五、一些形成C–C键的基本反应
（三）自由基参与的反应

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自由基参与的C-C键形成反应：基本过程

引发

$$In\bullet + R'_3SnH \rightarrow R'_3Sn\bullet + In{-}H$$

增长

$$R{-}X + R'_3Sn\bullet \rightarrow R\bullet + R'_3Sn{-}X$$

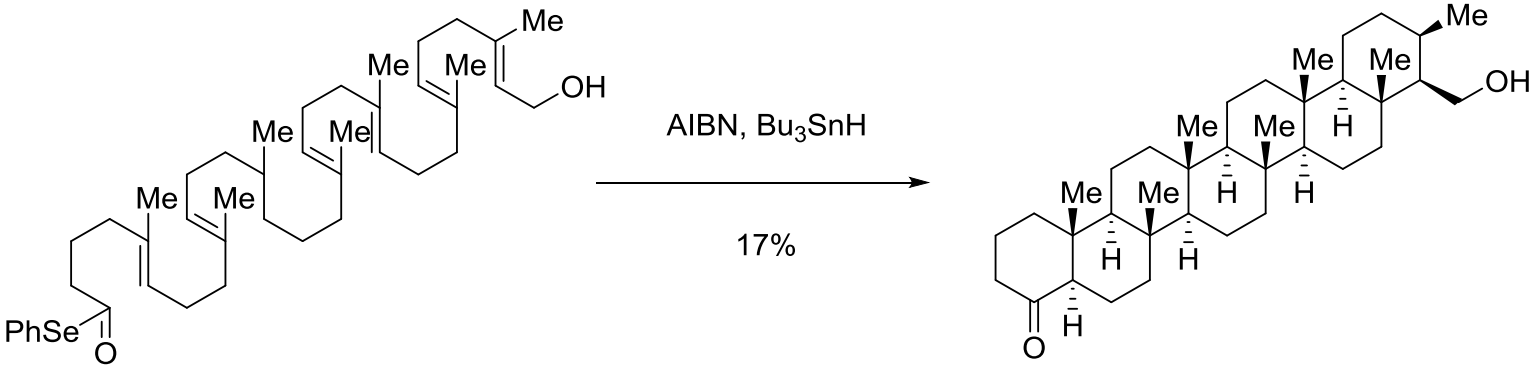
$$R\bullet + Y{=}Z \rightarrow R{-}Y{-}Z\bullet$$

$$R{-}Y{-}Z\bullet + R'_3SnH \rightarrow R{-}Y{-}Z{-}H + R'_3Sn\bullet$$

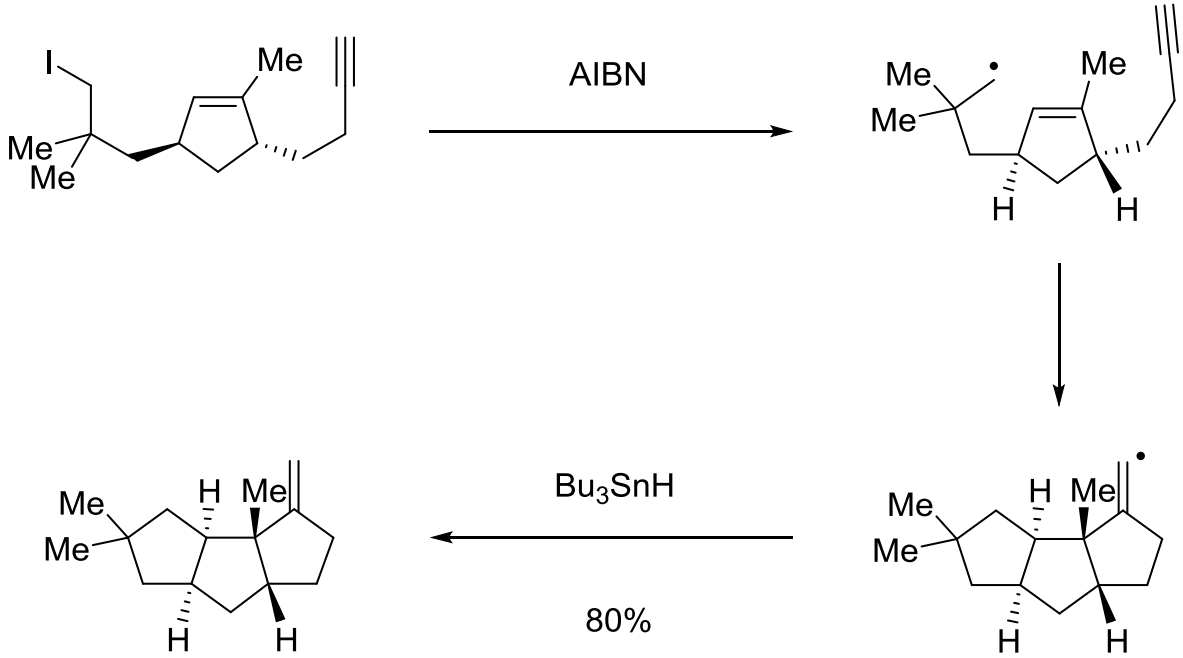
自由基参与的C–C键形成反应：优点

- Neutral reaction conditions
- Compatibility with radical acceptors containing functional groups – carbonyls, enol ethers, and enamines
- Compatibility with Lewis acids
- No necessity for protection of alcohol and amine functional groups
- Compatibility with protic solvents – potential for reaction in aqueous systems
- Ease of quaternary center formation

自由基的优点：两个经典实例

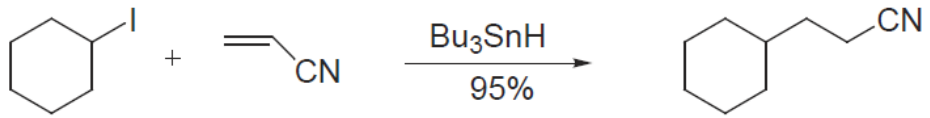


G. Pattenden, et al. *J. Chem. Soc., Perkin Trans. 1*, **1999**, 843.



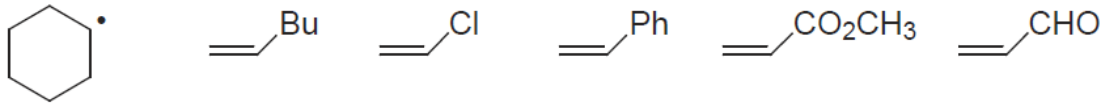
D. P. Curran, et al. *J. Am. Chem. Soc.* **1985**, *107*, 1448.

