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Regio- and stereospecific cleavage of α,β-epoxysilanes with lithium phenylsulfide

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Abstract

Trimethyl- or dimethylphenylsilylepoxides react with lithium phenylsulfide to give regio- and stereodefined vinyl sulfides resulting from α-ring opening and Peterson elimination. When the epoxide bears the bulky *tert*-butyldiphenylsilyl group the reaction is more puzzling. Depending on the β-substitution and the presence of aluminium chloride, we obtained silyl enol ethers, α-silylaldehydes or α-hydroxy-β-phenylthiosilanes, all resulting from β-opening.

The considerable importance of regio- and stereospecificity to organic synthesis makes the continued search for such methodology a high priority challenge. α,β-Epoxysilanes are interesting synthons because they can serve as versatile *Z* or *E* vinyl cation equivalents. They undergo regio- and stereospecific α-opening by a variety of nucleophiles to give diastereomerically pure β-hydroxysilanes,[1,2] which experience *syn* or *anti* β-elimination[3] providing a convenient route to a number of heterosubstituted olefins of known stereochemistry.[4]

We have recently reported[5] that dimethylphenyl- and *tert*-butyldiphenylsilylepoxides react with lithium diphenylphosphide and then with methyl iodide giving regio- and stereodefined vinylphosphonium iodides resulting from α-opening and subsequent Peterson elimination. When the methylation was omitted vinylphosphines were isolated. Otherwise, when an α-hindered *tert*-butyldiphenylsilylepoxide bore a β-phenyl group we obtained stereospecifically the corresponding silyl enol ether by β-opening followed by the Brook rearrangement with simultaneous *anti*-elimination of methyldiphenylphosphine.

We have now found that silylepoxides prepared by epoxidation[6,7] of vinylsilanes, obtained, in turn, by dimethylphenylsilyl-[8] and *tert*-butyldiphenylsilylcupration[7] from alkynes, react with lithium phenylsulfide in THF[9] to give different products depending on the nature of the silyl group and also of the substitution pattern of the epoxides (Scheme 1). All new compounds showed satisfactory spectroscopic and analytical data.[10]

Trimethyl- or dimethylphenylsilylepoxides **1a**–**d** and **1g** react under mild conditions (−78°C→0°C, when R=H; −78°C→rt, when R=Bu, Ph), and in short time reactions (1–4 h), providing regio- and

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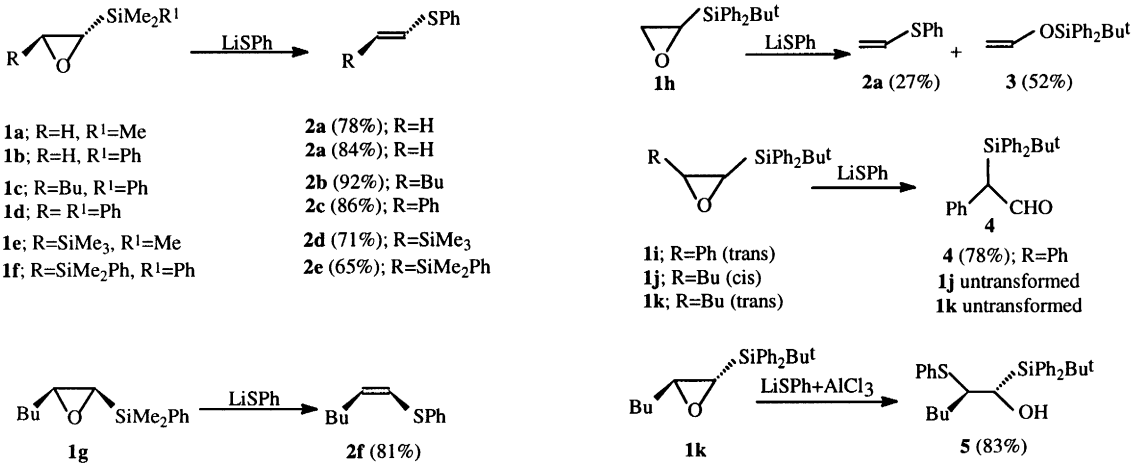
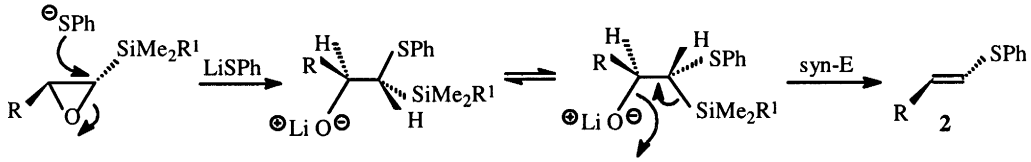


