JOC*Note*

Regio- and Stereoselective Homolytic Hydrostannylation of Propargyl Alcohols and Ethers with Dibutylchlorostannane

Katsukiyo Miura,* Di Wang, Yukihiro Matsumoto, Naoki Fujisawa, and Akira Hosomi*

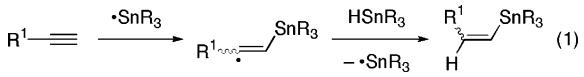
Department of Chemistry, 21st Century COE, Graduate School of Pure and Applied Sciences, University of Tsukuba, and CREST, Japan Science and Technology Corporation (JST), Tsukuba, Ibaraki 305-8571, Japan

miura@chem.tsukuba.ac.jp; hosomi@chem.tsukuba.ac.jp

Received July 13, 2003

Abstract: The Et_3B-initiated reaction of γ-unsubstituted propargyl alcohols with dibutylchlorostannane (Bu_2SnClH) at low temperature gave (*Z*)-vinylstannanes with high regio- and stereoselectivity. The corresponding alkyl propargyl ethers also underwent regio- and stereoselective homolytic hydrostannylation with Bu_2SnClH; however, the regioselectivity was not so high as that with the propargyl alcohols.

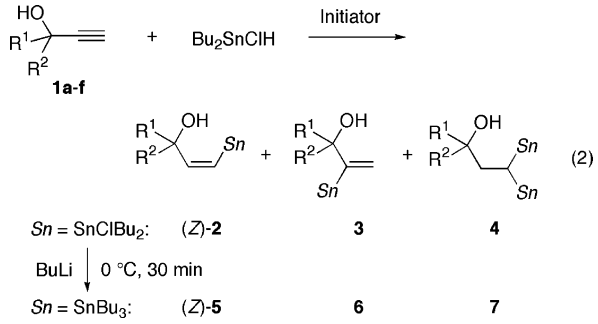
The addition of hydrostannanes to alkynes provides a straightforward and efficient route to vinylstannanes, which are important reagents working as vinyl anion equivalents for carbon−carbon bond formation.[1] The hydrostannylation is induced by a radical initiator,[2] a transition metal catalyst,[3] or a Lewis acid.[4] The radical chain process is considerably valuable for the preparation of functionalized vinylstannanes (eq 1); however, it often exhibits low stereoselectivity due to the stannyl radical-induced isomerization of the products.[5]



(1)

Previously, we have reported that dibutylchlorostannane (Bu_2SnClH)[6] exhibits high chemoselectivity toward homolytic hydrostannylation of allyl and homoallyl alcohols.[7] The chemoselectivity is attributable to the coordination of the hydroxy group to the Lewis acidic tin center in the β-stannylalkyl radical intermediate. This deduction prompted us to utilize such an intramolecular interaction for regio- and stereoselective hydrostannylation of alkynes bearing a polar functional group. In this context, Davies and his co-workers have shown that the reaction of 2-methyl-3-butyn-2-ol with Bu_2SnClH affords a 2:1 mixture of terminal and internal adducts, and the terminal addition proceeds with high *Z*-selectivity.[8] In addition, Mitchell et al. have recently reported highly regio- and stereoselective hydrostannylation of γ-unsubstituted propargyl ethers with Bu_2SnXH (X = Cl, Br).[9] We herein provide some new and important information on homolytic hydrostannylation of propargyl alcohols and ethers with Bu_2SnClH.[10]

Initially, the reaction of 1-undecyn-3-ol (**1a**, R^1 = n-C_8H_{17}, R^2 = H) with Bu_2SnClH was examined under various reaction conditions (eq 2 and Table 1). In all



cases, the hydrostannylation gave (*Z*)-vinylstannane **2a** as the major product along with its regioisomer **3a**. As expected from the previous report,[8,9] Bu_2SnClH spontaneously added to **1a** in the absence of a radical initiator. The isomeric ratio was dependent on the solvent used (entries 2−4). Lowering the reaction temperature to 0 °C did not improve the regioselectivity (entry 5). Interestingly, addition of Et_3B as a radical initiator[2b] not only accelerated the hydrostannylation but also raised the ratio of (*Z*)-**2a** to **3a** (entry 6). The Et_3B-initiated reaction at lower temperature achieved higher selectivity (entries 7−8). However, the reproducibility of the reaction efficiency at −78 °C was invariably poor, which may be due to poor solubility of **1a** at this temperature.

