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# Palladium Pincer-Complex Catalyzed Allylation of Tosylimines by Potassium Trifluoro(allyl)borates

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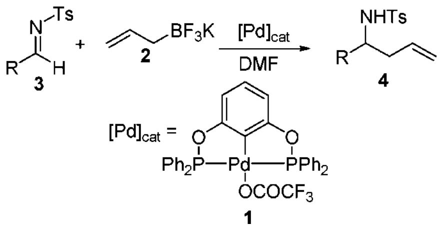
## ABSTRACT



**Palladium pincer complex 1 catalyzes the reaction of trifluoro(allyl)borate 2 with a wide range of tosylimines (3) under mild and neutral reaction conditions. This catalytic transformation affords homoallylic amines (4) in good to excellent yield. Mechanistic studies suggest that a transmetalation reaction between complex 1 and the borate salt 2 provides an $\eta^1$-allylpalladium complex, which subsequently reacts with the imine substrate.**

Allylpalladium chemistry is one of the most successful areas in transition-metal catalysis. In the most common application of this methodology, an allylpalladium intermediate is generated, which subsequently reacts with nucleophiles.[1] Recently, however, possibilities to extend allylpalladium chemistry to electrophilic substrates have attracted much attention, as certain allylpalladium species[2,3] have been shown to react with electrophiles. In these catalytic reactions, the active allylpalladium species are usually generated in a transmetalation reaction between an allylstannane and a palladium complex. Because of the toxicity of organo-tin reagents, and the tedious separation of the tin-containing byproducts,[4] it would be desirable to replace the allylstannane component of the reaction with other allylmetal species.[5] We have now found that in palladium-catalyzed electrophilic substitution reactions allylstannanes can be replaced by potassium trifluoro(allyl)borate **2.**[6] Thus, palladium pincer complex **1** catalyzes the allylation of tosylimines **3** with the borate salt **2** (Scheme 1). A wide range of tosylimines (**3a**−**i**) can be allylated by this procedure in good to excellent yields (Table 1).

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(1) (a) Tsuji, J. *Palladium Reagents and Catalysts: Innovations in Organic Synthesis*; Wiley: Chichester, 1995. (b) Hegedus. L. S. *Transition Metals in the Synthesis of Complex Organic Molecules*; University Science Books: Mill Valley, CA, 1999.

(2) (a) Nakamura, K.; Iwama, H.; Yamamoto, Y. *J. Am. Chem. Soc.* **1996**, *118*, 6641. (b) Nakamura, H.; Shim, J.-G.; Yamamoto, Y. *J. Am. Chem. Soc.* **1997**, *119*, 8113. (c) Nakamura, H.; Nakamura, K.; Yamamoto, Y. *J. Am. Chem. Soc.* **1998**, *120*, 4242. (d) Nakamura, K.; Nakamura, H.; Yamamoto, Y. *J. Org. Chem.* **1999**, *64*, 2614. (e) Nakamura, H.; Kouichi, A.; Shim, J.-G.; Yamamoto, Y. *J. Am. Chem. Soc.* **2001**, *123*, 372. (f) Fernandes, R. A.; Stimac, A.; Yamamoto, Y. *J. Am. Chem. Soc.* **2003**, *125*, 14133. (g) Kiji, J.; Okano, T.; Nomura, T.; Saiki, K.; Sai, T.; Tsuji, J. *Bull. Chem. Soc. Jpn.* **2001**, *74*, 1939. (h) Solin, N.; Narayan, S.; Szabó, K. J. *J. Org. Chem.* **2001**, *66*, 1686. (i) Solin, N.; Narayan, S.; Szabó, K. J. *Org. Lett.* **2001**, *3*, 909. (j) Wallner, O. A.; Szabó, K. J. *Org. Lett.* **2002**, *4*, 1563. (k) Wallner, O. A.; Szabó, K. J. *Chem. Eur. J.* **2003**, *68*, 2934. (l) Wallner, O. A.; Szabó, K. J. *Chem. Eur. J.* **2003**, *9*, 4025. (m) Szabó, K. J. *Chem. Eur. J.* **2000**, *6*, 4413. (n) For a recent review, see: Szabó, K. J.; *Chem. Eur. J.* **2004**, *10*, 5268.

(3) (a) Solin, N.; Kjellgren, J.; Szabó, K. J. *Angew. Chem., Int. Ed.* **2003**, *42*, 3656. (b) Solin, N.; Kjellgren, J.; Szabó, K. J. *J. Am. Chem. Soc.* **2004**, *126*, 7026. (c) Wallner, O. A.; Szabó, K. J. *Org. Lett.* **2004**, *6*, 1829.

