Cooperative Metal Catalysis for Efficient Organic Synthesis

Yoshiaki Nakao

Graduate School of Engineering, Division of Chemical Science and Engineering, Kyoto University, Kyoto, Japan

E-mail: nakao.yoshiaki.8n@kyoto-u.ac.jp

Abstract

Metal catalysis has long served as one of the most powerful and reliable strategies for the construction of complex organic molecules, enabling the formation of carbon–carbon and carbon–heteroatom bonds under conditions that are often difficult to achieve by conventional stoichiometric methods. In this presentation, we envision that the synthetic potential of metal catalysis can be further expanded through the rational design of cooperative catalytic systems composed of two or more distinct metal complexes, in which each metal center performs a complementary function in the activation of substrates, the generation of reactive intermediates, or the control of elementary steps within the catalytic cycle.

Unlike traditional single-metal catalytic processes, cooperative metal catalysis allows multiple reaction components to be activated in a coordinated manner, thereby creating new opportunities for transformations that are otherwise inefficient, poorly selective, or inaccessible. In particular, doubly activating cooperative metal catalysis provides a powerful platform for promoting challenging bond-forming reactions by combining the unique reactivity profiles of different transition-metal complexes or metal/Lewis acid pairs. Through this approach, substrates bearing relatively inert or less reactive chemical bonds can be converted into synthetically valuable products with improved efficiency and selectivity.

We demonstrate that several novel C–C and C–heteroatom bond-forming reactions can be achieved by exploiting such cooperative activation modes. Representative examples include site-selective hydro(hetero)arylation reactions, catalytic C–H borylation, and demanding C–F and C–O functionalization processes. These transformations illustrate how cooperative metal catalysis can overcome limitations associated with conventional catalytic systems and provide new strategies for selective molecular functionalization.

Overall, these studies highlight cooperative metal catalysis as a versatile and conceptually important approach for efficient organic synthesis. By integrating the complementary functions of multiple metal catalysts into a single reaction system, this strategy offers a promising direction for the discovery of unprecedented transformations and the development of more selective, efficient, and broadly applicable synthetic methodologies.