

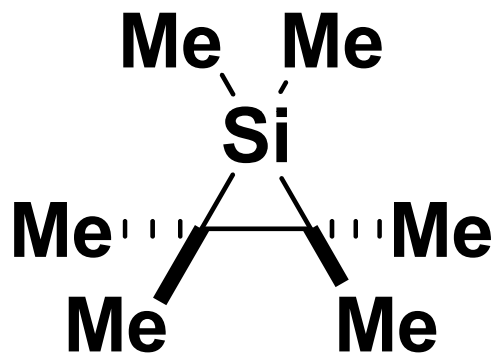
Silacyclopropanes

Anne-Marie Dechert

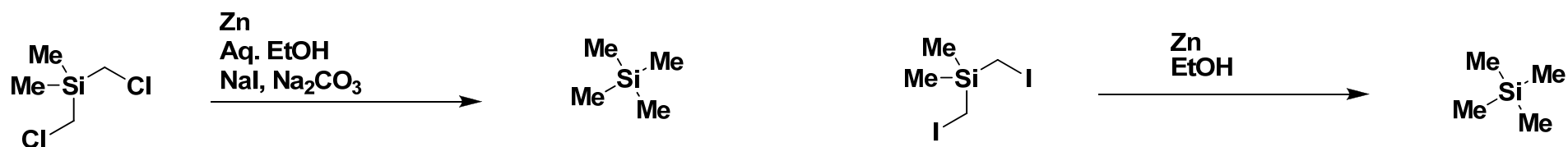
June 25, 2008

Outline

- History
- Synthesis
- Reactions of Silacyclopropanes
- Applications to Synthesis
- Summary/Conclusion



Prior Attempts



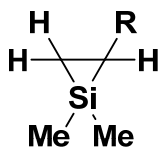
Many attempts to synthesize silacyclopropanes

Failure can be attributed to the excessive ring strain introduced by the silicon atom

Roberts, J.; Dev, S. *J. Am. Chem. Soc.* **1951**, 73, 1879.

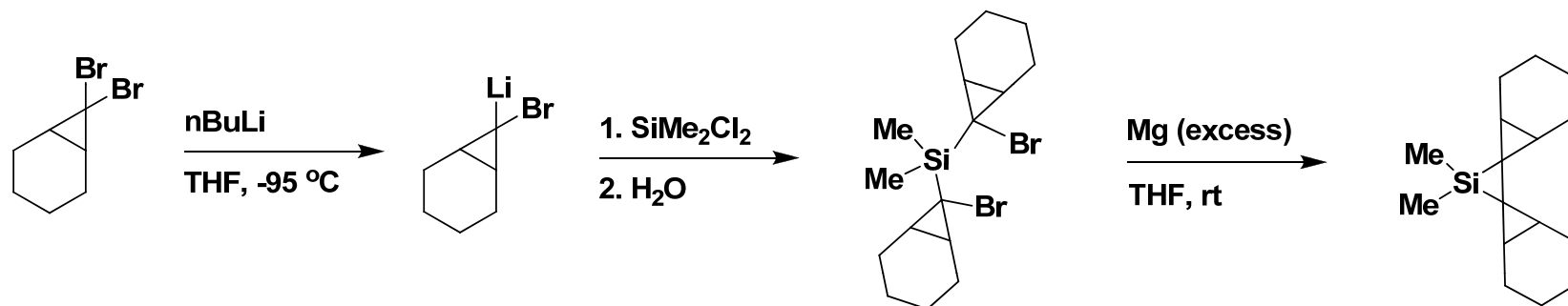
Tang, Y.; Gennaro, G.; Su, Y. *J. Am. Chem. Soc.* **1972**, 94, 4357.

First Isolated Silacyclopropane



R = H or alkyl

Prior to Seyferth's work, attempts to synthesize silacyclopropanes were directed toward "lightly" substituted silacyclopropanes.

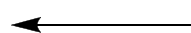
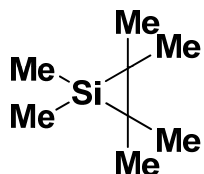
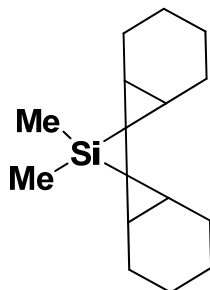


Wurtz type coupling

air sensitive
(unsurprisingly) highly reactive

Still, the question remains: are all siliranes stable?
Is there something special about the dispiro structure?
If the dispiro structure was important, was it important due to steric bulk or electronic factors?

Other Isolated Silacyclopropanes

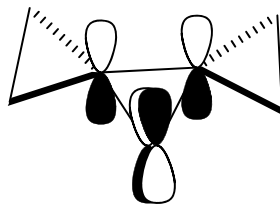


considerably less stable

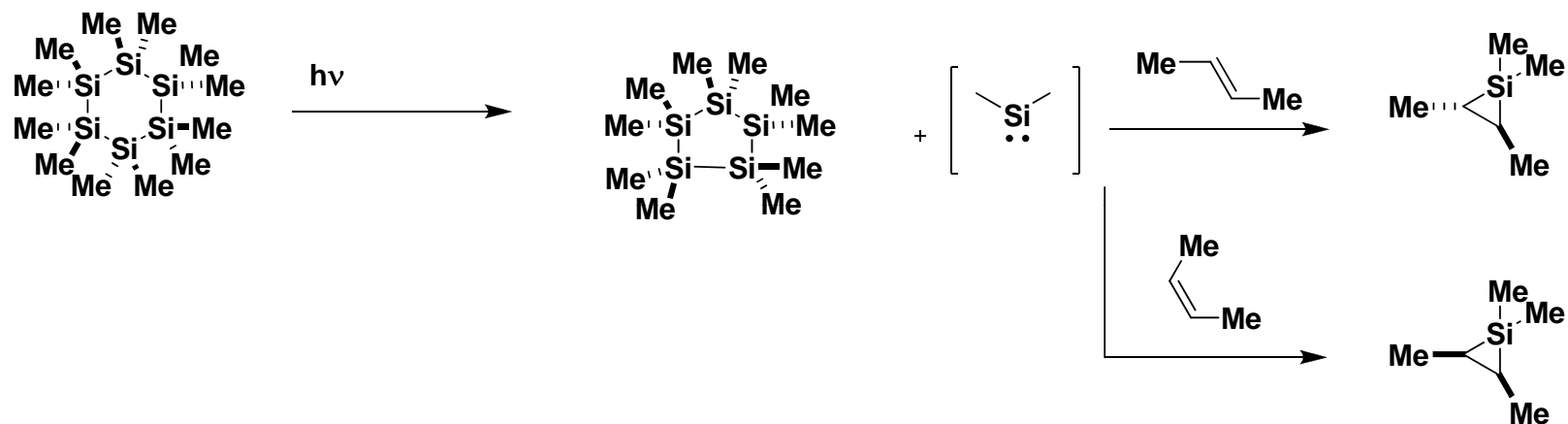
- Stable under an inert atmosphere at room temp for about 9 days
dispiro system has a half life of 7 days at 63 °C