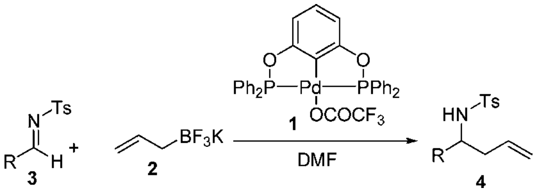
(4) Farina, V.; Krishnamurthy, V.; Scott, W. J. *Org. React.* **1997**, *50*, 1.

(5) For possiblities to replace allylstannanes with allylsilanes see ref 2d.

(6) (a) Batey, R. A.; Thadani, A. N.; Smil, D. V. *Tetrahedron Lett.* **1999**, *40*, 4289. (b) Batey, R. A.; Thadani, A. N.; Smil, D. V. Lough, A. J. *Synthesis* **2000**, 990. (c) Thadani, A. N.; Batey, R. A. *Org. Lett.* **2002**, *4*, 3827. Thadani, A. N.; Batey, R. A. *Tetrahedron Lett.* **2002**, *44*, 8051. (d) Sze-Wan, L.; Batey, R. A. *Chem. Commun.* **2004**, 1382.

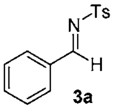
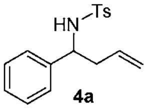
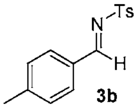
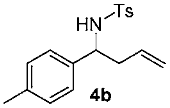
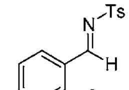
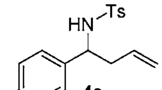
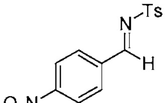
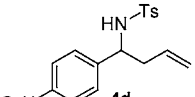
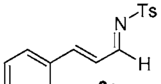
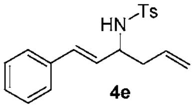
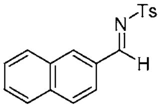
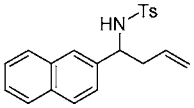
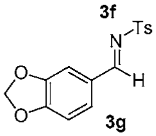
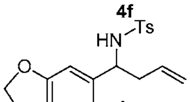
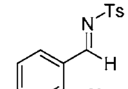
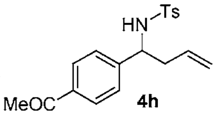
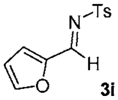
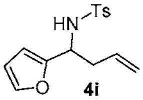
10.1021/ol0475010 CCC: $30.25

**Scheme 1.** Allylation of Tosylimines by Pincer-Complex Catalyst **1**



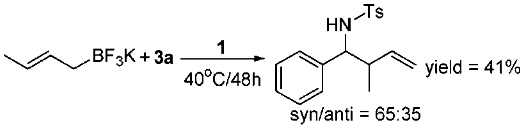
In a typical procedure, the imine **3** (0.10 mmol), borate salt **2** (0.11 mmol) and pincer complex **1** (0.005 mmol, 5 mol %) in DMF (300 $\mu$L) were reacted for 24 h at 25−50 °C. After workup, the crude product was purified by column chromatography. The reactions were typically carried out at 40 °C (entries 1−6); however, bulky (**3f**, entry 7) or deactivated (**3g**, entry 8) imines required 50 °C reaction temperature, while activated imines **3h** (entry 9) and **3i** (entry 10) could be allylated at 25 °C. The mild and neutral reaction conditions are compatible with many functional groups, such as MeCO, $NO_2$, acetals, and CN. In this regard, the imine functionality of **3c** and **3h** could be selectively allylated in the presence of the cyano and keto groups. To assess the stereochemistry of the catalytic allylation reaction we reacted **3a** with (*E*)-crotyltrifluoroborate[6b] (Scheme 2). This reaction, however, proceeds with a poor yield and stereoselectivity.

**Table 1.** Palladium-Catalyzed Allylation of Tosylimines[a]

| Entry | Imine | Temp. [°C] | Product | Yield[b] |
|---|---|---|---|---|
| 1 |  **3a** | 40 |  **4a** | 95 |
| 2 | **3a** | 40 | **4a** | 66[c] |
| 3 |  **3b** | 40 |  **4b** | 95 |
| 4 |  **3c** | 40 |  **4c** | 88 |
| 5 |  **3d** | 40 |  **4d** | 86 |
| 6 |  **3e** | 40 |  **4e** | 90 |
| 7 |  **3f** | 50 |  **4f** | 95 |
| 8 |  **3g** | 50 |  **4g** | 95 |
| 9 |  **3h** | 25 |  **4h** | 79 |
| 10 |  **3i** | 25 |  **4i** | 95 |

[a] Unless otherwise stated, the reactions were conducted in DMF for 24 h using 5 mol % of complex **1** as catalyst and 1.1 equiv of borate salt **2**. [b] Isolated yield. [c] 5 mol % of $Pd(OAc)_2$ and 5 mol % of $PPh_3$ were used as catalyst.

