ChemPubSoc Europe

DOI: 10.1002/chem.201304255

CHEMISTRY A European Journal Communication

Cross-Coupling Chemistry

Silver-Catalyzed Cross-Coupling of Propargylic Alcohols with Isocyanides: An Atom-Economical Synthesis of 2,3-Allenamides

Jianquan Liu,[a] Zhenhua Liu,[a] Nannan Wu,[a] Peiqiu Liao,[a] and Xihe Bi*[a, b]

Abstract: Cross-coupling reactions between propargylic alcohols and isocyanides, by means of silver catalysis, have been described. This new reaction is both atom and step efficient and is applicable to a broad scope of substrates, allowing the synthesis of a range of synthetically valuable 2,3-allenamides in moderate to excellent yields.

Transition-metal-catalyzed C–C bond formation, by the cross-coupling reaction of two components, has displayed a fundamental role in modern organic synthesis. Enormous research efforts devoted to this area in the past decades has led to a myriad of C–C bond forming reactions.[1] However, the development of chemoselective cross-coupling reactions that use simple starting materials remains an important research challenge. Propargylic alcohols are very useful bifunctional building blocks and the close proximity of the hydroxyl group to the C≡C bond provides these molecules with the potential to undergo reactions that are not possible with the corresponding alkynes.[2] The transition-metal-catalyzed C–C bond formation at the α- or β-carbon atom of propargylic alcohols, along with oxygen transposition by cross-coupling with a coupling partner, is especially striking because it constitutes a powerful strategy towards oxygen-functionalized unsaturated compounds.[3–5] However, such a useful synthetic strategy remains underexploited so far. Several kinds of α-C–C coupling and 1,3-oxygen transposition of propargylic alcohols with coupling partners, including aldehydes, imines, allyl carbonates, and diaryliodonium salts, have been achieved by the Trost and Gaunt groups, allowing otherwise inaccessible α-functionalized enones to be synthesized.[3] By comparison, reports regarding β-C–C coupling and oxygen transposition of propargylic alcohols are rare, and are limited to 1) ruthenium-catalyzed cross-coupling of propargylic alcohols with an alkyne or alkene species to give enones;[4] and 2) a rhodium-catalyzed tandem reaction between propargylic alcohols and diazoacetates to afford

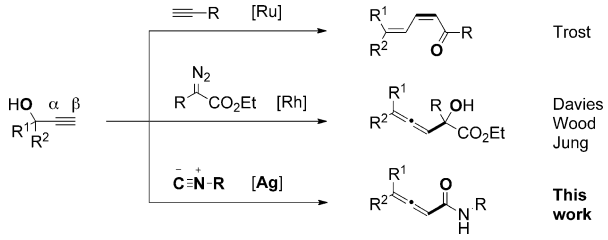


Figure 1. Transition-metal-catalyzed C–C bond formation at the β-carbon atom of propargylic alcohols along with oxygen transposition.

α-hydroxy allenes (Figure 1).[5] The difficulty in developing new C–C coupling methods that involve the oxygen transposition of propargylic alcohols is due to the difficulty of finding both an appropriate coupling partner and a catalyst.

Isocyanides are versatile reagents and are analogous to carbon monoxide (CO) in carbene character.[6] The strategic use of isocyanides in forming C–C bonds and assembling complex molecules by insertion into carbon–metal bonds has become an active research field in recent years.[7] However, the coupling of isocyanides and terminal alkynes to form C–C bonds is scarcely reported.[8] Reports of silver-catalyzed alkyne-involving organic reactions have been rapidly increasing in the past decade.[9] One of the advantages of silver catalysis is that oxidative coupling of terminal alkynes is skillfully avoided.[10] As part of our efforts towards developing novel transition-metal-catalyzed organic reactions,[11] we recently, and almost at the same time as Lei and co-workers,[12a] reported the first silver-catalyzed tandem coupling and cyclization of terminal alkynes with isocyanides, leading to oligosubstituted pyrroles.[12] We envisaged, thereafter, that utilization of propargylic alcohols, instead of simple alkynes, in this silver-catalyzed protocol might lead to a different reaction pattern because of the close proximity of a highly reactive hydroxyl group to the alkyne unit.[2] Delightfully, our experimental results confirmed this hypothesis and disclosed an unprecedented β-C–C coupling and oxygen transposition of propargylic alcohols with isocyanides, thereby providing a novel route to a variety of synthetically valuable 2,3-allenamides (Figure 1).[13] To the best of our knowledge, this represents the first example of a C–C coupling reaction between propargylic alcohols and isocyanides.[2,6,14] Herein, we communicate our results regarding this exciting transformation.