- Seyferth suggests that electronic as well as steric factors are important in making the dispiro silacyclopropanes so stable

- Proposed that the dispiro compound is stabilized considerable by hyperconjugation (overlap of the filled Walsh orbitals of the spiroannulated cyclopropane ring with vacant silicon 3d orbitals)

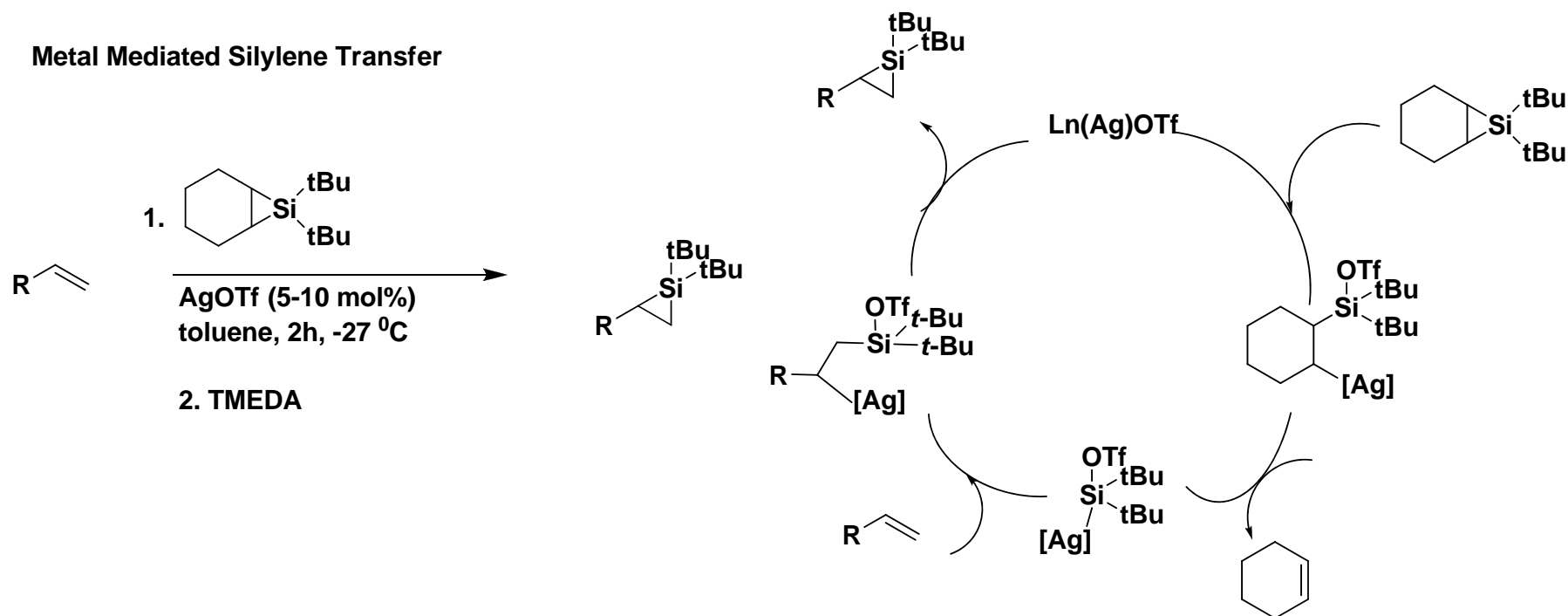


Synthesis of Silacyclopropanes



short coming: siliranes generated under these conditions are unstable giving rise to isomeric products

Metal Mediated Silylene Transfer

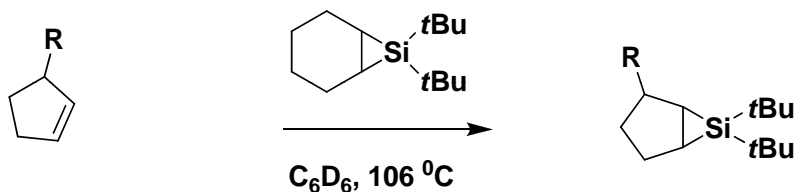


Ishikawa, M.; Kumada, M. *J. Organomet. Chem.* **1972**, *42*, 325.

Cirakovic, J.; Driver, T.; Woerpel, K. *J. Am. Chem. Soc.* **2002**, *124*, 9370.

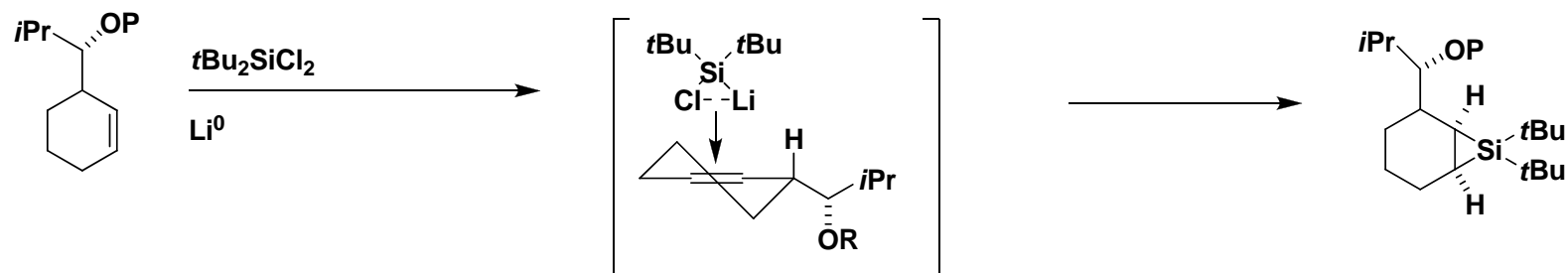
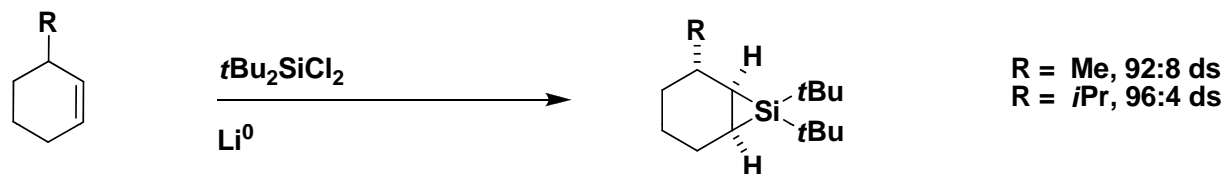
Synthesis of Silacyclopropanes

Thermal generation of silylenes



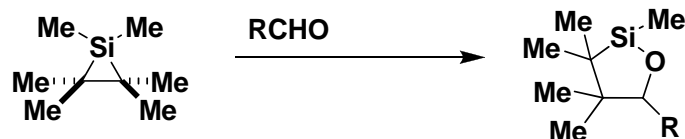
Broad functional group tolerance, increased yields
Cannot be used for cyclohexenes or 1,1 disubstituted alkenes