Scheme 1.

stereodefined[11] vinyl thioethers **2a**–**c** and **2f**, in one step[12] and with good-to-excellent yields. α,β-Bis-silylepoxides **1e** and **1f** are shown to be less reactive. In order to obtain good yields of interesting β-silylvinyl thioethers **2d** and **2e**, it was necessary to heat the reaction mixture in THF at reflux for longer reaction times (15–20 h). Fortunately, under these conditions the *E* geometry of **2d** and **2e** is retained.

The regio- and stereochemical outcome is consistent with an α-opening with inversion of configuration followed by a *syn* β-elimination process (Scheme 2).

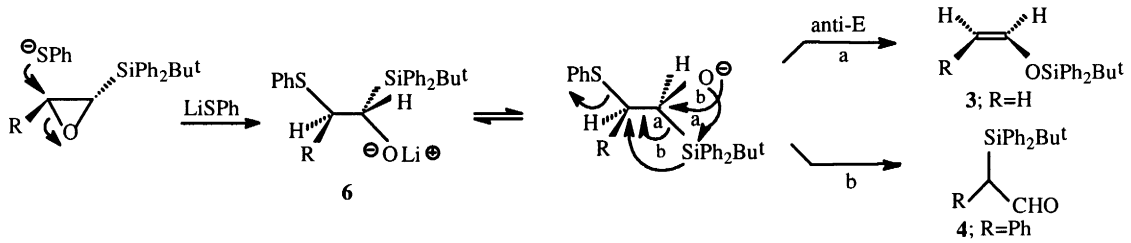


Scheme 2.

On the other hand, the bulky *tert*-butyldiphenylsilyl group changes the regioselectivity and introduces useful differences in the chemistry of the silylepoxides. The behaviour and reactivity of *tert*-butyldiphenylsilylepoxides **1h**–**k** toward lithium phenylsulfide depends on the β-substitution type. Thus, the β-unsubstituted silylepoxide **1h** is predominantly attacked by sulfide at the β-position.[13] In its reaction with lithium phenylsulfide it affords a 1:2 mixture of the vinyl thioether **2a**, resulting from α-attack (Scheme 2) and the silyl enol ether **3**. The latter is presumably formed by β-opening followed by Brook rearrangement of the intermediate **6** with *anti*-elimination of the β leaving group (phenylthio)[14] (Scheme 3, path a). Although the silyl enol ether **3** has no stereochemistry, an *anti* stereochemistry was first demonstrated by Hudrlik et al.[15] for this elimination. Moreover, the same mechanism and stereochemistry has been proposed by us[5] to explain the formation of the *Z* silyl enol ether resulting from β-opening of *trans* 1-*tert*-butyldiphenylsilyl-2-phenyloxirane with lithium diphenylphosphide.

Likewise, the formation of α-silylaldehyde **4** resulting from β-phenylsilylepoxide **1i** may be logically explained via the same intermediate **6** by silicon migration to the β-carbon with concomitant loss of the β-leaving group[16] (Scheme 3, path b).