To isolate the hydrostannylation product by column chromatography, the reaction mixture obtained from **1a**

(1) (a) Davies, A. G. *Organotin Chemistry*; VCH: Weinheim, Germany, 1997. (b) Davies, A. G. In *Comprehensive Organometallic Chemistry II*; Abel, E. W., Stone, F. G. A., Wilkinson, G., Eds.; Pergamon Press: Oxford, UK, 1995; Vol. 2, pp 217−304. (c) Pereyre, M.; Quintard, J.-P.; Rahm, A. *Tin in Organic Synthesis*; Butterworths: London, UK, 1987.

(2) AIBN: (a) Leusink, A. J.; Budding, H. A. *J. Organomet. Chem.* **1968**, *11*, 533−539. Et_3B: (b) Nozaki, K.; Oshima, K.; Utimoto, K. *J. Am. Chem. Soc.* **1987**, *109*, 2547−2549. Photoinitiated reaction: (c) Mitchell, T. N.; Amamria, A. *J. Organomet. Chem.* **1983**, *252*, 47−56. Sonication: (d) Nakamura, E.; Imanishi, Y.; Machii, D. *J. Org. Chem.* **1994**, *59*, 8178−8186.

(3) (a) Ichinose, Y.; Oda, H.; Oshima, K.; Utimoto, K. *Bull. Chem. Soc. Jpn.* **1987**, *60*, 3468−3470. (b) Kikukawa, K.; Umekawa, H.; Wada, F.; Matsuda, T. *Chem. Lett.* **1988**, 881−884. (c) Zhang, H. X.; Guibé, F.; Balavoine, G. *J. Org. Chem.* **1990**, *55*, 1857−1867. (d) Betzer, J.-F.; Delaloge, F.; Muller, B.; Pancrazi, A.; Prunet, J. *J. Org. Chem.* **1997**, *62*, 7768−7780. (e) Mitchell, T. N.; Moschref, S.-N. *Synlett* **1999**, 1259−1260. (f) Maleczka, R. E., Jr.; Terrell, L. R.; Clark, D. H.; Whitehead, S. L.; Gallagher, W. P.; Terstiege, I. *J. Org. Chem.* **1999**, *64*, 5958−5965.

(4) (a) Asao, N.; Liu, J.-X.; Sudoh, T.; Yamamoto, Y. *J. Chem. Soc., Chem. Commun.* **1995**, 2405−2406. (b) Gevorgyan, V.; Liu, J.-X.; Yamamoto, Y. *Chem. Commun.* **1998**, 37−38.

(5) (a) Leusink, A. J.; Budding, H. A.; Drenth, W. *J. Organomet. Chem.* **1968**, *11*, 541−547. (b) Taniguchi, M.; Nozaki, K.; Miura, K.; Oshima, K.; Utimoto, K. *Bull. Chem. Soc. Jpn.* **1992**, *65*, 349−353.

(6) Preparation and reactions of Bu_2SnClH: (a) Sawyer, A. K.; Kuivila, H. G. *Chem. Ind.* **1961**, 260. (b) Neumann, W. P.; Pedain, J. *Tetrahedron Lett.* **1964**, 2461−2465.

(7) Miura, K.; Saito, H.; Uchinokura, S.; Hosomi, A. *Chem. Lett.* **1999**, 659−660.

(8) Davies, A. G.; Kinart, W. J.; Osei-Kissi, D. K. *J. Organomet. Chem.* **1994**, *474*, C11−C13.

(9) Mitchell, T. N.; Moschref, S.-N. *Chem. Commun.* **1998**, 1201−1202.

