

Facile and Highly Stereoselective Allylation of Aldehydes Using Allyltrichlorosilanes in DMF

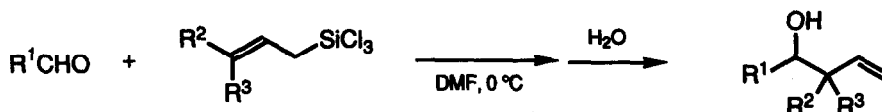
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Abstract: Allyltrichlorosilanes regioselectively react with aldehydes in *N,N*-dimethylformamide (DMF) without catalyst to afford the corresponding homoallylic alcohols in high yields. *Syn* and *anti* homoallylic alcohols are stereoselectively obtained from (*Z*)- and (*E*)-crotyltrichlorosilane, respectively, under neutral conditions.

Allylation reaction of carbonyl compounds using allyl metals is one of the most basic carbon-carbon bond forming methodologies in organic synthesis.¹⁾ In particular, the Lewis acid-promoted reaction using allyltrimethylsilane, which proceeds in high regioselectivities, is versatile and broadly applicable,²⁾ however, yields and stereoselectivities are sometimes moderate. Quite recently, highly diastereoselective allylation reaction of allyltrifluorosilane with aldehydes was reported, but even in this reaction more than stoichiometric amount of cesium fluoride was required as a promoter.³⁾

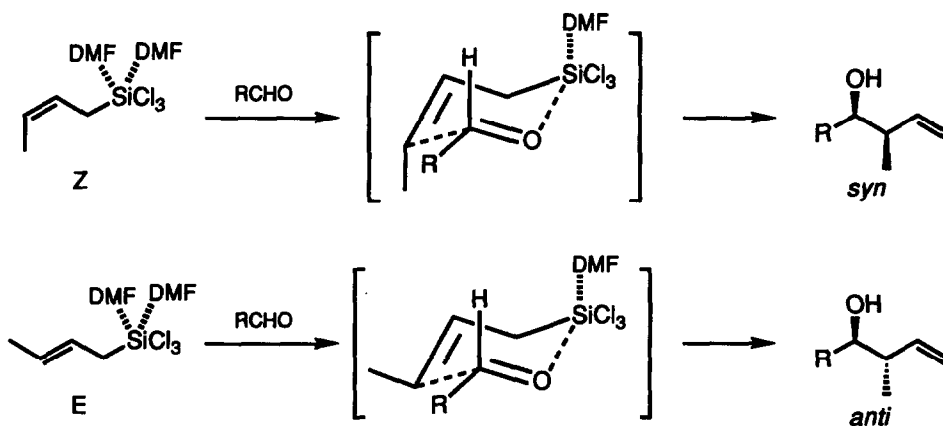
In this communication, we would like to report essentially simple and useful allylation reaction of aldehydes using allyltrichlorosilane under neutral conditions. The reaction proceeds *without catalyst* by just mixing allyltrichlorosilanes and aldehydes in *N,N*-dimethylformamide (DMF) at 0 °C, and high yields and high regio- and diastereoselectivities are attained.



A typical experimental procedure is described for the reaction of (*Z*)-crotyltrichlorosilane (1Z) with 3-phenylpropionaldehyde; a mixture of 1Z (*Z*/*E*⇒99/1, 0.40 mmol) and benzaldehyde (0.32 mmol) in DMF (2 ml) was stirred at 0 °C for 2 h. Saturated aqueous sodium hydrogen carbonate was added to quench the reaction, and the aqueous layer was extracted with ether. The ether layer was washed with water and brine successively and then

dried (Na_2SO_4). The crude product was purified by TLC (silica gel) to afford the corresponding homoallylic alcohol in 82% yield. ^1H and ^{13}C NMR showed a single isomer which was assigned as *syn* adduct after comparison with the ^1H NMR data of the literature.⁴⁾ Anti adduct was not observed in the NMR spectra.


