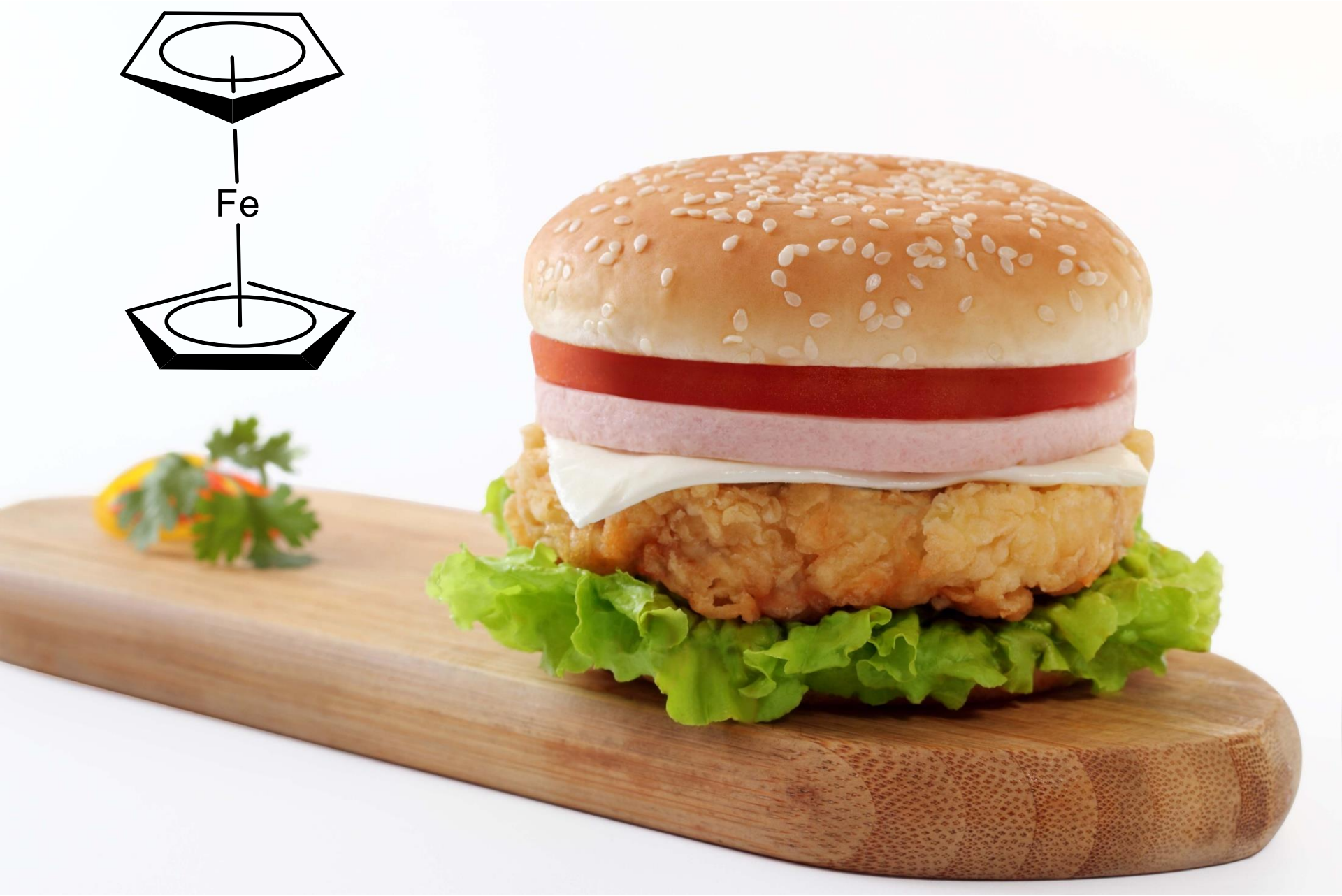
Literature Report

Chao Yang

Supervisor : Prof. **Yong Huang**

2016-04-17


Fe

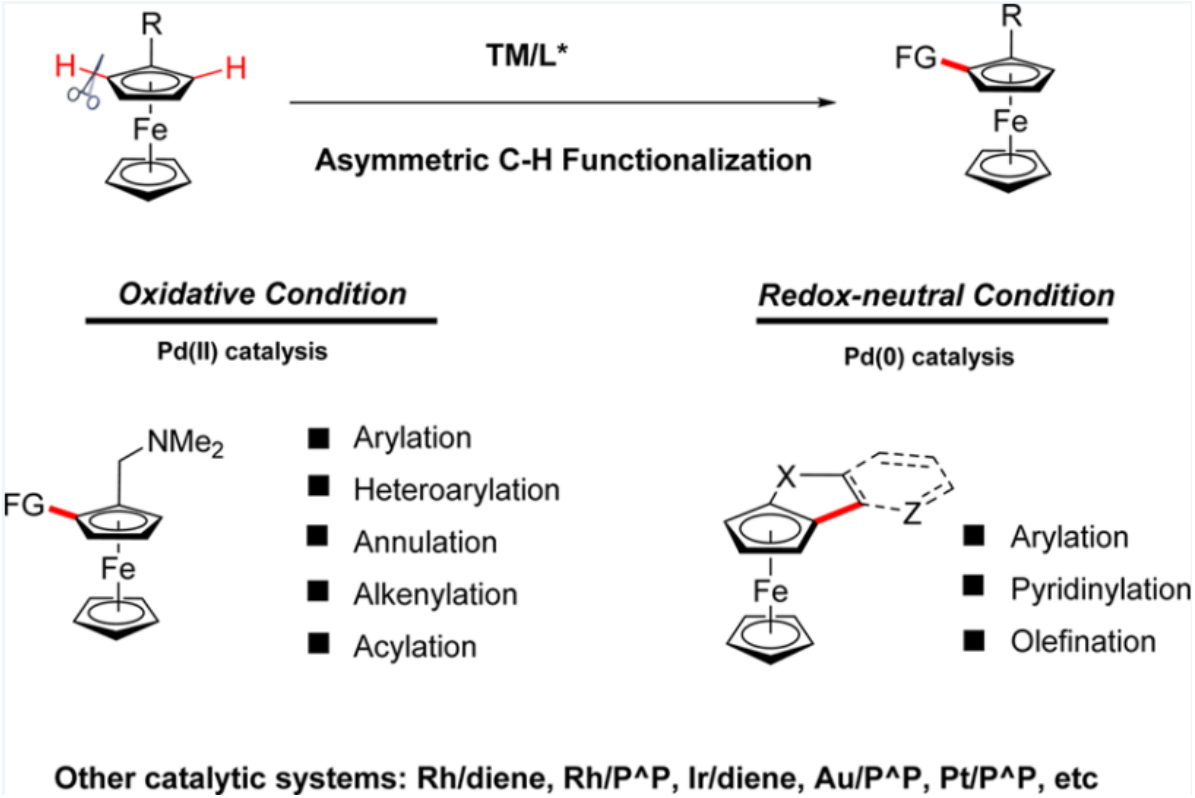
ACCOUNTS of chemical research

Article

pubs.acs.org/accounts

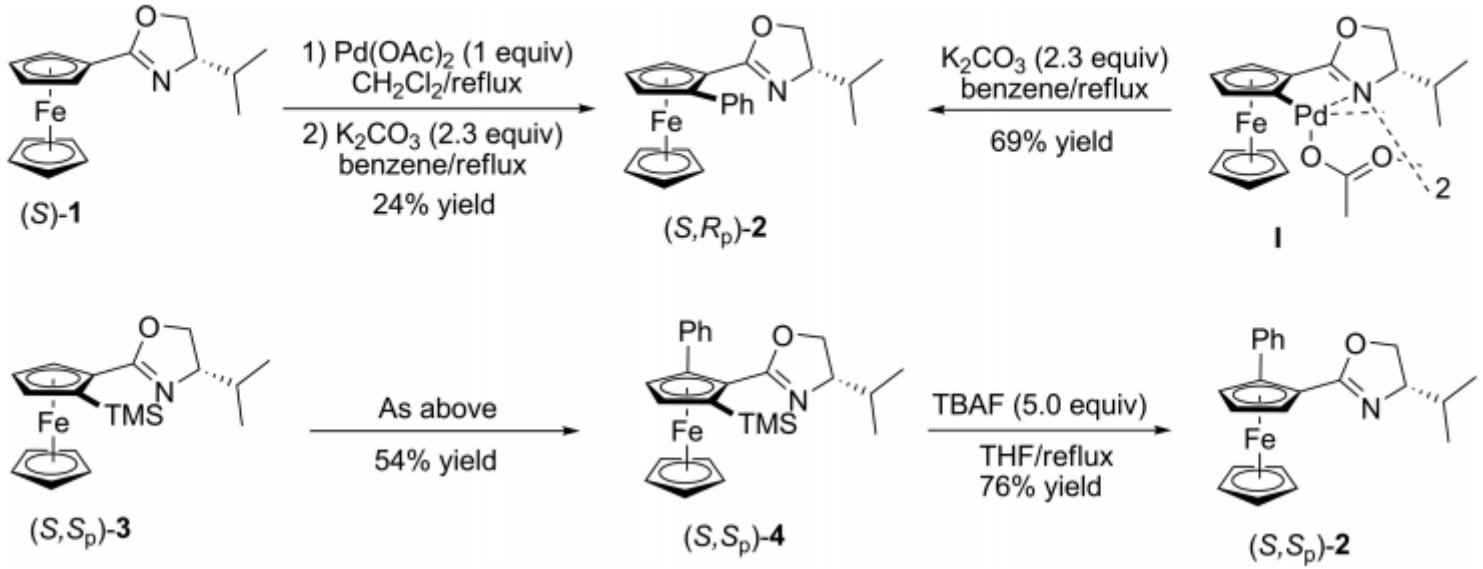
Synthesis of Planar Chiral Ferrocenes via Transition-Metal-Catalyzed Direct C–H Bond Functionalization

De-Wei Gao, Qing Gu, Chao Zheng, and Shu-Li You*



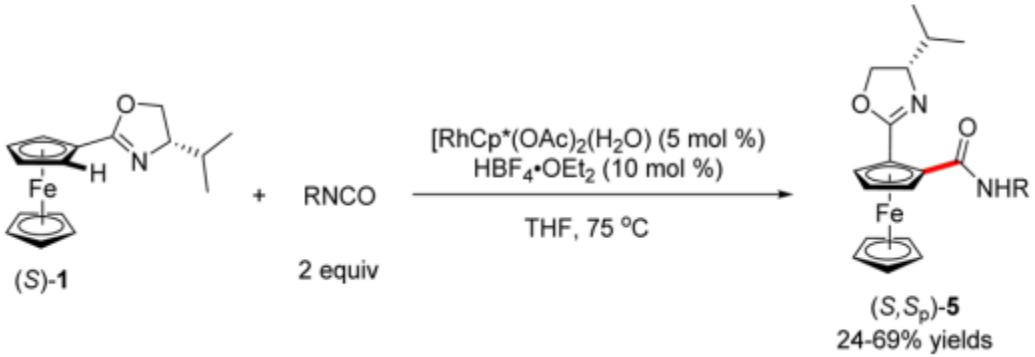
Diastereoselective and seminal enantioselective synthesis of planar chiral ferrocenes

Diastereoselective Cross-Coupling Reaction by Using Chiral Oxazoline as Directing Group



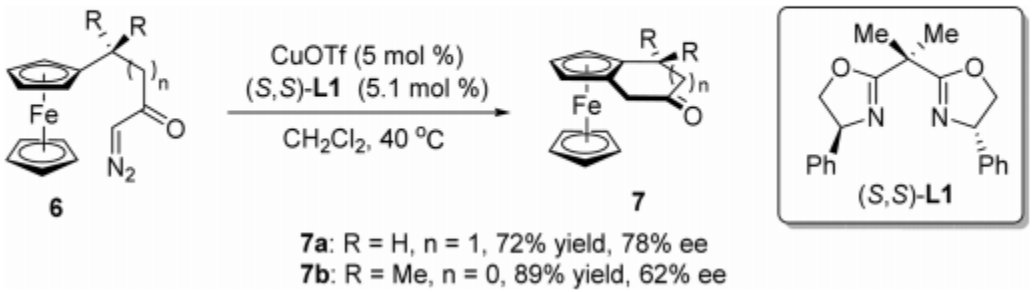
