Mass Transfer In Heterogeneous Catalysis

Appropriate for a one-semester undergraduate or first-year graduate course, this text introduces the quantitative treatment of chemical reaction engineering. It covers both homogeneous and heterogeneous reacting systems and examines chemical reaction engineering as well as chemical reactor engineering. Each chapter contains numerous worked-out problems and real-world vignettes involving commercial applications, a feature widely *praised by reviewers and teachers. 2003 edition. This is a book for developers of catalysts, and for practitioners working in the field of design, operation, and optimization of chemical reactors in which heterogeneous catalysis is performed. It is designed to give a better understanding of the phenomena which can influence catalyst performance. Since two disciplines, chemistry and chemical engineering, meet in catalyst research and development, this book covers the chemical point of view for engineers, and the engineering point of view for chemists. It starts with an introduction explaining selectivity, activity and effectiveness providing the fundamentals for the* *newcomer. Catalyst preparation and catalyst testing are also described. A method is introduced that can be used to calculate the effectiveness of catalyst pellets as a function of shape, size, pore size, type of kinetics and diffusion, and temperature and pressure conditions. Optimization of catalysts and troubleshooting are also covered. This is a book without any rilvals because of its practical relevance. Advanced Oxidation Processes – Applications, Trends, and Prospects constitutes a comprehensive resource for civil, chemical, and environmental engineers researching in the field of water and wastewater treatment. The book covers the fundamentals,* *applications, and future work in Advanced Oxidation Processes (AOPs) as an attractive alternative and a complementary treatment option to conventional methods. This book also presents state-of-the-art research on AOPs and heterogeneous catalysis while covering recent progress and trends, including the application of AOPs at the laboratory, pilot, or industrial scale, the combination of AOPs with other technologies, hybrid processes, process intensification, reactor design, scale-up, and optimization. The book is divided into four sections: Introduction to Advanced Oxidation Processes, General Concepts of Heterogeneous Catalysis, Fenton and Ferrate in*

Wastewater Treatment, and Industrial Applications, Trends, and Prospects.

Our knowledge of mass transfer processes has been extended and applied to various fields of science and engineering including industrial processes in recent years. Since mass transfer is primordial phenomenon, it plays a key role in the scientific researches and fields of mechanical, energy, environmental, materials, bio, and chemical engineering. In this book, energetic authors especially provide advances in scientific findings and technologies, and develop new theoretical models concerning mass transfer for sustainable energy and environment. This book brings valuable *references for research engineers working in the variety of mass transfer sciences and related fields. Since the constitutive topics cover the advances in broad research areas, the topics will be mutually stimulus and informative not only to research engineers, but also to university professors and students.*

The publication of the third edition of "Chemical Engineering Volume" marks the completion of the re-orientation of the basic material contained in the first three volumes of the series. Volume 3 is devoted to reaction engineering (both chemical and biochemical), together with measurement and process control. This *text is designed for students, graduate and postgraduate, of chemical engineering. Heterogeneous catalysis plays a part in the production of more than 80% of all chemical products. It is therefore essential that all chemists and chemical engineers have an understanding of the fundamental principles as well as the applications of heterogeneous catalysts. This book introduces the subject, starting at a basic level, and includes sections on adsorption and surface science, catalytic kinetics, experimental methods for preparing and studying heterogeneous catalysts, as well as some aspects of the design of industrial catalytic reactors. It ends with a chapter* *that covers a range of examples of important catalytic processes. The book leads the student to carrying out a series of "tasks" based on searches of the internet and also on the use of web-based search tools such as Scopus or Web of Science. These tasks are generally based on the text; they can be used entirely for self-study but they can also be tailored to the requirements of a particular course by the instructor/lecturer giving the course. The author has had over 40 years of experience in catalytic research as well as in lecturing on the principles of catalysis. He was for more than 20 years the Editor of Catalysis Today. Coverage of all aspects of catalysis in carefully organised text*

Inclusion of material on the historical development of the subject and the personalities involved All concepts illustrated by practical examples Inclusion of a wide range of problems and solutions, case studies, and supplementary web based material which will be regularly updated Author has over 40 years research experience of almost all covered subjects Provides companion materials webiste

