Catalytic Enantioselective Allyl−Allyl Cross-Coupling

Reporter: Xian-Feng Cai

Checker: Zhi-Shi Ye

Date: 2013/3/5

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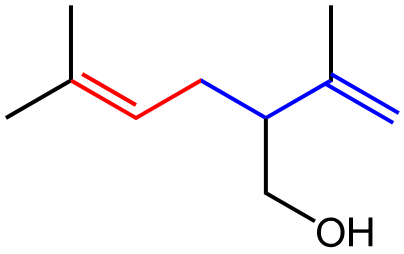
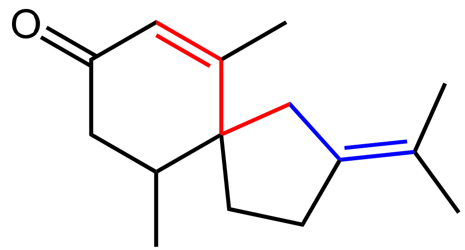
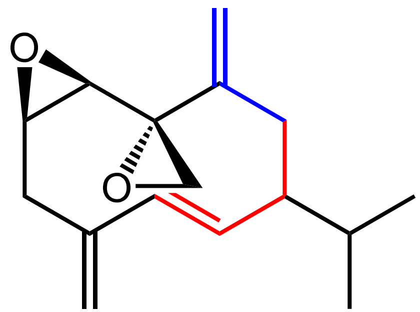
1. 简介



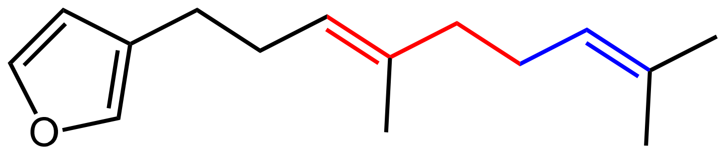
Lavandulol



β-Vetivone

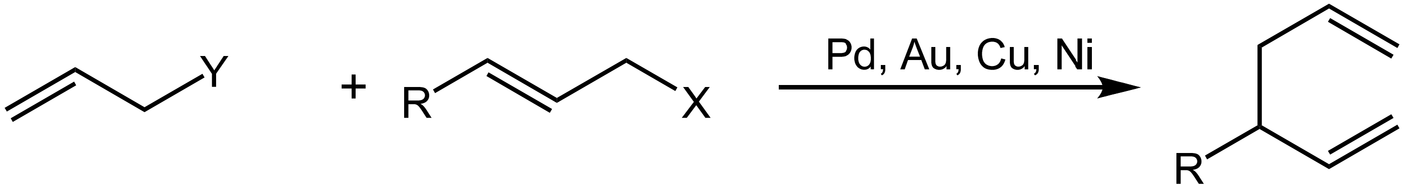


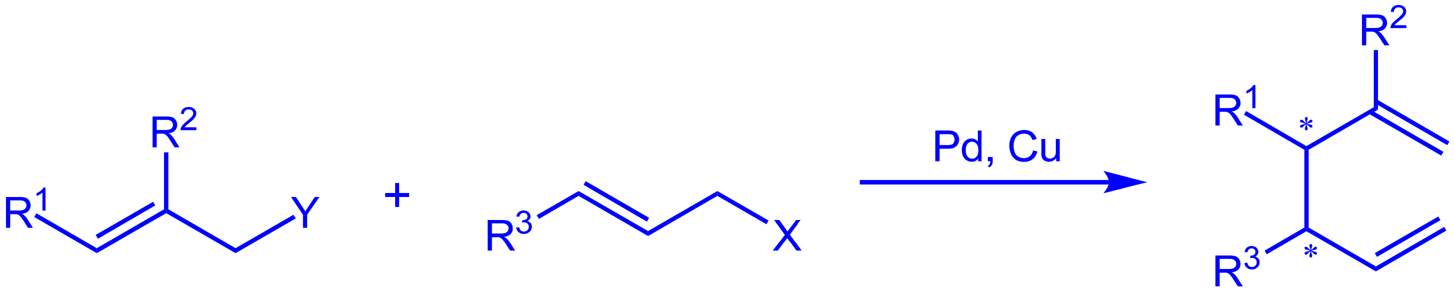
Periplanone



Dendrolasin

Catalytic Allyl−Allyl Cross-Coupling

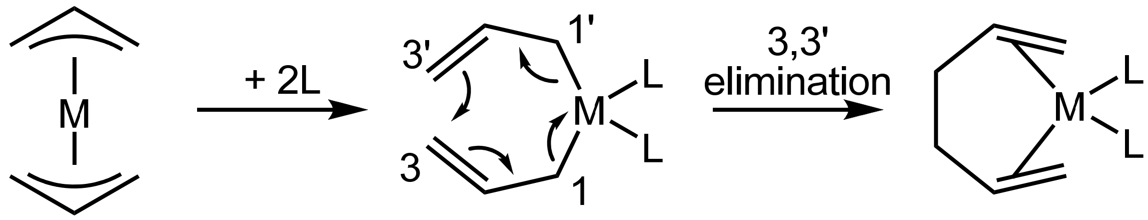




allylmetal species
Y = MgBr, B(pin) *etc.*

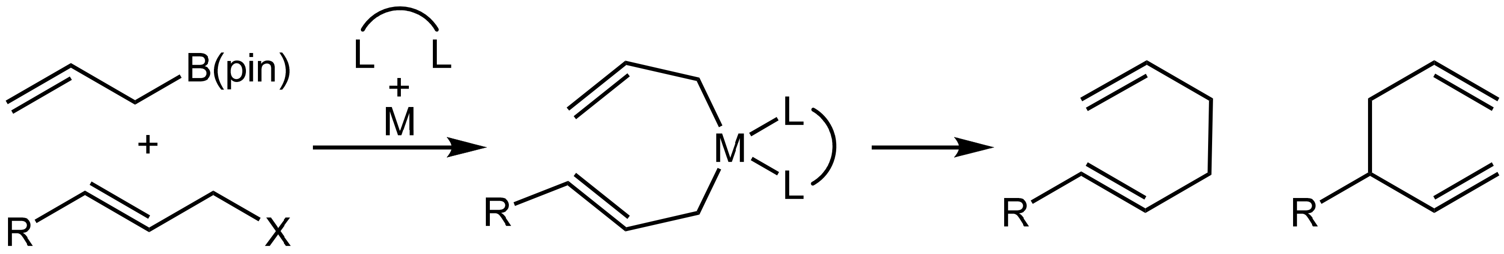
allylic electrophiles
X = Br, Cl, OBoc *etc.*