Xia, J.-B.; You, S.-L. *Organometallics* **2007**, *26*, 4869-4871

Rh(III)-Catalyzed Diastereoselective C–H Bond Amidation of Chiral Oxazolyl Ferrocene with Isocyanates



Takebayashi, S.; Shizuno, T.; Otani, T.; Shibata, T. *J. Org. Chem.* **2012**, *8*, 1844-1848.

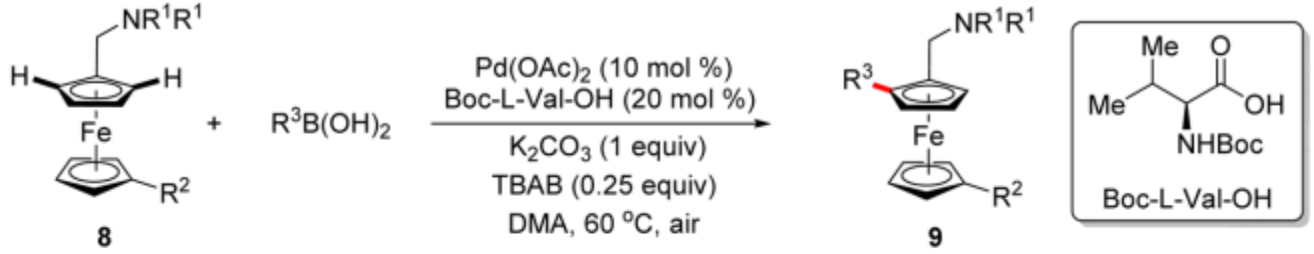
Cu-Catalyzed Enantioselective Insertion of Carbenoid into C–H Bond of Ferrocene

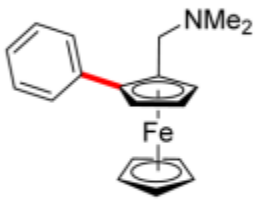


Siegel, S.; Schmalz, H.-G. *Angew. Chem., Int. Ed. Engl.* **1997**, *36,* 2456-2458.

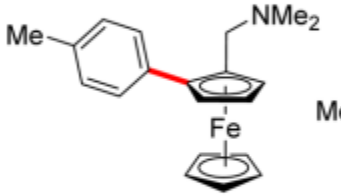
Enantioselective synthesis of planar chiral ferrocenes via Pd(II)-catalyzed direct C−H bond functionalization

