Tetrahedron Letters, Vol. 33, No. 46, pp. 7031-7034, 1992
Printed in Great Britain

0040-4039/92 $5.00 + .00
Pergamon Press Ltd

Radical Cyclization of 1-Allyloxy-2-halo-1-silacyclopentane. Application to Stereoselective Synthesis of 1,4,6-Triols

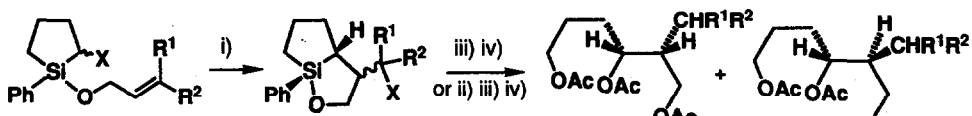
Kozo Matsumoto, Katsukiyo Miura, Koichiro Oshima,* and Kiitiro Utimoto*

Department of Industrial Chemistry, Faculty of Engineering, Kyoto University, Yoshida, Kyoto 606-01, Japan

Abstract: *Treatment of 1-allyloxy-1-phenyl-2-bromo-1-silacyclopentane with n-Bu_3SnH in the presence of catalytic amount of Et_3B provided 1-sila-2-oxabicyclo[3.3.0]-octane which was converted into 1,4,6-triol.*

Radical cyclization reactions developed in the last years represent a breakthrough for synthetic radical chemistry.[1] Silylmethyl radical cyclizations have been widely used as an indirect method for acyclic stereocontrol.[2] Recently we have reported[3] that an addition of lithium carbenoids such as $LiCHX_2$ (X = Br, I) to 1,1-dimethyl-1-silacyclobutane provided the corresponding 2-halo-1-silacyclopentanes. Here we wish to describe stereoselective cyclization of silylmethyl radicals derived from 1-allyloxy-2-halo-1-silacyclopentanes.

Intramolecular cyclization of 2-bromo-1-silacyclopentane **1a** (1.0 mmol) with *n*-Bu_3SnH (1.1 mmol) in the presence of a catalytic amount of triethylborane (0.2 mmol)[4] afforded the cyclized product **3a** which was converted into an isomeric mixture of triacetate **5a** and **6a** (**5a**:**6a** = 86:14)[5] by direct oxidation[6] followed by acetylation in an overall yield of 32% from **1a**. Treatment of **1b** or **1c** with *n*-Bu_3SnH-Et_3B and successive oxidation also gave an isomeric mixture of the corresponding triacetate **5b** and **6b** (**5b**:**6b** = 82:18) or **5c** and **6c** (**5c**:**6c** = 64:36) in 60% or 72% overall yield, respectively. Atom transfer cyclization[7] reaction of **2a**, **2b**, or **2c** with a catalytic amount of Et_3B gave the cyclized product **4a**, **4b**, or **4c** which was transformed into the same isomeric mixture of triacetate **5a**:**6a** = 88:12, **5b**:**6b** = 88:12, or **5c**:**6c** = 70:30 by successive treatment with *n*-Bu_3SnH, H_2O_2-KF-$KHCO_3$, and Ac_2O-pyridine in 37%, 35%, or 22% overall yield based on the starting silacyclopentane **2**.

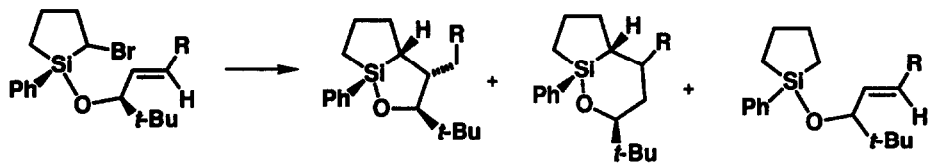


1 X = Br **2** X = I **3** X = H **4** X = I **5** **6**

a : $R^1 = R^2 = H$ **b** : $R^1 = H$ $R^2 = n$-Pr **c** : $R^1 = n$-Pr $R^2 = H$

