Acid-catalyzed Reaction Behavior of 1-Phenylselenocyclopropylmethanols

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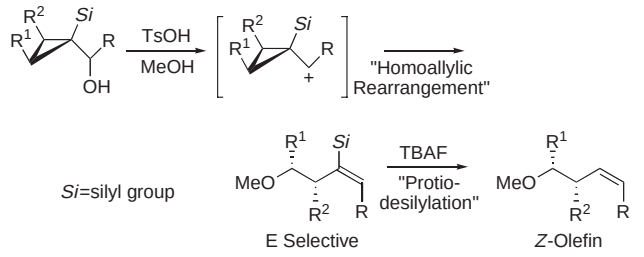
The reaction of 1-phenylselenocyclopropylmethanols with TsOH in methanol proceeded smoothly to afford the homoallylic ethers, ring-enlargement products, and ring-opening products depending upon the kind of substituent on the cyclopropane ring or α-carbon. On the other hand, in the case of the absence of methanol as nucleophile, 4*H*-selenochromene derivatives were obtained exclusively.

Cyclopropylmethyl cations are interesting species[1,2] and have been used extensively as useful intermediates in organic synthesis.[3] Especially, homoallylic rearrangement of cyclopropylmethyl cations is known as the Julia olefin synthesis that leads to the stereoselective formation of the *E*-homoallyl derivatives.[4–6] In this context, we have recently reported the homoallylic rearrangement of a cyclopropylmethyl cation having a silyl group at the 1-position of the cyclopropane ring (Scheme 1).[7] The reaction proceeded to give the corresponding *E*-homoallyl ethers, and then the protiodesilylation[8] of resulting homoallyl ethers proceeded with retention of configuration. In consequence, we presented that a bulky silyl group acted as a directing group for the stereoselectivity on this olefin synthesis and the geometry of the alkene moiety of protiodesilylated products was the opposite to that of a Julia reaction using the corresponding cyclopropylmethanols.[4] However, it was difficult to transform the silyl group into other functional groups, with the exception of protiodesilylation.[8]

The above observation prompted us to attempt the introduction of a phenylselenyl instead of a silyl group to the 1-position of the cyclopropane ring. Organic compounds containing selenium atom are very useful material in organic synthesis.[9] In particular, phenylselenyl groups are available for further versatile transformation.[9,10] In this paper, we describe the generation of cyclopropylmethyl cations by the reaction of 1-phenylselenocyclopropylmethanols with acid-catalyst and the following rearrangement reaction behavior. In these reactions, ring-enlargement compounds, ring-opening products, and 4*H*-selenochromene derivatives were yielded along with desired phenylselenohomoallylic compounds, depending upon the kind of substituent on starting cyclopropylmethanols and reaction conditions. Especially, it's notable that 4*H*-selenochromene derivative was formed, since few reports about the preparation of that compound have been published so far.[11]



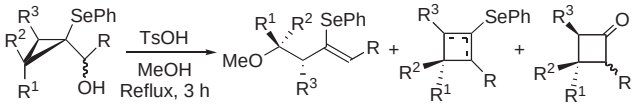
Scheme 1. Stereoselective construction of *Z*-homoallyl derivatives from 1-silylcyclopropylmethanols.

The phenylselenocyclopropylmethanols **1a–1f** having aliphatic groups on the cyclopropane ring were treated with TsOH in methanol. The results are shown in Table 1. The reaction was completed in 3 h under reflux and then a mixture of the usual homoallylic rearrangement products **2** and ring-enlargement products **3**[12] were obtained in good yields (Entries 1–5). The homoallylic rearrangement products **2** were yielded as a Z isomer regardless of the substituent on the cyclopropane ring and α-carbon. The ring-enlargement products **3** were obtained as a mixture of two types of regioisomeric cyclobutene derivatives. In addition, the cyclobutanone derivatives **4** were yielded in the reaction of cyclopropylmethanols having a phenyl group on the α-carbon (Entries 1, 3, and 5). These ring-enlargement products **3** and **4** would be formed via cyclobutyl cation[1] derived from cyclopropylmethyl cation.[7] Exceptionally, the formation of homoallyl derivatives was not observed at all in the reaction using cyclopropylmethanols **1f** as a starting material (Entry 6). In this reaction the cyclobutanone derivative **4** was yielded predominantly.

The treatment of cyclopropylmethanols **1g** and **1h** having a phenyl group at the 2-position of the cyclopropane ring and α-carbon was carried out under similar conditions as above. The results are shown in Table 2. It is noteworthy that these reactions proceeded to afford 3-phenylselenohomoallylic products **2** exclusively, as a mixture of geometrical isomers with preference for Z isomer, without the formation of ring expansion products, regardless of configuration of the cyclopropane ring in starting material **1**.