Pd-Catalyzed Asymmetric C−H Bond Arylation of Ferrocenes with Arylboronic Acids

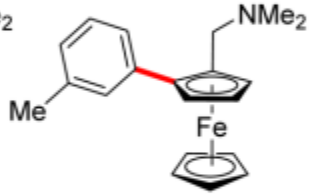




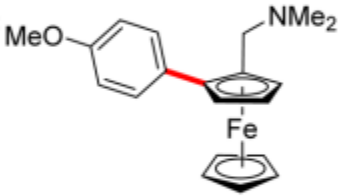
9a
79% yield
98% ee



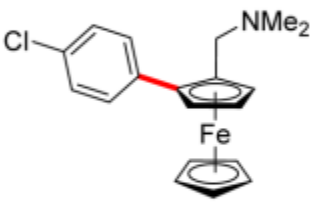
9b
70% yield
97% ee



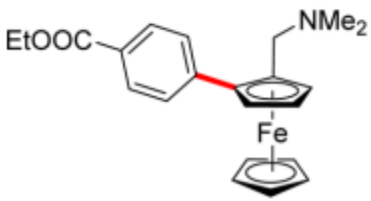
9c
81% yield
99% ee



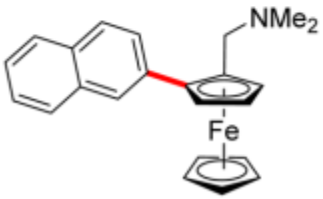
9d
59% yield
96% ee



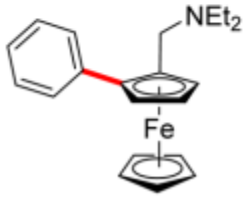
9e
72% yield
97% ee



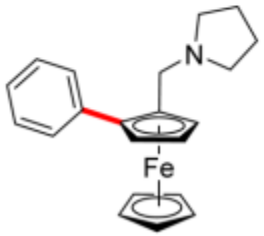
9f
72% yield
95% ee



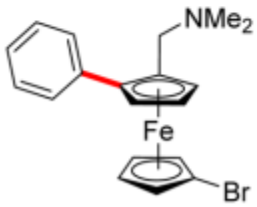
9g
75% yield
96% ee



9h
67% yield
90% ee

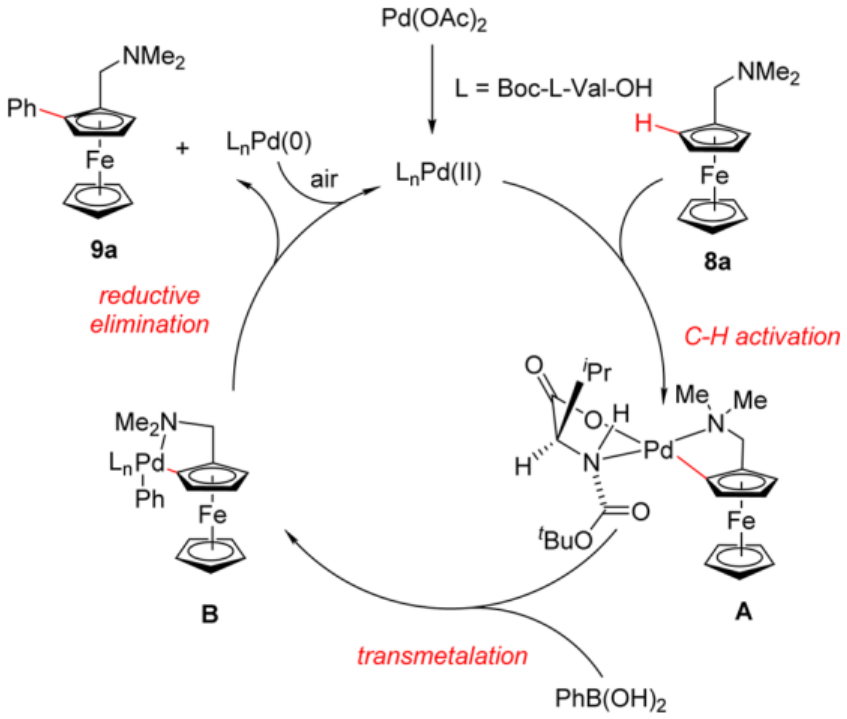


9i
71% yield
98% ee



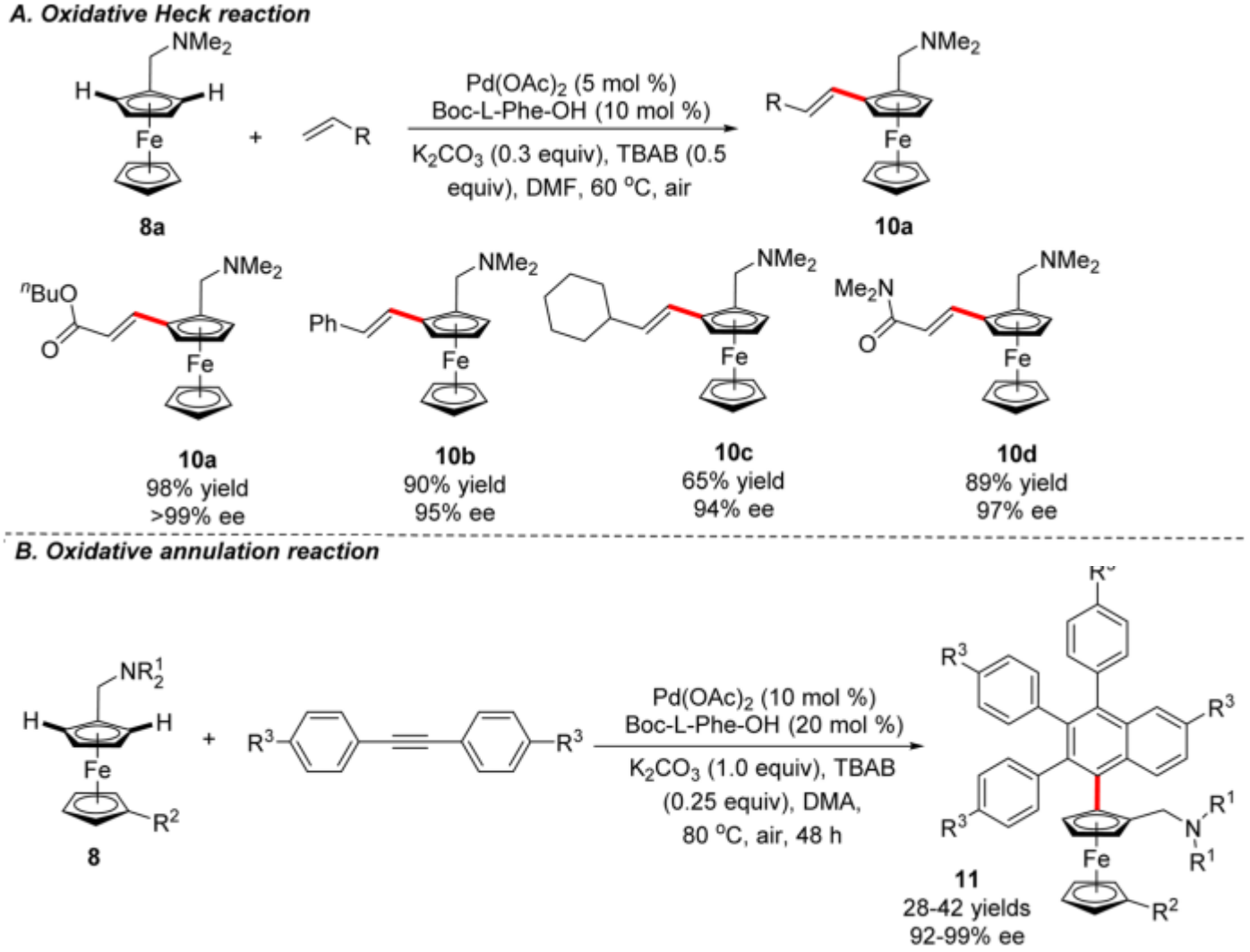
9j
69% yield
97% ee

Gao, D.-W.; Shi, Y.-C.; Gu, Q.; Zhao, Z.-L.; You, S.-L. *J. Am. Chem. Soc.* **2013**, *135*, 86-89.



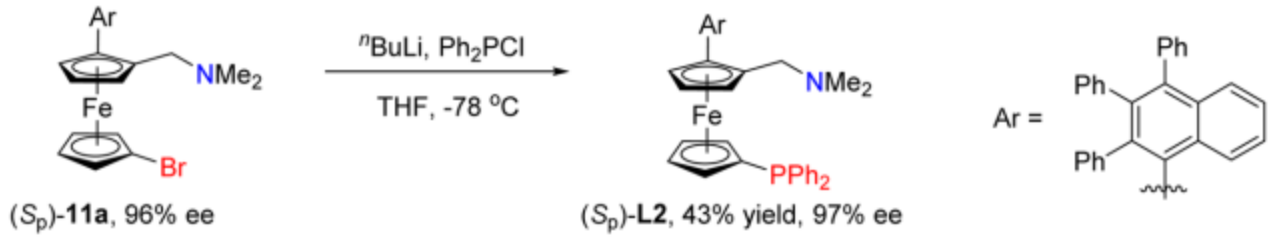
Plausible catalytic cycle of Pd-catalyzed asymmetric C–H bond arylation.