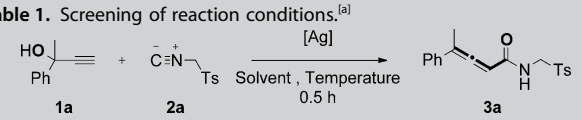
Our initial efforts focused on the optimization of reaction conditions by using the reaction of propargylic alcohol **1a** and tosylmethyl isocyanide (TosMIC) **2a** as a model (Table 1). A range of silver salts were firstly screened in 1,4-dioxane at

[a] J. Liu, Z. Liu, N. Wu, Dr. P. Liao, Prof. X. Bi
Department of Chemistry
Northeast Normal University
Changchun 130024 (China)
E-mail: bixh507@nenu.edu.cn

[b] Prof. X. Bi
State Key Laboratory of Elemento-Organic Chemistry, Nankai University
Tianjin, 300071 (China)

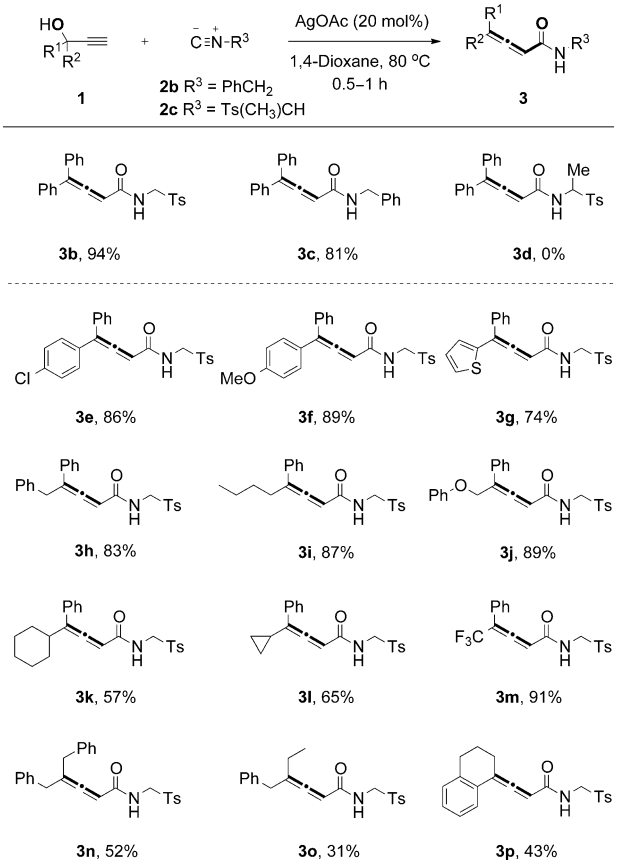
Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/chem.201304255.

Table 1. Screening of reaction conditions.[a]



Entry	Ag Source	Solvent	T [°C]	Yield [%][b]
1	AgOTf	1,4-dioxane	80	0
2	Ag_2SO_4	1,4-dioxane	80	0
3	AgOAc	1,4-dioxane	80	92
4	AgF	1,4-dioxane	80	73
5	$AgNO_3$	1,4-dioxane	80	0
6	$AgBF_4$	1,4-dioxane	80	0
7	Ag_3PO_4	1,4-dioxane	80	0
8	Ag_2CO_3	1,4-dioxane	80	0
9	AgOAc	CH_3CN	80	42
10	AgOAc	DMF	80	0
11	AgOAc	CH_2Cl_2	80	0
12	AgOAc	1,4-dioxane	80	0
13	–	1,4-dioxane	80	0
14	AgOAc	1,4-dioxane	40	51
15	AgOAc	1,4-dioxane	25	39

[a] Reactions were carried out on a scale of 0.5 mmol of **1a** and 0.6 mmol of **2a**, in the presence of silver salts (20 mol%), in 2 mL of solvent under ambient atmosphere for 0.5 h. [b] Yield of isolated product.

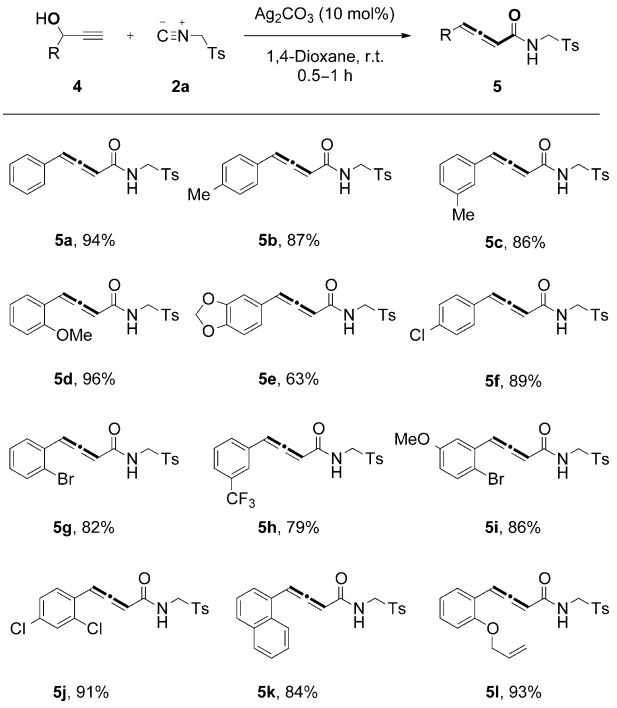


Scheme 1. Synthesis of trisubstituted allenes. Ts = tosyl.

