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COMMUNICATIONS

Insertions of Silylenes into Vinyl Epoxides: Diastereoselective Synthesis of Functionalized, Optically Active *trans*-Dioxasilacyclooctenes

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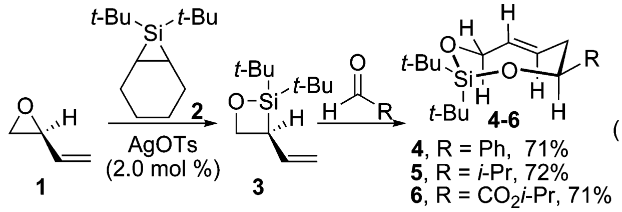
trans-Cyclooctenes[1] are unique members of the medium-ring *trans*-cycloalkene family. These strained cyclic compounds display stable planar chirality[2] at ambient temperature and adopt a crown conformation in which the olefin is severely distorted and has partially pyramidalized sp^2 carbons.[3] As a consequence, reactions where olefinic carbon centers undergo sp^2 to sp^3 rehybridization are greatly accelerated[4] and occur selectively on the face of the olefin outside the ring.[5] Although many synthetic routes to *trans*-cyclooctenes have been reported,[1,5b,6] preparation of functionalized[7] nonracemic *trans*-cyclooctenes remains a challenge. Consequently, general applications of these compounds in organic synthesis have not emerged.[8]

In this communication, we describe a reaction sequence that capitalizes on metal-catalyzed silylene insertion conditions developed in our laboratory[9] and the characteristics of *trans*-cyclooctenes to generate synthetically valuable molecules. This process involves stereospecific silylene insertions into the carbon−oxygen bonds of allylic epoxides to form reactive vinyl silaoxetane intermediates that can undergo nucleophilic additions to a variety of aldehydes, yielding strained *trans*-dioxasilacyclooctenes.

The insertions of silylenes into epoxides were first studied with vinyl epoxide **1**. Treatment of this epoxide with silacyclopropane **2** and a catalytic amount of AgOTs at 25 °C cleanly provided a new product (eq 1).[10] ^{1}H NMR and ^{29}Si NMR spectroscopy indicated that this product was the silaoxetane **3**, an allylic silane with a silicon atom embedded in a strained ring.[11]

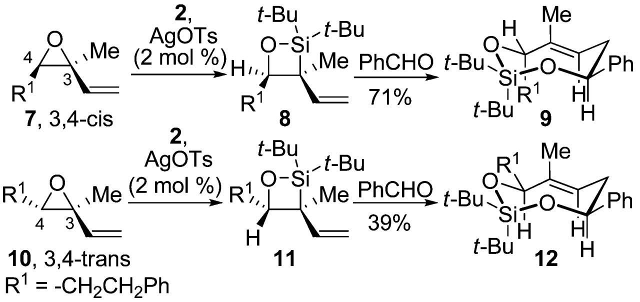


(1)

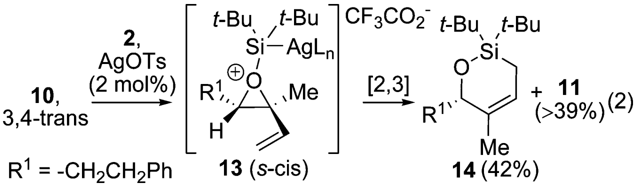
The high reactivity of strained allylic silanes suggested applications of these silaoxetanes for carbon−carbon bond-forming reactions. Strained allylic silanes display enhanced nucleophilicity in additions to unactivated aldehydes, serving as both the Lewis acid and the nucleophilic allyl moiety.[12,13] The reactivity of silaoxetane **3** was probed by addition of different aldehydes to the reaction mixture after insertion of the silylene (eq 1). Products **4**−**6** with trans double bonds in eight-membered rings were observed as single diastereoisomers and atropisomers (eq 1). The relative stereochemistry of the products was unambiguously determined using NMR spectroscopy.

Insertions of silylenes into vinyl epoxides and subsequent allylation are highly stereoselective. *trans*-Dioxasilacyclooctenes **9** and **12** were formed as single diastereoisomers from 2,3-*trans*- and 2,3-*cis*-vinyl epoxides **7** and **10**, respectively (Scheme 1). Spectroscopic data of vinylsilaoxetanes **8** and **11** (obtained after silylene insertion into **7** and **10**, respectively) did not show any epimerization at the allylic position (Scheme 1).

Scheme 1. Insertions of Silylenes into *cis*- and *trans*-Vinyl Epoxides

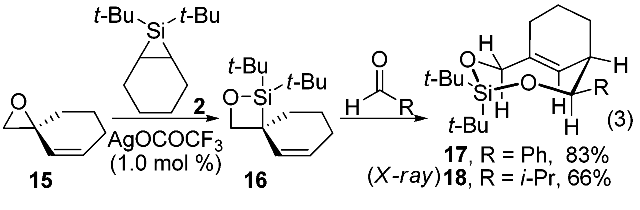


trans-Dioxasilacyclooctene **12** was obtained in lower yield because of the concurrent formation of oxasilacyclohexene **14** along with silaoxetane **11** during the silylene insertion step (Scheme 1 and eq 2).[14] Oxasilacyclohexene **14** was probably generated through a formal [2,3]-rearrangement of *s*-cis oxonium ylide **13**[9] (eq 2). The preference for 3,4-*cis*-vinyl epoxides to adopt *s*-trans conformations[15] could explain why silaoxetane **8** was formed selectively from epoxide **7** (Scheme 1).