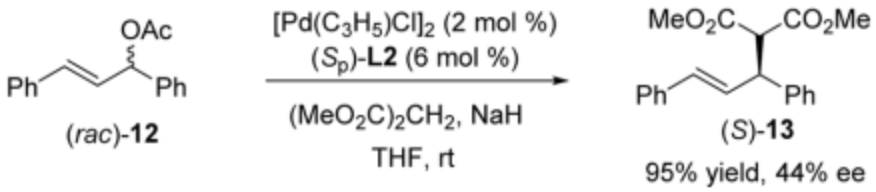
Pd(II)-Catalyzed Oxidative Heck and Annulation Reactions



Pi, C.; Li, Y.; Cui, X.; Zhang, H.; Han, Y.; Wu, Y. *Chem. Sci.* **2013**, *4*, 2675-2679.
Shi, Y.-C.; Yang, R.-F.; Gao, D.-W.; You, S.-L. J. *Org. Chem*. **2013**, *9*, 1891-1896.

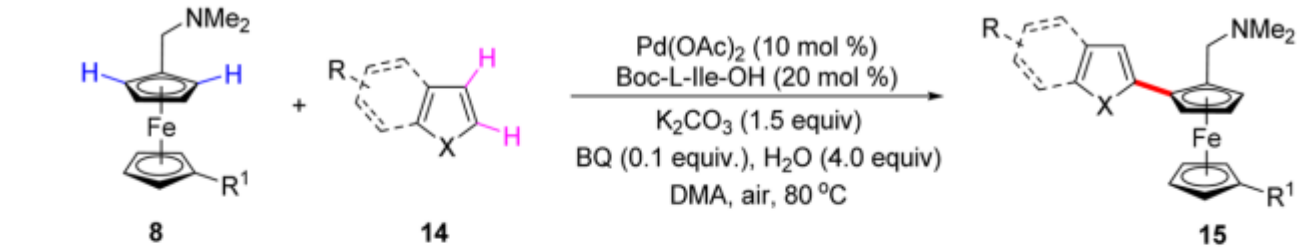
***C. Application of planar chiral ferrocene bearing substituted naphthalene* (11)**

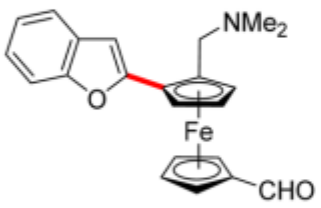




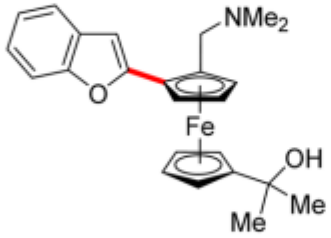
Shi, Y.-C.; Yang, R.-F.; Gao, D.-W.; You, S.-L. J. *Org. Chem*. **2013**, *9*, 1891-1896

Enantioselective oxidative C-H/C-H cross-coupling reaction of ferrocenes with heteroarenes

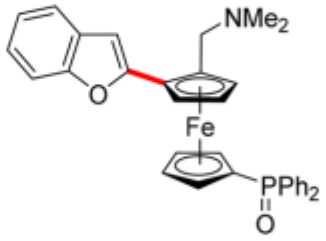




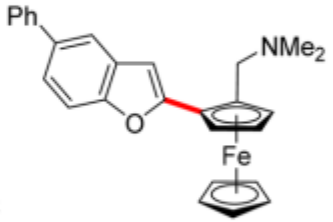
40% yield, 97% ee



73% yield, 98% ee

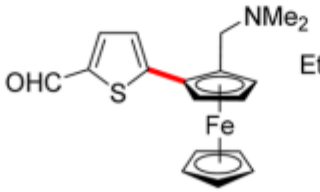


69% yield, 99% ee

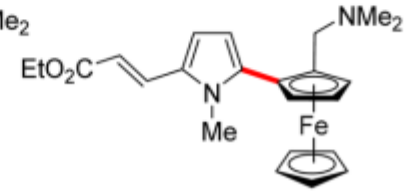


77% yield, 99% ee

76% yield, 99% ee



64% yield, 98% ee



48% yield, 95% ee

51% yield, 98% ee

Gao, D.-W.; Gu, Q.; You, S.-L. *J. Am. Chem. Soc.* **2016,** *138*, 2544-2547

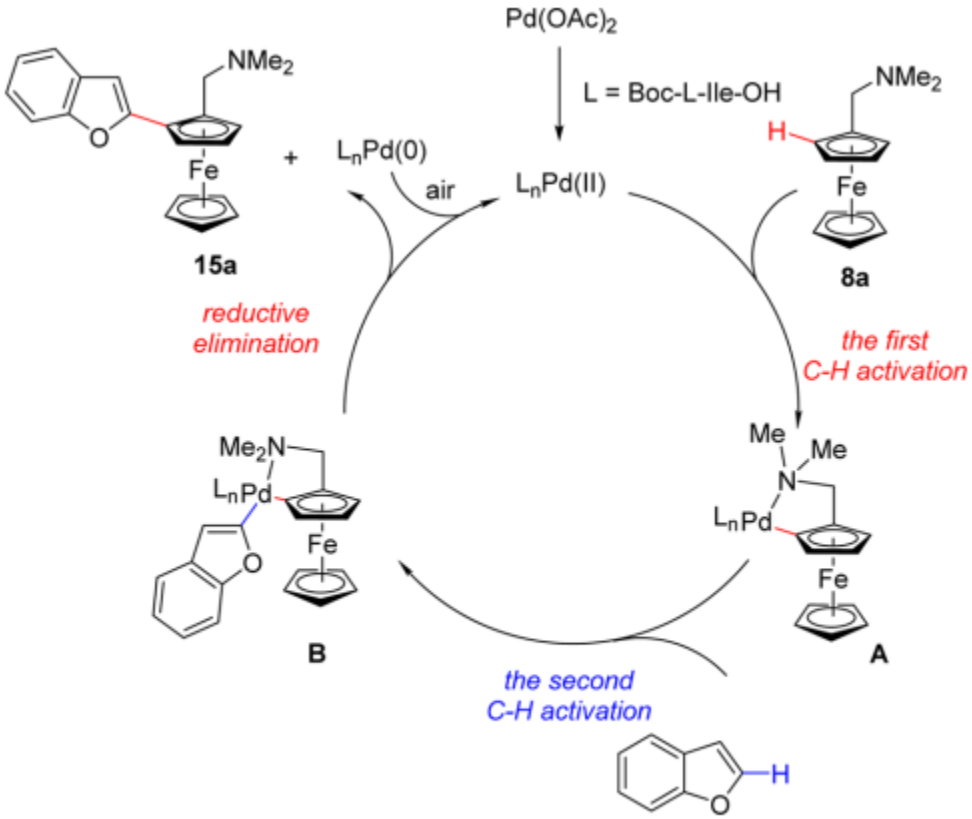
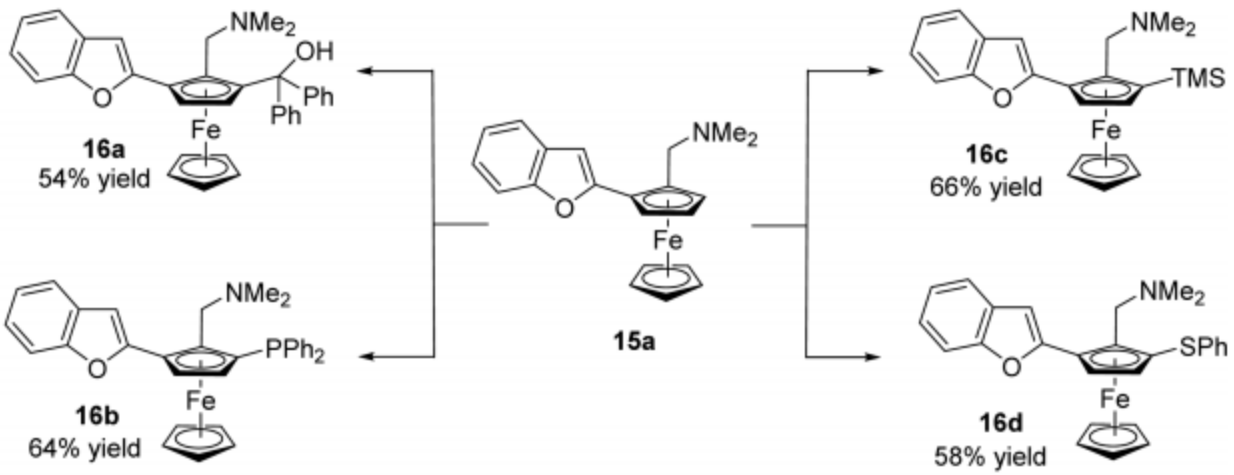


