

Copper(I) salt mediated 1,4-reduction of α,β -unsaturated ketones using hydrosilanes

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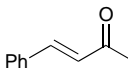
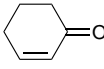
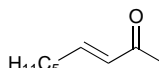
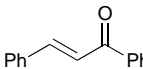
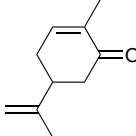
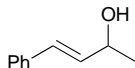
Reduction of α,β -unsaturated ketones with HSiPhMe_2 in the presence of $\text{CuF}(\text{PPh}_3)_3 \cdot 2\text{EtOH}$ proceeds in a 1,4-selective manner to give the corresponding saturated ketones in excellent yields.

Transfer of the organic groups of organosilanes to metallic species, *transmetalation*, has been our recent concern since a number of metal mediated synthetic reactions involve transmetalation as a key step.¹ The organometallic species thus formed may undergo further transformations, such as carbon-carbon or carbon-heteroatom bond formation, *via* reaction with several organic substrates.² We have disclosed that organosilicon compounds such as alkenyl-, aryl- and alkynyl-silanes induce homo-coupling reactions to yield the corresponding 1,3-dienes, biaryls and 1,3-diynes, respectively, in the presence of a copper(I) salt in a polar solvent.³ The findings suggest that transmetalation of the organosilanes to copper occurs to give the organocopper species, the novel transmetalation being remarkable since an organic group on silicon is assumed to transfer onto copper without using an additional activator.^{4,5} Our interest has accordingly turned to the transmetalation of hydrosilanes to copper to generate *copper hydride* species, with which reduction of a variety of organic molecules has been reported.⁶ Although the combination of a copper salt and hydrosilane has rarely been studied when compared with reagents made from copper salts and the hydrides of metals such as aluminium and tin,⁷ the desired reaction, we considered, would proceed with the proper choice of the counter ion and a ligand of copper. After screening several Cu^I species, we found that the $\text{CuF}(\text{PPh}_3)_3\text{-HSiPhMe}_2$ system could effect 1,4-selective reduction of α,β -unsaturated ketones under mild conditions.

The reaction was studied using 1-phenylbut-1-en-3-one **1a** as substrate and HSiPhMe_2 **2a** as the reducing agent in the presence of a copper(I) salt. The molar ratio of the substrate, hydrosilane and copper salt, as well as solvent, reaction temperature and reaction time were examined. We found that the use of 2 equiv. of **2a** and 1 equiv. of $\text{CuF}(\text{PPh}_3)_3 \cdot 2\text{EtOH}$ ⁸ in *N,N*-dimethylacetamide (DMA) were the optimum conditions to yield 1-phenylbutan-2-one **3a** in a quantitative yield.† Results are summarized in Table 1. The yield decreased to 63% when 1 equiv. of **2a** was used. Using a catalytic amount of $\text{CuF}(\text{PPh}_3)_3 \cdot 2\text{EtOH}$, the reaction similarly proceeded with a slight decrease in yield, along with the formation of a small amount of unidentified product as well as a trace amount of 1,2-reduction product **4a**. Concerning the hydrosilane, **2a** and triethylsilane **2b** exhibited high 1,4-selectivities to give the corresponding ketone in excellent yields, but diphenylsilane **2c** considerably decreased the selectivity to give **3a** and **4a** in 49 and 36% yields, respectively, in contrast with the results on rhodium-catalysed hydrosilylation of α,β -unsaturated ketones.⁹ No reaction occurred with HSiPhCl_2 **2d**.

Reactions using several other α,β -unsaturated ketones were carried out using similar optimized condition, as shown in Table 1. The reactions of **1a–e** proceeded in excellent yields with high 1,4-selectivity. However, sterically congested enones such as **1f–h** were recovered unchanged.‡ The results also contrast with those from the reactions catalysed by a rhodium complex,⁹

Table 1 Copper(I) salt mediated reactions of α,β -unsaturated ketones with hydrosilanes in the presence of $\text{CuF}(\text{PPh}_3)_3 \cdot 2\text{EtOH}$ ^a

