[4] peptides,[5] amino acids,[6] and unnatural molecules such as those used in Collum ortholithiation[7] or Soai reaction.[8] To satisfy

CONTACT Feijun Wang feijunwang@ecust.edu.cn; Key Laboratory for Advanced Materials, School of Chemistry & Molecular Engineering, East China University of Science and Technology, 130 Meilong Road, Shanghai 200237, P. R. China; Hao Wei haowei@sjtu.edu.cn Key Laboratory for Thin Film and Microfabrication Technology of Ministry of Education, School of Electronic Information and Electrical Engineering, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, P. R. China.

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/lsyc.

Supplemental data for this article can be accessed on the publisher's website.



Scheme 1. Autocatalytic hydrolysis.

the rapidly increasing demand for knowledge of the propagation of life, the intrinsic properties of many other biological processes[1] and the fascinating prospects for catalytic science[9] and materials science,[10] the challenges of the development of novel strategy to design new autocatalytic processes have become an important topic.

Acid-catalyzed ester hydrolysis is a classic example in autocatalysis.[1] However, the obtained acid with high pK_a, for example, 12.6 for acetic acid,[11] cannot be used as an effective acid catalyst and might limit the synthetic utility of this autocatalytic strategy (Scheme 1). Brønsted acid can activate a series of functional groups such as carbonyl, imino, alkenyl, alkynyl, and hydroxyl to receive the attack of nucleophilic reagents.[12] Therefore, instead of an acyl group in ester, we envisioned that the functional groups such as tosyl (Ts), which are the potential functional groups for the generation of Brønsted acid were used to develop their autocatalytic hydrolysis. 1-Tosyl-1*H*-1,2,3-triazole **1** bearing a tosyl group and having the N^2-nucleophilicity[13] of 1,2,3-triazole ring, which is easily prepared from the copper(I)-catalyzed "Click" reaction,[14] has recently received much attention because of its useful transformations through α-imino metal carbenes[15] and might be an ideal molecule to replace an ester.

Initiated by the remarkable discovery of click chemistry, the 1,2,3-triazoles have attracted great interest for its widespread applications,[14] especially in medicinal chemistry,[16] material chemistry,[17] and synthetic organic chemistry.[18] Within the 1,2,3-triazole categories, the 2*H*-1,2,3-triazoles are an important class which can be used as valuable intermediates for a series of important transformations[19] and ligands for metal coordination chemistry.[20] However, their potential applications are still far less exploited than they could be due to the lack of a general approach to their synthesis. In the past decades, many approaches for the synthesis of 4-aryl-*NH*-1,2,3-triazoles have been developed. In general, methods for the synthesis of 4-aryl-*NH*-1,2,3-triazoles are usually confined to the cycloaddition of activated alkynes and alkenes[21] or the deprotection of an *N*1-substituted group.[22] However, these strategies suffer from the use of volatile and toxic hydrazoic acid or metal catalyst under harsh reaction conditions.

Results and discussion

To address these challenges, an autocatalytic strategy was introduced to achieve high yields of *2H*-1,2,3-triazoles, utilizing the *p*-toluenesulfonic acid-promoted hydrolyzation of 4-aryl-1-tosyl-1,2,3-triazoles. This represents an effective and matel-free synthetic method to deliver 2*H*-1,2,3-triazoles in good yields.

Initially, hydrolysis of 4-phenyl-1-tosyl-1,2,3-triazole **1a** as the model substrate was performed in water. The result is summarized in Table 1. To our delight, under the presence of 1 mol% TsOH catalyst, **1a** was completely hydrolyzed at 80 °C after 4 h, affording 4-phenyl-2*H*-1,2,3-triazole **2a** in >99% yield (Table 1, entry 2). Reducing the temperature to 60 °C, remarkably, a low yield of **2a** was obtained (entry 4), and tosyl migration product **3a**[23] was surprisingly isolated. With the extension of reaction time to 45 h, the quantitative yield of **2a** could be obtained. Further reducing the temperature to 40 °C, even reacting for 7 d, only 31% yield of **2a** was obtained (entry 6). From the optimization of hydrolyzation conditions, it was generally found that higher reaction temperature and the addition of TsOH can significantly promote the hydrolysis of **1a**. Lower yields of **1a** were obtained without the addition of TsOH catalyst (entries 1, 3, and 5) than those in the presence of 1 mol% TsOH.