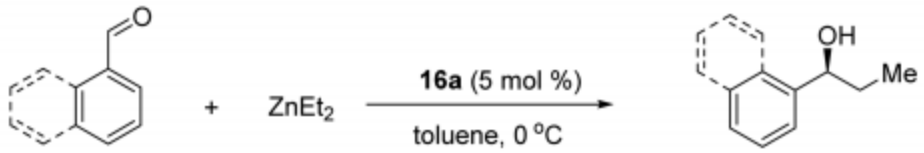
Figure 2. Plausible catalytic cycle of Pd-catalyzed asymmetric twofold C−H bond reaction.

Transformations of 15a and Asymmetric Diethylzinc Addition Reaction

A. DoM and quenched with electrophiles

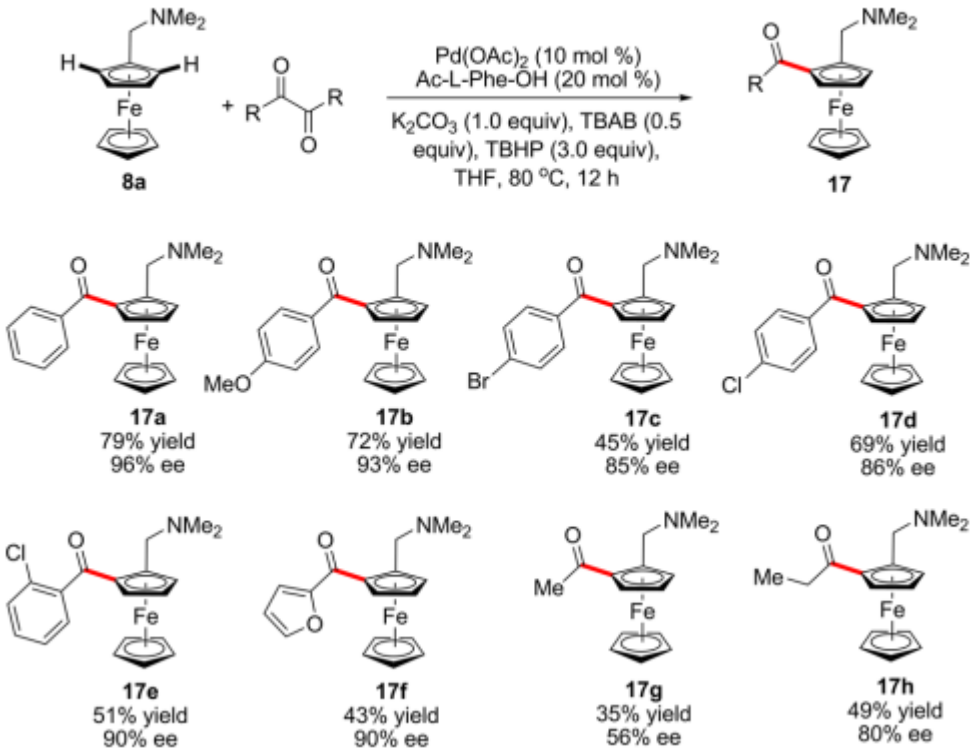


B. The application of 16a in asymmetric reaction of aldehyde with diethylzinc



from benzaldehyde: 90% yield, 86% ee
from 1-naphthaldehyde: 86% yield, 87% ee

Scheme 9. Catalytic Enantioselective C–H Acylation of Ferrocene Derivatives



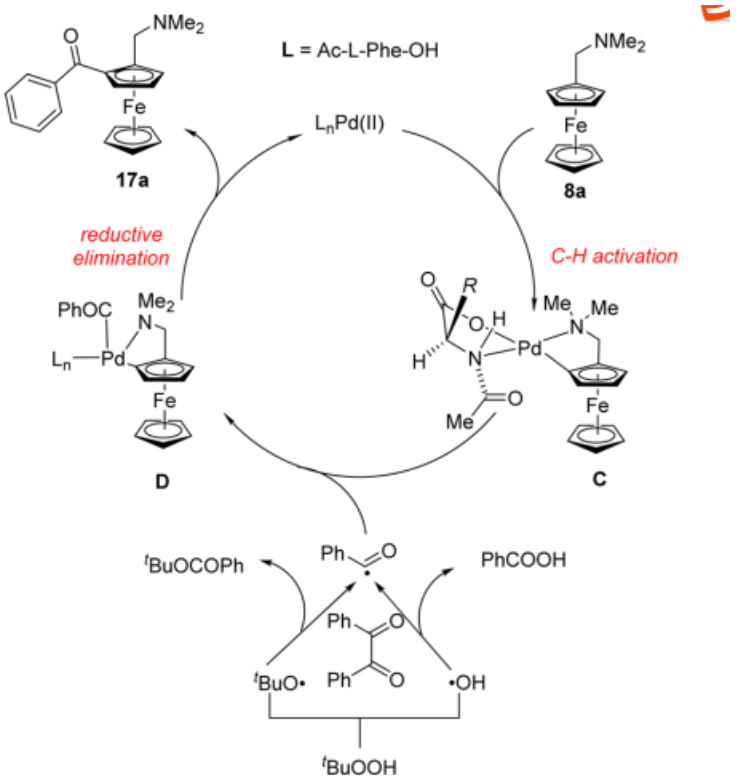
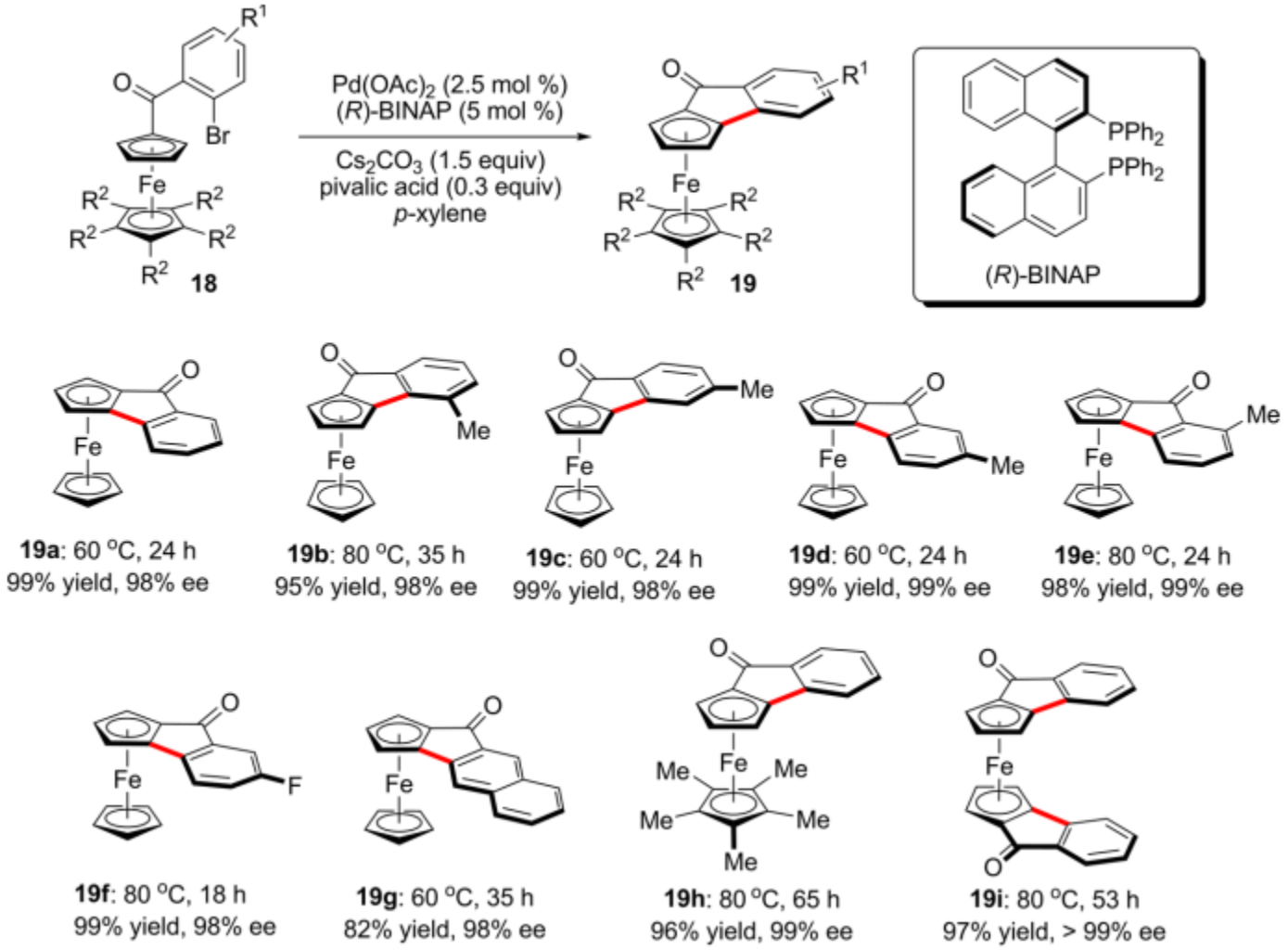


