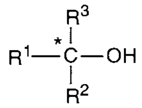
Synthesis and Optical Resolution of Novel Chiral Silanols

Atsunori Mori,* Fumihiko Toriyama, Hiroshi Kajiro, Kazunori Hirabayashi, Yasushi Nishihara, and Tamejiro Hiyama†
Research Laboratory of Resources Utilization, Tokyo Institute of Technology, Nagatsuta, Yokohama 226-8503
†*Department of Material Chemistry, Graduate School of Engineering, Kyoto University, Yoshida, Sakyo-ku, Kyoto 606-8501*

(Received March 24, 1999; CL-990206)

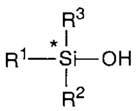
Silanols bearing an asymmetric center on silicon, methyl(2-phenylethenyl)(3,3,3-trifluoropropyl)silanol and methyl(phenyl)(vinyl)silanol are synthesized by alkylative cleavages of cyclic siloxanes with an organolithium. Optical resolution of their enantiomers is performed by HPLC with a chiral stationary phase column. Optical characters of thus separated enantiomers are also examined.

In contrast with numerous studies on chiral alcohols of type **1**, little has been remarked concerning *chiral silanols* **2**, the silicon analog of **1**.[1,2] Despite the comparable interest as an analogous 14 group element, silanols have not extensively been studied due to their difficulties, in synthesis, isolation and purification during which the compounds are easily converted to the corresponding siloxanes via self condensation thermally or in the presence of a trace amount of acid or base.



$$R^1\text{—}\overset{R^3}{\underset{R^2}{\overset{*}{C}}}\text{—}OH$$

1

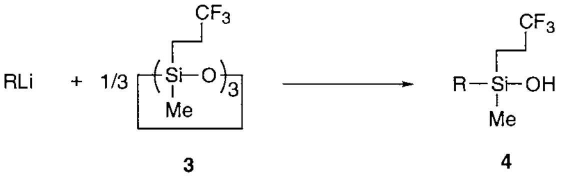


$$R^1\text{—}\overset{R^3}{\underset{R^2}{\overset{*}{Si}}}\text{—}OH$$

2

However, our recent success in a facile synthesis of silanols via alkylative cleavage of cyclic siloxanes with an organolithium reagent and successive aqueous work-up[3] encouraged us to study chemistry of chiral silanols bearing an asymmetric center on the silicon atom. We herewith report i) a synthesis of novel chiral silanols by alkylative cleavage of a cyclic siloxane with different substituents on silicon, ii) optical resolution of the chiral silanol by HPLC with a chiral column, and iii) preliminary studies on optical characters of the chiral silanols.

A cyclic trisiloxane we have initially chosen as a starting material is 1,3,5-tris(3,3,3-trifluoropropyl)-1,3,5-trimethylcyclotrisiloxane (**3**: D_3^F). The siloxane was treated with 3 mol amounts of an aryl- or alkenyllithium in diethyl ether at 0 °C. The mixture was gradually raised to room temperature and stirred for 15-28 h. Aqueous work-up followed by bulb-to-bulb distillation under reduced pressure at 100-150 °C afforded the corresponding aryl- or alkenylsilanols **4a**-**d** in 55-84% yield as represented in Scheme 1.[4,5] During these procedures no considerable extent of condensation to the corresponding disiloxane was observed.



R= C_6H_5- (**4a**) : 84%, $C_6H_5CH{=}CH$- (**4b**): 55%
1-Naphthyl (**4c**): 66%, 2-Naphthyl (**4d**): 74%

Scheme 1.

HPLC analysis of the silanols obtained was carried out using a column with a chiral stationary phase, Daisel Chiralpak AD, Chiralcel OD-H or OB. Using these columns, several silanols resulted in good separation using hexane/ethanol or hexane/2-propanol as an eluent.[6] Figure 1 shows the HPLC profile of **4b** as a representative example indicating clear separation.

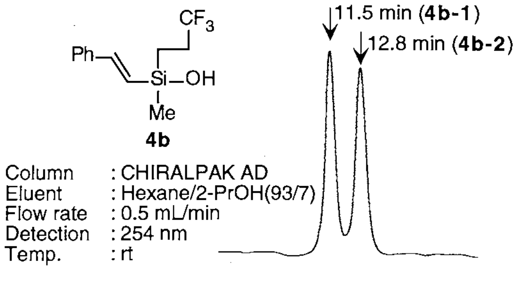


Figure1. HPLC profile of **4b**.