Generation of di-tert-butylsilenoid by lithium reduction of tBu_2SiCl_2

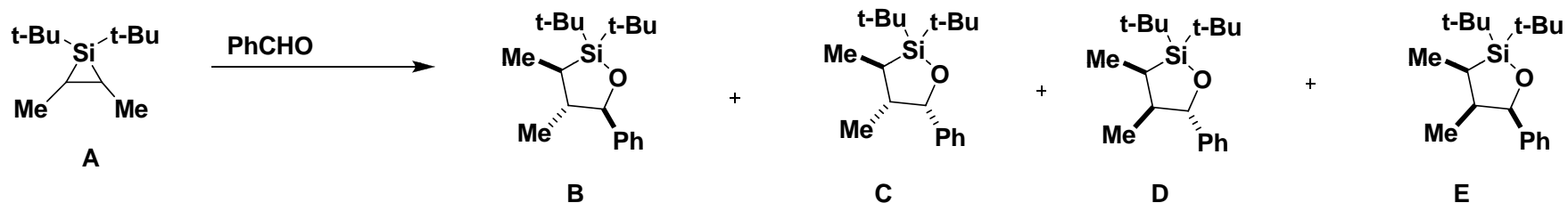


Investigated the influence of an ether substituent on the reaction. Ether functionality does not direct silacyclopropanation.
Not as broad of a scope as the thermal reaction.

Reactions of Silacyclopropanes: Insertions

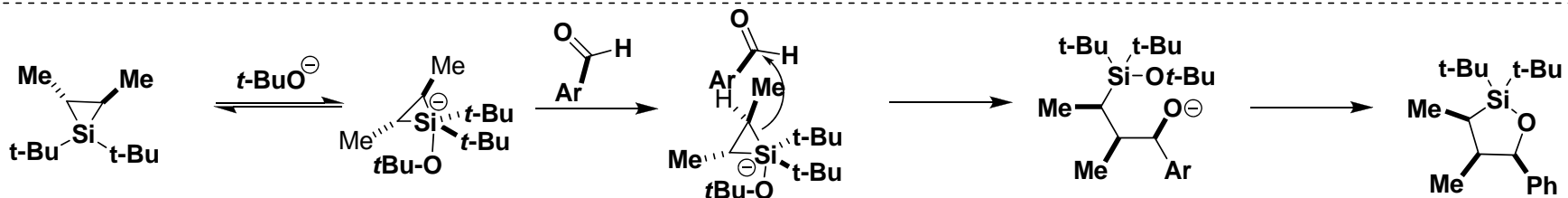
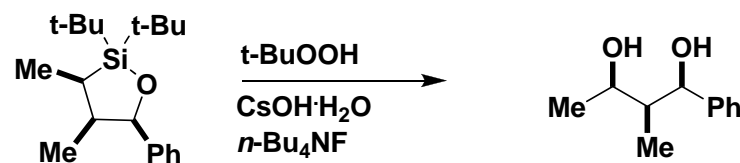


Seyferth, D.; Duncan, D.; Shannon, M. *Organometallics*. 1984, 3, 579.



silirane	conditions	1B	1C	1D	1E
trans A	100 °C	75	7	8	10
cis A	100 °C	48	6	32	14
trans A	25% KOt-Bu/ 18-crown-6	3	1	13	83
cis A	10% Ot-Bu/ 18-crown-6	69	30	<1	<1

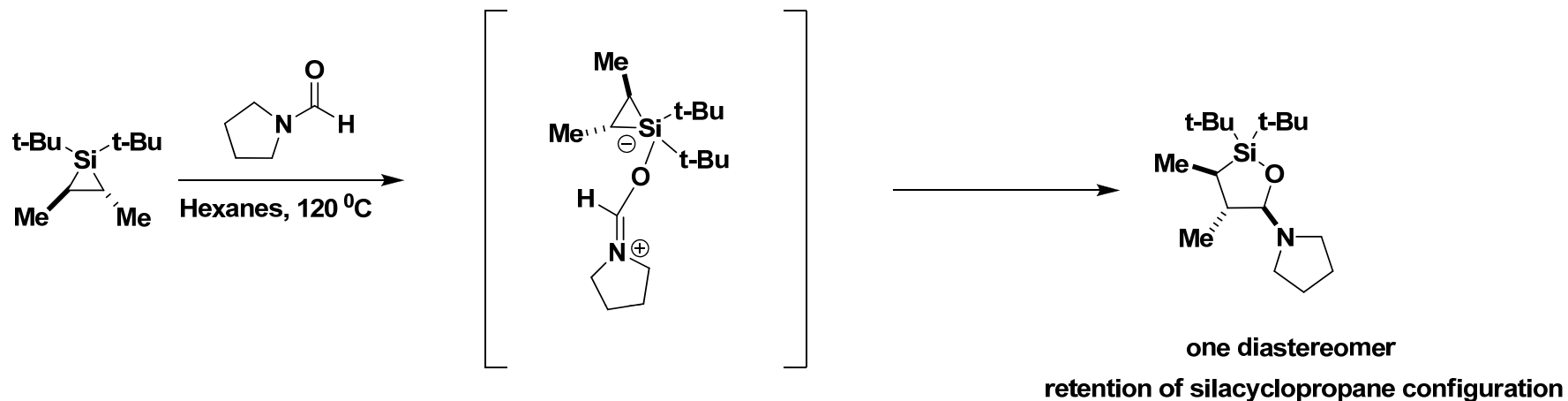
Stereochemically and regiochemically defined insertions of aldehydes
Outcome is dictated by reaction conditions
Further elaborated into 1,3 diols



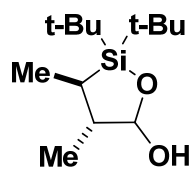
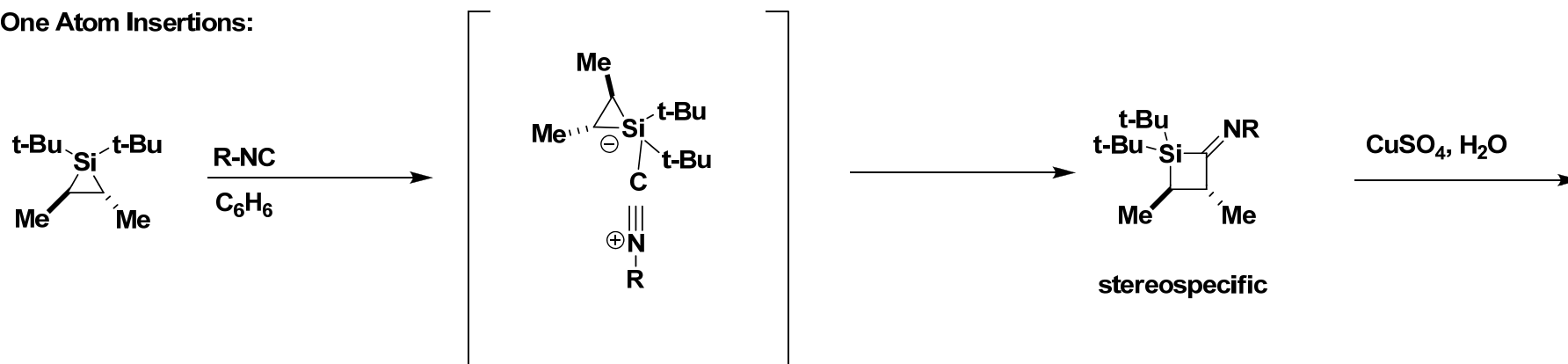
Bodnar, P.; Palmer, W.; Shaw, J.; Smitrovich, J.; Sonnenberg, J.; Presley, A.; Woerpel, K. *J. Am. Chem. Soc.* 1995, 117, 10575.