Figure 3. Proposed reaction mechanism of catalytic enantioselective C–H acylation.

Pi, C.; Cui, X.; Liu, X.; Guo, M.; Zhang, H.; Wu, Y. *Org. Lett.* **2014,** *16*, 5164-5167.

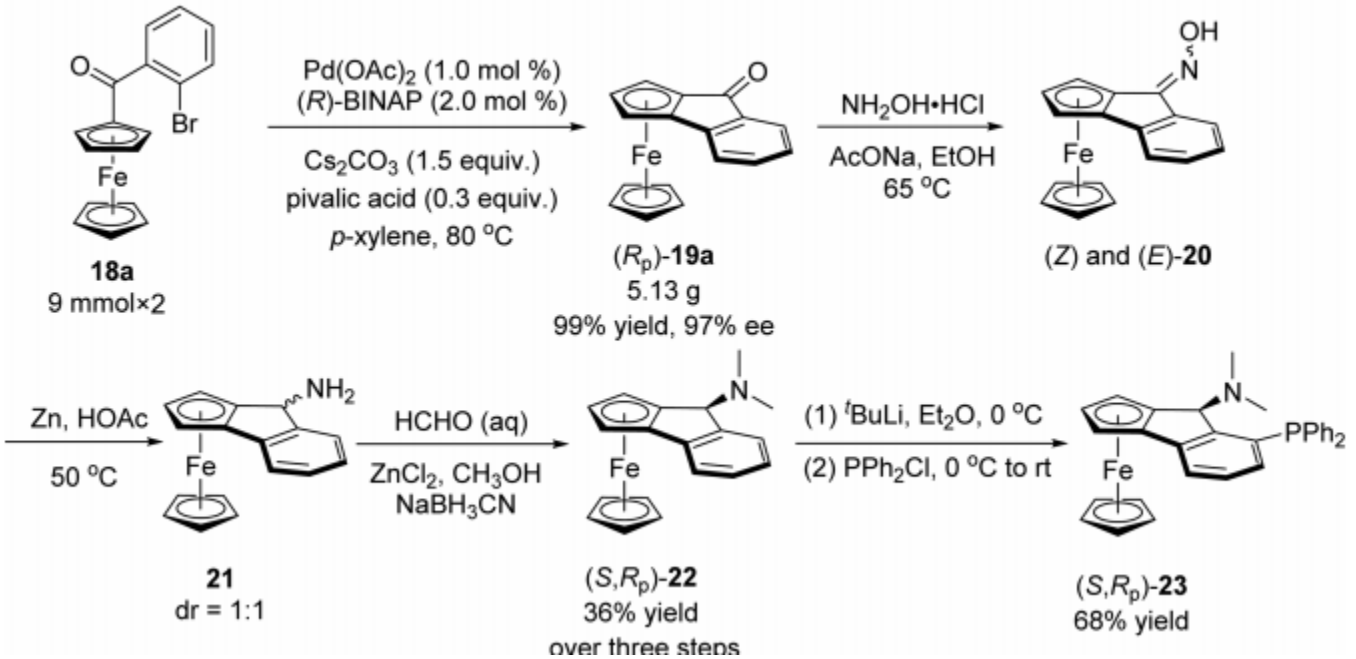
Enantioselective synthesis of planar chiral ferrocenes via Pd(0)-catalyzed direct C−H bond functionalization

Pd(0)-Catalyzed Enantioselective Intramolecular C−H Arylation

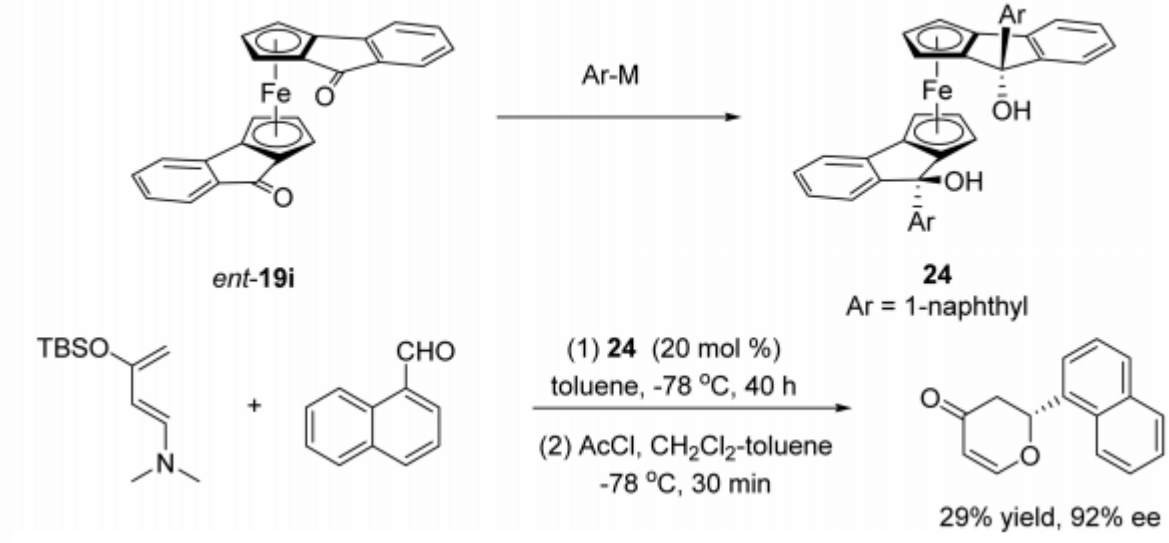


Gao, D.-W.; Yin, Q.; Gu, Q.; You, S.-L. *J. Am. Chem. Soc.* **2014**, *136*, 4841-4844.

