

Transition Metal Catalyzed C-C Bond Activation

***Jennifer Moore
10 March 2006
Organic Seminar***

Overview

- **General Information**
 - **Stoichiometric Reactions**
- **Catalytic Reactions**
 - **Cyclopropanes**
 - **olefination, hydrogenation, cycloadditions**
 - **Cyclobutanes**
 - **hydrogenolysis, arylation**
 - **Unstrained Substrates**
 - **alkyl elimination, multiarylation**
 - **Miscellaneous Transformations**

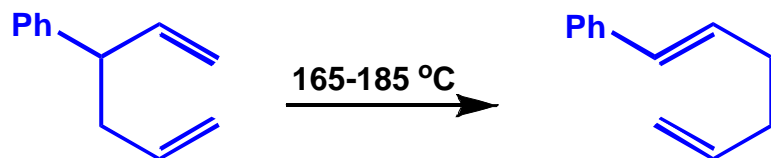
Importance of C-C Bond Activation

- Utilization of Hydrocarbons***
- Polymer Chemistry***
- Petroleum Industry***
- Another Tool for Functionalization***

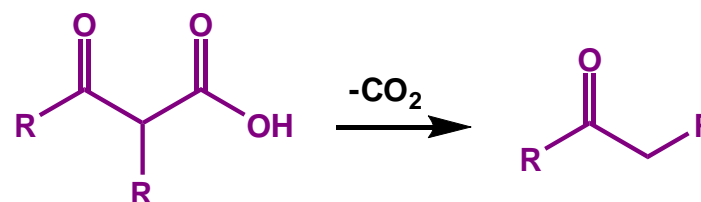
C-C Bond Activation

- Breaking of Carbon-Carbon Bonds

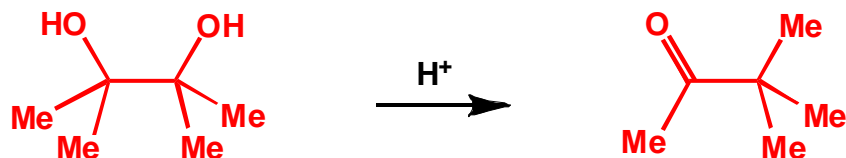
- Sigmatropic Rearrangement



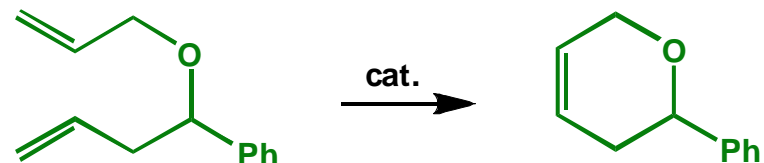
- Decarboxylation



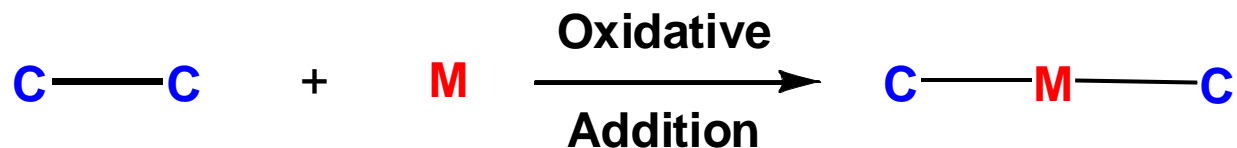
- 1,2 Alkyl Shifts



- Metathesis

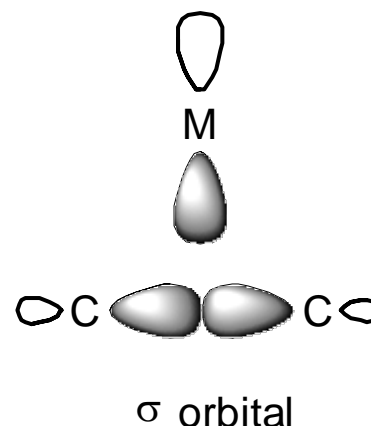
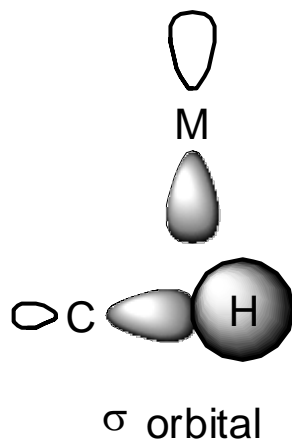


Transition Metal Catalyzed C-C Activation



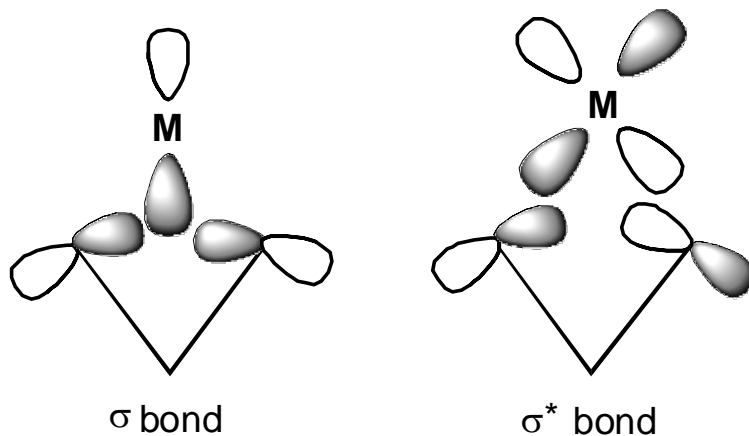
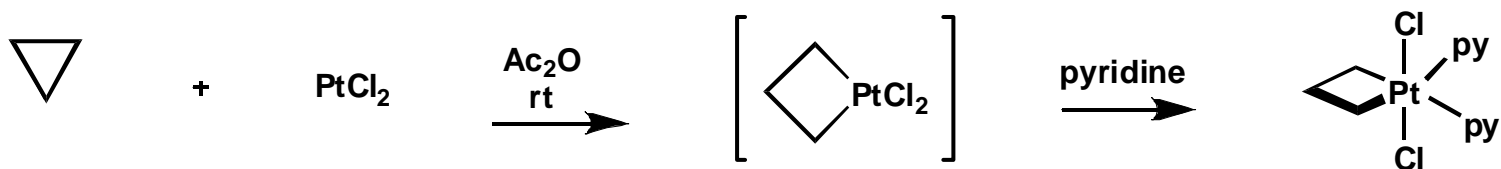
- ***Breaking of Carbon-Carbon σ -Bond***
 - ***Utilization of Ring Strain***
 - ***Chelation Assistance***
 - ***β - Alkyl Elimination***
 - ***Aromaticity***
 - ***Forced Proximity***

C-H vs. C-C Activation



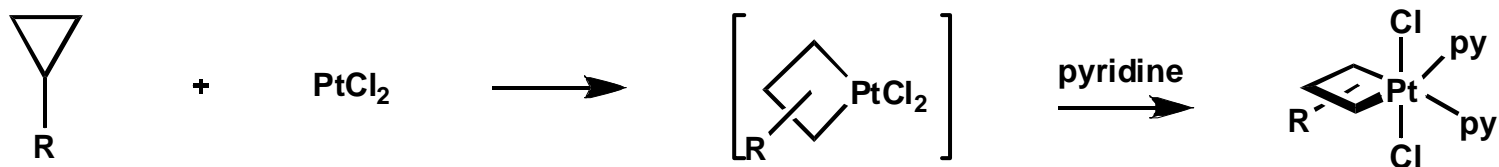
- **C-H lower activation barrier (~14-20 kcal/mol)**
- **C-H bond more accessible**
 - **steric interactions**
 - **orbital overlap**
- **Relative abundance of C-H bonds**

First Example of C-C Bond Activation by Transition Metal Insertion



Tipper, C. H. F. *J. Chem. Soc.* **1955**, 2045
Adams, D. M.; Chatt, J. *J. Chem. Soc.* **1961**, 738

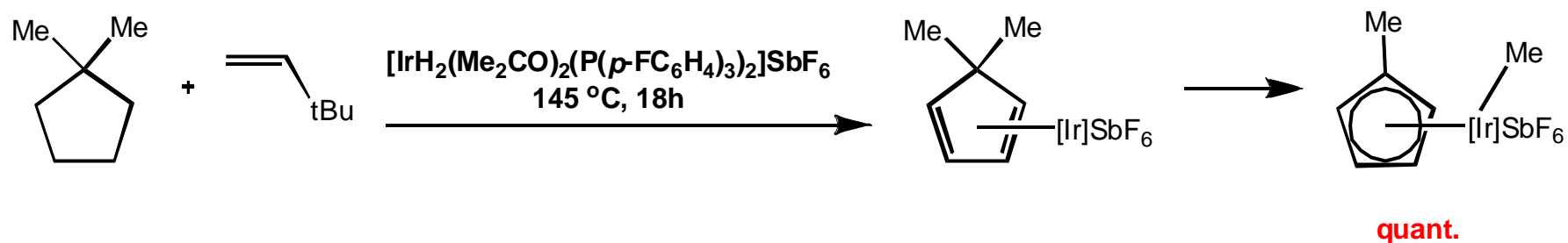
Effects of Substituents



$R = n\text{C}_6\text{H}_{13} > \text{PhCH}_2 > \text{Ph} > o\text{-NO}_2\text{C}_6\text{H}_4$
- Decreasing Reactivity -

$R = \text{CN}, \text{COMe}, \text{CO}_2\text{Me}$
- No Reaction -

Aromatization



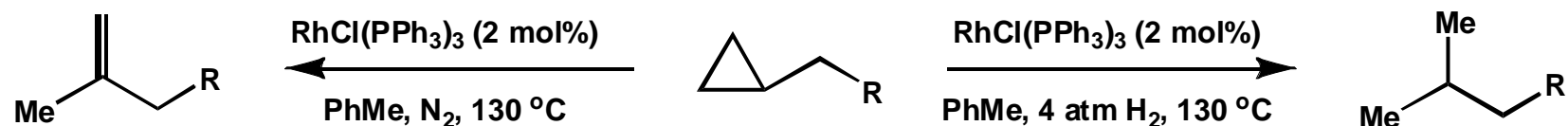
- *Driving Force is Aromaticity*

- *Stoichiometric Reaction*

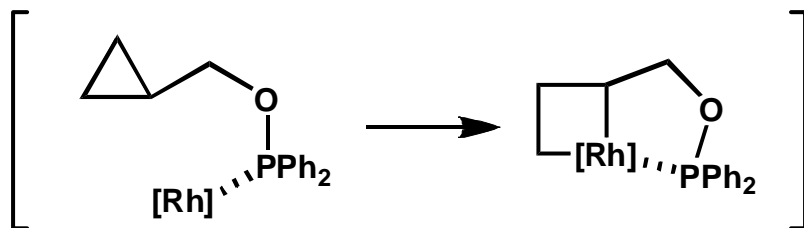
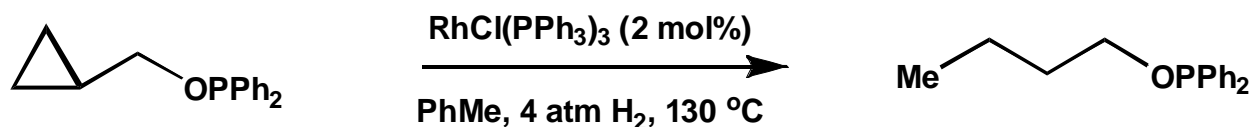
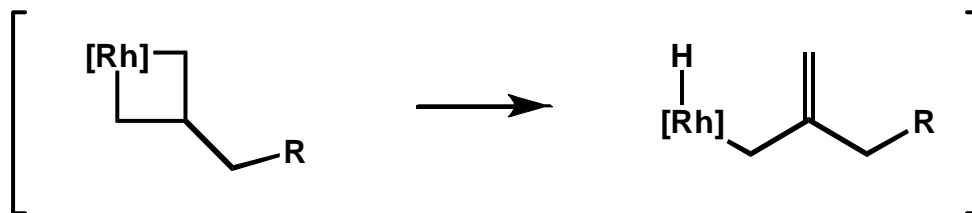
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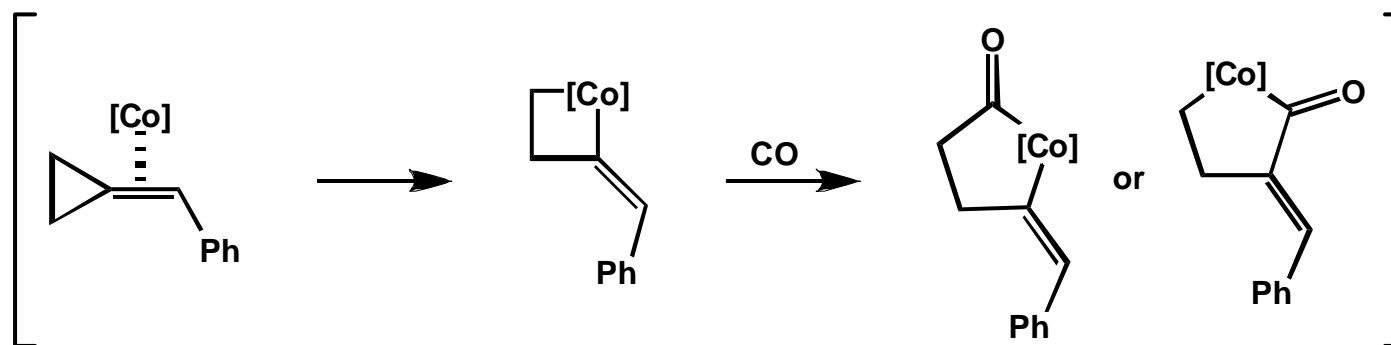
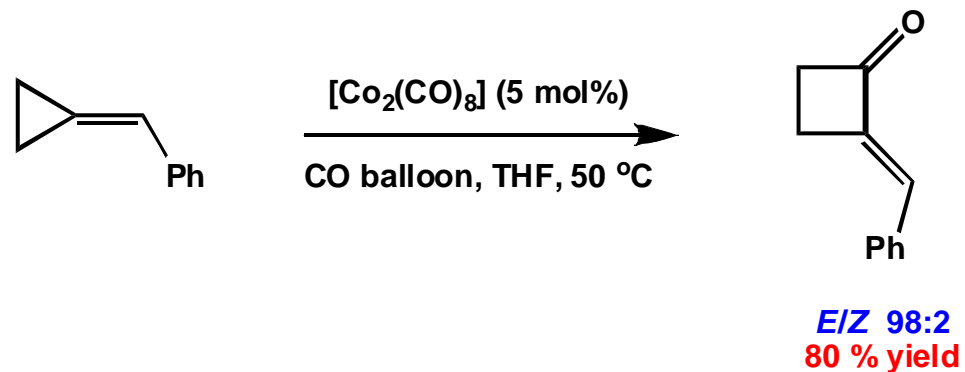
Regioselective Isomerization & Hydrogenation