80 °C. It was found that both AgOAc (Ac = acetyl) and AgF are effective catalysts; the former affording high yields (up to 92%, entries 3 and 4). The other silver salts that were screened did not result in desired allene product **3a** (entries 1, 2, and 5–8). Notably, no by-product was observed, from the homocoupling of the terminal alkyne, in the presence of AgOAc and AgF. The solvent also exhibited significant influence on this reaction. For example, whereas the use of acetonitrile (CH_3CN) proceeded well, albeit with a lower product yield of 42% (entry 9), dimethylformamide (DMF) and methylene dichloride (CH_2Cl_2) were ineffective (entries 10 and 11). In a control experiment, the necessity of a silver catalyst was demonstrated (entry 13). When the reaction temperature was lowered to 40 and then 25 °C, a gradual decrease in product yield, from 51 to 39%, was observed (entries 14 and 15). Therefore, the conditions listed in entry 3, being optimal, were selected for further investigations.

The reaction scope for the synthesis of trisubstituted allenes was evaluated with respect to both the isocyanide and the tertiary propargylic alcohol (Scheme 1). The first experiments were conducted with tertiary propargylic alcohol **1b** and a series of differently substituted isocyanides. A remarkable effect on the outcome of the reaction was observed, for example, TosMIC, **2a**, and benzyl isocyanide **2b** underwent clean conversion into the corresponding 2,3-allenamides (**3b** and **3c**, respectively) in excellent yields, unlike the reaction of 1-tosylethyl isocyanide **2c**, which did not afford desired product **3d**. As a result, convenient and inexpensive TosMIC was selected as the isocyanide component for screening different tertiary propargylic alcohols. The results showed that various tertiary propargylic alcohols are suitable reaction partners for TosMIC **2a** in the formation of trisubstituted allenes (**3e**–**3p**). Bis-(hetero)aryl-substituted propargylic alcohols reacted smoothly, affording the desired products in good to high yields (**3e**–**3g**). The presence of alkyl substituents, such as *n*-butyl and benzyl, had no effect on the outcome of the reaction (**3h**, **3i**). Moreover, several functional groups, including ether, cyclopropyl, and trifluoromethyl groups, were introduced into the allene products by choosing an appropriate substrate, resulting in good to excellent yields of the functionalized allenes (**3j**–**3m**). Although trifluoromethylated allenes are useful for the synthesis of fluorinated organic compounds, only a limited number of protocols are available in the literature for their preparation.[15] Furthermore, bisalkyl-substituted and cyclic propargylic alcohols were also applicable to this silver-catalyzed procedure with good to moderate yields (**3n**–**3p**). The results shown in Scheme 1 demonstrate the potency of this new reaction for the synthesis of functionalized trisubstituted allenes.[14d]

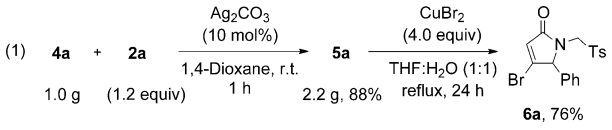
Next, the scope of this reaction, with respect to the secondary propargylic alcohols, was explored. Contrary to the synthesis of trisubstituted allenes, silver carbonate (Ag_2CO_3) showed slightly better catalytic performance than silver acetate (AgOAc). As shown in Scheme 2, even though the substrates included a variety of aryl and fused-aryl propargylic alcohols, transformations that afforded the corresponding disubstituted allenes in good to excellent yields (**5a**–**5l**) were achieved. Importantly, substrates with both electron-donating and electron-withdrawing groups underwent transformation into the desired products. It is noteworthy that substituents at different positions on the arene group (*para*, *meta*, or *ortho* positions)



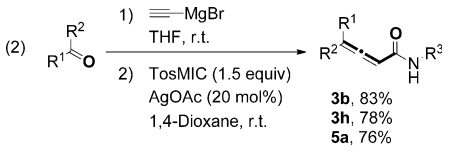
Scheme 2. Synthesis of disubstituted allenes.

did not affect the reaction efficiency significantly, but more importantly, that the halo-substituted aryl propargylic alcohols were tolerated well, thus leading to halo-substituted products **5f**, **5g**, and **5i**, which could be used in further modifications.[16] Moreover, the propargylic alcohol containing an additional double bond was easily accommodated into the allene scaffold without any difficulties (**5l**). This 1,n-allenene structural motif could be useful in transition-metal-catalyzed cycloisomerizations.[17] Notably, cyclization of the allenamides was not observed under these silver-catalyzed reaction conditions, demonstrating the stability of the products.[18]

