Literature Report VII

Transition Metal-Catalyzed Enantioselective C-C Bond Cleavage of Cyclobutanols and Cyclobutanones

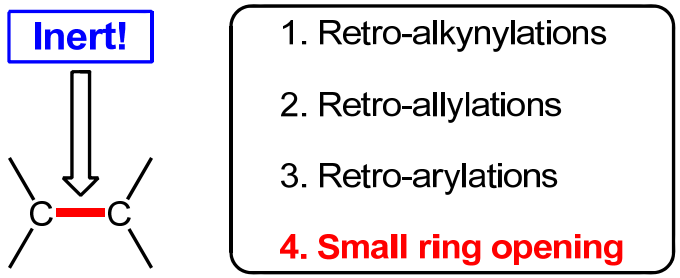
Huang, W.-X. checker: Yu, C.-B.

2014-04-29

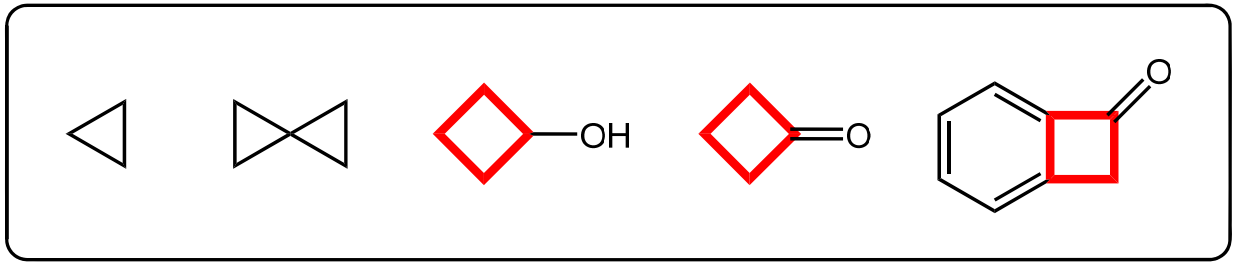
Contents

1. Background Information

Figure 1. Inert C-C Bond



1. Retro-alkynylations
2. Retro-allylations
3. Retro-arylations
4. **Small ring opening**



Ring Strain Liberated!

Figure 2. Two Major Pathways for C-C Activation

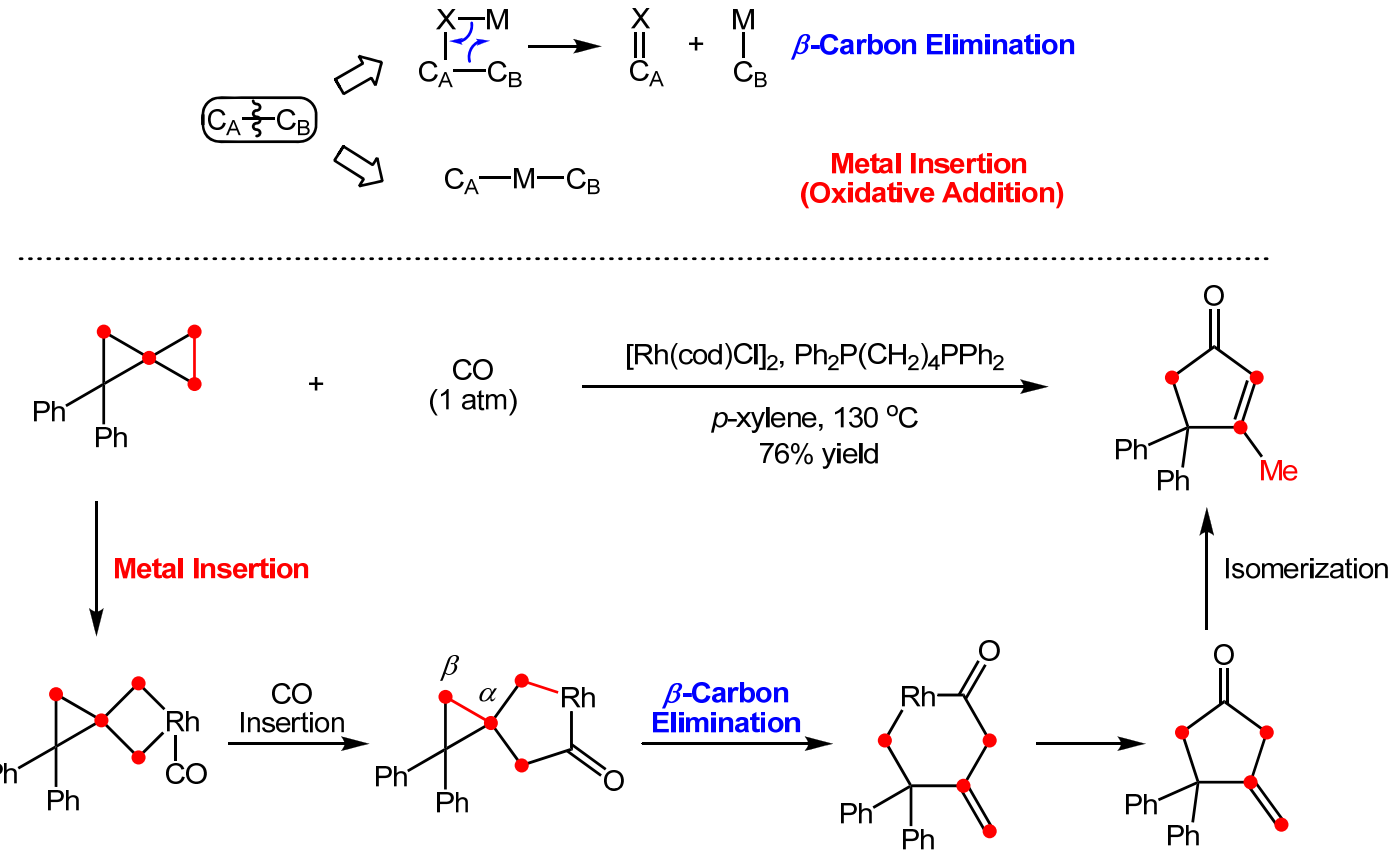
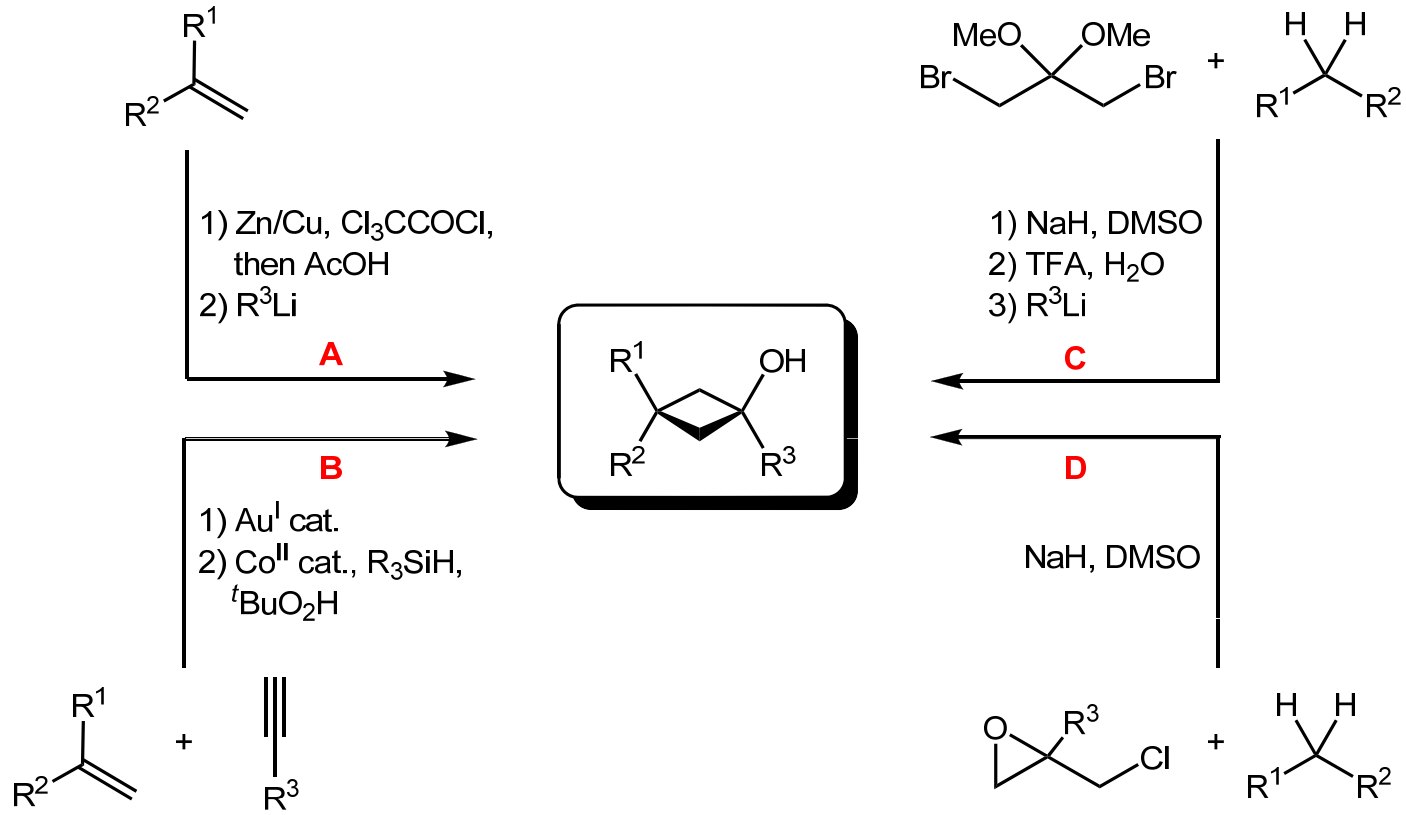


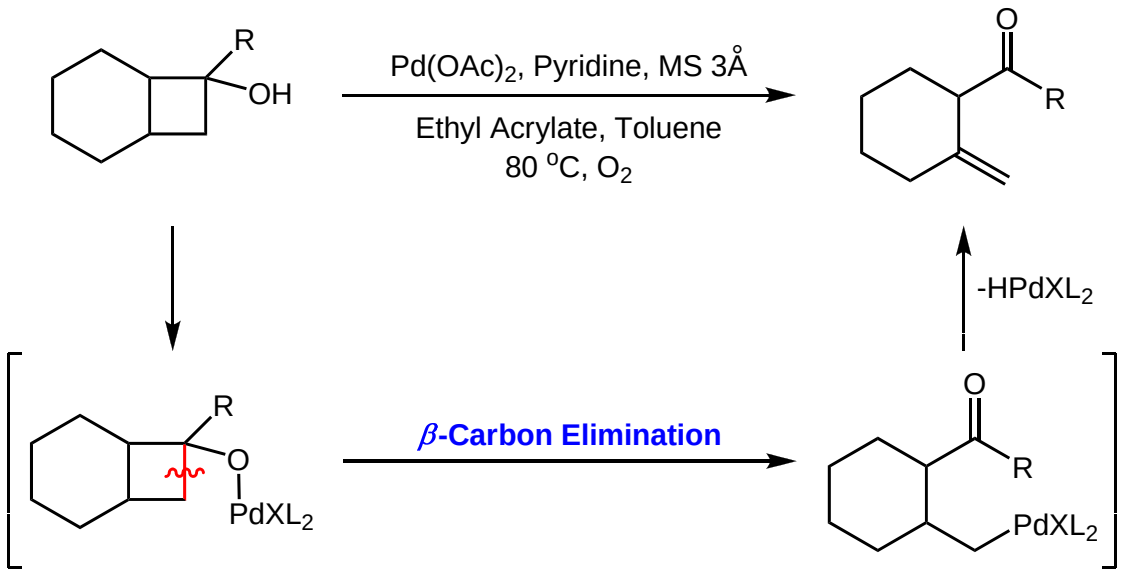
Figure 3. General Synthetic Strategies for the Cyclobutanols



Cramer, N. *et al. Synlett* **2011**, *4*, 449.