Plasma catalysis is gaining increasing interest for various gas conversion applications, such as CO2 conversion into value-added chemicals and fuels, N2 fixation for the synthesis of NH3 or NOx, methane conversion into higher hydrocarbons or oxygenates. It *is also widely used for air pollution control (e.g., VOC remediation). Plasma catalysis allows thermodynamically difficult reactions to proceed at ambient pressure and temperature, due to activation of the gas molecules by energetic electrons created in the plasma. However, plasma is very reactive but not selective, and thus a catalyst is needed to improve the selectivity. In spite of the growing interest in plasma catalysis, the underlying mechanisms of the (possible) synergy between plasma and catalyst are not yet fully understood. Indeed, plasma catalysis is quite complicated, as the plasma will affect the catalyst and vice versa. Moreover, due to the reactive plasma* *environment, the most suitable catalysts will probably be different from thermal catalysts. More research is needed to better understand the plasma–catalyst interactions, in order to further improve the applications.*

Fundamentals and Applications

Reaction Kinetics and the Development and Operation of Catalytic Processes

An Integrated Textbook for Students

Structured Catalysts and Reactors

A Microreactor System for High-pressure, Multiphase Homogeneous and Heterogeneous Catalyst Measurements Under Continuous Flow

from Laboratory Synthesis to Industrial Production
Fundamentals of Chemical Reaction Engineering
Advances in Sustainable Energy and Environment Oriented Numerical Modeling
Molecular Heterogeneous Catalysis
Chemical Reactor Development
Essentials, Exercises and Examples

Heterogeneous catalysis and mathematical modeling are essential components of the continuing search for better utilization of raw materials and energy, with reduced impact on the environment. Numerical modeling of chemical systems has progressed rapidly due to increases in computer *power, and is used extensively for analysis, design and development of catalytic reactors and processes. This book presents reviews of the state-of-the-art in modeling of heterogeneous catalytic reactors and processes. Reviews by leading authorities in the respective areas Up-to-date reviews of latest techniques in modeling of catalytic processes Mix of US and European authors, as well as academic/industrial/research institute perspectives Connections between computation and experimental methods in some of the chapters*

This book covers a wide variety of topics related to advancements in different stages of mass transfer modelling *processes. Its purpose is to create a platform for the exchange of recent observations, experiences, and achievements. It is recommended for those in the chemical, biotechnological, pharmaceutical, and nanotechnology industries as well as for students of natural sciences, technical, environmental and employees in companies which manufacture machines for the above-mentioned industries. This work can also be a useful source for researchers and engineers dealing with mass transfer and related issues. Characterization of the interactions of hydrogen with catalytic metal surfaces and the mass transfer processes involved in heterogeneous catalysis are important for* *catalyst development. Although a range of technologies for studying catalytic surfaces exists, much of it relies on high-vacuum conditions that preclude in-situ research. In contrast, atomic force microscopy (AFM) provides an opportunity for direct observation of surfaces under or near actual reaction conditions. Tapping-mode AFM was explored here because it expands AFM beyond the usual topographic information toward speciation and other more subtle surface information. This work describes using phase-angle data from tapping-mode AFM to follow the interactions of hydrogen with palladium. Both gas-solid and liquid-solid interfaces were studied. Real-time AFM phase-*

angle data allowed for the observation of multiphase mass transfer to and from the surface of palladium at atmospheric pressure and room temperature without the need for complex sample preparation. The AFM observations were quantitatively benchmarked against and confirm mass transfer predictions based on bulk hydrogen diffusion estimates. Additionally, they support recent studies that demonstrate the existence of multiple hydrogen states during interactions with palladium surfaces.

