



Synthesis of cyclic allenylsilanes via an intramolecular substitution reaction of 1-siloxy-2,3-epoxyalkanes

Keiji Tanino,* Yuhko Honda and Masaaki Miyashita*

Division of Chemistry, Graduate School of Science, Hokkaido University, Sapporo 060-0810, Japan

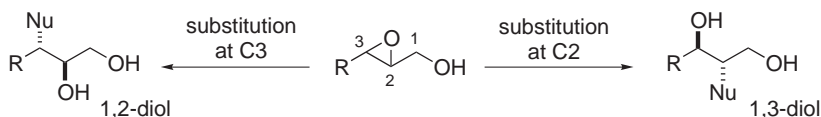
Received 17 August 2000; accepted 22 September 2000

Abstract

Intramolecular substitution reactions of 1-(alkynylsiloxy)-2,3-epoxyalkanes under acidic or basic conditions were investigated. In the presence of *t*-butyllithium, cyclic allenylsilanes, which can be easily converted to the corresponding allenes, were obtained in good yields. The regioselectivity was highly dependent on the configuration of the epoxide moiety, which was rationalized by assuming chair-like transition state models of the 6-*endo* type cyclization reactions. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: allenes; alkynes; epoxides; silicon and compounds; substitution.

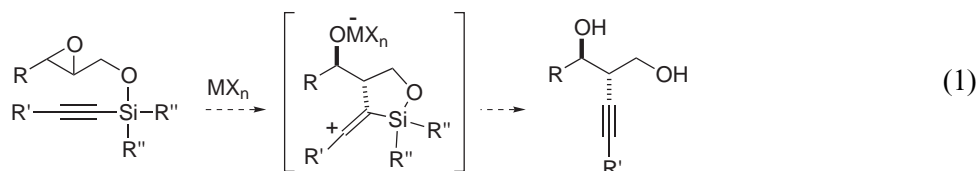
Nucleophilic substitution reactions of 2,3-epoxyalkanols, which are easily prepared as an optically active form,¹ provide a powerful method for stereoselective construction of a carbon framework.² The utility of this type of reaction is critically dependent on regioselectivity, and several methods have been developed on the basis of the characteristic features of organometallic compounds (Scheme 1). For example, use of an organoaluminum reagent leads to a 1,2-diol via substitution at the C3 position,³ while a Gilman-type reagent prefers a reaction at the C2 position to give a 1,3-diol.⁴ However, introduction of an alkynyl group at the C2 position seems to be difficult because of the low reactivity of alkynylcopper reagents.



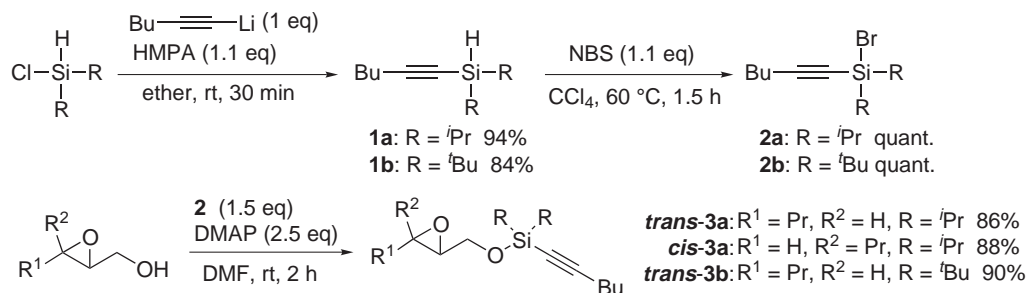
Scheme 1.

* Corresponding authors.

On the other hand, we have recently reported a diastereoselective intramolecular alkylation reaction of an α -(alkynylsiloxy)aldehyde promoted by a Lewis acid.⁵ The results led us to design a new synthetic method for 2-alkynyl-1,3-alkanediols from a 1-(alkynylsiloxy)-2,3-epoxyalkane (Eq. (1)). We envisioned that treatment of the silicon-tethered compound with a Lewis acid would effect alkylation at the C2 position via 5-*exo* type cyclization, followed by desilylation.⁶

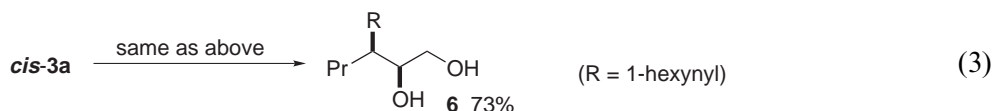
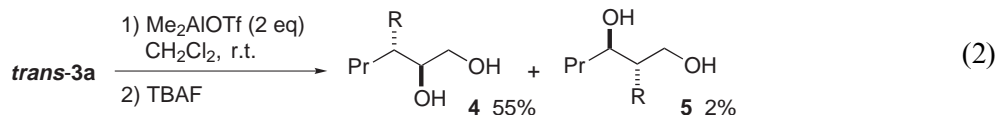


Synthesis of 1-(alkynylsiloxy)-2,3-epoxyalkanes was accomplished as shown in Scheme 2. Treatment of alkynylsilane **1**, which was prepared from dialkylchlorosilane and 1-hexynyllithium, with *N*-bromosuccinimide yielded silyl bromide **2** quantitatively. In the presence of 4-(dimethylamino)pyridine, a 2,3-epoxy-1-alkanol reacted with **2** to afford the desired silyl ether **3** in high yield.



