6958 *J. Org. Chem.* **1993**, *58*, 6958–6960

Aqueous Reactions with a Lewis Acid and an Organometallic Reagent. The Scandium Trifluoromethanesulfonate-Catalyzed Allylation Reaction of Carbonyl Compounds with Tetraallyltin

Iwao Hachiya and Shū Kobayashi*

Department of Applied Chemistry, Faculty of Science, Science University of Tokyo (SUT),
Kagurazaka, Shinjuku-ku, Tokyo 162, Japan

Received August 9, 1993[•]

Summary: The allylation reaction of a wide variety of carbonyl compounds with tetraallyltin was successfully carried out in aqueous media by using scandium trifluoromethanesulfonate (scandium triflate) as a catalyst.

Development of carbon–carbon bond-forming reactions that can be carried out in aqueous media is one of the most challenging tasks in organic synthesis.[1]

The utility of aqueous reactions is now generally recognized. For example, it is desirable to perform reactions of unprotected sugars or peptides in aqueous media because of their solubility. Compounds containing water of crystallization or other water-soluble compounds require tedious procedures to remove the water. These steps are not necessary if the reactions can be successfully carried out in aqueous media. Moreover, aqueous reactions of organic compounds avoid the use of harmful organic solvents.[2]

On the other hand, water often interferes with organic reactions. Although Lewis acids[3] or organometallic reagents[4] have played important roles in modern organic synthesis, even a small amount of water stops reactions using these reagents because the reagents immediately react with water rather than the substrates.

In order to realize aqueous reactions, we thought that new reagents which can be used in water were required. Recently, we have developed novel Lewis acids, lanthanide[5] or scandium[6] compounds, which can be used not only in organic solvents but also in aqueous media. In this paper, we report aqueous allylation reactions of carbonyl compounds[7] using scandium trifluoromethanesulfonate (scandium triflate, $Sc(OTf)_3$) and tetraallyltin.[8]

The allylation reactions of carbonyl compounds proceeded smoothly under the influence of 5 mol % of $Sc(OTf)_3$[6,9] by using tetraallyltin as an allylating reagent.[10] Some examples are shown in Table I. The characteristic features of the allylation reaction follow. (1) The reactions proceed smoothly in the presence of only a catalytic amount of $Sc(OTf)_3$ under extremely mild conditions, and the adducts, homoallylic alcohols, are obtained in high yields. (2) Ketones can also be used in the reaction (entries 5–8). (3) In most cases, the reactions are successfully carried out in aqueous media. While most Lewis acids decompose or deactivate in water, $Sc(OTf)_3$ is stable in aqueous media and efficiently activates aldehydes as a Lewis acid. Unprotected sugars react directly to give the adducts in high yields (entries 9–11). The allylated adducts are intermediates for the synthesis of higher sugars.[7h] Moreover, aldehydes containing water of crystallization, such as phenylglyoxal monohydrate, react with tetraallyltin to give the diallylated adduct in high yield (entry 12). (4) Under the present reaction conditions, salicylaldehyde and 2-pyridinecarboxaldehyde react with tetraallyltin to afford the homoallylic alcohols in good yields (entries 13 and 14). Under general Lewis acid conditions, these compounds react with the Lewis acids rather than the nucleophile. (5) Several kinds of solvents can be used. The reactions also proceed under nonaqueous conditions. Reactions with substrates prone to acid-catalyzed hydrolysis can be conducted in an appropriate organic solvent (entries 15 and 16). (6) Stoichiometry of an aldehyde and tetraallyltin was investigated in aqueous media (H_2O:THF = 1:9); benzaldehyde:tetraallyltin = 1:1, 89% yield; 2:1, 94% yield (entry 2); 4:1, 84% yield. These results indicate that four allyl groups can be transferred.

Following are typical experimental procedures for the $Sc(OTf)_3$-catalyzed allylation reaction in aqueous and organic solvents. In aqueous media: To a mixture of $Sc(OTf)_3$ (0.015 mmol, 5 mol %) and D-arabinose (0.3 mmol) in H_2O/CH_3CN (1:4, 1.5 mL) was added tetraallyltin (0.15 mmol) in CH_3CN (1.5 mL) at rt. The mixture was stirred

---

[•] Abstract published in *Advance ACS Abstracts*, November 15, 1993.

