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Scandium Trifluoromethanesulfonate-Catalyzed Chemoselective Allylation Reactions of Carbonyl Compounds with Tetraallylgermane in Aqueous Media

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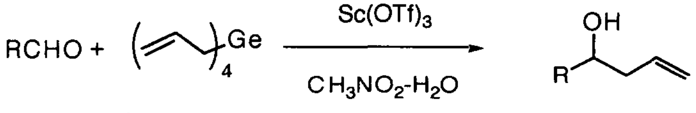
Abstract: Scandium(III) triflate-catalyzed allylation of carbonyl compounds with tetraallylgermane proceeded readily in aqueous nitromethane to afford homoallyl alcohols in excellent to good yields. The presence of H_2O is indispensable for the allylation of aldehydes to proceed smoothly. Aldehydes were allylated exclusively in the presence of ketone moieties.

Lewis acid-promoted allylation of carbonyl compounds is one of the most important reactions in synthetic organic chemistry. A number of allylmetals as well as various kinds of effective Lewis acids have been developed so far.[1] For the reaction with allylic metals of group 14 elements, the Lewis acid-promoted allylation reactions utilizing allyltin[2,3] and allylsilane[4] have been thoroughly investigated. In striking contrast, little attention has been paid to germanium compounds by synthetic organic chemists.[5,6] From the standpoint of the lower toxicity of organogermanium compounds in comparison to organotin compounds,[7] exploration of the synthetic utility is highly desired.

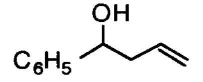
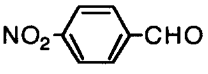
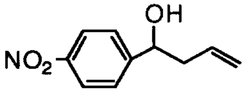
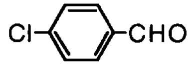
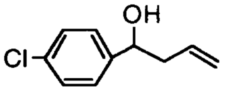
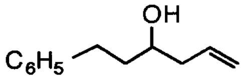
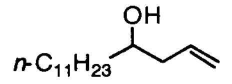
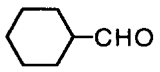
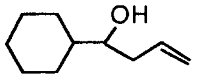
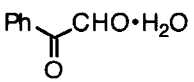
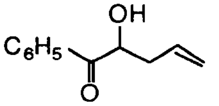
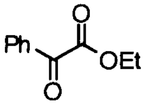
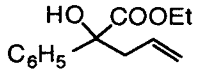
Recently, development of carbon-carbon bond formation reactions in aqueous media is a challenging target in organic synthesis.[3b,8] Regarding the allylation reactions, tetraallyltin has been employed as a nucleophile, surviving in aqueous media; Kobayashi et al. have reported lanthanide(III) triflate promoted reactions in aqueous media,[3a] and Yamamoto has disclosed a chemoselective allylation of carbonyl compounds in acidic aqueous media.[3b] As part of our program toward development of novel synthetic reactions using organogermanium compounds, we focused on tetraallylgermane[9] as a stable allylmetal for the first time. We wish to report herein scandium(III) trifluoromethanesulfonate[10]-promoted allylation reactions of carbonyl compounds with tetraallylgermane in aqueous media, wherein the presence of water is required.



Scheme 1

At the outset, treatment of tetraallylgermane (1.0 equiv) and benzaldehyde with scandium(III) trifluoromethanesulfonate (15 mol% based on benzaldehyde) in CH_3CN at room temperature furnished the corresponding homoallyl alcohol (**1**) in 68% yield.[11] Interestingly, addition of 14 mol equiv of H_2O based on $Sc(OTf)_3$ improved the yield of **1** to 83%. After screening the solvents, it was found that use of CH_3NO_2 as a solvent significantly accelerated the allylation reaction.[12] The results of the Sc(OTf)$_3$-promoted allylation of carbonyl compounds are shown in Table 1. In the present reaction, the amount of water strongly influenced both the yields and the reaction rate. While the allylation reaction was complete in less than 10 min without water, **1** was obtained in 64% yield (entry 1). As the amount of water was increased, the yield began to improve though the rate of the reaction slowed. Excellent yields were obtained when 30-40 mol equiv of water based on Sc(OTf)$_3$ was employed. Thus, use of 36 molar equiv of water in CH_3NO_2 afforded **1** in 94% yield (entry 2).[13] Further increase of the amount of water retarded the reaction considerably (entry 3). It is noted that more than one of the allyl groups on germanium reacted with carbonyl compounds and **1** was obtained in 78% yield when 0.5 equiv of tetraallylgermane was employed (entry 4).