Scheme 2.

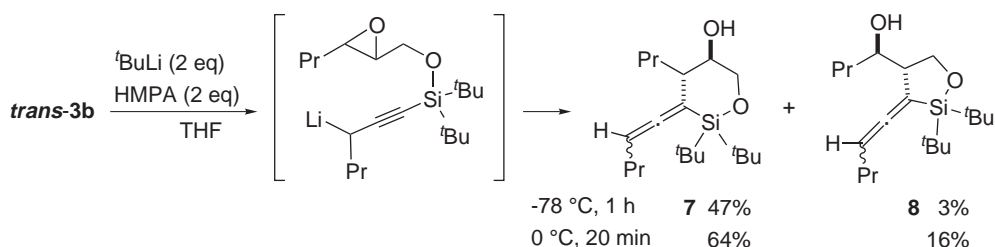
At first, intramolecular substitution reactions of *trans*- and *cis*-**3a** were examined under the influence of several Lewis acids. Although the reactions with metal chlorides such as TiCl₄, SnCl₄ or EtAlCl₂ resulted in formation of a complex mixture containing chlorohydrin derivatives, use of Me₂AlOTf induced an alkylation reaction. The main products were found, however, to be 1,2-diols **4** and **6**⁷ arising from the substitution reaction at the C3 position (Eqs. (2) and (3)).



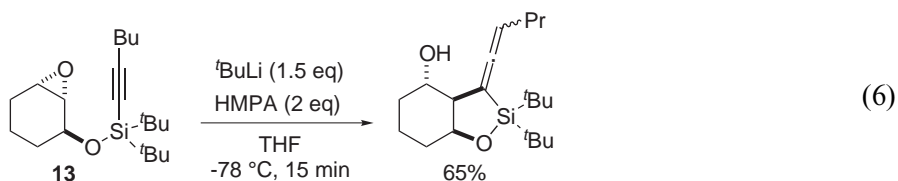
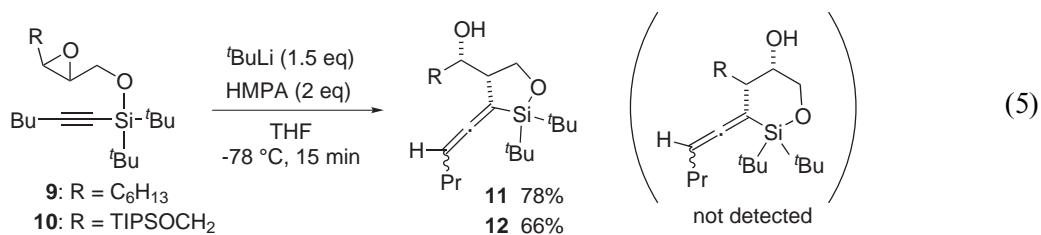
As the unexpected regioselectivity suggested a possibility of an intermolecular reaction pathway, we examined an alternative intramolecular reaction under basic conditions.⁸ Thus,

trans-**3a** was treated with *t*-butyllithium with a view to generating a propargyl lithium species which would undergo a cyclization reaction to yield a cyclic silyllallene derivative. Although the reaction of *trans*-**3a** resulted in cleavage of the Si–O bond, *trans*-**3b** afforded six-membered allene **7** along with a small amount of five-membered product **8** (Eq. (4)).

These results indicate that a *trans*-1-(alkynylsiloxy)-2,3-epoxyalkane prefers a 6-*endo* type cyclization reaction under both cationic and anionic conditions, which may come from the relatively long Si–O and Si–C bonds.



However, this is not the case for the reaction of an epoxide with *cis* configuration. Thus, treatment of *cis*-epoxides **9** and **10** with *t*-butyllithium resulted in selective formation of five-membered silyllallenes **11** and **12**, respectively (Eq. (5)). Cyclohexane derivative **13**, which has a *cis*-epoxide moiety, also underwent an intramolecular substitution reaction at the C2 position (Eq. (6)).



The different behavior between a *trans*-epoxide and a *cis*-epoxide could be accounted for by assuming chair-like transition state models of the 6-*endo* type cyclization reactions (Fig. 1). The reaction of an allenyllithium generated from a *trans*-epoxide mainly proceeds through chair-like transition state **TS-1**, which has the substituent R at the quasi equatorial position. On the contrary, the corresponding transition state **TS-2** suffers from the severe 1,3-diaxial steric repulsion between R and the *t*-butyl group on the silicon. Therefore, *cis*-epoxides predominantly undergo a 5-*exo* type cyclization reaction.