[1] (a) Reissig, H.-U. In *Organic Synthesis Highlights*; VCH: Weinheim, 1991; p 71. (b) Einhorn, C.; Einhorn, J.; Luche, J.-L. *Synthesis* **1989**, 787.

[2] For example: Zhang, H.-C.; Daves, G. D., Jr. *Organometallics* **1993**, *12*, 1499 and references cited therein.

[3] Schinzer, D., Ed. *Selectivities in Lewis Acid Promoted Reactions*; Kluwer Academic Publishers: Dordrecht, 1989.

[4] Wilkinson, G., Stone, F. G. A., Abel, E. W., Eds. *Comprehensive Organometallic Chemistry*; Pergamon Press: New York, 1982.

[5] (a) Kobayashi, S. *Chem. Lett.* **1991**, 2087. (b) Kobayashi, S.; Hachiya, I. *Tetrahedron Lett.* **1992**, *33*, 1625. (c) Kobayashi, S.; Hachiya, I.; Takahori, T.; Araki, M.; Ishitani, H. *Ibid.* **1992**, *33*, 6815. (d) Kobayashi, S.; Hachiya, I.; Takahori, T. *Synthesis* **1993**, 371.

[6] Kobayashi, S.; Hachiya, I.; Araki, M.; Ishitani, H. *Tetrahedron Lett.* **1993**, *34*, 3755.

[7] The allylation reactions of carbonyl compounds using allyl halides and Zn, Sn, or In in aqueous media were previously reported. (a) Nokami, J.; Otera, J.; Sudo, T.; Okawara, R. *Organometallics* **1983**, *2*, 191. (b) Petrier, C.; Luche, J.-L. *J. Org. Chem.* **1985**, *50*, 910. (c) Petrier, C.; Einhorn, J.; Luche, J.-L. *Tetrahedron Lett.* **1985**, *26*, 1449. (d) Einhorn, C.; Luche, J.-L. *J. Organomet. Chem.* **1987**, *322*, 177. (e) Mattes, H.; Benezra, C. *Tetrahedron Lett.* **1985**, *26*, 5697. (f) Wilson, S. R.; Guazzaroni, M. E. *J. Org. Chem.* **1989**, *54*, 3087. (g) Wu, S.; Huang, B.; Gao, X. *Synth. Commun.* **1990**, *20*, 1279. (h) Schmid, W.; Whitesides, G. M. *J. Am. Chem. Soc.* **1991**, *113*, 6674. (i) Li, C. J.; Chan, T. H. *Tetrahedron Lett.* **1991**, *32*, 7017. (j) Oda, Y.; Matsuo, S.; Saito, K. *Tetrahedron Lett.* **1992**, *33*, 97.

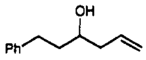
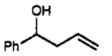
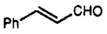
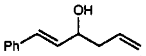
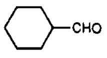
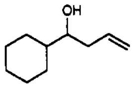
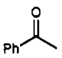
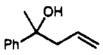
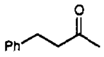
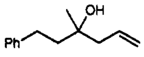
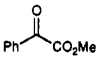
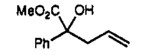
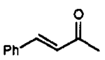
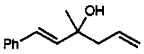
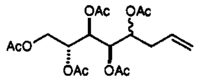
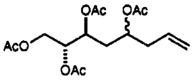
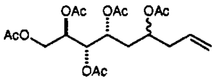
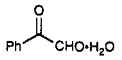
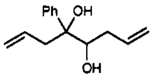
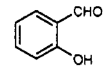
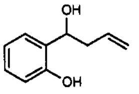
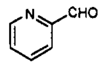
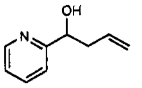
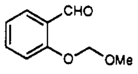
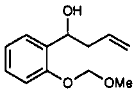
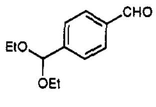
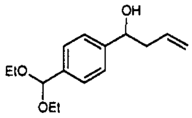
[8] For the reactions of carbonyl compounds with tetraallyltin, see: (a) Peet, W. G.; Tam, W. *J. Chem. Soc., Chem. Commun.* **1983**, 853. (b) Daude, G.; Pereyre, M. *J. Organomet. Chem.* **1980**, *190*, 43. (c) Harpp, D. N.; Gingras, M. *J. Am. Chem. Soc.* **1988**, *110*, 7737. See also: (d) Fukuzawa, S.; Sato, K.; Fujinami, T.; Sakai, S. *J. Chem. Soc., Chem. Commun.* **1990**, 939. Quite recently, Yamamoto et al. reported allylation reactions of aldehydes with tetraallyltin in the presence of hydrochloric acid. (e) Inoue, H.; Yanagisawa, A.; Yamamoto, H. *Abstracts of Papers*, the 65th Annual Meeting of the Chemical Society of Japan, Tokyo, March 1993; 4G106, p 383. (f) Yanagisawa, A.; Inoue, H.; Morodome, M.; Yamamoto, H. *J. Am. Chem. Soc.*, in press.