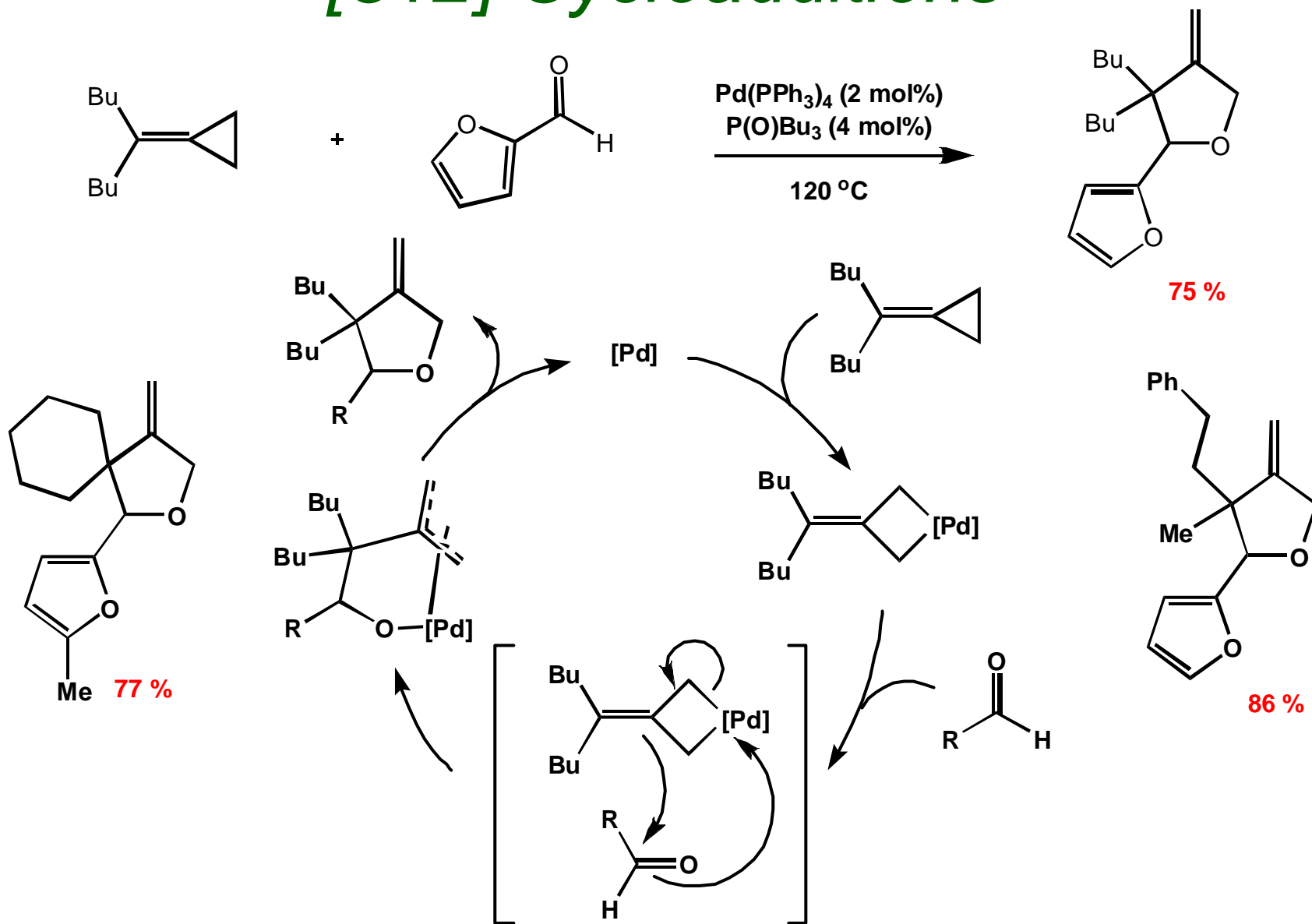
R = OSiMe₃, OAc, OEt, OPr



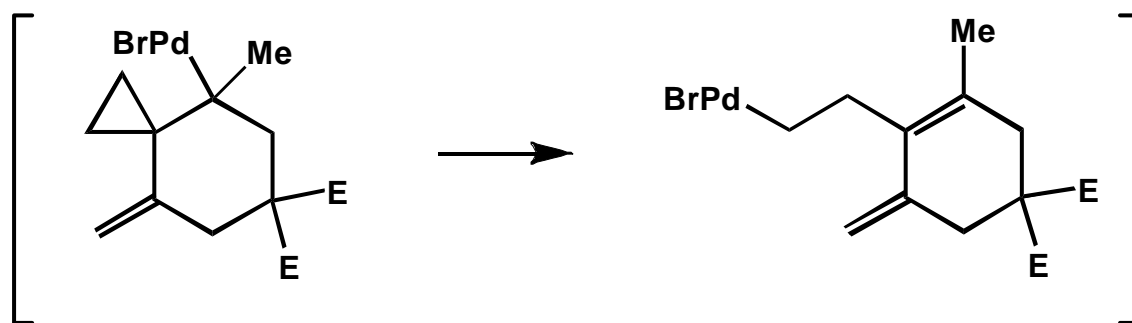
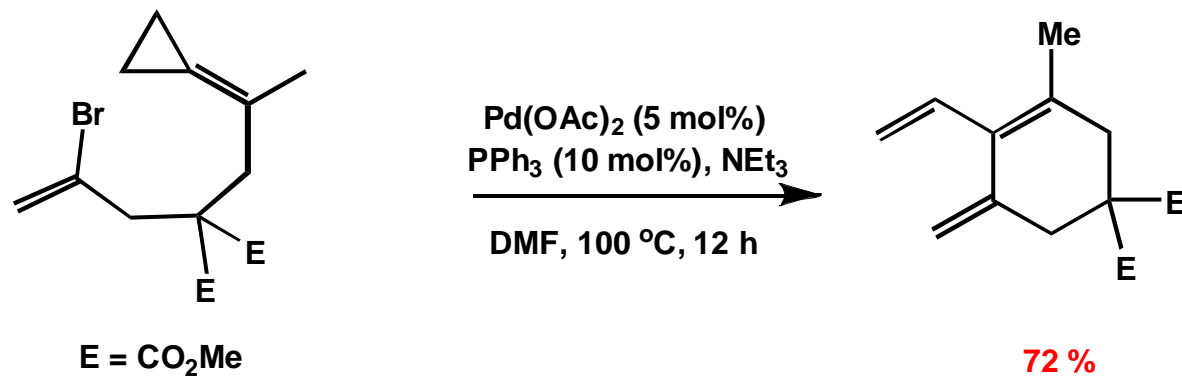
[3+1] Cycloaddition



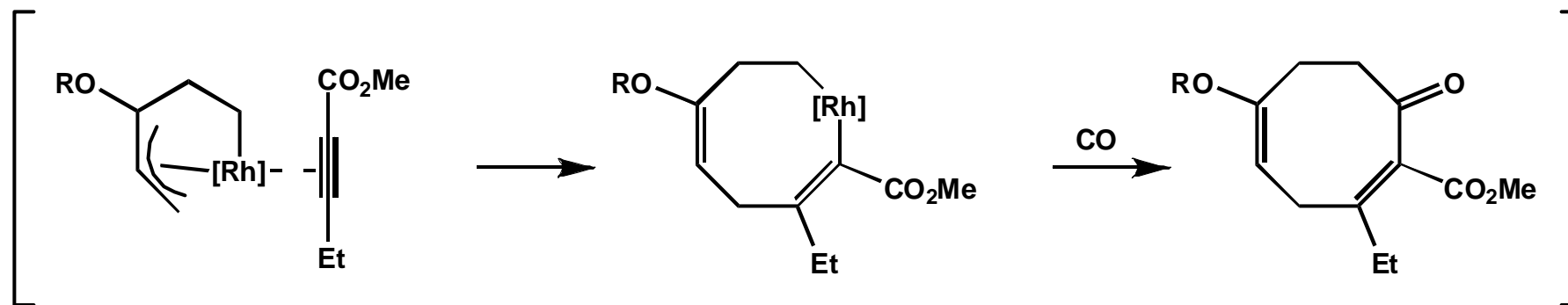
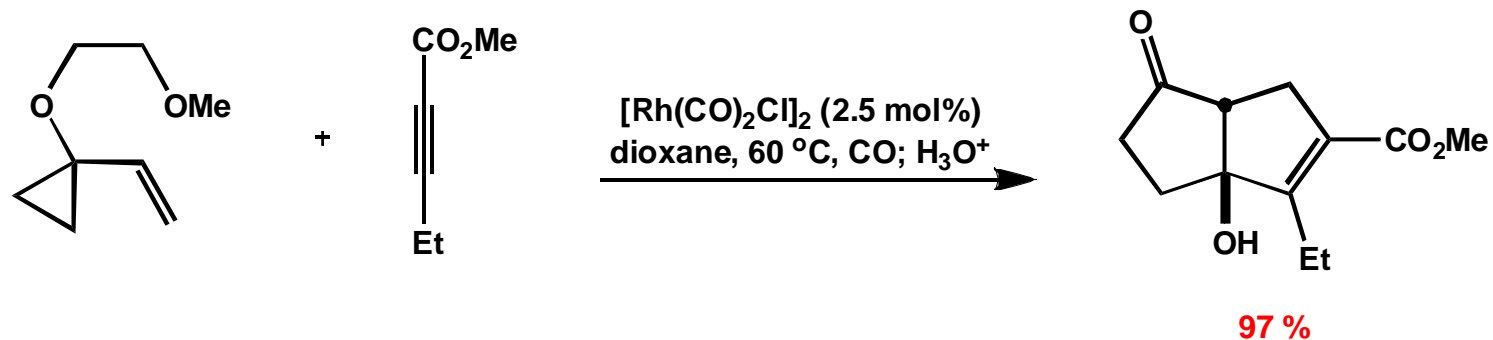
[3+2] Cycloadditions



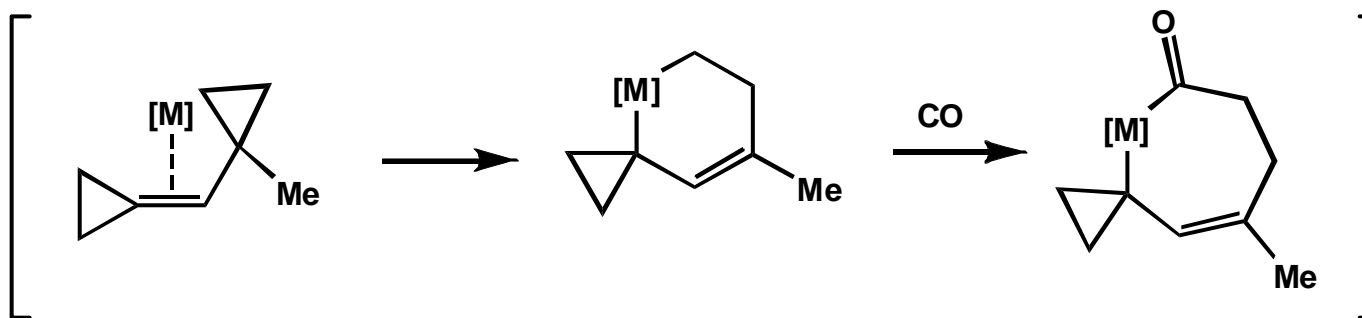
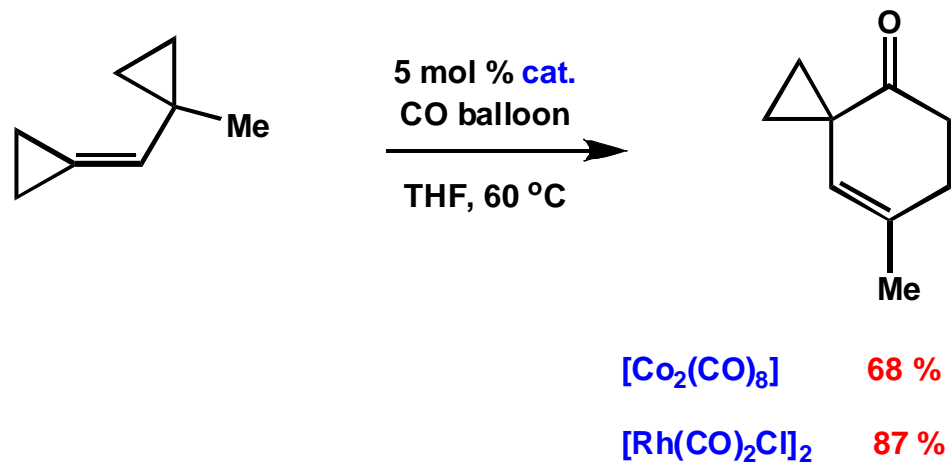
Heck-Type Reactions



