



A convenient one-pot, organoaluminum mediated vinylsilane synthesis from non-enolizable ketones via the Peterson protocol

Man Lung Kwan* and Merle A. Battiste

Department of Chemistry, University of Florida, Gainesville, FL 32611, USA

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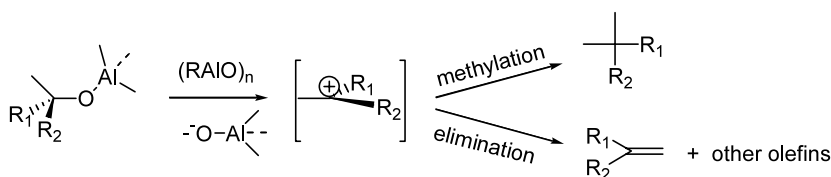
Abstract—Vinylsilanes serve as convenient vinyl anion equivalents which have gained popularity over decades. A variety of non-enolizable aromatic ketones are converted to the corresponding vinylsilanes in a one-pot procedure involving the addition of (trimethylsilylmethyl)lithium to aromatic ketones followed by addition of diethylaluminum chloride and then small amounts of water. Halide and alkoxide substituents are tolerated, and this *trans*-stereoselective (broad generalization; the most sterically bulky group on the double bond is *trans* to the trimethylsilyl group) reaction affords vinylsilanes in good yield. © 2002 Elsevier Science Ltd. All rights reserved.

Countless natural, unnatural products and synthetic intermediates contain alkene functionality, which has driven the development of stereospecific alkene synthetic methodology. Vinylsilanes serve as vinyl anion equivalents in stereospecific electrophilic substitution reactions,¹ a property that has drawn considerable attention. Although vinylsilane synthetic routes from alkynes have been developed,² few effective synthetic methods using ketones have been developed and the obvious Wittig approach from ketones and/or aldehydes, using $\text{Ph}_3\text{P}=\text{CHTMS}$, is ineffective.³ A recently developed method for the conversion of non-enolizable aldehydes to vinylsilanes using $\text{Cp}_2\text{TiCH}_2\cdot\text{AlMe}_2\text{Cl}$ (Tebbe's reagent) has been reported.⁴ Treatment of lithium alkoxides resulting from addition of $(\text{CH}_3)_3\text{SiCH}_2\text{Li}$ to aromatic aldehydes with Tebbe's reagent affords the corresponding (*E*)-vinylsilanes in fair to good yield. Attempts to convert ketones to the corresponding vinylsilanes with this protocol afford multiple products together with the desired vinylsilanes. Other methods for the transformation of ketones to

vinylsilanes generally suffer from multiple synthetic steps, poor stereoselectivity, and/or costly or hazardous reagents.⁵

The Peterson olefination,⁶ a useful alternative to the Wittig reaction, converts β -hydroxysilanes to desilylated olefins under either acidic or basic conditions. Gröbel and Seebach^{5g} applied this protocol to the conversion of non-enolizable aldehydes and ketones to vinylsilanes. Treatment of bis(trimethylsilyl)methyl lithium, generated in situ from the reaction of *t*-butyl lithium with bis(trimethylsilyl)methane in THF/HMPA, with non-enolizable carbonyl compounds afforded vinylsilanes.

Since Ziegler⁷ and colleagues discovered the direct synthesis of trialkylaluminums and their applications to olefin polymerizations, organoaluminum reagents (alanes) have been widely accepted in industry and laboratory. Alanes are amphoteric in the sense that the aluminum atom may function as a Lewis acid center,



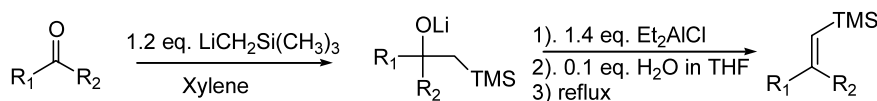
Scheme 1.

* Corresponding author. Present address: Department of Chemistry, John Carroll University, 20700 N Park Boulevard, University Heights, OH 44118, USA. Tel.: 1-216-397-4243; fax: 1-216-397-1791; e-mail: mlkwan@jcu.edu

while the anionic alkyl ligands may act as a base (or nucleophile). Capitalizing on this duality, organoaluminum reagents have been broadly employed as alkylating reagents, Lewis acids, and reducing agents. Mole and coworkers reported on the ability of trimethylaluminum to act as an exhaustive methylating reagent in its reactions with ketones, tertiary alcohols and benzylic alcohols.⁸ Treatment of the above substrates with trimethylaluminum at elevated temperature afforded methylated product together with rearrangement and alkene byproducts (Scheme 1). Mole suggested a carbo-

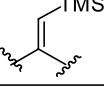

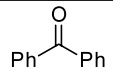
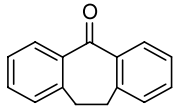
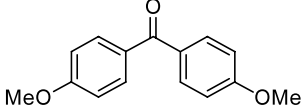
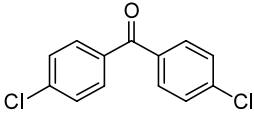
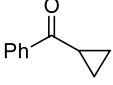
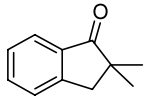
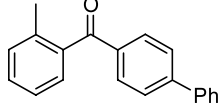
cation was produced prior to methylation, allowing for the possibility of elimination and rearrangement.