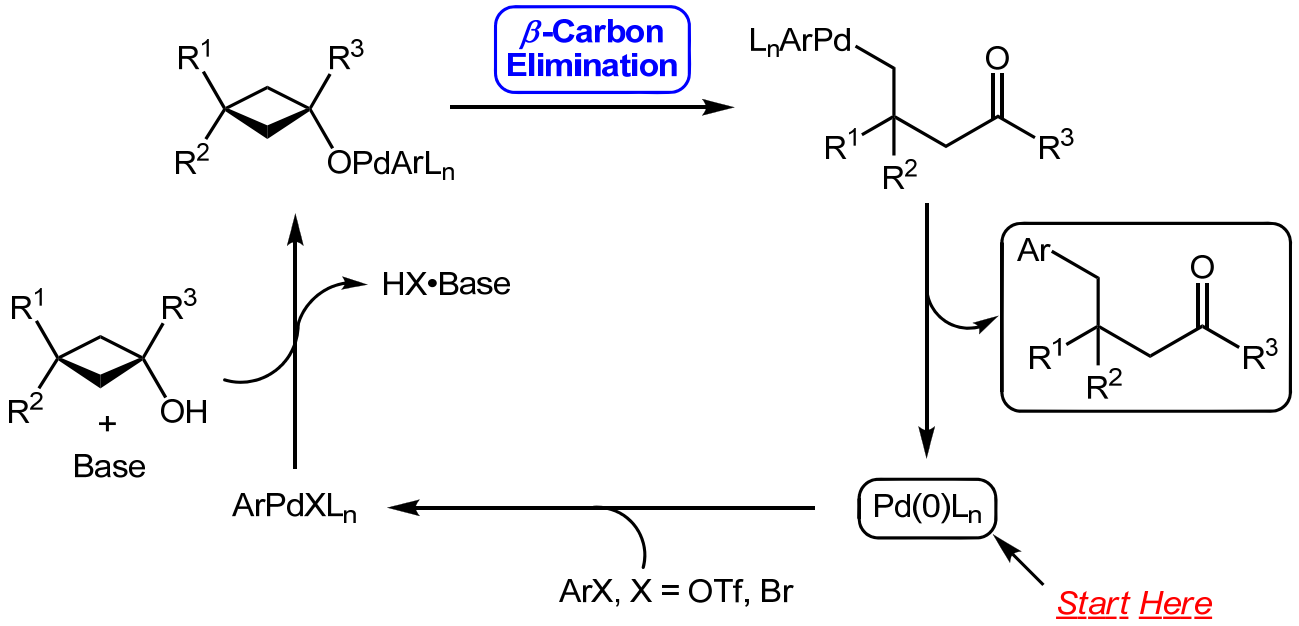
2. Pd-Catalyzed Enantioselective C-C Bond Cleavage

Figure 4. Pd-Catalyzed Oxidative Ring Cleavage of *tert*-Cyclobutanols



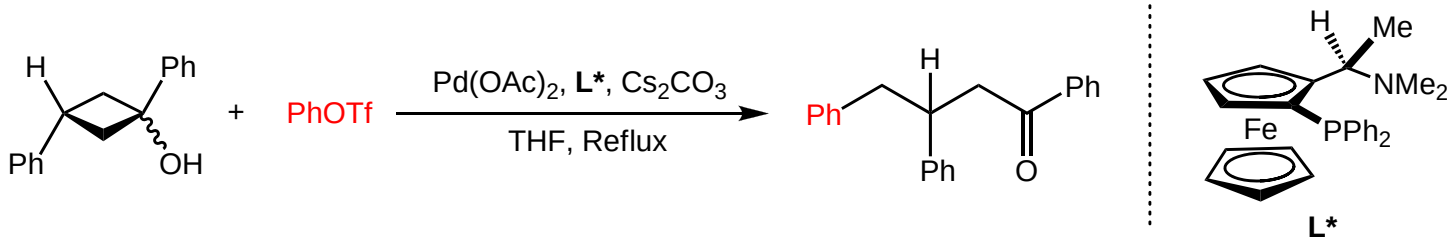
Uemura, S. *et al. J. Am. Chem. Soc.* **1999**, *121*, 2654.

Figure 5. Pd-Catalyzed Enantioselective C-C Bond Cleavage of Cyclobutanols



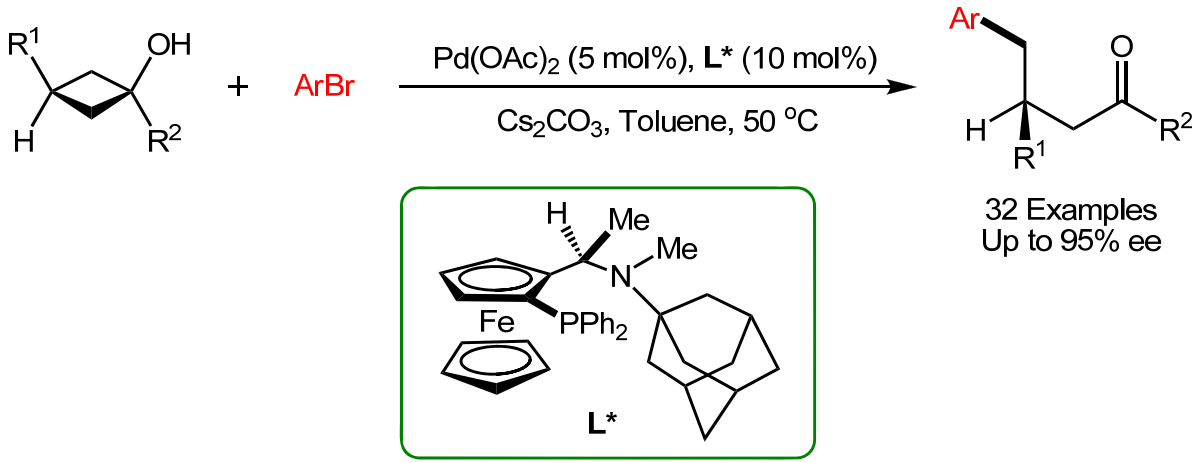
Uemura, S. *et al. J. Am. Chem. Soc.* **2003**, *125*, 8862.

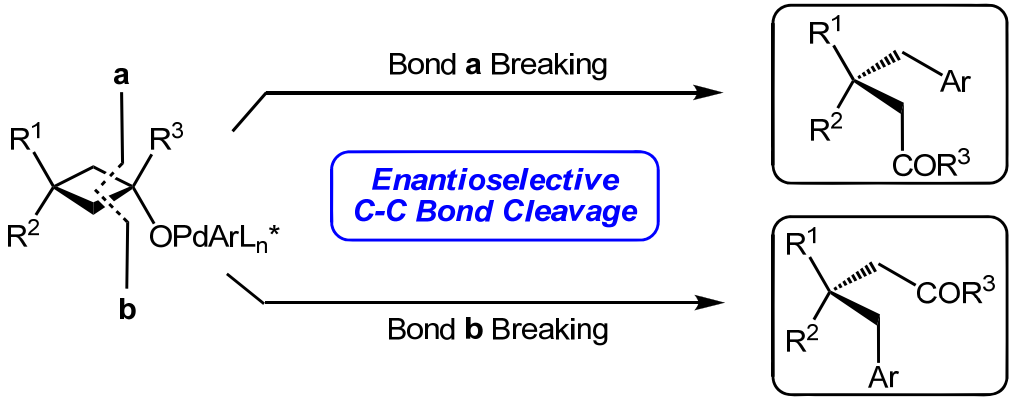
Figure 6. Pd-Catalyzed Asymmetric Arylation of Cyclobutanols



Entry	*Cis/Trans*	GLC yields (%)	Ee (%)
1	80/20	16	36
2	85/15	36	43
3	90/10	40	50
4	95/5	33	54
5	98/2	42	59

Figure 7. Asymmetric Arylation of *tert*-Cyclobutanols with Aryl Bromide

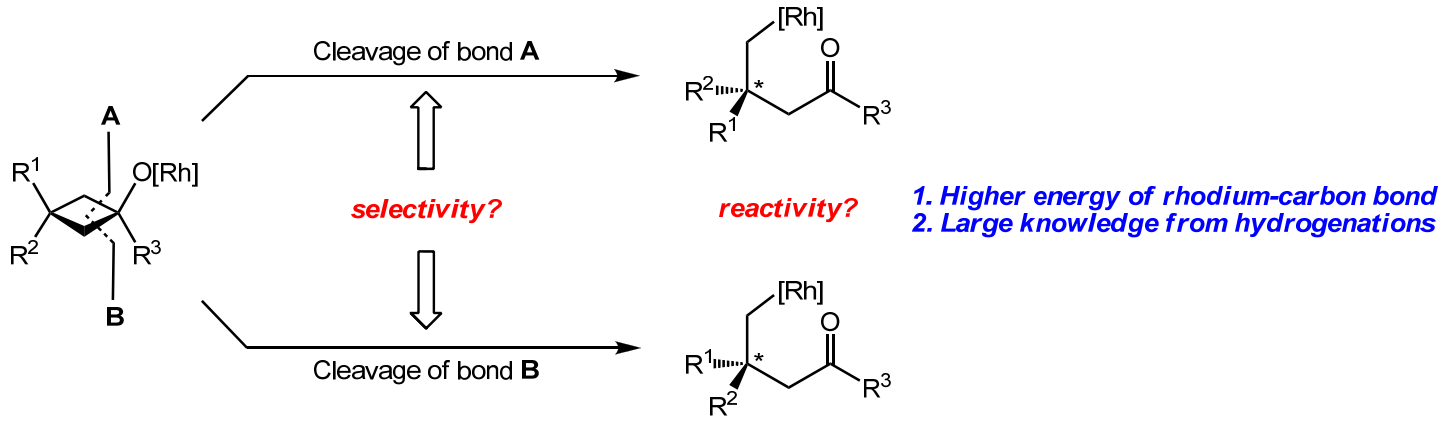




Uemura, S. *et al. J. Am. Chem. Soc.* **2003**, *125*, 8862.