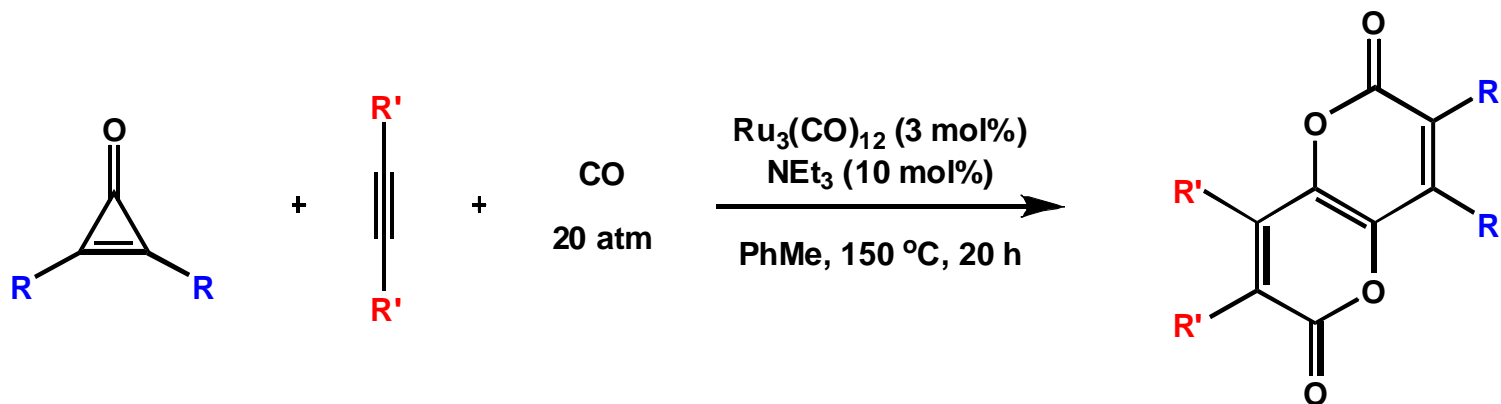
[5+2+1] Cycloaddition



[5+1] Cycloaddition

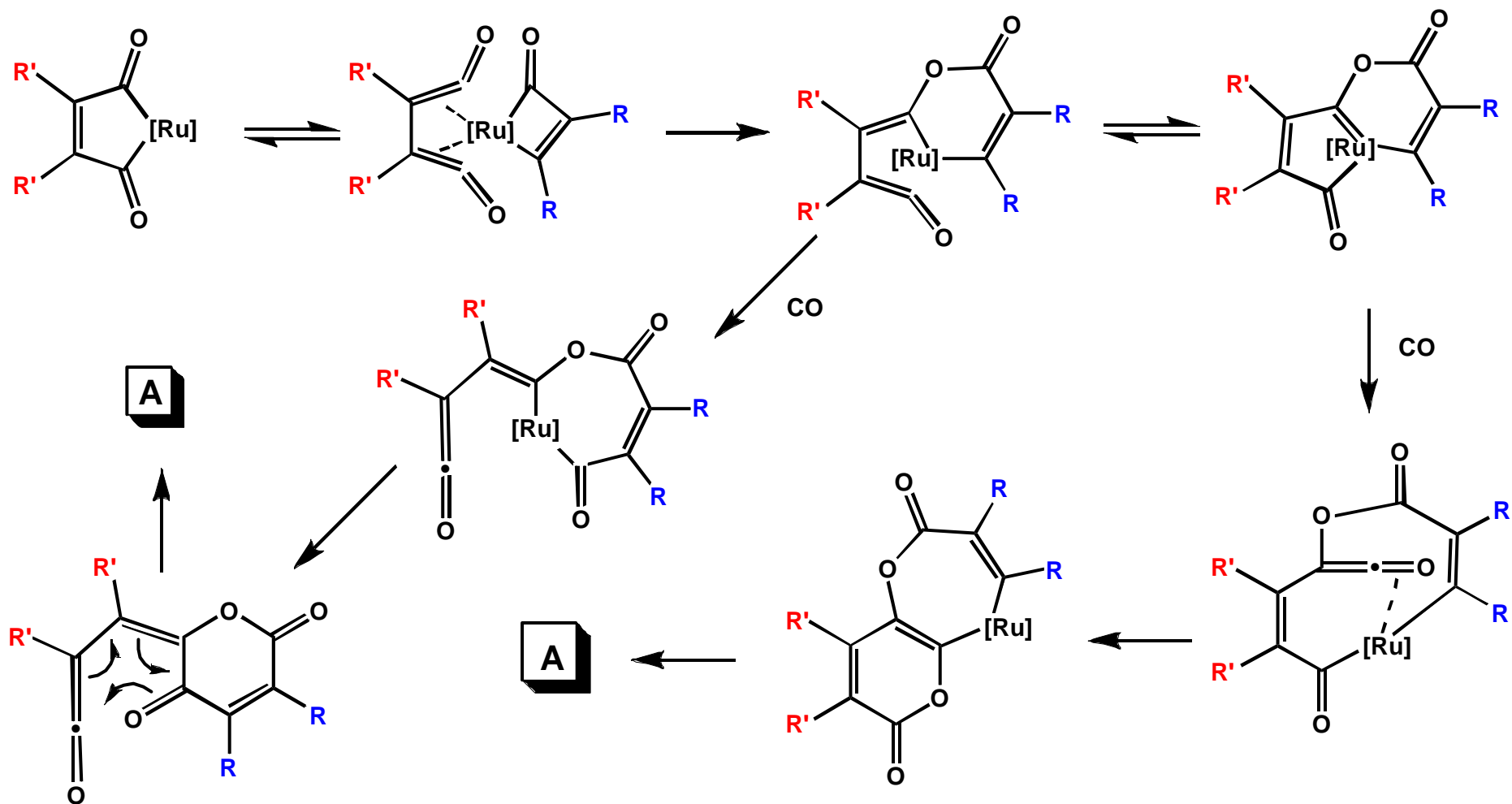
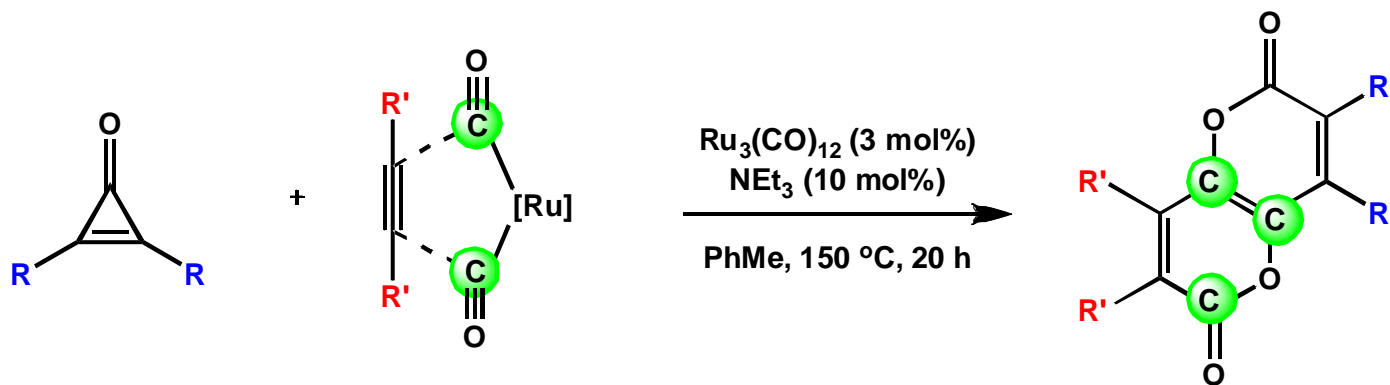


Cross Carbonylation



R	R'	Yield (%)
Et	Pr	54
Pr	Bu	63
Pr	$n\text{-C}_5\text{H}_{11}$	71
$-(\text{CH}_2)_6-$	$n\text{-C}_5\text{H}_{11}$	82

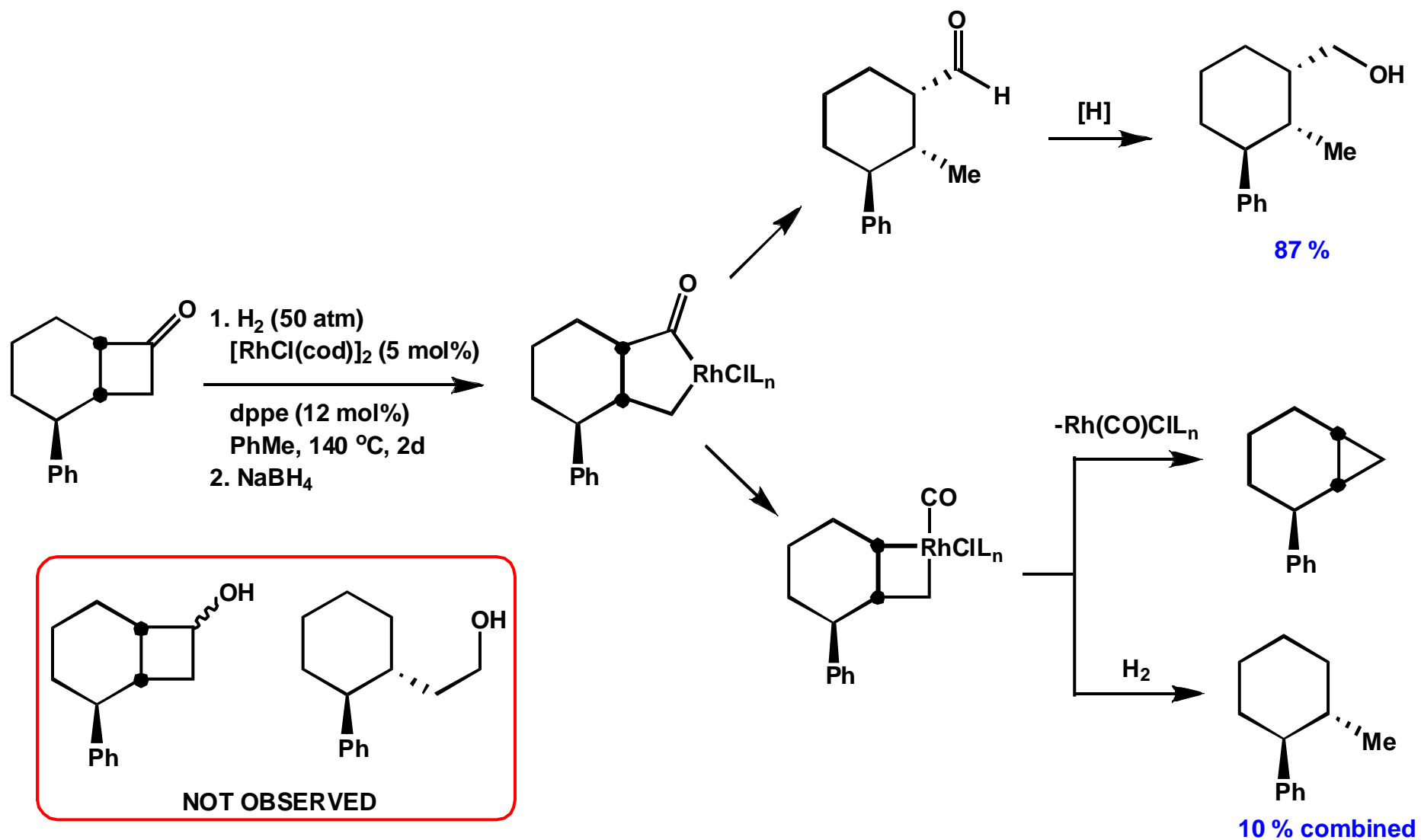
Kondo, T. K.; Kaneko, Y. K.; Taguchi, Y.; Nakamura, A.; Okada, T.; Shiotsuko, M.; Ura, Y.; Wada, K.; Mitsudo, T. *J. Am. Chem. Soc.* **2002**, 124, 6824