The features of this book which will be of special interest to academic organic chemists are the introduction (Chapter 1), which presents a short course on the concepts and language *of heterogeneous catalysis, covers organic reaction mechanisms of hydrogenation (Chapter 2), hydrogenolysis (Chapter 4), and oxidation (Chapter 6), a presents problems and solutions specific for running heterogeneous catalytic organic reactions in solution. These materials can supplement advanced chemistry courses. Most synthetic organic chemists use a variety of "protecting groups" which they attach to functional groups (reactive groups of atoms) while some reaction is being conducted on another part of the molecule. These protecting groups prevent reactions of the functional groups during other reactions and are removed later by a heterogeneous catalytic method called* *hydrogenolysis. One unique feature of this book, not found in other books on catalysis, is an exhaustive chapter (Chapter 4) on hydrogenolysis, which is dredged from the recent synthetic literature published by modern organic chemists. Academic organic chemists should find this chapter extremely useful and may wish to adopt the book as a supplement for advanced organic chemistry courses designed for seniors and for graduate students. It will also be useful for professors and their research groups engaged in synthetic organic chemistry. Many academic organic chemists are not aware of recent advances in heterogeneous enantioselective catalysis (Chapter 3) or in selective low* *temperature, liquid phase heterogeneous catalytic oxidations by hydrogen peroxide (Chapter 6). These specialty topics are timely and may be new to academic organic chemists and can be used to supplement their advanced courses. Several features of this book will also be of special interest to industrial chemists who are unfamiliar with heterogeneous catalysis. Many good organic chemists are hire by industry. They synthesize a new compound using standard organic synthetic techniques but are informed by their supervisor that they must convert some of their synthetic steps into heterogeneous catalytic steps. They may not have been exposed to heterogeneous catalysis and have few places to* *turn. This book offers them a crash course in heterogeneous catalysis as well as many examples of reactions and conditions with which they can start their search. Those industrial organic chemists already familiar with heterogeneous catalysis will find this book useful as a reference to many examples in the recent literature. They will find recent surface science discoveries correlated with heterogeneous catalysis or organic reactions and mechanistic suggestions designed to stimulate innovative nontraditional thinking about organic reactions on surfaces. Written by organic chemists for organic chemists Introduces heterogeneous catalysis concepts and language Presents a* *comprehensive compilation of protecting group removal procedures Covers liquid-phase hydrogenations, hydrogenolysis, and oxidations Addresses heterogeneous methods for producing pure enantiomers of chiral products Examines the emerging field of heterogenized homogeneous catalysts Mixes practical applications with mechanistic interpretations*

With well over 90% of all processes in the industrial chemical production being of catalytic nature, catalysis is a mature though ever interesting topic. The idea of this book is to tackle various aspects of heterogeneous catalysis from the engineering point of view and go all the way from *engineering of catalysis, catalyst preparation, characterization, reaction kinetics, mass transfer to catalytic reactors and the implementation of catalysts in chemical technology. Aimed for graduate students it is also a useful resource for professionals coming from the more academic side.*

Written by an excellent, highly experienced and motivated team of lecturers, this textbook is based on one of the most successful courses in catalysis and as such is tried-and-tested by generations of graduate and PhD students, i.e. the Catalysis-An-Integrated-Approach (CAIA) course organized by NIOK, the Dutch Catalysis research school. It covers all *essential aspects of this important topic, including homogeneous, heterogeneous and biocatalysis, but also kinetics, catalyst characterization and preparation, reactor design and engineering. The perfect source of information for graduate and PhD students in chemistry and chemical engineering, as well as for scientists wanting to refresh their knowledge*

