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# One-pot chemoselective functionalization of arylsilanes *via* cascade metal–metal exchange reactions

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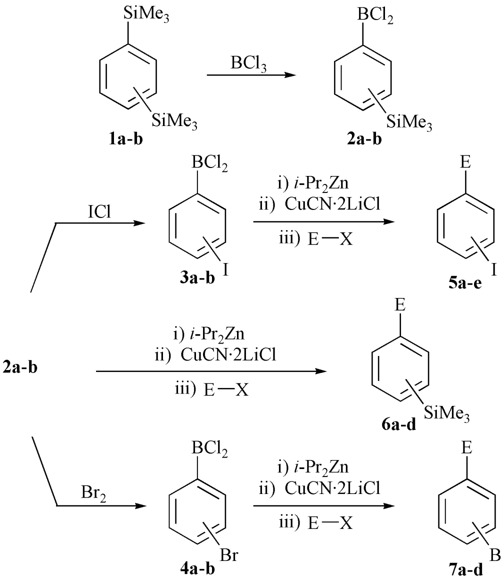
**A cascade-transmetallation sequence allows a one-pot conversion of arylsilanes into functionalized arylcoppers; they react with various types of electrophiles (allylic halides, acid chlorides, bromoalkynes); bimetallic zinc–copper-reagents can be prepared by this method either directly or in a sequential fashion.**

Cascade reactions allow the preparation of complex molecules *via* highly reactive intermediates.[1] Herein, we wish to report a one-pot reaction involving up to three successive transmetallation reactions which allows the conversion of arylsilanes into a range of organic products with excellent chemoselectivity. Arylsilanes are readily prepared but undergo the formation of new carbon–carbon bonds only sluggishly.[2] This is due to the covalent character of the carbon–silicon bond and to the absence of low-lying vacant orbitals available to participate in bond formations. For these reasons, arylsilanes of type $ArSiMe_3$ are poor substrates for direct transmetallation to the corresponding zinc species $Ar_2Zn$. However, the propensity of arylsilanes to undergo *ipso*-substitutions[3] allows smooth transmetallation from silicon to boron by treatment with $BCl_3$, leading to $ArBCl_2$.[4] Previously, we have shown that various organoboranes, including arylboranes, undergo a fast boron–zinc exchange.[5] Herein, we report that the use of $i$-$Pr_2Zn$[6] allows a fast and quantitative boron–zinc exchange of various arylsilanes under very mild conditions (25 °C, 2 h). Thus, the treatment of phenylboron dichloride with $i$-$Pr_2Zn$ (3.0 equiv.) furnished $Ph_2Zn$ after the removal of the excess of $i$-$Pr_2Zn$ and the solvents under vacuum. After a further transmetallation with $CuCN{\cdot}2LiCl$,[7] the resulting phenylcopper derivative reacted with an excess of propionyl chloride (25 °C, 3 h) providing propiophenone in 84% yield. By using this method, *para*- and *meta bis*-trimethylsilyl aromatics **1a**,**b** were reacted with electrophiles with high chemoselectivity in a one-pot procedure leading to products of type **5–7** (Scheme 1).

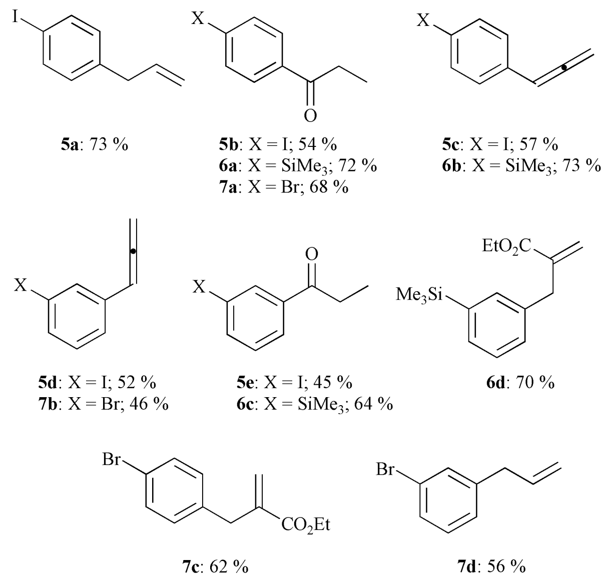
Thus, the reaction of **1a**,**b** with $BCl_3$ (3.0 equiv., 25 °C, 10 h) furnished the corresponding *para*- and *meta* mixed bimetallics **2a**,**b**. They could be reacted with ICl (1.0 equiv., 25 °C, 16 h) leading to the *para*- and *meta*-iodoarylboranes **3a**,**b**. Similarly, the reaction of **2a**,**b** with bromine (1.0 equiv., 25 °C, 16 h) provided the *para*- and *meta*-bromoarylboranes **4a**,**b**. The reaction of **2–4** with $i$-$Pr_2Zn$ (3.0 equiv., 25 °C, 2 h) followed by the addition of $CuCN{\cdot}2LiCl$ (−30 °C, 10 min) and an electrophile furnished products **5–7** in good overall yields (45–73 %)(Fig. 1). Allylation reactions did lead to products **5a**, **6d**, **7c**, and **7d** under very mild conditions. The use of propargyl bromide as electrophile furnished arylated allenes (**5c**, **5d**, **6b** and **7b**) in 46–73% yield. The reaction with propionyl chloride led to the expected ketones (**5b**, **6a**, **7a**, **5e** and **6c**) in 45–72% yield (Fig. 1).