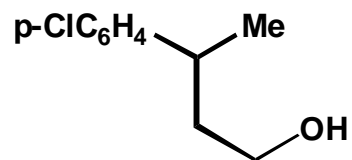
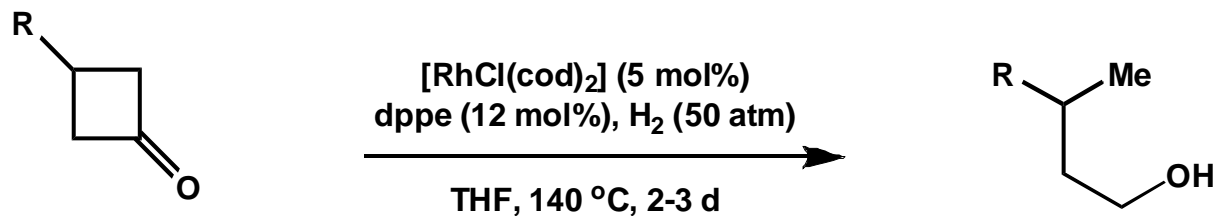
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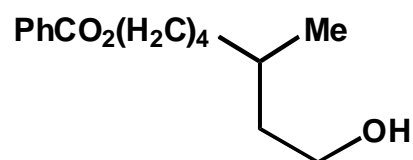
Hydrogenolysis of Cyclobutanones



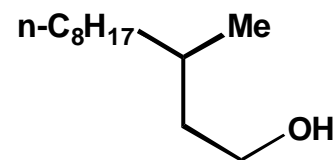
Hydrogenolysis of Cyclobutanones



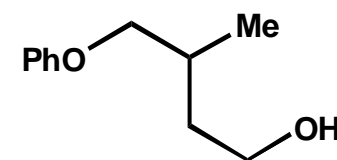
81 %



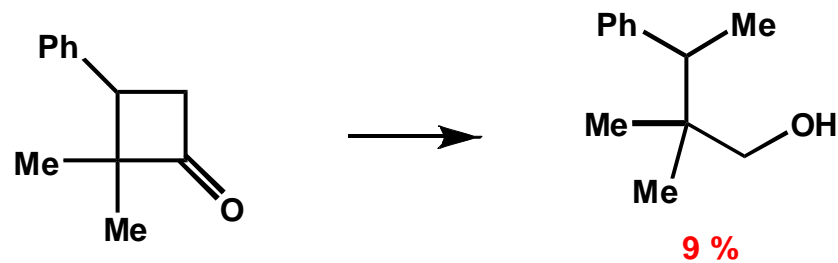
71 %



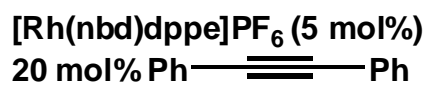
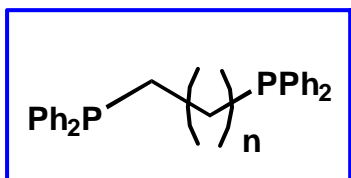
80 %



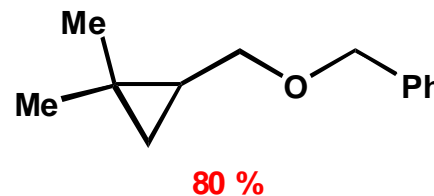
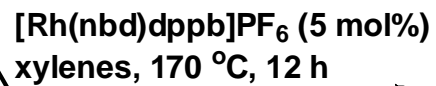
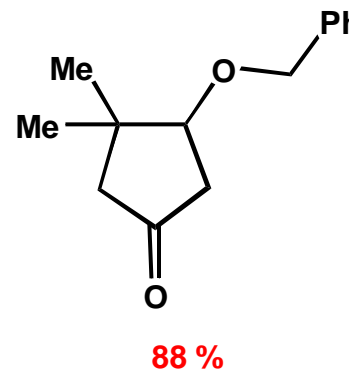
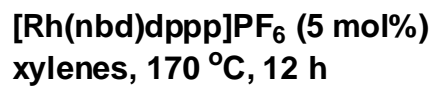
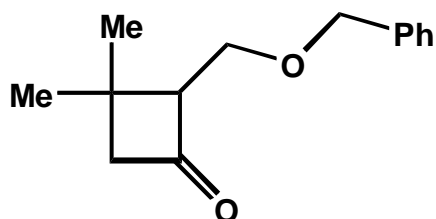
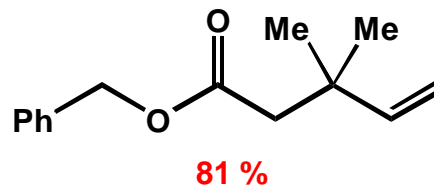
71 %