Catalysis is a multidisciplinary activity which is reflected in this book. The editors have chosen a novel combination of basic disciplines - homogeneous catalysis by metal complexes is treated jointly with heterogeneous catalysis with metallic and non-metallic solids. The main theme of the book is the *molecular approach to industrial catalysis. In the introductory section Chapter 1 presents a brief survey of the history of industrial heterogeneous and homogeneous catalysis. Subsequently, a selection of current industrial catalytic processes is described (Chapter 2). A broad spectrum of important catalytic applications is presented, including the basic chemistry, some engineering aspects, feedstock sources and product utilisation. In Chapter 3, kinetic principles are treated. The section on fundamental catalysis begins with a description of the bonding in complexes and to surfaces (Chapter 4). The elementary steps on complexes and surfaces are described. The chapter on* *heterogeneous catalysis (5) deals with the mechanistic aspects of three groups of important reactions: syn-gas conversion, hydrogenation, and oxidation. The main principles of metal and metal oxide catalysis are presented. Likewise, the chapter on homogeneous catalysis (6) concentrates on three reactions representing examples from three areas: carbonylation, polymerization, and asymmetric catalysis. Identification by in situ techniques has been included. Many constraints to the industrial use of a catalyst have a macroscopic origin. In applied catalysis it is shown how catalytic reaction engineering deals with such macroscopic considerations in heterogeneous as well as* *homogeneous catalysis (Chapter 7). The transport and kinetic phenomena in both model reactors and industrial reactors are outlined. The section on catalyst preparation (Chapters 8 and 9) is concerned with the preparation of catalyst supports, zeolites, and supported catalysts, with an emphasis on general principles and mechanistic aspects. For the supported catalysts the relation between the preparative method and the surface chemistry of the support is highlighted. The molecular approach is maintained throughout. The first chapter (10) in the section on catalyst characterization summarizes the most common spectroscopic techniques used for the characterisation of heterogeneous* *catalysts such as XPS, Auger, EXAFS, etc. Temperature programmed techniques, which have found widespread application in heterogeneous catalysis both in catalyst characterization and simulation of pretreatment procedures, are discussed in Chapter 11. A discussion of texture measurement, theory and application, concludes this section (12). The final chapter (13) gives an outline of current trends in catalysis. Two points of view are adopted: the first one focusses on developments in process engineering. Most often these have their origin in demands by society for better processes. The second point of view draws attention to the autonomous developments in catalysis, which is becoming* *one of the frontier sciences of physics and chemistry. In this book emphasis is on those reactions catalyzed by heterogeneous and homogeneous catalysts of industrial relevance. The integrative treatment of the subject matter involves many disciplines, consequently, the writing of the book has been a multi-author task. The editors have carefully planned and harmonized the contents of the chapters.*

Optimizing Catalysts and Processes

A Study of Mass Transfer Effects in Heterogeneous Catalysis ...

Chemical Reaction Engineering
Catalysis Looks to the Future
Chapter 1. Basis of Heterogeneous Catalysis
Advancement in Process Modelling
Theory, Design, Manufacturing, and Applications
Heterogeneous Catalysis in Industrial Practice
Mass Transfer for Heterogeneous Catalysis in a Slurry Reactor
Studying Liquid-phase Heterogeneous Catalysis Using the Atomic Force Microscope

Provides a holistic approach to multiphase catalytic reactors from their modeling and design to their

applications in industrial manufacturing of chemicals Covers theoretical aspects and examples of fixed-bed, fluidized-bed, trickle-bed, slurry, monolith and microchannel reactors Includes chapters covering experimental techniques and practical guidelines for lab-scale testing of multiphase reactors Includes mathematical content focused on design equations and empirical relationships characterizing different multiphase reactor types together with an assortment of computational tools Involves detailed coverage of multiphase reactor applications such as Fischer-Tropsch synthesis, fuel processing for fuel cells, hydrotreating of oil fractions and biofuels processing This textbook is a perfect introduction to

heterogeneous catalysis focusing on the industrial implementation. It is written in a comprehensible manner using language that is easy accessible and provides problems to practice.

Blending theory and practice, this text provides the information needed to work with solid catalysts in the laboratory, pilot plant or commercial installation. This revised and expanded edition incorporates recent theories and industrial applications.

The shift towards biomass and lower quality fossil fuel feedstocks will require new conversion approaches. Catalysis will be critical in the processing of these new feedstocks. By studying catalysis at industrially relevant conditions, it may be

possible to reduce the time and cost of developing new catalyst systems. Microreactors enable the study of multiphase catalyst systems at pressures that were previously difficult to attain on the laboratory scale. The reduced length scales, characteristic of microchemical systems, provide additional benefits such as enhanced heat and mass transfer and a reduction of hazardous waste. The improved heat and mass transfer allow for kinetics to be probed at isothermal conditions in the absence of complicating mass transfer effects. A high-pressure microreactor system for catalyst study was designed, fabricated, and tested. The system allows for the multiphase study of homogenously and heterogeneously

