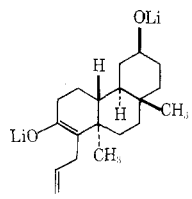
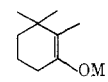
(4) For other methods of kinetic generation of enolates, cf. (a) M. J. Weiss, R. E. Schaub, G. R. Allen, Jr., J. F. Poletto, C. Pidacks, R. B. Conrow, and C. J. Coscia, *Tetrahedron*, **20**, 357 (1964); (b) D. Caine, *J. Org. Chem.*, **29**, 1868 (1964); (c) G. Stork and P. F. Hudrlik, *J. Am. Chem. Soc.*, **90**, 4462 (1968); (d) H. O. House, L. J. Czuba, M. Gall, and H. D. Olmstead, *J. Org. Chem.*, **34**, 2324 (1969); (e) R. K. Boeckman, Jr., *ibid.*, **39**, 275 (1974); (f) R. M. Coates and L. O. Sandefur, *ibid.*, **39**, 275 (1974).

(5) It has recently been suggested[4e] that, when β substitution is present, enolate equilibration, resulting in loss of regiospecificity, will be a major, if not exclusive, process. With reference to enolate **3**, we have found this not to be the case (vide supra).[6] To our knowledge two examples exist (cf. i[2] and ii[4f]) in which α,β,β,β-tetrasubstituted enolates undergo regiospecific alkylation with no enolate equilibration.

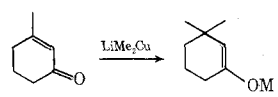


i



ii

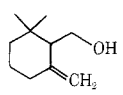
(6) S. Danishefsky and J. Eggler have regiospecifically generated enolate iii from 3-methylcyclohexenone and alkylated exclusively with methyl iodide at C-2 (private communication).



iii

(7) NMR spectra (CCl_4, 60 MHz) and ir spectra were obtained for all intermediates and were in every instance in accord with the assigned structure. Chemical shifts are expressed in parts per million downfield from TMS and coupling constants are expressed in hertz. Satisfactory C, H data and/or high resolution mass spectral data were obtained for all intermediates. Yields are for chromatographically pure substances unless indicated otherwise.

(8) Compound **7** was identical in all respects with a sample prepared from the homoallylic alcohol iv[9] via mesylation, displacement by cyanide ion, and reduction (DIBAL).



iv

(9) We thank Bernard Kane, Glidden Organics, Jacksonville, Fla., for a generous gift of iv.

(10) Treatment of 3-methylcyclohexenone with dimethyloxosulfonium methylide in DMSO afforded cyclopropyl ketone **2** in ~90% yield according to the procedure of E. J. Corey and M. Chaykovsky, *J. Am. Chem. Soc.*, **87**, 1353 (1965).

(11) Reductive alkylation of 2 provided exclusively the C-2 allylated ketone **4** (R = allyl). A solution of 372 mg (3 mmol) of **2** in 12 ml of dry glyme and 0.28 ml (3 mmol) of *tert*-butyl alcohol was added to 63 mg (9 mmol) of lithium in 125 ml of anhydrous liquid ammonia. After 40 min, allyl bromide (2 ml) was added all at once. Evaporation of the ammonia gave the desired ketone **4** (R = allyl) in ~70% yield after chromatography. Similarly, methyl iodide (73%) and methallyl bromide (35%) underwent exclusive C-2 alkylation. No products resulting from enolate equilibration or polyalkylation could be detected by GPC analysis.[5] Attempts to alkylate **3** with methyl bromoacetate resulted in a disappointingly low yield (<10%) of C-2 alkylated product. It is apparent from the above that reductive alkylations can be accomplished regiospecifically, albeit in low yield in some instances, under mild conditions with β-substituted cyclopropyl ketones.

(12) A. W. Herriott and D. Picker, *Tetrahedron Lett.*, 1511 (1974).

(13) R. Greenwald, M. Chaykovsky, and E. J. Corey, *J. Org. Chem.*, **28**, 1128 (1963).

(14) P. A. Grieco, Y. Masaki, and D. Boxler, *J. Am. Chem. Soc.*, **97**, 1597 (1975).

(15) Attempts to prepare **14** directly via the Grignard reagent derived from iodide **11** followed by oxidation were thwarted by our inability to prepare the required Grignard reagent. Presumably this was due to traces of water or peroxides which we were not able to get rid of.

