Design and Applications of Single-Site Heterogeneous Catalysts

Progress in catalysis has been, is, and always will be driven by the needs of society. It is indeed remarkable that the manufacturing processes of 90% of all commercial chemical products involve catalysts at some stage. Catalysis was exploited industrially decades before the basic foundations for understanding the catalytic process were established. The fact that catalysis emerged as a technology earlier than as a science leads to the continuing evolution of this vibrant research area in the never-ending search for better materials, cleaner processes, alternative raw materials with a wider use of renewable feedstocks, reduced energy consumption, new ways to produce and store energy, etc. In analogy to the vital role of the heart for the functioning of the human body, catalysts drive processes by controlling reaction paths, thus giving sense to all the pipework and multiple unit operations of a huge chemical plant.

Advances in the synthesis and characterization of heterogeneous catalysts, with a better understanding of the relationship between their properties and performance, provide the essential ingredients for "rational catalyst design", which ultimately targets sustainable manufacturing practices. Here, "sustainable" implies satisfying the objectives of economic growth, social progress, and environmental protection.

This book, written by the distinguished Welsh chemist and educator Sir John Meurig Thomas, fits the purpose like a glove, giving a comprehensive overview of the contribution of single-site heterogeneous catalysts (SSHCs) to cleaner technologies in a wide range of commercially important applications. As one expects from a leading scientist in heterogeneous catalysis, solid-state chemistry, and materials science, as well as an outstanding communicator, this book is a joy to read, bridging between fundamental and applied research, and making frequent excursions from general to specialized concepts. All this is achieved with impeccable clarity. The narrative is enriched by interesting examples and personal experiences from a lifelong involvement in the area. The book consists of eight chapters divided into three well-balanced thematic parts. It is nicely illustrated and includes references to both well-established literature and recent important publications.

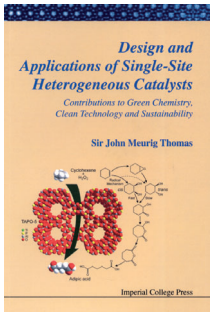
Part I introduces the concept of the single-site heterogeneous catalyst, with emphasis on analogies between SSHCs and enzymes, and differences between SSHCs and immobilized homogeneous catalysts. SSHCs have active centers of a quasi-identical nature that are spatially isolated yet accessible, and function in essentially independent ways. Such a situation can be achieved in porous inorganic or hybrid solids with well-defined structures. This approach makes it possible to gain an improved molecular-level understanding of heterogeneous catalysts, which often consist of sites that differ widely in structure and composition, and thus in reactivity.

Part II deals with the application of microporous structures for the design and realization of novel SSHCs. The first chapter concentrates on structural features of zeolites (aluminosilicates) and zeotypes such as aluminophosphates, metalloaluminophosphates, and silico-aluminophosphates, and describes approaches to introducing isolated catalytically-active sites into these frameworks. The following chapter describes the applications of SSHCs produced by different methods in a wide variety of acid-, redox-, and bifunctional-catalyzed reactions, including examples of industrial relevance, ranging from bulk to fine chemistry. For each case, structural and mechanistic details are described, giving an insight into the catalytic behavior, while maintaining a good balance of depth and conciseness throughout. The author stresses the environmental and economic advantages derived from the use of SSHCs (high turnover, reduction of side-products, solvent-free operation, use of benign reagents or renewable feedstocks, one-pot reactions, etc.).

Keeping a structure similar to that of Part II, Part III deals with the introduction of active centers into ordered mesoporous materials and the corresponding applications. Major emphasis is placed on mesoporous silicas with grafted metals and metal complexes, while also touching upon materials such as clays and metal-organic frameworks.

The last chapters of the book cover interesting aspects such as the utilization of confinement in ordered porous solids for asymmetric conversions, and the use of bimetallic nanoclusters (fewer than 20 atoms) stabilized on well-defined pores for applications in solvent-free hydrogenation. These challenging topics are still in their infancy, which further illustrates the timeliness of the book.

In summary, this book succeeds in its aim of equipping readers with interconnected and state-of-the-art concepts in the synthesis and characterization of single-site heterogeneous catalysts. The result is admirable, firmly establishing the position of SSHCs within the broad field of heterogeneous catalysis, and highlighting the ways in which they can be applied beneficially to the design of more efficient processes in an environmentally responsible manner.



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The didactic yet detailed writing style ensures that the book will be an excellent learning resource, both for advanced undergraduate and graduate students wishing to apply modern concepts of catalysis, materials, and green chemistry, and certainly also as a source of inspiration for one's own research.

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