2. 钯催化的不对称烯丙基-烯丙基偶联反应



A
η^3 bonding mode

B
η^1 bonding mode

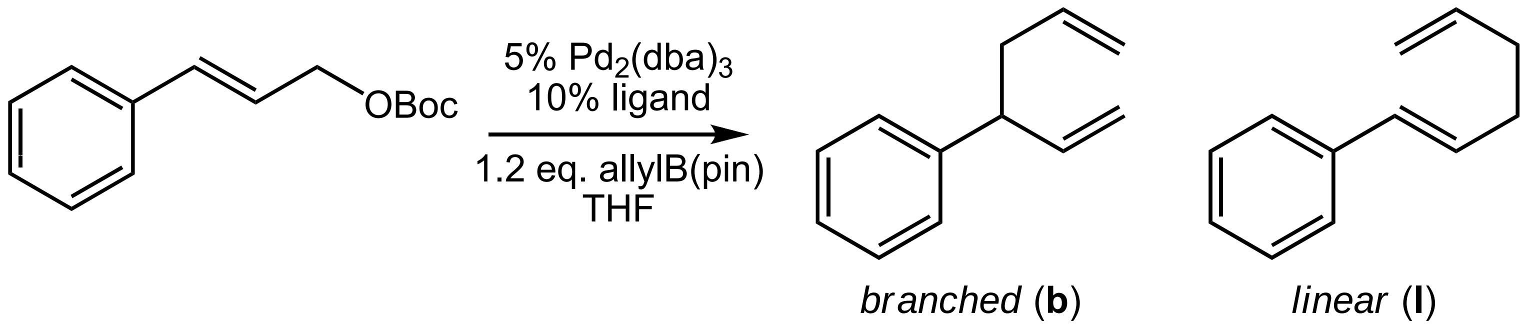


C

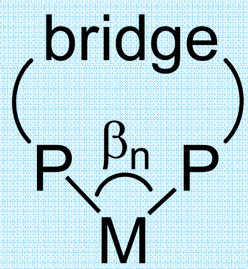
1,1' product

3,3' product

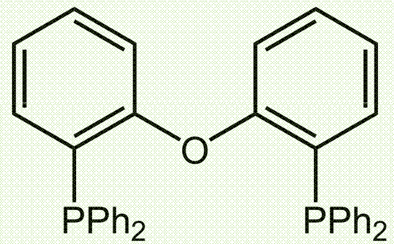
Echavarren, A. M. et al *Chem.-Eur. J.* **2002**, *8*, 3620
Morken, J. P. et al *J. Am. Chem. Soc.* **2010**, *132*, 10686



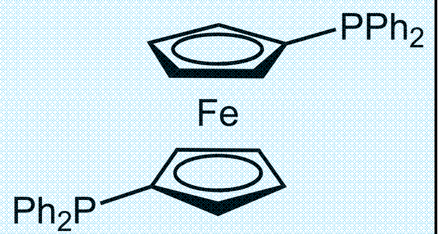
entry	ligand	bite angle	yield (%)	b/l
1	PPh_3	--	96	1:>20
2	dpp-benzene	83	70	97:3
3	dppe	85	77	98:2
4	dppp	91	80	97:3
5	dppf	96	43	94:6
6	dppb	98	77	38:62
7	DPEphos	102	58	72:28



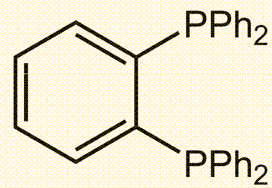
Bite angle :
The ligand-metal-ligand angle of bidentate ligands



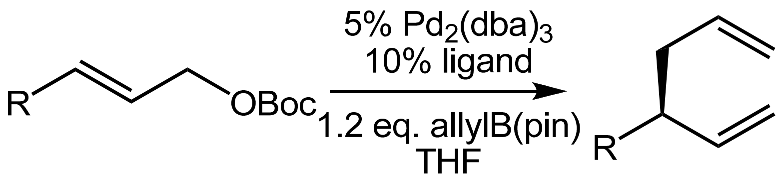
DPEphos

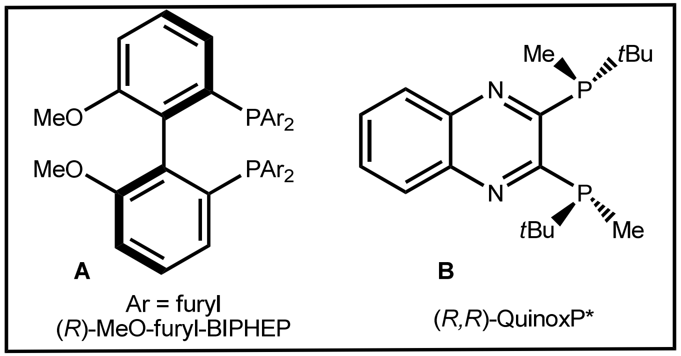


dppf

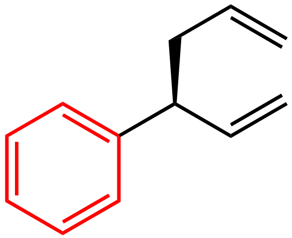


dpp-benzene

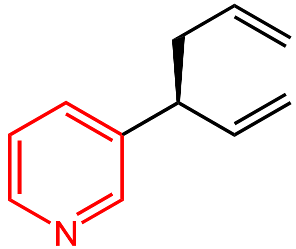




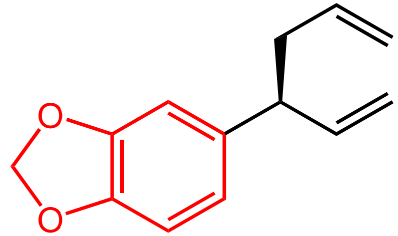
ligand **A**:



yield : 72%
b/l : >20:1
ee : 91%

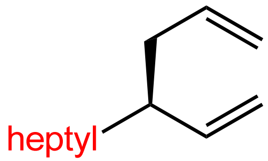


yield : 52%
b/l : >20:1
ee : 90%

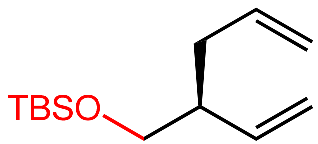


yield : 83%
b/l : >20:1
ee : 91%

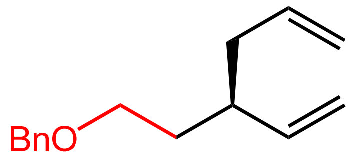
ligand **B**:



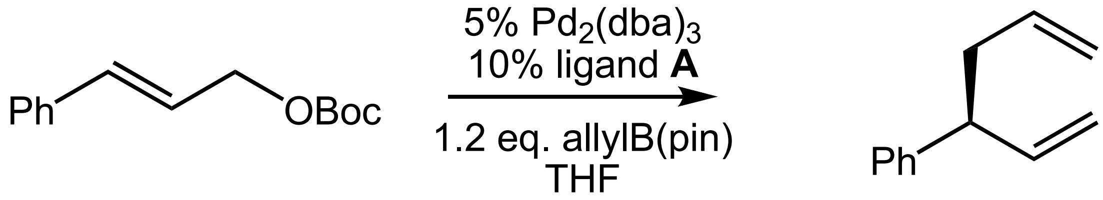
yield : 80%
b/l : 11:1
ee : 84%



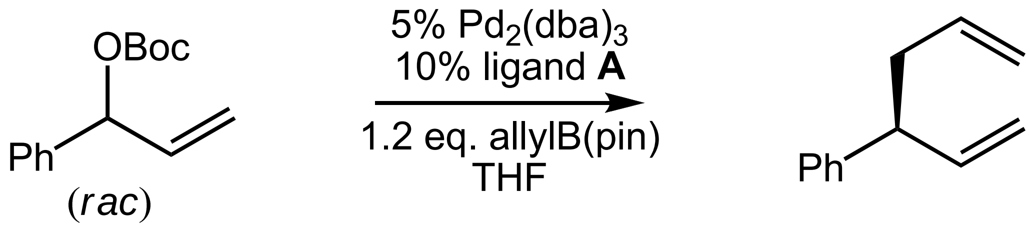
yield : 91%
b/l : >20:1
ee : 90%



yield : 75%
b/l : >20:1
ee : 85%

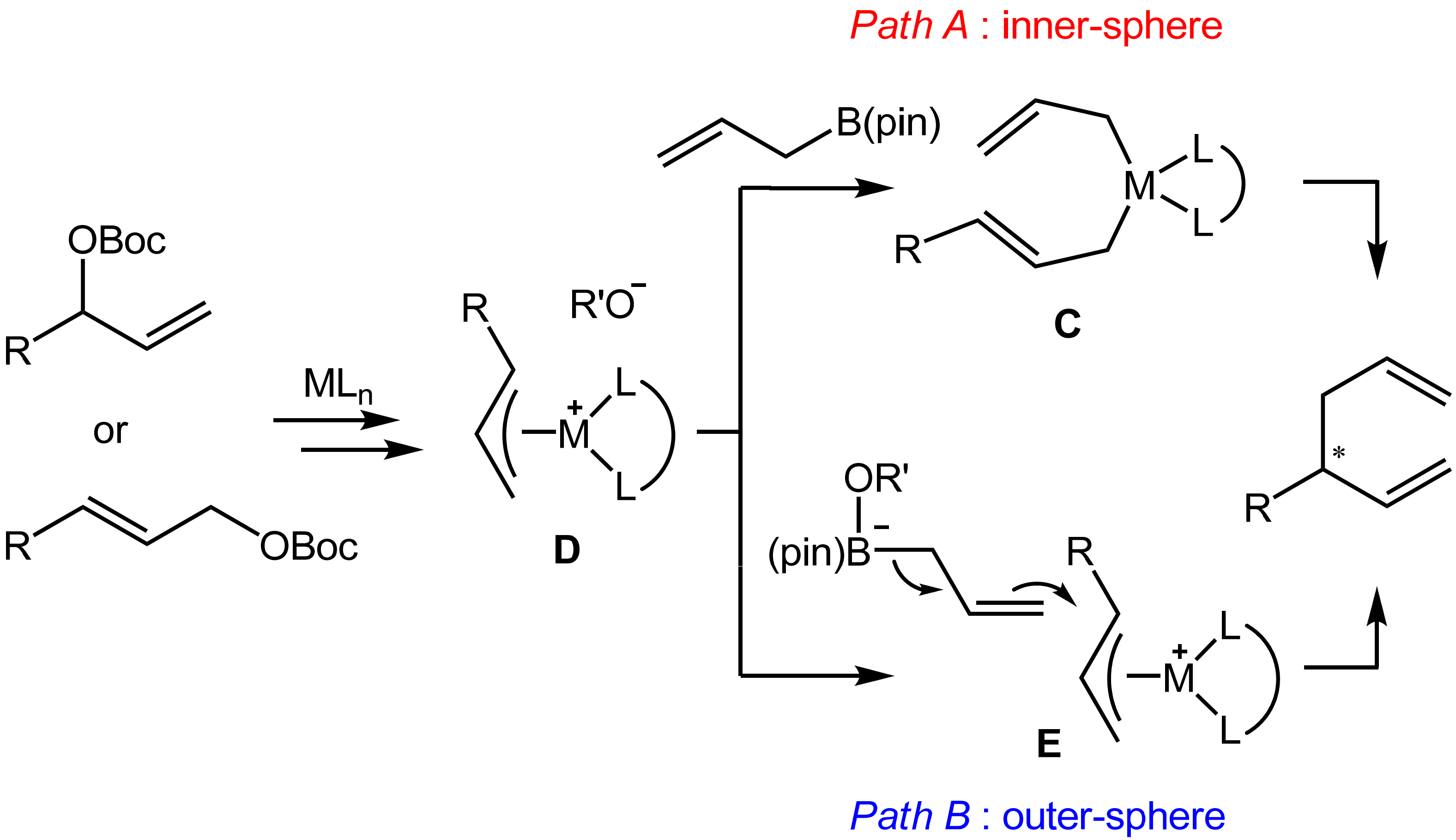


yield : 72%
dr : >20:1
ee : 91%

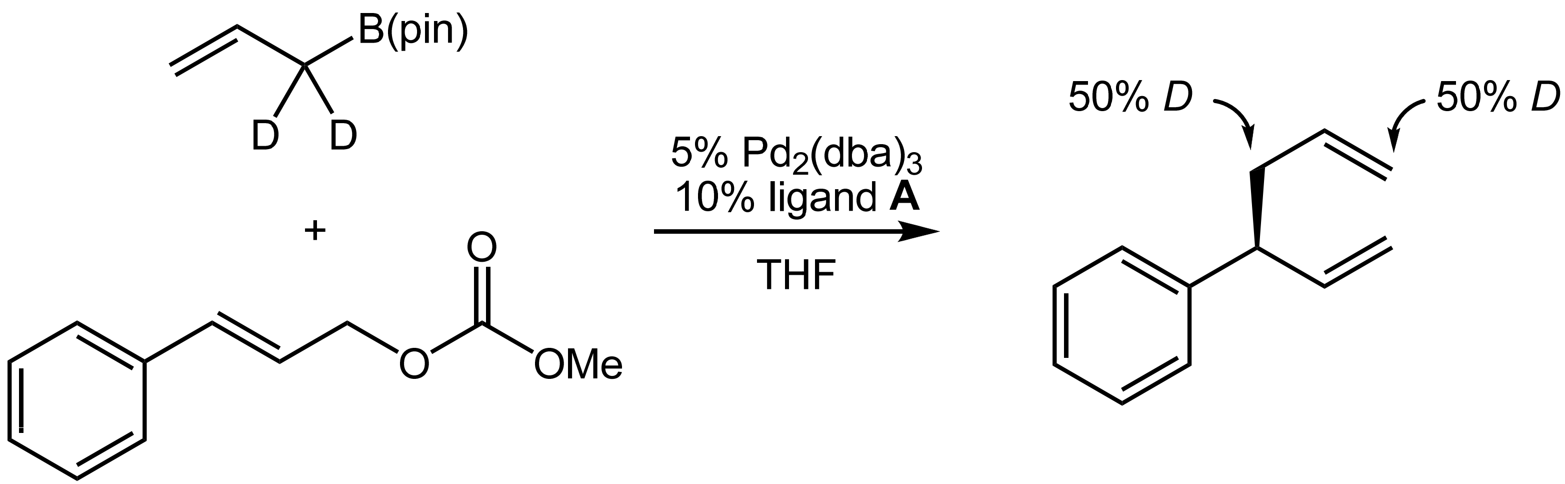


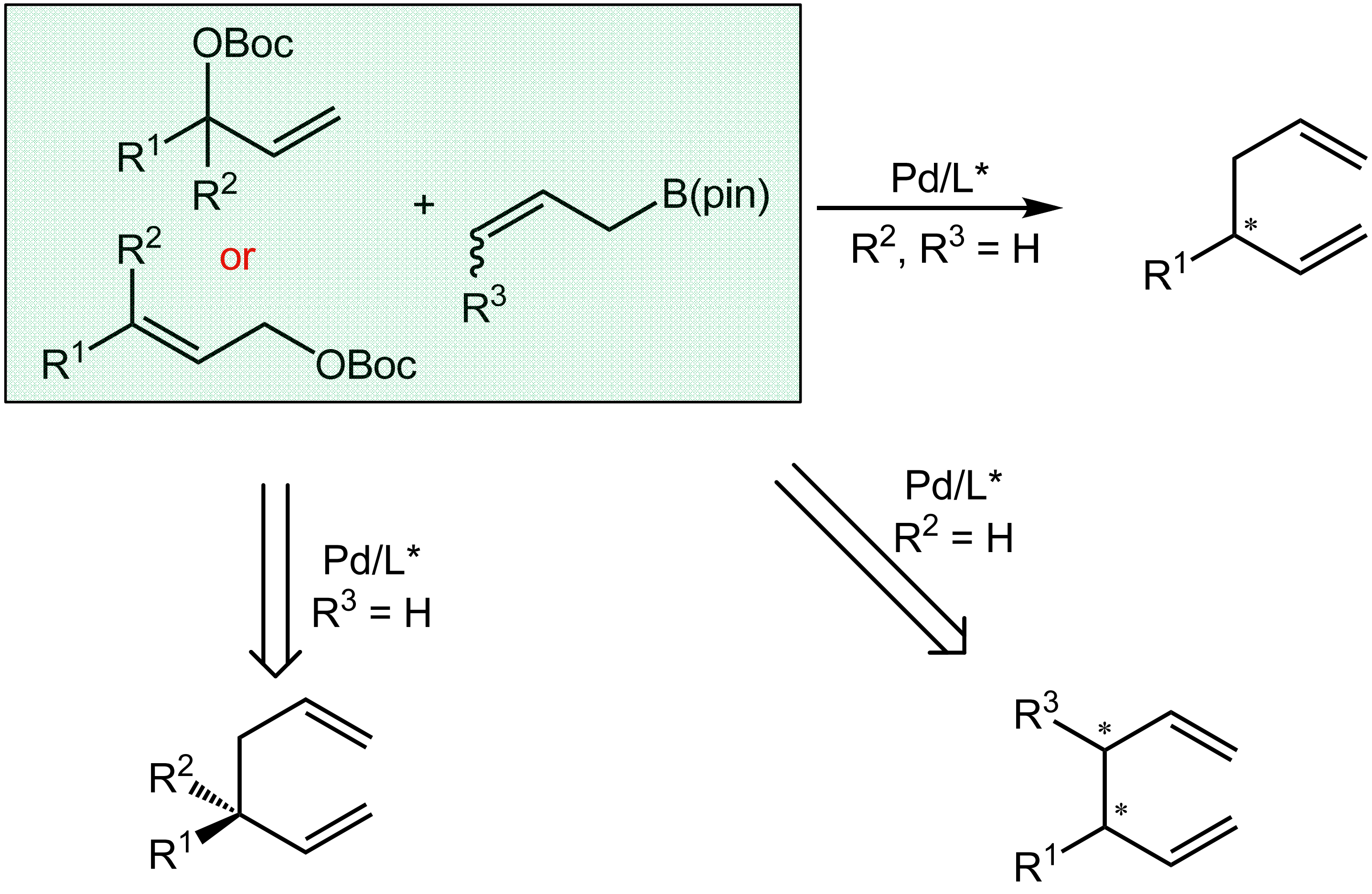
yield : 75%
dr : >20:1
ee : 91%

Plausible Mechanism



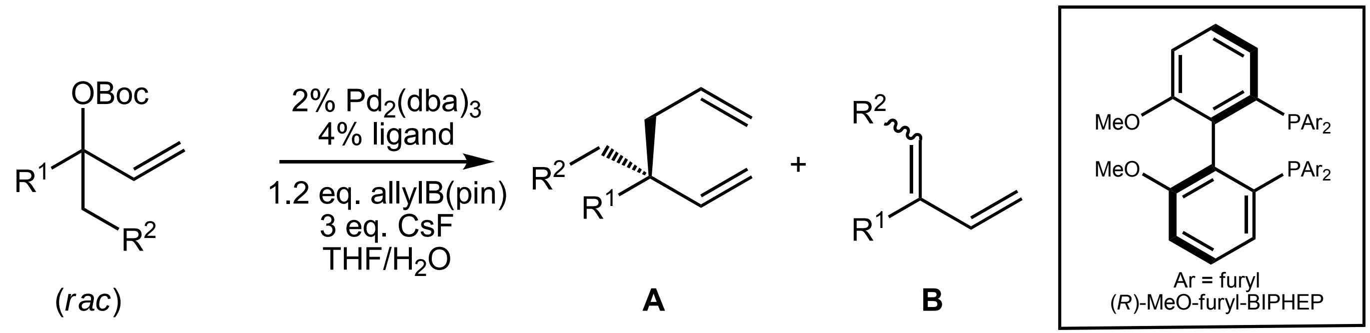
Isotopic Labeling Experiment

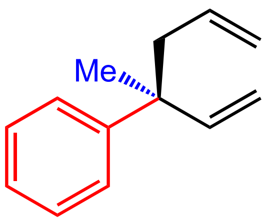




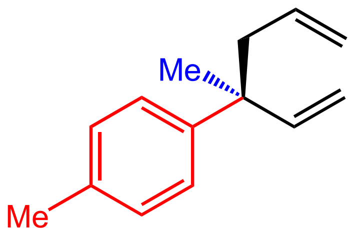
J. Am. Chem. Soc. **2011**, *133*, 9716