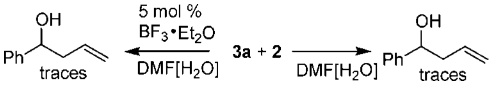
**Scheme 2.** Catalytic Allylation Using (*E*)-Crotyltrifluoroborate Substrate



We also tested $Pd(OAc)_2$ as catalyst anticipating the formation of a bis-allylpalladium intermediate, which would be able to allylate imine **3a**.[2j] Using 5 mol % $Pd(OAc)_2$ and 5 mol % $PPh_3$, imine **3a** was allylated in 66% yield (entry 2). Use of $PPh_3$ proved to be indispensable to get an acceptable yield, as $Pd(OAc)_2$ alone or other phosphine free catalysts (such as $[Pd(allyl)Cl]_2$) gave a low conversion of **3a**.

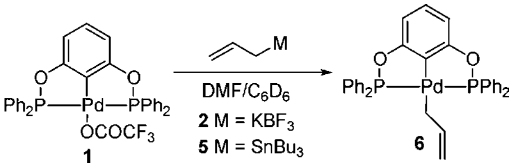
We have also performed a control experiment using the reaction conditions given in entry 1 without adding palladium catalyst (Scheme 3). In this experiment, homoallylic amine **4a** was not formed at all. The only product observed in this reaction was a trace of homoallyl alcohol. This product is probably formed by the reaction of benzaldehyde (resulted from partial hydrolysis of the imine) and **2**.

**Scheme 3.** Reactions in the Absence of Palladium Catalyst **1**



**Mechanistic Aspects**. Batey and Sze-Wan[6d] showed that tosylimines are allylated in excellent yield by two equivalents of borate salt **2** in $CH_2Cl_2$ using 5 mol % of $BF_3$·$Et_2O$ as Lewis acid catalyst. We have attempted to perform this Lewis acid-catalyzed reaction with **3a** and **2** in DMF (Scheme 3); however, we did not observe any formation of the desired homoallylamine product (**4a**). This probably can be explained by the deactivation of the employed Lewis acid ($BF_3$·$Et_2O$) by the DMF solvent. A clear advantage of using **1** as catalyst is that application of 1.1 equiv. of **2** is sufficient to obtain high yields, while employment of Lewis acid catalyst $BF_3$·

**Scheme 4.** Stoichiometric Reactions with Pincer Complex **1** and Allylmetal Reagents **2** and **5**



$Et_2O$ requires the use of 2 equiv of the allylic substrate (**2**). On the other hand, Batey's conditions give higher yield and stereoselectivity with crotyltrifluoroborate, than the pincer-complex catalyzed reaction (Scheme 2).

To gain more mechanistic insights into the above catalytic process (Scheme 1), we monitored the stoichiometric reaction of **1** and **2** by $^{31}P$ NMR spectroscopy. Complex **1**, dissolved in a mixture of DMF/$C_6D_6$ (10:1), was reacted with **2** at room temperature (Scheme 4). Addition of **2** led to a decrease of the $^{31}P$ NMR peak of **1** at $\delta$ 146.0 ppm, while a new peak appeared at $\delta$ 148.4 ppm clearly indicating a reaction between the palladium complex (**1**) and the allylic substrate (**2**). To clarify the nature of this reaction we performed a similar stoichiometric experiment using allylstannane (**5**) in place of **2** (Scheme 4). In this process we observed again a downfield shift by $\delta$ 2.4 ppm of the $^{31}P$ NMR shift of complex **1**. In a recent study we have shown[3b] that pincer complex **1** reacts with allylstannanes to form $\eta^1$-allylpalladium complex **6**. Therefore, the fact that either of allylstannane **5** or borate salt **2** gives the same product when reacted with complex **1** strongly indicates that **2** also undergoes a transmetalation reaction[7] with complex **1** resulting in ($\eta^1$-allyl)palladium complex **6** (Scheme 4). Complex **6** subsequently undergoes electrophilic attack by tosylimine **3**[3] affording homoallylic amines **4**.

In summary, we have developed a palladium pincer-complex catalyzed allylation reaction, where tosylimines were allylated with borate salt **2**. This reaction is assumed to proceed via ($\eta^1$-allyl)palladium intermediate (**6**). Application of this procedure eliminates the use of toxic tin compounds, thereby extending the synthetic utility of the palladium catalyzed electrophilic substitution reaction.

**Acknowledgment.** This work was supported by The Swedish Research Council (VR).

**Supporting Information Available:** Experimental procedures, NMR data, as well as $^1H$ and $^{13}C$ NMR spectra of products **4a**−**j**. This material is available free of charge via the Internet at http://pubs.acs.org.

OL0475010

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[7] For studies on the transmetalation reaction between palladium complexes and potassium trifluoro(organo)borates, see: (a) Molander, G. A.; Bialatto, B. *J. Org. Chem.* **2003**, *68*, 4302. (b) Darses, S.; Genet, J.-P. *Eur. J. Org. Chem.* **2003**, 4313.