With the optimized reaction conditions on hand, the substrate scope was further explored. Various substituted 1-tosyl-1,2,3-triazoles **1** were tested (Table 2), affording the desired 2*H*-1,2,3-triazole **2** in good yields. The electronic property of substituents on the phenyl ring of **1** had little influence on this reaction. In addition, the hydrolysis of 1-(4-methylphenylsulfonyl) benzotriazole **1j** proceeded smoothly, and benzotriazole **2j** was obtained in up to 97% yield (entry 9).

To verify this reaction having an autocatalytic behavior, a kinetic study of hydrolysis of **1a** was performed in water with the addition of 1 mol% TsOH at 80 °C. From the comparison of ^{1}H NMR spectra of **1a** and **2a**, it was found that **1a** has a signal for $\mathbf{H^a}$ at 8.3 ppm, while **2a** has a signal for $\mathbf{H^b}$ at 8.0 ppm. Therefore, the hydrolyzed reaction mixture can be directly analyzed by ^{1}H NMR. These crude ^{1}H NMR spectra, as shown in Figure 1, were obtained for every 0.5 h. The consumption of $\mathbf{H^a}$-signal and the enhancement of $\mathbf{H^b}$-signal can be observed along with the extension of reaction time. It is noteworthy that the

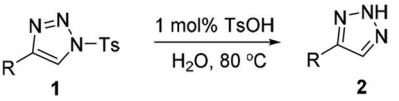
Table 1. Optimization of hydrolysis of 4-phenyl-1-tosyl-1,2,3-triazole **1a**[a].

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

Entry	Temperature (°C)	*x*	*t*	**2a**Yield[b] (%)	**3a**Yield (%)
1	80	–	4 h	90	–
2	80	1%	4 h	>99	–
3	60	–	24 h	48 (>99)[c]	14
4	60	1%	24 h	63 (>99)[c]	12
5	40	–	7 d	25	Trace
6	40	1%	7 d	31	Trace

[a]The reaction of **1a** (1.0 mmol) and TsOH (*x* mol%) in water (10 mL) was stirred at different reaction temperatures for different hours.
[b]Isolated yields are reported.
[c]Reacted for 45 h.

Table 2. Scope of hydrolysis of 1-tosyl-1,2,3-triazoles 1[a].



Entry	1,2,3-Triazole	R	Yield[b] (%)
1	**2b**	2-F-C_6H_4	82
2	**2c**	3-F-C_6H_4	80
3	**2d**	4-F-C_6H_4	81
4	**2e**	4-Cl-C_6H_4	75
5	**2f**	4-Br-C_6H_4	78
6	**2g**	4-CN-C_6H_4	70
7	**2h**	4-CH_3-C_6H_4	85
8	**2i**	4-OCH_3-C_6H_4	88
9	Benzotriazole **2j**		97
10	**2k**	*n*-Pr	80

[a]1,2,3-Triazole **1** (1.0 mmol) and TsOH (1 mol%) in water (10 mL) were stirred at 80 °C for 4 h.
[b]Isolated yields are reported.

H^b-signal was too low to be found from 0 to 1 h, and only one set of peaks for **2a** was found at 4 h. The ^{1}H NMR spectrum suggests that the hydrolysis of **1a** was completely finished. According to these crude ^{1}H NMR spectra, the yield of **2a** can be preliminarily obtained. The kinetic profile as shown in Figure 2 suggests that the hydrolysis of **1a** has an exponential autocatalytic behavior.

With the *p*-toluenesulfonic acid-promoted autocatalytic hydrolyzation of 4-aryl-1-tosyl-1,2,3-triazoles on hand, we also envisioned that 1-tosyl-1*H*-1,2,3-triazole **1a** could be reacted with alcohols to give the autocatalytic amination through the TsOH-promoted formation of carbocations from alcohols and subsequently nucleophilic attack of the