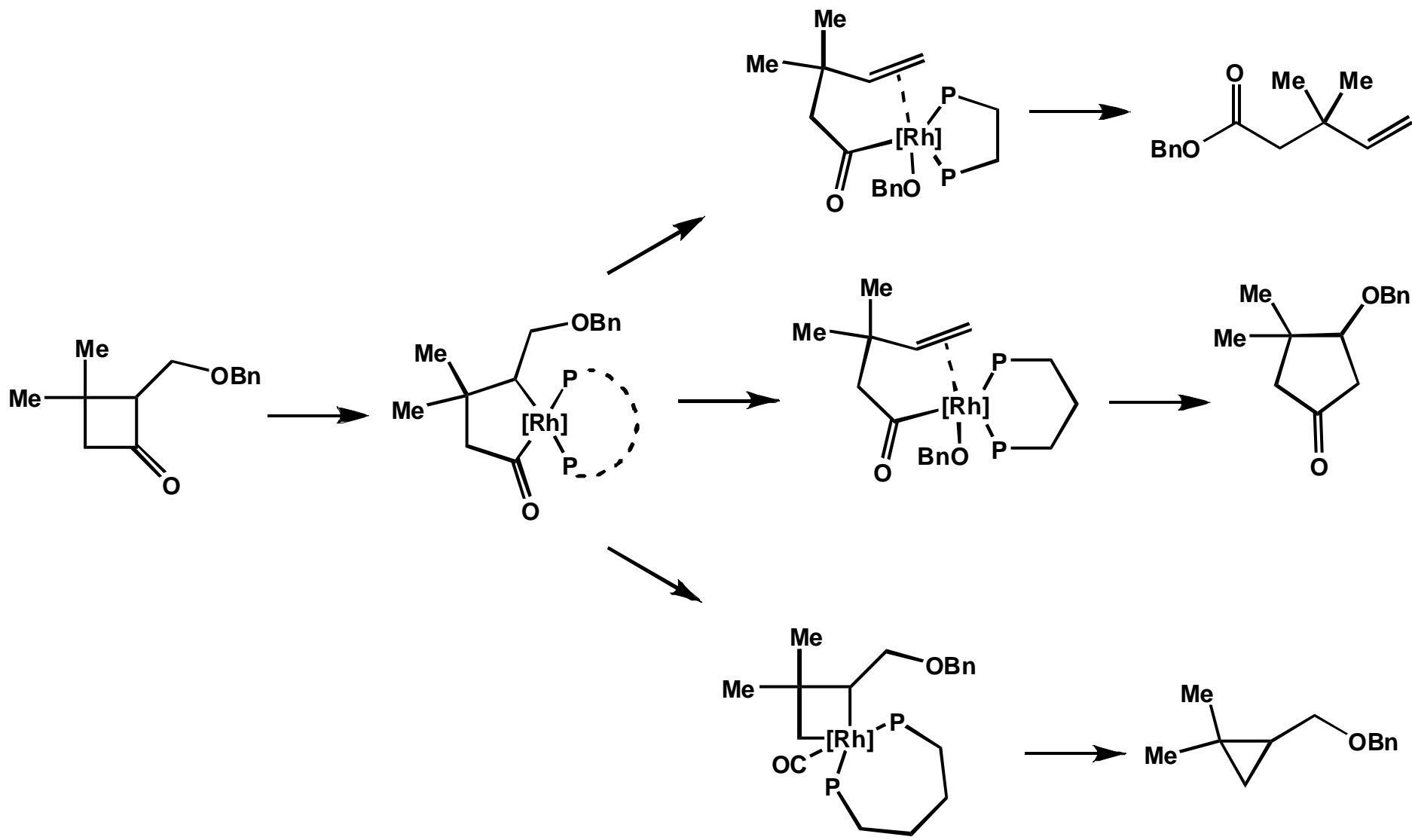
Ligand Effects



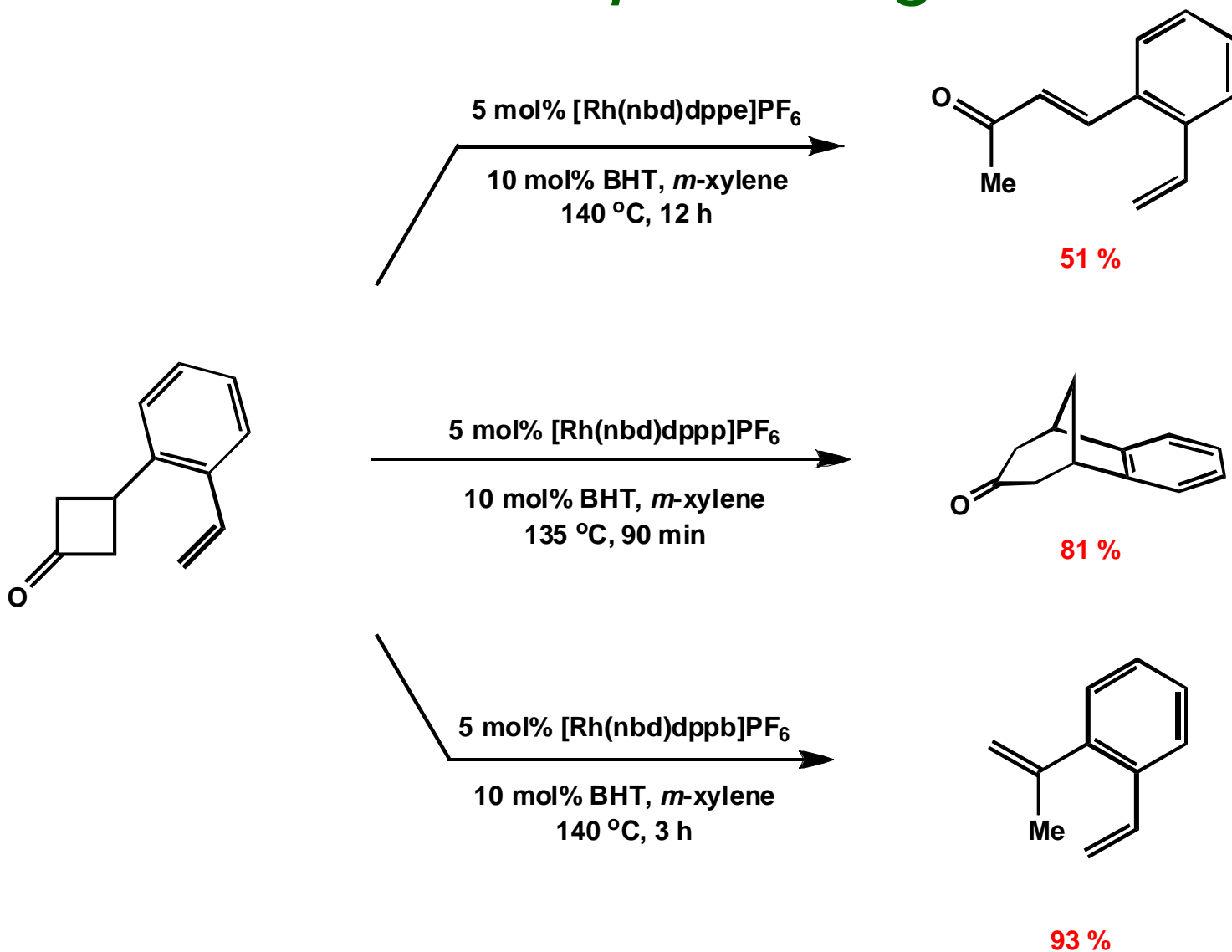
xylenes, 170 °C, 24 h



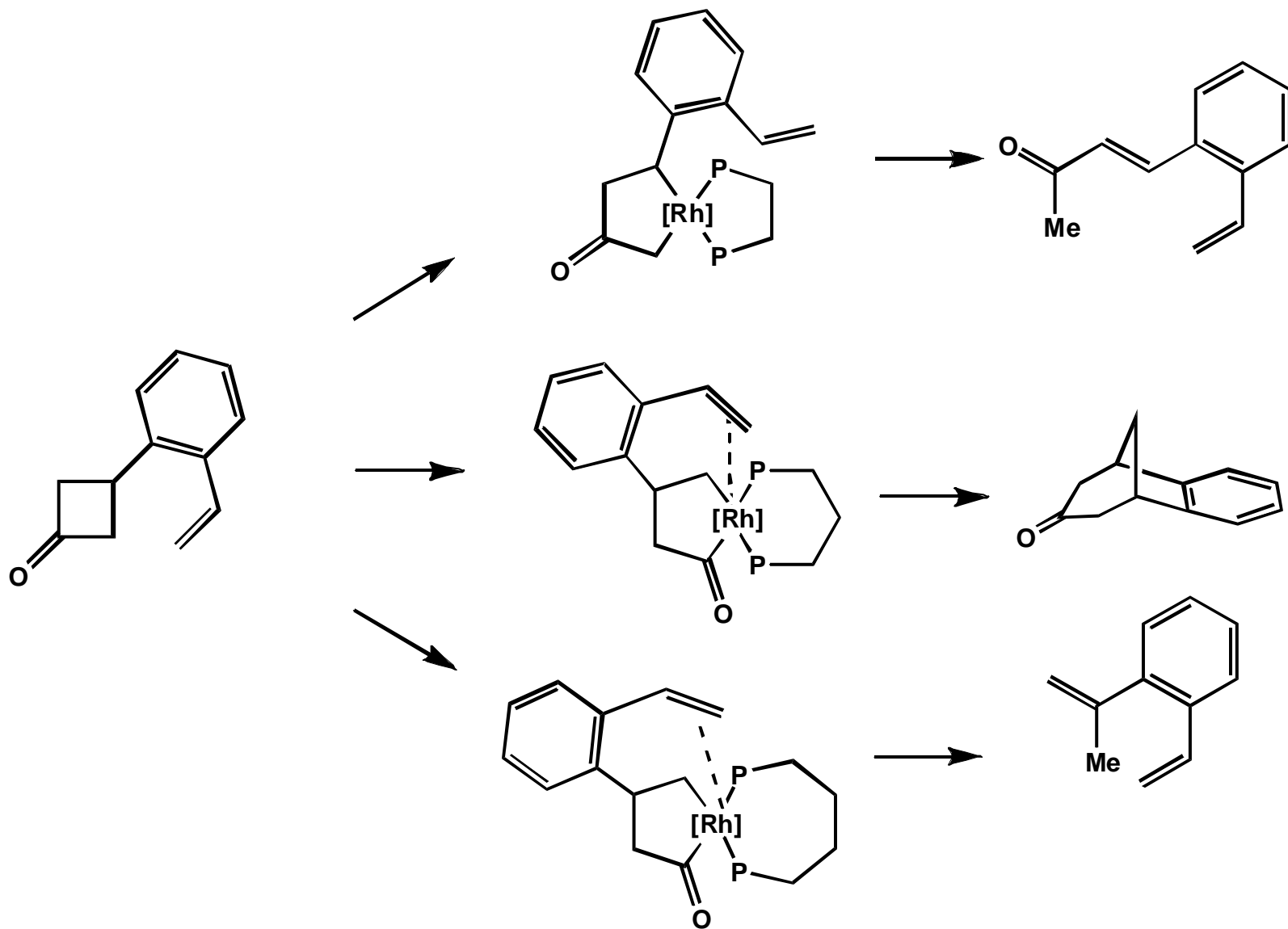
Ligand Effects



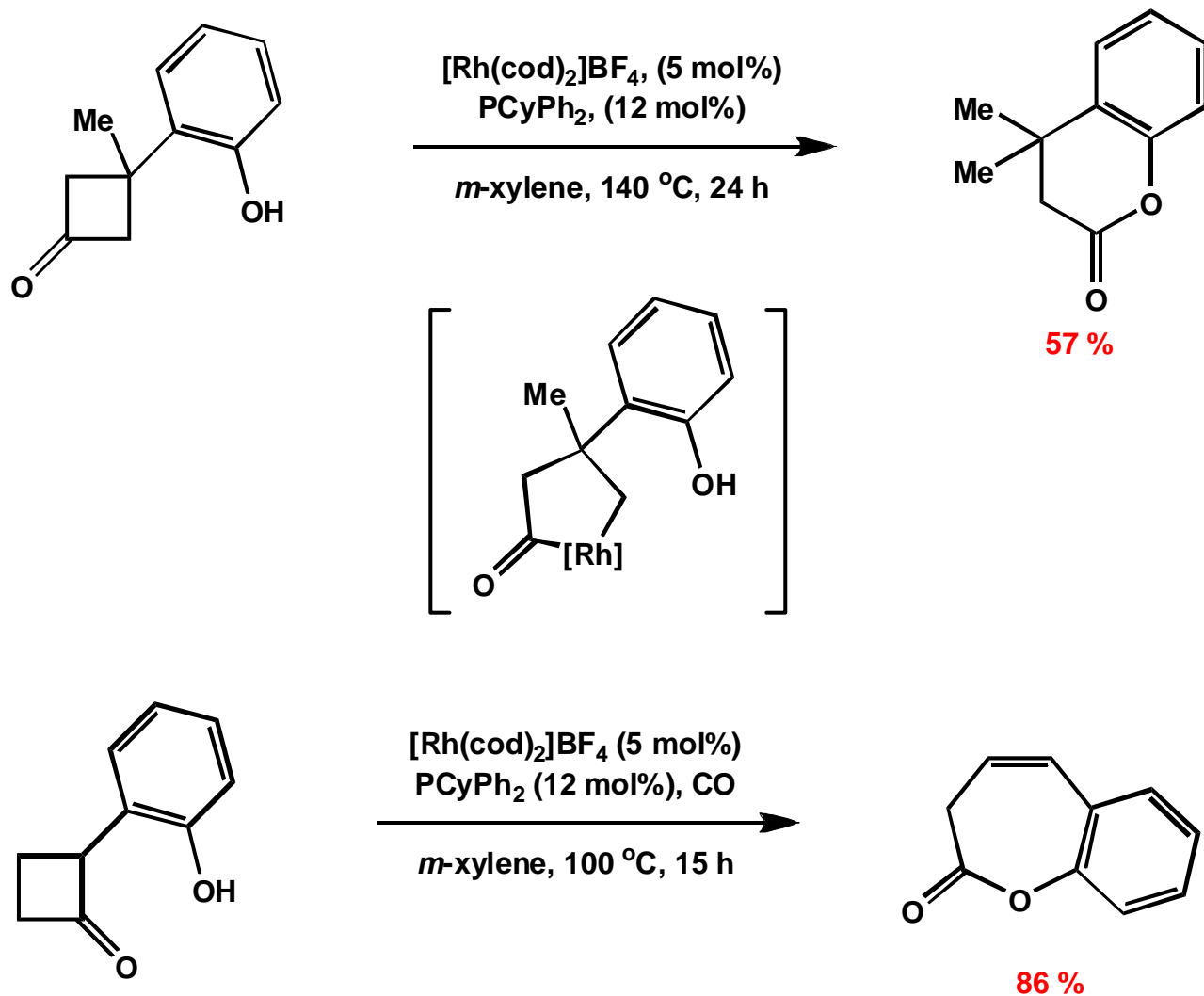
Another Example of Ligand Effects



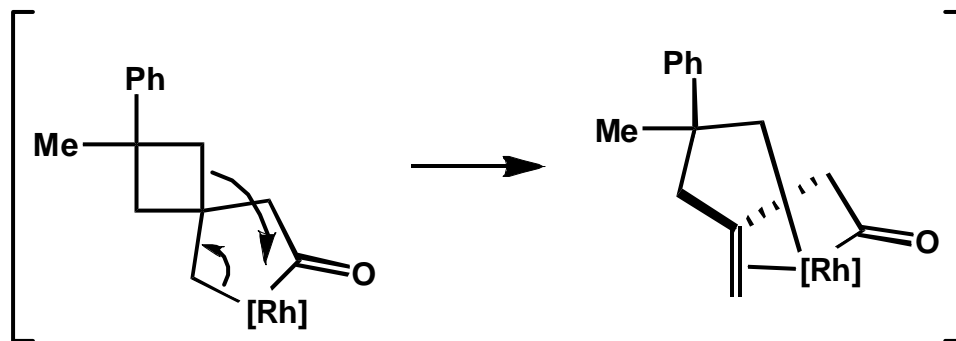
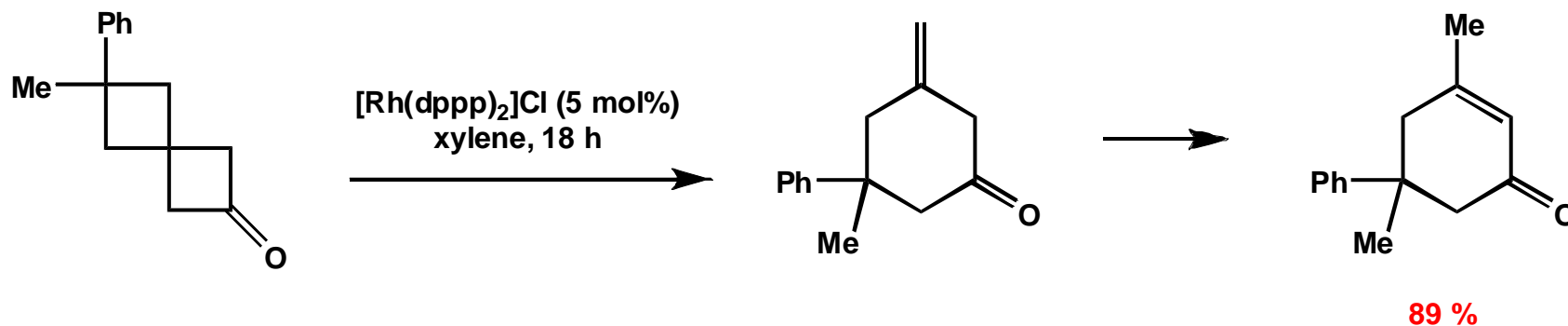
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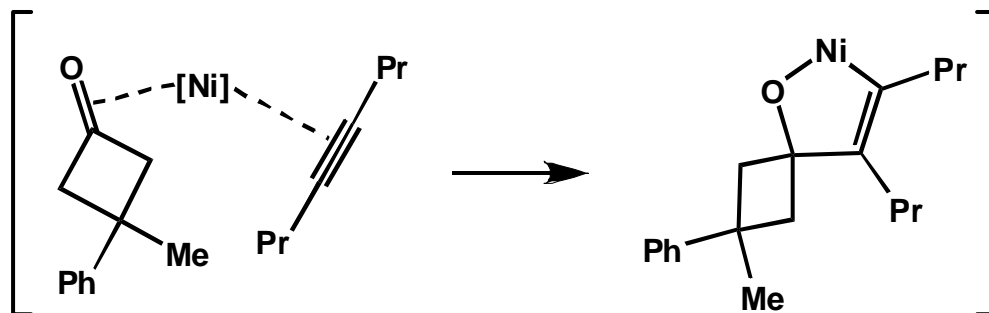
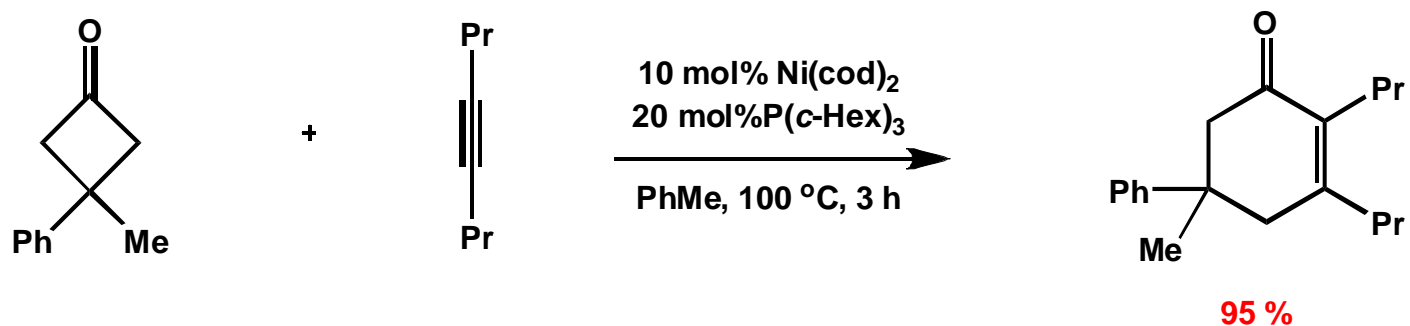
Lactone Formation



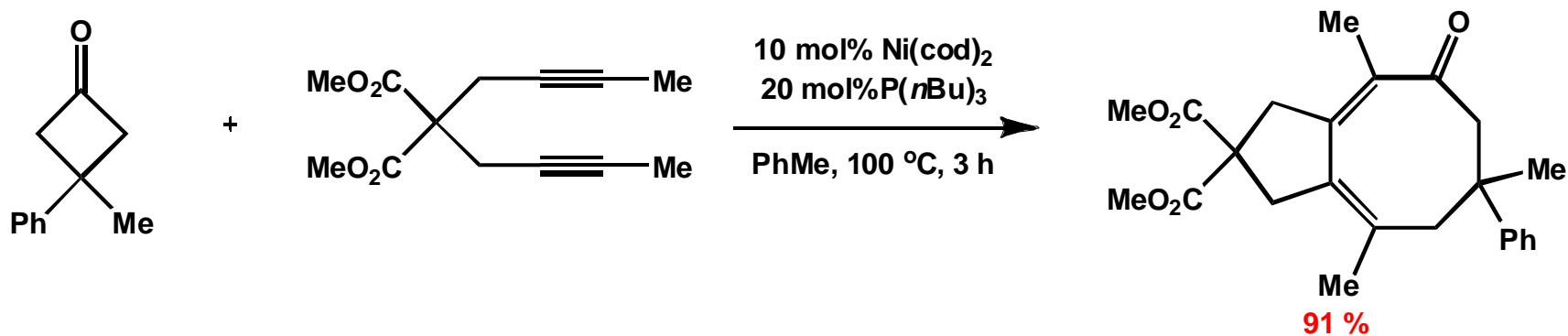
β -Alkyl Elimination of Strained Molecules