Recognizing the ability of organoaluminum reagents to cleave carbon–oxygen bonds, we explored its reactions with β -silylalkoxides.^{9,10} A typical example involves the addition of 1.2 equiv. (trimethylsilylmethyl)lithium to non-enolizable aromatic ketones, with 1.4 equiv. of diethylaluminum chloride followed by addition of 0.1 equiv. of water in tetrahydrofuran (Scheme 2). Unlike the method described by Gröbel, ours uses a mono-silyl



Scheme 2.

Table 1. Vinylsilanes from non-enolizable aromatic ketones

Entry	Substrate ^a	Isolated yield (%) ^d	 : 
1.		66	10 ¹² : 1
2.		76	6 : 1
3.		83	c
4.		79	19 : 1
5.		79 ^b	78 : 1 (<i>E</i> : <i>Z</i> = 1:19) ^e
6.		61	c (<i>E</i> : <i>Z</i> = 60:1)
7.		85 ^b	11 : 1 (<i>E</i> : <i>Z</i> = 2:1)

^a all substrates have a concentration of 0.1 M in xylene.

^b the yield of the product was determined by ¹H NMR spectroscopy, using anisole as an internal standard.

^c not detected.

^d isolated as a mixture of vinylsilane(s) and olefin product(s) (< 5 %).

^e all diastereotopic ratios and the geometry of the individual vinylsilane isomers were determined by NOE experiments.

reagent. As stated in the previous sections, the Peterson olefination converts aldehydes and ketones to desilylated alkenes under either acidic or basic condition. Since organoaluminum reagents are amphoteric, a logical prediction of our reaction product should be a desilylated olefin. Interestingly, after 12–16 h under reflux, the reactions afford a mixture of vinylsilanes and olefin products with vinylsilanes as major products (Table 1).⁹

In the course of our investigation, reaction of 9-xanthone, yielded 25% the ethylated product, 9-trimethylsilylmethyl-9-ethyl-9*H*-xanthone together with the desired vinylsilane product (Scheme 3).¹⁰ This result combined with Mole's observation indicates that the reaction proceeds via an E-1 like pathway, the β -silyl group providing additional stabilization of the carbocation intermediate.

In the organoaluminum-mediated synthesis of vinylsilane from aromatic ketones, 0.1 equiv. of water is needed to enhance the chemoselectivity (desired proton abstraction versus trimethylsilyl group abstraction) and (*E*)-stereoselectivity¹⁰ (broad generalization; the most sterically bulky group on the double bond is *trans* to the trimethylsilyl group). GC analysis suggests the desilylated olefin is produced in the initial stage of the reaction. No significant desilylated alkene formation is observed at a latter stage. This is presumably due to an increase in the amount of oligomeric organoaluminums, including alumoxanes,¹¹ (RAIO)_n, as the elimination process proceeds. Using a preformed alumoxane (methylalumoxane) in xylene solvent, instead of diethylaluminum chloride with 0.1 equiv. of water, did not afford desired product.

The use of organoaluminum reagents to promote elimination is rare. This procedure employs an organoalane to mediate E1-like vinylsilane formation with good chemo- and stereoselectivity. We are continuing to explore the scope and versatility of this reaction.

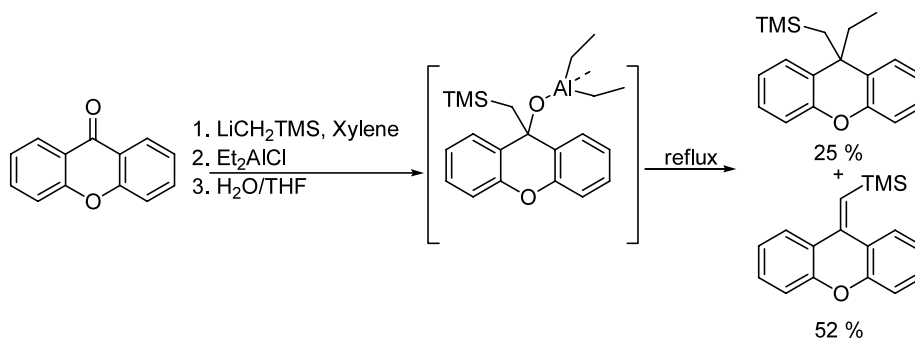
Acknowledgements

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Scheme 3.

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9. General procedure: Under an inert atmosphere, 1.2 equiv. of TMSCH₂Li (1 M) was added to a solution of ketone (500 mg) in xylene in a schlenk flask. After stirring at room temperature for 15 min, 1.4 equiv. of diethylaluminum chloride (1.8 M in toluene) and then 0.1 equiv. of water in THF (1 M) were added, forming a white cloudy solution. The tube was closed, then heated under reflux for 22–27 h (see Table 1). The resulting mixture was washed with a 20 mL mixture of 0.5 % sodium carbonate solution and extracted with ether. The combined ether extract was dried over anhydrous sodium sulfate for 15 min and evaporated. Reduced pressure distillation afforded a clear oil.
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