Bodnar, P.; Palmer, W.; Ridgway, B.; Shaw, J.; Smitrovich, J.; Woerpel, K. *J. Org. Chem.* 1997, 62, 4737.

Reactions of Silacyclopropanes: Insertions



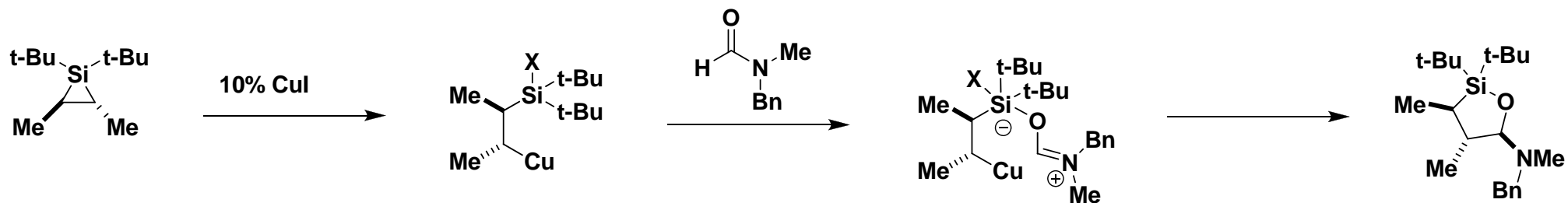
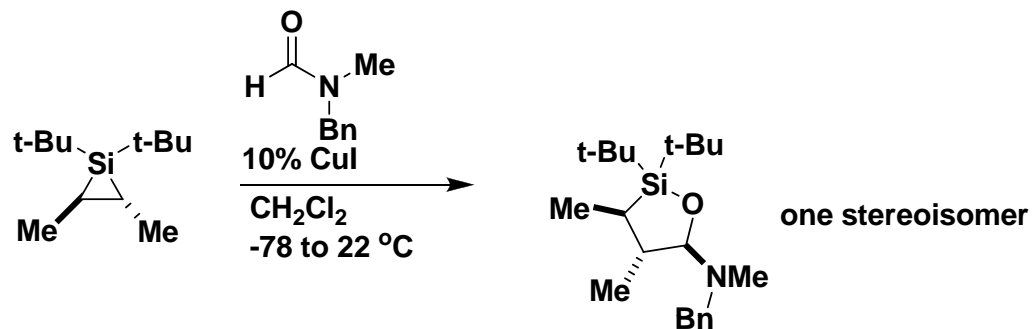
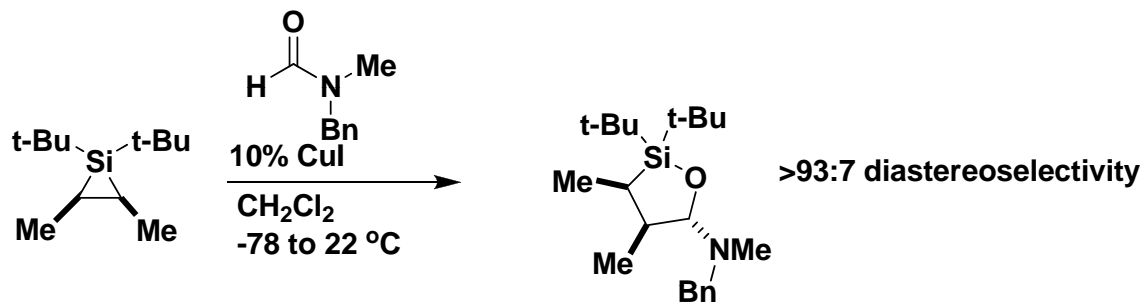
One Atom Insertions:



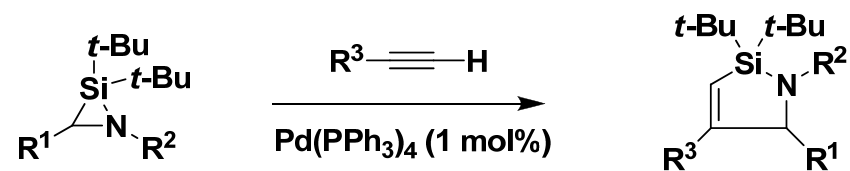
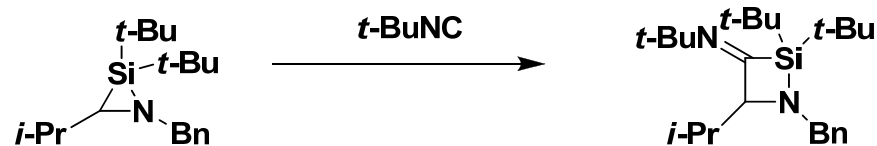
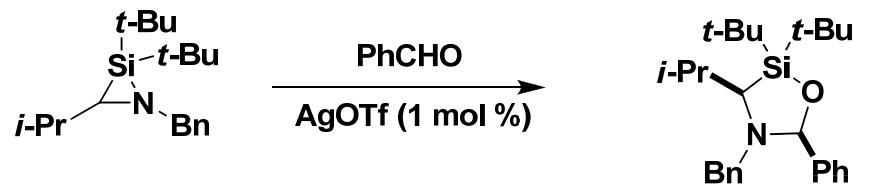
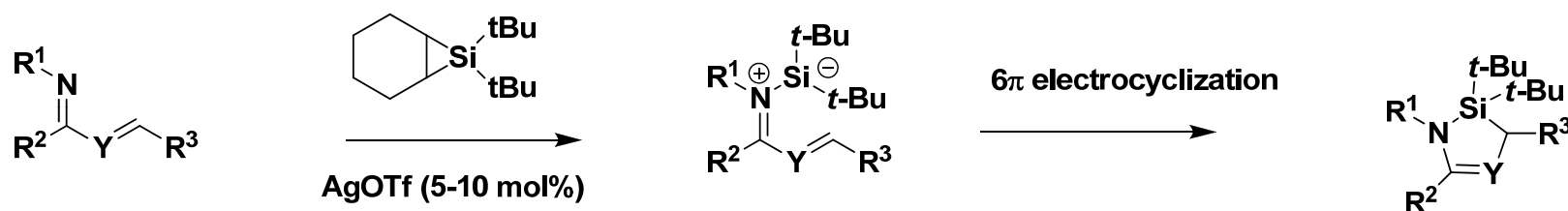
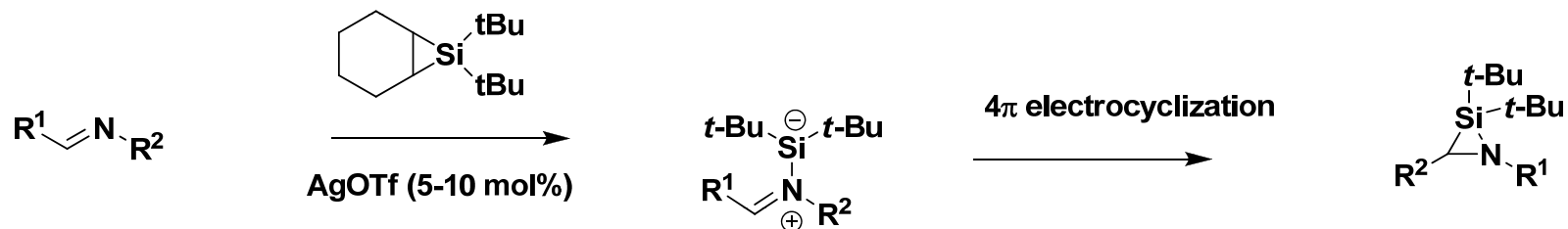
Shaw, J.; Woerpel, K. *J. Org. Chem.* **1997**, *62*, 442.
 Nguyen, P.; Palmer, W. Woerpel, K. *J. Org. Chem.* **1999**, *64*, 1843.