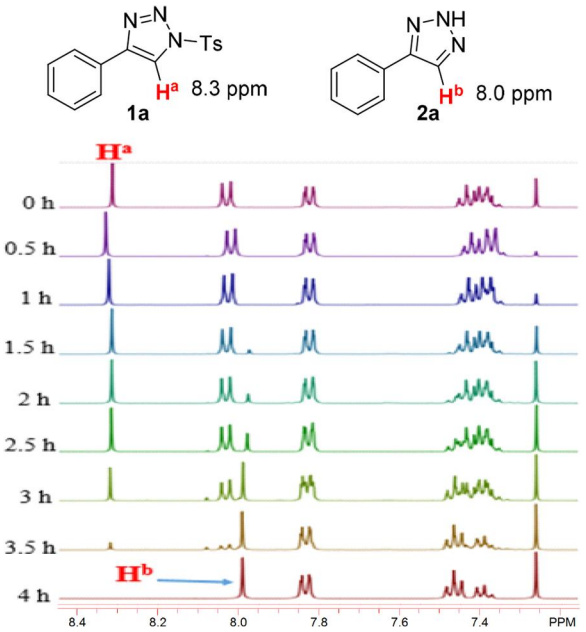


Figure 1. The crude ^{1}H NMR spectroscopy of hydrolysis of **1a**.

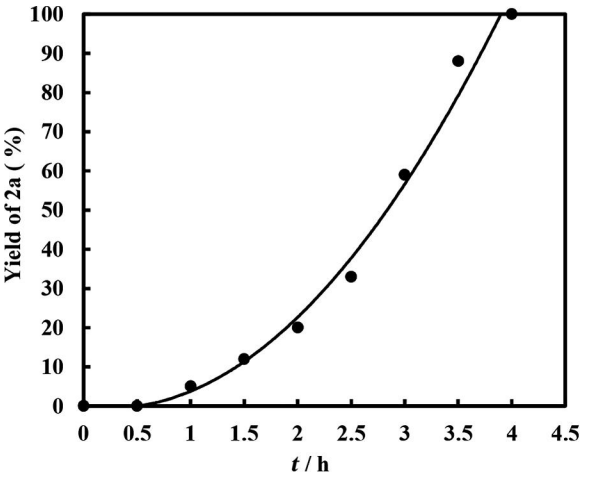


Figure 2. Evidence of autocatalysis in the hydrolysis of **1a**.

1,2,3-triazole ring. 1-Tosyl-1*H*-1,2,3-triazole **1a** was used to react with 1,3-diphenyl-2-propen-1-ol **4**, and the desired N^2-allylated 2*H*-1,2,3-triazole **5** was easily obtained in 80%. Furthermore, the kinetic profile in the reaction of 1-tosyl-1*H*-1,2,3-triazole **1a** with alcohol **4** in the presence of 0.1 mol% TsOH was investigated. It is worth noting that this curve (Fig. 3) represents an exponential autocatalytic behavior according to the ratio of **5** and **4**, which was monitored by ^{1}H NMR spectroscopy.

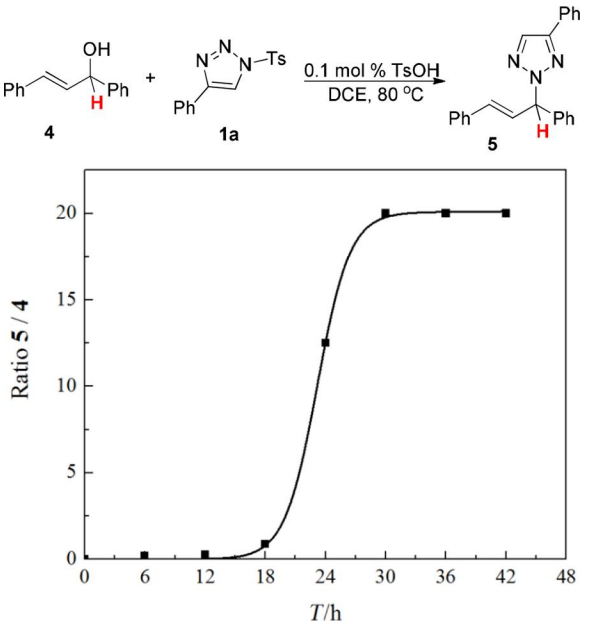


Figure 3. The kinetic study of the reaction of **1a** with alcohol **4**.