Both *cis* and *trans* β-butylsilylepoxides **1j** and **1k** are recovered untransformed even after prolonged heating with lithium phenylsulfide in THF at reflux. Nevertheless, when aluminium chloride is added to the mixture of **1k** and lithium phenylsulfide, the *erythro* α-hydroxysilane **5,** resulting from β-attack on the backside, is isolated. In this case, ring β-opening would be expected to be governed by the relative



Scheme 3.

stability of an incipient β-silyl carbocation generated by the initial electrophile coordination. In these conditions, the intermediate similar to **6** (probably an aluminium α-alkoxysilane) does not undergo Brook rearrangement and affords **5** in the final hydrolysis.

In summary, since epoxysilanes have been obtained by epoxidation of vinylsilanes, the overall process using trimethyl- or dimethylphenylsilyl derivatives provides a general regio- and stereospecific method for converting vinylsilanes into vinylsulfides with retention of configuration. Other methods for preparing vinylsulfides, such as addition of thiols[17] to alkynes or reactions of carbonyl compounds with sulfur-modified Wittig or related reagents,[18] are not stereospecific. Apart from the known applications of vinyl thioethers[19] we should point out the special utility of sulfur and silicon bifunctionalized olefins **2d** and **2e** in organic synthesis.[20] For example, they serve as reagents for thiophenyl-functionalized cyclopentenone annulations via Nazarov cyclizations.[21]

On the other hand, all β-opening products obtained starting from *tert*-butyldiphenylsilylepoxides are of great synthetic utility. The silyl enol ether is one of the more versatile functional groups.[22] The formation of α-*tert*-butyldiphenylsilyl aldehyde **4** is particularly noteworthy since attempts to isolate α-trimethylsilyl and α-dimethylphenylsilyl aldehydes were unsuccessful.[23] Moreover, they are useful reagents for the stereoselective synthesis of α-vinylcarbonyl compounds.[24] Finally, the synthetic possibilities of β-sulfur *gem*-hydroxysilanes as precursors of silyl enol ethers, β-sulfur acylsilanes, β-silyl sulfones, etc, will be the subject of later research.

Acknowledgements

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References

1. (a) Hudrlik, P. F.; Hudrlik, A. M.; Rona, R. J.; Misra, R. N.; Withers, G. P. *J. Am. Chem. Soc.* **1977**, *99*, 1993. (b) Hudrlik, P. F.; Peterson, D.; Rona, R. J. *J. Org. Chem.* **1975**, *40*, 2263.
2. Fleming, I.; Lawrence, N. J. *J. Chem. Soc., Perkin Trans. 1* **1992**, 3309.
3. For reviews, see: Ager, D. J. *J. Org. React.* **1990**, *38*, 1, and *Synthesis* **1984**, 384.
4. Hudrlik, P. F.; Peterson, D. *Tetrahedron Lett.* **1974**, 1133; *J. Am. Chem. Soc.* **1975**, *97*, 1464.
5. Cuadrado, P.; González-Nogal, A. M. *Tetrahedron Lett.* **1997**, *38*, 8117.
6. Fleming, I.; Newton, T. W. *J. Chem. Soc., Perkin Trans. 1* **1984**, 119.
7. Barbero, A.; Cuadrado, P.; Fleming, I.; González-Nogal, A. M.; Pulido, F. J.; Sánchez, A. *J. Chem. Soc., Perkin Trans. 1* **1995**, 1525.
8. Fleming, I.; Newton, T. W.; Roessler, F. *J. Chem. Soc., Perkin Trans. 1* **1981**, 2527.
9. General procedure: To a stirred THF solution of lithium phenylsulfide [prepared from benzenethiol (0.1 ml, 1 mmol) and butyllithium (0.625 ml, 1.6 M solution in hexane, 1 mmol) in THF (5 ml) at −78°C under an N_2 atmosphere for 10 min] was added dropwise a solution of epoxysilane (1 mmol) in THF (5 ml). Depending on the reactivity of the silylepoxide, the

resulting solution was allowed to warm up to 0°C for **1a** and **1b**, to room temperature for **1c**, **1d**, **1g** and **1i**, or heated at reflux for **1e** and **1f**. The reaction mixture was stirred at this temperature until TLC indicated complete reaction. Ammonium chloride solution was added and the mixture was extracted with ether, washed with 5% aqueous sodium hydroxide solution, dried ($MgSO_4$) and chromatographed.