Several examples of the present allylation reaction are shown in Table 1. Allyltrichlorosilane, (E)- and (Z)-crotyltrichlorosilane, and even sterically hindered prenyltrichlorosilane smoothly react with aldehydes to give the corresponding homoallylic alcohols in high yields with γ -selectivities. One of the most characteristic points of these reactions is the excellent regio- and diastereoselectivities. New carbon-carbon bond formation takes place only at γ -positions of allyltrichlorosilanes. On the other hand, *syn* isomers are obtained from (Z)-crotyltrichlorosilane, while *anti* isomers are produced from (E)-crotyltrichlorosilane in almost complete selectivities. These can be explained by the six-membered cyclic transition state⁵⁾ as shown in Scheme 1.




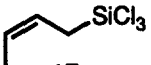
Scheme 1.

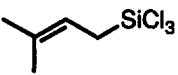
In the present reaction, use of DMF is crucial. We examined several solvents, but the reaction proceeded only in DMF. ^{29}Si NMR spectra of **1Z**⁶⁾ indicated that DMF coordinated to silicon atom of **1Z** to form the corresponding five or six coordinated organosilicate.⁷⁾ This hypervalent silicate has enough Lewis acidity based on the electron withdrawing chlorine groups as well as nucleophilicity due to electron donation from the hypervalent silicon atom to the allyl π systems (σ - π conjugation),⁸⁾ which enable the reaction to proceed smoothly and stereoselectively. We previously showed that trimethylsilyl cyanide (TMS-CN) smoothly reacted with aldehydes to afford the corresponding cyanohydrin trimethylsilyl ethers in excellent yields in the presence of a catalytic amount of Lewis base such as amine, phosphine, arsine or antimony.⁹⁾ In this reaction, the Lewis bases would coordinate to TMS-CN to form the reactive intermediate, pentacoordinated silicate, which bears a potential for reacting with aldehydes to give the corresponding cyanohydrin trimethylsilyl ethers. A same kind of

Table 1. Allylation Reaction of Allyltrichlorosilanes with Aldehydes in DMF

Entry	Allyltrichlorosilane	Aldehyde	Yield / % ^{a)}	syn / anti ^{b)}
1		PhCHO	91	—
2		Ph(CH ₂) ₂ CHO	90	—
3		PhCH=CHCHO	88	—

4		PhCHO	89	3 / 97
5	1 E (Z/E = 3/97) ^{c)}	Ph(CH ₂) ₂ CHO	87	3 / 97
6		PhCH=CHCHO	88	7 / 93
7		c-C ₆ H ₁₁ CHO	83	4 / 96 ^{d)}

8		PhCHO	82	> 99 / 1 ^{e)}
9	1 Z (Z/E = >99/1) ^{c)}	Ph(CH ₂) ₂ CHO	85	> 99 / 1 ^{e)}
10		PhCH=CHCHO	88	96 / 4
11		c-C ₆ H ₁₁ CHO	85	97 / 3 ^{d)}

12		PhCHO	89	—
13		PhCH=CHCHO	82	—
14		Ph(CH ₂) ₂ CHO	87	—

a) Isolated yield.

b) Determined by ¹H NMR.

c) Determined by GC.

d) The reaction was carried out at r.t.

e) Anti isomer was not observed in ¹H and ¹³C NMR.

intermediate is now assumed in the present allylation reaction, and it should be noted that the reactive species is prepared by using DMF as a solvent.

In addition to synthetic utilities of the quite simple procedure under neutral conditions and the high regio- and stereoselectivities, the present reaction is valuable because the starting materials, allyltrichlorosilanes, are commercially and readily available or can be easily prepared not only from the corresponding halides but also from the dienes via hydrosilylation reactions stereoselectively.^{3b,10)}

Further investigations to utilize the unique characters of the hypervalent silicates in synthetic reactions as well as to clarify the precise mechanism is now in progress.

References and Notes

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