(16) Fellow of the Alfred P. Sloan Foundation, 1974–1976.

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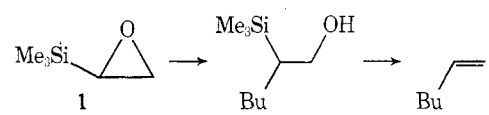
Reactions of α,β-Epoxysilanes with Organocuprate Reagents. A New Stereospecific Olefin Synthesis[1]

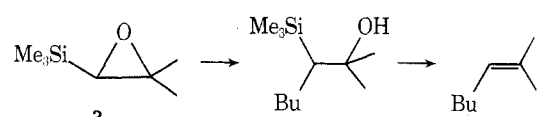
Summary: α,β-Epoxysilanes react with organocuprate reagents in a regio- and stereospecific manner to give good yields of β-hydroxyalkylsilanes, which can be stereospecifically converted to olefins in high yield under mild conditions.

Sir: Olefin-forming elimination reactions of β-hydroxyalkylsilanes have recently been used for the synthesis of a wide variety of compounds;[2] usually isomeric mixtures of cis and trans olefins have been formed. Using a diastereomerically enriched β-hydroxyalkylsilane, we have recently shown that these elimination reactions are stereospecific, and that the acid- and base-induced reactions take opposite stereochemical courses.[3] We now report the first method for the regio- and stereospecific synthesis of β-hydroxyalkylsilanes.[4] This method, coupled with the facile elimination reactions, provides a new, highly stereospecific olefin synthesis of potential generality, and in addition constitutes a definitive proof of the stereochemical course of the elimination reactions of β-hydroxyalkylsilanes.

We have found that the reactions of α,β-epoxysilanes[5] with organocuprate reagents[8] result in regiospecific opening of the epoxide ring to form β-hydroxyalkylsilanes in good yields.[9] Thus, treatment of trimethylsilylethylene oxide (**1**)[10] with lithium di-*n*-butyl cuprate[11] (2 equiv, ether, −25°, 5 hr) produced, in 88% yield, 2-trimethylsilyl-1-hexanol (**2**).[12,13] A similar reaction with epoxide **3**[12] (prepared from isobutenyltrimethylsilane[14] in 79% yield by treatment with *m*-chloroperbenzoic acid in CH_2Cl_2) yielded the alcohol **4**[12,15] in 75% yield.



1 2



3 4

Both silyl alcohols underwent facile β elimination reactions to the corresponding olefins. Treatment of alcohol **2** with potassium hydride (THF, room temperature, 1 hr) produced 1-hexene in 95% yield by VPC; treatment of alcohol **4** with sodium acetate in acetic acid (room temperature, 1 hr) gave 2-methyl-2-heptene in quantitative yield (by NMR; isolated yield 81%).

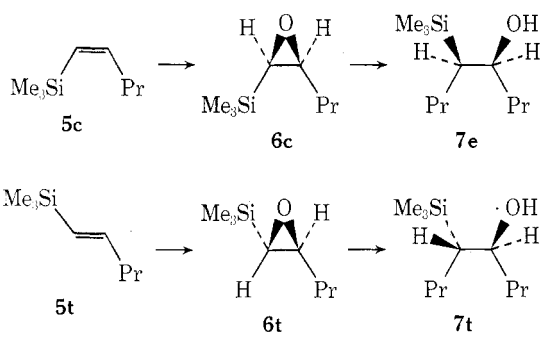
To determine the stereospecificity of these reactions, we have treated both cis and trans epoxysilanes **6c** and **6t** with an organocuprate reagent and have subjected the resulting β-hydroxyalkylsilanes to the conditions which we have previously shown to cause stereospecific β elimination.[3] The epoxides were synthesized in the following manner. *cis*-1-Pentenyltrimethylsilane (**5c**)[12,16,17] (98% cis by VPC) [ir (film) 6.23, 13.1 μm; NMR (CCl_4) δ 5.32 (d, 1 H, J = 14 Hz), 6.16 (m, 1 H)] was treated with *m*-chloroperbenzoic acid in CH_2Cl_2 to give, in 65% yield, the cis epoxide **6c**[12] [NMR (CCl_4) δ 1.90 (d, 1 H, J = 5 Hz), 2.83 (m, 1 H); mass spectrum *m/e* 158.1115 (calcd for $C_8H_{18}OSi$: 158.1126)]. An analogous sequence served to convert *trans*-1-pentenyltrimethylsilane (**5t**)[12,16b,19] [ir (film) 6.20, 10.1 μm; NMR (CCl_4) δ 5.52 (d, 1 H, J = 19 Hz), 6.02 (m, 1 H)] to the trans epoxide **6t**[12] [NMR ($CHCl_3$) δ 1.91 (d, 1 H, J = 4 Hz), 2.73