自由基参与的C–C键形成反应：电子效应

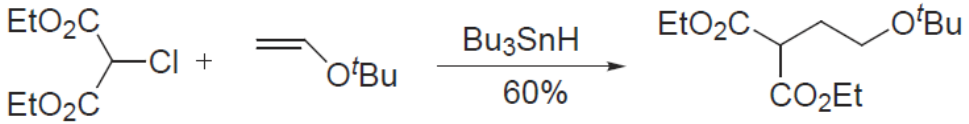


Nucleophilic radical

Electrophilic acceptor alkene

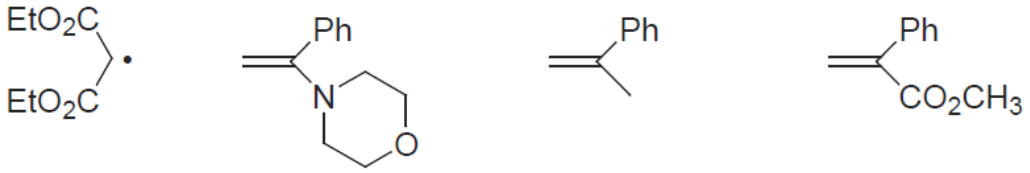


k_{rel}	1.0	8.4	84	3000	8500



Electrophilic radical

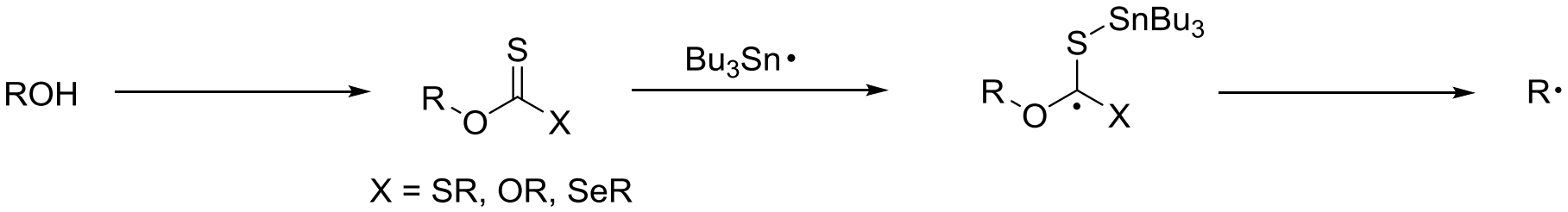
Nucleophilic acceptor alkene



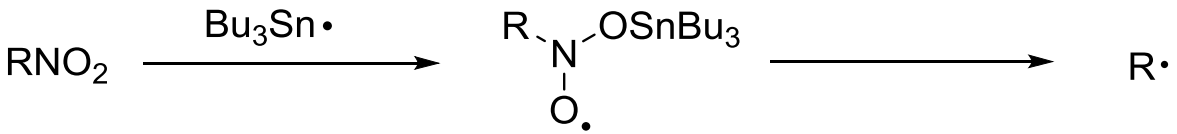
k_{rel}	23	3.5	1

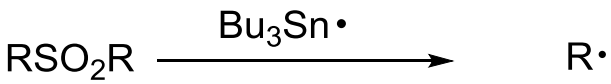
自由基参与的C–C键形成反应：引发官能团

Initiator Groups



X = SR, OR, SeR

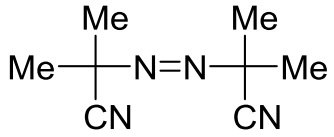




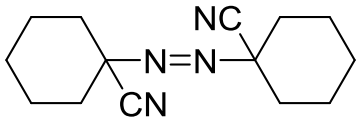
自由基参与的C–C键形成反应：引发剂、氢化物

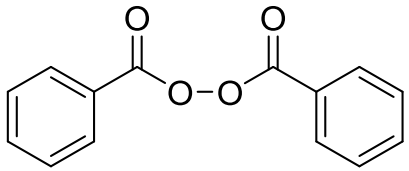
引发剂

AIBN:



ACCN:



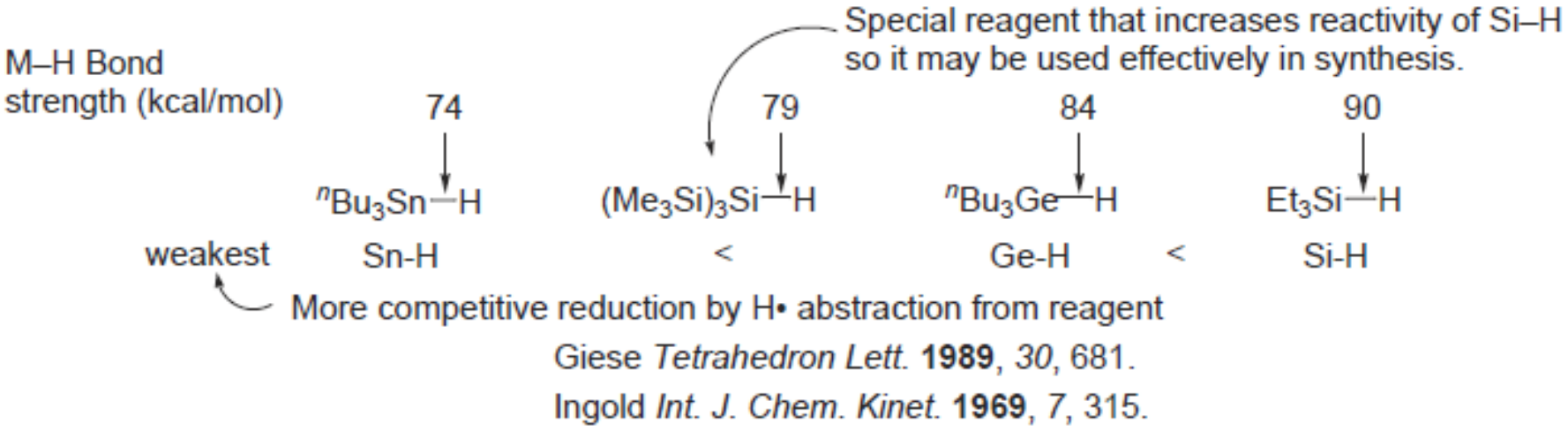


Et_3B/O_2, Et_2Zn/O_2, Me_3Al/O_2

hv

氢化物

Ru/Ir complex or organic dye, visible light

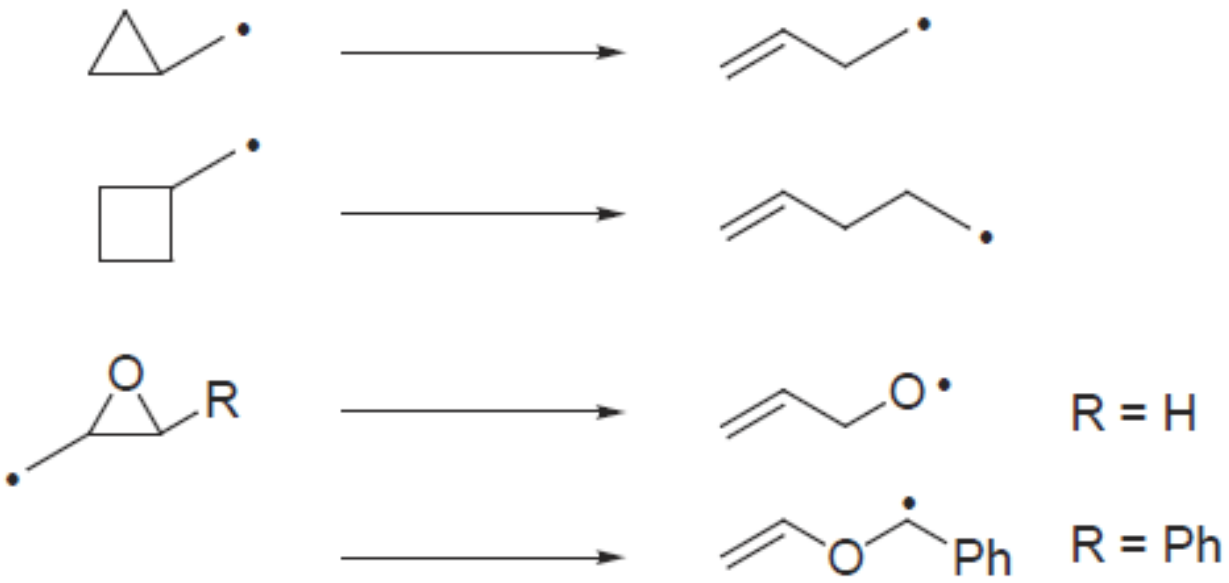


Giese *Tetrahedron Lett.* **1989**, *30*, 681.

Ingold *Int. J. Chem. Kinet.* **1969**, *7*, 315.