Substrate	Hydrosilane	Product (% yield)
	2a HSiPhMe_2	3a (>99)
1a	2a HSiPhMe_2	3a (63) ^b
1a	2a HSiPhMe_2	3a (69)
1a	2b HSiEt_3	3a (95)
1a	2c H_2SiPh_2	3a (49)
1a	2d HSiPhCl_2	—
	2a HSiPhMe_2	3b (91)
	2a HSiPhMe_2	3c (91)
	2a HSiPhMe_2	3d (98)
	2a HSiPhMe_2 ^d	3e (85) ^e
		
		—
		—
		4a (trace) ^c
		—
		4a (36)
		—

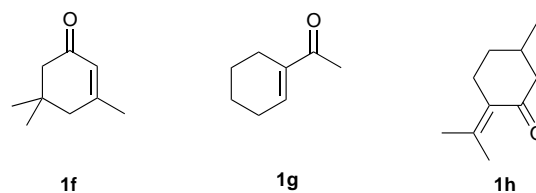
^a Reactions were carried out using enone **1** (1.0 mmol), silane **2** (2.0 mmol) and $\text{CuF}(\text{PPh}_3)_3 \cdot 2\text{EtOH}$ **3** (1.0 mmol) unless otherwise specified. The yields are based on ¹H NMR analyses using $\text{Cl}_2\text{C}=\text{CHCl}$ as an internal standard.

^b One equiv. of **2a** was used. Accompanied by recovery of **1a** (21%).

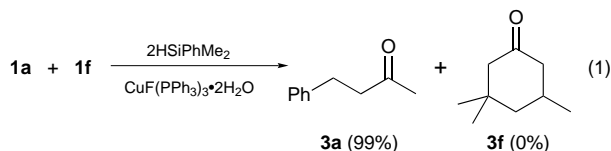
^c $\text{CuF}(\text{PPh}_3)_3$ (5 mol%) was used. ^d 4 equiv. of **2a** was used.

^e Diastereoisomeric ratio was *ca.* 8:1.

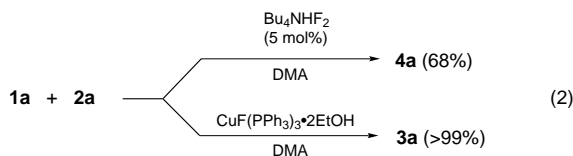
which reduced enones **1f–h** smoothly in a highly 1,4-selective manner. In this sense, our systems appears to be highly chemoselective. Indeed, the reaction of a 1:1 mixture of **1a** and **1f** with **2a** in the presence of $\text{CuF}(\text{PPh}_3)_3 \cdot 2\text{EtOH}$ cleanly



produced **3a** (99%), along with complete recovery of **1f** (97%) [eqn. (1)].



Although a mechanistic study of the transmetalation of organosilane to copper has yet to be undertaken, the activation of hydrosilanes by $\text{CuF(PPh}_3)_3 \cdot 2\text{EtOH}$ seems to be rather different from that by Bu_4NF or the related reagents. The reaction of **1a** and **2a** in the presence of 5 mol% of Bu_4NHF_2 ¹² resulted in predominantly 1,2-reduced product **4a** in 68% yield. Thus, 1,4- and 1,2-selective reduction of α,β -unsaturated ketones with hydrosilanes are accessible by a suitable choice of copper(I) fluoride or Bu_4NHF_2 in a highly selective manner, respectively [eqn. (2)].



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Footnotes and References

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† Typical experimental procedure: $\text{CuF(PPh}_3)_3 \cdot 2\text{EtOH}$ (0.25 mmol) was dissolved in 2 ml of DMA to give a colourless clear solution, to which was added HSiPhMe_2 **2a** (0.5 mmol) at 0 °C to give a red homogeneous solution. The colour of the solution gradually changed to yellow after the addition of 1-phenylbut-1-en-3-one (**1a**, 0.25 mmol). The temperature of the reaction

mixture was gradually raised to room temperature, and stirring was continued for 6 h to furnish **4a** in a quantitative yield after workup.

‡ The reaction of an α,β -unsaturated ester (methyl cinnamate) also resulted in no reaction. On the other hand, an α,β -unsaturated aldehyde (cinnamaldehyde) was found to effect 1,2-reduction, predominantly.

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