J. Am. Chem. Soc. **2011**, *133*, 16778

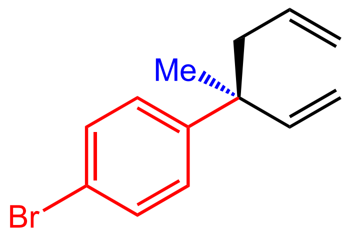




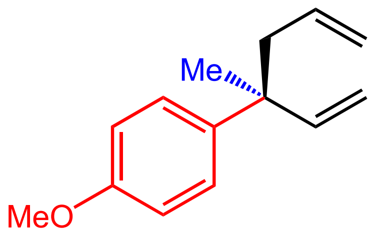
(**A**+**B**) yield : 90%
A/**B** : >20:1
er of **A** : 96:4



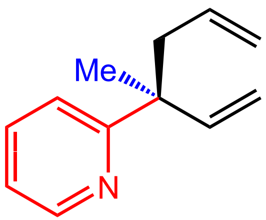
(**A**+**B**) yield : 76%
A/**B** : 17:1
er of **A** : 96:4



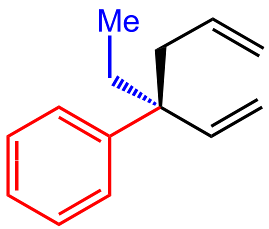
(**A**+**B**) yield : 90%
A/**B** : 20:1
er of **A** : 94:6



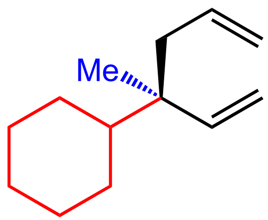
(**A**+**B**) yield : 83%
A/**B** : 12:1
er of **A** : 95:5



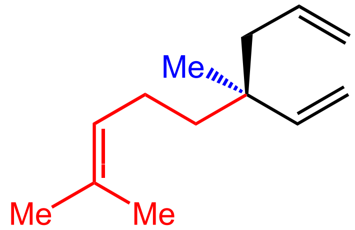
(**A**+**B**) yield : 81%
A/**B** : >20:1
er of **A** : 95:5