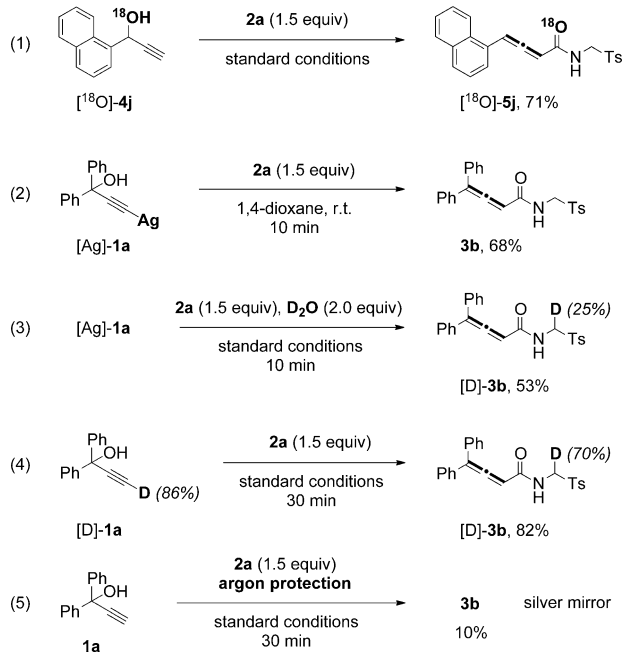
To investigate the synthetic potential of this method, the reaction of propargylic alcohol **4a** with TosMIC **2a** was carried out on a gram scale. To our delight, corresponding allene **5a** was obtained in 88% yield. Furthermore, good conversion of **5a** into 4-bromopyrrol-2-one **6a** was achieved under copper-mediated conditions [Eq. (1)].[13b]



The practicality of this silver-catalyzed coupling of propargylic alcohols with isocyanides was further investigated by the direct synthesis of allenes starting from ketones and aldehydes, without the isolation of propargylic alcohols. Delightfully, three representative allenes (**3b**, **3h**, and **5a**) were prepared in good yields by using this protocol. This procedure dramatically reduces cost and waste, making it suitable for a large range of applications.



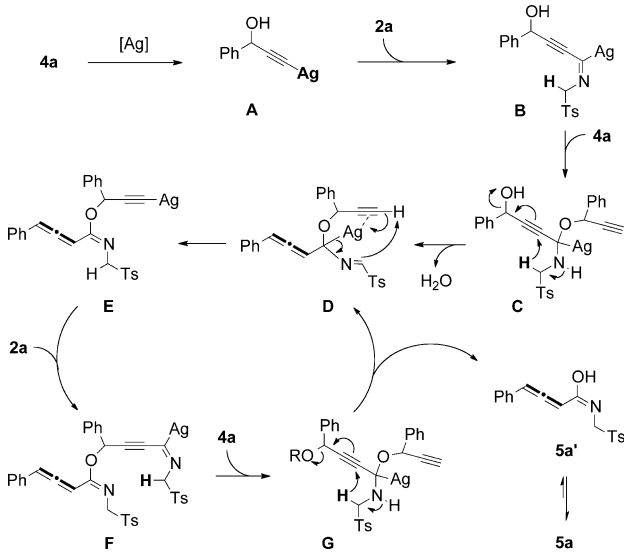
Control experiments were carried out to provide insights into the reaction pathway (Scheme 3). ^{18}O-Labeled substrate [^{18}O]-**4j** was first subjected to the standard conditions, giving



Scheme 3. Mechanistic investigations.

71% yield of [^{18}O]-**5j** [Scheme 3, Eq. (1)]. However, [^{18}O]-**5j** was not detected by HRMS when the reaction of **4j** and **2a** was carried out in the presence of external $H_2{}^{18}O$ (2.0 equivalents). Evidently, the transfer of a hydroxyl group from the propargylic alcohol to the isocyanide part of the product is an intramolecular process. In the absence of Ag_2CO_3, silver acetylide [Ag]-**1a** reacted with **2a** and afforded the allene product in 68% yield within a shorter time [Scheme 3, Eq. (2)], suggesting that silver acetylide is the intermediate initially formed during the reaction. Interestingly, when two equivalents of deuterium oxide (D_2O) were added to the reaction of [Ag]-**1a** with **2a**, deuterium was exclusively incorporated (25% deuterium content) into the methylene moiety of product [D]-**3b** [Scheme 3, Eq. (3)]. A similar result was obtained when the deuterated substrate [D]-**1a** was used [Scheme 3, Eq. (4)]. Intriguingly, in both experiments, the presence of deuterium was not observed at the allenic hydrogen position (see the Supporting Information for ^1H NMR spectra). Finally, it was demonstrated that it is necessary for the reaction to be open to air; only a trace amount of allene **3b** was produced under an atmosphere of argon, instead a silver mirror was observed [Scheme 3, Eq. (5)].