Reactions of Silacyclopropanes: Insertions

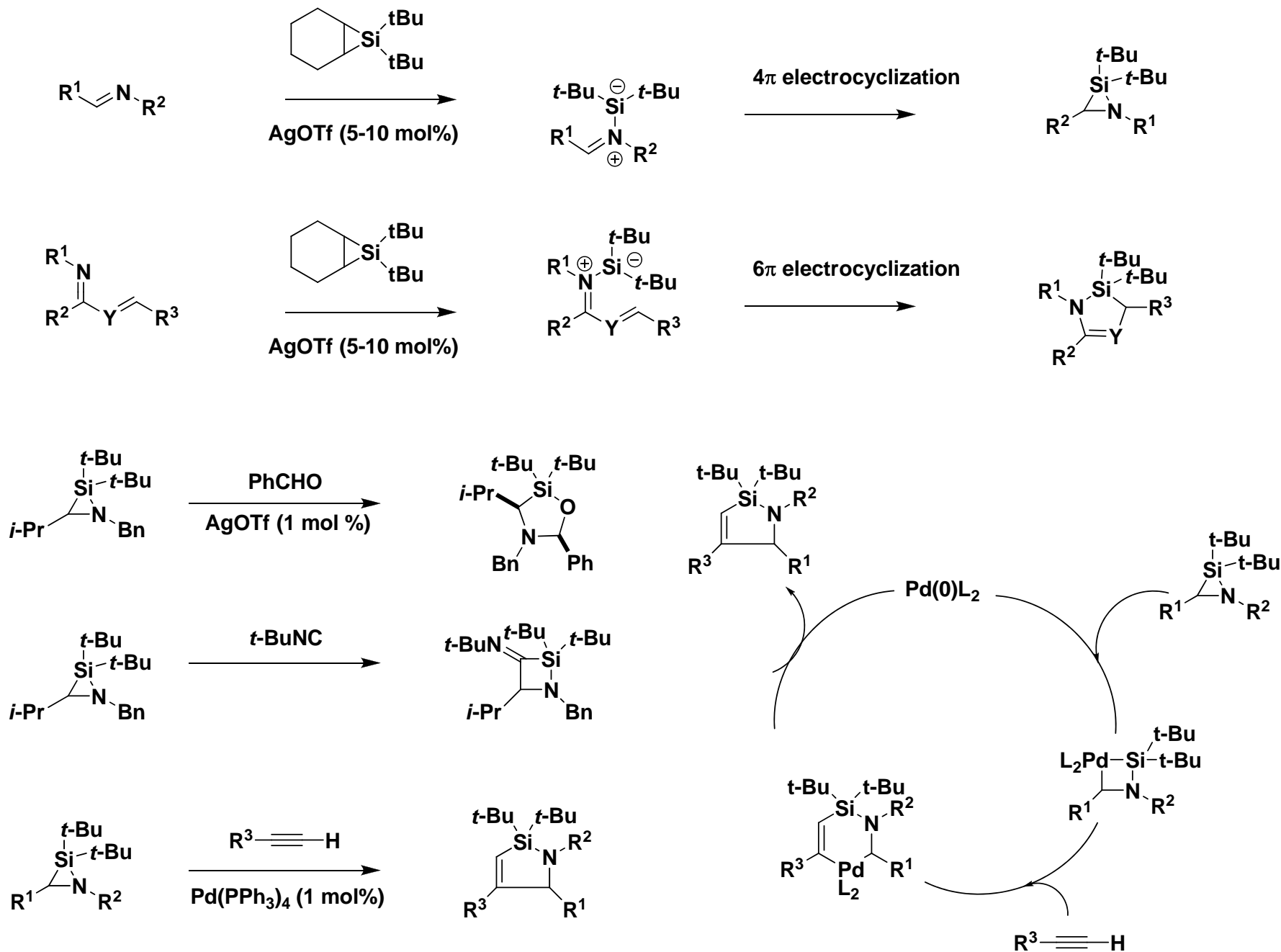
Metal catalyzed Insertion reactions of formamides are stereospecific



