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Advances in asymmetric catalysis: from mechanisms to applications

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I am delighted to see the launch of this Special Issue, "Advances in Asymmetric Catalysis: From Mechanisms to Applications", edited by Guest Editors Mario Waser and Shengcai Zheng. Having had the opportunity to propose the theme of this Special Issue, I am especially pleased to see it come to fruition.

The synthesis of chiral compounds in high optical purity is critically important in medicinal and agrochemical chemistry. K. Barry Sharpless, Ryoji Noyori, and William S. Knowles were awarded the 2001 Nobel Prize in Chemistry for their pioneering contributions to asymmetric oxidation and asymmetric reduction catalysis. These transformations have been primarily achieved using transition-metal catalysts based on elements such as titanium, ruthenium, and rhodium. Subsequently, a wide variety of asymmetric carbon–carbon bond-forming reactions employing chiral Lewis acid and chiral Lewis base catalysts were developed, leading to remarkable advances in asymmetric catalysis.

Traditionally, acid–base catalysis relied primarily on compounds of main-group elements. However, organocatalysis emerged rapidly in the early 2000s, culminating in the award of the 2021 Nobel Prize in Chemistry to Benjamin List and David W. C. MacMillan for the development of asymmetric organocatalysis. The evolution of asymmetric organocatalysis has enabled many asymmetric carbon–carbon bond-forming reactions, previously achieved using chiral Lewis acid and Lewis base catalysts, to be performed under metal-free conditions.

More recently, redox-type asymmetric coupling reactions, which have traditionally been the domain of transition-metal catalysis, have also become increasingly accessible through chiral halogen catalysis. Furthermore, advances in Light-Emitting Diode (LED) technology have enabled precise control of photochemical processes, attracting considerable interest in hybrid catalytic systems that combine photocatalysis with chiral organocatalysis. In the development of pharmaceuticals and agrochemicals, chiral compounds with optical purities exceeding 99% ee are generally required. When asymmetric catalytic reactions afford chiral compounds with high enantioselectivities, optical purities greater than 99% ee can often be achieved through purification methods such as recrystallization or optical resolution using HPLC equipped with chiral stationary phases.

Although asymmetric catalysis is often regarded as a mature discipline, having already produced two Nobel Prizes in Chemistry, numerous challenges remain to be addressed. These include element strategies, remote asymmetric induction, the construction of quaternary stereogenic centers, and the simultaneous control of multiple selectivities, including enantioselectivity, diastereoselectivity, regioselectivity, chemoselectivity, site selectivity, substrate selectivity, and reaction selectivity. In

addition, practical issues such as scale-up, production costs, toxicity, and safety continue to demand innovative solutions. Indeed, the pursuit of fundamentally new concepts in asymmetric catalysis remains one of the grand challenges in modern synthetic and catalytic chemistry. In light of the needs of modern society, particularly the creation of new pharmaceuticals and agrochemicals, continued innovation in asymmetric catalysis is more important than ever.

I sincerely hope that this Special Issue will stimulate further advances in asymmetric catalysis and inspire the development of new catalytic concepts, thereby contributing to a sustainable society and the well-being of humankind.

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Associate Editor-in-Chief