catalyzed systems, with a unique reactor designed for each application. A multicomponent gas phase is delivered simultaneously with a liquid stream, resulting in regular segmented (slug) flow. The isobaric system is operated at pressures of up to 100 bar. Gas and liquid flow rates, and therefore residence time, are specified independently of pressure. The system is capable of being operated at temperatures of up to 350°C and residence times of up to 15 minutes. Inline analysis, using an attenuated total reflection FTIR flow cell, and sample collection for offline analysis can be performed simultaneously. Both homogeneous and heterogeneous catalysis were demonstrated in the high-pressure system. A kinetic

expression was derived for the homogeneous hydroformylation of terminal alkenes, catalyzed by Wilkinson's catalyst. The empirical reaction orders for the dependence on catalyst, hydrogen, and carbon monoxide were determined, along with the activation energy and pre-exponential factor. These results were then reconciled with a mechanistic model. The hydrogenation of cyclohexene over platinum catalysts was chosen to demonstrate the performance of the heterogeneous reactor. This reaction proceeded rapidly allowing mass transfer to be characterized in the microreactor. Observed mass transfer rates were two orders of magnitude higher than in traditional systems.

Laurence Belfiore's unique treatment meshes two mainstream subject areas in chemical engineering: transport phenomena and chemical reactor design. Expressly intended as an extension of Bird, Stewart, and Lightfoot's classic Transport Phenomena, and Froment and Bischoff's Chemical Reactor Analysis and Design, Second Edition, Belfiore's unprecedented text explores the synthesis of these two disciplines in a manner the upper undergraduate or graduate reader can readily grasp. Transport Phenomena for Chemical Reactor Design approaches the design of chemical reactors from microscopic heat and mass transfer principles. It includes simultaneous consideration of kinetics and heat transfer, both

critical to the performance of real chemical reactors. Complementary topics in transport phenomena and thermodynamics that provide support for chemical reactor analysis are covered, including: Fluid dynamics in the creeping and potential flow regimes around solid spheres and gas bubbles The corresponding mass transfer problems that employ velocity profiles, derived in the book's fluid dynamics chapter, to calculate interphase heat and mass transfer coefficients Heat capacities of ideal gases via statistical thermodynamics to calculate Prandtl numbers Thermodynamic stability criteria for homogeneous mixtures that reveal that binary molecular diffusion coefficients must be positive In

addition to its comprehensive treatment, the text also contains 484 problems and ninety-six detailed solutions to assist in the exploration of the subject. Graduate and advanced undergraduate chemical engineering students, professors, and researchers will appreciate the vision, innovation, and practical application of Laurence Belfiore's Transport Phenomena for Chemical Reactor Design.

The impact of catalysis on the nation's economy is evidenced by the fact that catalytic technologies generate U.S. sales in excess of $400 billion per year and a net positive balance of trade of $16 billion annually. This book outlines recent accomplishments in the science and technology of catalysis and

summarizes important likely challenges and opportunities on the near horizon. It also presents recommendations for investment of financial and human resources by industry, academe, national laboratories, and relevant federal agencies if the nation is to maintain continuing leadership in this field--one that is critical to the chemical and petroleum processing industries, essential for energy-efficient means for environmental protection, and vital for the production of a broad range of pharmaceuticals.

High throughput experimentation has met great success in drug design but it has, so far, been scarcely used in the field ofcatalysis. We present in

this book the outcome of a NATO ASI meeting that was held in Vilamoura, Portugal, between July 15 and 28, 2001, with the objective of delineating and consolidating the principles and methods underpinning accelerated catalyst design, evaluation, and development. There is a need to make the underlying principles of this new methodology more widely understood and to make it available in a coherent and integrated format. The latter objective is particularly important to the young scientists who will constitute the new catalysis researchers generation. Indeed, this field which is at the frontier offundamental science and may be a renaissance for catalysis, is one which is much more complex than

classical catalysis itself. It implies a close collaboration between scientists from many disciplines (chemistry, physics, chemical and mechanical engineering, automation, robotics, and scientific computing in general). In addition, this emerging area of science is also of paramount industrial importance, as progress in this area would collapse the time necessary to discover new catalysts or improve existing ones.