3. Rh-Catalyzed Enantioselective C-C Bond Cleavage

Figure 8. Enantioselective β-Alkyl Cleavage by Rhodium



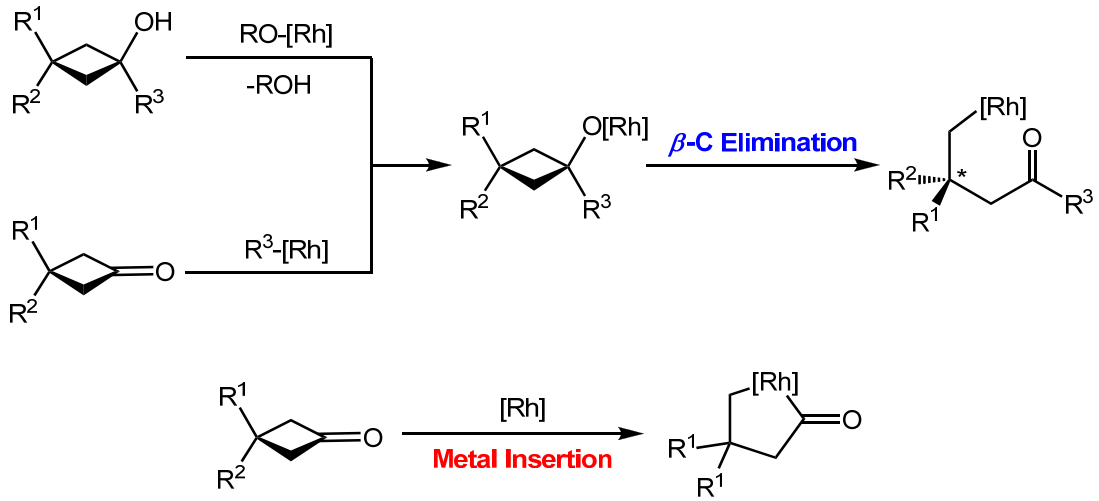
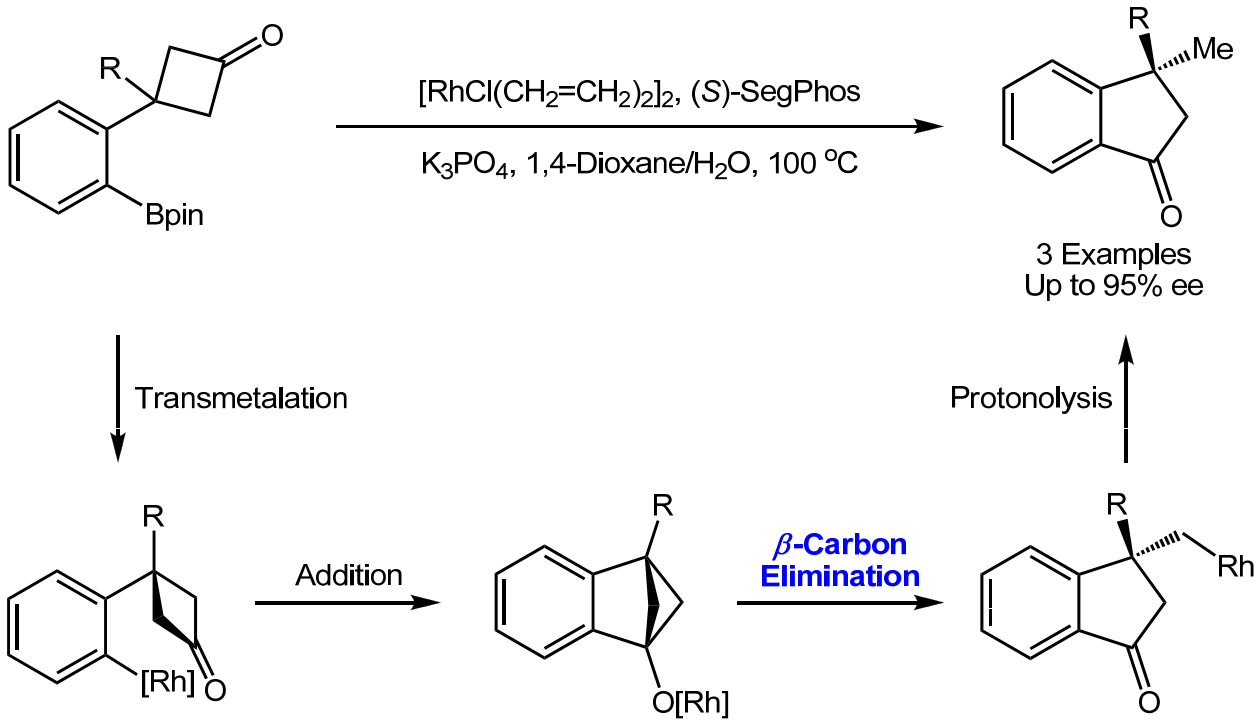
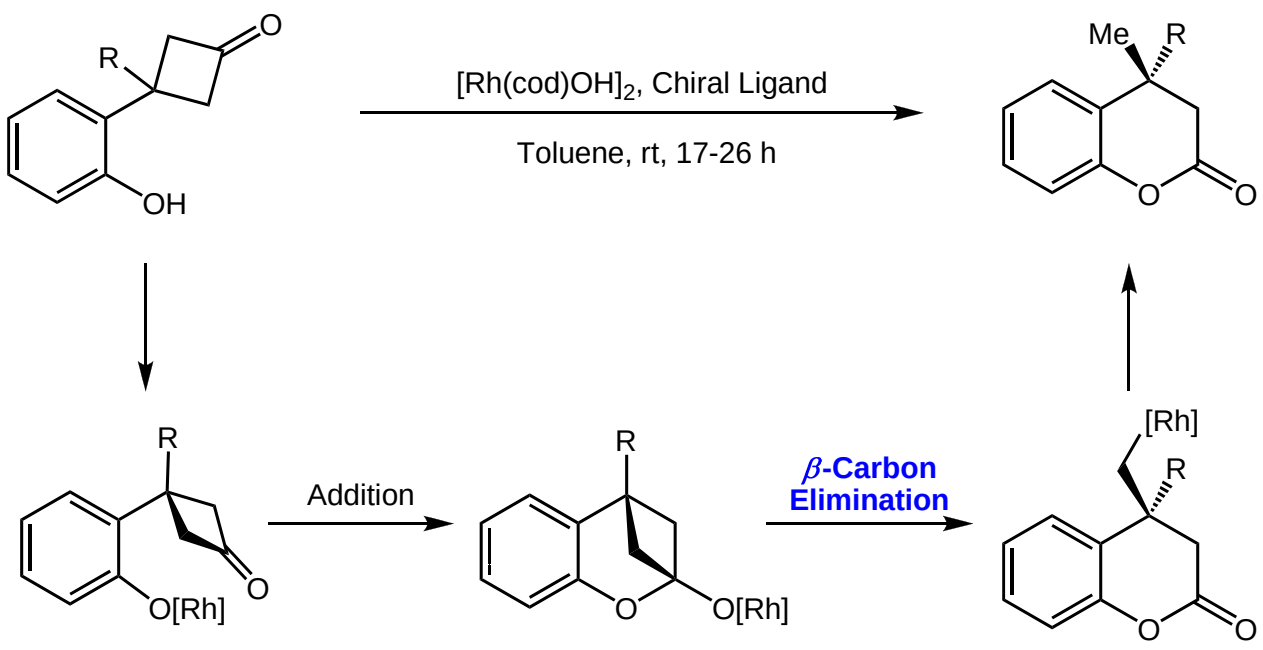


Figure 9. Rh-catalyzed Addition and Ring-Opening



Murakami, M. *et al. Org. Lett.* **2006**, *8*, 3379.

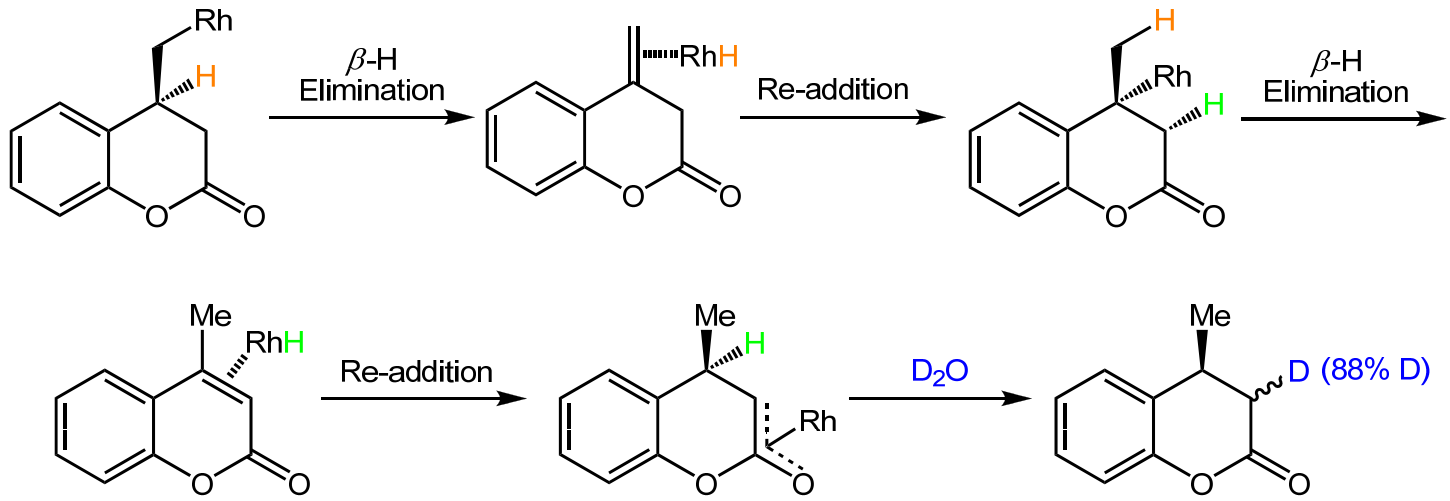
Figure 10. Rh-Catalyzed Reaction of Cyclobutanones



Murakami, M. *et al. J. Am. Chem. Soc.* **2007**, *129*, 12086.