Intermolecular Alkyne Insertion

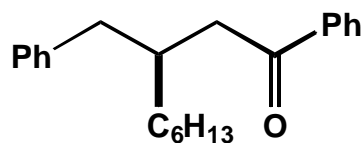
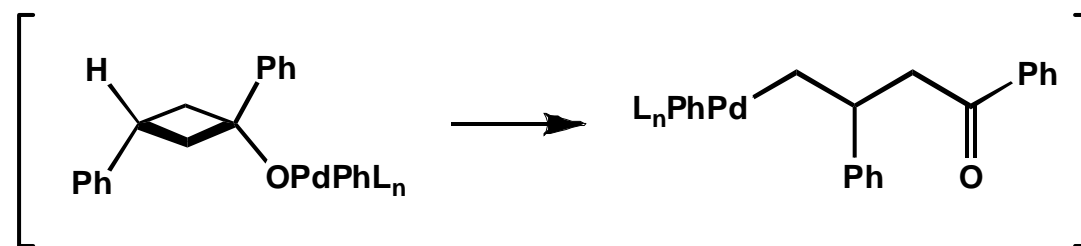
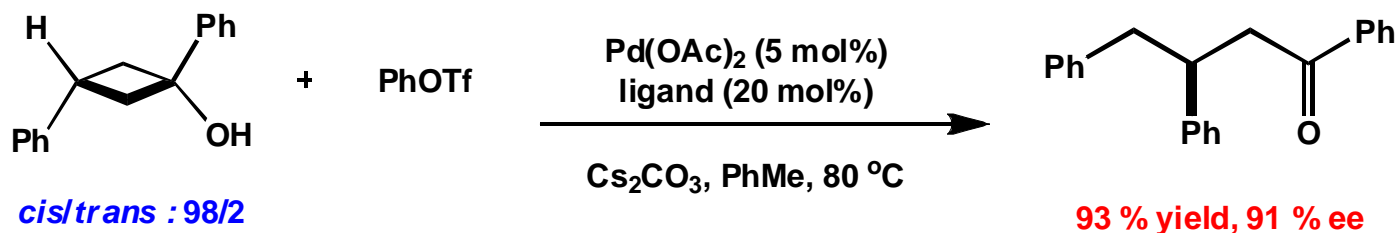
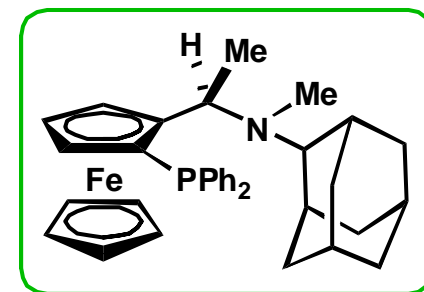


Murakami, M.; Ashida, S.; Matsuda, T. *J. Am. Chem. Soc.* **2005**, *127*, 6932-6933

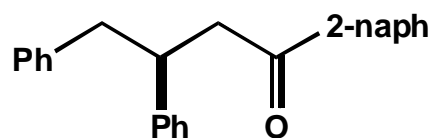


Murakami, M.; Ashida, S.; Matsuda, T. *J. Am. Chem. Soc.* **2006**, *128*, 2166-2167

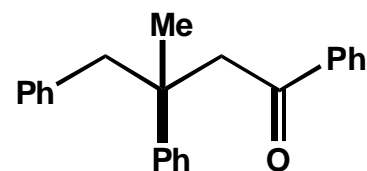
Asymmetric Arylation



99 % yield, 82 % ee

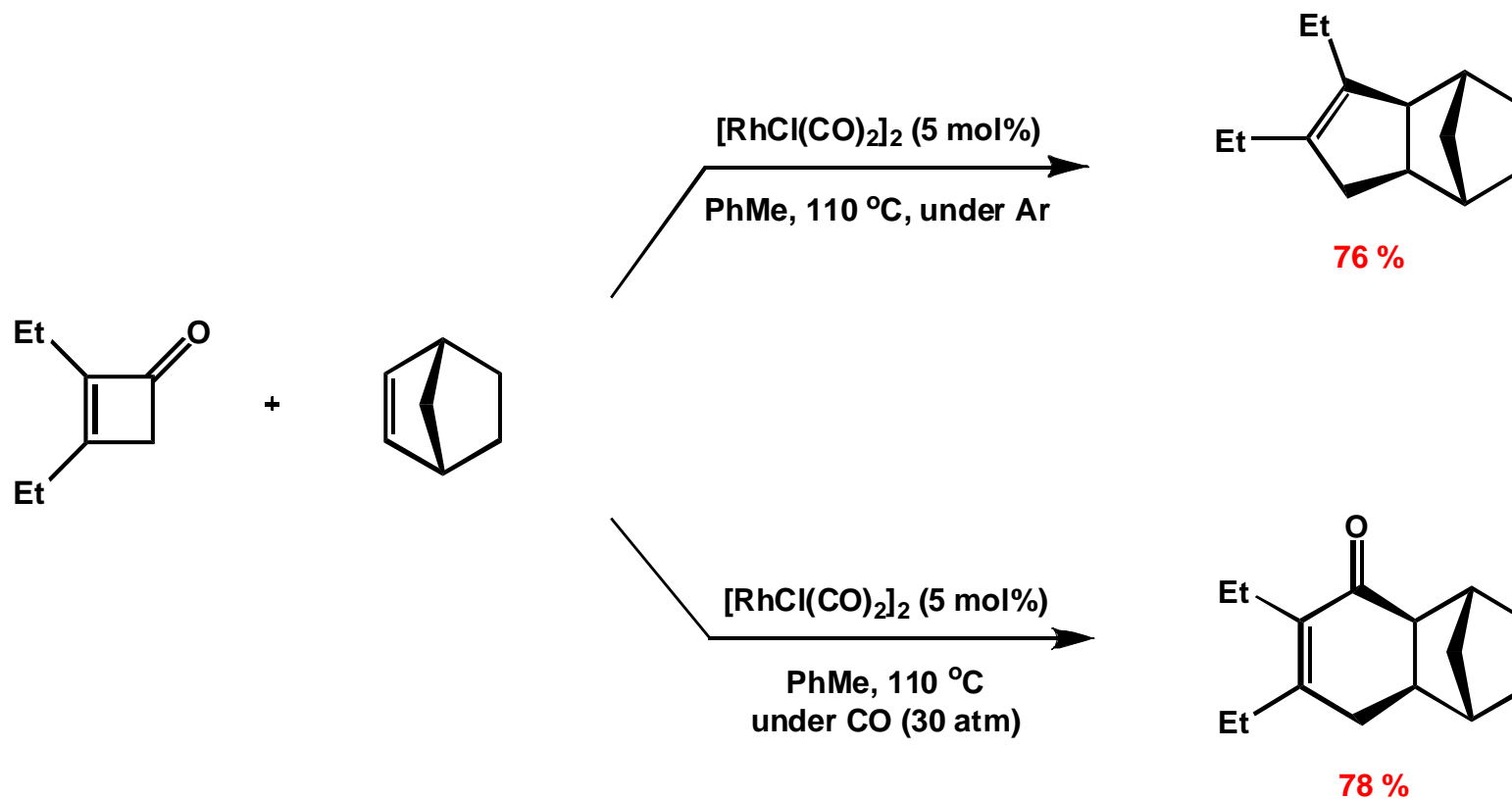


99 % yield, 93 % ee

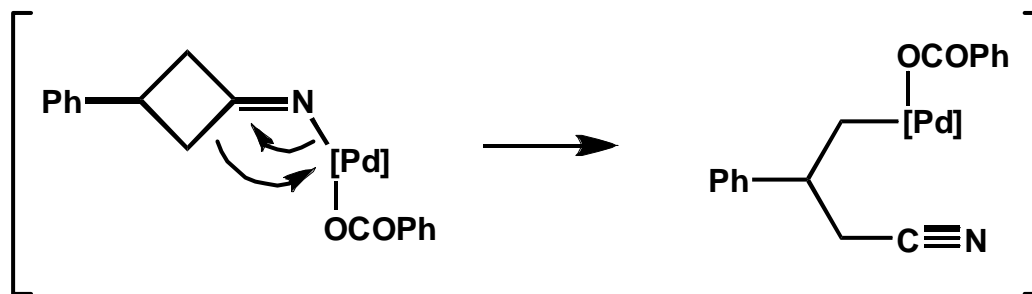
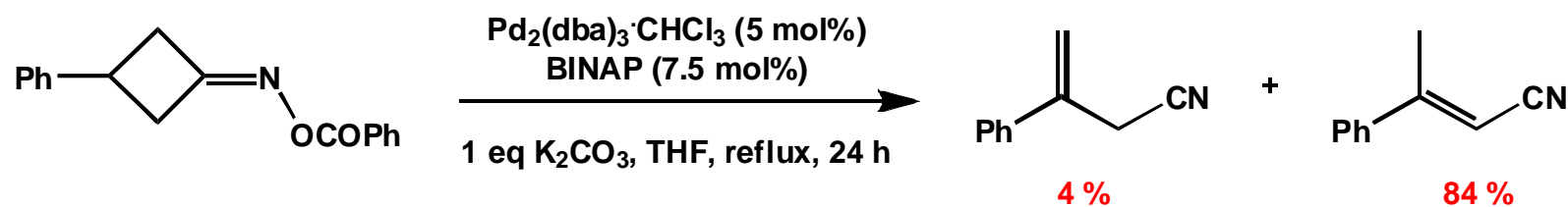


83 % yield, 90 % ee

Reactions of Cyclobutenones



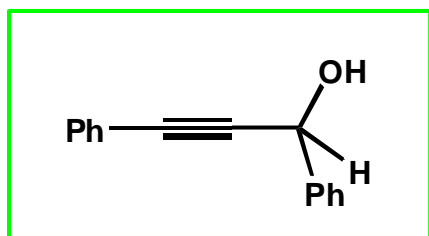
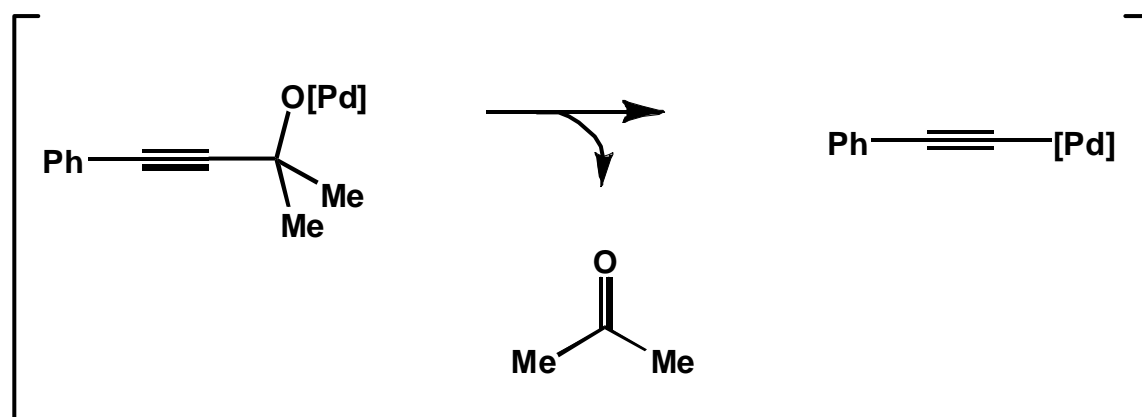
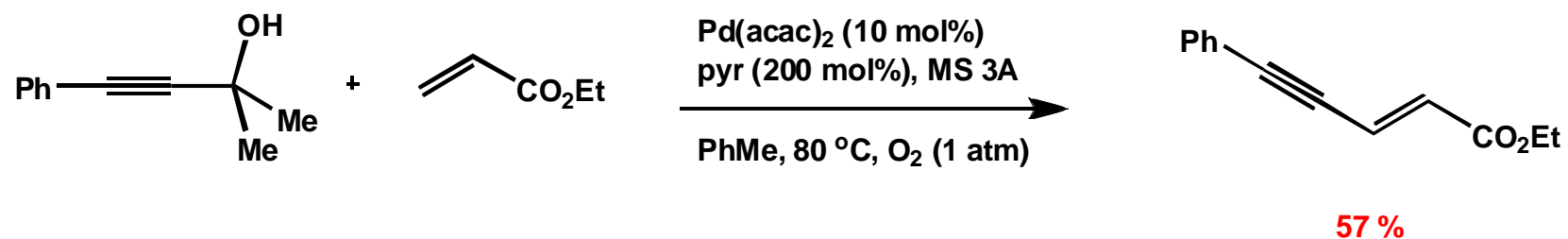
Formation of Nitriles from *o*-Acyl Oximes