(10) Recently, Baba et al. have reported that an ate complex derived from Bu_2SnIH is valuable for highly regioselective hydrostannylation of simple aliphatic terminal alkynes forming α-alkyl-substituted vinylstannanes. Shibata, I.; Suwa, T.; Ryu, K.; Baba, A. *J. Am. Chem. Soc.* **2001**, *123*, 4101−4102.

10.1021/jo035012s CCC: $25.00
Published on Web 10/09/2003

TABLE 1. Hydrostannylation of Propargyl Alcohol 1a with Bu_2SnClH[a]

entry	initiator	solvent	time/h	temp/°C	conv/%	(*Z*)-**2a**:**3a**[b]
1	none	none	3	rt	100	91:9
2	none	PhMe	3	rt	91	91:9
3	none	Et_2O	3	rt	97	81:19
4	none	MeOH	3	rt	100	91:9
5	none	PhMe	3	0	75	91:9
6	Et_3B-O_2[c]	PhMe	3	0	100	93:7
7	Et_3B-O_2[c]	PhMe	6	−60	97	98:2
8	Et_3B-O_2[c]	PhMe	6	−78	50−100[d]	>99:1

[a] All reactions were performed with Bu_2SnClH (1.10 mmol) and **1a** (1.00 mmol) in solvent (2.5 mL) or without solvent (entry 1). In entries 2−8, the resultant mixture was treated with galvinoxyl (0.05 mmol), evaporated, and subjected to ^1H NMR analysis. [b] Determined by 270-MHz ^1H NMR analysis. [c] 1 M Et_3B in hexane (0.10 mmol) and dry air (10 mL) were introduced. [d] The reproducibility of the conversion was poor.

TABLE 2. Et_3B-Initiated Hydrostannylation of Propargyl Alcohols 1 with Bu_2SnClH Followed by Butylation[a]

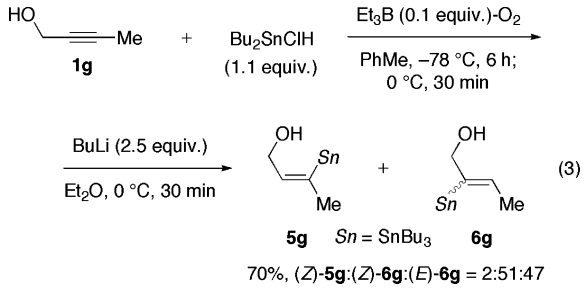
	substrate				yield	
entry	R^1	R^2	no.	temp/°C	((*Z*)-**5**+**6**)/%	(*Z*)-**5**:**6**[b]
1	*n*-C_8H_{17}	H	**1a**	−60	81[c]	98:2
2	*c*-C_6H_{11}	H	**1b**	−78	85[c]	99:1
3	Ph	H	**1c**	−78	72[c]	99:1
4	Me	Me	**1d**	−78	96[d]	96:4
5	$(CH_2)_5$		**1e**	−78	92[d]	97:3
6	H	H	**1f**	−78	71[c] (81)[e]	>99:1

[a] All reactions were performed with Bu_2SnClH (1.10 mmol), **1** (1.00 mmol), Et_3B (0.10 mmol), and dry air (10 mL) in toluene (2.5 mL). The mixture was stirred at −78 or −60 °C for 6 h and 0 °C for 30 min. The resultant mixture was diluted with Et_2O (4 mL) and treated with BuLi (2.5 mmol) at 0 °C for 30 min. Before an aqueous workup, CCl_4 (1 mL) was added to the reaction mixture to suppress the stannyl radical-induced isomerization. [b] The isomeric ratio was determined by 270-MHz ^1H NMR analysis (entries 1−3 and 6) or isolated yields of (*Z*)-**5** and **6** (entries 4 and 5). [c] Bisstannylated product **7** was isolated in 1−5% yield. [d] (*Z*)-**5d**,**e** were isolated in 93% and 89% yields, respectively. [e] Instead of BuLi, BuMgBr was used.