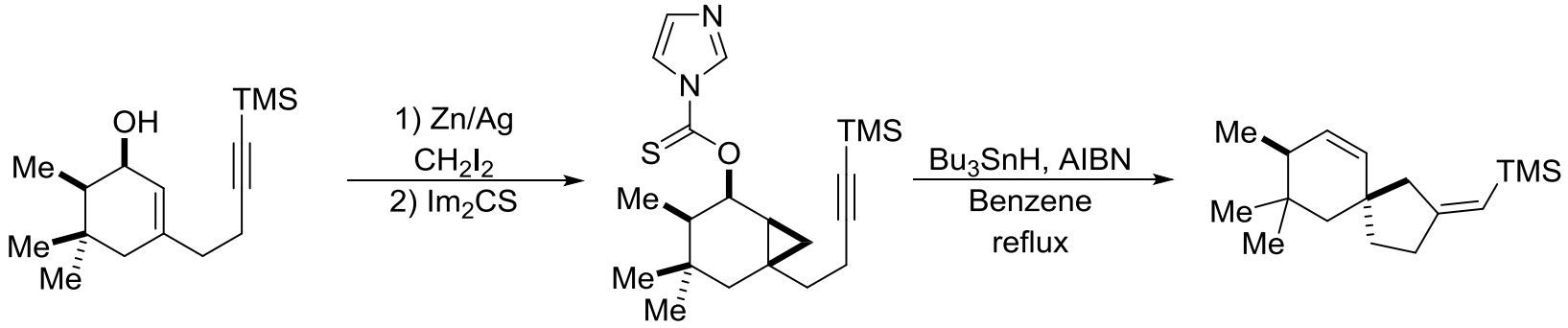
自由基引发的断裂反应

Rearrangements are possible

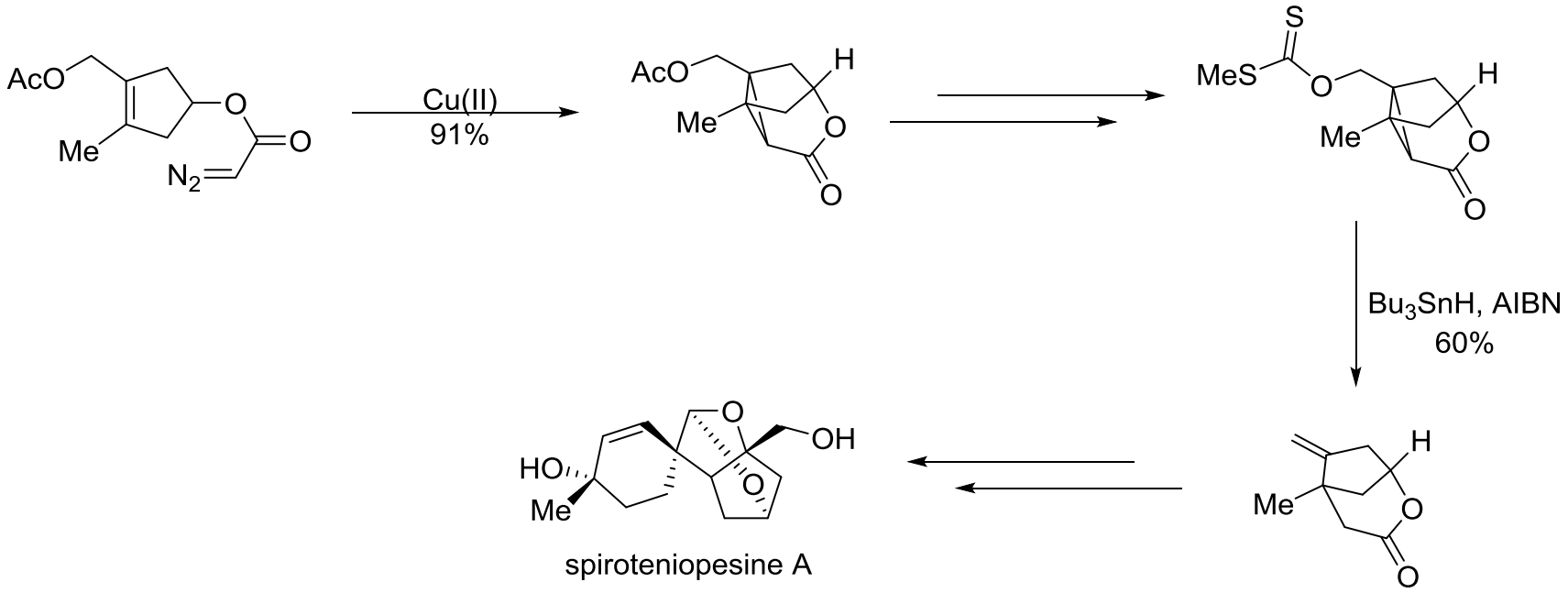


可用于检验反应中是否涉及自由基中间体

自由基引发的断裂反应的应用

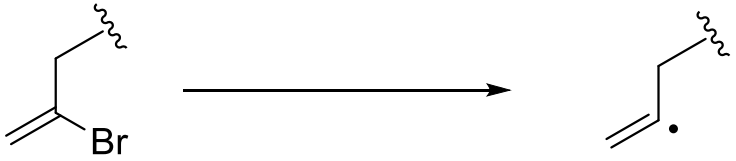


R. A. Batey, J. D. Harling, W. B. Motherwell, *Tetrahedron* **1992**, *48*, 8031.

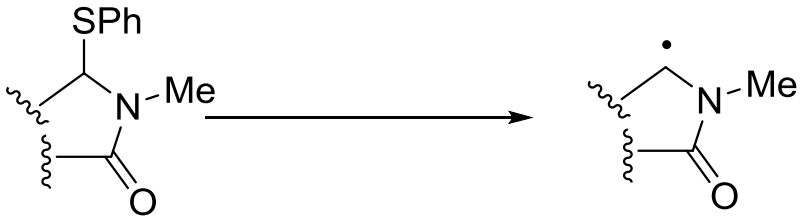


M. J. Dai, S. J. Danishefsky, *J. Am. Chem. Soc.* **2007**, *129*, 3498.

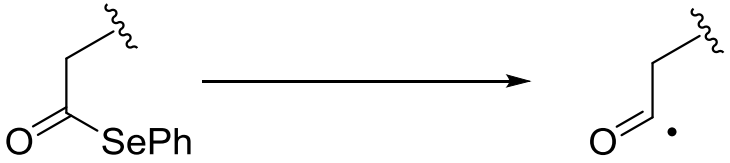
官能化的自由基



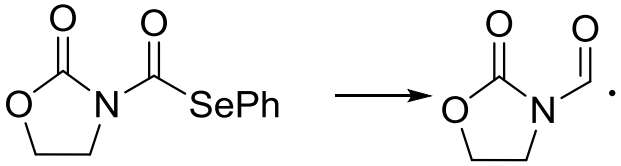
Stork, vinyl radicals



Hart. *J. Am. Chem. Soc*. **1997,** *117*, 6226

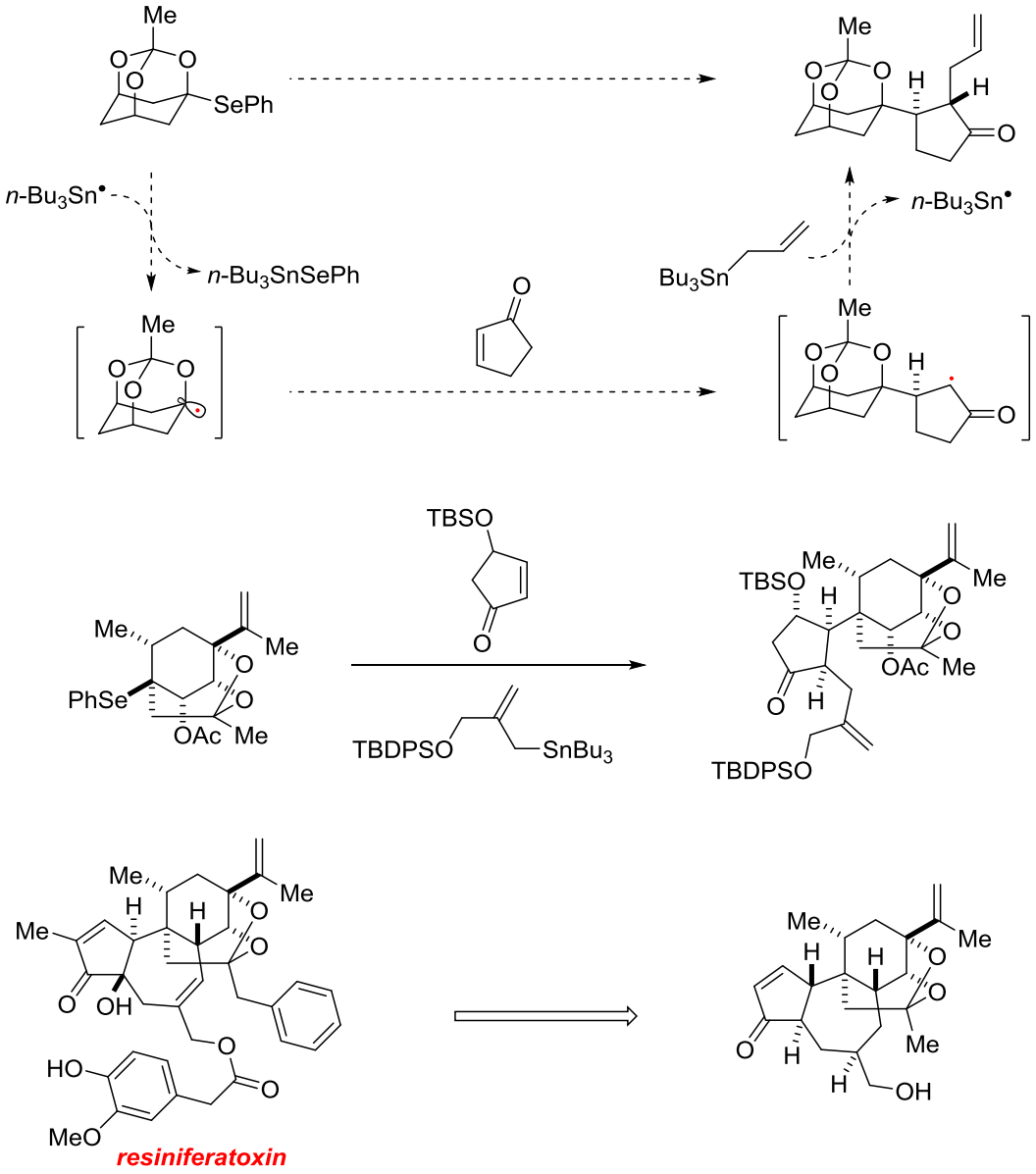


Chem Rev, **1999,***99*, 1991.



