Tetrahedron Letters,Vol.30,No.47,pp 6487-6490,1989
Printed in Great Britain

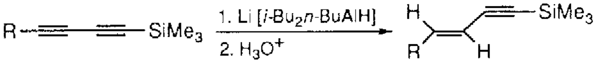
0040-4039/89 \$3.00 + .00
Pergamon Press plc

DIRECTIVE EFFECTS IN HYDROBORATIONS OF 1-(TRIALKYLSILYL)-1,3-DIYNES. SYNTHESES OF *(Z)*-ENYNES AND α-KETOACETYLENES

Elaine C. Stracker, William Leong, Joseph A. Miller, Timothy M. Shoup, and George Zweifel*
Department of Chemistry, University of California
Davis, California 95616, USA

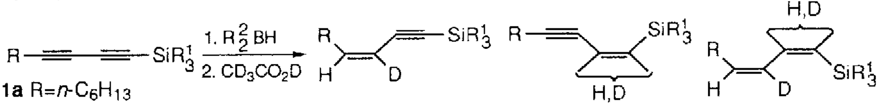
Abstract: Chemo- and regioselective hydroborations of 1-(dimethylthexylsilyl)-1,3-diynes with dicyclohexylborane or with [bis(1,2-dimethylpropyl)borane] furnishes organoboranes which afford on protonation *(Z)*-enynes and on oxidation alkynyl ketones.

We have previously shown that monohydroborations of symmetrically dialkyl-substituted 1,3-diynes with dialkylboranes proceed to place the boron preferentially at the internal positions of the diyne system. Protonolysis of the organoboron intermediates with acetic acid affords the corresponding *(Z)*-enynes.[1] However, this *(Z)*-enyne synthesis unfortunately cannot be employed for the preparation of unsymmetrical enynes since hydroborating agents do not discriminate in their addition between the triple bonds of unsymmetrically alkyl-substituted diynes. On the other hand, we have recently shown that the presence of a trimethylsilyl moiety imparts appreciably different reactivities to the triple bonds of 1-(trimethylsilyl)-1,3-diynes in reactions with lithium diisobutyl-n-butylaluminum hydride, providing an efficient method for preparing *(E)*-1-(trimethylsilyl)-3-alken-1-ynes.[2]



We now report that by proper choice of the alkyl groups on silicon in 1-(trialkylsilyl)-1,3-diynes **1** it is possible to prepare regiodefined enynylboranes, and via protonolysis of these to obtain *(Z)*-enynes thus complementing the above *(E)*-enyne synthesis. Moreover, oxidation of the enynylboranes with alkaline hydrogen peroxide furnishes α-ketoacetylenes.

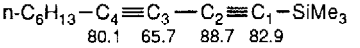
Hydroboration of 1-(trimethylsilyl)-1,3-decadiyne **1a** with an equimolar amount of dicyclohexylborane in THF at 0°C resulted in the complete uptake of the hydride. The reaction mixture was treated with acetic acid-d_4, heated at 75-80°C, oxidized with alkaline hydrogen peroxide, and worked up. GLC analysis of the organic extract revealed preferential formation of the deuterated *(Z)*-1-(trimethylsilyl)-3-decen-1-yne (**2**, 61%) along with deuterated *(Z)*-1-(trimethylsilyl)-1-decen-3-yne (**3**, 8%), silyldiene (**4**, 16%), and starting material (**1**, 15%).



1a R=n-C$_6$H$_{13}$
b c-C$_6$H$_{11}$
c R$^1_3$Si

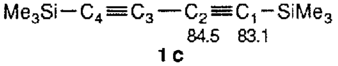
2 **3** **4**

^{1}H-NMR analysis of the product mixture showed that deuterium incorporation in the enyne **2** was nearly exclusively at C-3.[3] This observed preferential attack of the boron at C-3 must result from a combination of electronic and steric effects. It has been suggested that the ^{13}C chemical shift behavior exhibited by the sp-carbons in 1-(trimethylsilyl)-1,3-diynes is a measure of the distribution of electron density in the 1,3-butadiyne system.[4,5] Thus, the ^{13}C chemical shifts (ppm downfield from Me_4Si in $CDCl_3$) observed for the diynes **1a,c** and **5**, which were assigned using ^{13}C-H coupling data, would appear to indicate not only that the C_3 carbon in **1a** (R^1=CH_3) has the highest electron density, but also that the two triple bonds do not interact appeciably.