Interestingly, our typical reaction sequence left the benzylic silane function of the mixed benzylic-aromatic disilane **8** unaffected,[4] furnishing the functionalized benzylic silanes **10a–c** in 58–76% yield (Scheme 2), the first step being the formation of the mixed Si,B-bimetallic species **9**. After transmetallation of **9** to the zinc species ($i$-$Pr_2Zn$, 3.0 equiv., 25 °C, 2 h) and further to the copper intermediate (addition of $CuCN{\cdot}2LiCl$), the addition of electrophiles like propionyl chloride, ethyl (2-bromomethyl)acrylate and 1-bromo-2-trimethylsilylethyne[8] furnished the expected products **10a–c** (Scheme 2).



**Scheme 1**

Finally, bis-silylated aromatics were double-functionalized by this approach. Thus, the reaction of the bis-silane **11** with $BCl_3$, followed by the addition of $i$-$Pr_2Zn$ (6.0 equiv., 25 °C, 2 h) and then $CuCN{\cdot}2LiCl$ (2.0 equiv., −30 °C, 10 min) provided *via* the intermediate zinc-copper compound **12** the reaction products **13** in 75% yield (reaction with allyl bromide) and **14** in



**5a**: 73 %
**5b**: X = I; 54 %
**6a**: X = $SiMe_3$; 72 %
**7a**: X = Br; 68 %
**5c**: X = I; 57 %
**6b**: X = $SiMe_3$; 73 %
**5d**: X = I; 52 %
**7b**: X = Br; 46 %
**5e**: X = I; 45 %
**6c**: X = $SiMe_3$; 64 %
**6d**: 70 %
**7c**: 62 %
**7d**: 56 %

**Fig. 1** Products of type **5–7** obtained by the one-pot procedure described in Scheme 1. Yields of analytically pure products.

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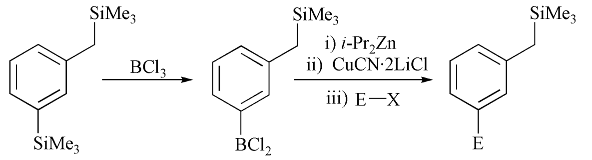

**8** **9** **10a**: E = COEt 76 %
**10b**: E = $CH_2{=}C(CO_2Et)CH_2$ 58 %
**10c**: E = $C{\equiv}C{-}SiMe_3$ 69 %

**Scheme 2**

68% yield (reaction with 1-bromo-2-trimethylsilylethyne)[8] (Scheme 3).

In summary, we have developed a new one-pot procedure allowing the conversion of various arylsilanes into several classes of polyfunctional compounds. Both carbon–silicon bonds react chemoselectively. Bimetallic zinc–copper reagents like **12** can be prepared by this method. Extension to more complex arylsilanes is currently underway.[9]

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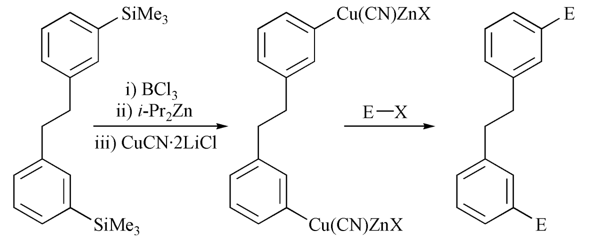

**11** **12** **13**: E = allyl 75 %
**14**: E = $C{\equiv}C{-}SiMe_3$ 68 %

**Scheme 3**

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9 Typical procedure: preparation of 1-(4-iodophenyl)propan-1-one (**5b**): to 1,4-bis(trimethylsilyl)benzene (1.0 mmol, 222 mg) in $CH_2Cl_2$ (1.5 mL) at 0 °C was added $BCl_3$ (3.0 equiv., 3.0 mmol, 3 mL, 1 M in $CH_2Cl_2$). The reaction mixture was stirred at room temperature for 10 h. After pumping off the volatiles (0.1 mm Hg, 25 °C, 30 min), $CH_2Cl_2$ (2 mL) was added and the reaction mixture was cooled to 0 °C. After addition of ICl (1.0 equiv., 1.0 mmol, 162 mg) the reaction mixture was stirred for 16 h at 25 °C. After pumping off the volatiles (0.1 mm Hg, 25 °C, 30 min), *i*-$Pr_2Zn$ (3.0 equiv., 3.0 mmol, 0.5 mL, 6.0 M in $Et_2O$) was added carefully and the mixture was stirred for 2 h at 25 °C. The volatiles were pumped off (0.1 mm Hg, 25 °C, 0.5 h), the residue was diluted with THF (2 mL) and cooled to –30 °C. A freshly prepared solution of CuCN·2LiCl (1.0 equiv., 1.0 mmol, 1.0 mL, 1 M in THF) was slowly added over 10 min and the mixture was stirred for 10 min at −30 °C. Propionyl chloride (3.0 equiv., 3.0 mmol, 278 mg) in THF (1 mL) was added slowly (10 min). The mixture was allowed to warm up to room temperature and stirred at this temperature for 3 h. The reaction mixture was then poured into a saturated aqueous $NH_4Cl$ solution (150 mL) containing $NH_3$ (aq) (2 mL, 30% in $H_2O$). After extraction with $Et_2O$ (3 × 100 mL) the combined organic phases were dried over $MgSO_4$. The solvent was removed and the crude product purified by column chromatography ($SiO_2$) affording **5b** as a colourless oil (54%, 0.54 mmol, 140 mg).