Following these preliminary mechanistic studies, a plausible reaction pathway is tentatively outlined in Scheme 4. The initial step is formation of silver acetylide intermediate **A** from the interaction of reactant **4a** with catalyst Ag_2CO_3.[19] Following this, a 1,1-insertion of the isocyanide into the silver–carbon bond takes place, generating acetylenic imido complex **B**. This imido complex subsequently undergoes intermolecular addition to another molecule of **4a** to yield aminal adduct **C**,[20] which is ultimately converted through intramolecular hydride transfer into complex **D**.[21] Next, an intramolecular rearrangement ensues to yield silver acetylide intermediate **E**, which is then subjected to 1,1-insertion of the isocyanide **2a**, resulting in complex **F**. Finally, a sequential imide addition and hydride transfer takes place to furnish intermediate **5a′**, with the regeneration of complex **D** for the next reaction. Product **5a** results through an amide–hydroxyl imide tautomerism of **5a′**. This reaction pathway is in agreement with the observations in the mechanistic studies (Scheme 3), except for the role of dioxygen that is hitherto unclear.



Scheme 4. A plausible reaction pathway.

In conclusion, an unprecedented cross-coupling of propargylic alcohols with isocyanides by means of silver catalysis has been described. This reaction is a unique type of β-C–C coupling and oxygen transposition of propargylic alcohols that provides a novel route to a variety of synthetically valuable 2,3-allenamides in moderate to excellent yields. The increased accessibility of these highly functionalized products provides opportunities for their use as building blocks in organic synthesis. Although the exact reaction pathway is thus far unclear, some mechanistic aspects of this reaction are interesting and would potentially attract the attention of chemists focusing on alkyne or isocyanide chemistry and silver catalysis.

Acknowledgements

This work was supported by NSFC (21172029, 21202016, 21372038) and NCET-13-0714.

Keywords: 2,3-allenamides · cross-coupling · isocyanides · propargylic alcohols · silver catalysis

[1] a) *Metal-Catalyzed Cross-Coupling Reactions* (Eds.: F. Diederich, P. J. Stang), Wiley-VCH, Weinheim, **1998**; b) *Metal-Catalyzed Cross-Coupling Reactions*, 2nd ed., (Eds.: A. de Meijere, F. Diederich), Wiley-VCH, Weinheim, **2004**.