Table I
Elimination Reactions of the Alcohols 7e (Erythro) and 7t (Threo)

Precursor	Elimination conditions	4-Octene [a] % yield	% cis	% trans
7e	KH/THF, room temp, 1 hr	98	98	2
7e	BF_3·Et_2O/CH_2Cl_2, 0°, 1 hr	102	2	98
7e	H_2SO_4/THF, room temp, 18 hr	96	1	99
7t	KH/THF, room temp, 1 hr	93	*b*	100
7t	BF_3·Et_2O/CH_2Cl_2, 0°, 1 hr	98	99.5	0.5
7t	H_2SO_4/THF, room temp, 18 hr	94	99.5	0.5

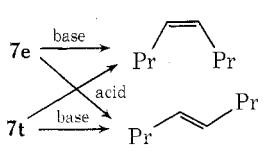
[a] Yields and isomer ratios were determined by VPC using an internal standard. [b] Undetectable; about 0.5% would have been detectable.

(m, 1 H); mass spectrum *m/e* 158.1091 (calcd for $C_8H_{18}OSi$: 158.1126)] in 87% yield.



Treatment of the cis epoxide **6c** with lithium di-*n*-propyl cuprate (ether, −78° warmed to 5° over 4 hr) yielded the erythro alcohol **7e**[20] in 70% yield.[21] In a similar reaction, the trans epoxide **6t** gave the threo alcohol **7t**[20] in 82% yield.

Both alcohols **7e** and **7t** could be converted into either *cis*- or *trans*-4-octene in virtually quantitative yields by proper choice of the conditions used for the elimination reaction. The results are shown in Table I.



This work demonstrates that the opening of α,β-epoxysilanes with organocuprate reagents is both regiospecific and stereospecific, and also proves unequivocally that the stereochemistry of the base-induced β elimination reactions is syn,[22] while that of the acid-catalyzed eliminations is anti. The high stereospecificity of this olefin synthesis and its applicability to mono-, di-, and trisubstituted olefins indicate its synthetic promise. Applications to the stereospecific synthesis of trisubstituted olefins and to the synthesis of insect hormones and pheromones are in progress.

Acknowledgments. We are grateful to Johnson and Johnson for a Fellowship to D.P., and we thank the National Science Foundation, the donors of the Petroleum Research Fund, administered by the American Chemical Society, the Rutgers Research Council, and Research Corporation for partial support of this work. We thank Mr. John C. Hogan for some of the preparations.

