
Preface

The primary objective of this book is to present an up-to-date account of the science and engineering and industrial practice which underlie major areas of the chemical process industry. The heart of the book is contained in 42 chapters covering seven areas of the chemical process industry. It is to be noted that the products and processes associated with a particular area are discussed in the context of the corresponding chapter rather than in the isolated manner characteristic of an encyclopedia.

This edition of the *Handbook of Industrial Chemistry and Biotechnology*, the 13th, includes the topics addressed in the 12th edition, all of which have been carefully reviewed, updated, and revised as necessary. In addition, this edition includes six entirely new Chaps. 31, 32, 33, 38, 39, and 40. This edition starts off with defining industrial chemistry as the manufacturing art concerned with the transformation of matter into useful materials in useful amounts. *This transformation of available materials into more desirable ones involves some kind of a process, following a recipe. In turn the process may involve grinding, mixing together various ingredients, dissolving, heating, allowing ingredients to interact (chemically or biochemically react forming new compositions of matter), cooling, evaporating or distilling, growing crystals, filtering, and other physical-chemical-biological operations.*

Unlike in the previous editions, the 13th edition is organized into seven sections, each section being devoted to a specific area of industrial chemistry and biotechnology. These sections, each containing several relevant topics, are as follows: **Section 1: Raw Materials for the Chemical Process Industries, Section 2: Industrial Organic Chemistry, Section 3: Industrial Inorganic Chemistry, Section 4: Polymer Chemistry, Section 5: Biochemistry, Section 6: Emerging Fields of Industrial Chemistry, and Section 7: Industrial Processing and Engineering.**

This version also introduces a wealth of new, timely, and very useful “infrastructure” material, especially dealing with *electrochemical energy conversion and storage, process control and latest developments in distillation technologies, and CO₂ capture, storage, and utilization.* We also introduce a chapter on industrial chemistry of steel, a commonly used material in the industrial world. This chapter discusses not only the production processes of steel making but also the chemistry involved in these processes, and the

economics, environmental, and safety aspects of making steel. In keeping with past practice, all the chapters have been written by individuals with demonstrated expertise in their respective fields and been updated by including the latest statistics and technological developments. All told, the work may in many respects be regarded as a sourcebook for practice in the chemical process industries.

Concerning the infrastructure or contextual material mentioned above, Section 1 of the Handbook addresses the various raw materials that are the basis of chemical industries. These include petroleum, coal, natural gas, wood, and biomass which are the nuclei of major industrial operations. The chapter on “Biomass Conversion” is included in this section as it is the feedstock for new refineries that will produce fermentable sugars and chemical intermediates from which much needed forms of fuels can be made. Written by a team whose primary work lies in that area, it provides comprehensive coverage of the subject from biomass structure and composition to thermochemical and biological routes for conversion to energy and a host of chemicals and products including liquid transportation fuels.

Section 2 covers industrial organic chemistry based processes, which starts with an introduction to synthetic organic chemicals produced by the transformation of carbonaceous feedstocks into functionalized molecules through one or more chemical reactions. This is followed by a detailed description of pharmaceutical chemistry, the chemistry of dye intermediates, structural adhesives, the agrochemical industry, fertilizers, pigments, dyes, polymer coatings and printing inks, animal and vegetable fats, oils and waxes, sugars, soaps, fatty acids and synthetic detergents, chemical explosives, and the nuclear industry in Chaps. 8–18.

Section 3, which includes Chaps. 19–23, deals with synthetic nitrogen products, phosphorus and phosphates, sulfur and sulfuric acid, salt, the chlor-alkali industry, and industrial gases.

Section 4 addresses manufactured textile fibers, synthetic resins and plastics, and rubber in Chaps. 24–26.

Section 5 is comprised of topics in Biochemistry. Biotechnology first appeared in the (formerly) Riegel’s Handbook some time ago as a chapter titled “Industrial Fermentation.” It has since been updated several times and more recently was joined by a chapter on “Industrial Cell Culture.” Also, as might be expected by persons knowledgeable in the field, Chap. 14 “Animal and Vegetable Fats, Oils, and Waxes” is rich in related biotechnical content, as is effectively described in the chapter’s early pages. Chapter 27 introduces the industrial aspects of biotechnology from the discovery stage to delivery stage.

The focus of Section 6 is emerging technologies, which include nanotechnologies, energy conversion and storage, and CO₂ capture, storage, and utilization. The chapter on nanoparticles discusses basic principles for the formation of nanomaterials and their applications which have already made a societal impact and is shaping our lives.

The presently available renewable energy sources include wind, solar, tidal, biomass, and geothermal. To make an efficient use of these sources, it is essential that a reliable energy storage approach is available. Batteries, in

sizes accommodating pacemakers to megawatt load-leveling applications, are a more practical strategy for energy storage. Output energies typically exceed 90% of input energy at low power. Because high energy density battery manufacturing generates CO₂, high cycle life is essential. There are concerns with mass deployment of electric vehicles that rely on coal-fired plants for primary electricity. Internal combustion (IC) engines release less CO₂ per kilometer than an electric vehicle recharged with electricity from coal combustion.

Another class of highly efficient and environmentally friendly energy conversion devices is fuel cells, which are receiving increasing attention and are steadily moving towards commercialization. Fuel cells deliver electricity and heat, based on the spontaneous electrochemical oxidation of fuels at the anode and the reduction of oxygen at the cathode, without combustion. There are four leading types of fuels reviewed in this chapter, proton exchange membrane fuel cells (PEMFCs) operating on clean hydrogen, direct alcohol (primarily methanol) fuel cells (DAFCs), solid oxide fuel cells (SOFCs), and molten carbonate fuel cells (MCFCs). PEMFCs and DAFCs normally operate at below 100 °C and are targeted primarily for transportation and mobile applications, while SOFCs and MCFCs, which run at temperatures above 600 °C, can run on a wide variety of fuels and are intended mostly for stationary combined heat and power (CHP) applications. This review focuses on a description of each of these technologies, with an emphasis on the materials used in the electrodes, the electrolyte that separates them, and the current collectors.

