Intramolecular Carbostannylation of Allyl- and Vinylstannanes *via* a Radical Chain Process

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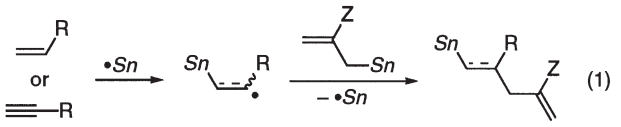
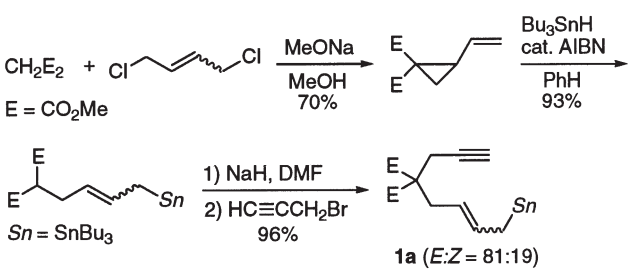
In the presence of Bu_3SnH and AIBN, 8-tributylstannyl-6-octen-1-ynes were efficiently cyclized to 2-allyl-1-(tributylstannylmethylene)cyclopentanes by intramolecular homolytic allylstannylation. 8-Tributylstannyl-1,6-octadienes as well underwent the radical cyclization in high efficiency. This radical-based method was applicable to the intramolecular vinylstannylation of alkynes and alkenes.

Intramolecular carbometalation provides a powerful tool for the stereoselective construction of a wide range of carbocycles and heterocycles.[1,2] A notable advantage of this cyclization is that the cyclized products can be easily utilized for further transformation by reaction with various electrophiles. With some exceptions,[3,4] most of the known intramolecular carbometalations proceed *via* a concerted path in which a reactive carbon-metal bond participates. Previously, we have reported intermolecular homolytic allylstannylation of alkenes and alkynes with allylstannanes bearing an electron-withdrawing group at the β-position (eq 1).[5,6] We herein describe an intramolecular version of the allylstannylation in addition to intramolecular homolytic vinylstannylation.[7]

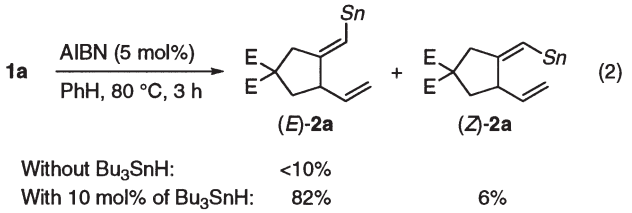


Z = electron-withdrawing group
Sn = $SnBu_3$

Initially, 1,6-enyne **1a**, an allylstannane bearing an alkynyl group, was selected as a substrate. It could be easily prepared from dimethyl malonate in three steps (62% total yield) as shown in Scheme 1. The AIBN-initiated reaction of **1a** in benzene at 80 °C formed the desired allylstannylation product **2a** in only a poor yield (eq 2). However, addition of Bu_3SnH (10 mol%) to the reaction mixture effectively promoted the cycloisomerization to give (*E*)-**2a** in 82% isolated yield along with a small quantity of its geometrical isomer.[8] Thus, unlike the intermolecular homolytic allylstannylation (eq 1), the present intramolecular version does not require the substrate to have an electron-withdrawing group β to the stannyl group.

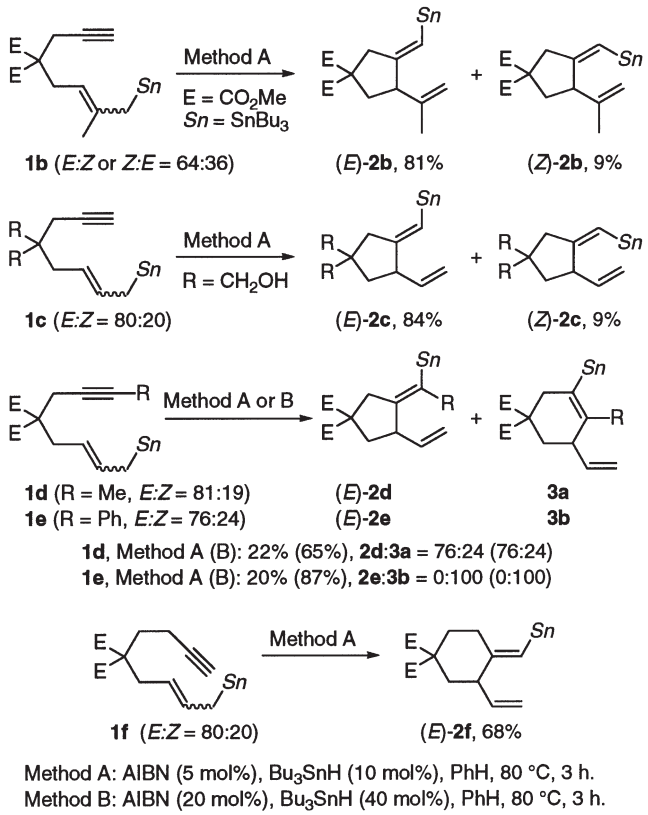


Scheme 1.