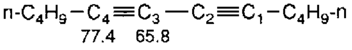
$n\text{-}C_6H_{13}-\underset{80.1}{C_4}\equiv\underset{65.7}{C_3}-\underset{88.7}{C_2}\equiv\underset{82.9}{C_1}-SiMe_3$

1a



$Me_3Si-C_4\equiv C_3-\underset{84.5}{C_2}\equiv\underset{83.1}{C_1}-SiMe_3$

1c



$n\text{-}C_4H_9-\underset{77.4}{C_4}\equiv\underset{65.8}{C_3}-C_2\equiv C_1-C_4H_9\text{-}n$

5

That the trimethylsilyl group does exert a powerful directive effect is evident when one examines the regiochemistry of hydroboration of the diyne in which the trimethylsilyl group in **1a** has been replaced by the *t*-butyl group. In this case, addition of B-H to the diyne system places nearly equal amounts of the boron at both internal positions of the triple bonds.[1,6]

A marked improvement in chemoselectivity for B-H addition to the alkyl-substituted triple bond was observed when the diyne **1a** (R^1=CH_3) was hydroborated with the more hindered disiamylborane [bis(1,2-dimethylpropyl)borane]. Deuterolysis-oxidation of the resultant organoboranes furnished a 78:6:7:9 mixture of compounds **2**, **3**, **4**, and **1**, respectively. When the size of the alkyl group on silicon was also increased, we were pleased to observe that chemo- and regioselective hydroboration of 1,3-diynes was achieved.Thus, replacing the trimethylsilyl group in **1a** by the *t*-butyldimethylsilyl or even better by the dimethylthexylsilyl moiety and using disiamylborane as the hydroborating agent resulted, after protonation, in the nearly selective formation of the enyne **2**. A similar dependence in chemo- and regioselectivity of hydroboration upon the size of the trialkylsilyl group was observed with the cyclohexyl substituted diyne **1b**.[7]

Hydroboration of the symmetrically-substituted 1,4-bis(trimethylsilyl)-1,3-butadiyne (**1c**, R^1=CH_3) with disiamylborane followed by treatment of the resultant enynylborane with acetic acid-d_4 furnished a 26:74 mixture of enynes deuterated at the C-1 and C-2 positions, respectively. In this connection it should be noted that hydroboration of symmetrically alkyl-substituted 1,3-diynes with disiamylborane places 95±3% of the boron at the internal positions of the triple bonds. A diminished regioselectivity for addition of boron to the bis-silylated diyne as compared with the symmetrically alkyl-substituted diynes is predicted based on the the ^{13}C chemical shifts observed for the diynes **1c** and **5**, respectively. Regioselective B-H addition at the C-2 carbons of the bis-silylated diyne was achieved when both of the trimethylsilyl groups in **1c** were replaced by dimethylthexylsilyl groups.[11]

The availability of regiodefined enynylboranes **6** derived from hydroboration of 1-(dimethylthexylsilyl)-1,3-diynes with dialkylboranes provides, via oxidation with alkaline hydrogen peroxide, the synthetically valuable 1-(trialkylsilyl)-3-oxo-alk-1-ynes **7**.[12,13] Protonolysis of the diyne monohydroboration products with glacial acetic acid affords the corresponding *(Z)*-1-trialkylsilyl-3-alken-1-ynes **8**[13,15] possessing the easily manipulable trialkylsilyl ethynyl moiety. Desilylation of **8** with n-Bu_4NF in THF furnishes the corresponding *(Z)*-3-alken-1-ynes **9** whose structural feature is embodied in a number of biological active compounds.[15] A summary of the results obtained is shown in the Table.