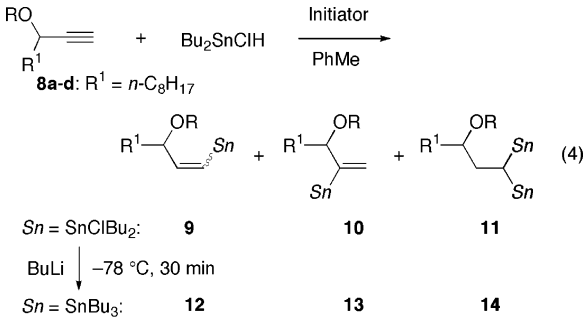
and Bu_2SnClH was treated with BuLi. The Et_3B-initiated hydrostannylation (−60 °C, 6 h, then 0 °C, 30 min) and the subsequent butylation (0 °C, 30 min) afforded a 98:2 mixture of (*Z*)-**5a** and **6a** in 81% yield. Bisstannylated product **7a** also was isolated in a small quantity (5%). The results with several propargyl alcohols **1a**−**f** are summarized in Table 2. In all entries, (*Z*)-vinylstannanes **5** were obtained with high regio- and stereoselectivity. In the reaction of 2-methyl-3-butyn-2-ol (**1d**), the present method achieved high regioselectivity unlike the result reported by Davies et al. (entry 4 of Table 2).[8]

The Et_3B-initiated addition of Bu_3SnH to **1a** in toluene, which was much slower than that of Bu_2SnClH, showed low *Z*-selectivity (rt, 6 h, 49% conversion, (*Z*)-**5a**:(*E*)-**5a**:**6a** = 66:26:8). The hydrostannylation of 1-dodecyne with Bu_2SnClH (0 °C, 6 h) and the subsequent butylation provided 1-tributylstannyl-1-dodecene with *E*-selectivity (95%, *Z*:*E* = 13:87). These observations suggest that the coordination of the hydroxy oxygen to the Lewis acidic tin center is operative for the *Z*-selective addition of Bu_2SnClH to **1** (vide infra).

Homolytic hydrostannylation of 2-butyn-1-ol (**1g**) with Bu_3SnH has been reported to give (Z)-**6g** with high regio- and stereoselectivity.[11] The Et_3B-initiated reaction of **1g** with Bu_2SnClH at −78 °C also gave **6g** predominantly, but with lower stereoselectivity (70%, (*Z*)-**5g**:(*Z*)-**6g**:(*E*)-**6g** = 2:51:47, eq 3). The use of the Lewis acidic hydrostannane did not affect the sense of regioselectivity.



To examine the applicability of the present method, methyl propargyl ether **8a** was selected as a substrate. The Et_3B-initiated reaction with Bu_2SnClH (1.1 equiv) at −60 °C for 6 h led to a mixture of adduct **9a**, its regioisomer **10a**, and bisstannylated product **11a** (eq 4,



87% conversion, (*Z*)-**9a**:(*E*)-**9a**:**10a**:**11a** = 80:1:10:9). Increasing the reaction temperature to 0 °C gave a similar regioselectivity (6 h, 100% conversion, (*Z*)-**9a**:(*E*)-**9a**:**10a**:**11a** = 85:<1:11:4). Interestingly, the AIBN-initiated reaction with Bu_2SnClH (1.05 equiv) at 60 °C showed higher regioselectivity (0.5 h, 100% conversion, (*Z*)-**9a**:(*E*)-**9a**:**10a**:**11a** = 91:<1:7:2).[12] Mitchell et al. have reported that the spontaneous reaction of γ-unsubstituted propargyl ethers with Bu_2SnClH at room temperature forms only (*Z*)-vinylstannanes.[9] However, the hydrostannylation of **8a** under the same conditions resulted in only modest regioselectivity (12 h, 98% conversion, (*Z*)-**9a**:(*E*)-**9a**:**10a**:**11a** = 87:<1:12:1).