Under the same reaction conditions using 10 mol% of Bu_3SnH (method A), allylstannanes **1b-f** as well underwent the intramolecular allylstannylation (Scheme 2). The result with **1c** indicates that the present cyclization is compatible with a hydroxy group as an advantage of radical process. The cyclization of **1d** (R=Me), bearing an internal triple bond, formed a mixture of two regioisomers (*E*)-**2d** and **3a** in a poor yield. Increasing the amounts of AIBN and Bu_3SnH (method B) improved the yield without change in the isomeric ratio. In contrast with **1d**, **1e** (R=Ph) was converted into **3b** exclusively. The complete regiocontrol is probably due to the high radical-stabilizing ability of the phenyl group. As shown in the case with **1f**, the intramolecular allylstannylation is applicable to a substrate with one more methylene tether.

We next investigated the radical-initiated allylstannylation of

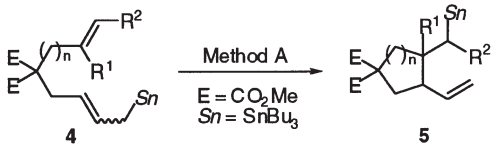


Method A: AIBN (5 mol%), Bu_3SnH (10 mol%), PhH, 80 °C, 3 h.
Method B: AIBN (20 mol%), Bu_3SnH (40 mol%), PhH, 80 °C, 3 h.

Scheme 2.

dienylstannanes **4**. The results are summarized in Table 1. The cyclization of **4a** was not observed without Bu_3SnH, while its addition to the reaction system is quite effective in the formation of **5a** (entry 1). Introduction of the substituent R^1 increased the yield of **5** (entries 2–4). In contrast, substitution at the terminal sp^2 carbon and homologation of the methylene tether resulted in no cyclized products (entries 5 and 6).

Table 1. Cyclization of dienylstannanes **4**[a]

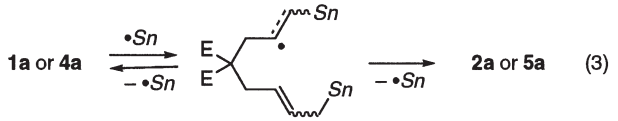


4 **5**

Entry	Dienylstannane[b]				Yield/%	*cis:trans*[c]
	R^1	R^2	n			
1	H	H	1	**4a**	88	82:18
2	Me	H	1	**4b**	90	42:58
3	Ph	H	1	**4c**	quant.	55:45
4	CN	H	1	**4d**	96	68:32
5	H	Me	1	**4e**	0	
6	H	H	2	**4f**	0	

[a]All reactions were carried out with 0.50 mmol of **4** according to method A. See Scheme 2. [b]*E:Z* = *ca.* 4:1. [c]The isomeric ratio and the relative configuration were determined by ^1H and ^{13}C NMR analysis.

The propagation process of the present radical cyclization consists of the reversible addition of $\bullet SnBu_3$ and the subsequent intramolecular homolytic substitution (eq 3).[9] The addition of Bu_3SnH would promote the former step by increasing the concentration of $\bullet SnBu_3$. The latter radical cyclization, which is much faster than intermolecular homolytic allylation, allows the successful allylstannylation of unactivated allylstannanes. The *E*-selectivity in the cyclization of **1** results from the fact that the C-C bond formation takes place in the opposite side to the stannyl group to avoid its steric hindrance.[5]



We further attempted the intramolecular vinylstannylation of alkynes and alkenes (Scheme 3). The reaction of 2-stannyl-1,6-enyne **6a** by method A did not afford the desired product **7a**, but a small amount of bisstannylated carbocycle **8** was obtained. This product would be formed by hydrostannylation of **7a**, which should suppress the cycloisomerization of **6a** to **7a**. To retard the side reaction, 1-substituted 1,6-enyne **6b** was used as a substrate. As a result, the desired dienylstannane **7b** was obtained in a moderate yield by method B. 2-Stannyl-1,6-diene **6c** was converted into the desired product **7c** although the yield was rather low. The cyclization of 1-phenyl-substituted 1,6-diene **6d** smoothly proceeded even under the conditions of method A.

In conclusion, we have demonstrated that the intramolecular allylstannylation of alkynes and alkenes is effectively catalyzed by Bu_3SnH-AIBN. The present radical-based carbometalation provides a new route to functionalized five- and six-membered rings.

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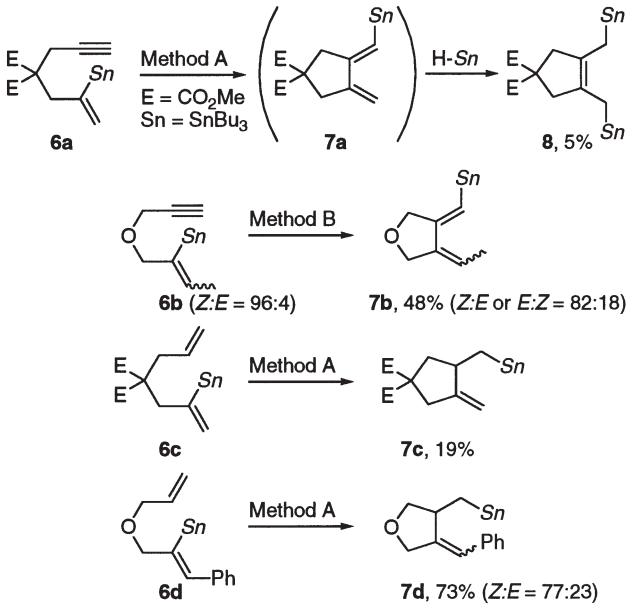

Scheme 3.

Dedicated to Professor Teruaki Mukaiyama on the occasion of his 75th birthday.

References and Notes

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