(2)

Spiroepoxides also undergo silylene insertion and subsequent carbon−carbon bond formation. Silylene transfer to spiroepoxide **15** followed by addition of benzaldehyde and isobutyraldehyde (eq 3) afforded as single diastereoisomers the corresponding products **17** and **18** having trans double bonds in bridged eight-membered rings (anti-Bredt olefins[16]).[10] X-ray crystallographic analysis of alkene **18** showed substantial twisting and pyramidalization of the alkene, as detailed in the Supporting Information.



(3)

The diastereoselectivity and scope of the silylene insertion−allylation sequence was established using enantiomerically enriched vinyl epoxide (+)-**19** (Scheme 2). After silylene insertion, addition of

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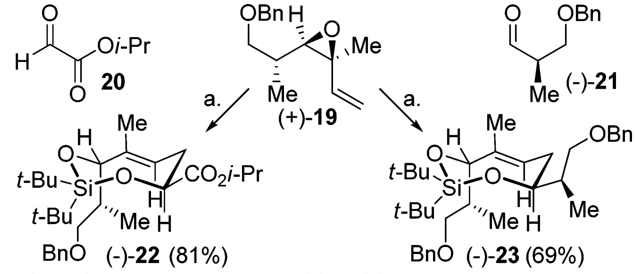
glyoxylate **20** or chiral, nonracemic aldehyde (−)-**21** to the reaction mixture gave *trans*-dioxasilacyclooctene (−)-**22** or (−)-**23**, respectively, as single diastereoisomers.

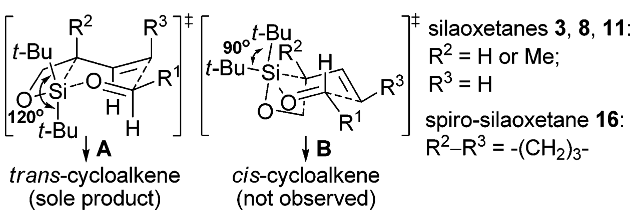
Scheme 2. Synthesis of Nonracemic *trans*-Dioxasilacyclooctenes



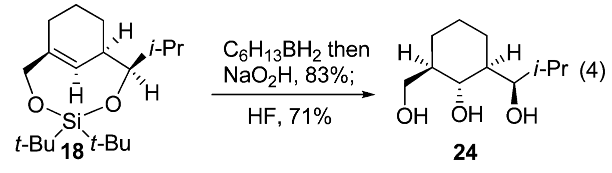
a. **2**, AgOTs (2.0 mol %), then **20** or **21**

The diastereoselectivity of the addition of vinyl silaoxetanes to aldehydes can be explained by considering chairlike six-membered closed transition states **A** and **B**.[17] In these transition states, the silicon atoms bind to the aldehyde to form hypervalent complexes with trigonal bipyramidal geometry (Scheme 3).[12,18] Transition state **A**, leading to *trans*-cycloalkene products, should be favored on the basis of the preferential pseudoequatorial position[19] of the $-CH_2-$ group of the silaoxetane ring and basal position of the *tert*-butyl groups in the trigonal bipyramidal complex. In contrast, formation of the *cis*-cycloalkene through transition state **B** requires one *tert*-butyl group to occupy an apical position, causing a severe steric interaction between the two large *tert*-butyl groups.

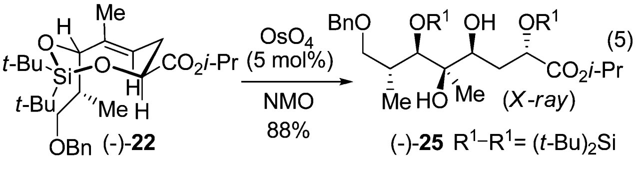
Scheme 3. Proposed Transition States



The cyclic *trans*-alkene products underwent highly diastereoselective reactions. Hydroboration of anti-Bredt olefin **18** and subsequent deprotection of the silyl group gave a cyclohexanol with four contiguous stereocenters (**24**, eq 4). Osmium tetroxide-catalyzed dihydroxylation of trisubstituted alkene (−)-**22** reached completion in less than 30 min, providing diol (−)-**25** as one diastereoisomer (eq 5). The reactivity of this strained cyclic alkene is higher than those of acyclic trisubstituted alkenes bearing an allylic alkoxy group, which typically react sluggishly with OsO_4.[20a−c] In addition, the stereochemical outcome exhibited by alkene (−)-**22** is complementary to that generally observed in substrate-controlled dihydroxylation of comparable acyclic systems.[20c,d]



(4)



(5)

In summary, the combination of insertion of silylenes into vinyl epoxides and subsequent allylations of aldehydes represent a powerful strategy for generating functionalized *trans*-dioxasilacyclooctenes. Diastereoselective additions to these alkenes allow efficient transfer of planar chirality to chirality at stereogenic carbon atoms.

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Supporting Information Available: Experimental procedures, spectroscopic and analytical data for the product, and X-ray data (CIF) for **18** and **25**. This material is available free of charge via the Internet at http://pubs.acs.org.

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