Mass Transport in Solids

Surface Organometallic Chemistry: Molecular Approaches to Surface Catalysis

Heterogeneous Catalysis

Computational Catalysis

Plasma Catalysis
Chemical and Catalytic Reaction Engineering
Modeling and Simulation of Heterogeneous Catalytic Processes
Heterogeneous Catalysis of Mixed Oxides
Applications, Trends, and Prospects
Transport Phenomena for Chemical Reactor Design
Catalysis

An integrated approach to the molecular theory of reaction mechanism in heterogeneous catalysis, largely based on the knowledge among the growing theoretical catalysis community over the past half century, and covering all major catalytic systems. The authors develop a general conceptual framework, including in-

depth comparisons with enzyme catalysis, biomineralisation, organometallic and coordination chemistry. A chapter dedicated to molecular electrocatalysis addresses the molecular description of reactions at the liquid-solid interphase, while studies range from a quantum-chemical treatment of individual molecular states to dynamic Monte-Carlo simulations, including the full flexibility of the many-particle systems. Complexity in catalysis is explained in chapters on self-organization and self-assembly of catalysts, and other sections are devoted to evolutionary, combinatorial techniques as well as artificial chemistry.

This book presents a comprehensive review of the methods and approaches being adopted to push forward

the boundaries of computational catalysis.
Surface organometallic chemistry is a new field bringing together researchers from organometallic, inorganic, and surface chemistry and catalysis. Topics ranging from reaction mechanisms to catalyst preparation are considered from a molecular basis, according to which the "active site" on a catalyst surface has a supra-molecular character. This. the first book on the subject, is the outcome of a NATO Workshop held in Le Rouret. France, in May. 1986. It is our hope that the following chapters and the concluding summary of recommendations for research may help to provide a definition of surface organometallic chemistry. Besides catalysis. the central theme of the Workshop, four main

topics are considered: 1) Reactions of organometallics with surfaces of metal oxides, metals. and zeolites; 2) Molecular models of surfaces, metal oxides, and metals; 3) Molecular approaches to the mechanisms of surface reactions; 4) Synthesis and modification of zeolites and related microporous solids. Most surface organometallic chemistry has been carried out on amorphous high-surf ace-area metal oxides such as silica. alumina. magnesia, and titania. The first chapter. contributed by KNOZINGER. gives a short summary of the structure and reactivity of metal oxide surfaces. Most of our understanding of these surfaces is based on acid base and redox chemistry; this chemistry has developed from X-ray and spectroscopic data, and much has been

inferred from the structures and reactivities of adsorbed organic probe molecules. There are major opportunities for extending this understanding by use of well-defined (single crystal) oxide surfaces and organometallic probe molecules.

Our understanding of catalytic reactions exists at various levels which are mainly defined from detailed knowledge of reaction mechanism. When viewed in terms of the stoi chiometric reaction equation, most catalytic reactions are complex processes which occur via a sequence of elementary (i. e. irreducible) steps, and the elucidation ofthese elementary steps and the identification of a rate determining step (if one exists) constitutes the traditional approach to the problem of mechanism. The term

"traditional" is not used here in a pejorative sense since mechanistic knowledge of this sort makes an important contribution to catalyst design, improvement, and optimization. This is the field which is discussed by Professor R. L. Burwell in Chapter 1 where the very wide range of useful approaches and techniques is made apparent, even when one is restricted to quasi-steady state conditions. Techniques which depend on observations under non steady state conditions (i. e. relaxation methods) have also been used in mechanistic studies, increasingly so in recent years. This topic is discussed in detail by Professor K. Tamaru in Chapter 2. At a deeper level of understanding, one may seek to enquire how an elementary reaction proceeds in terms of

movement in a multicoordinate space where the variables define atomic positions and energy. This is a problem of great complexity even in relatively simple cases. Nevertheless, despite the problems some progress is being made, and this and allied topics are discussed in Chapter 3 by Professor G. L. Haller and Dr. G. W. Coulston.