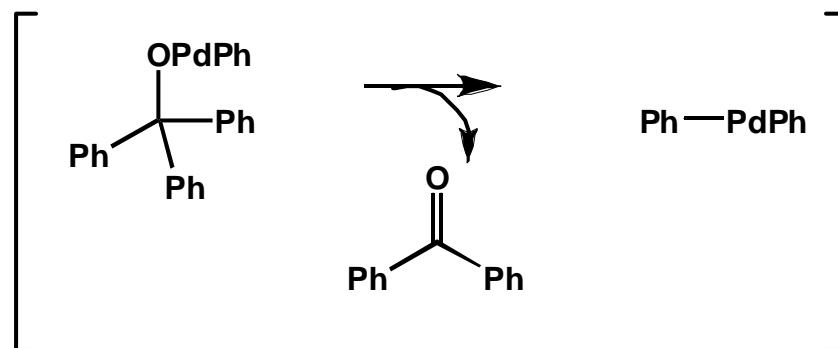
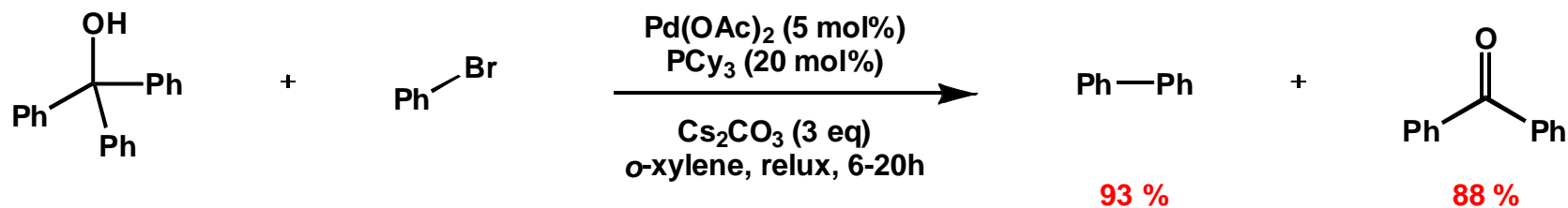
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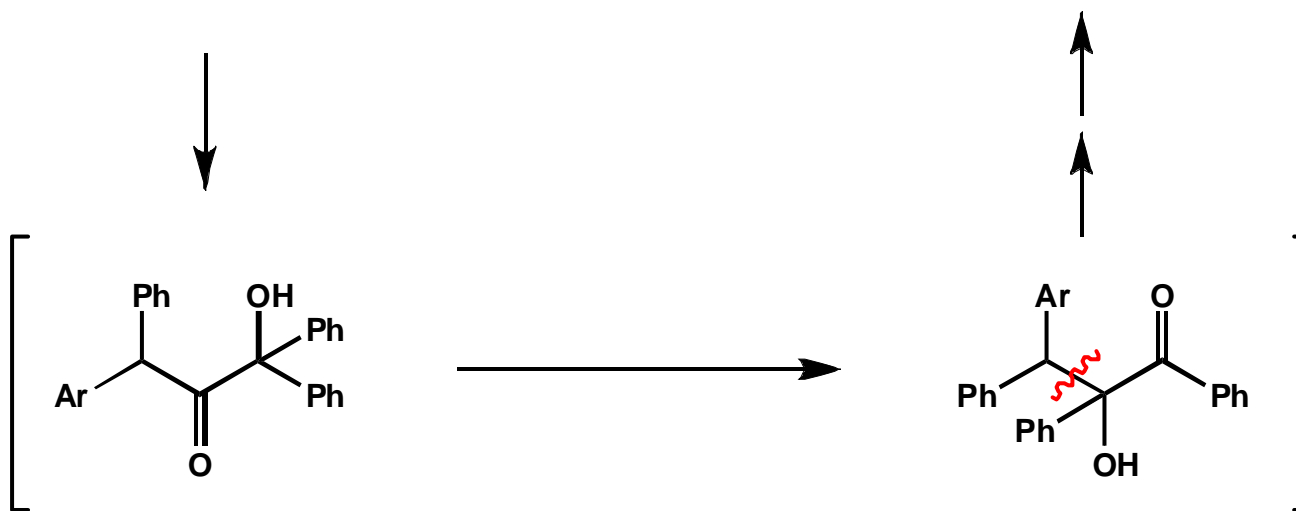
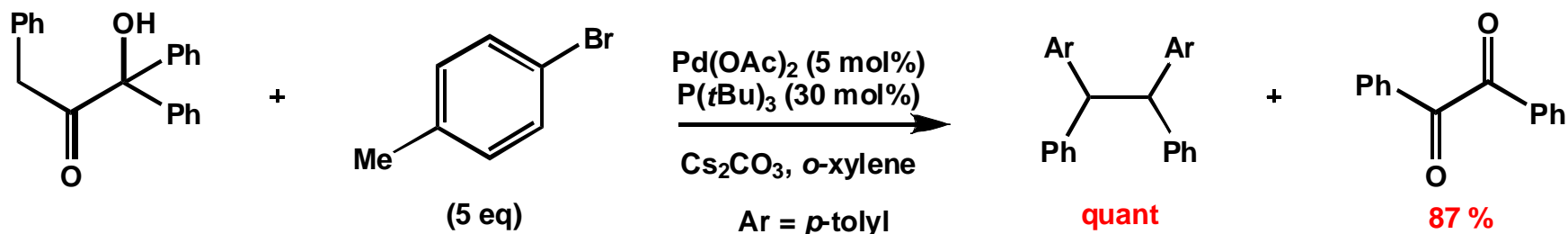
Oxidative Alkynylation of Alkenes



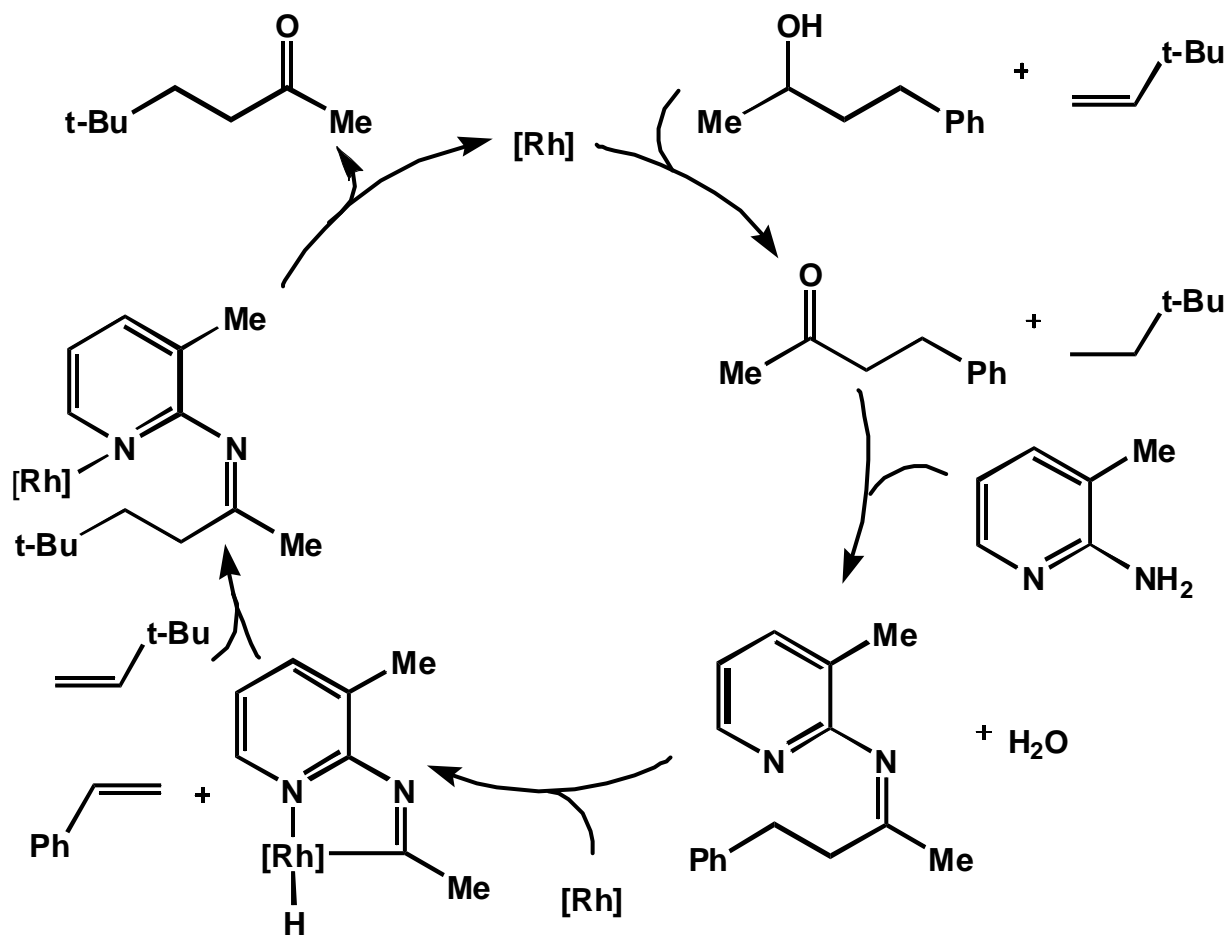
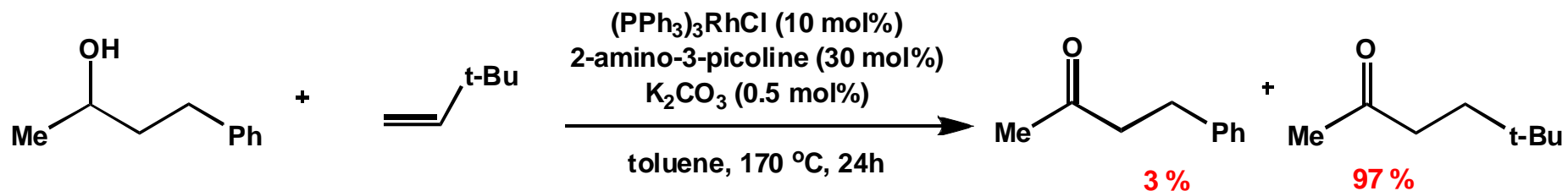
Csp²-Csp² Coupling