Keck, *Synlett,* **1999,** 1657

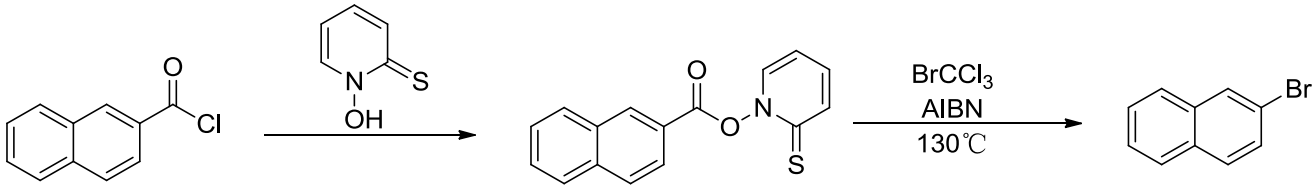
官能化的自由基



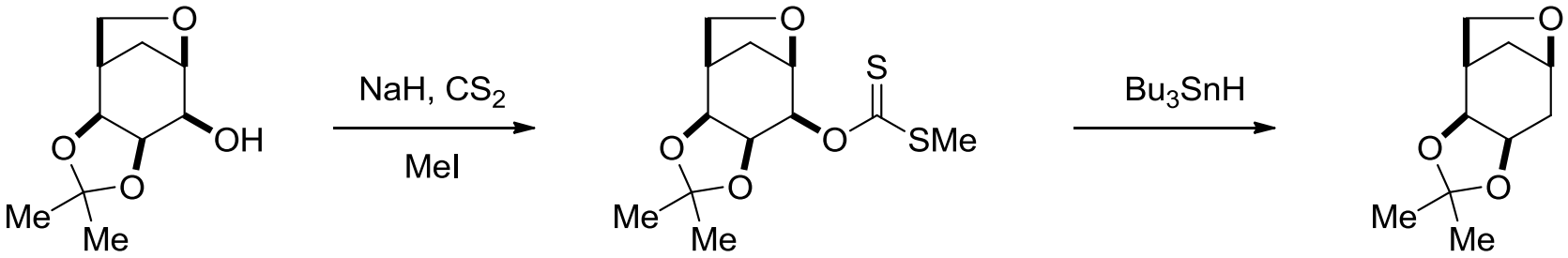
M. Inoue et al. *Chem. Sci.* **2013**, *4*, 2364.

