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Masked α -Arylalkenyllithium Reagents for Efficient Syntheses of Functionalized Monosubstituted and 1,1-Disubstituted Ethylenes

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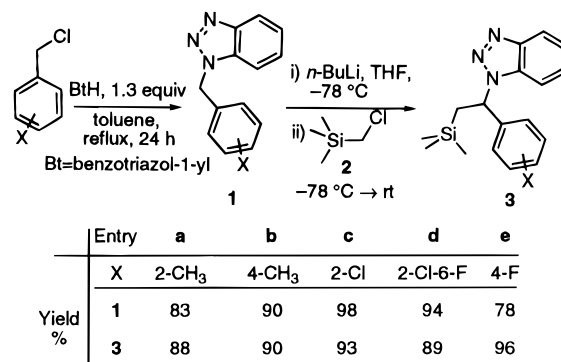
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Due to its ability to favor α -carbanion formation, benzotriazole has proven to be a good tool for the introduction of silicon into organic molecules.¹ The potentially powerful transformations attributed to the presence of silicon in organic molecules, thus, become available. One of the most useful transformations in this category is the formation of an alkene by vicinal elimination of silicon (for comprehensive reviews of these types of reactions see ref 2). We now present a versatile method for the introduction of 1-arylethenyl moieties into organic molecules by the vicinal elimination of silicon from (2-benzotriazolyl-2-arylethyl)silanes. These intermediates act as masked 1-arylethenyl units that can be transformed into the corresponding alkene when needed (cf. the concept of "silicon-masked enones" introduced by Fleming³). The vicinal elimination of silicon can be accomplished by several protocols including pyrolysis, [1,4]-Brook rearrangement, and fluoride ion induced β -elimination. Examples are documented illustrating potentially general methods for the preparation of styrenes, 1,2-disubstituted allyl alcohols, α -substituted acrylamides, 1,3-disubstituted homoallyl alcohols, and γ,δ -unsaturated ketones.

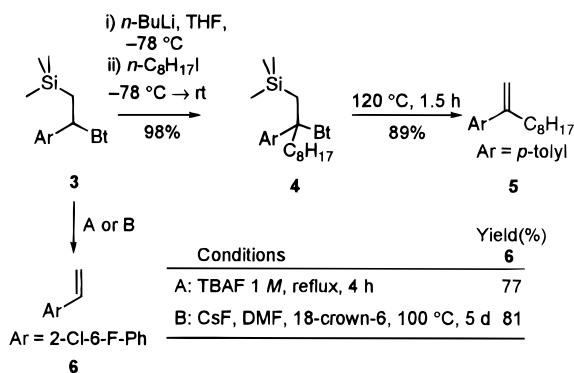
Previous methods for generating alkenyllithiums use either the Shapiro reaction, applied to carbonyl compounds,^{4,5} or lithium-halogen exchange, applied to the corresponding vinyl halides.⁶ Our approach utilizes 1-(arylmethyl)benzotriazoles (**1**) that can be easily prepared from the corresponding arylmethyl chlorides in high yields (Scheme 1). Compounds **1** can be deprotonated to give the corresponding benzyllithiums and then reacted with electrophiles in high yields (for leading examples see 7). The nucleophilic displacement of chlorine in (chloromethyl)trimethylsilane (**2**) by the carbanion derived from **1** gives rise to reagents **3a–e** in high yields (Scheme 1). The reagents **3a–e** are highly stable solid compounds which can be distilled under reduced pressure without decomposition.⁸

The vicinal elimination of silicon in compounds **3** can be accomplished by treatment with fluoride ion. Both tetrabutylammonium fluoride (TBAF, 1 M solution in THF) and cesium fluoride in dimethylformamide work well with **3d** to give the

Scheme 1



Scheme 2



corresponding styrene **6** (Scheme 2) in high yield. The main reason why TBAF shows a higher elimination rate is the higher concentration of "naked" fluoride ions (for recent discussion see ref 9 and references therein). 18-Crown-6 was used to increase the solubility of cesium fluoride in DMF.¹⁰ However, the elimination rate is still slower compared to that of TBAF.