Experimental section

Procedure for the preparation of 4-aryl-2H-1,2,3-triazole

4-Aryl-1-tosyl-1,2,3-triazole (1.0 mmol) was loaded in a 25-mL reaction tube charged with 10 mL of deionized water. Then, *p*-toluenesulfonic acid (1.0 mol%) was added into the reaction tube. The resulting mixture was heated at 80 °C for 4 h. The reaction mixture was cooled to room temperature, exacted with dichloromethane, dried over anhydrous Na_2SO_4, concentrated in vacuo, and purified through flash chromatography.

Procedure for the preparation of 5

4-Phenyl-1-tosyl-1,2,3-triazole (0.2 mmol) and 1,3-dipheny-2-propen-1-ol **4** were loaded in a 10-mL reaction tube charged with 1.0 mL DCE. Then, *p*-toluenesulfonic acid (0.1 mol%) was added into the reaction tube. The resulting mixture was heated at 80 °C for 48 h. The reaction mixture was cooled to room temperature, then concentrated in vacuo and purified through flash chromatography.

Conclusion

In conclusion, *p*-toluenesulfonic acid (TsOH)-promoted autocatalytic hydrolysis of 1-tosyl-1*H*-1,2,3-triazoles with high efficiency was developed and reported, presenting a metal-free and practical way to the synthesis of 2*H*-1,2,3-triazoles. Currently, only limited reports relating to organocatalyst-based autocatalytic reactions were observed.[24] Further application of TsOH-promoted autocatalytic transformation of 1-tosyl-1,2,3-triazoles based on the catalytic activities of TsOH was also reported.

Funding

We are grateful for the financial support from the National Natural Science Foundation of China (21372075, 81670958, and 81371178), the Shanghai Pujiang Program (16PJD017 and 16PJD027), and the Medical-Engineering Crossover Fund of Shanghai Jiao Tong University (YG2015MS23 and YG2016MS71).

References

[1] (a) Gánti, T. *The Principles of Life*; Oxford University Pres: Oxford, 2003; (b) Luisi, P. L. *The Emergence of Life*; Cambridge University Press: Cambridge, UK, 2006; (c) Ruiz-Mirazo, K.; Briones, C.; de la Escosura, A. *Chem. Rev.* **2014**, *114*, 285.

[2] (a) Blackmond, D. G. *Angew. Chem. Int. Ed.* **2009**, *48*, 386; (b) Dadon, Z.; Wagner, N.; Ashkenasy, G. *Angew. Chem. Int. Ed.* **2008**, *47*, 6128.

[3] (a) Bissette, A. J.; Fletcher, S. P. *Angew. Chem. Int. Ed.* **2013**, *52*, 12800; (b) Tsogoeva, S. B. *J. Syst. Chem.* **2010**, *1*, 8.

[4] (a) Inoue, T.; Orgel, L. E. *Science* **1983**, *219*, 859; (b) Engelhart, A. E.; Powner, M. W.; Szostak, J. W. *Nat. Chem.* **2013**, *5*, 390.

[5] (a) Lee, D. H.; Granja, J. R.; Martinez, J. A.; Severin, K.; Ghadiri, M. R. *Nature* **1996**, *382*, 525; (b) Yao, S.; Ghosh, I.; Zutshi, R.; Chmielewski, J. *Nature* **1998**, *396*, 447; (c) Carnall, J. M. A.; Waudby, C. A.; Belenguer, A. M.; Stuart, M. C. A.; Peyralans, J. J.-P.; Otto, S. *Science* **2010**, *327*, 1502.

[6] Klussmann, M.; Iwamura, H.; Mathew, S. P.; Wells Jr, D. H.; Pandya, U.; Armstrong, A.; Blackmond, D. G. *Nature* **2006**, *441*, 621.