几个重要的自由基人名反应

Barton Decarboxylation

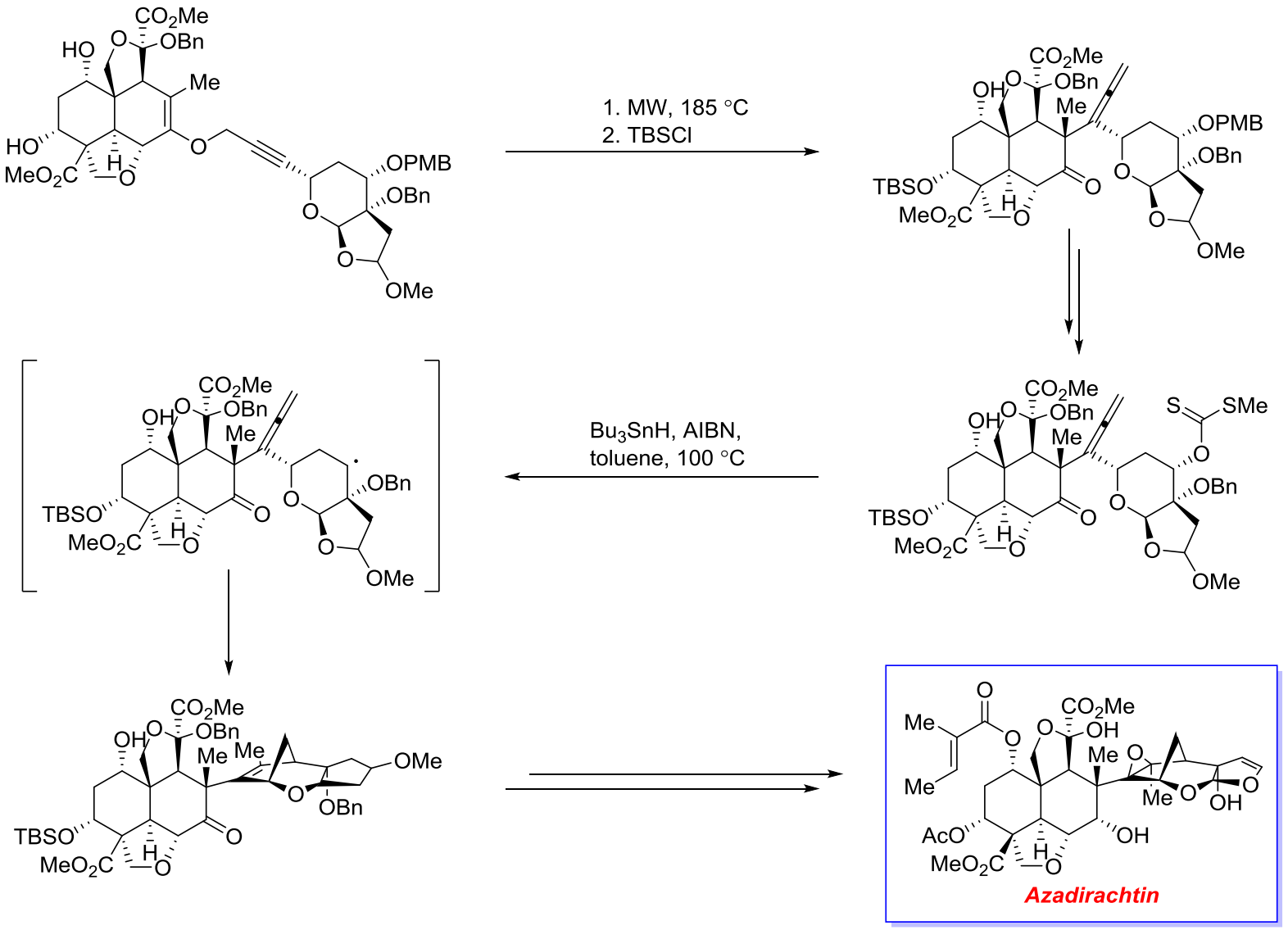


Barton−McCombie Deoxygenation



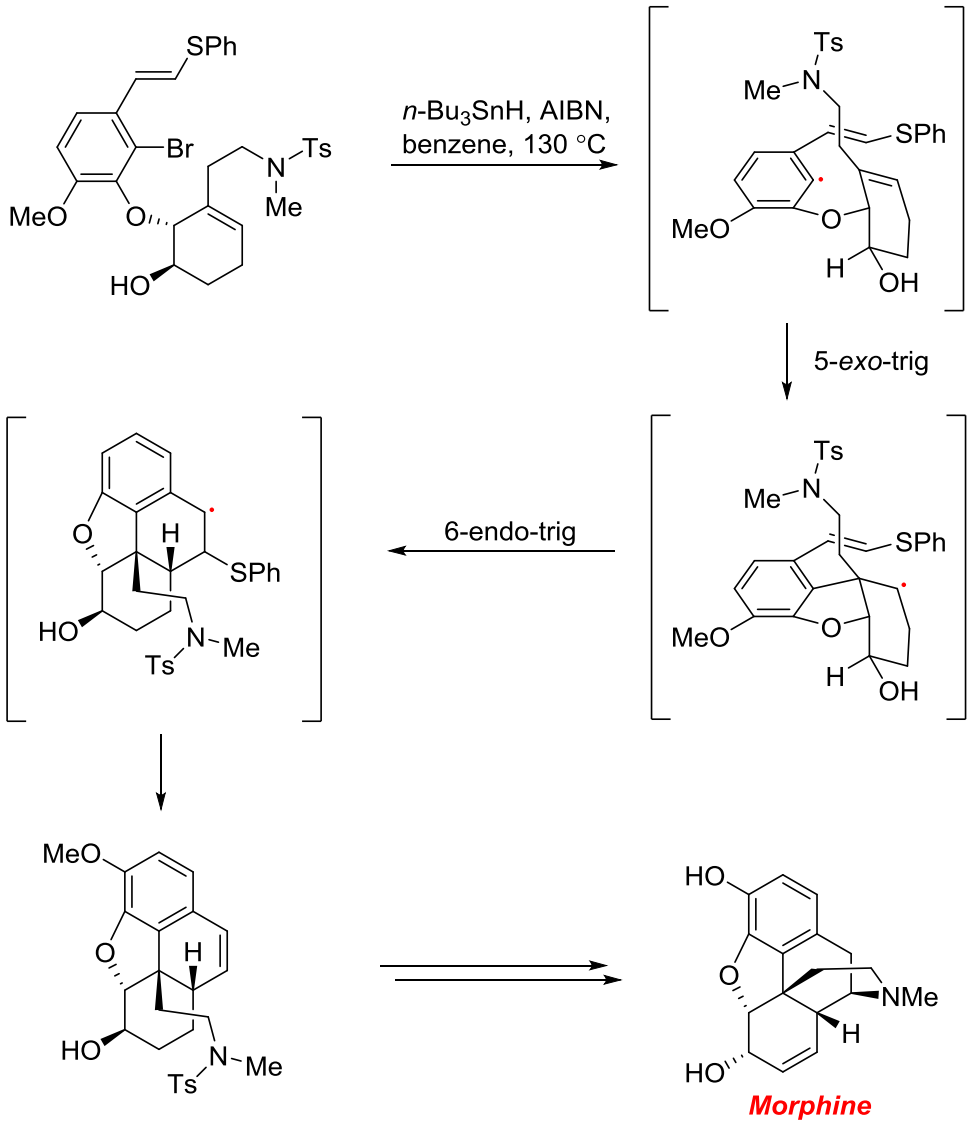
Barton, Mccombie *J. Chem. Soc*, Perkin1 **1975**,1574.

自由基参与的C–C键形成反应：实例1 桥环的构建



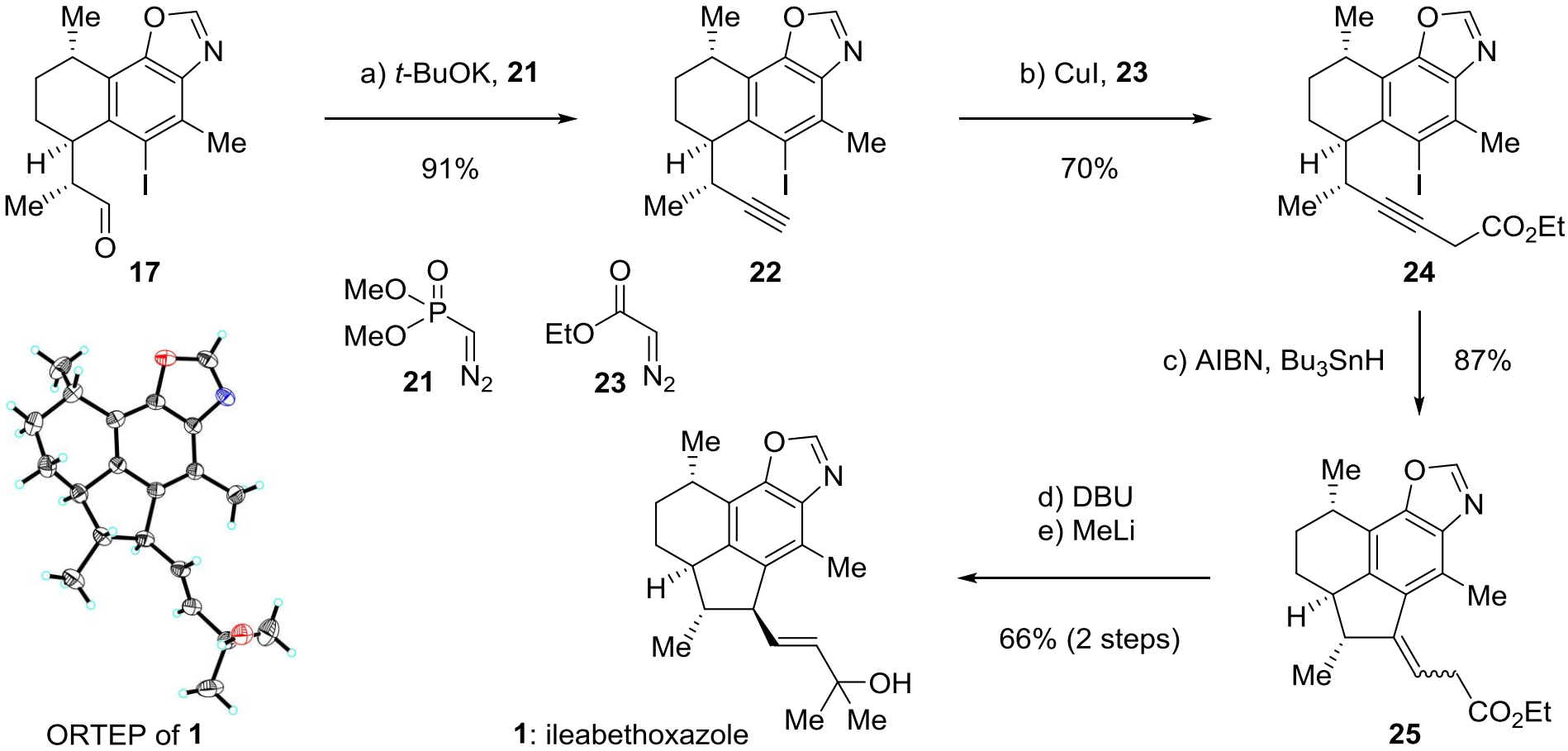
S. V. Ley, et al. *Angew. Chem. Int. Ed.* **2007**, *46*, 7629.

