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Stereoselective Synthesis of Alkenes by Using Unimolecular Chain Transfer Reactions of Silicon Hydrides

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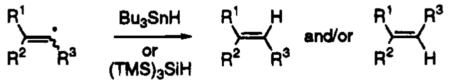
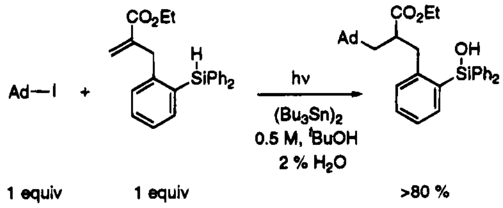
The stereoselective formation of double bonds by radical reactions has been widely studied (eq 1).[1,2] Typically, vinyl radicals are allowed to react with a hydrogen donor such as tributyltin hydride or tris(trimethylsilyl)silicon hydride. Substituent effects in these bimolecular atom transfer reactions are reasonably well understood, but high stereoselection is possible with only a few classes of radicals. Thermodynamic control can also sometimes be achieved.[3]



(1)

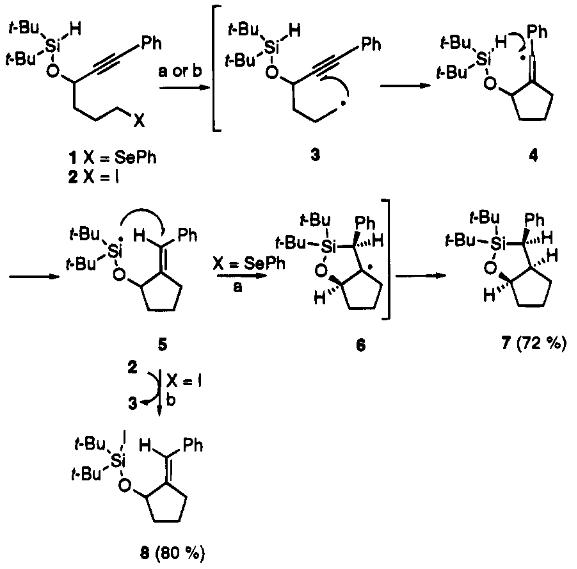
Recently, we have demonstrated[4] the advantages of using unimolecular chain transfer (UMCT) reactions of silicon hydrides to control bimolecular radical reactions.[5] For example, the bimolecular addition shown in eq 2 occurs in high yield at high concentration and with a 1/1 ratio of reactants.[4c] These desirable features arise because the silicon hydride is too poor a hydrogen donor to rapidly react with radicals in a bimolecular fashion but will react in an intramolecular fashion. As an extension of this work, we now report that UMCT reactions of silicon hydrides can be used to conduct intramolecular radical cyclizations to alkynes with strict control of *E*/*Z* geometry of the alkene products.



(2)

A recent paper by Clive and Cantin[6] provided a natural starting point to test our ideas. These workers observed that the slow addition of Ph_3SnH to phenylselenide **1** (Scheme 1, path a) led to cyclic silyl ether **7** in 72% yield. A number of related precursors reacted analogously. This transformation occurs by a sequence of (a) 5-*exo-dig* cyclization, (b) intramolecular 1,5-hydrogen transfer,[6] (c) 5-*endo-trig* cyclization of the silicon-centered radical, and (d) hydrogen transfer from Ph_3SnH. Even though an intramolecular hydrogen transfer from a silicon hydride is involved (**4** → **5**), this is not a UMCT reaction. This is because the 5-*endo* cyclization of the silyl radical **5** is faster than the bimolecular abstraction of phenylselenium group from **1**, thereby breaking the UMCT chain. The transformation of **1** to **7** is a standard radical reduction and requires 1 equiv of triphenyltin hydride.

Scheme 1[a]



[a] Reagents: (a) Ph_3SnH (slow addition in 2 h), AIBN, benzene, reflux; (b) $(Bu_3Sn)_2$, *hν*, benzene, 80 °C.

To propagate a UMCT reaction requires that bimolecular "X-abstraction" of silicon radical **5** be faster than 5-*endo* cyclization. This requirement can be met simply by replacing the phenylselenium group by an iodine atom.[7] Irradiation of a benzene solution of iodide **2** and 10% hexabutylditin with a UV lamp under standard conditions[4] resulted in smooth conversion to alkoxy silicon iodide **8** (Scheme 1 and Table 1, entry 1). Surprisingly, this silicon iodide was stable to flash chromatography and could be stored in the dark under argon for several days in a freezer. The geometry of the exocyclic double bond was assigned as *E* by X-ray diffraction analysis.[8] This transformation is an isomerization (no tin hydride is required) that occurs by a UMCT chain (Scheme 1, path b). The 1,5-hydrogen transfer (**4** → **5**) must be more rapid than the bimolecular iodine abstraction reaction of vinyl radical **4** from iodide **2**.[9]

Table 1 summarizes the results of a series of cyclizations conducted under the standard conditions.[10] Isomer-

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(1) (a) Curran, D. P.; Porter, N. A.; Giese, B. *Stereochemistry of Radical Reactions: Concepts, Guidelines and Synthetic Applications*; VCH: Weinheim, in press. (b) Giese, B. *Angew. Chem., Int. Ed. Engl.* **1989**, *28*, 969.

