Applications of Allenylsilanes in Organic Synthesis

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Introduction

Allenylsilanes are versatile reagents widely used in organic synthesis. Generally, allenylsilanes react as propargyl anion equivalents in Lewis acid mediated or thermal nucleophilic addition to electrophiles such as carbonyls, imines, Selectfluor, and N-bromosuccinimide, etc. The regioselective addition of allenylsilanes provides a β-vinyl cation, which is stabilized by a C–Si bond, which is called β effect. The C–Si bond in allenylsilanes is oriented cis-coplanar to the p-orbital of the carboxation and provides direct stabilization. Allenylsilanes undergo [3+2] annulations with α,β-unsaturated carbonyls, carbonyl compounds, imines, and nitrosyl cations to form cyclopentenones, dihydropyranons, dihydropyrroles, and isoxazoles, respectively.

The efficient methods for the synthesis of allenylsilanes are copper-mediated 1,3-substitution reactions of carbon nucleophiles to propargylic substrates having a leaving group at the propargylic position.

Scheme 1 Synthesis of allenylsilanes

Abstracts

(A) Reactions with Aldehydes: Allenylsilanes react with aldehydes and ketones in the presence of titanium tetrachloride to provide homopropargylic alcohols in a regioselective manner. The reaction of chiral allenylsilanes with chiral aldehydes leads to the formation of mainly syn homopropargylic alcohols. The reaction of chiral 3,3-disubstituted allenylsilane with paraformaldehyde in the presence of TiCl₄·2THF generates chiral homopropargylic alcohol, which is the key intermediate in the total synthesis of (-)-histrionicotoxin.

(B) Reactions with Aldehydes: The reaction of chiral 2-silyl-substituted α-allenic alcohol with aldehyde in the presence of InBr₃ give rise to chiral homopropargylic alcohol. The reaction proceeds via formation of oxocarbenium ion, which undergoes a [3,3]-sigmatropic rearrangement to form the alcohol. The alcohol is the key intermediate in the total synthesis of the natural product (+)-neopeltolide.
(C) Reactions with Aldehydes: The addition of γ-trimethylsilyl alkenes 13 to aldehydes 14 in the presence of i-PrOLi leads to the formation of regiospecific γ-carbinols 18. The addition of anionic catalyst i-PrOLi leads to the intermediate 15, which possess enolate-like reactivity. The nucleophilic addition of intermediate 15 to aldehyde 14 generates intermediate 16. Then, the silyl group undergoes a 1,3-shift and the nucleophile eliminates to form the intermediate 17. This reaction is the key step in the total synthesis of the [3.2.1] bicyclic natural product vitisinol D.10

(D) Reactions with Imines: The enantioenriched allenylsilane 20 reacts with the in situ generated iminium ion generated from benzynes 23 and aldehydes 21 in the presence of BF3·OEt2 to form substituted 4,5-dihydropyrroles 24. Similarly, the reaction of allenylsilane 20 with an iminium ion, generated in situ from methyl carbamate 23 and aldehydes 21 in the presence of TMSOTf, forms substituted 4,5-dihydropyrroles 25.11

(E) Gold-Catalyzed Cycloisomerization: In the presence of AuCl3, the γ-silyl-substituted allenyl ketones 29 undergoes cycloisomerization to 3-silyl furans 32. The cyclization of the allenyl ketone 29 give rise to the intermediate gold-carbene 31, and upon the 1,2-Si shift, the 3-silyl furan 32 is produced.15

(F) The Pauson–Khand Reaction of 1,1-Disubstituted Allenylsilanes: The Pauson–Khand reaction of 1,1-disubstituted allenylsilanes with terminal alkynes leads to 4-alkylidene-2-cyclopenten-1-ones in three-membered iron metacycle is generated by reaction of allenylsilane 33 with the in situ generated iminium ion generated from benzynes 33 with diiron nonacarbonyl. The iron metacycle undergoes complexation with alkyne 34, and finally, a reductive elimination takes place to provide the 4-alkylidene-2-cyclopenten-1-one 35.11

(G) [2+2+2] Cycloaddition with Benzynes: Benzynes possess a strained triple bond and are highly electrophilic. Allenylsilanes 37 react with two equivalents of benzynes 36 to generate (α-phenanthryl)vinylsilanes 38 in excellent yields. The reaction proceeds through a [2+2+2] pathway.14

References