自由基参与的C–C键形成反应：实例4 季碳构建/串联反应



K. A. Parker, et al. *J. Am. Chem. Soc.* **1992**, *114*, 9688.

自由基参与的C–C键形成反应：实例5 自由基和其他反应的互补性

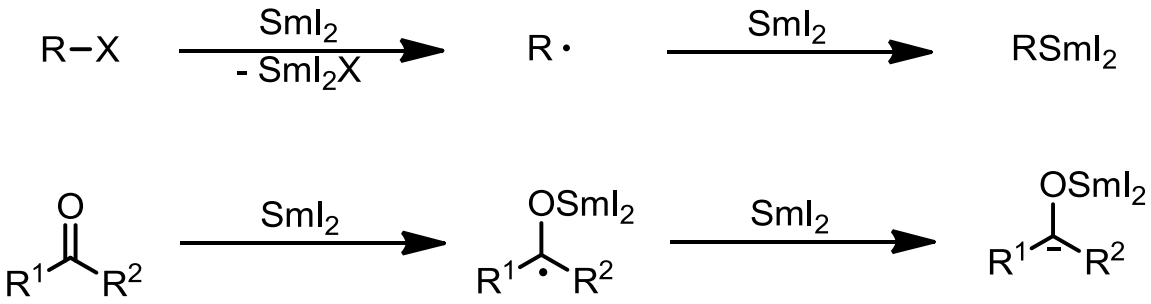


M. Yang, X. Yang, H. Sun, A. Li, *Angew. Chem. Int. Ed.* **2016**, *55*, 2851.

SmI_2的基本性质

制备：Sm/I_2, Sm/ICH_2CH_2I
性质：reduction potential up to 2.05 V in the presence of HMPA
Aldrich：0.1 M/100 mL, 625.95 RMB

a) SmI_2-mediated activation of alkyl hlides

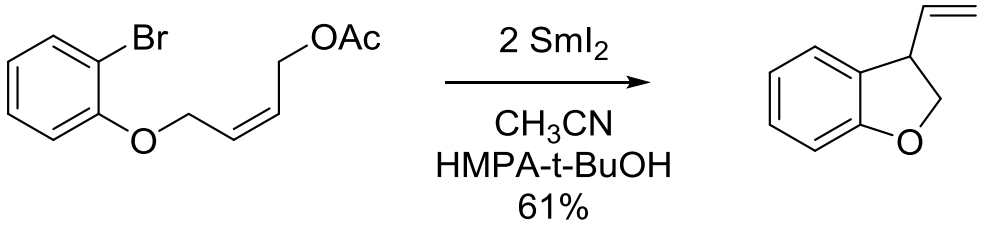


- Barbier reaction
- Ketyl-olefin coupling reaction
- Pinacol type coupling reaction
- Reduction

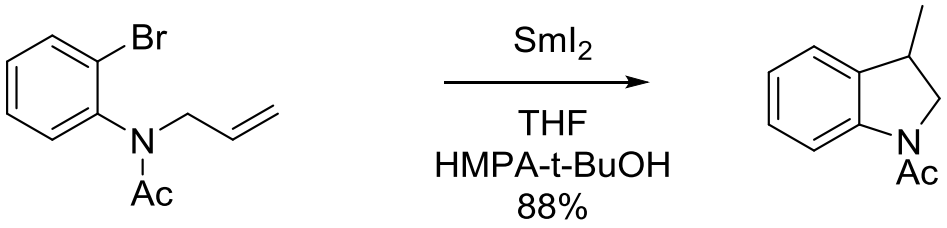
P. Girard, J. L. Namy and H. B. Kagan “Divalent Lanthanide Derivatives in Organic Synthesis. 1. Mild Preparation of SmI_2 and YbI_2 and Their Use as Reducing or Coupling Agents”. *J. Am. Chem. Soc.* **1980**, *102* , 8, 2693.

K. C. Nicolaou, S. P. Ellery, J. S. Chen. “Samarium Diiodide Mediated Reactions in Total Synthesis”. *Angew. Chem. Int. Ed.* 2009, **48**, 7140.

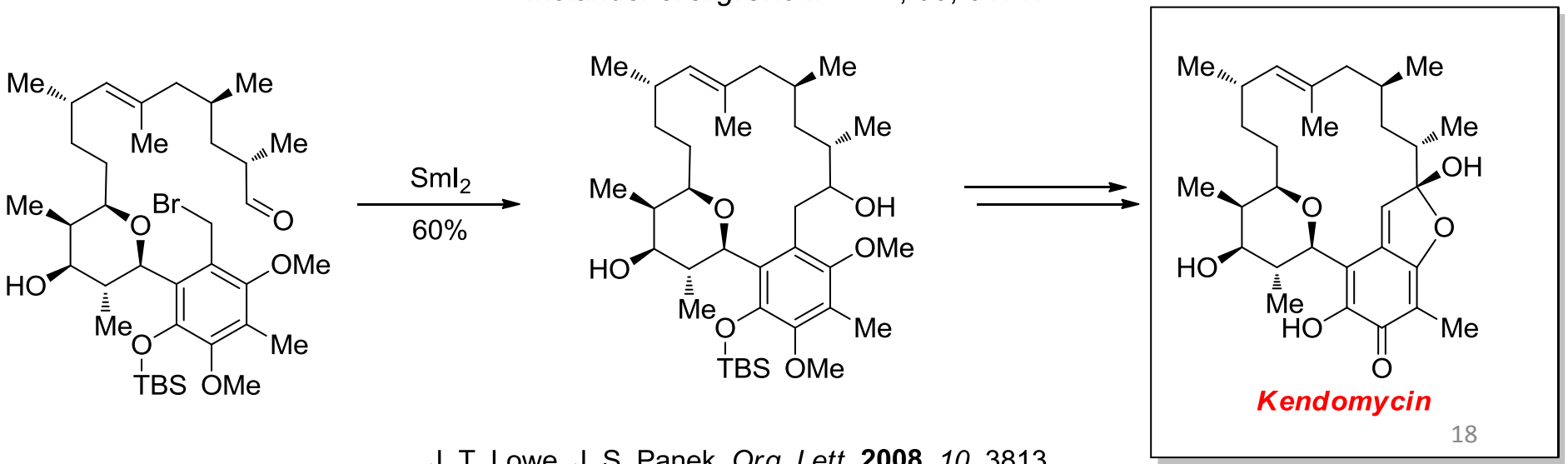
SmI_2参与的C−C键形成反应：实例 Barbier reaction



Inanaga *Tetrahedron Lett.* **1991**,*32,*1737.