Finally, removal of the silyl group from the cyclic allenylsilanes was briefly examined. Although protodesilylation of **7** or **11** by using protic acids was unsuccessful, these cyclic

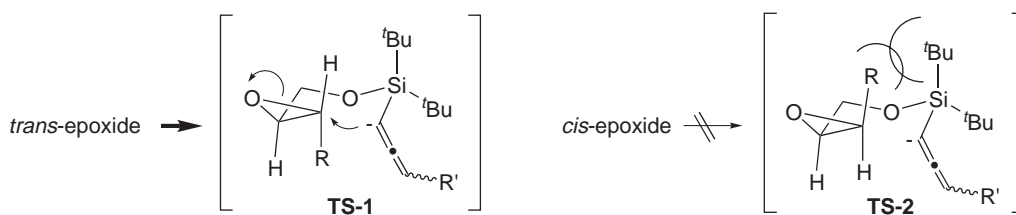
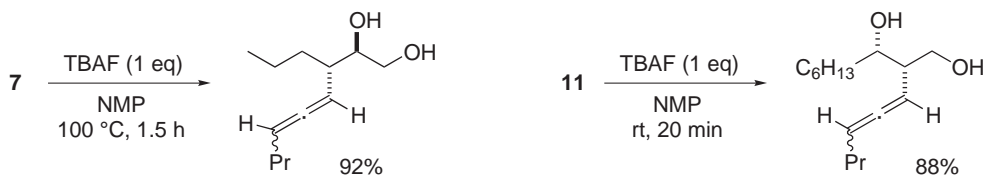


Figure 1.

allenylsilanes were cleanly transformed into the corresponding allenes under the influence of tetrabutylammonium fluoride in 1-methyl-2-pyrrolidinone (NMP).



In conclusion, intramolecular substitution reactions of 1-(alkynylsiloxy)-2,3-epoxyalkanes under acidic or basic conditions were investigated. In the presence of *t*-butyllithium, cyclic allenylsilanes, which can be easily converted to the corresponding allenes, were obtained in good yields. The regioselectivity was highly dependent on the configuration of the epoxide moiety, which was rationalized by assuming chair-like transition state models of the 6-*endo* type cyclization reactions. We are currently investigating synthetic reactions using the cyclic allenylsilanes as a nucleophile.⁹

Acknowledgements

Financial support from the Ministry of Education, Science, Sports and Culture of Japan (a Grant-in-Aid for Scientific Research (A) (No. 12304042), a Grant-in-Aid for Scientific Research on Priority Areas (No. 706: Dynamic Control of Stereochemistry), and a Grant-in-Aid for JSPS Fellows (No. 2709) is gratefully acknowledged.

References

1. Katsuki, T.; Sharpless, K. B. *J. Am. Chem. Soc.* **1980**, *102*, 5974–5976. For a review, see: Johnson, R. A.; Sharpless, K. B. In *Catalytic Asymmetric Synthesis*; Ojima, I., Ed.; VCH: New York, 1993; pp. 103–158.
2. (a) Posner, G. H. *Org. React.* **1975**, *22*, 253–400. (b) Lipshutz, B. H.; Sengupta, S. *Org. React.* **1992**, *41*, 135–631.
3. (a) Suzuki, T.; Saimoto, H.; Tomioka, H.; Oshima, K.; Nozaki, H. *Tetrahedron Lett.* **1982**, *23*, 3597–3600. (b) Roush, W. R.; Adam, M. A.; Peseckis, S. M. *Tetrahedron Lett.* **1983**, *24*, 1377–1380.
4. (a) Johnson, M. R.; Nakata, T.; Kishi, Y. *Tetrahedron Lett.* **1979**, 4343–4346. (b) Tius, M. A.; Fauq, A. H. *J. Org. Chem.* **1983**, *48*, 4131–4132. (c) Chong, J. M.; Cyr, D. R.; Mar, E. K. *Tetrahedron Lett.* **1987**, *28*, 5009–5012. See also Ref. 2.
5. Tanino, K.; Shimizu, T.; Kuwahara, M.; Kuwajima, I. *J. Org. Chem.* **1998**, *63*, 2422–2423.

6. For reviews of alkynylsilanes, see: (a) Colvin, E. W. In *Silicon in Organic Synthesis*; Butterworths: London, 1981; pp. 165–173. (b) Weber, W. P. In *Silicon Reagents for Organic Synthesis*; Springer Verlag: Berlin, 1983; pp. 129–158.
7. Treatment of a mixture of diols **4** and **5** with NaIO_4 resulted in selective cleavage of **4** to give an aldehyde.
8. A 5-*exo* type cyclization reaction of *E*-2-(phenylsulfonyl)vinyl ethers of 2,3-epoxyalkanols under basic conditions is reported: McCombie, S. W.; Shankar, B. B.; Ganguly, A. K. *Tetrahedron Lett.* **1985**, *26*, 6301–6304.
9. For a review of allenylsilanes, see: Fleming, I.; Dunogués, J.; Smithers, R. *Org. React.* **1989**, *37*, 57–575.