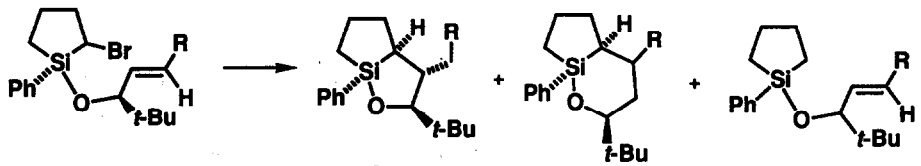
i) *n*-Bu_3SnH - Et_3B or Et_3B ii) *n*-Bu_3SnH iii) H_2O_2-KF,$KHCO_3$ iv) Ac_2O-pyridine

The cyclization of 2-bromo-1-silacyclopentanes prepared from secondary allylic alcohols proved to proceed with high stereospecificity. An addition of $LiCHBr_2$ to allyloxysilacyclobutane **19d** (See *infra*) provided a mixture of two diastereomers[8] **7a** and **11a** in a 1:1 ratio which were separated each other by silica-gel column chromatography. Treatment of a benzene solution of **7a** with n-Bu_3SnH-Et_3B at 25 °C gave 1-sila-2-oxabicyclo[3.3.0]octane **8a** and 1-sila-2-oxabicyclo[4.3.0]nonane **9a** in 65% and 9% yields. In addition to the formation of cyclized product, the reduction product **10a** was obtained in 15% yield. In contrast, the diastereomer **11a** provided **12a** (41%), **13a** (9%), and **10a** (16%) upon treatment with n-Bu_3SnH-Et_3B. In these reactions, the 5-exo mode cyclization predominated, but the 6-endo mode could also be observed. Meantime, cyclization reaction of **7b** or **11b** gave only 5-exo mode product, **8b** or **12b**.



7a R = H **8a** 65% **9a** 9% **10a** 15%

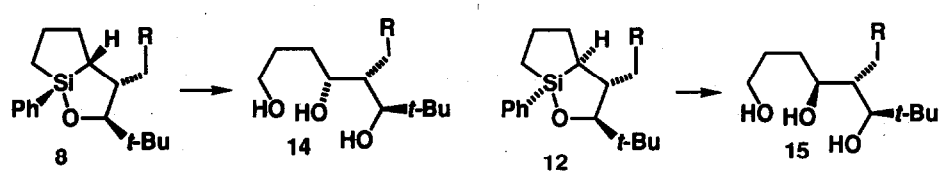
7b R = CH_3 **8b** 49% **9b** 0% **10b** 20%



11a R = H **12a** 41% **13a** 9% **10a** 16%

11b R = CH_3 **12b** 50% **13b** 0% **10b** 31%

It is worth noting that the product **8a**, **8b**, **12a**, or **12b** was obtained as a single stereoisomer without any contamination by other diastereomers. Whereas the oxidative cleavage of carbon-silicon bonds of **8a** with H_2O_2-KF-$KHCO_3$ provided (4R*,5S*,6S*)-5,7,7-trimethyloctane-1,4,6-triol **14a**,[9] oxidation of **12a** afforded a stereoisomeric (4S*,5S*,6S*)-triol **15a**.

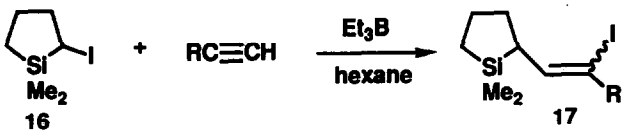


8 **14** **12** **15**

a : R = H **b** : R = CH_3 **a** : R = H **b** : R = CH_3

Intermolecular reaction of 2-halo-1-silacyclopentane with carbon-carbon multiple bonds was examined. An addition of Et_3B to a hexane solution of 1,1-dimethyl-2-iodo-1-silacyclopentane **16** and phenylacetylene or trimethylsilylacetylene provided iodoalkene **17a** (E:Z = 24:76) or **17b** (E:Z = 13:87) in 41% or 55% yield. The reaction of **16** with other carbon-carbon multiple bonds such as 1-dodecyne, methyl acrylate, and 1-dodecene resulted in a recovery of the starting material along with reduced 1,1-dimethyl-1-

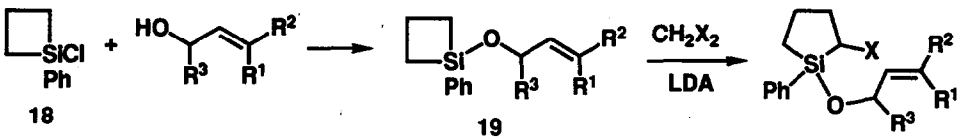
silacyclopentane.