Silanol **4b** whose enantiomers exhibited good separation by analytical HPLC was subjected to optical resolution using a chiral column of id = 10 mm (25 cm length, flow rate: 2.4 mL·min^{-1}). The separation was carried out with 77.4 mg of racemic **4b** in 50 portions to give 29.6 and 30.0 mg of the corresponding enantiomers, respectively. Silanol from the former elute (**4b-1**) showed optical rotation of $[\alpha]^{26}_D = +15.8$ (c 1.4, THF), whereas **4b-2**, from the latter; $[\alpha]^{26}_D = -15.6$ (c 1.4, THF). Enantiomeric purities of both separated enantiomers

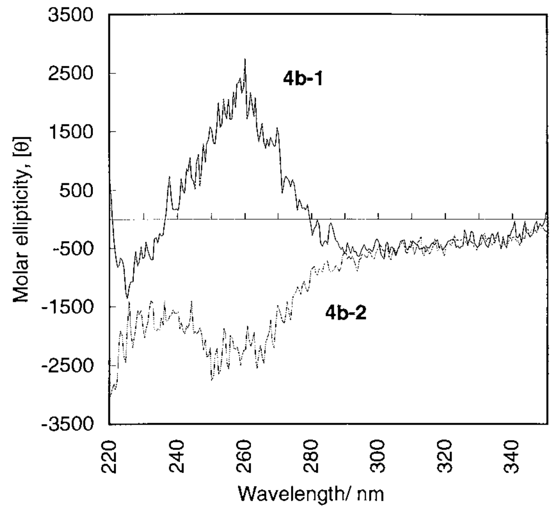
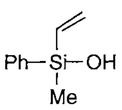


Figure 2. CD spectra of **4b-1** and **4b-2**.

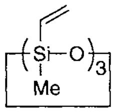
were confirmed to be >99% by HPLC analyses.

Figure 2 shows CD spectra of **4b-1** and **4b-2**. The spectra were measured in THF solutions of 4.14×10^{-4} mol·L^{-1} and 4.61×10^{-4} mol·L^{-1}, respectively. The former, **4b-1** showed (+)-ellipticity, whereas the latter, **4b-2** being (-). The molar ellipticities $[\theta]$ whose maxima exhibited good correspondence with λ_{max} values of UV spectra[5] were around 2500 deg·cm^2·dmol^{-1}.

In addition, methyl(phenyl)(vinyl)silanol (**5**), whose racemic mixture was previously shown to be prepared by the cleavage of 1,3,5-trimethyl-1,3,5-trivinylcyclotrisiloxane (**6**, D_3^V) with phenyllithium and used as a substrate for the Simmons-Smith cyclopropanation,[3b] was also found to be separated with Daicel Chiralpak AD column to give the corresponding enantiomers using hexanes/ethanol = 90:10 (v/v) as an eluent; the former, **5-1** being $[\alpha]^{26}_D = -4.9$ (c 4.8, EtOH), the latter, **5-2**: $[\alpha]^{26}_D = +5.0$ (c 4.8, EtOH). It is noteworthy that the measurement of the rotation in hexane as a solvent exhibited the opposite signs to that in ethanol, **5-1**; (+) whereas **5-2**; (-),[7] as occasionally observed in cases of several optically active alcohols.[8]



5



6

In conclusion, chiral silanols with a silicon-centered chirality were synthesized by the alkylative cleavage of cyclic siloxanes **3** and **6** and resolved by preparative HPLC with a chiral stationary phase column. Studies on the determination of the absolute configuration, reactions of the chiral silanols involving a chirality transfer process from silicon to carbon are in progress.

The authors thank Professor Katsuhiko Tomooka of Tokyo Institute of Technology for fruitful discussion. This work was supported by Yamada Science Foundation. Organosilicon compounds were kindly donated by Shin-Etsu Chemical Co. Ltd.