Figure 11. Deuterium-Labeling Experiment

R = H, 3 examples, up to 99% ee



Murakami, M. *et al. J. Am. Chem. Soc.* **2007**, *129*, 12086.

Figure 12. Asymmetric Synthesis of 4,4-Disubstituted 3,4-Dihydrocoumarins

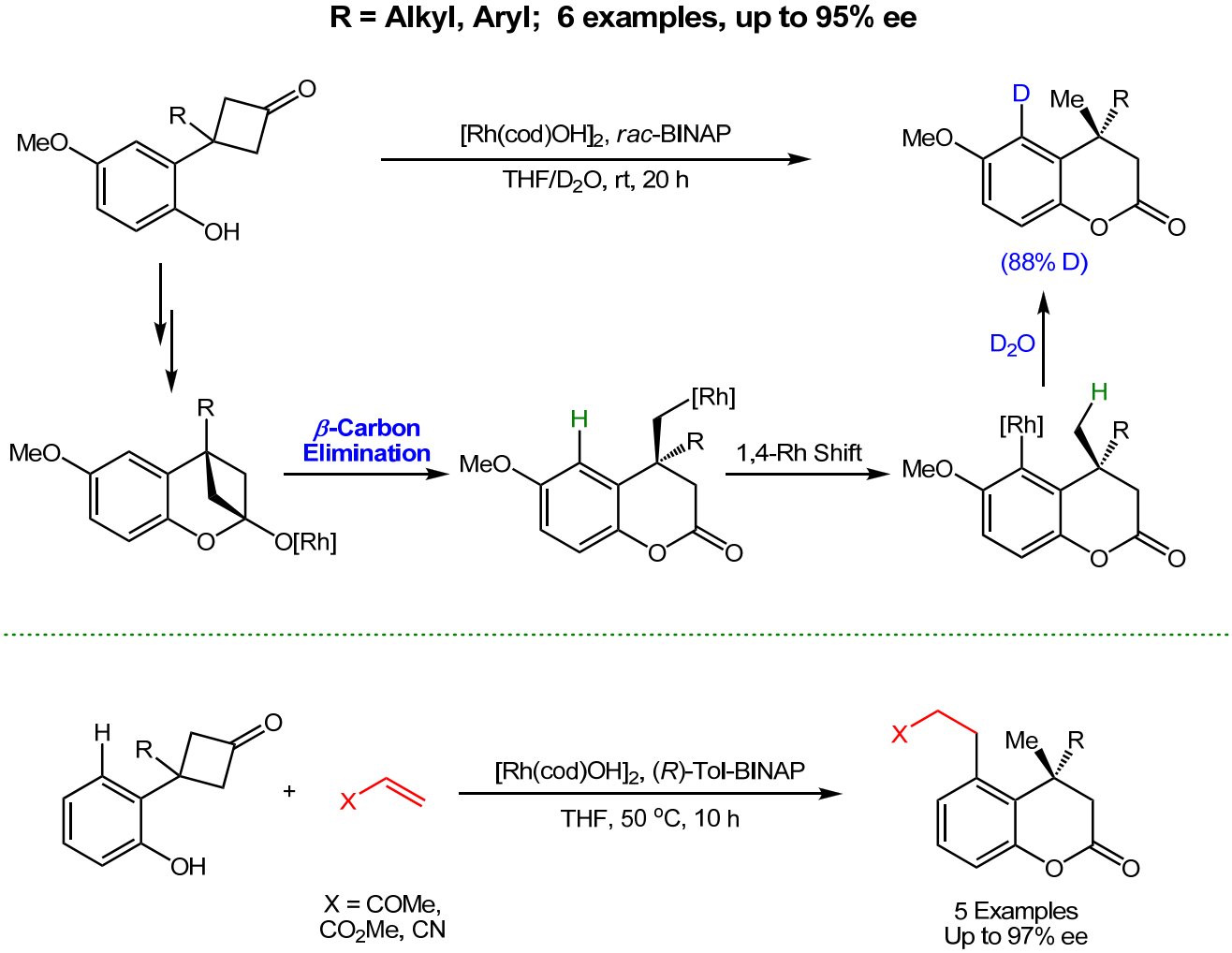
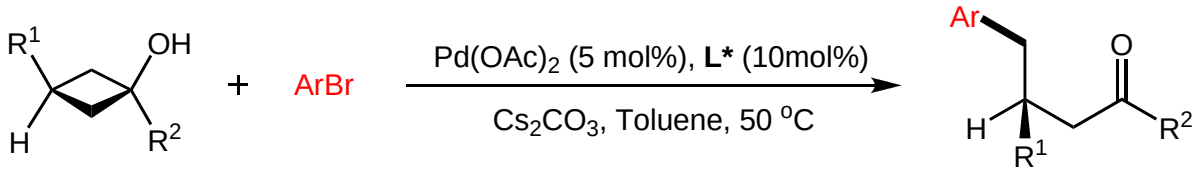
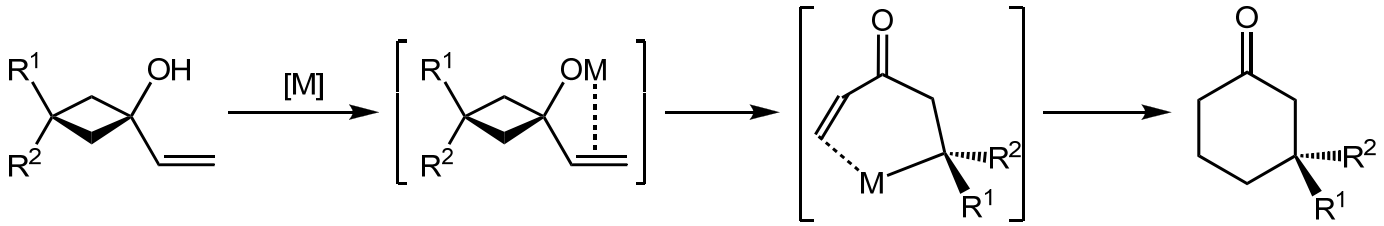


Figure 13. C-C Bond Activation for the Synthesis of Cyclic Ketones



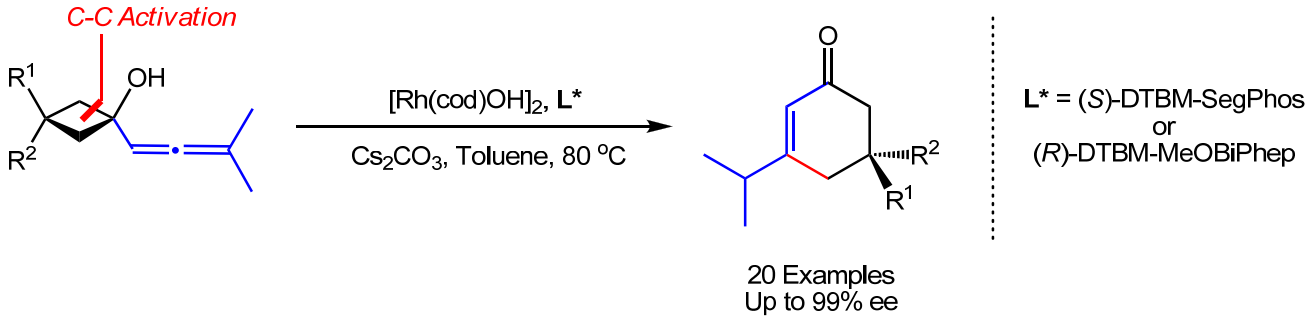
32 Examples
Up to 95% ee

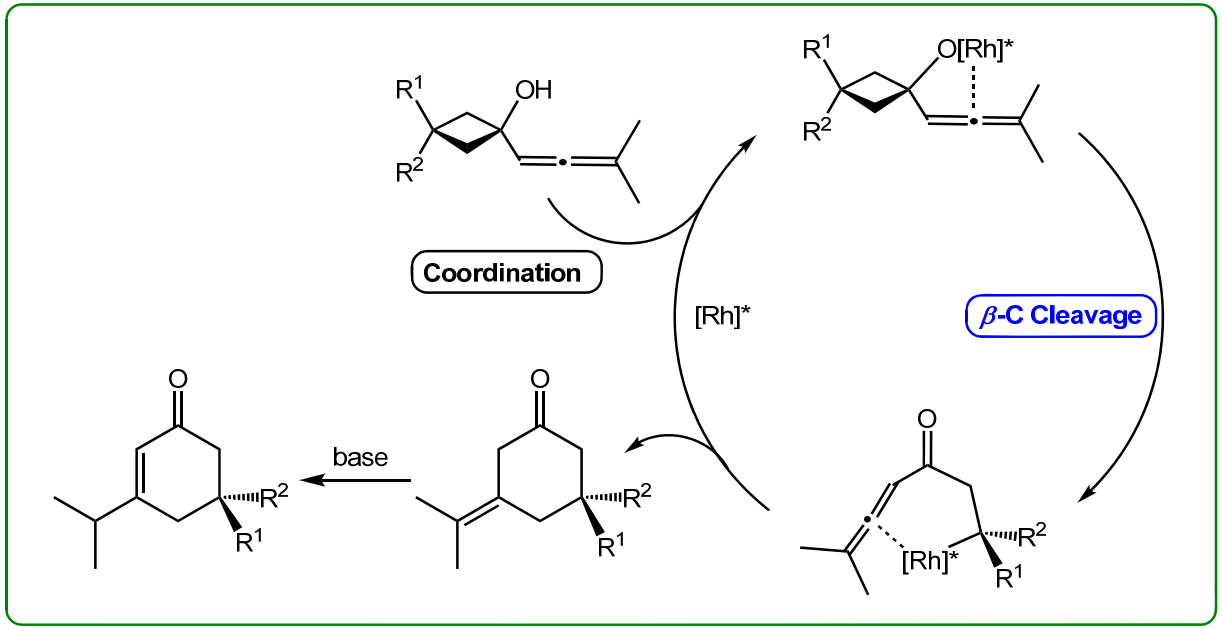
Uemura, S. *et al. J. Am. Chem. Soc.* **2003**, *125*, 8862.



