

# Chromatography-free Pd-catalyzed deprotection of allyl ethers using PS-DEAM as a scavenger of boronic acids and Pd catalyst

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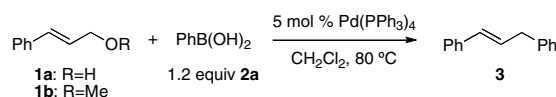
**Abstract**—Polystyrene-bound diethanolamine (PS-DEAM) work-up for a newly developed Pd(PPh<sub>3</sub>)<sub>4</sub>-catalyzed cleavage of allylic alkyl ethers using phenylboronic acid can effectively release Pd-free parent alcohols. Furthermore, chromatography-free deallylation can be conducted by using vinylboronic anhydride pyridine complex as an allyl scavenger with a catalytic amount of Pd(OAc)<sub>2</sub> and 4-(diphenylphosphino)benzoic acid instead of Pd(PPh<sub>3</sub>)<sub>4</sub> to yield the desired products in high purities and yields after removal of volatile byproducts and the phosphine-derived contaminants by evaporation and sequestration through acid–base interaction with PS-DEAM, respectively.

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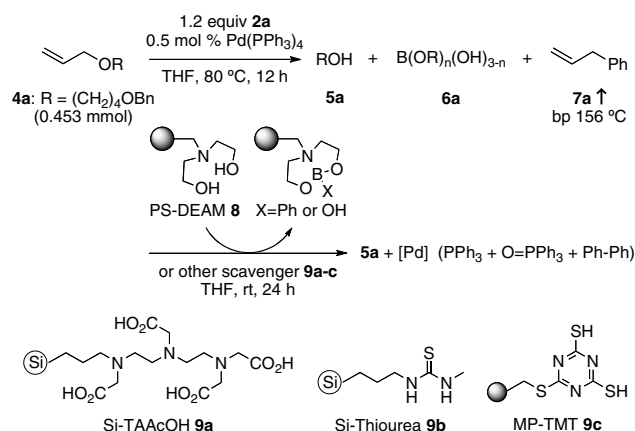
Allyl group is one of the most useful protecting groups for alcohols due to its stability towards both acidic and basic conditions.<sup>1</sup> Although its palladium-catalyzed removal had been a problem owing to poor leaving ability of the ether group, it was nearly solved by recent developed deallylation methods using *p*-toluenesulfinic acid,<sup>2a,b</sup> polymethylhydrosiloxane–ZnCl<sub>2</sub>,<sup>2c</sup> 1,3-dimethylbarbituric acid (DMBA),<sup>2d,e</sup> and anilines<sup>2f</sup> as allyl scavengers. Our original deallylation using DMBA as a soft carbonucleophile has advantages of commercial availability of reagents, compatibility with a wide variety of functional groups, high yields, and simple operation over other ones.<sup>2a–c,f,3</sup> However, they require more than a few mol % palladium catalyst loadings and purification of the deallylated product with column chromatography to remove the palladium catalyst as well as the allylated scavengers.<sup>4</sup> Therefore, there is still a need to develop an alternative method, which can remove the palladium catalyst and byproducts without the use of column chromatography.<sup>5</sup>

Previously, we reported the Pd<sup>0</sup>-catalyzed direct cross-coupling reaction of allyl alcohols with phenylboronic acid (PBA, **2a**) as a hard carbonucleophile.<sup>6</sup> Boronic acid moiety in **2a** would work as Lewis acid to improve poor leaving ability of the hydroxyl group. We also confirmed that allyl ether **1b** as well as allyl alcohol **1a** could

be coupled with PBA under the palladium catalysis (Scheme 1). This result encouraged us to utilize **2a** as the allyl scavenger for the cleavage of alkyl allyl ethers, because the allylated scavenger, that is, allylbenzene, is volatile.



Scheme 1. Pd(PPh<sub>3</sub>)<sub>4</sub>-catalyzed cross-coupling of **1a–b** with **2a**.



Scheme 2. Pd(PPh<sub>3</sub>)<sub>4</sub>-catalyzed deallylation of **4a** with **2a** followed by scavenging.

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**Table 1.** Scavenger effect on the removal of Pd

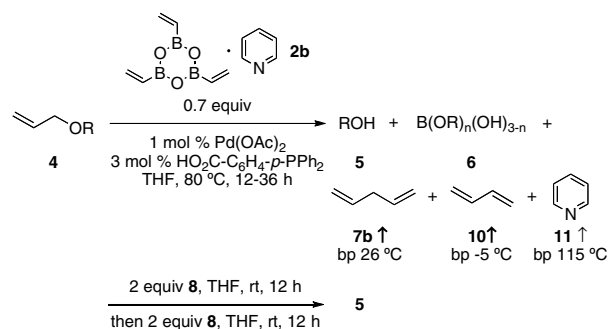
Entry	Scavenger	Loading (mmol/g)	Weight	Residual Pd (ppm) <sup>a</sup>	Reduction in Pd (%)
1	<b>8</b>	1.7	0.53 g <sup>b</sup>	15.63	99.4
2	Polystyrene	—	0.53 g	1424	49.5
3	<b>9a</b>	0.7	13.0 mg <sup>c</sup>	1157	60.6
4	<b>9b</b>	1.1	8.3 mg <sup>c</sup>	50.32	98.3
5	<b>9c</b>	1.0	9.1 mg <sup>c</sup>	82.36	97.1

<sup>a</sup> The initial concentration was around 2800 ppm. The residual Pd concentration was determined by ICP-ES.