(**A**+**B**) yield : 97%
A/**B** : 6:1
er of **A** : 96:4

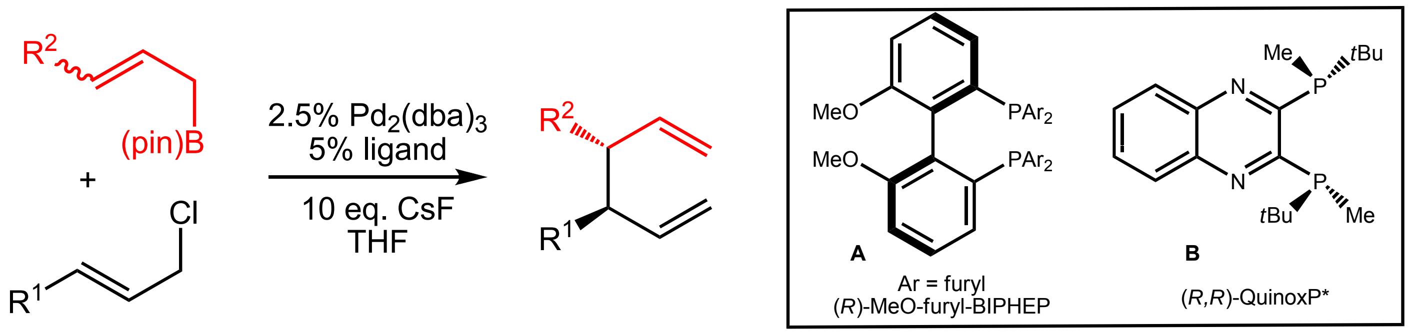


(**A**+**B**) yield : 45%
A/**B** : 8:1
er of **A** : 93:7

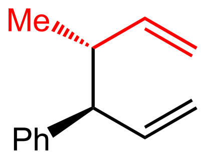


(**A**+**B**) yield : 96%
A/**B** : 4:1
er of **A** : 76:24

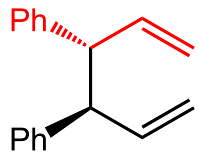
Morken, J. P. et al *J. Am. Chem. Soc.* **2011**, *133*, 9716



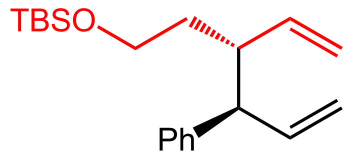
ligand **A**:



yield : 90%
dr : 6:1
er : >99:1

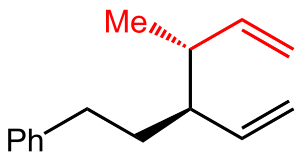


yield : 80%
dr : 14:1
er : 97:3

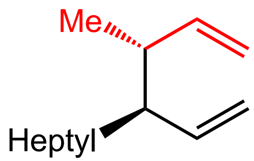


yield : 87%
dr : 10:1
er : >99:1

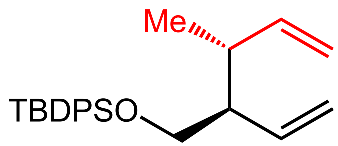
ligand **B**:



yield : 64%
dr : 7:1
er : 96:4



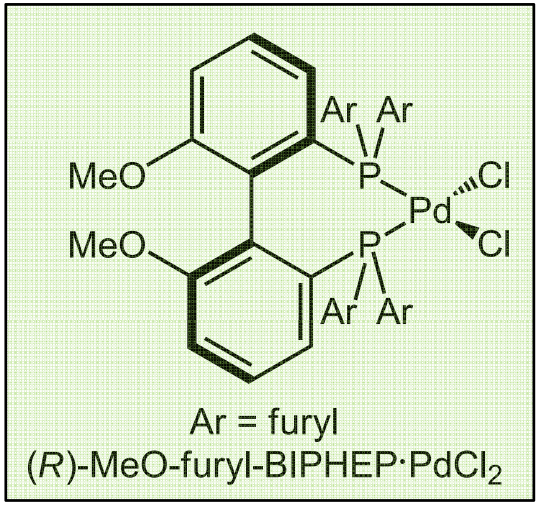
yield : 67%
dr : 7:1
er : 95:5

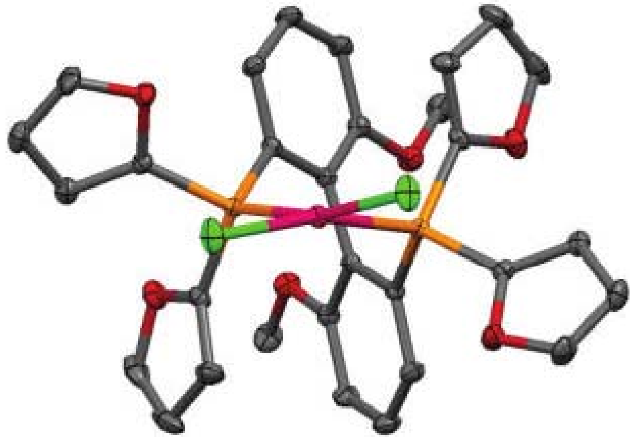


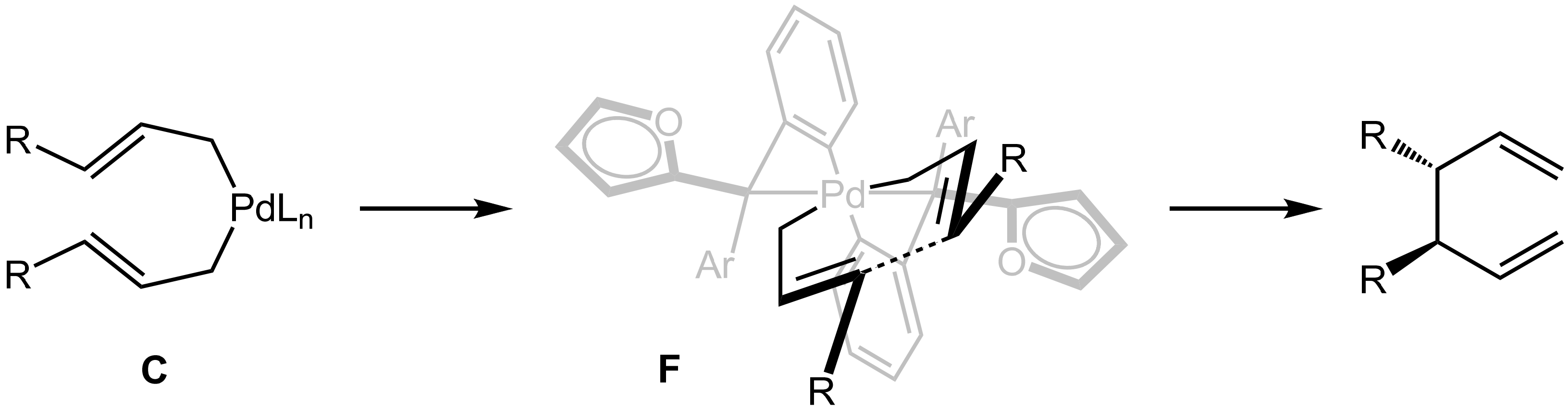
yield : 51%
dr : 6:1
er : 97:3

Morken, J. P. et al *J. Am. Chem. Soc.* **2011**, *133*, 16778

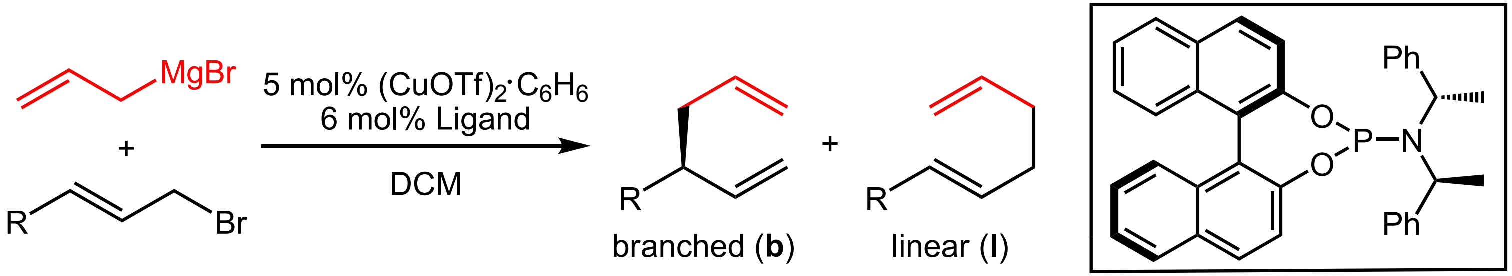
Model for stereochemical outcome in allyl-allyl couplings