Interest in structured catalysts is steadily increasing due to the already proven, as well as potential, advantages of these catalysts. Updating the comprehensive coverage of the first edition published in 1998 with the latest science and applications, Structured Catalysts and Reactors, Second Edition gives detailed information on all aspects of structured catalysts and reactors, including: materials,

mass transfer, selectivity, activity, and stability; catalyst preparation, design, and characterization; process development; modeling and optimization; reactor design; and operation costs and considerations. The book first examines how monolithic catalysts are used to clean exhaust gas from gasoline engines, treat industrial off-gases, burn fuels in commercial settings, and synthesize chemicals in two- and three-phase processes. It discusses configurations, microstructure, physical properties, and manufacture of ceramic and metallic monoliths before directing its focus to arranged catalysts and structured packings in terms of mass transfer. The book then explores catalytically active membranes and filters, featuring metallic membranes, permeation

mechanisms, preparation and modeling, commercial membranes, and the latest applications, such as zeolitic membranes. Finally, several chapters present techniques for incorporating catalytic species into the structured catalyst support and controlling catalyst nanoporosity. This book conveys the scientific as well as economic advantages of using these unconventional catalytic techniques. With over 1500 references, tables, drawings, and photographs, as well as in-depth discussions and a new approach to catalytic processes, Structured Catalysts and Reactors, Second Edition is an essential reference for anyone working with or studying catalysis. Atomic transport in solids is a field of growing importance in solid state physics and chemistry, and one

which, moreover, has important implications in several areas of materials science. This growth is due first to an increase in the understanding of the fund amentals of transport processes in solids. Of equal importance, however, have been the improvements in the last decade in the experi mental techniques available for the investigation of transport phenomena. The advances in technique have stimulated studies of a wider range of materials; and expansion of the field has been strong ly encouraged by the increasing range of applied areas where transport processes play an essential role. For example, mass transport phenomena play a critical role in the technology of fabrication of components in the electronics industry. Transport processes are involved *both during the fabrication and operation of devices and with the growing trend to miniaturisation there are increasing demands on accurate control of diffusion processes. The present book (which is based on a NATO sponsored Advanced Study Institute held in 1981 at Lannion, France) aims to present a general survey of the subject, highlighting those areas where work has been especially active in recent years.*

Chemical Reaction Engineering: Essentials, Exercises and Examples presents the essentials of kinetics, reactor design and chemical reaction engineering for undergraduate students. Concise and didactic in its approach, it features over 70 resolved examples and many exercises.The work is organized in two parts: in the

first part kinetics is presented

Mass Transfer in Multicomponent Mixtures
Applied Heterogeneous Ca...
An Integrated Approach to Homogeneous, Heterogeneous and Industrial Catalysis
Science and Technology
Essentials for Chemical Engineers
Engineering Catalysis
Mass Transfer
Mass Transfer in Heterogeneous Catalysis
Chemical and Biochemical Reactors and Process Control
Industrial Catalysis
Advanced Oxidation Processes

Describes how to conduct kinetic experiments with

heterogeneous catalysts, analyze and model the results, and characterize the catalysts Detailed analysis of mass transfer in liquid phase reactions involving porous catalysts. Important to the fine chemicals and pharmaceutical industries so it has appeal to many researchers in both industry and academia (chemical engineering and chemistry departments
Designed to give chemical engineers background for managing chemical reactions, this text examines the behavior of chemical reactions and reactors; conservation equations for reactors; heterogeneous reactions; fluid-fluid and fluid-solid reaction systems; heterogeneous catalysis and catalytic kinetics; diffusion and heterogeneous catalysis; and analyses and design of heterogeneous reactors. 1976 edition.
Chemical Reactor Development is written primarily for

chemists and chemical engineers who are concerned with the development of a chemical synthesis from the laboratory bench scale, where the first successful experiments are performed, to the design desk, where the first commercial reactor is conceived. It is also written for those chemists and chemical engineers who are concerned with the further development of a chemical process with the objective of enhancing the performance of an existing industrial plant, as well as for students of chemistry and chemical engineering. In Part I, the `how' and the `why' of chemical reaction engineering are explained, particularly for those who are not familiar with this area. Part II deals with the effects of a number of physical phenomena on the outcome of chemical reactions, such as micro and meso-mixing and residence time distribution, mass transfer between two phases, and the formation of another phase, such as in precipitations. These scale-dependent effects are not only important in view of the conversion of chemical reactions, but also with regard to the selectivity, and in the case of solid products, to their morphology. In Part III, some applications are treated in a general way, including organic syntheses, the conversion and formation of inorganic solids, catalytic processes and polymerizations. The last chapter gives a review of the importance of the selectivity for product quality and for the purity of waste streams. For research chemists and chemical engineers whose work involves chemical reaction engineering. The book is also suitable as a supplementary graduate text.

