

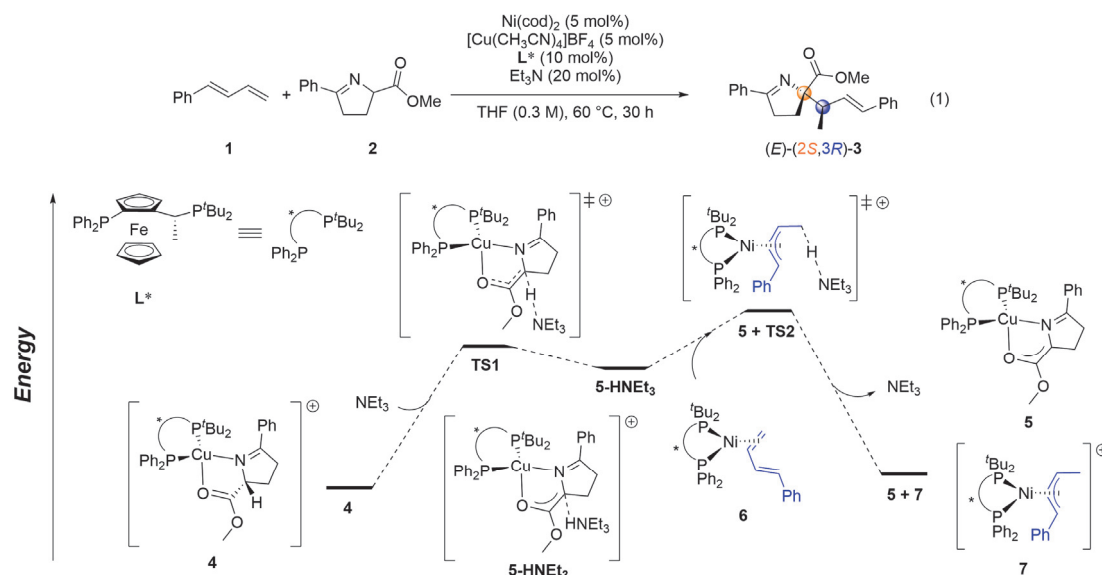
Mechanism of Asymmetric Coupling of 1,3-Dienes and C-Nucleophiles by Ni/Cu Cooperative Catalysts by DFT Calculations

(¹Graduate School of Engineering Science, Osaka University, ²School of Chemistry and Chemical Engineering, Shanghai Jiao Tong University) ○Haruki Nagae,¹ Jingzhao Xia,^{1,2} Shoichiro Katayama,¹ Takahiro Hirai,¹ Wanbin Zhang,² Kazushi Mashima¹

Keywords: Nickel; Copper; π -Allyl Complex; Enolate Complex; Asymmetric Allylic Alkylation

Asymmetric hydrofunctionalization of 1,3-dienes with C-nucleophiles has been paid considerable attentions as atom- and step-economical reactions for constructing vicinal two stereocenters in one step.¹ Such the coupling reaction has mainly been demonstrated by novel Pd and Rh catalysts, and the catalytic systems using earth abundant metals such as first-row transition metals suffered from the low diastereoselectivity.² We found that the cooperative catalyst system of Ni and Cu with a chiral JOSIPHOS-type bisphosphine ligand **L*** exhibited the high catalytic activity with high enantio- and diastereoselectivity toward the asymmetric coupling of 1,3-diene **1** and C-nucleophile **2** to give the corresponding product (2*S*,3*R*)-**3** (eq. 1). Herein, we report the details of the reaction mechanism for the asymmetric coupling based on the experimental results and the DFT calculations.

The first step of the asymmetric coupling is deprotonation of Cu complex **4** by Et₃N to give an intermediate **5-HNEt₃** via a transition state **TS1**. The ammonium cation is transferred to Ni complex **6**, and complex **6** is protonated via **TS2** to afford the key intermediates, Cu enolate complex **5** and π -allyl Ni complex **7**. The highest activation barrier of the proton transfer step in this reaction pathway suggested that the proton transfer step is the rate determining step. Next, α -carbon of enolate moiety of **5** attacks to the 3-position of π -allyl moiety of **7** to yield the corresponding product (2*S*,3*R*)-**3** with vicinal two stereocenters. In addition, we discuss how the Ni/Cu catalyst system controls the stereoselectivity of this asymmetric coupling reaction.



1) Adamson, N. J.; Malcolmson, S. J. *ACS Catal.* **2020**, *10*, 1060. 2) (a) Cheng, L.; Li, M.-M.; Xiao, L.-J.; Xie, J.-H.; Zhou, Q.-L. *J. Am. Chem. Soc.* **2018**, *140*, 11627; (b) Shao, W.; Besnard, C.; Guénée, L.; Mazet, C. *J. Am. Chem. Soc.* **2020**, *142*, 16486.