16 17

a : R = Ph 41% b : R = $SiMe_3$ 55%

1-Allyloxy-2-halo-1-silacyclopentanes were prepared as follows. Treatment of 3-chloropropyldichlorophenylsilane with magnesium gave 1-chloro-1-phenyl-1-silacyclobutane **18** (bp 54 °C/0.5 Torr, 59% isolated yield) according to the reported procedure.[11] An addition of allylic alcohols to a benzene solution of **18** in the presence of pyridine afforded allyloxysilacyclobutanes **19**. Treatment of **19** with lithium carbenoid $LiCHBr_2$ or $LiCHI_2$ provided the corresponding silacyclopentanes **1**, **2**, **7**, and **11**.[12]



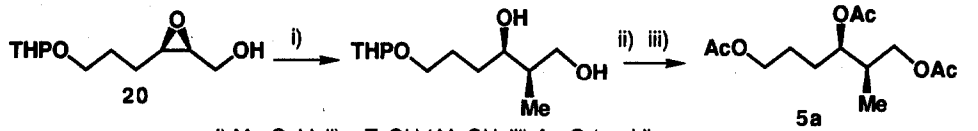
18 19

a: $R^1 = R^2 = R^3 = H$	73%	X = I 47%	X = Br 44%
b: $R^1 = H$ $R^2 = n$-Pr $R^3 = H$	82%	X = I 58%	X = Br 66%
c: $R^1 = n$-Pr $R^2 = R^3 = H$	77%	X = I 73%	X = Br 41%
d: $R^1 = R^2 = H$ $R^3 = t$-Bu	48%		X = Br 74%
e: $R^1 = H$ $R^2 = CH_3$ $R^3 = t$-Bu	66%		X = Br 76%

References and Notes

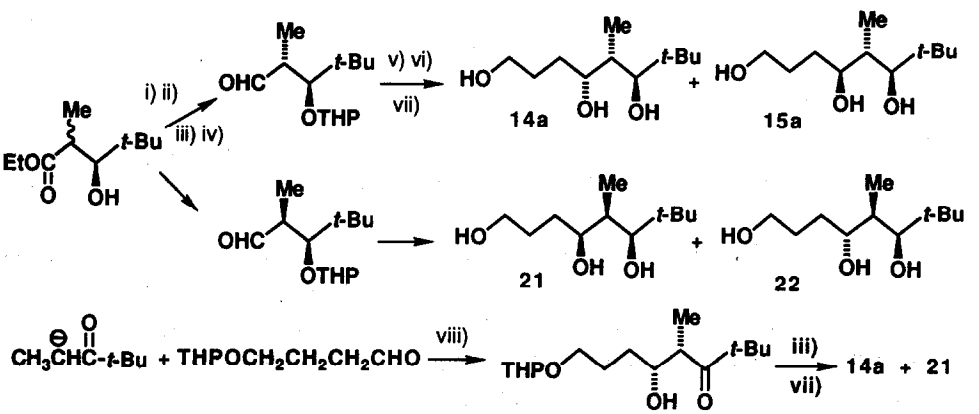
1. Giese, B. *Radicals in Organic Synthesis: Formation of Carbon-Carbon Bonds;* Pergamon Press: Oxford, 1986, pp. 141-209; Hart, D. J. *Science* **1984**, *223*, 883-887; Stork, G. *Bull. Chem. Soc. Jpn.* **1988**, *61*, 149-154.
2. Nishiyama, H.; Kitajima, T.; Matsumoto, M.; Itoh, K. *J. Org. Chem.* **1984**, *49*, 2298-2300; Stork, G.; Kahn, M. *J. Am. Chem. Soc.* **1985**, *107*, 500-501; Wilt, J. W. *Tetrahedron* **1985**, *41*, 3979-4000; Magnol, E.; Malacria, M. *Tetrahedron Lett.* **1986**, *27*, 2255-2256; Stork, G.; Sofia, M. J. *J. Am. Chem. Soc.* **1986**, *108*, 6826-6828; Koreeda, M.; George, I. A. *ibid.* **1986**, *108*, 8098-8100; Tamao, K.; Maeda, K.; Yamaguchi, T.; Ito, Y. *ibid.* **1989**, *111*, 4984-4985.
3. Matsumoto, K.; Oshima, K.; Utimoto, K. *Tetrahedron Lett.* **1990**, *31*, 6055-6058.
4. Miura, K.; Ichinose, Y.; Nozaki, K.; Fugami, K.; Oshima, K.; Utimoto, K. *Bull. Chem. Soc. Jpn.* **1989**, *62*, 143-147. We thank Tosoh Akzo Co. for a gift of Et_3B.
5. The assignment of the stereochemistry of the triacetate **5a** and **6a** was performed as follows. Treatment of cis epoxy alcohol **20** with Me_2CuLi (Johnson, M. R.; Nakata, T.; Kishi, Y. *Tetrahedron Lett.* **1979**, 4343-4346) followed by removal of hydroxy protective group and acetylation provided erythro triacetate **5a** (For nomenclature of threo and erythro, see: Noyori, R.; Nishida, I.; Sakata, J. *J. Am. Chem. Soc.* **1981**, *103*, 2106-2108) which was identical with a major product. **5a**: Bp 77.5 °C/0.5 Torr;