Global warming resulting from the emission of greenhouse gases has received widespread environment and energy attention in the recent years. Among these greenhouse gases, CO₂ contributes over 60% to global warming due to its huge emission amount over 30 Gt CO₂ a year. Global CO₂ concentrations just passed 400 ppm in March, 2015, which is significantly higher than the preindustrial level of about 300 ppm. Chapter 33 addresses the world's existing and underdeveloped technologies for CO₂ utilization with focus on direct utilization of CO₂ and conversion of CO₂ to chemicals and energy products.

Section 7 contains chapters on “green chemistry,” providing a comprehensive discussion of Green Engineering, and application of the methods of green chemistry and engineering to process and product development activities, whether for new products and processes, or for upgrading older ones. Succinctly put, *green chemistry*, also termed *sustainable chemistry*, is described by that chapter's authors as “the use of chemistry to reduce pollution at the source, through the design of chemical products and processes that reduce or eliminate the use or generation of unwanted or hazardous substances.” *Green engineering* is defined as “the design, commercialization, and use of processes and products that are feasible and economical, yet at the same time minimize (1) generation of pollution at the source, and (2) risk to human health and the environment.” Risk assessment methods used in pollution prevention can help quantify the degree of impact for individual chemicals and thus are valuable tools for intelligent design of products and processes by focusing on the most beneficial methods to minimize risk.

A cursory look at the literature on green chemistry shows that catalysis is regarded as a very important tool. After all, if in the idealized case one can produce desired product B from A, with no unwanted side reactions or by-products, by choosing appropriate reaction conditions and a suitable catalyst, one will have done a great deal to promote efficiency and prevent pollution. Thus, the chapter on “Industrial Catalysis: a Practical Guide” is of special relevance. The chapter on “Environmental Chemical Determinations” discusses the many complex factors involved in detecting, tracking, and measuring chemical species which have found their way into the environment.

Chapter 38 provides developments in distillation technology as this unit operation is one of the important, if not the most important separation technologies in the chemical industry. Distillation is typically selected because the technology provides highly refined products, operational flexibility, scalability, and advantaged economics. Distillation is an energy intensive process and typically accounts for more than 40–50% of a plant’s total operating and capital costs.

Another important facet of industrial chemical operations is the need for a control system that should account for the desired system performance and the installation and maintenance costs. Having a clear idea of control system objectives is critical to a successful installation. Chapter 39 addresses the objectives of a process control system to economize the process, realize safety and environmental compliance, and protect the equipment.

The topic of Chap. 40 is new to this handbook. This chapter provides a global overview of the chemistry and technology of steel production along with a critical review of the economic, environmental, and safety aspects of steel production. Steel is the world’s most useful and inexpensive material. It is the material from which much of the modern world is made, from skyscrapers to washing machines. The structure of the Pyramid of the Louvre, canned food, oil platforms, catalytic converters, paper clips, mounts for electronic chips, etc., are all made of steel. All construction, all cars, all ships, and all airplanes employ steel in one shape or other. It is estimated that there are over 20 billion tons of steel in use, equivalent to well over 2 tons for every person on earth.

As mentioned earlier, this 13th edition of the Handbook comprises of 42 chapters which are devoted to various areas of the chemical process industry. This information, together with supporting “infrastructure” material described above, viz. process safety, emergency preparedness, statistical methods, and green engineering and chemistry, provides *in toto* many sophisticated and useful tools to aid in the design of new products and processes and for the study and evaluation of older ones. The handbook should prove useful also to individuals who possess a background in chemistry or chemical engineering and work in related areas such as regulatory agencies and environmental organizations. Among other benefits, it will help ensure that the work of such individuals reflects knowledge of relevant contemporary science and engineering and industry practices. Reflecting new realities in the world energy situation, this edition also includes a chapter titled “The Nuclear Industry.”

Individuals who have responsibilities in the chemical process industries are usually engaged, consciously or otherwise, in continually reviewing their operations to ensure that they are safe, efficient, and in compliance with current environmental regulations. They are also, or should be, anticipating future needs. It is hoped that the information contained herein will provide the wherewithal by which chemists, chemical engineers, and others who have a peripheral interest in the process industries, for whatever reason, can ensure that they have touched every base, dotted every *i*, and crossed every *t* in their quest to make the processes and products for which they are responsible as environmentally sound, safe, and efficient as possible.

Because of the scope of the book and the large number of products and processes it covers, some redundancy is inevitable. For example, more than one chapter includes discussions of gasification and hydrogen production. However, there are significant differences in emphasis in the various discussions. Thus, rather than distract readers by referring them to information in locations other than the one of their primary interest, such topics have been left intact in the context in which they are discussed.

Dr. James Kent was the architect of all the earlier versions of this work, serving as designer and editor. We are happy to acknowledge the unselfish and enthusiastic way the contributing authors have shared their knowledge and insights so that many others may learn and still others may benefit. The picture of a bit of knowledge, acting like a stone tossed into a quiet pond, spreading the result of the impact ever more widely, is, I think, apt. There is a saying that knowledge is power, and the authors who have contributed their knowledge and expertise to this work are pleased to have had the opportunity to empower others. All the authors have been unstinting in their efforts to make their contributions as complete and informative as possible, within the space available, and I am indeed humbled and honored to have had a part in bringing it about. Needless to state, errors of omission and shortcomings in organization are mine.

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