[2] The Nicholas reaction is a well-known cobalt-catalyzed transformation of propargylic alcohols, for a recent example, see: a) C. Valderas, M. C. de La Torre, I. Fernández, M. P. Muñoz, M. A. Sierra, *Organometallics* **2013**, *32*, 951–956; For selected examples of transition-metal-catalyzed reactions of propargylic alcohols, see: b) G. Cera, S. Piscitelli, M. Chiarucci, G. Fabrizi, A. Goggiamani, R. S. Ramón, S. P. Nolan, M. Bandini, *Angew. Chem.* **2012**, *124*, 10029–10033; *Angew. Chem. Int. Ed.* **2012**, *51*, 9891–9895; c) T. Kimura, K. Kamata, N. Mizuno, *Angew. Chem.* **2012**, *124*, 6804–6807; *Angew. Chem. Int. Ed.* **2012**, *51*, 6700–6703; d) P. Lenden, D. A. Entwistle, M. C. Willis, *Angew. Chem.* **2011**, *123*, 10845–10848; *Angew. Chem. Int. Ed.* **2011**, *50*, 10657–10660; e) N. Chinkov, A. Warm, E. M. Carreira, *Angew. Chem.* **2011**, *123*, 3014–3018; *Angew. Chem. Int. Ed.* **2011**, *50*, 2957–2961; f) M. Ikeda, Y. Miyake, Y. Nishibayashi, *Angew. Chem.* **2010**, *122*, 7447–7451; *Angew. Chem. Int. Ed.* **2010**, *49*, 7289–7293; g) S. Minakata, I. Sasaki, T. Ide, *Angew. Chem.* **2010**, *122*, 1331–1333; *Angew. Chem. Int. Ed.* **2010**, *49*, 1309–1311; h) R. Shintani, K. Takatsu, T. Katoh, T. Nishimura, T. Hayashi, *Angew. Chem.* **2008**, *120*, 1469–1471; *Angew. Chem. Int. Ed.* **2008**, *47*, 1447–1449; i) H. Jiang, C. Qiao, W. Liu, *Chem. Eur. J.* **2010**, *16*, 10968–10970; j) T. Miura, Y. Funakoshi, M. Morimoto, T. Biyajima, M. Murakami, *J. Am. Chem. Soc.* **2012**, *134*, 17440–17443; k) L. Ye, W. He, L. Zhang, *J. Am. Chem. Soc.* **2010**, *132*, 8550–8551; l) S. Yoshida, K. Fukui, S. Kikuchi, T. Yamada, *J. Am. Chem. Soc.* **2010**, *132*, 4072–4073; m) B. M. Trost, R. C. Livingston, *J. Am. Chem. Soc.* **2008**, *130*, 11970–11978; n) X. Pu, J. M. Ready, *J. Am. Chem. Soc.* **2008**, *130*, 10874–10875; o) D. K. Friel, M. L. Snapper, A. H. Hoveyda, *J. Am. Chem. Soc.* **2008**, *130*, 9942–9951; p) Y. Sugawara, W. Yamada, S. Yoshida, T. Ikeno, T. Yamada, *J. Am. Chem. Soc.* **2007**, *129*, 12902–12903; q) D. Zhang, J. M. Ready, *J. Am. Chem. Soc.* **2007**, *129*, 12088–12089; r) Y. Yamauchi, G. Onodera, K. Sakata, M. Yuki, Y. Miyake, S. Uemura, Y. Nishibayashi, *J. Am. Chem. Soc.* **2007**, *129*, 5175–5179; s) Y. Yamamoto, J.-i. Ishii, H. Nishiyama, K. Itoh, *J. Am. Chem. Soc.* **2005**, *127*, 9625–9631; t) N. Bluthe, J. Gore, M. Malacria, *Tetrahedron* **1986**, *42*, 1333–1334; u) J. A. Marshall, E. D. Robinson, *J. Org. Chem.* **1990**, *55*, 3450–3451; v) A. S. K. Hashmi, L. Schwarz, J.-H. Choi, T. M. Frost, *Angew. Chem.* **2000**, *112*, 2382–2385; *Angew. Chem. Int. Ed.* **2000**, *39*, 2285–2288; w) A. W. Sromek, A. V. Kel'in, V. Gevorgyan, *Angew. Chem.* **2004**, *116*, 2330–2332; *Angew. Chem. Int. Ed.* **2004**, *43*, 2280–2282.

[3] a) B. M. Trost, S. Oi, *J. Am. Chem. Soc.* **2001**, *123*, 1230–1231; b) B. M. Trost, C. K. Chung, *J. Am. Chem. Soc.* **2006**, *128*, 10358–10359; c) B. M. Trost, X. Luan, *J. Am. Chem. Soc.* **2011**, *133*, 1706–1709; d) B. M. Trost, X. Luan, Y. Miller, *J. Am. Chem. Soc.* **2011**, *133*, 12824–12833; e) B. S. L. Collins, M. G. Suero, M. J. Gaunt, *Angew. Chem.* **2013**, *125*, 5911–5914; *Angew. Chem. Int. Ed.* **2013**, *52*, 5799–5802; For a theoretical study, see: f) M. Kalek, F. Himo, *J. Am. Chem. Soc.* **2012**, *134*, 19159–19169.

[4] a) B. M. Trost, J. A. Flygare, *J. Am. Chem. Soc.* **1992**, *114*, 5476–5477; b) B. M. Trost, M. T. Rudd, *J. Am. Chem. Soc.* **2001**, *123*, 8862–8863; c) B. M. Trost, M. T. Rudd, *J. Am. Chem. Soc.* **2002**, *124*, 4178–4179; d) B. M. Trost, M. T. Rudd, *J. Am. Chem. Soc.* **2005**, *127*, 4763–4776; e) B. M. Trost, A. C. Gutierrez, *Org. Lett.* **2007**, *9*, 1473–1476; f) B. M. Trost, N. Maulide, M. T. Rudd, *J. Am. Chem. Soc.* **2009**, *131*, 420–421.

[5] a) Z. Li, V. Boyarskikh, J. H. Hansen, J. Autschbach, D. G. Musaev, H. M. L. Davies, *J. Am. Chem. Soc.* **2012**, *134*, 15497–15504; b) G. A. Moniz, J. L. Wood, *J. Am. Chem. Soc.* **2001**, *123*, 5095–5097; c) M. E. Jung, J. Pontillo, *Org. Lett.* **1999**, *1*, 367–370.

[6] *Isocyanide Chemistry: Applications in Synthesis and Material Science*, 1st ed., (Ed.: V. G. Nenajdenko), Wiley-VCH, Weinheim, **2012**.

[7] a) G. Qiu, Q. Ding, J. Wu, *Chem. Soc. Rev.* **2013**, *42*, 5257 – 5269; b) S. Lang, *Chem. Soc. Rev.* **2013**, *42*, 4867 – 4880.