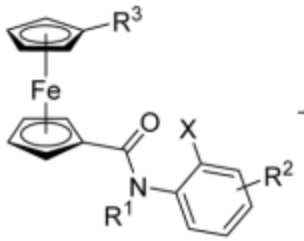
(a) *Synthesis of planar chiral P,N-ligand 23*



(b) *Synthesis of planar chiral diol 24 and application in asymmetric hetero-Diels-Alder reaction*



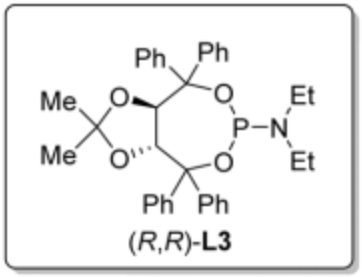
Enantioselective Intramolecualr C–H Arylation of *N*-(2-Haloaryl)ferrocenecarboxamides



25

conditions

26



(*R*,*R*)-**L3**

Liu and *Zhao*

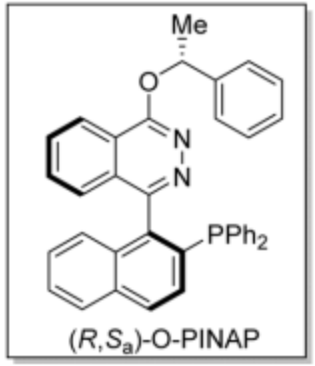
Pd_2dba_3 (5 mol %)
(*R*,*R*)-**L3** (10 mol %)
PivOH (30 mol %)
Cs_2CO_3 (1.5 equiv)
toluene, 80 °C, 8 h

70-91% yields
82-96% ee

Gu

$Pd(OAc)_2$ (5 mol %)
(R,S_a)-O-PINAP (15 mol %)
Cs_2CO_3 (2.5 equiv)
toluene, 120 °C, 12 h

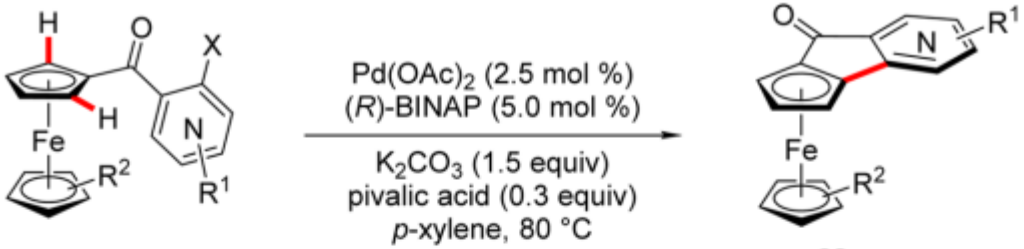
50-98% yields
28-67% ee



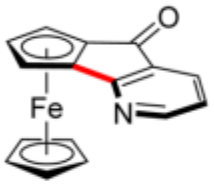
(R,S_a)-O-PINAP

Liu, L.; Zhao, W.-X. *Org. Lett.* **2014**, *16*, 5336-5338.
Ma, X.; Gu, Z. *RSC Adv.* **2014**, *4*, 36241-36244.

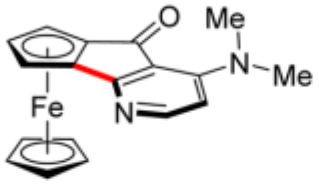
A. Substrate scope of enantioselective synthesis of planar chiral ferrocenylpyridines



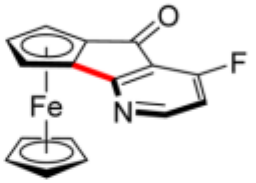
27 **28**



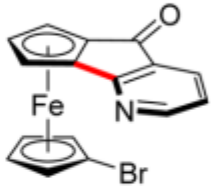
28a
X = Br, 7 h
99% yield, 98% ee
X = Cl, 16 h
99% yield, 98% ee



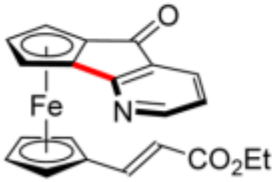
28b
X = Br, 8 h
99% yield, 99% ee



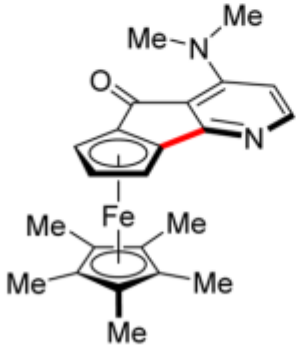
28c
X = Br, 16 h
97% yield, 98% ee



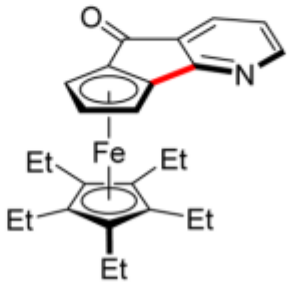
28d
X = Br, 11 h
98% yield, 97% ee



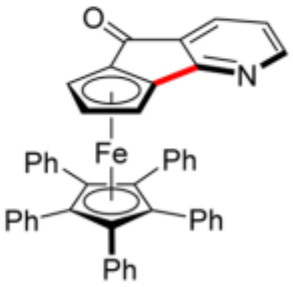
28e
X = Br, 58 h
92% yield, 99% ee



28f
X = Br, 21 h
97% yield, 99% ee



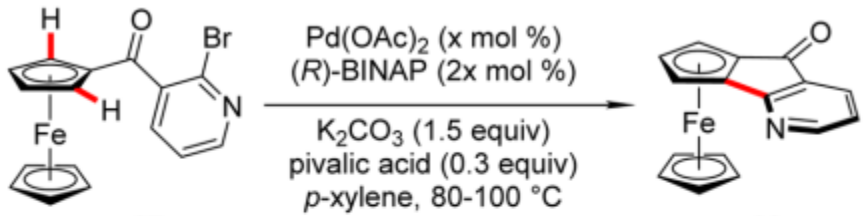
28g
X = Br, 18 h
99% yield, 99% ee



28h
X = Br, 47 h
99% yield, 99% ee

Gao, D.-W.; Zheng, C.; Gu, Q.; You, S.-L. *Organometallics* **2015**, *34*, 4618-4625.

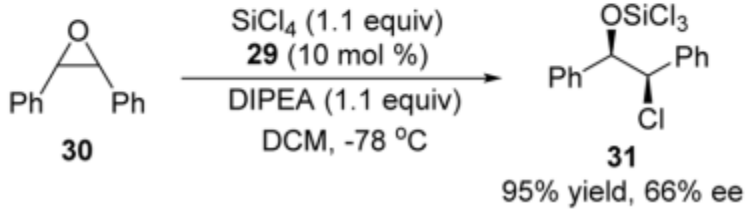
B. Large-scale reaction at a low catalyst loading



27a **28a**

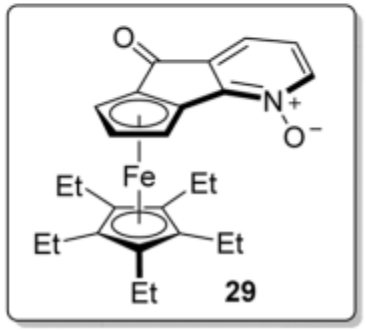
x = 2.5: 99% yield, 99% ee (4 mmol scale)
x = 0.2: 99% yield, 98% ee (8 mmol scale)

C. Asymmetric opening of meso-epoxide



30 **31**

95% yield, 66% ee

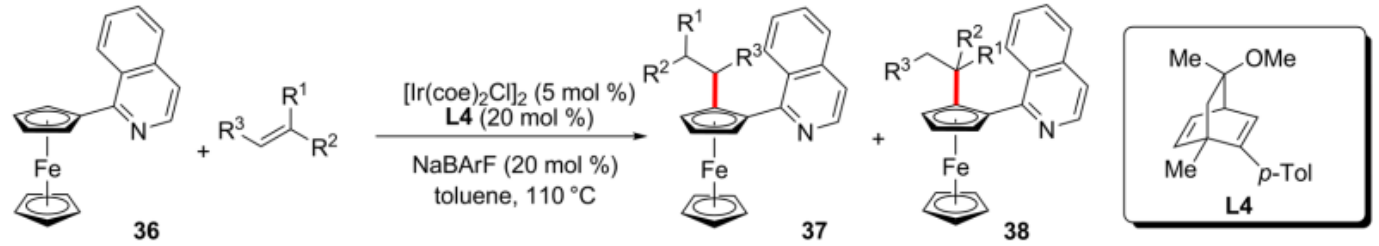


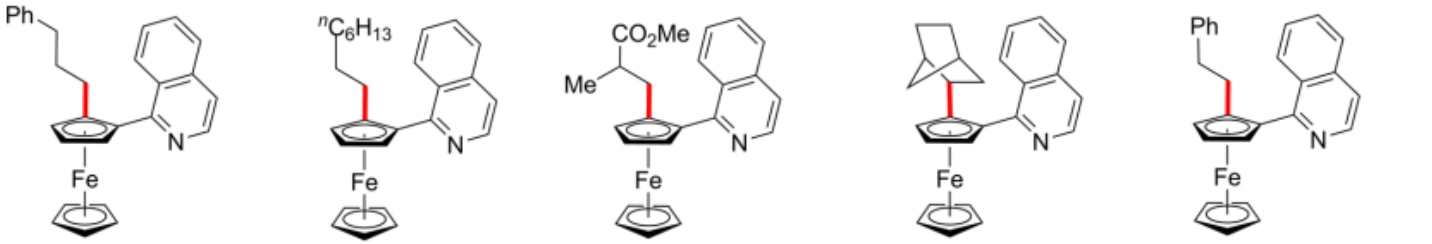
29

Gao, D.-W.; Zheng, C.; Gu, Q.; You, S.-L. *Organometallics* **2015**, *34*, 4618-4625.