The AIBN-initiated hydrostannylation of **8a** (R = Me, R^1 = *n*-C_8H_{17}) at 60 °C for 30 min (method A) and the subsequent butylation gave (*Z*)-**12a** in a good yield with high stereo- and regioselectivity (eq 4 and entry 1 in Table 3). The reactions of benzyl and methoxymethyl ethers, **8b** and **8c**, showed lower *Z*-selectivity (entries 2 and 4). The stereoselectivity could be improved by the Et_3B-initiated reaction at 0 °C (method B), in which the regioselectivity slightly decreased (entries 3 and 5). In contrast to the results with **8a**−**c**, the use of TBDMS ether **8d** afforded (*E*)-**12d** predominantly (entry 6). The

(11) Ensley, H. E.; Buescher, R. R.; Lee, K. *J. Org. Chem.* **1982**, *47*, 404−408.

(12) Without AIBN, the hydrostannylation of **8a** at 60 °C showed slightly lower regioselectivity (0.5 h, 89% conversion, (*Z*)-**9a**:(*E*)-**9a**:**10a**:**11a** = 89:1:9:1).

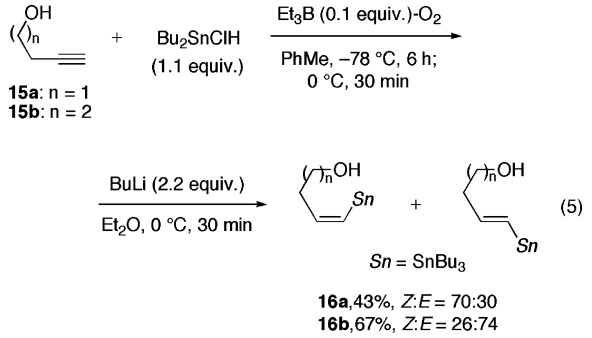
TABLE 3. Hydrostannylation of Propargyl Ethers 8 with Bu_2SnClH Followed by Butylation[a]

entry	substrate R	substrate no.	method[a]	yield (**12**)/% (*Z*:*E*)[b]	yield (**13**+**14**)/% (**13**:**14**)[b]
1	Me	**8a**	A	86 (>99:1)[c]	9 (90:10)
2	Bn	**8b**	A	75 (89:11)[c]	8 (>99:1)
3	Bn	**8b**	B	72 (95:5)[c]	12 (>99:1)
4	MOM	**8c**	A	87 (88:12)[d]	6 (>97:3)
5	MOM	**8c**	B	75 (96:4)[d]	8 (88:12)
6	TBDMS	**8d**	A	74 (7:93)[d]	12 (>99:1)

[a] All reactions were performed with Bu_2SnClH (1.05 mmol) and **8** (1.00 mmol) in toluene (2.0 mL). Method A: AIBN (0.05 mmol), 60 °C, 30 min. Method B: Et_3B (1 M in hexane, 0.10 mmol), dry air (10 mL), 0 °C, 6 h. The reaction mixture was diluted with Et_2O (5 mL) and treated with BuLi (1.20 mmol) at −78 °C for 1 h. [b] The *Z*:*E* ratio and the ratio of **13** to **14** were determined by ^1H NMR analysis. [c] Isolated yield. [d] The yield was determined by ^1H NMR analysis of a mixture of **12**−**14**.

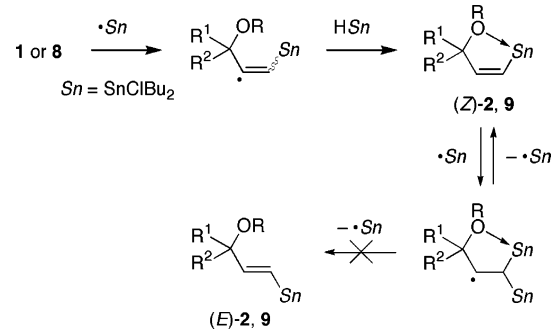
inverse selectivity is probably because the silyl group hinders the coordination of the ether oxygen by its bulkiness and π-electron-withdrawing ability.[13]

We further examined the reactions of homo- and bishomo-propargyl alcohols, **15a** and **15b**, with Bu_2SnClH. The hydrostannylation followed by butylation gave only terminal addition products **16**; however, the stereoselectivity is rather low (eq 5). Interestingly, the *Z*-selectivity decreased as the methylene tether elongated.