(2) Recent examples: (a) Curran, D. P.; Chen, M.-H.; Kim, D. *J. Am. Chem. Soc.* **1989**, *111*, 6265. (b) Lowinger, T. B.; Weiler, L. *J. Org. Chem.* **1992**, *57*, 6099. (c) Miura, K.; Itoh, D.; Hondo, T.; Hosomi, A. *Tetrahedron Lett.* **1994**, *35*, 9605. (d) Kopping, B.; Chatgilialoglu, C.; Zehnder, M.; Giese, B. *J. Org. Chem.* **1992**, *57*, 3994. (e) Giese, B.; Gonzalez-Gomez, J. A.; Lachheim, S.; Metzger, J. O. *Angew. Chem., Int. Ed. Engl.* **1987**, *26*, 479. (f) Haaima, G.; Lynch, M. J.; Routledge, A.; Weavers, R. T. *Tetrahedron* **1993**, *49*, 4229.

(3) Chatgilialoglu, C.; Ballestri, M.; Ferreri C.; Vecchi, D. *J. Org. Chem.* **1995**, *60*, 3826.

(4) (a) Curran, D. P.; Xu, J.; Lazzarini, E. *J. Am. Chem. Soc.* **1995**, *117*, 6603. (b) Curran, D. P.; Xu, J.; Lazzarini, E. *J. Chem. Soc., Perkin Trans. 1*, in press. (c) Curran, D. P.; Xu, J. *J. Chem. Soc., Perkin Trans. 1*, in press.

(5) (a) Giese, B. *Radicals in Organic Synthesis*; Pergamon: Oxford, 1986. (b) Curran, D. P. *Synthesis* **1988**, 417.

(6) Clive, D. L. J.; Cantin, M. *J. Chem. Soc., Chem. Commun.* **1995**, 319.

(7) Iodides are well known to be superior radical precursors to phenylselenides. See ref 5.

(8) The X-ray diffraction analysis of this unusual compound will be published separately. Martinez-Grau, A.; Curran, D. P.; Geib, S. J. Manuscript in preparation.

(9) (a) Curran, D. P.; Chen, M. H.; Kim, D. *J. Am. Chem. Soc.* **1986**, *108*, 2489. (b) Curran, D. P.; Kim, D. *Tetrahedron* **1986**, *27*, 5821.

(10) Precursors in entries 1, 2, 4, and 5 were prepared by methods analogous to those of Clive (ref 6). The precursor in entry 3 was prepared by acetylide addition to 1-(2-(tetrahydropyranyloxy)ethyl)-cyclopentanone. See: (a) Ashby, E. C; Laemmle, J. T. *Chem. Rev.* **1975**, *75*, 521. (b) Battioni, J. P.; Capmau, M. L.; Chodkiewicz, W. *Bull. Soc. Chim. Fr.* **1969**, 976.

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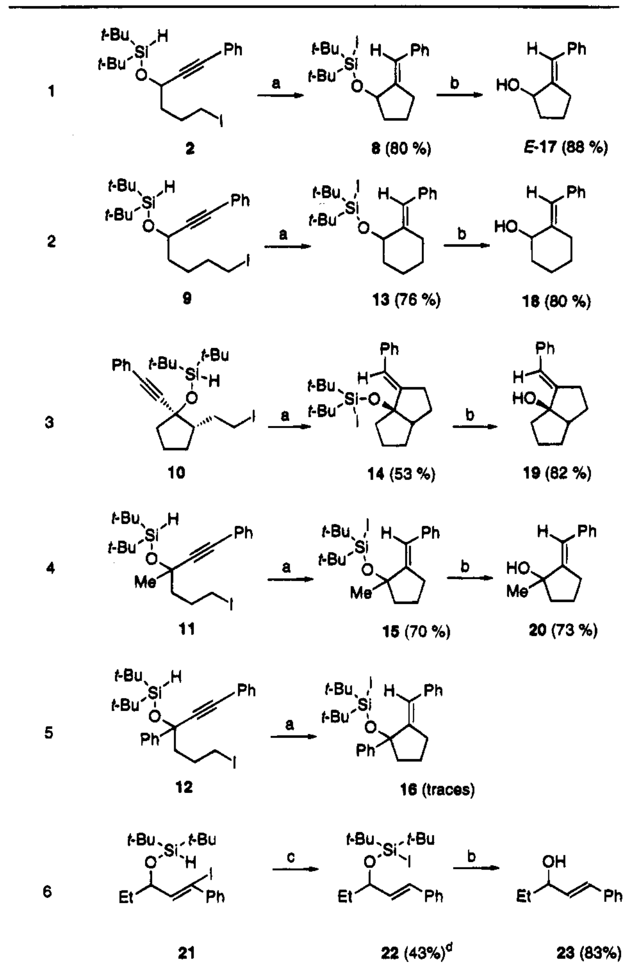
Table 1. Control of Alkene Geometry by UMCT Reactions of Silicon Hydrides[a]