Table 1. Results of the Sc(OTf)$_3$-catalyzed allylation of carbonyl compounds.[a]

Entry	Carbonyl Compounds	Product	Amount of Sc(OTf)$_3$[b]	Amount of H_2O[c]	Reaction Time / h	Yield /%
1	PhCHO	 **1**	0.10	0	0.1	64
2			0.10	36	0.75	94
3			0.10	80	18	75
4			0.10	34	24	78[d]
5			0.10	36	2.7	99
6			0.10	36	2.0	quant
7	PhCH$_2$CH$_2$CHO		0.15	43	3.5	92
8			0.15	0	0.1	33
9	n-C$_{11}$H$_{23}$CHO		0.20	43	4	92
10			0.20	0	0.1	45
11			0.20	39	2.5	75
12			0.20	28	0.5	87
13			0.20	0	114	92

a) The reactions were carried out using tetraallylgermane (1.0 equiv) and a carbonyl compound at room temperature in CH_3NO_2. b) mol equiv based on carbonyl compounds. c) mol equiv based on Sc(OTf)$_3$. d) 0.5 equiv of tetraallylgermane was used.

Allylation of both aromatic and aliphatic aldehydes proceeded smoothly to afford the corresponding homoallyl alcohols in excellent to good yields (entries 5, 6, 7, 9, and 11). Whereas 10 mol% of the catalyst sufficed for the aromatic aldehydes, use of 15-20 mol% of the catalyst was requisite for the aliphatic aldehydes (entries 7, 9, and 11). The effect of water is also prominently observed with aliphatic aldehydes such as 3-phenyl propanal and lauraldehyde, wherein removal of the water noticeably reduced the yields of the corresponding homoallyl alcohols (entries 8 and 10). Phenylglyoxal monohydrate, which possesses water of crystallization, afforded the mono-allylated product predominantly in 87% yield (entry 12). Ketones were inert under the standard conditions.[14] For example, acetophenone did not give the corresponding homoallyl alcohol. An activated ketone afforded the corresponding adduct. While allylation of an α-keto ester under the optimized reaction conditions did not take place, allylation of an α-keto ester completed without water after 114 h to furnish the adduct in 92% yield (entry 13).

Discrimination of aldehydes and ketones in the allylation reaction is not so easy. A high level of chemoselectivity has not been achieved except in a few instances.[3b,15] It is worth noting that the present system exhibited high chemoselectivity toward aldehydes. Competitive allylation reactions of aldehyde and ketone were thus examined under the influence of 10 mol% of $Sc(OTf)_3$ based on benzaldehyde in CH_3NO_2 in the presence of water and the results are shown in Table 2. In the presence of benzaldehyde and acetophenone (1: 1), benzaldehyde exclusively underwent allylation to afford **1** in 96% yield (entry 1). Chemoselective allylation of benzaldehyde also proceeded in the presence of an α-keto ester (entry 2).

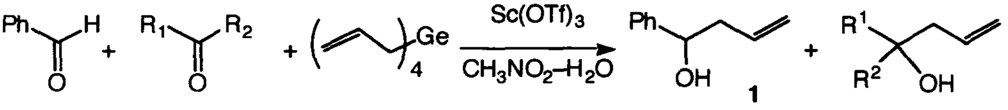


Table 2. Chemoselective allylation

Entry	Ketone	Yield of **1** / %	Yield of ketone adduct / %
1	$PhCOCH_3$	96	<1
2	PhCOCOOEt	95	<1

The present allylation reactions of aldehydes required 30-40 equiv of H_2O based on $Sc(OTf)_3$ for the reaction to proceed smoothly. Appropriate Lewis acidity appears to be essential to achieve the smooth reaction. H_2O would coordinate to scandium and lower the Lewis acidity of the catalyst. Addition of further amount of water decreased the Lewis acidity of $Sc(OTf)_3$ significantly, thus retarding the allylation reaction remarkably.[16]

In summary, we have developed a novel allylation reaction utilizing tetraallylgermane. Salient features of the present allylation reaction are: 1) the less toxic organogermanium compound has been utilized as an allylmetal, 2) allylation took place smoothly in the presence of water, 3) readily accessible tetraallylgermane was employed as an allylating reagent for the first time, 4) high chemoselectivity was achieved toward aldehydes.