[7] (a) Singh, K. J.; Hoepker, A. C.; Collum, D. B. *J. Am. Chem. Soc.* **2008**, *130*, 18008; (b) Ma, Y.; Hoepker, A. C.; Gupta, L.; Faggin, M. F.; Collum, D. B. *J. Am. Chem. Soc.* **2010**, *132*, 15610; (c) Hoepker, A. C.; Gupta, L.; Ma, Y.; Faggin, M. F.; Collum, D. B. *J. Am. Chem. Soc.* **2011**, *133*, 7135.
[8] (a) Soai, K.; Shibata, T.; Sato, I. *Acc. Chem. Res.* **2000**, *33*, 382; (b) Soai, K.; Shibata, T.; Morioka, H.; Choji, K. *Nature* **1995**, *378*, 767.
[9] (a) Kondepudi, D. K.; Asakura, K. *Acc. Chem. Res.* **2001**, *34*, 946; (b) Mikami, K.; Yamanaka, M. *Chem. Rev.* **2003**, *103*, 3369; (c) Flegeau, E. F.; Bruneau, C.; Dixneuf, P. H.; Jutand, A. *J. Am. Chem. Soc.* **2011**, *133*, 10161; (d) Rao, C. N.; Hoz, S. *J. Am. Chem. Soc.* **2011**, *133*, 14795; (e) Giri, R.; Hartwig, J. F. *J. Am. Chem. Soc.* **2010**, *132*, 15860; (f) Mauksch, M.; Tsogoeva, S. B.; Martynova, I. M.; Wei, S. *Angew. Chem. Int. Ed.* **2007**, *46*, 393.
[10] Yun, Y.; Gellman, A. *J. Nat. Chem.* **2015**, *7*, 520.
[11] Bordwell, F. G.; Algrim, D. *J. Org. Chem.* **1976**, *41*, 2507.
[12] Akiyama, T.; Mori, K. *Chem. Rev.* **2015**, *115*, 9277.
[13] Namba, K.; Osawa, A.; Ishizaka, S.; Kitamura, N.; Tanino, K. *J. Am. Chem. Soc.* **2011**, *133*, 11466.
[14] Kolb, H. C.; Finn, M. G.; Sharpless, K. B. *Angew. Chem. Int. Ed.* **2001**, *40*, 2004.
[15] (a) Chattopadhyay, B.; Gevorgyan, V. *Angew. Chem. Int. Ed.* **2012**, *51*, 862; (b) Gulevich, A. V.; Gevorgyan, V. *Angew. Chem. Int. Ed.* **2013**, *52*, 1371; (c) Davies, H. M. L.; Alford, J. S. *Chem. Soc. Rev.* **2014**, *43*, 5151.
[16] (a) Thirumurugan, P.; Matosiuk, D.; Jozwiak, K. *Chem. Rev.* **2013**, *113*, 4905; (b) Moses, J. E.; Moorhouse, A. D. *Chem. Soc. Rev.* **2007**, *36*, 1249; (c) Tron, G. C.; Pirali, T.; Genazzani, A. A. *Med. Res. Rev.* **2008**, *28*, 278; (d) Agalave, S. G.; Maujan, S. R.; Pore, V. S. *Chem. Asian J.* **2011**, *6*, 2696.
[17] (a) Chu, C.-H.; Liu, R.-H. *Chem. Soc. Rev.* **2011**, *40*, 2177; (b) Lau, Y. H.; Rutledge, P. J.; Watkinson, M. *Chem. Soc. Rev.* **2011**, *40*, 2848; (c) Astruc, D.; Liang, L.-Y.; Ruiz, J. *Acc. Chem. Res.* **2012**, *45*, 630; (d) Muller, T.; Brase, S. *Angew. Chem.* **2011**, *123*, 12046 (e) Muller, T.; Brase, S. *Angew. Chem. Int. Ed.* **2011**, *50*, 11844.