References

1 a) R. Tacke, H. Linoh, L. Ernst, U. Moser, E. Mutschler, S. Sarge, H. K. Cammenga, and G. Lambrecht, *Chem. Ber.*, **120**, 1229 (1987). b) K. Yamamoto, Y. Kawanami, and M. Miyazawa, *J. Chem. Soc., Chem. Commun.*, **1993**, 436. c) B. Feibush, C. L. Woolley, and V. Mani, *Anal. Chem.*, **65**, 1130 (1993). d) K. Tomooka, A. Nakazaki, and T. Nakai, 74th Annual Meeting of Chemical Society of Japan, Tokyo, March 1998, Abstr., No 1D648.

2 Concerning silicon centered chirality other than silanol, for example: a) L. H. Sommer, C. L. Frye, G. A. Parker, and K. W. Michael, *J. Am. Chem. Soc.*, **86**, 3271 (1964). b) D. Terunuma, N. Yamamoto, H. Kizaki, and H. Nohira, *Nippon Kagaku Kaishi*, **1990**, 451. c) Y. Li and Y. Kawakami, *Macromolecules*, **31**, 5592 (1998). d) T. Ohta, M. Ito, A. Tsuneto, and H. Takaya, *J. Chem. Soc., Chem. Commun.*, **1994**, 2525. e) K. Kobayashi, T. Kato, M. Unno, and S. Masuda, *Bull. Chem. Soc. Jpn.*, **70**, 1393 (1997).

3 a) K. Hirabayashi, E. Takahisa, Y. Nishihara, A. Mori, and T. Hiyama, *Bull. Chem. Soc. Jpn.*, **71**, 2409 (1998). b) K. Hirabayashi, A. Mori, and T. Hiyama, *Tetrahedron Lett.*, **37**, 461 (1997). See also: c) K. Takaku, H. Shinokubo, and K. Oshima, *Tetrahedron Lett.*, **37**, 6781 (1996). d) T. Akiyama and S. Imazeki, *Chem. Lett.*, **1997**, 1077. e) T. H. Chan, L. M. Chen, and D. Wang, *J. Chem. Soc., Chem. Commun.*, **1988**, 1280.

4 a) A. Mori, T. Hishida, Y. Soga, and Y. Kawakami, *Chem. Lett.*, **1995**, 107. b) A. Mori, H. Sato, K. Mizuno, T. Hiyama, K. Shintani, and Y. Kawakami, *Chem. Lett.*, **1996**, 517.

5 Methyl((*E*)-2-phenylethenyl)(3,3,3-trifluoropropyl)silanol (**4b**): Bp 120 °C (bath temp, 0.3 Torr); IR (neat) 3300 (br), 3027, 2964, 1605, 1574, 1266, 1208, 1125, 1067, 899, 851 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.34 (s, 3H), 0.97 (m, 2H), 1.79 (s, 1H), 2.15 (m, 2H), 6.39 (d, J = 19 Hz, 1H), 7.04 (d, J = 19 Hz, 1H), 7.25-7.39 (m, 3H), 7.43-7.49 (m, 2H); ^{13}C NMR ($CDCl_3$) δ -1.8, 8.6, 28.0 (q, J = 30 Hz), 124.5, 126.6, 127.7 (q, J = 276 Hz), 128.6, 128.8, 137.4, 146.7; ^{19}F NMR ($CDCl_3$) δ -69.01 (t, J = 10 Hz); UV (THF) λ_{max} = 257 nm (ε: 20000); Anal. Found: C, 55.56; H, 5.65%. Calcd for $C_{12}H_{15}F_3OSi$: C, 55.36; H, 5.81%.

6 For **4b**: t_Rs = 11.5 and 12.8 min (hexane/2-propanol = 93:7, flow rate 0.5 mL/min, AD); **4c**: t_Rs = 15.5 and 16.7 min (hexane/2-propanol = 93:7, flow rate 0.5 mL/min, OD-H); **4d**: t_Rs = 16.6 and 17.7 min (hexane/2-propanol = 93:7, flow rate 0.5 mL/min, OD-H). The silanol, **4a** was inseparable under several attempted conditions.

7 The former, **5-1**: $[\alpha]^{26}_D = +1.9$ (c 2.1, hexane); the latter, **5-2**: $[\alpha]^{25}_D = -1.9$ (c 2.1, hexane).

8 For example: G. E. Keck and D. Krishnamurthy, *Org. Synth.*, **75**, 12 (1998).