This book is a critical account of the principles of the kinetics of heterogeneous catalytic reactions in the light of recent developments in surface science and catalysis science. Originally published in 1984. The Princeton Legacy Library uses the latest print-on-demand technology to again make available previously out-of-print books from the distinguished backlist of Princeton University Press. These editions preserve the original texts of these important books while presenting them in durable paperback and hardcover editions. The goal of the Princeton Legacy Library is to vastly increase access to the rich scholarly heritage found in the thousands of books published by Princeton University Press since its founding in 1905.

A concise introduction is given to the fundamental knowledge

required to understand the heterogeneous catalysis of mixed oxides and to the concept of catalyst design. The fundamental knowledge includes the rate versus equilibrium relation; rate equation; the mechanism of catalytic reaction; essential functions of a catalyst, namely, activity, selectivity, and durability (or life); and catalytic reaction engineering such as mass and heat transfer. Typical methods for the preparation and characterization of catalysts and for the elucidation of the reaction mechanism, as well as a short history of industrial catalysts, are also provided.
Reaction Kinetics and the Development and Operation of Catalytic Processes is a trendsetter. The Keynote Lectures have been authored by top scientists and cover a broad range of topics like fundamental aspects of surface chemistry,

in particular dynamics and spillover, the modeling of reaction mechanisms, with special focus on the importance of transient experimentation and the application of kinetics in reactor design. Fundamental and applied kinetic studies are well represented. More than half of these deal with transient kinetics, a new trend made possible by recent sophisticated experimental equipment and the awareness that transient experimentation provides more information and insight into the microphenomena occurring on the catalyst surface than steady state techniques. The trend is not limited to purely kinetic studies since the great majority of the papers dealing with reactors also focus on transients and even deliberate transient operation. It is to be expected that this trend will continue and amplify as the community becomes more aware of the predictive potential of fundamental kinetics when combined with detailed realistic modeling of the reactor operation.

The science of catalytic reaction engineering studies the catalyst and the catalytic process in the laboratory in order to predict how they will perform in production-scale reactors. Surprises are to be avoided in the scaleup of industrial processes. The laboratory results must account for flow, heat and mass transfer influences on reaction rate to be useful for scaleup. Calculated performance based on these results must also be useful to maximization of profit and safety and minimization of pollution. To this end, information on products as well as byproducts and heat produced must be generated. If a sufficiently large database of knowledge is produced, optimization studies will be possible later if economic conditions change. The field of reaction engineering required new tools. For kinetic and catalyst testing, the most successful of these tools was the internal recycle reactor. Studies in recycle reactors can be made under well-defined conditions of flow and associated transfer processes, and close to commercial operation. The recycle reactor eliminates or minimizes the effect of transfer process, and allows the remaining ones to be known. Features of this book: • Provides insight into a field that is neither well understood nor properly appreciated. • Gives a deeper understanding of reaction engineering practice. • Helps avoid frustration and disappointment in industrial research. This book is short and clear enough to assist all members of the R&D and

Engineering team, whether reaction engineers, or specialists in other fields. This is critical in this new age of computation and communication, when team members must each know at least something of their colleagues' fields. Additionally, many scientists in more exploratory or fundamental fields can use recycle reactors to study basic phenomena free of transfer interactions.

Experiments in Catalytic Reaction Engineering
Kinetics of Heterogeneous Catalytic Reactions
Multiphase Catalytic Reactors
A Conceptual and Computational Approach
Kinetics of Catalytic Reactions
Heterogeneous Catalysis in Organic Chemistry
Principles and Methods for Accelerated Catalyst Design and

Testing