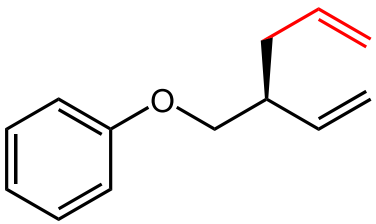




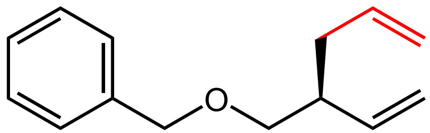


3. 铜催化的不对称烯丙基-烯丙基偶联反应

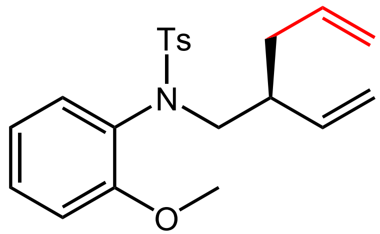




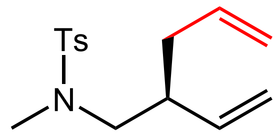
yield : 87%
b/**l** : 70:30
er : 95:5



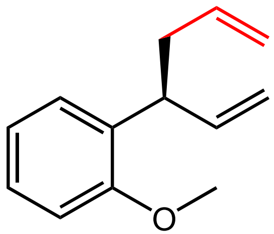
yield : 76%
b/**l** : 82:18
er : 95:5



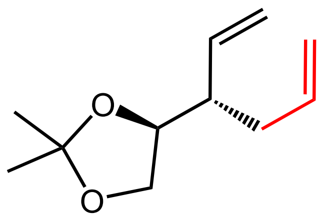
yield : 87%
b/**l** : 91:9
er : 97:3



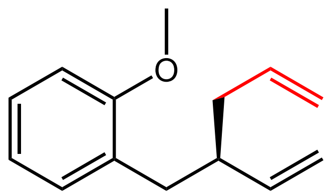
yield : 81%
b/**l** : 74:26
er : 96:4



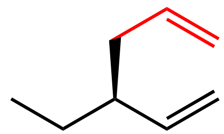
yield : 90%
b/**l** : 73:27
er : 95:5



yield : 81%
b/**l** : 70:30
er : 85:15

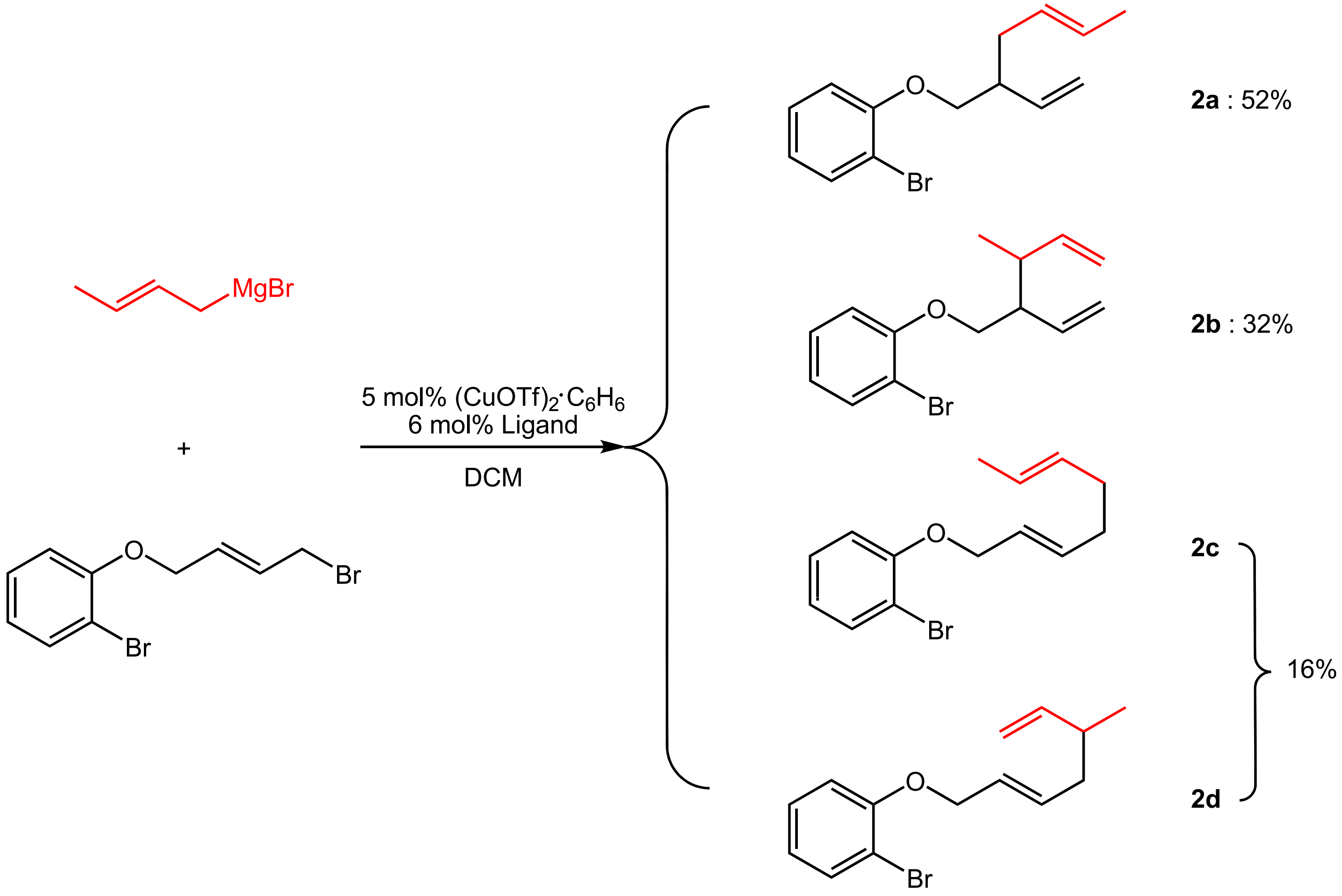


yield : 84%
b/**l** : 85:15
er : 91:9

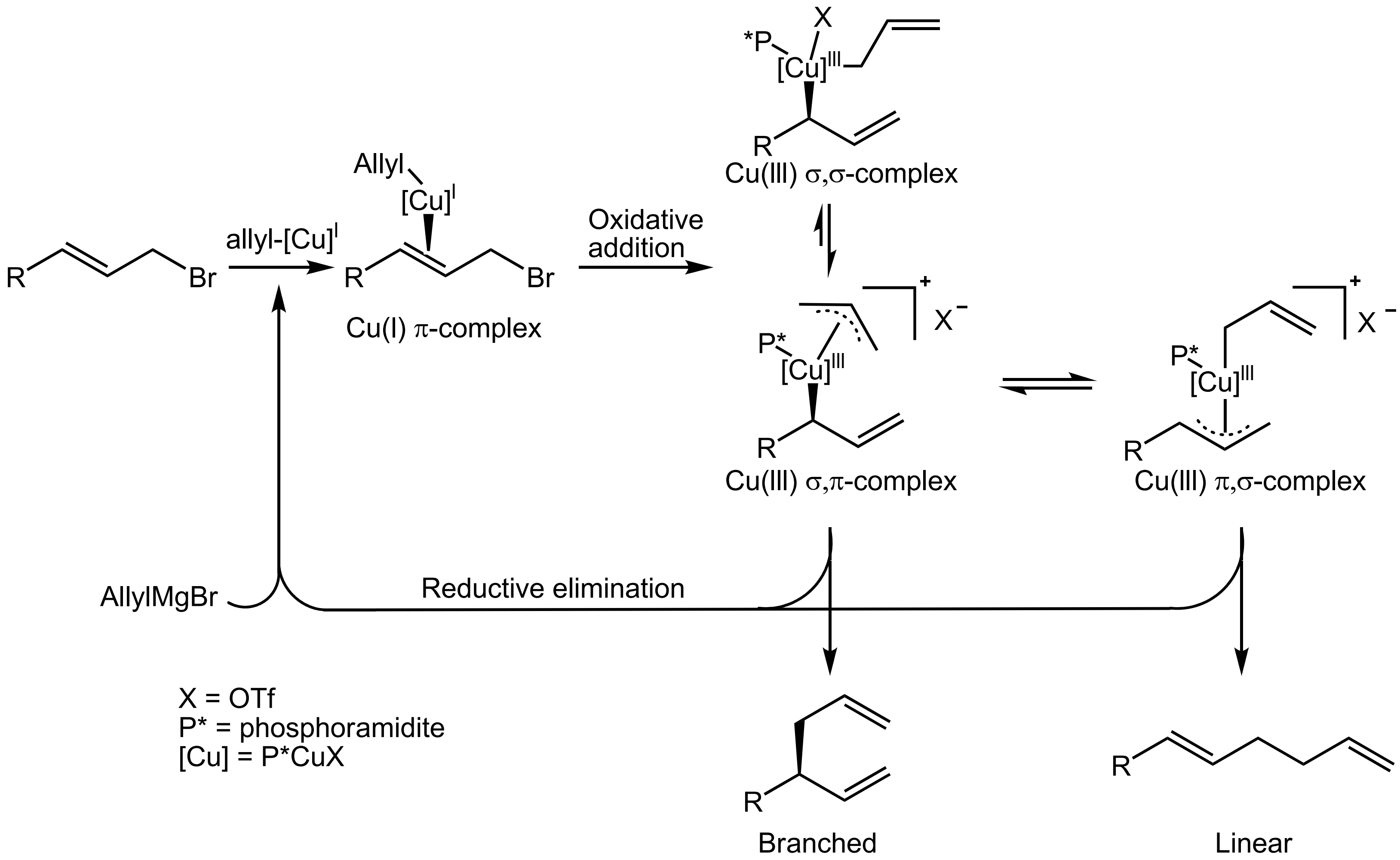


yield : 91%
b/**l** : 88:12
er : 97:3

Feringa, B. J. et al *J. Am. Chem. Soc.* **2013**, *135*, 2140


MgBr
+
Br
O
Br
5 mol% (CuOTf)2·C6H6
6 mol% Ligand
DCM
2a : 52%
2b : 32%
2c
2d
16%