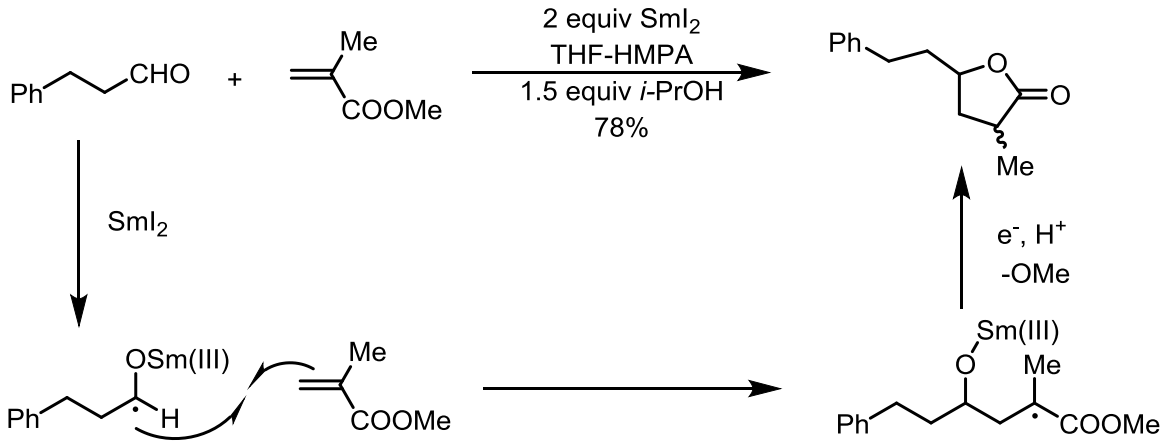


Molander *J.Org.Chem*.**1990**, *55*, 6171.

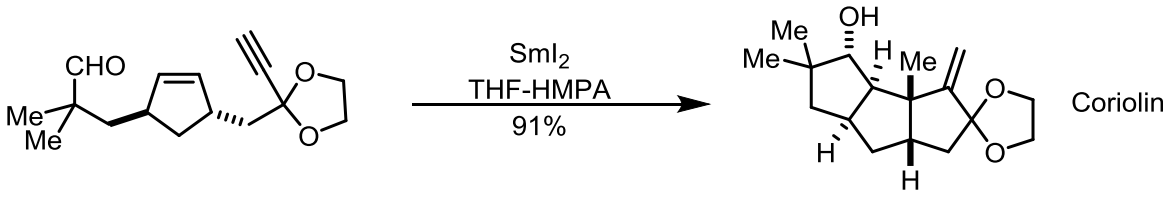


J. T. Lowe, J. S. Panek, *Org. Lett*. **2008**, *10*, 3813.

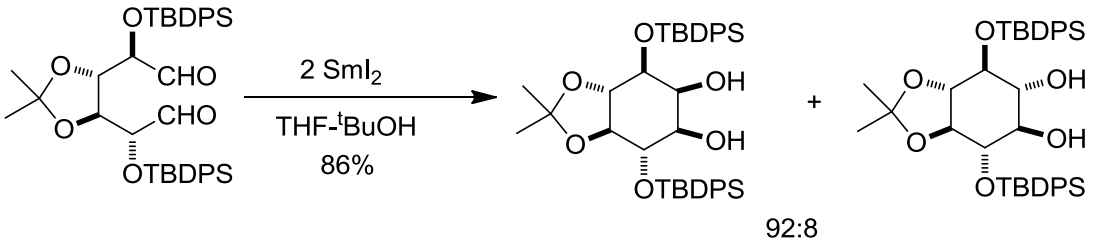
SmI_2参与的C–C键形成反应：羰基-烯烃和pinacol类型偶联



Inanaga, *Tetrahedron Lett*. **1986**, 27, 5763

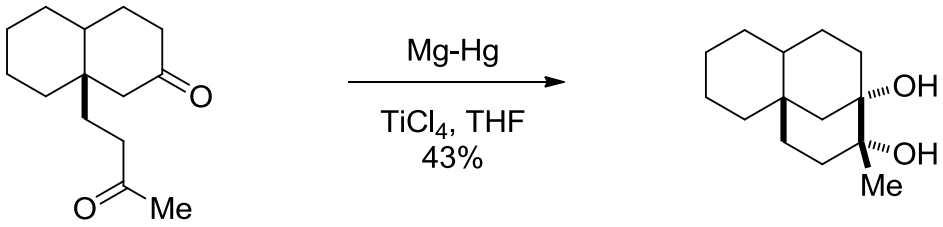


Curran, *J. Am. Chem. Soc*. **1988**, *110*, 5064.

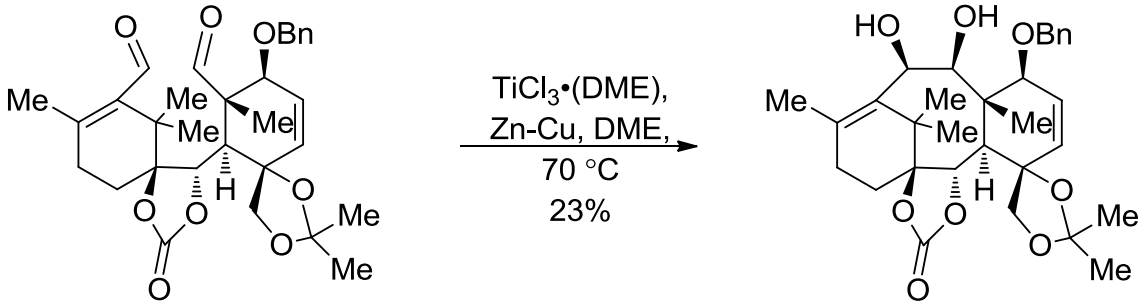


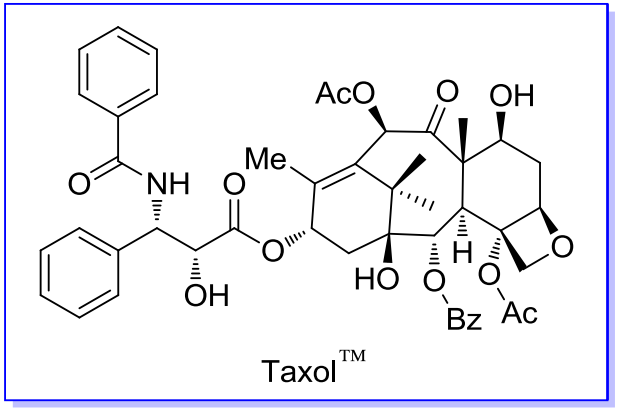
Chiara *Tetrahedron Lett*. **1994**, *35*, 2969.

Ti(III)参与的C–C键形成反应：McMurry反应



McMurry *J Org Chem*. **1977**, *42*, 2655.





K. C. Nicolaou, Z. Yang, et al. *Nature* **1994**, *367*, 630.