Upon deprotonation, reagents **3** react with electrophiles regioselectively α to the benzotriazole to give the corresponding adducts. Thus, with alkyl halides, compounds of type **4** are obtained cleanly (Scheme 2). Heating these adducts at 120 °C affords the corresponding 1,1-disubstituted ethylenes in excellent yields as illustrated by the transformation **4** \rightarrow **5** (Scheme 2).

Addition of the carbanions derived from **3** to non-enolizable aldehydes is a facile process. Aryl and tertiary alkyl aldehydes gave trimethylsilyl allyl ethers by a [1,4]-Brook rearrangement (Scheme 3).^{11,12} This process is most likely intramolecular, since the stereochemistry of the intermediate alkoxides **7** dramatically influences the reaction conditions required. Thus, when the phenyl group of the incoming nucleophile possesses no substituents in the 2- or 6-position, the rearrangement of the alkoxide **7** takes place on simple warming from -78 °C to room temperature (rt), as is the case with compounds **8a–c** (Scheme 3). For **3a**, heating the alkoxide **7** under reflux in THF for 3 h was necessary to yield the corresponding **8d**. Upon treatment of **8d** with TBAF, the free allyl alcohol **9** was isolated in 70% yield (Scheme 3).

The reaction of **3b** with phenyl isocyanate gave the intermediate alkoxide **10** which upon aqueous workup afforded the

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(8) When centimolar amounts of compounds **3a–e** were prepared, purification by distillation with a Kugelrohr apparatus at 0.1 Torr and 100–120 °C was found to be more convenient than flash column chromatography.

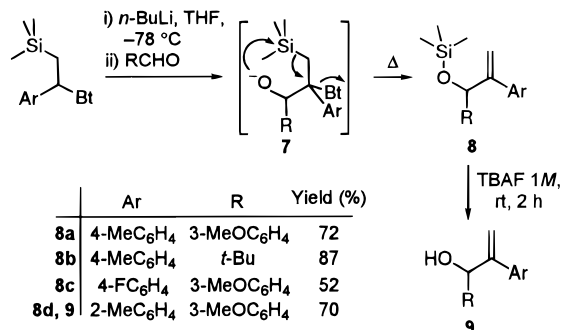
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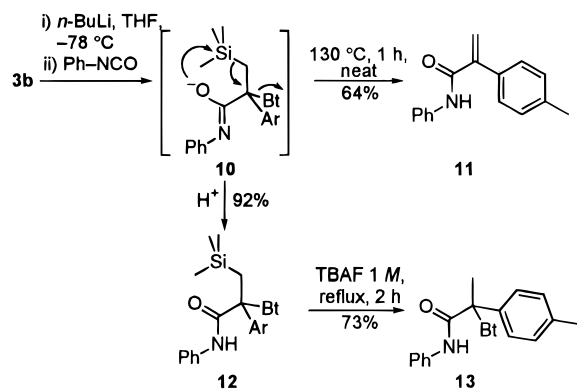
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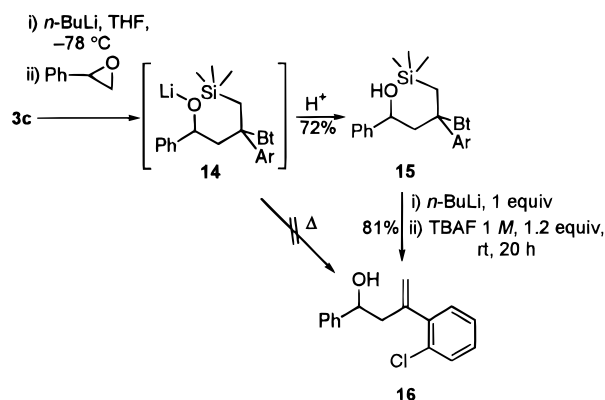
Scheme 3