Cramer, N. *et al. Angew. Chem. Int. Ed.* **2008**, *47*, 9294.

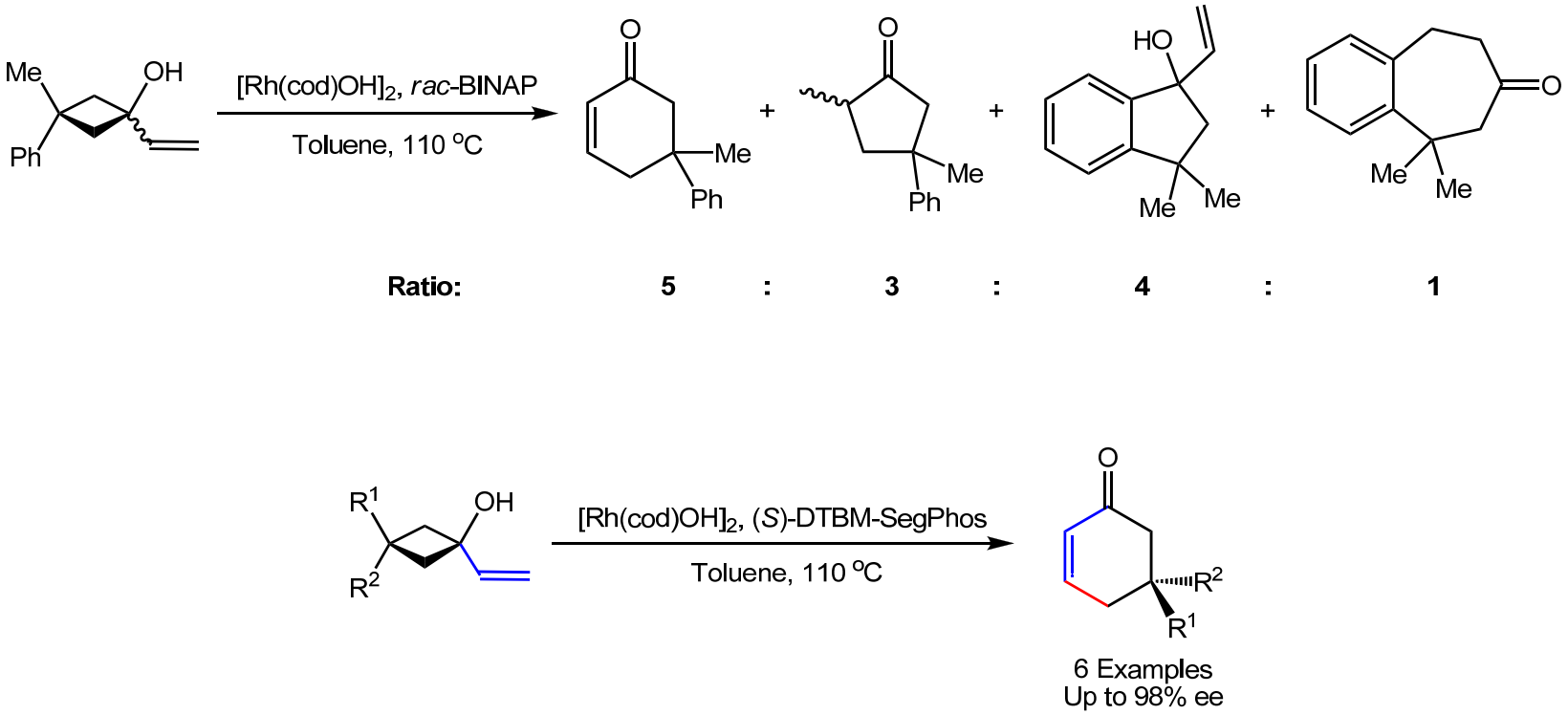
Figure 14. Rhodium-Catalyzed C-C Activation of Cyclobutanols





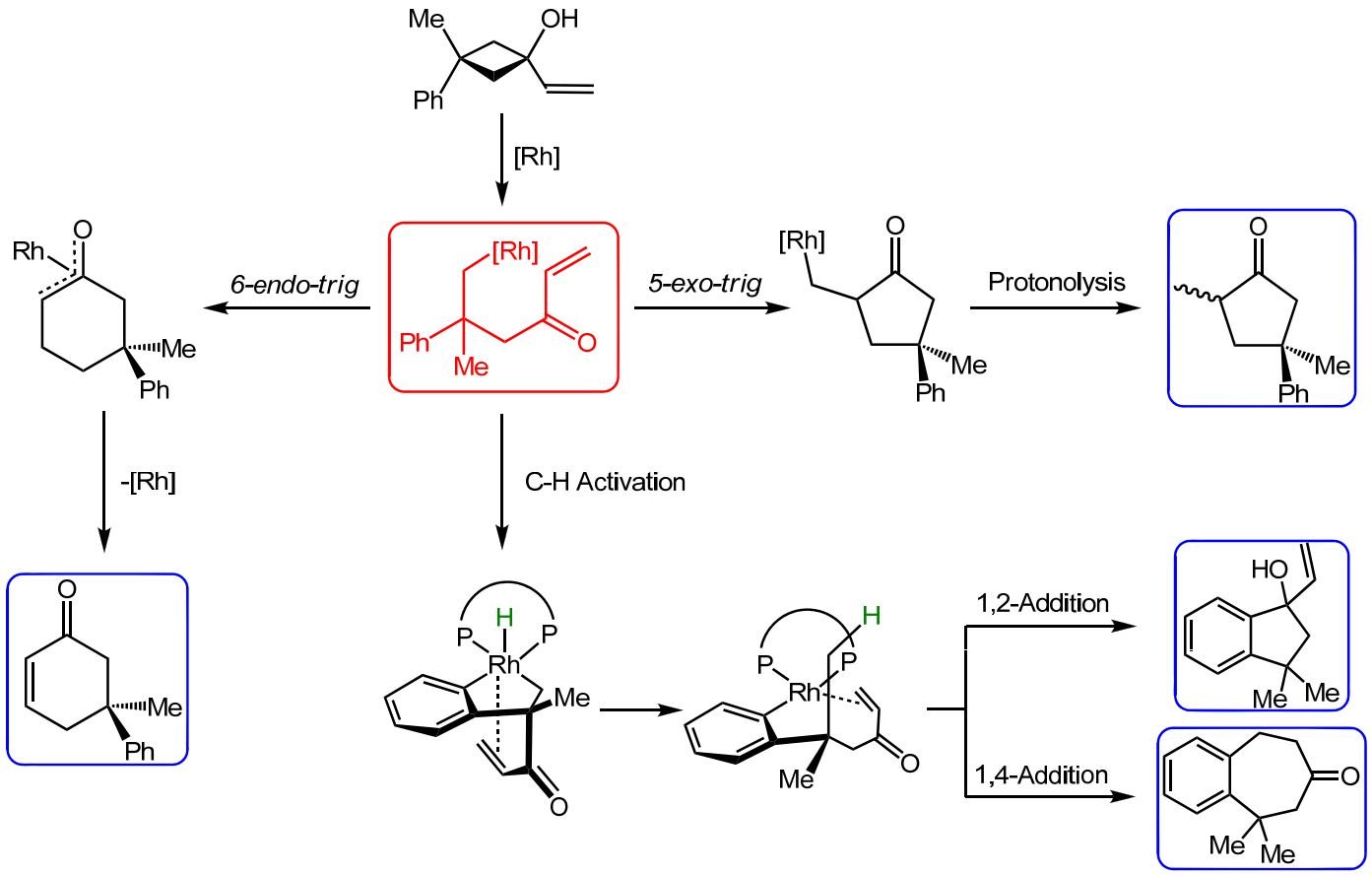
Cramer, N. *et al. Angew. Chem. Int. Ed.* **2008**, *47*, 9294.

Figure 15. Rh-Catalyzed Rearrangement of Allylic *tert*-Cyclobutanols



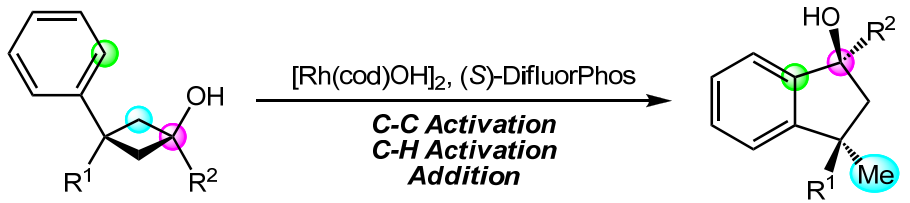
Cramer, N. *et al. Chem. Eur. J.* **2010**, *16*, 3383.

Figure 16. Mechanistic Manifold for the Observed Product Distribution



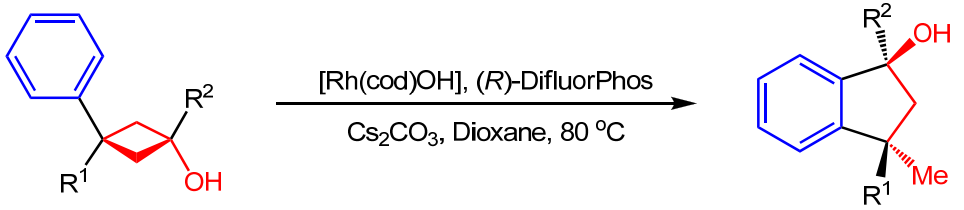
Cramer, N. *et al. Chem. Eur. J.* **2010**, *16*, 3383.

Figure 17. Enantioselective Synthesis of Indanols from *tert*-Cyclobutanols



24 Examples
Up to 99% ee, 20:1 d.r.

Cramer, N. *et al. Angew. Chem. Int. Ed.* **2009**, *48*, 6320.



7 Examples
Up to 99% ee, up to 93:7 d.r.

Murakami, M. *et al. Chem. Eur. J.* **2009**, *15*, 12929.