Entry

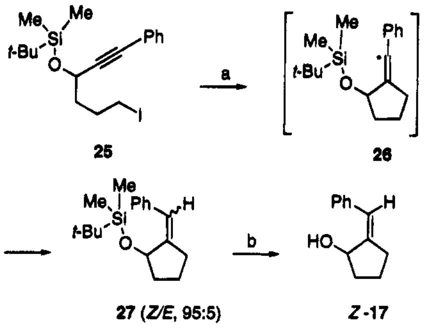


[a] Reagents: (a) 10% $(Bu_3Sn)_2$, hν, benzene, 80 °C; (b) TBAF, THF, rt; (c) 20% $(Bu_3Sn)_2$, hν, benzene, 80 °C; (d) an elimination product, $EtCH(OSi^tBu_2H)C \equiv CPh$ (**24**), was also isolated in 23% yield.

ization of compounds **9**–**11** by UV irradiation in the presence of 10% hexabutylditin provided a single (*E*)-alkene isomer of the corresponding silicon iodides **13**–**15** in good to excellent yields. For reasons that are not clear, **12** provided only traces of **16** (identified by GC–MS) under these conditions; 70% of **12** was recovered after the reaction. Like **8**, silyl iodides **13**–**15** are stable to flash chromatography but cannot be stored for extended periods. Further reaction of compounds **8** and **13**–**15** with TBAF led to the (*E*)-allyl alcohols **17**–**20**.[11] Simple reductive deiodination can also be conducted without 5-*endo-trig*-silyl radical cyclization, as shown by conversion of **21** to **23** via **22**. These results show that the UMCT method can be used to conduct radical cyclizations to triple bonds and that the geometry of the resulting alkene is strictly controlled by the intramolecular hydrogen transfer step.

To compare the UMCT reactions with results obtained from a standard reductive radical cyclization, we prepared the TBS ether **25** (Scheme 2). This is not a silicon hydride, so intramolecular hydrogen transfer is not possible. Slow addition of Bu_3SnH to a benzene solution of **25** provided a 95/5 mixture of *Z*/*E* isomers **27** according to GC analysis of the crude mixture. After purification by chromatography and treatment of the major *Z*-isomer with TBAF, the alcohol (*Z*)-**17** was obtained in 50% yield. The predominant formation of the *Z*-isomer in the bimolecular reaction of radical **26** is expected based on approach of the tin hydride to the less hindered side of a linear π-radical.[1,12,13]

Scheme 2[a]



[a] Reagents: (a) Bu_3SnH, AIBN, benzene, 80 °C; (b) TBAF, THF, rt.

Thus, in this particular example at least, the intra- and intermolecular hydrogen transfer reactions are complementary and provide stereoisomeric products ((*E*)- and (*Z*)-**17**). In vinyl radical **4** (Scheme 1), the silicon substituent donates the hydrogen intramolecularly, yielding the *E*-alkene. In contrast, the silicon substituent in **26** (Scheme 2) plays a shielding role in promoting the formation of (*Z*)-**27**. More generally, the stereoselectivity in the UMCT process should always be controlled by the intramolecular nature of the hydrogen transfer reaction, while the selectivity of analogous bimolecular hydrogen transfer reactions will vary depending on substituents.[1]

In summary, this work describes how the stereoselective hydrogen transfer reactions of radical reactions from α-phenyl-substituted vinyl radicals can be modified by varying the hydrogen transfer method (1,5-hydrogen abstraction or tin hydride method). The unimolecular chain transfer reactions of silicon hydrides can be used for alkynyl iodide cyclizations with complete and predictable control of the geometry of the product alkene. However, the generality of this method remains to be established, and it is not yet clear how often UMCT chains will be interrupted by 5-*endo-trig* silyl radical cyclizations and whether this problem can be routinely solved by using iodide precursors. An analogous strategy to control relative configuration by intramolecular hydrogen transfer reactions to sp^3-hybridized radicals is readily envisioned.

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Supporting Information Available: Spectroscopic characterizations of all precursors and products in Table 1 and representative experimental procedures (5 pages).

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[11] Assignment of the double bond geometry was confirmed by comparison with ^1H NMR spectra of the previously reported alcohols **17** and **18**. (a) Peijnenburg, W. J. G. M.; Buck, H. M. *Tetrahedron* **1988**, *44*, 4927. (b) Sanghvi, Y. S.; Rao, A. S. *J. Heterocycl. Chem.* **1984**, *21*, 317.

[12] (a) Bennet, J. E.; Howard, J. A. *Chem. Phys. Lett.* **1971**, *9*, 460. (b) Neilson, G. W.; Symons, M. C. R. *J. Chem. Soc., Perkin Trans. 2* **1973**, 1405. (c) Ito, O.; Omori R.; Matsuda, M. *J. Am. Chem. Soc.* **1982**, *104*, 3934.

[13] (a) Kopchik, R. M.; Kampmeier, J. A. *J. Am. Chem. Soc.* **1968**, *90*, 6733. (b) Singer, L. A.; Chen, J. *Tetrahedron Lett.* **1969**, 4849.