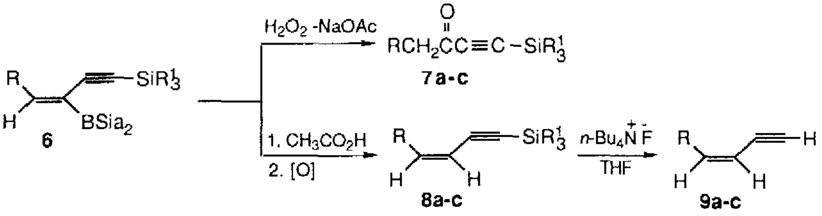
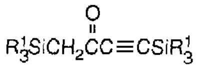


Table. Yields of Enynes and α-Ketoacetylenes Derived from 1,3-Diynes

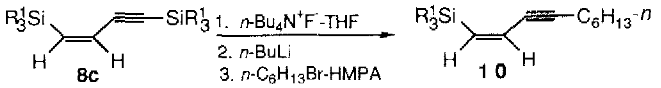
diyne	R	SiR^1_3[a]	R^1_2BH[c,d]	products[f,g] %		
				7	8	9
1a	n-C_6H_{13}	A	Cy_2BH	80	86 (97)	
		A	Sia_2BH		88 (98)	89
1b	c-C_6H_{11}	A	Cy_2BH	82	85 (97)	
		A	Sia_2BH		86 (98)	93
		B	Sia_2BH		88 (98)	
1c	$ThMe_2Si$[b]	A	Sia_2BH[e]	82	95 (99)	94

[a] A=Me_2thexylSi; B=(t-butyl)Me_2Si. [b] Me_2thexylSi. [c] Cy_2BH=dicyclohexylborane; Sia_2BH=disiamylborane. [d] 1.1 equiv. of the hydroborating agent was used. [e] 1.2 equiv. of the hydroborating agent was used. [f] Isolated yields. Isomeric purities are in parentheses. [g] The IR, ^1H-NMR, and mass spectral data of the compounds are consistent with the assigned structures.

Especially attractive because of their synthetic potential are the diyne **1c** (R^1=dimethylthexyl), its β-ketosilane derivative **7c** containing the enynylsilyl moiety, and the enyne **8c**. Although their utility as intermediates in organic synthesis remains to be explored, preliminary experiments revealed that **8c** may be elaborated to enyne **10** in 86% yield. Thus, the methodologies developed in this study provide access not only to 3-alken-1-ynes **9** but also to the isomeric 1-alken-3-ynes **10**, as exemplified below.


$R^1_3SiCH_2\overset{O}{\overset{\|}{C}}C\equiv CSiR^1_3$

7c



Acknowledgment: We thank the National Science Foundation (CHE-85-19555) for support of this work.

References and Notes

1. Zweifel, G.; Polston, N.L. *J. Am. Chem. Soc.* **1970**, *92*, 4068.
2. Miller, J.A.; Zweifel, G. *J. Am. Chem. Soc.* **1983**, *105*, 1383.
3. Integrations of the protons of the deuterated products by ^1H-NMR (300 MHz) were reproducible within ± 3%.
4. Hearn, M.T.W. *Aust. J. Chem.* **1976**, *29*, 2315. For ^{13}C chem. shift data of functionally substituted conjugated diynes, see Galli, R.; Neuenschwander, M. *Helv. Chim. Acta* **1988**, *71*, 1914.