Scheme 4



Scheme 5

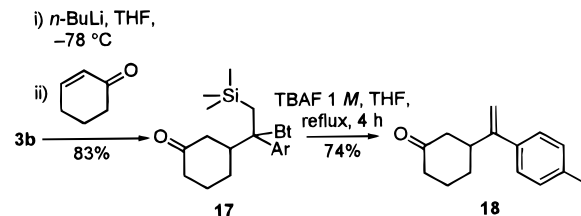


corresponding masked acrylamide **12** in excellent yield (Scheme 4). Attempted vicinal elimination of silicon in **12** with TBAF afforded only the desilylation product **13**, probably due to the proximity of the acidic amide proton. However, direct heating of intermediate **10** without a solvent at 130 °C gave the acrylamide **11** in 64% yield (Scheme 4). To the best of our knowledge, this silicon [1,4]-C → O rearrangement in amide systems is unprecedented.

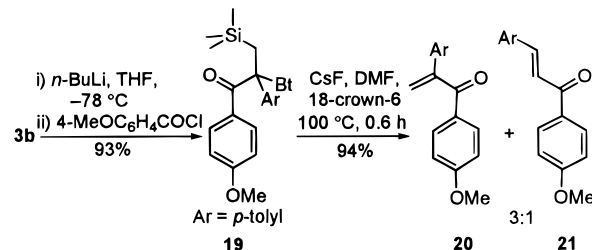
Phenyloxirane reacts with the carbanion derived from **3c** to give the intermediate **14**, which did not rearrange to the corresponding homoallylic alcohol by a [1,5]-Brook rearrangement on refluxing in THF; instead adduct **15** was obtained in 72% yield upon aqueous workup of **14** (Scheme 5). To accomplish the vicinal elimination of silicon, the alcohol **15** was first deprotonated to the corresponding alkoxide and then treated with TBAF to afford the desired elimination product **16** in 81% yield (Scheme 5).

Conjugate addition of alkenyllithiums is usually accomplished *via* previous conversion into the cuprate. This was not necessary in our case, as deprotonation of **3b** with *n*-BuLi and subsequent reaction with an enone gave regiospecifically the conjugate addition product **17** in 83% yield (Scheme 6). The final

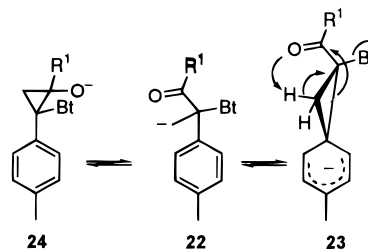
Scheme 6



Scheme 7



Scheme 8



elimination is accomplished with TBAF to convert **17** into the γ,δ -unsaturated ketone **18** in 74% yield.

To synthesize enones, we needed to react the anion derived from **3b** with a carboxylic acid derivative. Esters gave complex mixtures, but an acid chloride afforded the adduct **19** in excellent yield. Suitable reaction conditions to accomplish the elimination from this substrate are CsF in DMF and a crown ether to enhance the solubility of the fluoride. These conditions afforded a mixture of the desired enone **20** in 74% yield together with the chalcone **21** as the *E*-regioisomer (Scheme 7). The formation of compound **21** can be explained by a Grovenstein–Zimmerman rearrangement^{13,14} in which the intermediate carbanion **22** is stabilized by formation of the bridged phenonium anion **23** or alternatively by conversion of carbanion **22** into intermediate **24** (Scheme 8).

In summary, we have shown that reagents of type **3** show high promise for the regiospecific preparation of compounds containing a silicon-masked α -arylalkenyl moiety. These intermediates can eliminate the protecting group under a variety of conditions to give the corresponding terminal alkene containing compounds. More detailed studies of this methodology are currently being pursued.

Supporting Information Available: Typical experimental procedures and characterization data for all new compounds (12 pages). See any current masthead page for ordering and Internet access instructions.

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