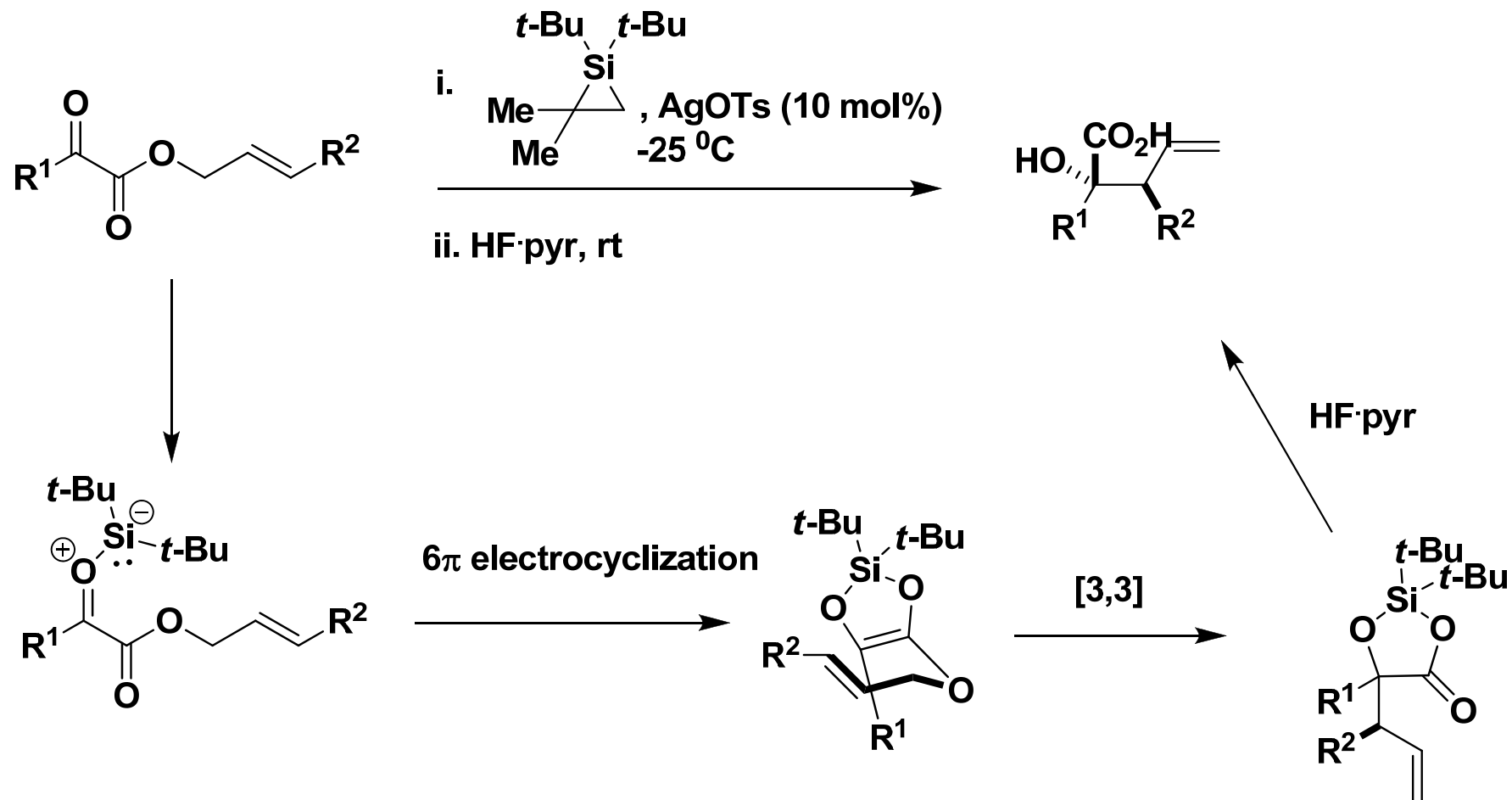
Reactions of Silacyclopropanes: Imines



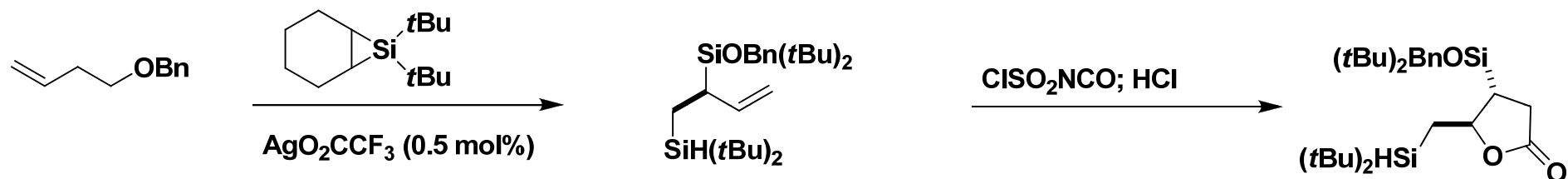
Reactions of Silacyclopropanes: Imines



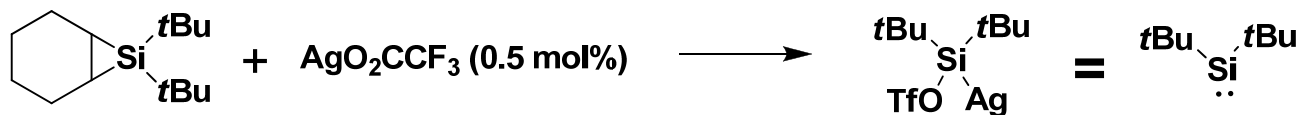
Interesting Transformations of Silacyclopropanes



Interesting Transformations of Silacyclopropanes



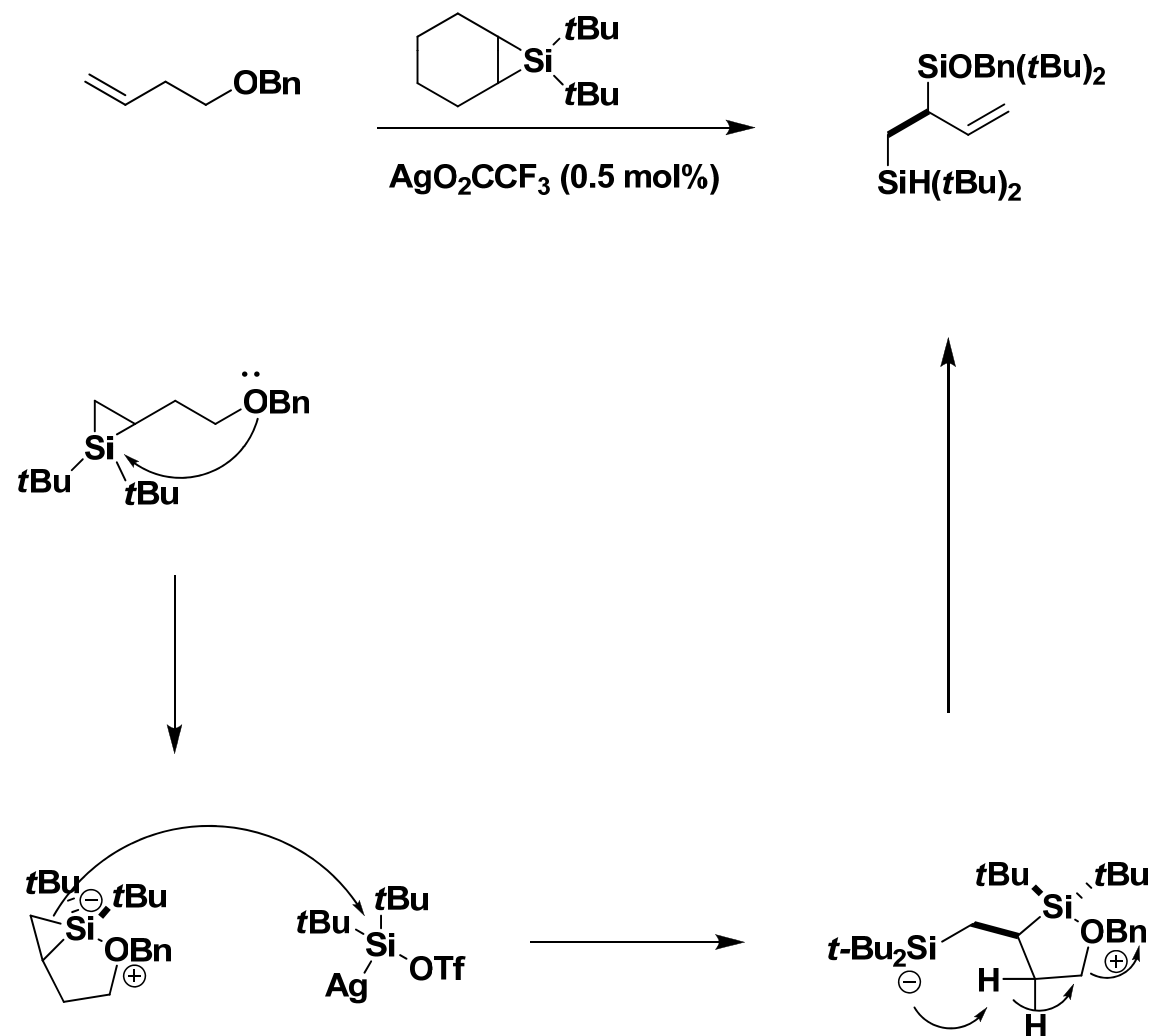
Hint:



Cleary, P.; Woerpel, K. *Org. Lett.* **2005**, 7, 5531.

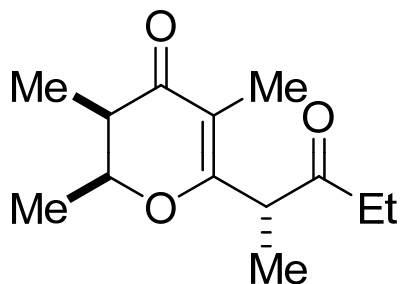
Peng, Z.; Woerpel, K. *Org. Lett.* **2001**, 3, 675.

Interesting Transformations of Silacyclopropanes

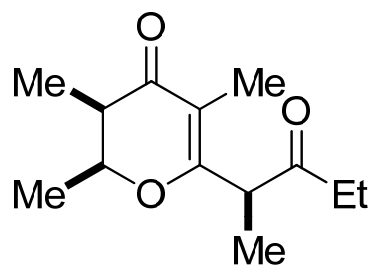


Cleary, P.; Woerpel, K. *Org. Lett.* **2005**, 7, 5531.
Peng, Z.; Woerpel, K. *Org. Lett.* **2001**, 3, 675.

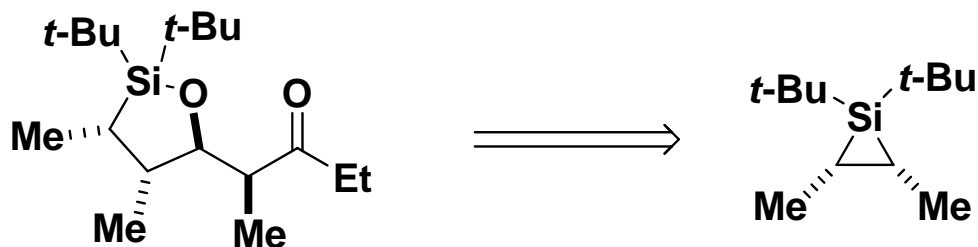
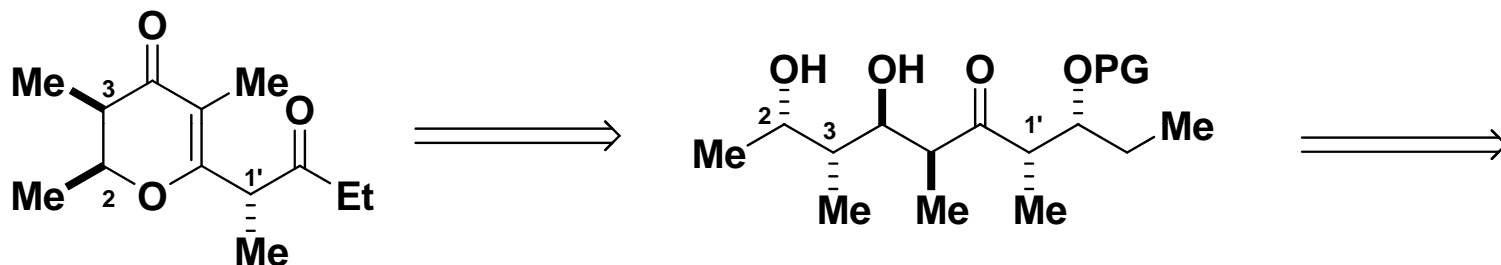
Application To Total Sythesis: (+/-)-Epi-Stegobinone



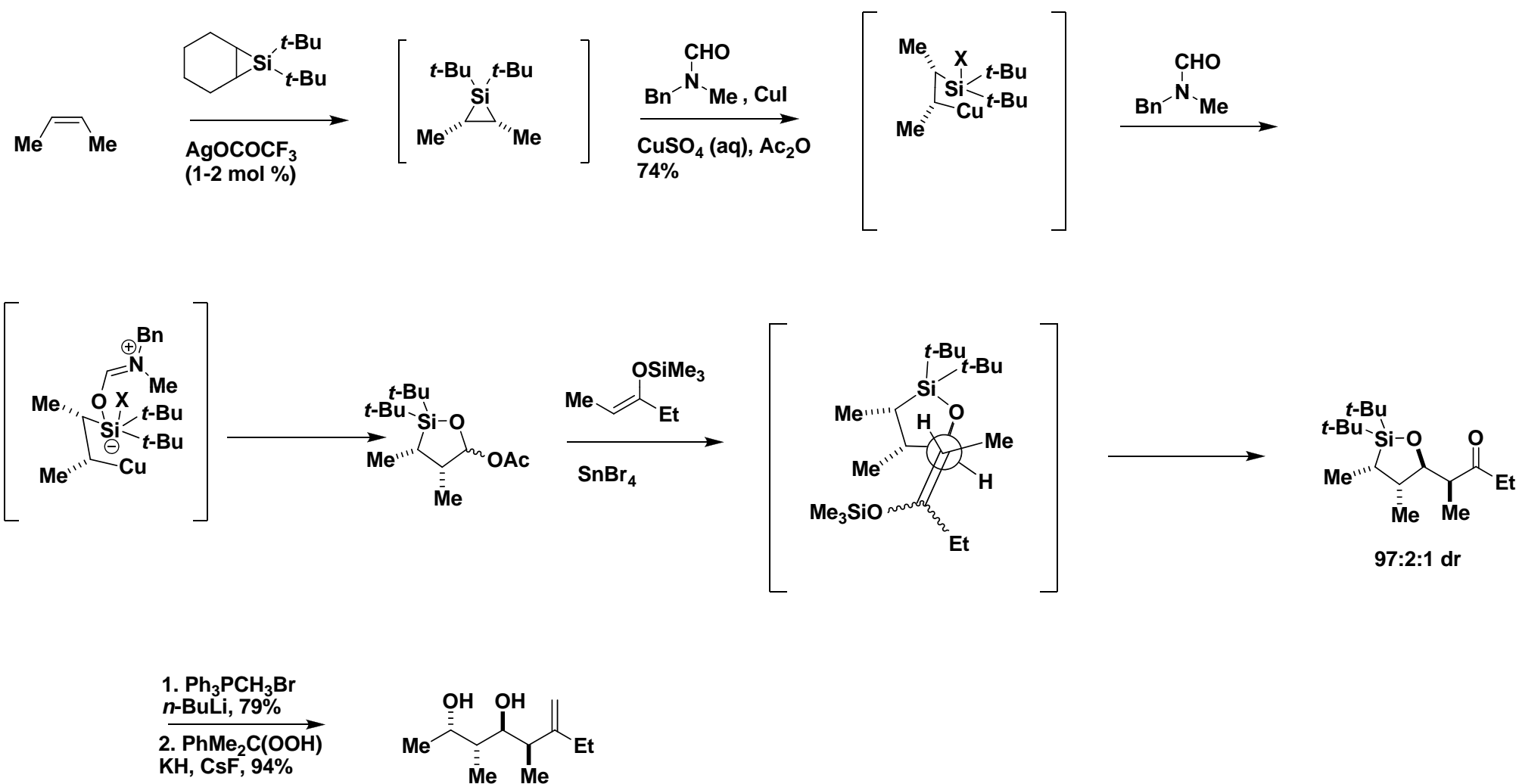
- Female-produced sex pheromone of the drugstore beetle and the furniture beetle
- Readily isomerizes to epi-stegobinone, which is a repellent to the male species