[9] Thom, K. F. US Patent 3615169 (1971); *Chem. Abstr.* **1972**, *76*, 5436a.

[10] Lewis acid-promoted allylation reactions of carbonyl compounds with allyltrialkyltin were reported. (a) Yamamoto, Y.; Yatagai, H.; Naruta, Y.; Maruyama, K. *J. Am. Chem. Soc.* **1980**, *102*, 7107. (b) Pereyre, M.; Quintard, J.-P.; Rahm, A. *Tin in Organic Synthesis*; Butterworths: London, 1987; p 216.

0022-3263/93/1958-6958$04.00/0

Table I. Sc(OTf)$_3$-Catalyzed Allylation Reactions of Carbonyl Compounds[a]

entry	carbonyl compd	product	solvent	yield (%)
1			H_2O/THF (1:9 H_2O/EtOH (1:9) H_2O/CH_3CN (1:9) EtOH CH_3CN	92 96 96 86 94
2	PhCHO		H_2O/THF (1:9) CH_3CN	94 82
3			H_2O/THF (1:9) CH_3CN	98 94
4			H_2O/THF (1:9) CH_3CN	83 74
5			CH_2Cl_2	77
6			CH_2Cl_2	78
7			H_2O/THF (1:9)	87
8			CH_2Cl_2	82
9	D-arabinose		H_2O/THF (1:4) H_2O/EtOH (1:4) H_2O/CH_3CN (1:9)	81[b] 89[c] 93[d]
10	2-deoxy-D-ribose		H_2O/THF (1:9)	89[e]
11	2-deoxy-D-glucose		H_2O/THF (1:9)	88[f]
12			CH_3CN	78[g]
13			H_2O/THF (1:9) CH_3CN	quant 90
14			H_2O/THF (1:9) CH_3CN	quant 84
15			CH_3CN	87
16			CH_3CN	90

[a] Carried out at 25 °C except for entries 10 and 11 (60 °C). [b] The products were isolated after acetylation (see the typical experimental procedure). [c] Syn/anti = 28/72. [d] Syn/anti = 27/73. [e] Syn/anti = 26/74. [f] Syn/anti = 50/50. [g] Diastereomer ratio = 88/12. Relative configuration assignment was not made.

for 60 h at this temperature. After the solvents were removed under reduced pressure, pyridine (3 mL) and Ac_2O (1.5 mL) were added, and the mixture was stirred for 5 h. Cold 1 N HCl was added, and the organic layer was extracted with Et_2O. The crude product was chromatographed on silica gel to afford the pentaacetylated adducts (93%). When the reaction was carried out at 60 °C for 3 h, almost the same yield was obtained. In organic solvent: To a solution of Sc(OTf)$_3$ (0.015 mmol, 5 mol %) in CH_3CN (1.5 mL) was added a mixture of 3-phenylpropionaldehyde (0.3 mmol) and tetraallyltin (0.15 mmol) in CH_3CN (1.5 mL) at rt. The mixture was stirred for 0.5 h at this temperature, and water was then added. The aqueous layer was extracted with CH_2Cl_2, and the organic extract was dried (Na_2SO_4). The solvents were removed under reduced pressure, and the crude product was chromatographed on silica gel to afford the corresponding homoallylic alcohol (94%).

In summary, we have developed an efficient allylation reaction of carbonyl compounds which can be successfully carried out in aqueous media. The reaction also proceeds in several kinds of solvents, even in organic solvents under strict anhydrous conditions. The reaction strongly depends on the unique character of $Sc(OTf)_3$. Further applications to other synthetic reactions using $Sc(OTf)_3$ as a catalyst are now in progress.

Acknowledgment. This work was partially supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture, Japan. I.H. is thankful for the JSPS fellowship for Japanese Junior Scientists.

Supplementary Material Available: ^{1}H NMR and ^{13}C NMR spectra of structures (32 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.