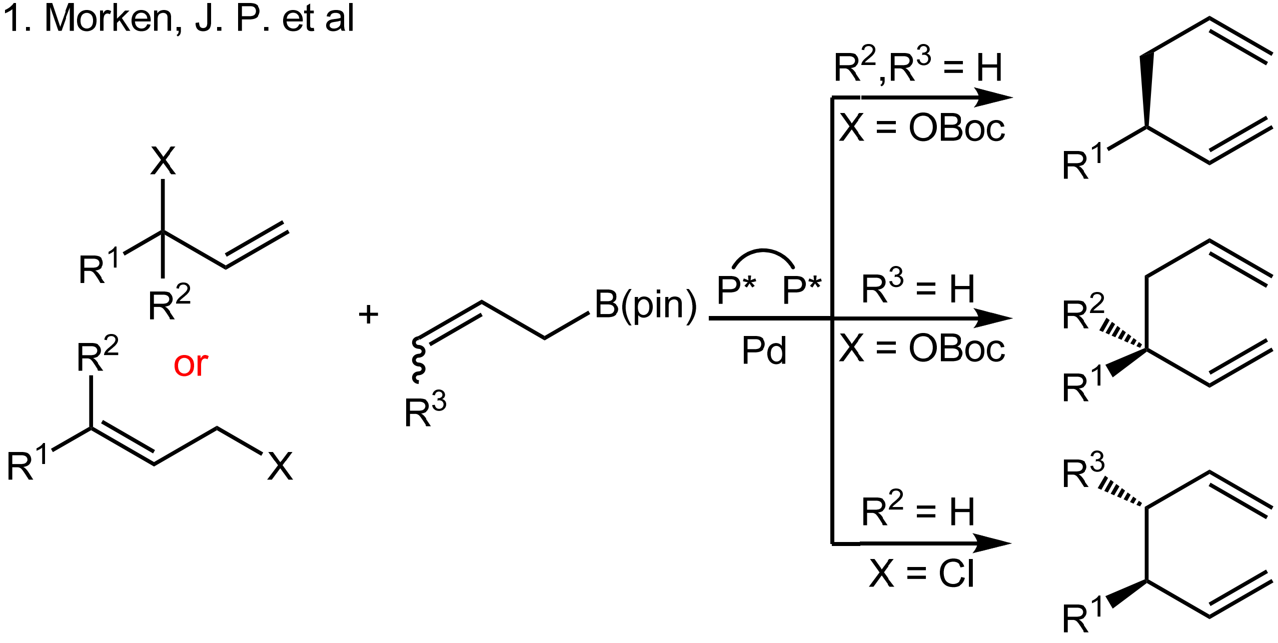
Proposed catalytic cycle



X = OTf
P* = phosphoramidite
[Cu] = P*CuX

4. 总结与讨论

1. Morken, J. P. et al

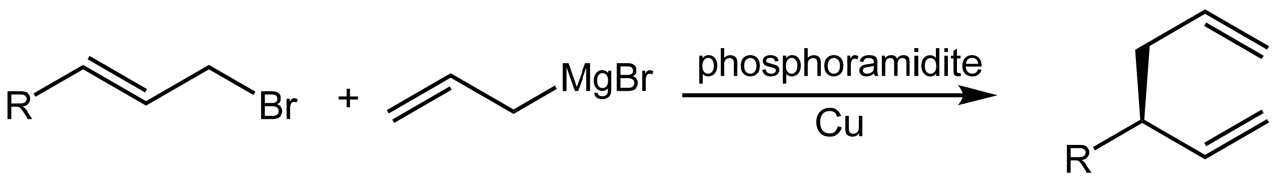


b/l : up to >20:1
ee : up to 91%

b/l : up to >20:1
er : up to 96:4

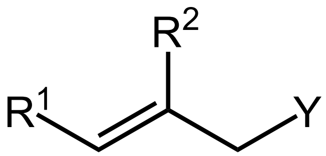
dr : up to 14:1
er : up to >99:1

2. Feringa, B. L. et al



b/l : up to 91:9
er : up to 97:3

1. New allylmetal speices



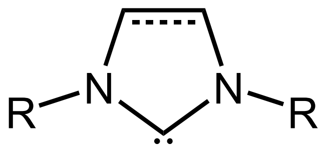
allylmetal species

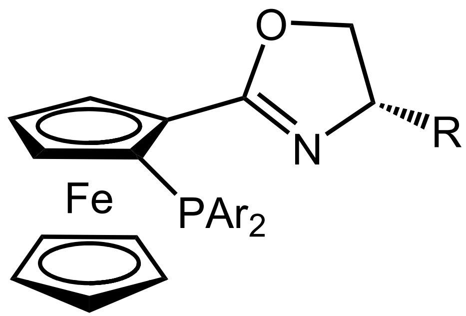
Y = $SnBu_3$, ZnBr, SiF_3 *etc*

2. New metals:

Ni, Au *etc*

3. New ligands:

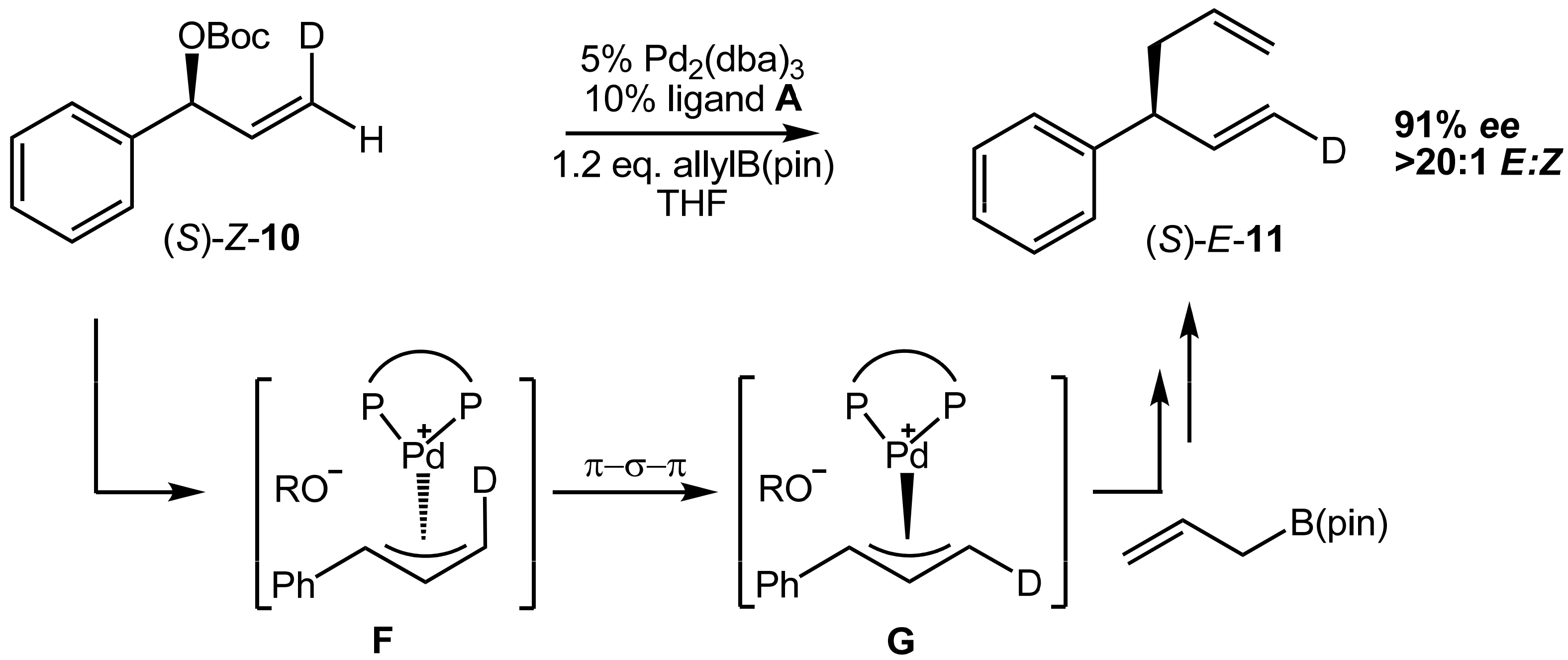




etc

Catalytic asymmetric C−C bond formation methodologies with high efficiency and selectivity are among the most important tools in organic synthesis. Of particular importance is the metal-catalyzed allyl−allyl cross-coupling between allylmetal species and allylic electrophiles, which has the capacity to establish a stereogenic center bearing both an allyl and a vinyl group. These chiral 1,5-diene structures are abundant in naturally occurring terpenes and also serve as highly versatile intermediates and building blocks in organic synthesis. Several transition-metal catalysts, including Pd, Au, Cu, and Ni, have been employed to enable catalytic allyl−allyl cross-coupling. Nonetheless, high levels of enantioselectivity have only been achieved recently by the use of Pd catalysis. Morken and co-workers described the Pd-catalyzed regio- and enantioselective cross-coupling of allylic carbonates and allylboronate involving an inner-sphere 3,3′-reductive elimination mechanism. This catalytic allylation represents a highly valuable synthetic tool but leaves ample opportunities to develop non-Pd-based alternatives. To the best of our knowledge, Cu-catalyzed enantioselective allyl−allyl cross-coupling is unprecedented.

In summary, the first Cu-catalyzed asymmetric allyl−allyl cross-coupling has been described. The use of commercially available allylmagnesium bromide and easily accessible allylic bromides with cheap Cu-phosphoramidite catalyst is key for the success of this reaction. The only waste produced in this novel transformation is $MgBr_2$. The use of Cu complexes with noncoordinating counteranions as present in $(CuOTf)_2 \cdot C_6H_6$ was found beneficial to increase the regioselectivity of the reaction. The potential applications in total synthesis were demonstrated in a three-step synthesis of the biologically active Martinelline alkaloid chromene derivative core structure.


OBoc
D
H
(S)-Z-10
5% Pd2(dba)3
10% ligand A
1.2 eq. allylB(pin)
THF
D
91% ee
>20:1 E:Z
(S)-E-11
P
P
Pd
RO
D
Ph
F
π–σ–π
P
P
Pd
RO
Ph
D
G
B(pin)