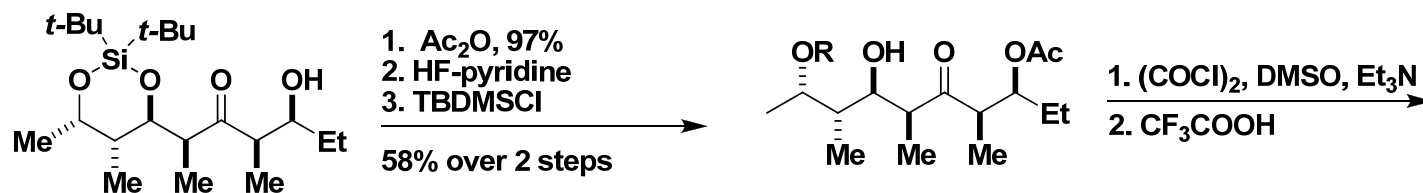
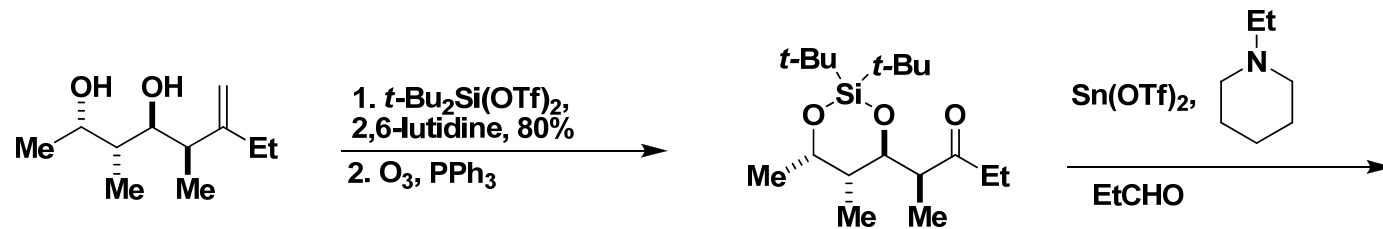
Retrosynthetic Analysis



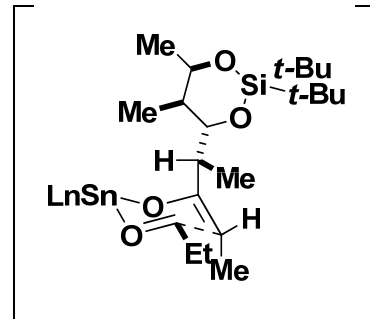
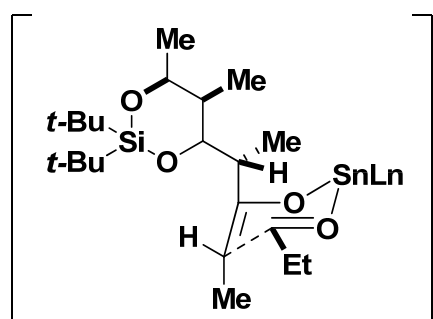
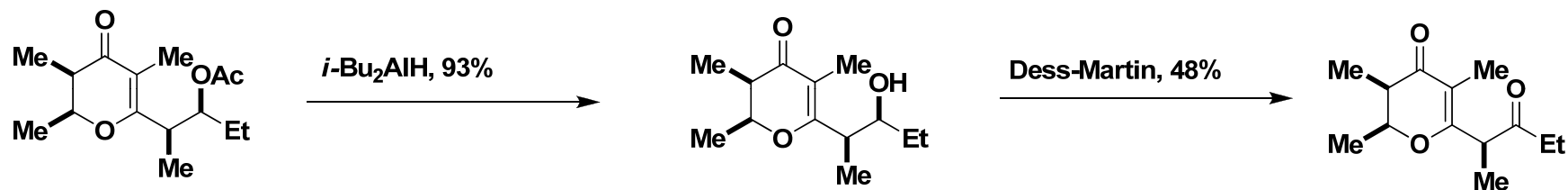
Synthesis



Completed Synthesis



R= TBDMS



Calad, S.; Cirakovic, J.; Woerpel, K. *J. Org. Chem.* **2007**, *72*, 1027.

Conclusion

- There are several ways to synthesize silacyclopropanes
 - Photochemical trapping of silylenes
 - Metal mediated transfer of silylenoids
 - Thermal generation of silylenes
 - Lithium assisted generation of silenoids through α -elimination
- Aldehydes, formamides, isocyanides, and imines all undergo insertion reactions with silylcyclopropanes
- Products of insertions between silylcyclopropanes can be manipulated to form 1,3 diols, enantioenriched α -hydroxy carboxylic acids (with 2 contiguous stereocenters), and various 5 membered rings
- Reactions of silacyclopropanes have been applied to several syntheses including the total synthesis of (+/-)-Epi-Stegobinone

Further Reading

- mini review:

Franz, A.; Woerpel, K. *Acc. Chem. Res.* **2000**, 33, 813.

- transition state structures/ explanations for attack on 5-membered ring oxacarbenium ions:

Bear T.; Shaw, J.; Woerpel, K. *J. Org Chem* **2002**, 67, 2056.

Larsen, C.; Rideway, B.; Shaw, J.; Woerpel, K. *J. Am. Chem. Soc.* **1999**, 121, 12208.

- Ireland Claisen methodology:

Calad, S.; Woerpel, K. *J. Am. Chem. Soc.* **2005**, 127, 2046.