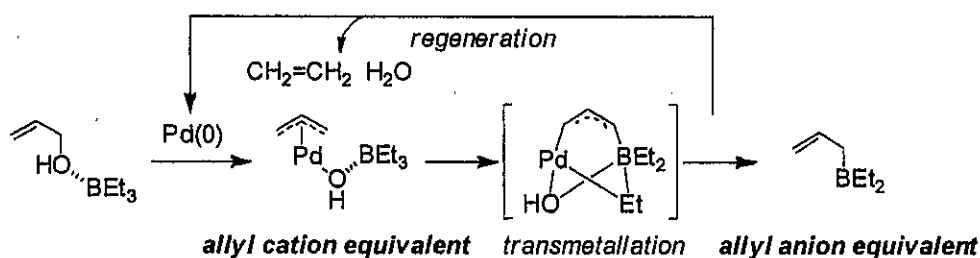


Advances in Electrophilic, Nucleophilic, and Amphiphilic Allylation Promoted by Synergy Effect of Palladium and Lewis Acids

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Tsuji-Trost reaction is one of the most reliable methods in organic synthesis. Since the pioneering work of π -allylpalladium chemistry by Tsuji and Trost, many efficient catalyst systems have been developed and are widely applied to natural and unnatural compounds. Various allyl substrates such as allylic acetates, esters and carbonates have been used in Tsuji-Trost reaction. However, direct use of allyl alcohol is very rare owing to the poor leaving ability of hydroxyl group, although development of a direct catalytic allylic substitution reaction is the most straightforward and desirable. Combination of Pd catalyst and triethylborane promotes electrophilic allylation of various nucleophiles with allyl alcohols to proceed C-C bond transformation. In this system, Et_3B activates allyl alcohols toward oxidative addition of palladium species by coordinating to hydroxyl group to form π -allylpalladium intermediates. This π -allylpalladium species serves as an allyl cation equivalent. On the contrary, in the absence of nucleophiles, π -allylpalladium accelerates allyl-ethyl exchange reaction to provide allyldiethylborane as an allyl anion equivalent (Scheme 1).

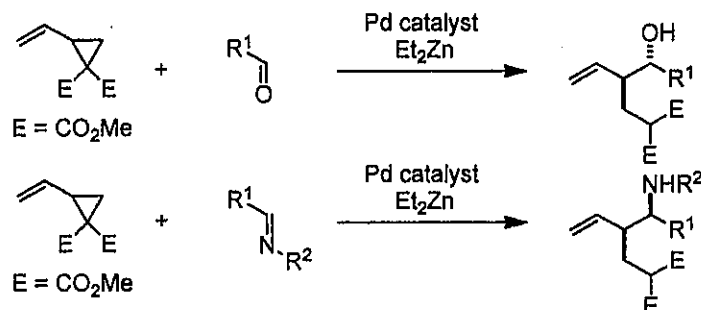
Scheme 1. Pd-catalyzed, Et_3B -promoted amphiphilic allylation by an allyl cation and an allyl anion species.



The author developed novel and synthetically useful catalytic reactions via allyl cation equivalents and allyl anion equivalents by use of a palladium catalyst and Lewis acid. The thesis is composed of three chapters. Chapter 1 describes palladium catalyst and diethylzinc system promoted nucleophilic allylation of aldehydes and aldimines with vinylcyclopropane. A palladium-catalyzed nucleophilic allylation of aldehydes with vinylcyclopropane in the presence of diethylzinc proceeded to provide homoallyl alcohols with *anti* stereoselectivity (Scheme 2). Aldimines prepared from aldehyde and primary amines in situ underwent a similar nucleophilic allylation to give homoallylamines with *syn* stereoselectivity. The resulting homoallyl alcohols

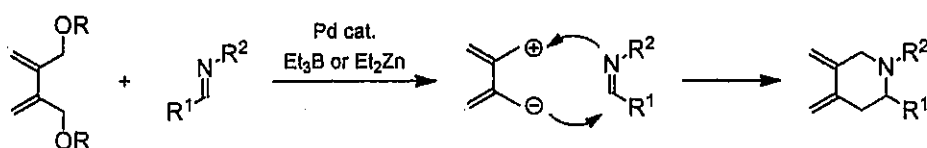
and homoallylamines could be converted by treatment with a tetranuclear zinc cluster into γ -vinyl- δ -valerolactones and γ -vinyl- δ -valerolactams, respectively.

Scheme 2 Pd-catalyzed nucleophilic allylation of aldehydes or aldimines with allyl alcohols



In chapter 2, consecutive double amphiphilic allylation of nitriles with 2-methylenepropane-1,3-diol catalyzed by palladium/triethylborane system is described. The combination of a Pd catalyst and triethylborane promotes the double amphiphilic allylation of nitriles with 2-methylenepropane-1,3-diol to serve as a 1,3-dipolar equivalent, providing pyrrolizidine derivatives. This double amphiphilic allylation can be expected as a highly efficient synthetic method of important pyrrolizidine alkaloids. In chapter 3, the amphiphilic allylation of aldimines with 2,3-bismethylenebutane-1,4-diol derivatives to serve as a 1,4-dipolar equivalent proceeded by combination of palladium catalyst and diethylzinc preparing 3,4-bismethylenepiperidines is described. The combination of Pd catalyst and diethylzinc promotes the amphiphilic allylation of aldimines with 2,3-bismethylenebutane-1,4-diol derivatives to serve as a 1,4-dipolar equivalent to form 3,4-bismethylenepiperidines via a formal [4 + 2] cycloaddition reaction (Scheme 3). Thus, the combination of palladium catalyst and Lewis acids such as triethylborane and diethylzinc promotes novel and synthetically useful amphiphilic allylation via umpolung of π -allylpalladium intermediates.

Scheme 3. Amphiphilic Allylation of Aldimines with 2,3-Dimethylenebutane- 1,4-diols



Chapter 4 describes palladium catalyst with phosphine-borane ligand system promoted direct allylic amination of allyl alcohols. When ethylene-linked phosphine-borane compound L1 was used as a ligand, electrophilic allylation of *N*-methylaniline with cinnamyl alcohol proceeded to give the corresponding allylamine in excellent yield for 1 hour at ambient temperature (eq. 1) The method allowed us to access easily to allylic amines from various allyl alcohols