5. For correlations of ^{13}C chemical shifts of sp-carbons with the regioselectivity of B-H additions to the triple bond of 1-halo-1-alkynes, see Nelson, D.J.; Blue, C.D.; Brown, H.C. *J. Am. Chem. Soc.* **1982**, *104*, 4917.
6. For a discussion of directive effects in hydroborations of 1-(trialkylsilyl)-1-alkynes, see Soderquist, J.A.; Colberg, J.C.; Del Valle, L. *J. Am. Chem. Soc.* **1989**, *111*, 4873.
7. The 1-(*t*-butyldimethylsilyl)- and 1-(dimethylthexylsilyl)-1,3-diynes were prepared from the corresponding 1-(trimethylsilyl)-1,3-diynes[8] via desilylation (KF/DMF),[9] lithiation (*n*-BuLi) and silylation with *t*-butyldimethylsilyl chloride or dimethylthexylsilyl chloride[10], respectively.
8. Miller, J. A.; Zweifel, G. *Synthesis* **1983**, 128.
9. Corey, E.J.; Ruden, R.A. *Tetrahedron Lett.* **1973**, 1495.
10. Wetter, H.; Oertle, K. *Tetrahedron Lett.* **1985**, *26*, 5515.
11. Prepared from *(Z)*-1-methoxybut-1-en-3-yne using either trimethylsilyl chloride or dimethylthexylsilyl chloride. In the latter case, the reaction mixture was strirred for 1.5 h at 25°C instead for 1 h at 25°C. Zweifel, G.; Rajagopalan, S. *J. Am. Chem. Soc.* **1985**, *107*, 700.
12. Logue, M.; Teng, K. *J. Org. Chem.* **1982**, *47*, 2549; Giacomelli, G.; Rosini, C,; Caporusso, A.M.; Palla, F. *J. Org. Chem.* **1983**, *48*, 4887.
13. The ketoacetylenes **7a,b** were prepared as follows. The diynes **1a,b** (3.0 mmol) in THF (1 mL) were added to a solution of dicyclohexylborane (3.3 mmol)[14] in THF maintained at 0° C. The mixtures were stirred at 0°C for 3 hr and then at 25°C for 15 min. For the preparation of **7c**, the diyne **1c** was hydroborated with disiamylborane (1.2 equiv.)[14] at -10° C. The mixture was stirred at 0°C for 30 min and then at 25°C for 3 hr. The organoboranes **6a-c** formed were oxidized by treatment with 3 M NaOAc (0.7 mL) followed by dropwise addition of 30% H_2O_2 (1 mL) while maintaining the temperature at 25°C. Extraction with *n*-pentane, concentration, chromatography on Florisil using *n*-hexane as eluent, and distillation (Kugelrohr) furnished the ketones **7a,b**. The ketosilane **7c** was purified on silica gel (60-200 mesh) using a 5 to 95 ether-*n*-hexane mixture as eluent.
    The enynes **8a-c** were obtained by protonolysis of the enynylboranes with glacial acetic acid (0.75 mL) by refluxing the mixtures at 85°C for 4 hr. The residual C-B bonds were oxidized at 30-50°C with 3 N NaOH (4 mL) and 30% H_2O_2 (1 mL). The reaction mixtures were stirred at ambient temperature for 30 min, the phases formed were separated, and the aqueous phases were extracted with pentane. To remove the by-products, 3-methyl-2-butanol and cyclohexanol, respectively, the residues obtained after evaporation of the solvents were chromatographed on Florisil using *n*-hexane as eluent. Distillation (Kugelrohr) furnished the enynes **8a-c**.
    The enynes **8a-c** (2.0 mmol) in THF (2 mL) were desilylated by stirring them with a 1 M solution of n-Bu_4NF (4 mL, Aldrich) in THF at 25°C for 30 min. The mixtures were poured into 3 M HCl, and the layers formed were separated. The aqueous phases were extracted with *n*-pentane, the combined organic extracts were sequentially washed with 3 M HCl, saturated aqueous $NaHCO_3$, and brine. The solvents were removed, and the residues obtained were chromatographed on silica gel using *n*-hexane an eluant. Distillation (Kugelrohr) yielded the enynes **9a-c**.
14. Brown, H.C.; Mandel, A.K.; Kulkarni, S.U. *J. Org. Chem.* **1977**, *42*, 1392.
15. For alternative syntheses of *(Z)*-1-(trialkylsilyl)-3-en-1-ynes, see: Holmes, A.B.; Raphael, R.A.; Wellward, N.K. *Tetrahedron Lett.* **1976**, 1539; Faulkner, D.J. *Tetrahedron* **1977**, *33*, 1421; Yamakado, Y.; Ishiguro, M.; Ikeda, N.; Yamamoto. H. *J. Am. Chem. Soc.* **1981**, *103*, 5568; Corey, E.J.; Rücker, C. *Tetrahedron Lett.* **1982**, 719; Jones, G.E.; Holmes, A.B. *Tetrahedron Lett.* **1982**, *23*, 3203.

(Received in USA 14 June 1989)