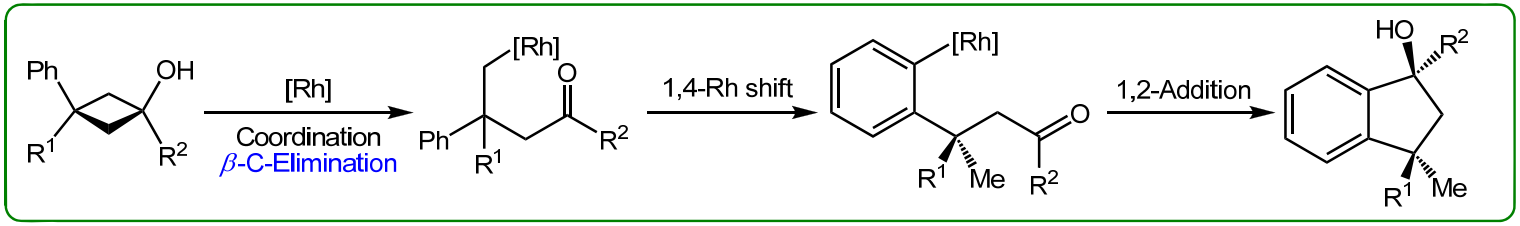
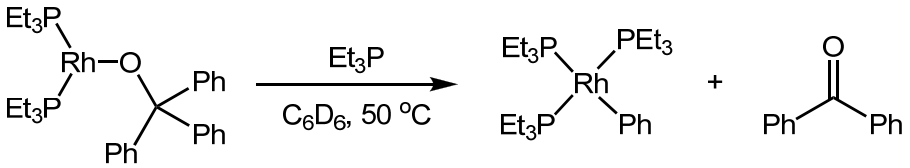
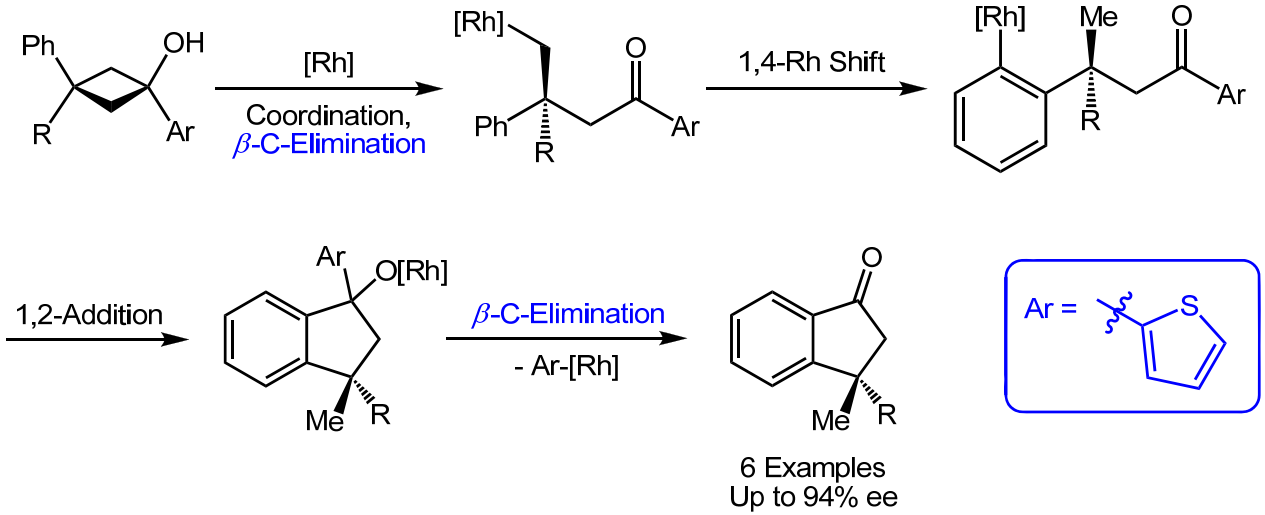


Figure 18. Enantioselective Synthesis of Indanones from *tert*-Cyclobutanols

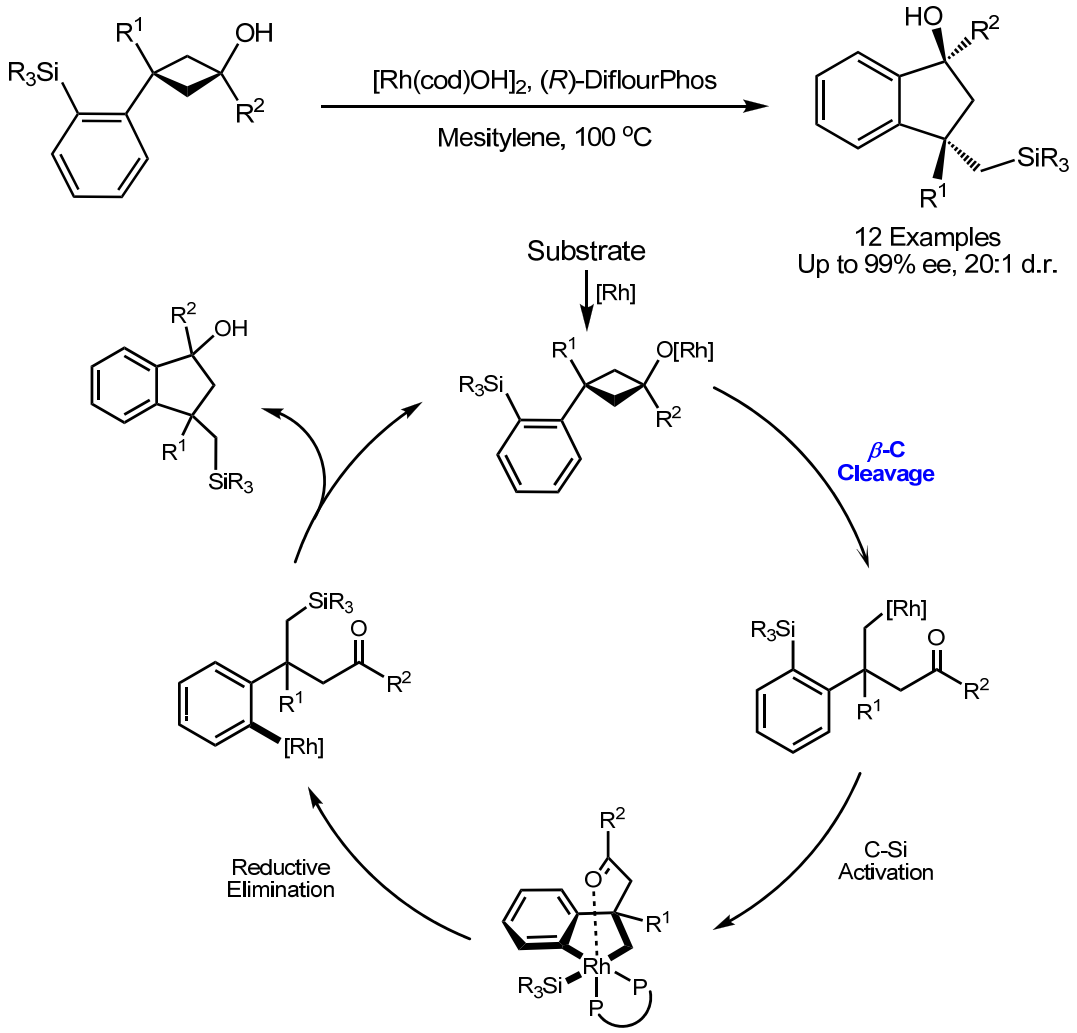


Hartwig, J. F. *et al. J. Am. Chem. Soc.* **2006**, *128*, 3124.



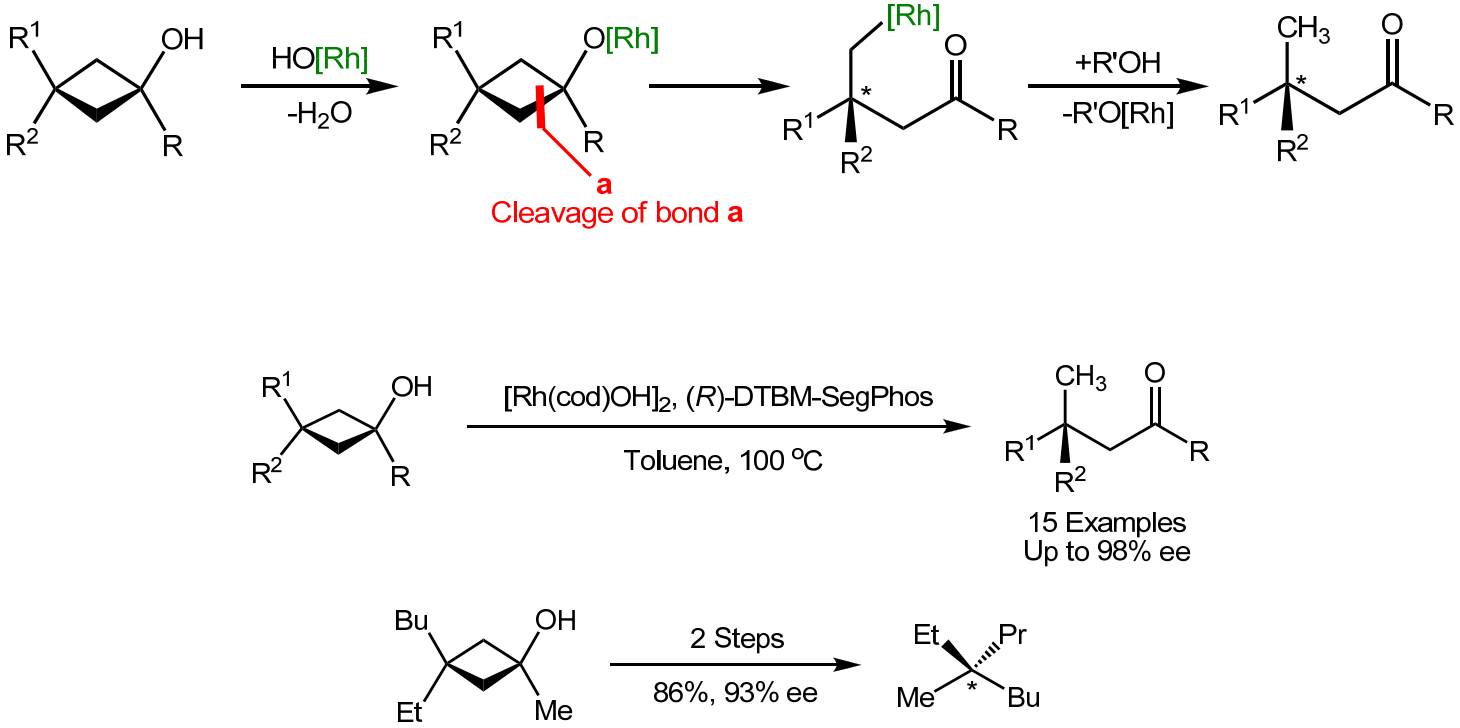
Cramer, N. *et al. Synlett* **2010**, 1699.