10. Selected spectroscopy data: compound **2e**:^{1}H NMR ($CDCl_3$) δ 7.54–7.51 (m, 2H, PhSi), 7.43–7.27 (m, 8H, PhSi and PhS), 6.75 (d, 1H, J=18.0, =CHS), 5.99 (d, 1H, J=18.0, =CHSi), 0.36 (s, 6H, Me_2Si); ^{13}C NMR ($CDCl_3$) δ 140.70 (=CHS), 139.74, 129.28, 127.45, 127.12 (PhS), 137.03, 133.01, 129.06, 127.74 (PhSi), 126.05 (=CHSi), 0.92 (Me_2Si). Compound **3**: ^{1}H NMR ($CDCl_3$) δ 7.83–7.19 (m, 10H, PhSi), 6.44 (dd, 1H, J=13.5, 5.8, =CHOSi), 4.56 (d, 1H, J=13.5, =CH *cis* to OSi), 4.14 (d, 1H, J=5.8, =CH *trans* to OSi), 1.18 (s, 9H, Me_3CSi); ^{13}C NMR ($CDCl_3$) δ 146.47 (=CHOSi), 135.75, 132.45, 129.79, 127.41 (PhSi), 94.74 (=CH_2), 26.49 (*Me*CSi), 19.05 (CSi). Compound **4**: IR (CCl_4)/cm^{-1} 1700 (C=O), 1100 (SiPh); ^{1}H NMR ($CDCl_3$) δ 9.86 (d, 1H, J=3.5, HC=O), 7.68–6.96 (m, 15H, PhC, Ph_2Si), 4.48 (d, 1H, J=3.5, C*H*CHO), 0.97 (s, 9H, ^{t}BuSi); ^{13}C NMR ($CDCl_3$) δ 200.09 (HC=O), 136.69, 132.27, 131.52, 129.90, 129.76, 127.79, 127.62 (Ph_2Si), 134.11, 129.47, 128.39, 126.18 (Ph), 53.68 (*C*HCHO), 27.72, 19.61 (^{t}Bu); MS *m/z* 358 (M$^+$, 17%), 301 (M−^{t}Bu, 18), 281 (M−Ph, 59), 239 (^{t}BuPh$_2$Si$^+$, 100). Compound **5**: IR (film)/cm^{-1} 3450 br (OH), 1100 (SiPh); ^{1}H NMR ($CDCl_3$) δ 7.82–7.35 (m, 15H, Ph_2Si, PhS), 4.28 (d, 1H, J=3.8, C*H*OH), 3.72 (m, 1H, CHS), 1.67 (s br, 1H, OH), 1.35 (m, 4H, CH_2–CH_2), 1.16 (s, 9H, ^{t}BuSi), 1.06 (m, 2H, CH_2), 0.71 (t, 3H, J=7.1, Me); ^{13}C NMR ($CDCl_3$) δ 136.19, 132.73, 129.77, 127.48 (PhSi), 136.67, 132.03, 129.61, 127.87 (PhS), 72.73 (CHOH), 55.38 (CHS), 34.06, 27.90, 22.18, 13.81 (Bu), 28.54, 18.85 (^{t}BuSi).
11. Although the overall process is stereospecific, the initial *Z* or *E* vinyl thioether undergoes postisomerization in solution in the presence of catalytic amounts of benzenethiol. To avoid this problem, the hydrolyzed reaction mixtures were washed with 5% aqueous sodium hydroxide solution.
12. Unpublished work by Hudrlik and Kulkarni (Hudrlik, P. F.; Hudrlik, A. M.; In *Advances in Silicon Chemistry*; Larson, G. L., Ed. α,β-Epoxysilanes. JAI Press: London, 1993; Vol. 2, p. 55) involving two steps (ring opening by PhSH/alumina and elimination by KH/THF or $BF_3 \cdot Et_2O$). We have found only one example of the formation of a *trans* vinyl sulfide resulting from the α-opening of a *trans* trimethylsilylepoxide with lithium phenylsulfide: Okamoto, S.; Yoshino, T.; Tsujiyama, H.; Sato, F. *Tetrahedron Lett*. **1991**, *32*, 5793.