Multiple Arylation

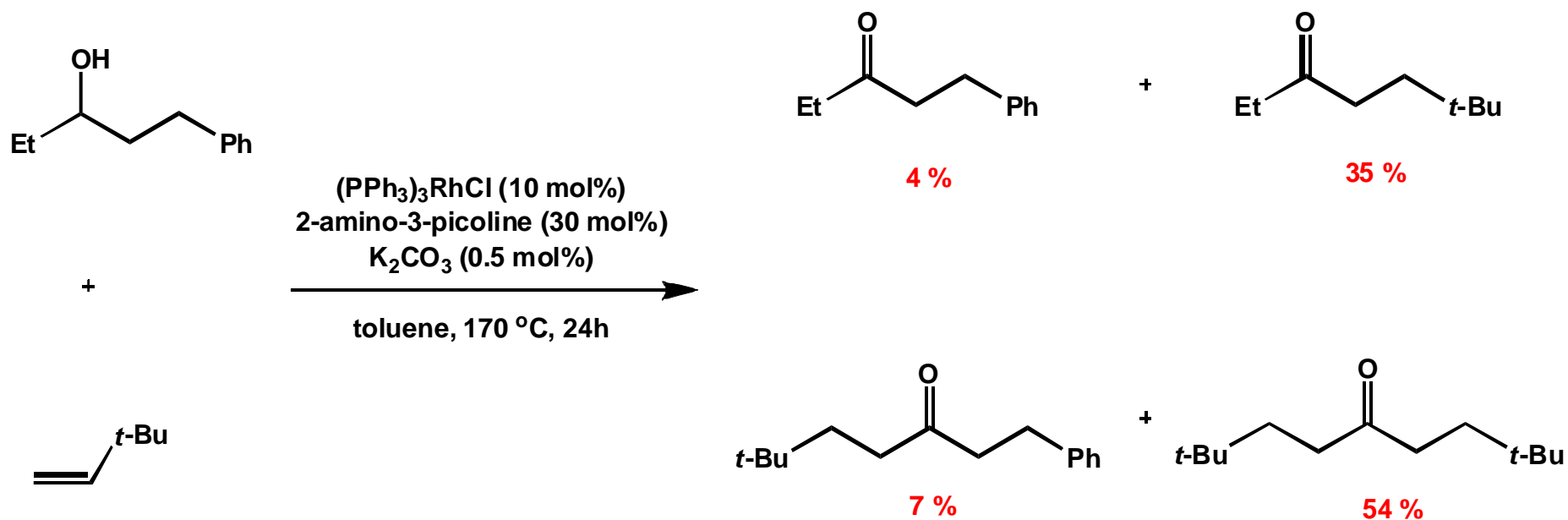


C-C Bond Activation of Alcohols

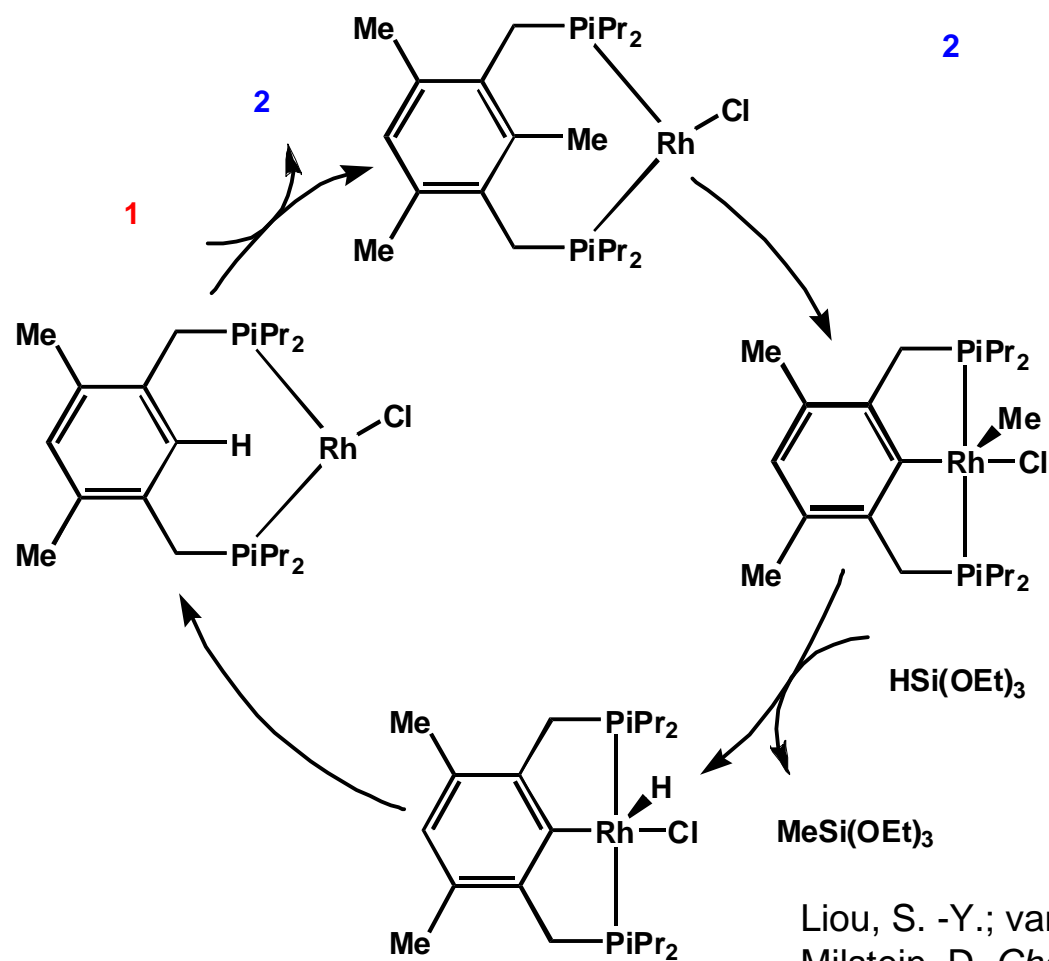
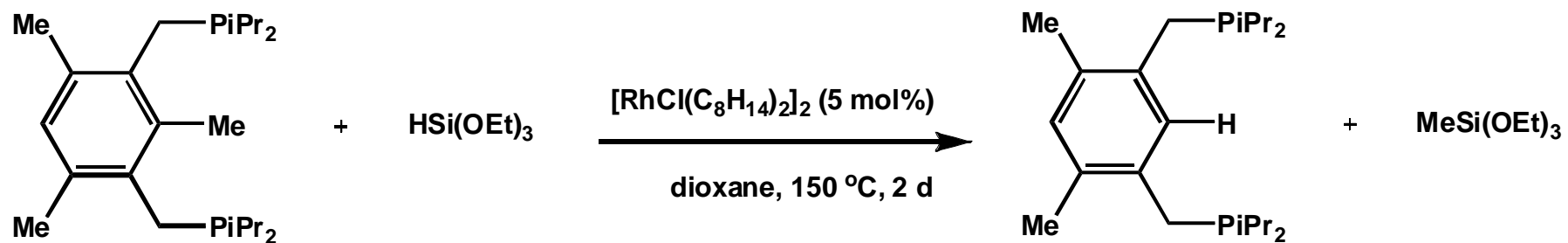


Jun, C.-H.; Lee, D.-Y.; Kim, Y.-H.; Lee, H. *Organometallics*, **2001**, *20*, 2928-2931

Competition Between C-C Bonds

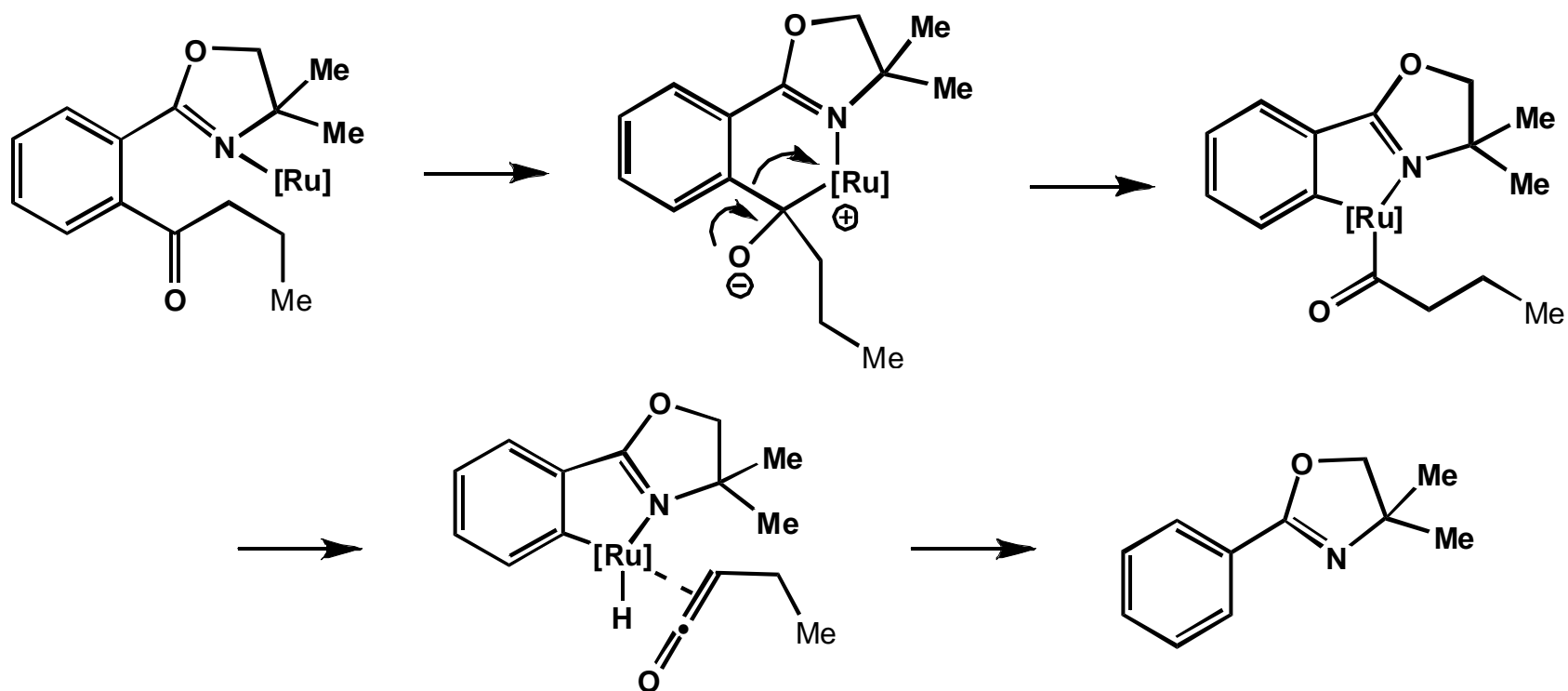
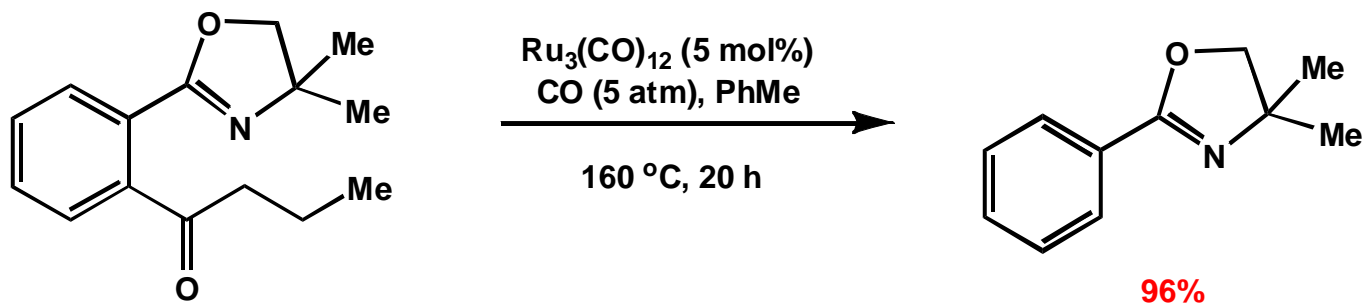


Pincer Type Ligands



Liou, S. -Y.; van der Boom, M. E.;
Milstein, D. *Chem. Comm.* **1998**, 687-688

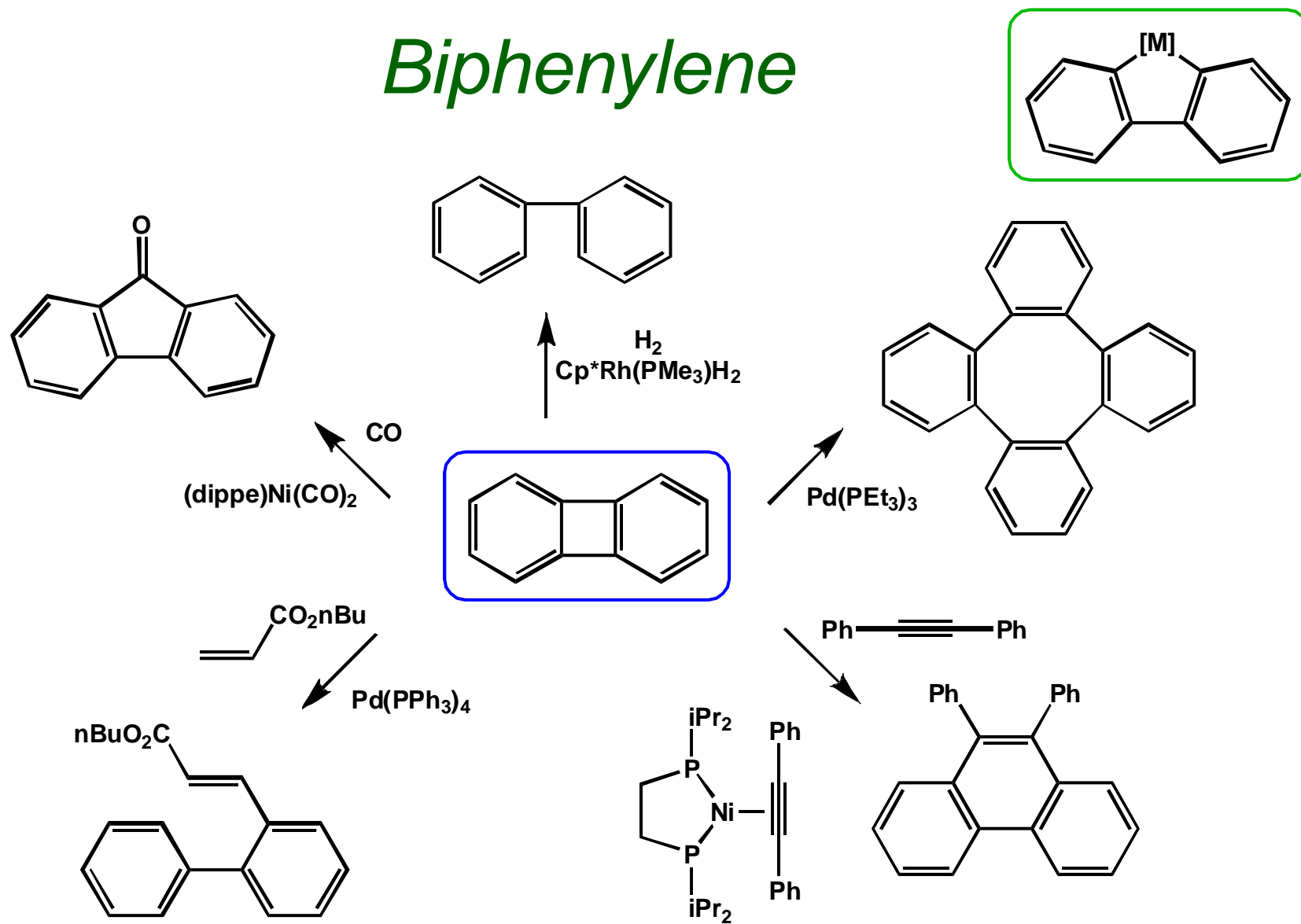
Chelation Assistance



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Biphenylene



Perthuisot, C.; Edelbach, B. L.; Zubris, D. L.; Simhai, N.; Iverson, C. N.; Müller, C.; Satoh, T.; Jone, W. D. *J. Mol. Catal. A: Chem.*, **2002**, 189, 157-168

Summary

- **C-C Bond Activation**
 - *Possible with Highly Reactive Molecules*
- **Potential**
 - *Asymmetric Reactions*
 - *Functionalization of Alkanes*
 - *Synthesis of Interesting Molecules*
- **Problems to Overcome**
 - *Harsh Reaction Conditions*
 - *Undefined Active Catalyst*
 - *Limited Substrate Scope*