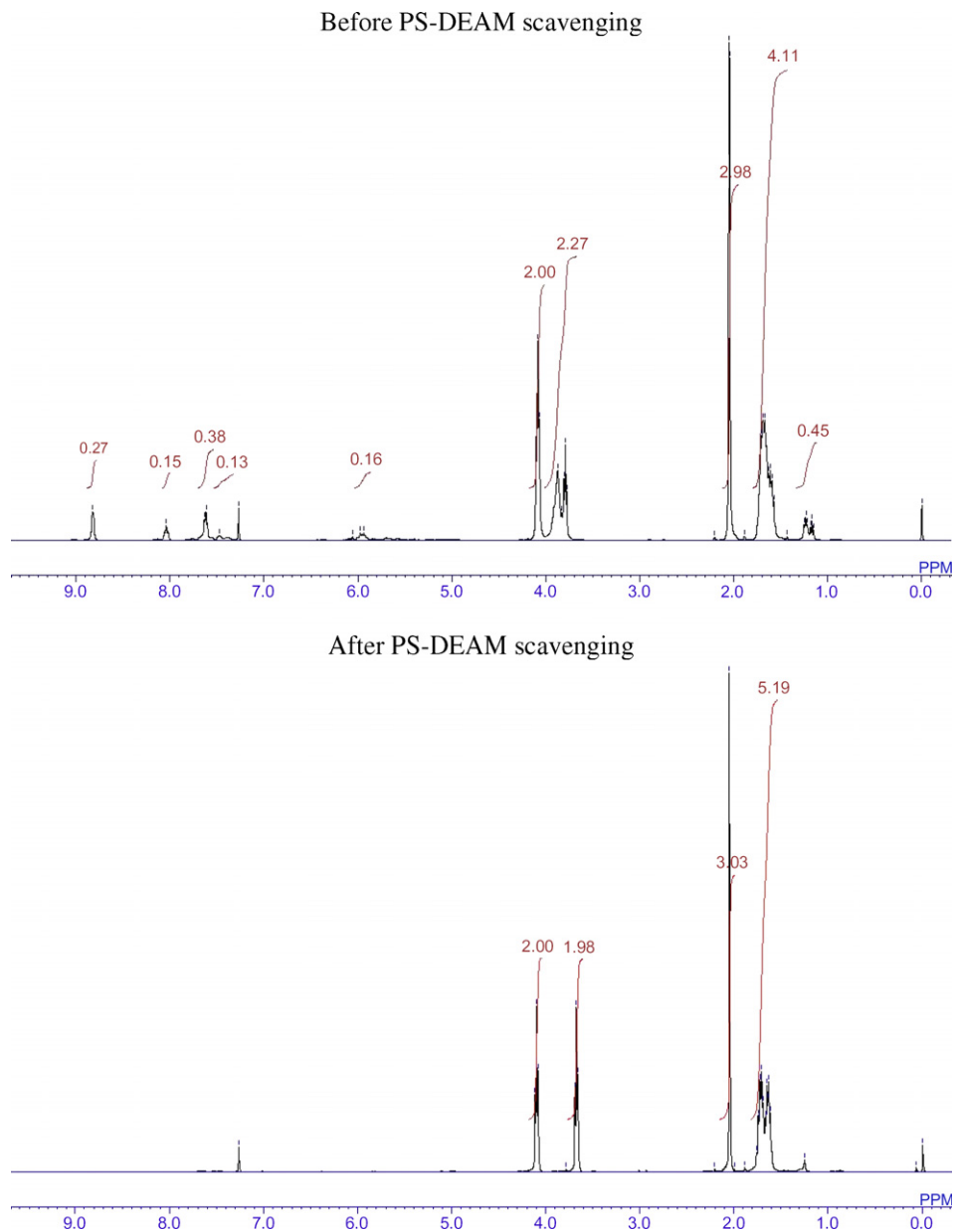
<sup>b</sup> 2 equiv of **8** to **4a** was used.

<sup>c</sup> 4 equiv of **9a–c** to Pd(PPh<sub>3</sub>)<sub>4</sub> was used.

Fortunately, further optimization of the reaction conditions revealed that the deallylation of **4a** proceeded and completed in the presence of less than 1 mol % of catalyst in THF instead of dichloromethane (Scheme 2).<sup>7</sup>

**Scheme 3.** Pd-catalyzed deallylation of **4** with **2b** followed by PS-DEAM scavenging.

In addition, we noticed that the use of readily prepared<sup>8</sup> or commercially available<sup>9</sup> polystyrene-bound dietha-

**Figure 1.** <sup>1</sup>H NMR spectra of **5d**.

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