In homolytic hydrostannylation of alkynes (eq 1), it has been reported that the *Z*-adducts are kinetically favored over the *E*-adducts because hydrogen abstraction of the β-stannylvinyl radical intermediates from hydrostannanes occurs exclusively in the less congested side opposite to the stannyl group. However, the hydrostannylation usually shows low stereoselectivity because of isomerization of the initially formed *Z*-adducts by addition−elimination of the stannyl radicals.[5] The origin of the present *Z*-selectivity would be that the isomerization is inhibited by the Sn−O coordinate bond in the *Z*-adduct (Scheme 1). In addition, the conformational fixation of

SCHEME 1



the vinyl radical intermediates by the Sn−O coordinate bond may also take part in the stereocontrol.

In conclusion, we have demonstrated that propargyl alcohols as well as their alkyl ethers undergo regio- and stereoselective hydrostannylation with Bu_2SnClH. The present results disclose that the coordination of the oxygen functionality to the Lewis acidic tin center plays a crucial role for the stereocontrol.

Experimental Section

Et_3B-Initiated Hydrostannylation Followed by Butylation (Typical Procedure). Bu_2SnH_2 (129 mg, 0.55 mmol) was added to a solution of Bu_2SnCl_2 (167 mg, 0.55 mmol) in toluene (1 mL) at 0 °C. After being stirred for 10 min, the mixture was cooled to −60 °C. A toluene (1 mL) solution of propargyl alcohol **1a** (168 mg, 1.00 mmol) was added to the mixture. After 10 min Et_3B (1.0 M in hexane, 0.10 mL, 0.10 mmol) and dry air (10 mL) were added. The mixture was stirred at −60 °C for 6 h, then at 0 °C for 30 min. After addition of Et_2O (4 mL), the resultant mixture was treated with BuLi (1.65 M in hexane, 1.5 mL, 2.5 mmol) and stirred for 30 min. After addition of CCl_4 (1 mL), the mixture was poured into aqueous NH_4Cl (10 mL). The extract with *t*-BuOMe was dried over Na_2SO_4 and evaporated. Purification of the crude product by silica gel column chromatography gave a mixture of (*Z*)-1-tributylstannyl-1-undecen-3-ol ((*Z*)-**5a**) and 2-tributylstannyl-1-undecen-3-ol (**6a**) (395 mg, (*Z*)-**5a**:**6a** = 98:2) in 81% yield. (*Z*)-**5a**: bp 125 °C (0.5 Torr, bath temperature). IR (neat) 3419 (br s, OH), 2956, 2925, 2854, 1601 (C=C), 1464 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.78−1.03 (m, 18H), 1.12−1.64 (m, 27H), 3.85−3.94 (m, 1H), 5.99 (dd, J = 12.7, 0.8 Hz, $^2J_{SnH}$ (coupling constant between ^{119}Sn and ^1H nuclei) = 65.7 Hz, 1H), 6.49 (dd, J = 12.7, 7.5 Hz, $^3J_{SnH}$ = 136.4 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 10.82 (3 × CH_2), 13.66 (3 × CH_3), 14.08 (CH_3), 22.66 (CH_2), 25.54 (CH_2), 27.32 (3 × CH_2), 29.18 (3 × CH_2), 29.25 (CH_2), 29.55 (CH_2), 29.70 (CH_2), 31.87 (CH_2), 37.35 (CH_2), 75.73 (CH), 130.73 (CH), 150.43 (CH). Anal. Calcd for $C_{23}H_{48}OSn$: C, 60.14; H, 10.53. Found: C, 60.09; H, 10.79.

Acknowledgment. This work was partly supported by Grants-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science, and Technology, Government of Japan.

Supporting Information Available: Analytical and spectral characterization data. This material is available free of charge via the Internet at http://pubs.acs.org.

JO035012S

(13) Bassindale, A. R.; Taylor, P. G. In *The Chemistry of Organic Silicon Compounds*; Patai, S., Rappoport, Z., Eds.; Wiley, Chichester, UK, 1989; Part 2, pp 893−963.