IR (neat) 2960, 1738, 1369, 1235, 1038, 966 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.96 (d, J = 7.0 Hz, 3H), 1.53–1.77 (m, 5H), 2.06 (s, 3H), 2.07 (s, 6H), 3.89 (dd, J = 6.4, 11.0 Hz, 1H), 4.00 (dd, J = 7.1, 11.0 Hz, 1H), 4.07 (t, J = 6.2 Hz, 2H), 4.90–5.05 (m, 1H); ^{13}C NMR ($CDCl_3$) δ 11.33, 20.82, 20.87, 20.92, 24.89, 27.93, 35.74, 63.91, 65.70, 73.10, 170.58, 170.97. Found: C, 56.72; H, 8.12%. Calcd for $C_{13}H_{22}O_6$: C, 56.92; H, 8.09%. Following the same procedure, threo triacetate **6a** was prepared starting from the corresponding trans epoxy alcohol. **6a**: Bp 77.5 °C/0.5 Torr; IR (neat) 2960, 1738, 1369, 1235, 1038, 966 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.97 (d, J = 7.0 Hz, 3H), 1.52–1.73 (m, 5H), 2.06 (s, 3H), 2.07 (s, 6H), 3.95–4.10 (m, 4H), 4.90–4.98 (m, 1H); ^{13}C NMR ($CDCl_3$) δ 13.46, 20.82, 20.92, 20.95, 24.53, 27.66, 35.96, 64.02, 65.55, 74.27, 170.58, 171.12.



i) Me_2CuLi ii) p-TsOH / MeOH iii) Ac_2O / pyridine

6. Tamao, K.; Ishida, N.; Kumada, M. *J. Org. Chem.* **1983**, *48*, 2120–2122. 1-Sila-2-oxabicyclo-[3.3.0]octane **3** and **4** were relatively unstable and oxidized directly without purification.
7. Curran, D. P. *Synthesis* **1988**, 417–439; 489–513.
8. Bromine was introduced stereoselectively, but the stereochemistry could not be determined.
9. The stereochemical assignment of **14a** and **15a** was performed by the comparison with authentic samples of four possible diastereomers **14a** (4R*,5S*,6S*), **15a** (4S*,5S*.6S*), **21** (4S*,5R*,6S*), **22** (4R*,5R*,6S*) prepared as shown below.



i) separation by silica-gel column chromatography ii) dihydropyran, p-TsOH iii) $LiAlH_4$
iv) DMSO-$(COCl)_2$, Et_3N v) $LiC{\equiv}CCH_2OTHP$ vi) H_2, PtO_2 vii) p-TsOH / MeOH viii) See ref 10

10. Kleschick, W. A.; Buse, C. T.; Heathcock, C. H. *J. Am. Chem. Soc.* **1977**, *99*, 247–248.
11. Laane, J. *J. Am. Chem. Soc.* **1967**, *89*, 1144–1147.

12. Financial supports by the Asahi Glass Foundation for Industrial Technology and the Ministry of Education, Science and Culture of Japan (Grant-in-Aid for Scientific Research in Priority Areas #04217214) are acknowledged.

(Received in Japan 20 July 1992)