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References and Notes

1. Yamamoto, Y.; Asao, N. *Chem. Rev.* **1993**, *93*, 2207-2293. Roush, W. R. In *Comprehensive Organic Synthesis*; Trost, B. M., Ed.; Pergamon Press: Oxford, 1991; Vol. 2, pp. 1-53. Fleming, I. In *Comprehensive Organic Synthesis*; Trost, B. M.; Fleming, I. Eds.; Pergamon Press: Oxford, 1991; Vol. 2, pp. 563-593.
2. Nishigaichi, Y.; Takuwa, A.; Naruta, Y.; Maruyama, K. *Tetrahedron* **1993**, *49*, 7395-7426. Aspinall, H. C.; Browning, A. F.; Greeves, N.; Ravenscroft, P. *Tetrahedron Lett.* **1994**, *35*, 4639-4640. Keck, G. E.; Tarbet, K. H.; Geraci, L. S. *J. Am. Chem. Soc.* **1993**, *115*, 8467-8468. Kobayashi, S.; Nishio, K. *Tetrahedron Lett.* **1995**, *36*, 6729-6732. Whitesell, J. K.; Apodaca, R. *Tetrahedron Lett.* **1996**, *37*, 3955-3958. Yanagisawa, A.; Nakashima, H.; Ishida, A.; Yamamoto, H. *J. Am. Chem. Soc.* **1996**, *118*, 4723-4724.
3. For the use of tetraallyltin: a) Hachiya, I.; Kobayashi, S. *J. Org. Chem.* **1993**, *58*, 6958-6960. Kobayashi, S.; Hachiya, I.; Yamanoi, Y. *Bull. Chem. Soc. Jpn.* **1994**, *67*, 2342-2344. Kobayashi, S.; Nagayama, S. *J. Org. Chem.* **1996**, *61*, 2256-2257. b) Yanagisawa, A.; Inoue, H.; Morodome, M.; Yamamoto, H. *J. Am. Chem. Soc.* **1993**, *115*, 10356-10357. c) Cokley, T. M.; Marshall, R. L.; McClusky, A.; Young, J. J. *Tetrahedron Lett.* **1996**, *39*, 1905-1908.
4. Majetich, G. In *Organic Synthesis, Theory and Applications.*; Hudlicky Ed.; JAI Press, Inc.: Greenwich, CT, 1989; pp. 173-241. Fleming, I.; Dunogues, J.; Smithers, R. *Org. React. (N.Y.)* **1989**, *37*, 57-575.
5. For the use of allylgermane as an allylmetal: Sano, H.; Miyazaki, Y.; Okawara, M.; Ueno, Y. *Synthesis* **1986**, 776-777. Yamamoto, Y.; Matsuya, S.; Yamada, J. *J. Org. Chem.* **1990**, *55*, 3118-3128. Sato, T.; Otera, J.; Nozaki, H. *J. Org. Chem.* **1990**, *55*, 6116-6121. Yamamoto, Y.; Okano, H.; Yamada, J. *Tetrahedron Lett.* **1991**, *32*, 4749-4752. Denmark, S. E.; Almstead, N. B. *J. Org. Chem.* **1991**, *56*, 6485-6487. Hashimoto, Y.; Kagoshima, H.; Saigo, K. *Tetrahedron Lett.* **1994**, *35*, 4805-4808.
6. For organogermanium compounds in organic synthesis: Yokoyama, Y.; Mochida, K. *Synlett* **1996**, 445-446. See also references cited therein.
7. Barnes, J. M.; Magos, L. *Organometal. Chem. Rev.* **1968**, *3*, 137-150.
8. Reissig, H. -U. In *Organic Synthesis Highlights*; VCH: Weinheim, 1991; pp. 71-76. Li, C.-J. *Chem. Rev.* **1993**, *93*, 2023-2035.
9. O'Brien, S.; Fishwick, M.; Mcdermott, B.; Wallbridge, M. G. H.; Wright, G. A. *Inorg. Synth.* **1971**, *13*, 73. Tetraallylgermane is fairly stable in acidic aqueous media.
10. Kobayashi, S.; Hachiya, I.; Ishitani, H.; Araki, M. *Synlett* **1993**, 472-474.
11. Other lanthanide triflates such as $Sm(OTf)_3$ and $Yb(OTf)_3$ were found to be less effective.
12. For the use of $Sc(OTf)_3$ in nitromethane: Aggarwal, V. K.; Vennall, G. P. *Tetrahedron Lett.* **1996**, *37*, 3745-3746.
13. A typical experimental procedure; To a suspension of scandium trifluoromethanesulfonate (13.1 mg, 0.0266 mmol) in nitromethane (0.8 mL) and H_2O (17 μL, 0.94 mmol) was added successively tetraallylgermane (63.4 mg, 0.268 mmol) and benzaldehyde (27 μL, 0.27 mmol) at room temperature. After being stirred at that temperature for 45 min, the reaction was quenched by addition of 1N HCl solution. The aqueous layer was extracted with ethyl acetate and the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, and concentrated to dryness. Purification of the crude mixture by column chromatography (SiO_2, hexane: ethyl acetate = 6 : 1, v/v) gave **1** (37.2 mg) in 94% yield.
14. The combined system of tetraallyltin and $Sc(OTf)_3$ afforded the ketone adduct in good yields: Phenylglyoxal exclusively afforded the diallylated adduct.[3a]
15. Okude, Y.; Hirano, S.; Nozaki, H. *J. Am. Chem. Soc.* **1977**, *99*, 3179-3181. Reetz, M. T.; Wendderoth, B. *Tetrahedron Lett.* **1982**, *23*, 5259-5262.
16. Effect of water on lanthanide(III)-triflate promoted reactions is discussed: Kobayashi, S. *Synlett* **1994**, 689-701.

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