Chirality Transfer during the [2,3]-sila-Wittig Rearrangement and Cyclopropanation Reaction of Optically Active [(*sec*-Allyloxy)silyl]lithiums

Atsushi Kawachi,* Hirofumi Maeda, Hiroshi Nakamura, Noriyuki Doi, and Kohei Tamao*

Institute for Chemical Research
Kyoto University, Uji, Kyoto 611-0011, Japan

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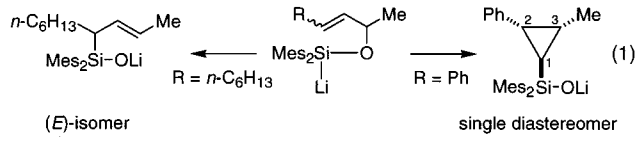
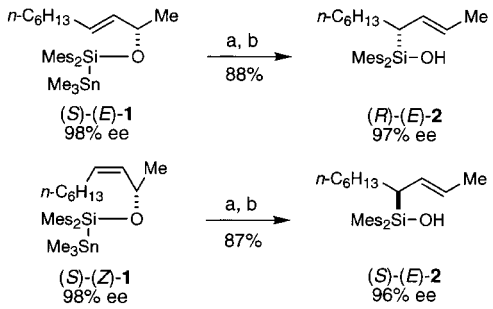
Intramolecular reactions of organolithium reagents with olefins have been extensively studied in organic synthesis. One representative reaction is the Wittig rearrangement[1] of α-alkoxyorganolithium compounds, which provides a versatile method for the regio- and stereoselective C−C bond formation along with the allylic transposition. Another topic is the intramolecular carbolithiation of olefins,[2] which allows regio- and stereoselective cyclizations. Much attention has recently been paid to asymmetric variants of these reactions.[1b−e,2a−d]

In contrast to this, less attention has been paid to the intramolecular reactions of silyllithium reagents[3] with olefins despite the potential utility for the regio- and stereoselective Si−C bond formations. Recently, we found two reaction modes for the intramolecular rearrangements of the [(*sec*-allyloxy)dimesitylsilyl]-lithiums,[4] as shown in eq 1. One is the [2,3]-sila-Wittig rearrangement, the silicon analogues to the [2,3]-Wittig rearrangement,[5] that is, the [(allyloxy)silyl]lithium bearing an alkyl group on the terminus of the olefin undergoes the [2,3]-rearrangement to afford the (*E*)-allylsilanes. The other is the cyclopropanation reaction in which the [(allyloxy)silyl]lithium bearing a phenyl group on the terminus of the olefin gives the corresponding substituted cyclopropylsilane as a single diastereoisomer.[6] We now disclose the chirality transfer of these reactions using enantioenriched *sec*-allylic alcohol derivatives; the center of chirality at one allylic carbon atom is intramolecularly transferred to the newly formed stereogenic centers, which leads to optically active allylsilanes[7] and cyclopropylsilane.[8,9]



We first investigated the 1,3-chirality transfer during the [2,3]-sila-Wittig rearrangement, as shown in Scheme 1. Treatment of the [(*sec*-allyloxy)dimesitylsilyl]stannane[10] (*S*)-(*E*)-**1** (98% ee) with *n*-BuLi (2.0 mol amt.) in THF at 0 °C for 3 h provided the

Scheme 1[a]



[a] (a) *n*-BuLi (×2), THF, 0 °C, 3 h. (b) 5% NH_4Cl aq.

allylsilane (*R*)-(*E*)-**2** in 88% yield with 97% ee.[11] In contrast, (*S*)-(*Z*)-**1** (98% ee) afforded the allylsilane (*S*)-(*E*)-**2** in 87% yield with 96% ee. Thus, the resulting stereochemistry of the new chiral center significantly depends on the olefin geometry of the substrate, while the resulting olefin geometry is always *E*.

These aspects provide an insight into the mechanism,[12] as shown in Scheme 2. For instance, the silyllithium (*S*)-(*E*)-**3** derived from (*S*)-(*E*)-**1** undergoes suprafacial attack on the olefin in the lower-energy conformer (*S*)-(*E*)-**3a**, to give the observed (*R*)-(*E*)-**2**, whereas the higher energy conformer (*S*)-(*E*)-**3b** due to the allylic strain would provide (*S*)-(*Z*)-**2**, but this is not experimentally observed. This is consistent with the general attributes of the [2,3]-Wittig rearrangement.[1a]

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(4) The term "*sec*-allylic" means that the allylic carbon is secondary.

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(10) The [(allyloxy)dimesitylsilyl]stannanes were prepared by the reaction of the corresponding enantio-enriched *sec*-allylic alcohols and the chloro-(dimesityl)silylstannane in THF in the presence of triethylamine and 4-(dimethylamino)pyridine; see ref 5. The optically active allylic alcohols were derived from commercially available (*S*)-(−)-3-butyn-2-ol (98% ee); see Supporting Information.

(11) The enantiomeric excess of **2** was directly determined by chiral HPLC analysis using CHIRALPAK AD column eluted with hexane/2-propanol (50/1). The absolute configuration of the allylsilanes was determined after conversion to the allylic alcohols by *m*-chloroperbenzoic acid according to the literature; Hayashi, T.; Okamoto, Y.; Kabeta, K.; Hagihara, T.; Kumada, M. *J. Org. Chem.* **1984**, *49*, 4224, and see ref 7i.