Figure 19. Rh-Catalyzed 1,4-Silicon Shift of Unactivated Silanes



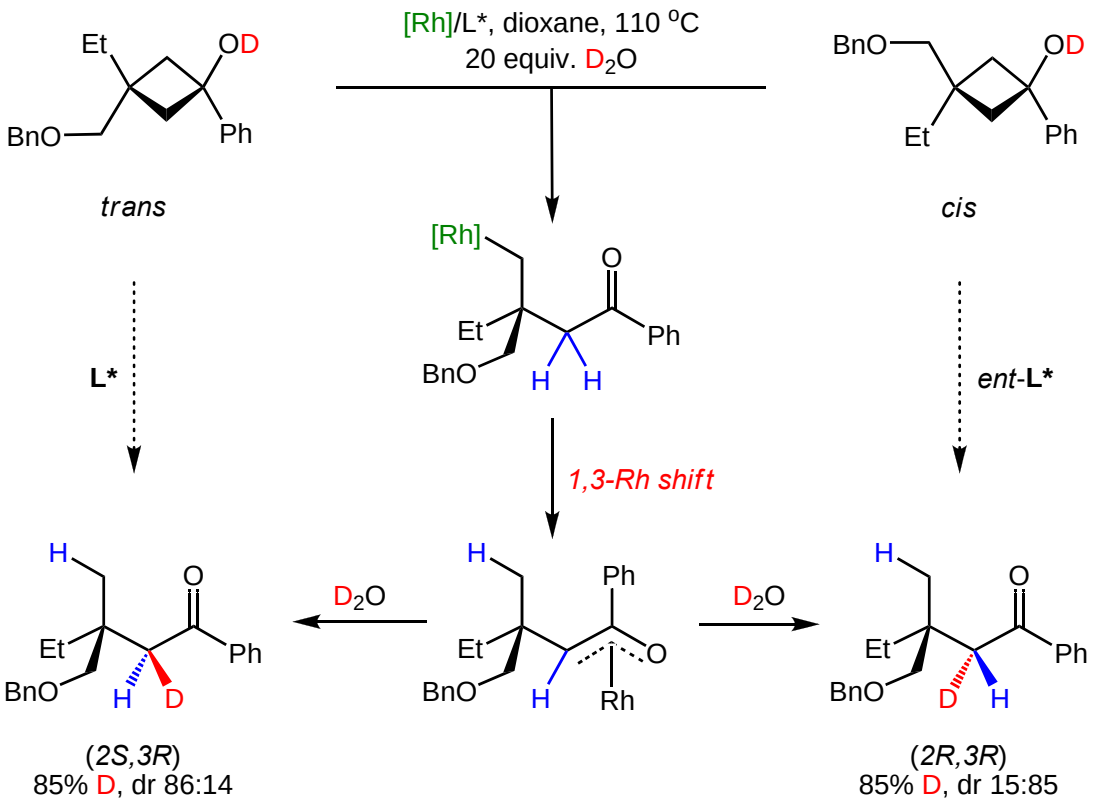
Cramer, N. *et al. Angew. Chem. Int. Ed.* **2010**, *49*, 10163.

Figure 20. Rh-Catalyzed Ring-Opening/Protonation Process



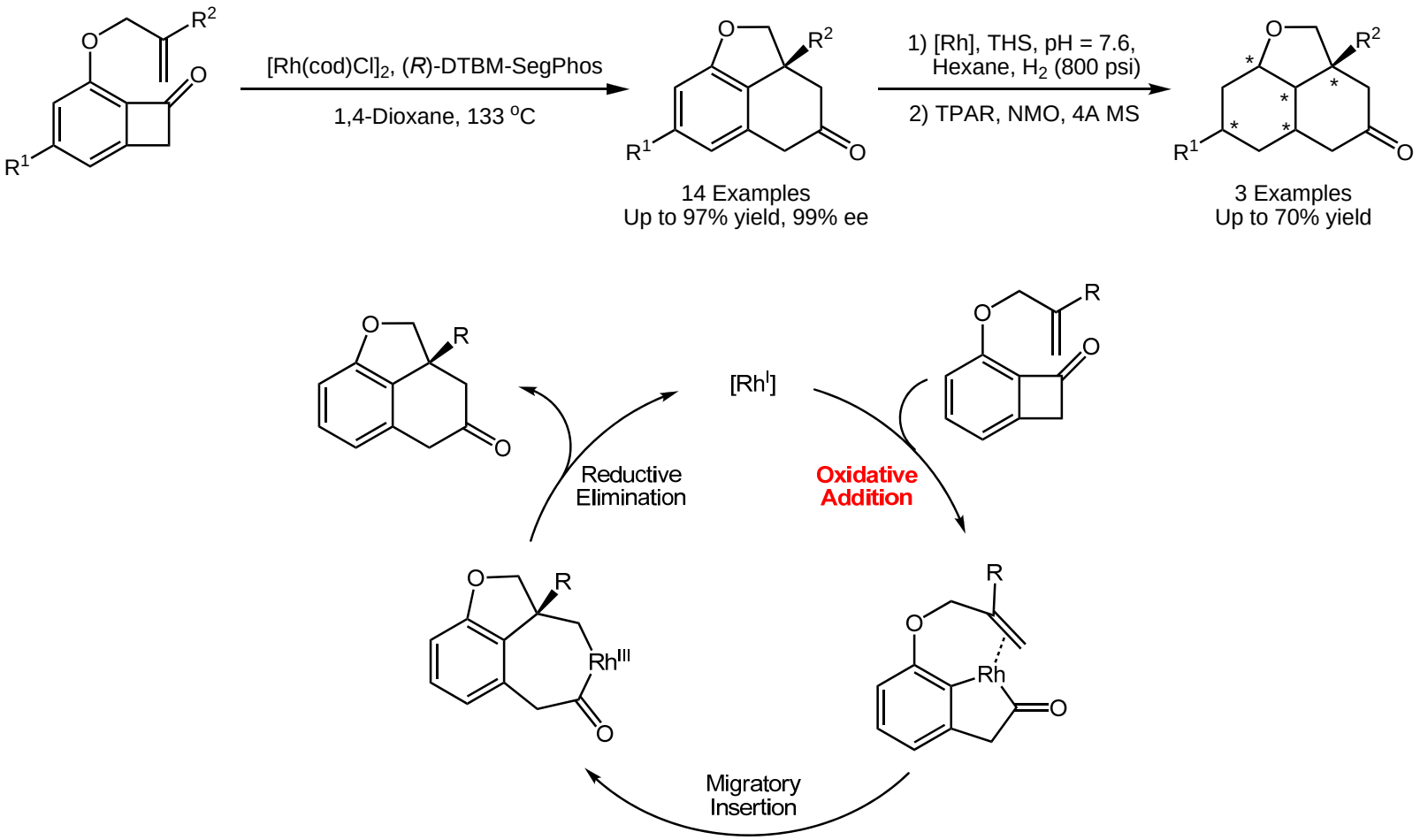
Cramer, N. *et al. J. Am. Chem. Soc.* **2010**, *132*, 5340.

Figure 21. 1,3-Rh Shift Leads to Diastereoselective Deuteration



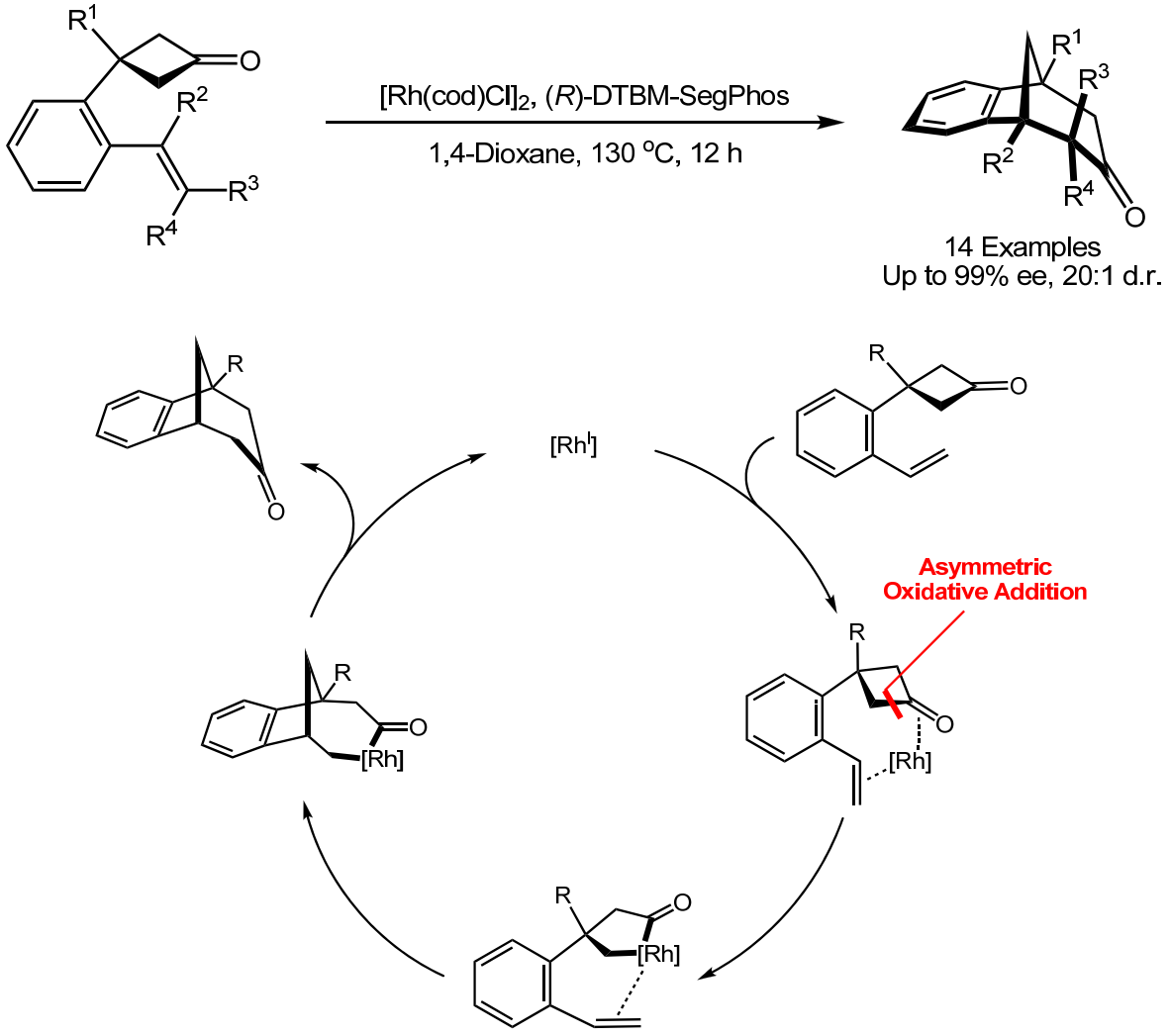
Cramer, N. *et al. J. Am. Chem. Soc.* **2010**, *132*, 5340.