Enantioselective synthesis of planar chiral ferrocenes via Ir- or Rh-catalyzed direct C−H bond functionalization

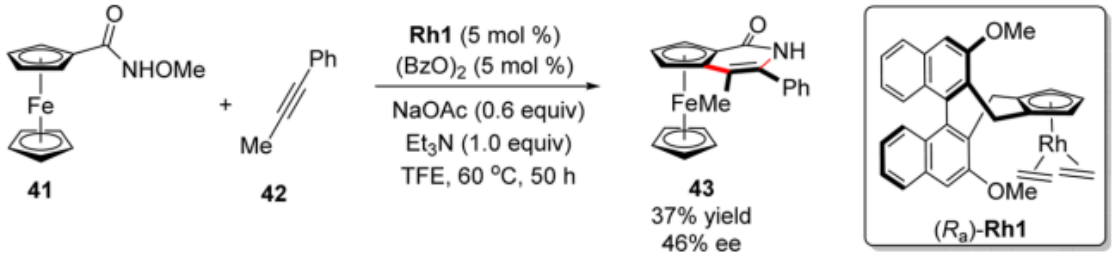
Ir-Catalyzed Enantioselective C−H Alkylation





Shibata, T.; Shizuno, T. *Angew. Chem., Int. Ed.* **2014**, *53*, 5410-5413.

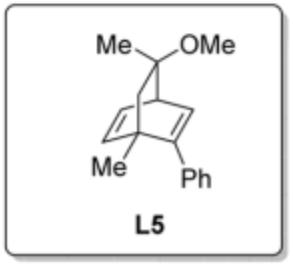
Rh(III)-Catalyzed Asymmetric Annulation Reaction

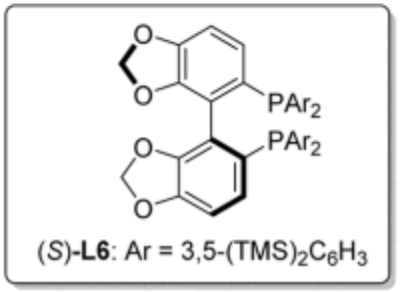


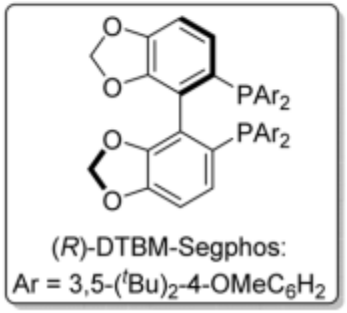
Wang, S.-B.; Zheng, J.; You, S.-L. *Organometallics* **2016**, *35*, 1420-1425.

Rh-Catalyzed Intramolecular Asymmetric C–H Silylation

Shibata	*He*	*Murai and Takai*
$[Rh(COE)_2Cl]_2$ (10 mol %)	$[Rh(COD)Cl]_2$ (5 mol %)	$[Rh(COD)Cl]_2$ (2.5 mol %)
L5 (24 mol %)	(*S*)-**L6** (10 mol %)	(*R*)-DTBM-Segphos (7.5 mol %)
3,3-dimethyl-1-butene (10 equiv)	toluene, rt-45 °C, 48 h	DCE, 30-50 °C, 24-48 h
toluene, 135 °C, 2-24 h	M = Fe, Ru	M = Fe, Ru,
M = Fe, X = Si, Ge	X = Si	X = Si
40-75% yields	41-98% yields	56-93% yields
5-86% ee	77-94% ee	77-93% ee



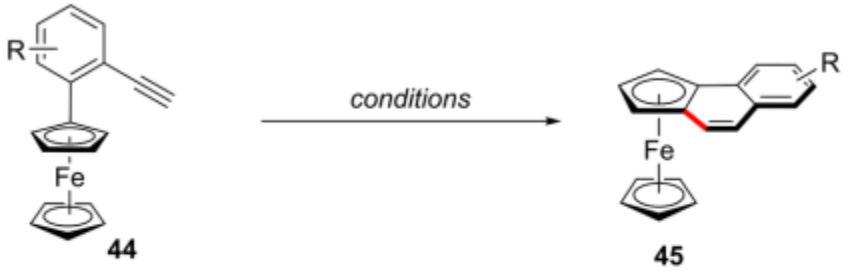




Shibata, T.; Shizuno, T.; Sasaki, T. *Chem. Commun.* **2015**, *51*, 7802-7804.
Zhang, Q.-W.; An, K.; Liu, L.-C.; Yue, Y.; He, W. *Angew. Chem., Int. Ed.* **2015**, *54*, 6918-6921.
Murai, M.; Matsumoto, K.; Takeuchi, Y.; Takai, K. *Org. Lett.* **2015**, *17*, 3102-3105.

Enantioselective synthesis of planar chiral ferrocenes via Au/Pt-catalyzed direct C−H bond functionalization

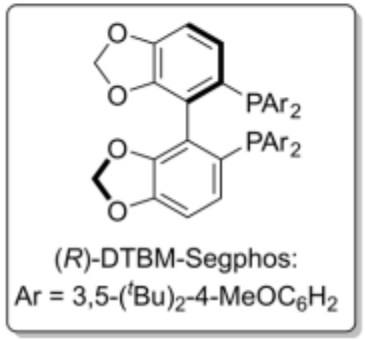
Enantioselective Synthesis of Planar Chiral Ferrocenes via Au/Pt-Catalyzed Cycloisomerization



44 **45**

Urbano and Carreño

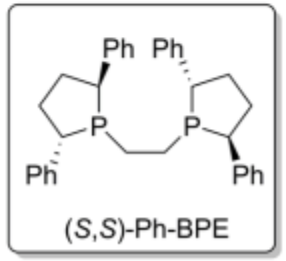
(*R*)-DTBM-Segphos $(AuCl)_2$ (10 mol %)
$AgSbF_6$ (20 mol %)
toluene, 0 °C, 3-15 h
74-92% yields
68-93% ee



(*R*)-DTBM-Segphos:
Ar = 3,5-(^{t}Bu)$_2$-4-MeOC$_6$H$_2$

Shibata

$PtCl_2$(cod) (10 mol %)
(*S*,*S*)-Ph-BPE (10 mol %)
$AgBF_4$ (20 mol %)
DCE, rt, 15-24 h
62-97% yields
18-97% ee



(*S*,*S*)-Ph-BPE

Urbano, A.; Carreno. *Chem. Commun.* **2016**, *52*, 6419-6422.
Shibata, T.; Kanyiva, K. S. *J. Org. Chem.* **2016**, *81*, 6266-627.

Summary & Outlook

- diastereoselective and enantioselective synthesis of planar chiral ferrocenes
- asymmetric syntheses of planar chiral ferrocenes via different metal catalyst
- step- and atom-economies over over traditional approaches

carbon-heteroatom bonds (C-P, C-N, C-S, etc.) has not been explored

catalytic activities are not sufficiently high for practical applications

preinstallation of directing groups

Thank you!