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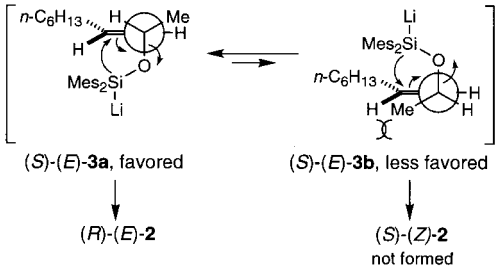
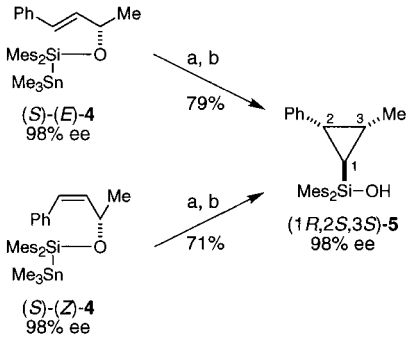
Scheme 2

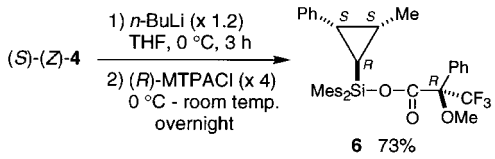


Scheme 3[a]



[a] (a) *n*-BuLi (×1.2), THF, 0 °C, 3 h. (b) 5% NH_4Cl aq.

Scheme 4

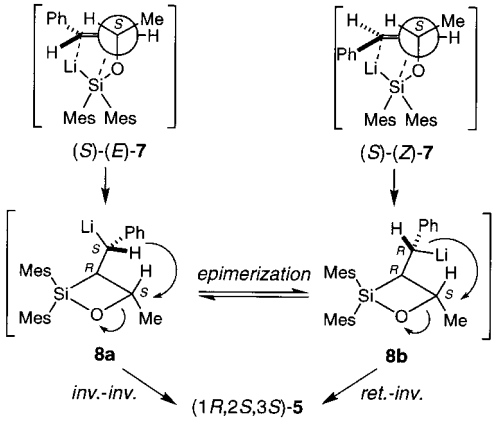


We next applied this chirality transfer technique to the cyclopropanation reaction, the other reaction mode of the [(*sec*-allyloxy)silyl]lithiums,[6] in which the sense of chirality at the allylic position in the substrate would define the absolute configuration of three stereocenters in the resulting cyclopropane. The results are shown in Scheme 3. Thus, treatment of the enantio-enriched (*S*)-(*E*)-**4** (98% ee)[10] with *n*-BuLi (1.2 mol amt.) in THF at 0 °C for 3 h afforded (1*R*,2*S*,3*S*)-**5** in 79% yield with 98% ee.[13] Under the same reaction conditions, (*S*)-(*Z*)-**4** (98% ee) gave the same stereoisomer (1*R*,2*S*,3*S*)-**5** in 71% yield with 98% ee. The absolute configuration (1*R*,2*S*,3*S*) of **5** was definitely determined by the X-ray crystallographic analysis of the ester **6** obtained by treatment with (*R*)-α-methoxy-α-(trifluoromethyl)phenylacetyl chloride, as shown in Scheme 4. Thus, the resulting stereochemistry depends on the absolute configuration of the allylic carbon independent of the olefin geometry in **4**, in sharp contrast to the [2,3]-sila-Wittig rearrangement mentioned above.

The stereochemical course is rationalized as follows.[6] An intramolecular *syn*-lithiosilylation via **7** proceeds in the initial step, facilitated by the stabilizing phenyl residue, as shown in Scheme 5. The intermediate **8a** is formed from (*S*)-(*E*)-**4** via (*S*)-(*E*)-**7**,

(13) The enantiomeric excess of **5** was directly determined by chiral HPLC analysis using CHIRALCEL OD column eluted with hexane/2-propanol (100/1.5).

Scheme 5



whereas **8b** results from (*S*)-(*Z*)-**4** via (*S*)-(*Z*)-**7**. The epimers **8a** and **8b** are expected to be configurationally labile at the benzylic center and are in equilibrium.[2b,c] Subsequently, cyclopropanation of the oxasilacyclobutanes **8a** and **8b** takes place from a conformation, avoiding steric strain between the phenyl residue and the mesityl group(s), with inversion at the C−O bond. For the formation of (*1R,2S,3S*)-**5** from **8a**, inversion of the benzylic center is required, whereas starting from **8b**, retention leads to the observed stereochemistry.[14]

In conclusion, we have achieved the chirality transfer in the [2,3]-sila-Wittig rearrangement and the cyclopropanation reaction of the chiral [(*sec*-allyloxy)silyl]lithiums. While the former reaction allows the stereoselective formation of one Si−C bond, the latter reaction allows the stereoselective formation of one C−C bond in addition to one Si−C bond and can define the absolute configurations of three stereocenters in the cyclopropane ring. Since a variety of optically active allylic alcohols are now available by established methods,[15,16] the present method will widen its variation. The scope and limitations are now under investigation.

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Supporting Information Available: Experimental details and X-ray structural information of **6** (PDF). An X-ray crystallographic file (CIF). This material is available free of charge via the Internet at http://pubs.acs.org.

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