[8] a) E. Barnea, T. Andrea, M. Kapon, J.-C. Berthet, M. Ephritikhine, M. S. Eisen, *J. Am. Chem. Soc.* **2004**, *126*, 10860 – 10861; b) K. Komeyama, D. Sasayama, T. Kawabata, K. Takehira, K. Takaki, *Chem. Commun.* **2005**, 634 – 636; c) K. Komeyama, D. Sasayama, T. Kawabata, K. Takehira, K. Takaki, *J. Org. Chem.* **2005**, *70*, 10679 – 10687; d) W.-X. Zhang, M. Nishiura, Z. Hou, *Angew. Chem.* **2008**, *120*, 9846 – 9849; *Angew. Chem. Int. Ed.* **2008**, *47*, 9700 – 9703.

[9] For reviews, see: a) *Silver in Organic Chemistry* (Ed.: M. Harmata), John Wiley & Sons Inc., Hoboken, **2010**; b) P. Belmont, E. Parker, *Eur. J. Org. Chem.* **2009**, 6075 – 6089; c) special issue on coinage metals, *Chem. Rev.* (Ed.: B. H. Lipshutz, Y. Yamamoto), **2008**, *108*, 8; for recent selected examples, see: d) J. F. Briones, H. M. L. Davies, *Org. Lett.* **2011**, *13*, 3984 – 3987; e) J. McNulty, K. Keskar, R. Vemula, *Chem. Eur. J.* **2011**, *17*, 14727 – 14730; f) P. Garcia, Y. Harrak, L. Diab, P. Cordier, C. Ollivier, V. Gandon, M. Malacria, L. Fensterbank, C. Aubert, *Org. Lett.* **2011**, *13*, 2952 – 2955; g) Q. Xiao, S. Ye, J. Wu, *Org. Lett.* **2012**, *14*, 3430 – 3433; h) X. Liu, Z. Wang, X. Cheng, C. Li, *J. Am. Chem. Soc.* **2012**, *134*, 14330 – 14333; i) D. Zheng, S. Li, J. Wu, *Org. Lett.* **2012**, *14*, 2655 – 2657; j) T. Xu, G. Liu, *Org. Lett.* **2012**, *14*, 5416 – 5419; k) D. Susanti, F. Koh, J. A. Kusuma, P. Kothandaraman, P. W. H. Chan, *J. Org. Chem.* **2012**, *77*, 7166 – 7175; l) S.-L. Shi, M. Kanai, M. Shibasaki, *Angew. Chem.* **2012**, *124*, 3998 – 4001; *Angew. Chem. Int. Ed.* **2012**, *51*, 3932 – 3935; m) V. H. L. Wong, T. S. A. Hor, K. K. Hii, *Chem. Commun.* **2013**, *49*, 9272 – 9274; n) T. Shen, T. Wang, C. Qin, N. Jiao, *Angew. Chem.* **2013**, *125*, 6809 – 6812; *Angew. Chem. Int. Ed.* **2013**, *52*, 6677 – 6680; o) C. Qin, P. Feng, Y. Ou, T. Shen, T. Wang, N. Jiao, *Angew. Chem.* **2013**, *125*, 8004 – 8008; *Angew. Chem. Int. Ed.* **2013**, *52*, 7850 – 7854; p) M.-B. Zhou, R.-J. Song, C.-Y. Wang, J.-H. Li, *Angew. Chem.* **2013**, *125*, 11005 – 11008; *Angew. Chem. Int. Ed.* **2013**, *52*, 10805 – 10808.

[10] a) C. He, S. Guo, J. Ke, J. Hao, H. Xu, H. Chen, A. Lei, *J. Am. Chem. Soc.* **2012**, *134*, 5766 – 5769; b) C. He, J. Hao, H. Xu, Y. Mo, H. Liu, J. Han, A. Lei, *Chem. Commun.* **2012**, *48*, 11073 – 11075.

[11] a) L. Zhang, X. Bi, X. Guan, X. Li, Q. Liu, B.-D. Barry, P. Liao, *Angew Chem*, **2013**, *52*, 11176 – 11180; *Angew. Chem. Int. Ed.* **2013**, *52*, 11303 – 11307; b) Z. Wang, X. Bi, P. Liao, X. Liu, D. Dong, *Chem. Commun.* **2013**, *49*, 1309 – 1311; c) Z. Wang, X. Bi, P. Liao, R. Zhang, Y. Liang, D. Dong, *Chem. Commun.* **2012**, *48*, 7076 – 7078; d) Y. Hu, X. Fu, B. Barry, X. Bi, D. Dong, *Chem. Commun.* **2012**, *48*, 690 – 692; e) T. Xiong, Y. Li, X. Bi, Y. Lv, Q. Zhang, *Angew. Chem.* **2011**, *123*, 7278 – 7281; *Angew. Chem. Int. Ed.* **2011**, *50*, 7140 – 7143; f) Y. Wang, X. Bi, D. Li, P. Liao, Y. Wang, J. Yang, Q. Zhang, Q. Liu, *Chem. Commun.* **2011**, *47*, 809 – 811; g) K. Wang, X. Bi, S. Xing, P. Liao, Z. Fang, X. Meng, Q. Zhang, Q. Liu, Y. Ji, *Green Chem.* **2011**, *13*, 562 – 565; h) L. Zhang, Z. Liu, H. Li, G. Fang, B. Barry, T. Belay, X. Bi, Q. Liu, *Org. Lett.* **2011**, *13*, 6536 – 6539.

