

The background of the cover is a deep blue with faint, light blue chemical structures. These include skeletal structures of alkenes with 'R' groups, carbonyl groups (C=O), and various coordination complexes involving cobalt (Co) and carbon monoxide (CO).

Industrial Catalysis:

Chemistry and Mechanism

James D. Burrington

Imperial College Press

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Industrial Catalysis:

Chemistry and Mechanism

To
Rebecca

Foreword

Why should we study catalysis?

- The vast majority of high-volume chemicals are produced using catalysis
- Catalysis is the most cost-effective form of chemistry: the highest cost materials are recycled
- Catalysis is the key to solving many of the world's environmental problems

Topics

- Introduction to Industrial Catalysis
- Acid Catalysis
- Oxidation Catalysis
- Polymerization Catalysis
- Reduction Catalysis/
Hydrogenation
- Environmental Catalysis
- Catalysis Characterization

Within the context of chemistry as a business, catalysis provides the means by which the vast majority of chemicals (on a volume basis) are produced. This can be understood based on the key features of a catalytic process — the efficient conversion of the lowest-cost raw materials to value-added products by processes in which the highest-cost components that effect the reaction are regenerated. In the chemical synthesis laboratory, where the formation of the desired products in the highest purity possible is more important than the cost of its production, these materials are called “reagents,” which are consumed in the process and discarded. Every chemist has used such reagents at some point, for example, potassium permanganate for oxidation or lithium aluminum hydride for reduction. Of course, for very high-value products, this strategy also makes commercial sense.

But even in those cases, there are growing environmental and economic driving forces for the use of catalysis as a means to reduce or prevent pollution as opposed to end-of-pipe waste treatment. Pollution that is not produced in the first place makes more cost-effective use of raw materials and reduces environmental impact of chemical operations.

Catalysis has also been a key technology for solving the world's growing emissions limitations, especially for passenger cars and heavy-duty diesel engines for which catalysts are the heart of commercialized emissions reduction devices. Future catalytic scientists and engineers will play a key role in meeting future emission and fuel economy requirements.

Catalysis is truly an interdisciplinary technology, the practice of which requires knowledge of many disciplines, among them, chemistry, chemical engineering and material science. Each of these studies, in their own right, defines a distinct and coherent body of knowledge and each contributes an important perspective on catalysis. And yet, catalysis remains, first and foremost, a chemical phenomenon, and its successful application starts with an understanding of the underlying chemistry. This text attempts to provide a chemical basis for that understanding as a primer for future industrial chemists.

The text is composed of seven chapters: the introduction; four chapters dealing with the major catalytic reaction types of commercial importance: acid catalysis, oxidation, polymerization, reduction/hydrogenation; a chapter devoted to catalytic processes for environmental applications, mainly exhaust gas treatment; and one of methods for analytical characterization.

Chapter 1 (Introduction) is an overview of the history and basic concepts of catalysis and commercial catalytic processes. Chapters 2–6 are presented in three sections: basic Concepts, which covers the fundamental chemical transformations and mechanistic principles, elements of Catalyst Design, which discusses the catalyst parameters important for design of industrial catalysts, and major industrial processes: reaction chemistry and mechanism and catalyst characterizations. Chapter 7 presents the principles and applications of several key analytical methods for catalyst characterization.

In addition to the core areas of study, there are also embedded in the chapters “Toolkit” Topics, which will help the student to master skills associated with the practice of industrial catalysis.

These include:

- (1) The representation of catalytic mechanisms using the Tolman formalism,
- (2) Methods for the preparation of industrial catalysts, especially heterogeneous catalysts,
- (3) Elements of catalyst process engineering, including measurement of process and catalyst efficiency and catalyst design,
- (4) Application of methods of analysis for a given catalyst and reaction situation,
- (5) Analysis of studies in catalysis from the scientific literature.

Toolkit Topic discussions will include practical examples for students to use in the study and mastery of these skills.

Catalysis “Toolkit” Topics

- Representing catalytic mechanisms
- Methods of catalyst preparation
- Catalysis process
- Engineering concepts
- Catalyst characterization/analysis
- Catalysis literature

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1

An Introduction to Industrial Catalysis

While catalysis is a multidisciplinary science, it is first and foremost a chemical phenomenon, and it is the intent of this text to emphasize its chemical aspects. At the heart of catalytic chemistry is the mechanism by which reactants interact with catalyst, catalytic intermediates are interconnected and products are formed. The foundations of mechanism covered in this chapter will be repeatedly used in subsequent discussions of the various catalytic reaction types.

Another important distinction in catalytic science and technology is that of homogeneous versus heterogeneous catalysis. It is not just a distinction based on the number of phases present in the reaction, but one which also encompasses fundamentally different chemistries and process engineering, with distinct advantages and disadvantages. Finally, in this chapter there will be a summary of the major industrial processes and reaction types, covered in greater detail in each of the subsequent chapters.

1.1 Historical Background

As with any new endeavor, it is useful to begin our studies with a historical perspective, a set of definitions, a few basic concepts and some examples which will provide the basis on which the rest of the course will be built.