Figure 22. Rh-Catalyzed Carboacylation of Olefins:



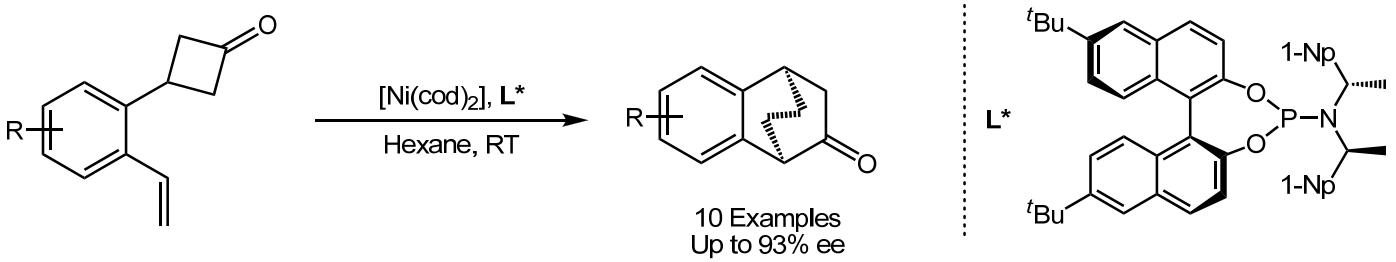
Dong, G.-B. *et al. J. Am. Chem. Soc.* **2012**, *134*, 20006.

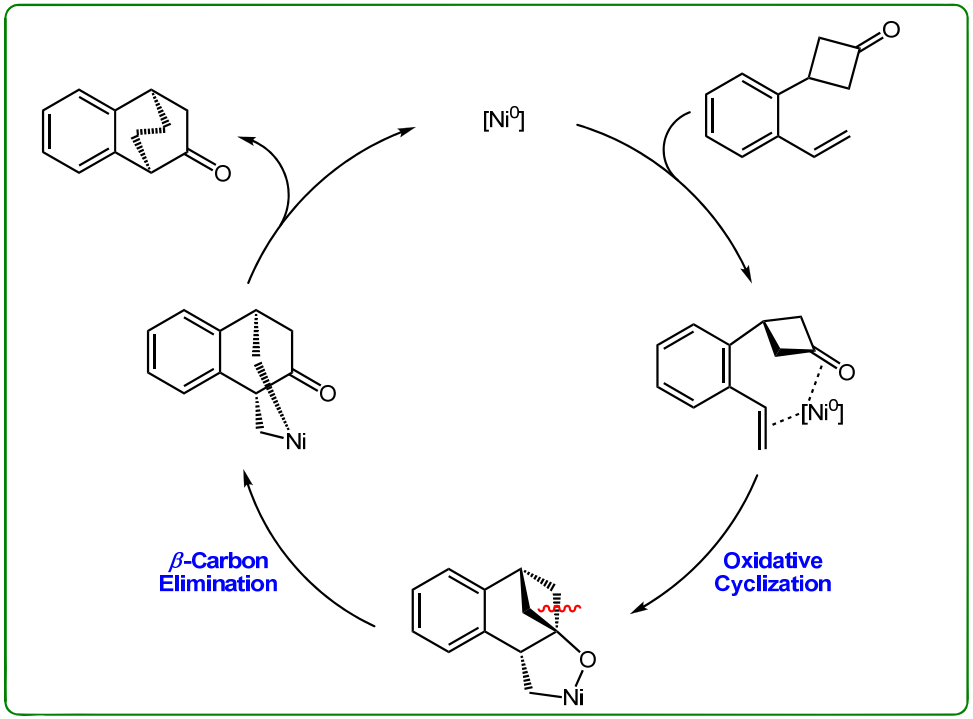
Figure 22. Rh-Catalyzed Enantioselective C-C Activation of Cyclobutanones



Cramer, N. *et al. Angew. Chem. Int. Ed.* **2014**, *53*, 3001.

4. Ni-Catalyzed Enantioselective C-C Bond Cleavage





Murakami, M. *et al. Angew. Chem. Int. Ed.* **2012**, *51*, 2485.

5. Summary

◆ **Introduction of the Corresponding Author**

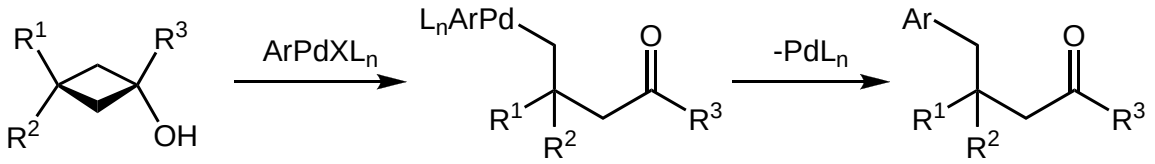
Masahiro Murakami
Kyoto University

Nicolai Cramer
EPFL Lausanne

Guangbin Dong
University of Texas at Austin

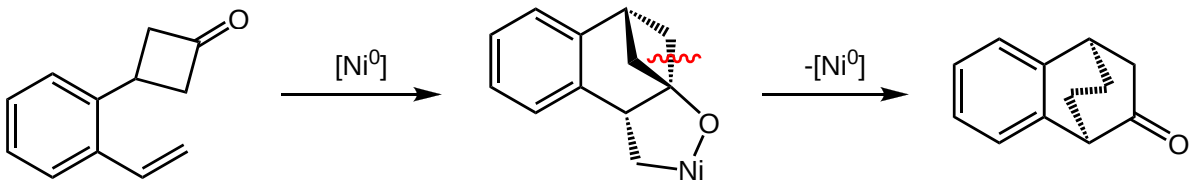
5. Summary

◆ Pd-Catalyzed Asymmetric C-C Bond Cleavage



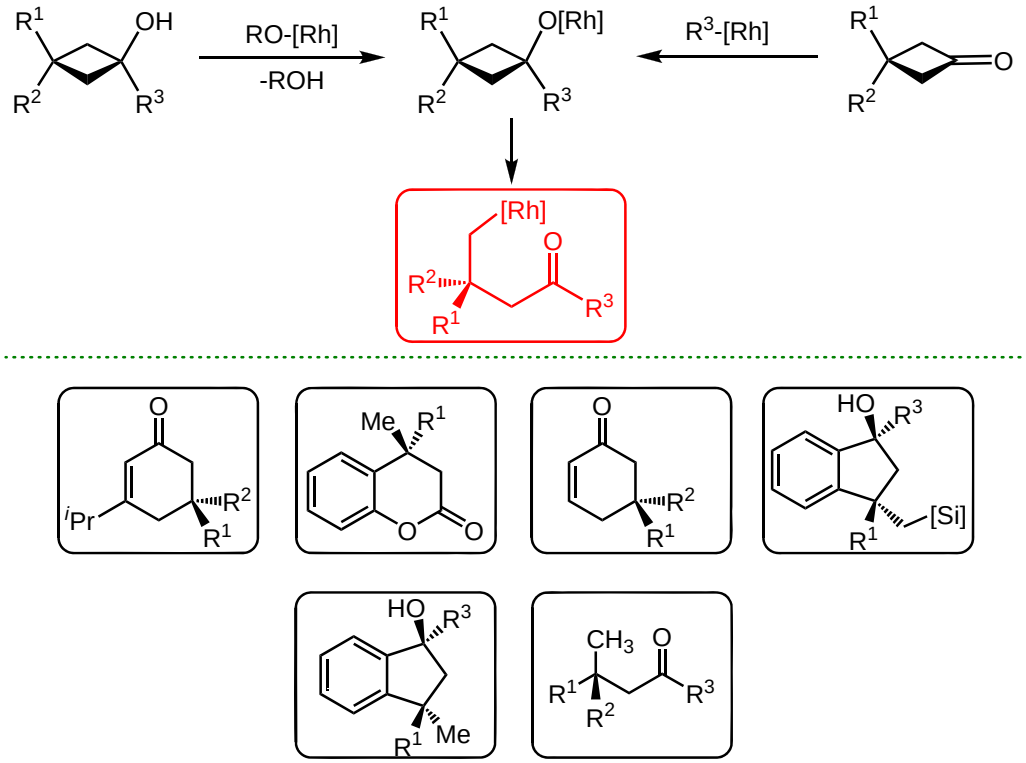
Enantioselective β-Carbon Elimination

◆ Ni-Catalyzed Asymmetric C-C Bond Cleavage



Asymmetric Oxidative Cyclization
Diastereoselective β-Carbon Elimination

◆ Rh-Catalyzed Asymmetric C-C Bond Cleavage



Intramolecular cyclization to an activated allene
β-Hydride elimination
Intramolecular cyclization to terminal enones
1,4-Rh/Si shifts by C(sp^2)-Si activation
1,4-Rh/H shifts by C(sp^2)-H activation
1,3-Rh/H shifts by C(sp^3)-H activation α to ketone

The selective functionalization of carbon-carbon (C-C) σ bonds by transition-metal catalysts is a prime challenge for organometallic chemistry and represents a complementary synthetic strategy that enables uncommon retrosynthetic disconnections. Important progress has been made over the past decade in the field of C-C activation. However, despite their recognized importance, the development of asymmetric reactions lags behind. For instance, most enantioselective variants have been reported for the β-carbon elimination mechanism that allows C-C bond cleavages adjacent to tertiary alcohols. For reactions involving C-C cleavage through oxidative addition at transition metals, strained ketones have proven highly versatile.

In summary, we report an asymmetric rhodium(I)-catalyzed C-C activation of cyclobutanones that gives efficient access to the valuable bicycloheptanone scaffold with exceptionally high enantioselectivity. This demonstrates the feasibility of selective oxidative additions of enantiotopic C-C bonds at high reaction temperatures. The method shown allows rapid access to complex cyclic structure and serves as a blueprint for the design of further asymmetric C-C bond activations.

谢谢大家，请多批评指正！