[12] a) M. Gao, C. He, H. Chen, R. Bai, B. Cheng, A. Lei, *Angew. Chem.* **2013**, *125*, 7096 – 7099; *Angew. Chem. Int. Ed.* **2013**, *52*, 6958 – 6961; b) J. Liu, Z. Fang, Q. Zhang, Q. Liu, X. Bi, *Angew. Chem.* **2013**, *125*, 7091 – 7095; *Angew. Chem. Int. Ed.* **2013**, *52*, 6953 – 6957.

[13] For examples of the synthetic applications of 2,3-allenamides, see: a) H. Hu, D. Smith, R. E. Cramer, M. A. Tius, *J. Am. Chem. Soc.* **1999**, *121*, 9895 – 9896; b) S. Ma, H. Xie, *Org. Lett.* **2000**, *2*, 3801 – 3803; c) G. Chen, C. Fu, S. Ma, *Org. Lett.* **2009**, *11*, 2900 – 2903; d) J. Ye, S. Li, S. Ma, *Org. Lett.* **2012**, *14*, 2312 – 2315; e) W. Yuan, X. Zhang, Y. Yu, S. Ma, *Chem. Eur. J.* **2013**, *19*, 7193 – 7202.

[14] For examples of allene syntheses by the coupling of two components, see: a) V. Lavallo, G. D. Frey, S. Kousar, B. Donnadieu, G. Bertrand, *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 13569 – 13573; b) J. Kuang, S. Ma, *J. Am. Chem. Soc.* **2010**, *132*, 1786 – 1787; c) D. A. Mundal, K. E. Lutz, R. J. Thomson, *J. Am. Chem. Soc.* **2012**, *134*, 5782 – 5785; d) Q. Xiao, Y. Xia, H. Li, Y. Zhang, J. Wang, *Angew. Chem.* **2011**, *123*, 1146 – 1149; *Angew. Chem. Int. Ed.* **2011**, *50*, 1114 – 1117, and references cited therein.

[15] a) T. Yamazaki, T. Yamamoto, R. Ichihara, *J. Org. Chem.* **2006**, *71*, 6251 – 6253; b) K. Aikawa, Y. Hioki, K. Mikami, *Org. Lett.* **2010**, *12*, 5716 – 5719; c) P. Li, Z.-J. Liu, J.-T. Liu, *Tetrahedron* **2010**, *66*, 9729 – 9732; d) T. S. N. Zhao, K. J. Szabó, *Org. Lett.* **2012**, *14*, 3966 – 3969; e) T. Yamazaki, Y. Watanabe, N. Yoshida, T. Kawasaki-Takasuka, *Tetrahedron* **2012**, *68*, 6665 – 6673.

[16] K.-S. Masters, M. Wallesch, S. Bräse, *J. Org. Chem.* **2011**, *76*, 9060 – 9067.

[17] C. Aubert, L. Fensterbank, P. Garcia, M. Malacria, A. Simonneau, *Chem. Rev.* **2011**, *111*, 1954 – 1993.

[18] Although Brandsma described the cyclization of 2,3-allenamides with AgOAc (3 mol%) in acetone at RT, we do not see traces of cyclized products under our conditions: N. A. Nedolya, N. I. Schlyakhtina, V. R. Zinov′eva, A. I. Albanov, L. Brandsma, *Tetrahedron Lett.* **2002**, *43*, 1569 – 1571.

[19] U. Létinois-Halbes, P. Pale, S. Berger, *J. Org. Chem.* **2005**, *70*, 9185 – 9190.

[20] For formation of the stable aminal adduct by vanadium-catalyzed addition of propargyl alcohols and imines, see ref. [3b].

[21] For examples of allene formation through the attack of a hydride species on a C≡C bond, see: a) C. Deutsch, B. H. Lipshutz, N. Krause, *Angew. Chem.* **2007**, *119*, 1677 – 1681; *Angew. Chem. Int. Ed.* **2007**, *46*, 1650 – 1653; b) C. Zhong, Y. Sasaki, H. Ito, M. Sawamura, *Chem. Commun.* **2009**, 5850 – 5852.

Received: October 31, 2013
Published online on January 29, 2014