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Preface to the special issue on "Analysis of solid-liquid interfaces in heterogeneous catalysis"

Heterogeneous catalysis is the basis of many processes in chemical industry including petrochemistry as well as increasingly emerging areas such as biomass valorization, renewable hydrogen production, CO_2 conversion, and plastic recycling. The favorable properties of solid catalysts related to synthesis, stability, and reusability help researchers in developing new, sustainable catalytic processes. The utmost important research topic of heterogeneous catalysis is elucidating and controlling the reactants' (liquids or gases) interaction with the catalyst's (solid) active sites, providing insightful information for rational catalyst design for various energy and environmental applications. This triggered the advancement of existing analytical techniques and the development of new techniques/methods to gain an in-depth understanding of the reactant-catalyst interaction at solid-gas and solid-liquid interfaces.

In recent years, significant attention has been shifted from classical heterogeneous gas-phase reactions (solid-gas interface) to heterogeneous liquid-phase reactions (solid-liquid interface) because many newly developed industrial processes occur at the interface between a solid catalyst and liquid reactants. However, the complex chemistry of the solid-liquid interfaces poses new challenges in elucidating realistic catalyst properties, which is vital for rational catalyst design that is desired for speeding up the development of efficient catalytic processes. Solvents are essential for liquid-phase heterogeneous catalysis to alter kinetics and product distribution. They affect the diffusion/adsorption properties of reactants and reactive intermediates by interacting competitively with solid catalysts. This usually complicates solid-liquid interface analysis. With the rising focus of heterogeneous catalysis on sustainable production and the use of renewable energy and feedstock, the focus is shifting towards heterogeneous photo- and electrocatalysis, which creates new challenges to the analysis of surface/interface chemistry.

Advances in spectroscopy and surface science achieved during the last two decades provide promising opportunities to study solid-liquid interfaces in heterogeneous catalysis. Particularly, Raman, infrared, UV–vis, and X-ray spectroscopy techniques have been extended to investigate liquid-phase reactions under working conditions. Thus, they enable now to study the nature/strength of active sites (e.g., acid-base and redox properties) and to identify reactive surface intermediates, adsorption/desorption properties, and reasons for catalyst deactivation. Considerable development has also been seen in microscopic studies, which help to visualize morphology changes such as size and shape of catalyst particles after or during the reaction. Besides, recent developments in density functional theory studies for understanding solvent effects, kinetics and mechanistic changes helped to identify reaction mechanisms on solid-liquid interfaces in heterogeneous catalysis.

This Special Issue entitled "Analysis of Solid-Liquid Interfaces in Heterogeneous Catalysis" highlights recent research endeavors and developments in liquid-phase heterogeneous catalysis, while shining light on the solid–liquid interfaces. The notable energy and environmental topics covered in this SI are biomass conversion, industrial catalysis, C-C/C-N bond formation, photocatalysis, and energy storage and conversion devices. Sustainable methods for solid catalyst synthesis using biomass waste and ultrasound, application of various advanced analytical techniques for solid catalysts characterization, and the role of microwave energy in heterogeneous catalysis are critically discussed in this SI. In addition, several contributions emphasized the role of solvent-free methods in heterogeneous catalysis as well as the role of solvents reactions catalyzed by metal oxides such as CeO_2 and $CuAl_2O_4$. All articles providede useful information on the structure and the behavior of solid catalysts in liquid phase reactions, as well as on the relationship between active sites and their interaction with reactants/reactive intermediates.

The Guest Editors would like to thank the authors for accepting the invitation and submitting their excellent results to this Special Issue. The Guest Editors would also like to thank the reviewers for evaluating the manuscripts and providing valuable comments/suggestions that helped to improve their quality significantly. We hope that catalysis researchers will find this Special Issue both informative and inspiring for their future research activities in liquid-phase heterogeneous catalysis.

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