[18] (a) Chattopadhyay, B.; Gevorgyan, V. *Angew. Chem.* **2012**, *124*, 886; (b) Miura, T.; Yamauchi, M.; Murakami, M. *Chem. Commun.* **2009**, 1470; (c) Chattopadhyay, B.; Gevorgyan, V. *Org. Lett.* **2011**, *13*, 3746; (d) Horneff, T.; Chuprakov, S.; Fokin, V. V. *J. Am. Chem. Soc.* **2008**, *130*, 14972; (e) Miura, T.; Fujimoto, Y.; Murakami, M. *Angew. Chem. Int. Ed.* **2015**, *54*, 9967; (f) Miura, T.; Fujimoto, Y.; Murakami, M. *Angew. Chem.* **2015**, *127*, 10105; (g) Zibinsky, M.; Fokin, V. V. *Angew. Chem. Int. Ed.* **2013**, *52*, 1507; (h) Zibinsky, M.; Fokin, V. V. *Angew. Chem.* **2013**, *125*, 1547; (i) Grimster, N.; Zhang, L.; Fokin, V. V. *J. Am. Chem. Soc.* **2010**, *132*, 2510; (j) Kwok, S. W.; Zhang, L.; Fokin, V. V. *Angew. Chem. Int. Ed.* **2014**, *53*, 3452; (k) Kwok, S. W.; Zhang, L.; Fokin, V. V. *Angew. Chem.* **2014**, *126*, 3520; (l) Urankar, D.; Pinter, B.; Kosmrlj, J. *Inorg. Chem.* **2010**, *49*, 4820; (m) Johnson, T. C.; Totty, W. G.; Wills, M. *Org. Lett.* **2012**, *14*, 5230; (n) Saleem, F.; Rao, G. K.; Singh, A. K. *Organometallics* **2013**, *32*, 3595.
[19] (a) Ueda, S.; Su, M.-J.; Buchwald, S. L. *Angew. Chem. Int. Ed.* **2011**, *50*, 8944; (b) Ueda, S.; Su, M.-J.; Buchwald, S. L. *Angew. Chem.* **2011**, *123*, 9106; (c) Wang, X.-J.; Zhang, L.; Senanayake, C. H. *Org. Lett.* **2009**, *11*, 5026; (d) Liu, Y.-X.; Yan, W.-M.; Shi, X.-D. *Org. Lett.* **2008**, *10*, 5389; (e) Chen, Y.-F.; Liu, Y.-X.; Shi, X.-D. *Chem. Commun.* **2008**, 3254; (f) Xu, K.; Thieme, N.; Breit, B. *Angew. Chem. Int. Ed.* **2014**, *53*, 7268; (g) Xu, K.; Thieme, N.; Breit, B. *Angew. Chem.* **2014**, *126*, 7396.
[20] (a) Duan, H.-F.; Sengupta, S.; Shi, X.-D. *J. Am. Chem. Soc.* **2009**, *131*, 12100; (b) Duan, H.-F.; Sengupta, S.; Shi, X.-D. *Organometallics* **2009**, *28*, 2352.
[21] (a) Hu, L.; Wang, T.; He, G.-F. *Chem. Eur. J.* **2016**, *22*, 911; (b) Hu, Q.-Q.; Li, Y.-J.; Chen, Y.-F. *Adv. Synth. Catal.* **2016**, *358*, 1689; (c) Journet, M.; Cai, D.-W.; Larsen, R. D. *Tetrahedron Lett.* **2001**, *42*, 9117; (d) Li, J.-H.; Wang, D.; Chen, B.-H. *Org. Lett.* **2009**, *11*, 3024; (e) Sengupta, S.; Duan, H.-F.; Shi, X.-D. *Org. Lett.* **2008**, *10*, 1493; (f) Ponpandian, T.; Muthusubramanian, S. *Tetrahedron Lett.* **2012**, *53*, 59; (g) Quan, X.-J.; Ren, Z.-H.; Guan, Z.-H.; *Org. Lett.* **2014**, *16*, 5728; (h) Amantini, D.; Fringuelli, F.; Vaccaro, L. J. *Org. Chem.* **2005**, *70*, 6526; (i) Barluenga, J.; Valdes, C.; Beltran, G. *Angew. Chem. Int. Ed.* **2006**, *45*, 6893; (j) Tsai, C. W.; Yang, S. C.; Wu, M. J. *Tetrahedron* **2009**, *65*, 8367.

[22] (a) Kamijo, S.; Jin, T.; Yamamoto, Y. *J. Am. Chem. Soc.* **2003**, *125*, 7786; (b) Kamijo, S.; Huo, Z. B.; Yamamoto, Y. *J. Org. Chem.* **2005**, *70*, 6389; (c) Kalisiak, J.; Sharpless, K. B.; Fokin, V. V. *Org. Lett.* **2008**, *10*, 3171; (d) Cohrt, A. E.; Jensen, J. F.; Nielsen, T. E. *Org. Lett.* **2010**, *12*, 5414.
[23] Motoshi, Y.; Tomoya, M.; Masahiro, M. *Heterocycles* **2010**, *80*, 177.
[24] Tsogoeva, S. B. *J. Sys. Chem.* **2010**, *1*, 8.