Additionally, the reaction of cyclopropylmethanols **1i–1l**

Table 1. Reaction of 1-phenylselenocyclopropylmethanols with TsOH

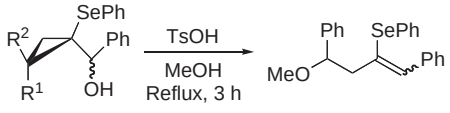


1 **2** **3** **4**

Entry	Substrate[a]	R^1	R^2	R^3	R	Ratio/%[b] 2	3	4	Yield/%[c]
1	**1a**	Me	H	Me	Ph	25	41	34	64
2	**1b**				*t*-Bu	27	73	—	78
3	**1c**	H	Me	Me	Ph	57	34	9	77
4	**1d**				*t*-Bu	34	66	—	81
5	**1e**	H	*n*-Bu	H	Ph	33	27	40	67
6	**1f**				*t*-Bu	—	14	86	81

[a]Molar ratio; cyclopropylmethanol:TsOH = 1:1.2. [b]Determined by ^{1}H NMR analysis. [c]Isolated yield.

Table 2. Reaction of 1-phenylselenocyclopropylmethanols having phenyl group on cyclopropane ring and α-carbon



1 **2**

Entry	Substrate[a]	R^1	R^2	Yield/%[b]	E/Z[c]
1	**1g**	Ph	H	57	11/89
2	**1h**	H	Ph	76	28/72

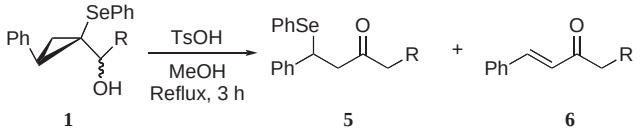
[a]Molar ratio; cyclopropylmethanol:TsOH = 1:1.2. [b]Isolated yield. [c]Determined by ^{1}H NMR analysis.

having a phenyl group at the 2-position of the cyclopropane ring and an alkyl group on the α-carbon was carried out. The results are shown in Table 3. In all cases two types of ketones, **5** derived by formal migration of the phenylselenyl group competing with the ring-opening and **6** derived by elimination of the phenylselenyl group, were yielded in moderate yields as a mixture with preference for **5**, regardless of the bulkiness of the alkyl substituent on the α-carbon of starting alcohols.

As mentioned above, in the reaction of 1-phenylselenocyclopropylmethanols with TsOH, the products having oxygen functions **2**, **4**, **5**, and **6** were obtained. The oxygen functions would be introduced by the nucleophilic addition of methanol used as solvent to cyclopropylmethyl cation or its ring-enlarged cyclobutyl cation intermediate. Then, we have become interested in the reaction behavior of cyclopropylmethyl cation in the absence of nucleophile. So the reaction of compound **1l** with TsOH in acetonitrile was carried out. The reaction was completed in 2 h at room temperature and gave the 4*H*-selenochromene derivative **7** in good yield. The results are shown in Table 4. In this reaction, the phenyl group on selenium would act as nucleophile instead of methanol, and then a C–C bond was formed between the carbons at the 2-position of the cyclopropane ring and *o*-position of the phenyl group. The same reactions using Lewis acid in dichloromethane were examined. The reaction with trimethylsilyl triflate as an acid afforded **7** in moderate yield (Entry 2). In contrast, the treatment of **1l** with boron trifluoride diethyl etherate gave **7** in high yield (Entry 3).

In summary, generation and reaction behavior of cyclopropylmethyl cations derived from 1-phenylselenocyclopropylmethanols with acid-catalyst have been described. The reaction of 1-phenylselenocyclopropylmethanols with TsOH in

Table 3. Ring-opening reaction of 2-phenyl-1-phenylselenocyclopropylmethanols with TsOH

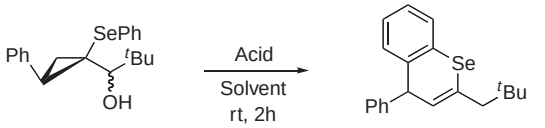


1 **5** **6**

Entry	Substrate[a]	R	Ratio/%[b]		Yield/%[c]
			5	**6**	
1	**1i**	Me	79	21	62
2	**1j**	Et	74	26	77
3	**1k**	*i*-Pr	78	22	68
4	**1l**	*t*-Bu	65	35	57

[a]Molar ratio; cyclopropylmethanol:TsOH = 1:1.2. [b]Determined by ^{1}H NMR analysis. [c]Isolated yield.

Table 4. Reaction of 1-phenylselenocyclopropylmethanols in the absence of nucleophiles



1l **7**

Entry	Acid[a]	Solvent	Yield/%[b]
1	TsOH	CH_3CN	69
2	TMSOTf	CH_2Cl_2	47
3	$BF_3 \cdot OEt_2$	CH_2Cl_2	85

[a]Molar ratio; cyclopropylmethanol:acid = 1:1.2. [b]Isolated yield.

methanol proceeded smoothly to afford the usual homoallylic rearrangement products, ring-enlargement products and ring-opening products depending upon the kind of substituents on the cyclopropane ring or α-carbon. On the other hand, in the case of the absence of nucleophile such as methanol, phenyl groups on selenium acted as nucleophile, and selenochromene derivative was obtained in good yield. Further studies to extend the scope of selenochromene derivatives synthesis are currently under way and will be reported including reaction mechanisms in due course.

References and Notes

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