References and Notes

(1) Presented in part at the 168th National Meeting of the American Chemical Society, Atlantic City, N.J., Sept 1974, Abstracts, ORGN 99.
(2) (a) D. J. Peterson, *J. Org. Chem.*, **33**, 780 (1968); (b) T. H. Chan and E. Chang, *ibid.*, **39**, 3264 (1974); (c) I. Ojima, M. Kumagai, and Y. Nagai, *Tetrahedron Lett.*, 4005 (1974). For additional examples, see the references cited in ref 3.
(3) P. F. Hudrlik and D. Peterson, *J. Am. Chem. Soc.*, **97**, 1464 (1975).
(4) The few reported stereospecific methods for the preparation of β-hydroxyalkylsilanes are not regiospecific. See (a) H. Gilman, D. Aoki, and D. Wittenberg, *J. Am. Chem. Soc.*, **81**, 1107 (1959); (b) G. J. D. Peddle, *J. Organomet. Chem.*, **14**, 115 (1968); (c) W. K. Musker and G. L. Larson, *Tetrahedron Lett.*, 3481 (1968).
(5) Stork has recently shown that α,β-epoxysilanes are versatile precursors to carbonyl compounds.[6] Reductions of α,β-epoxysilanes by lithium aluminum hydride to give β-hydroxyalkylsilanes are known,[7] but no analogous reactions with organometallic reagents have been reported.
(6) (a) G. Stork and E. Colvin, *J. Am. Chem. Soc.*, **93**, 2080 (1971); (b) G. Stork and M. E. Jung, *J. Am. Chem. Soc.*, **96**, 3682 (1974); see also (c) B.-T. Gröbel and D. Seebach, *Angew. Chem., Int. Ed. Engl.*, **13**, 83 (1974); (d) R. K. Boeckman, Jr., and K. J. Bruza, *Tetrahedron Lett.*, 3365 (1974).
(7) J. J. Eisch and J. T. Trainor, *J. Org. Chem.*, **28**, 2870 (1963).
(8) For previous studies of the reactions of epoxides with organocuprate reagents, see C. R. Johnson, R. W. Herr, and D. M. Wieland, *J. Org. Chem.*, **38**, 4263 (1973), and references cited therein.
(9) Reactions with Grignard and organolithium reagents did not give products of simple ring opening; thus, treatment of epoxide **1** with *n*-butylmagnesium bromide (ether, reflux 15 hr) gave 1-trimethylsilyl-2-hexanol in 65% yield, while *tert*-butyllithium (THF, −78°, 4 hr) gave 1-trimethylsilyl-1-*tert*-butylethylene in 53% yield. The scope and mechanisms of these reactions are under investigation. (P. F. Hudrlik, D. Peterson, and R. Misra, unpublished results.)
(10) (a) V. Bažant and V. Matoušek, *Collect. Czech. Chem. Commun.*, **24**, 3758 (1959); (b) J. W. Wilt, O. Kolewe, and J. F. Kraemer, *J. Am. Chem. Soc.*, **91**, 2624 (1969).
(11) The reagent was prepared from *n*-BuLi and CuI. The reaction could also be effected using catalytic quantities (10%) of CuI.
(12) Satisfactory ir, NMR, and mass spectra were obtained for this compound. For epoxides **3, 6c,** and **6t,** precise molecular weights obtained by high resolution mass spectroscopy confirmed the expected molecular formulas. We have so far had difficulty in obtaining satisfactory combustion analyses for these compounds.
(13) This compound was identical with a sample of **2** prepared independently from vinyltrimethylsilane, by treatment with *n*-PrLi (THF, −20°), followed by paraformaldehyde (80% yield).
(14) A. D. Petrov and G. I. Nikishin, *Dokl. Akad. Nauk SSSR*, **93**, 1049 (1953); *Chem. Abstr.*, **49**, 841*c* (1955).
(15) This compound was identical with a sample of **4** prepared independently from vinyltrimethylsilane, by treatment with *n*-PrLi (THF, −25°), followed by acetone (40% yield).
(16) (a) K. C. Frisch and R. B. Young, *J. Am. Chem. Soc.*, **74**, 4853 (1952); (b) R. A. Benkeser, M. L. Burrous, L. E. Nelson, and J. V. Swisher, *ibid.*, **83**, 4385 (1961).
(17) The cis vinylsilane **5c** was prepared from 1-pentynyltrimethylsilane[16] by treatment with dicyclohexylborane followed by protonolysis with acetic acid.[18]
(18) R. B. Miller and T. Reichenbach, *Tetrahedron Lett.*, 543 (1974).
(19) The trans vinylsilane **5t** was prepared by chloroplatinic acid catalyzed hydrosilylation (compare ref 6a and 16b) of 1-pentyne with Me_2HSiCl, followed by treatment with MeMgBr, and (on three occasions) by hydroboration–protonolysis of 1-pentynyltrimethylsilane by a procedure similar to that used for the preparation of the cis vinylsilane **5c**.[17,18] The reasons for the abnormal stereochemistry in these hydroboration experiments are not known.
(20) The diastereomeric alcohols **7e** and **7t** had ir, NMR, and mass spectra which were nearly identical with each other and with those of the mixtures of **7e** and **7t** which were prepared earlier,[3] and could not be separated by VPC. The assignment of erythro and threo configurations to these compounds is based on the previously reported reactions of epoxides with organocuprate reagents,[8] in which ring opening with predominant back-side attack was observed.
(21) The stereospecific conversion of **6c** to **7e** could also be effected with di-*n*-propylmagnesium in ether (P. F. Hudrlik and A. M. Hudrlik, unpublished results).
(22) Professor P. Dervan (California Institute of Technology) has independently demonstrated that the stereochemistry of the base-induced elimination reactions is syn, using β-hydroxyalkylsilanes prepared by a different route. We thank Professor Dervan for communicating his results to us prior to publication.

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