13. Regiospecific β-opening of *tert*-butyldiphenylsilylepoxides has been observed by us in their reactions with methyllithium at −25°C (Ref. 7) and with lithium diphenylphosphide (Ref. 5).
14. This result is different from the single example described of β-opening using lithium phenylsulfide: Lipshutz, B. H.; Lindsley, C. Susfalk, R.; Gross, T. *Tetrahedron Lett*. **1994**, *35*, 8999. They obtained the β-sulfur α-silyl alcohol resulting from β-opening of α-epoxytriisopropylsilane without Brook rearrangement.
15. Hudrlik, P. F; Hudrlik, A. M.; Kulkarni, A. K. *J. Am. Chem. Soc.* **1985**, *107*, 4260.
16. This pathway has also been observed in the reactions of acylsilanes with diazomethane: Brook, A. G.; Limburg, W. W.; MacRae, D. M.; Fieldhouse, S. A. *J. Am. Chem. Soc*. **1967**, *89*, 4384, and in the reactions of α-chloroacylsilanes with Grignard reagents: Sato, T.; Abe,T.; Kuwajima, I. *Tetrahedron. Lett.* **1978**, 259.
17. Oswald, A. A.; Griesbaum, K.; Hudson Jr., B. E.; Bregman, J. M. *J. Am. Chem. Soc*. **1964**, *86*, 2877.
18. (a) Peterson, D. J. *J. Org. Chem.* **1968**, *33*, 780. (b) Corey, E. J.; Shulman, J. I. *J. Org. Chem.* **1970**, *35*, 777. (c) Carey, F. A.; Court, A. S. *J. Org. Chem.* **1972**, *37*, 939. (d) Trost, B. M.; Keeley, D. E. *J. Am. Chem. Soc*. **1976**, *98*, 248.
19. For a description of the synthetic chemistry of vinylsulfides, see: (a) Trost, B. M.; Lavoie, A. C. *J. Am. Chem. Soc*. **1983**, *105*, 5075, and references cited therein. (b) Rigby, J. H.; Sage, J. M. *J. Org. Chem*. **1983**, *48*, 3591. (c) Morris, T. H.; Smith, E. H.; Walsh, R. *J. Chem. Soc. Chem. Commun.* **1987**, 964.
20. For a review of the chemistry of organosulfur-silicon compounds, see: Block, E.; Aslam, M. *Tetrahedron* **1988**, *44*, 281.
21. Magnus, P.; Quagliato, D. *J. Org. Chem.* **1985**, *50*, 1621.
22. For reviews, see: (a) Fleming, I. *Chimia* **1980**, *34*, 265. (b) Brownbridge, P. *Synthesis* **1983**, 1, 55. (c) Colvin, E. W. *Silicon in Organic Synthesis*; Butterworths: London, 1981; pp. 198–287. (d) Weber, W. P. *Silicon Reagents for Organic Synthesis*; Springer-Verlag: Berlin, 1983; pp. 206–272.
23. Hudrlik, P. F.; Hudrlik, A. M.; Misra, R. N.; Peterson, D.; Withers, G. P.; Kulkarni, A. K. *J. Org. Chem.* **1980**, *45*, 4444.
24. Hudrlik, P. F.; Kulkarni, A. K. *J. Am. Chem. Soc.* **1981**, *103*, 6251.