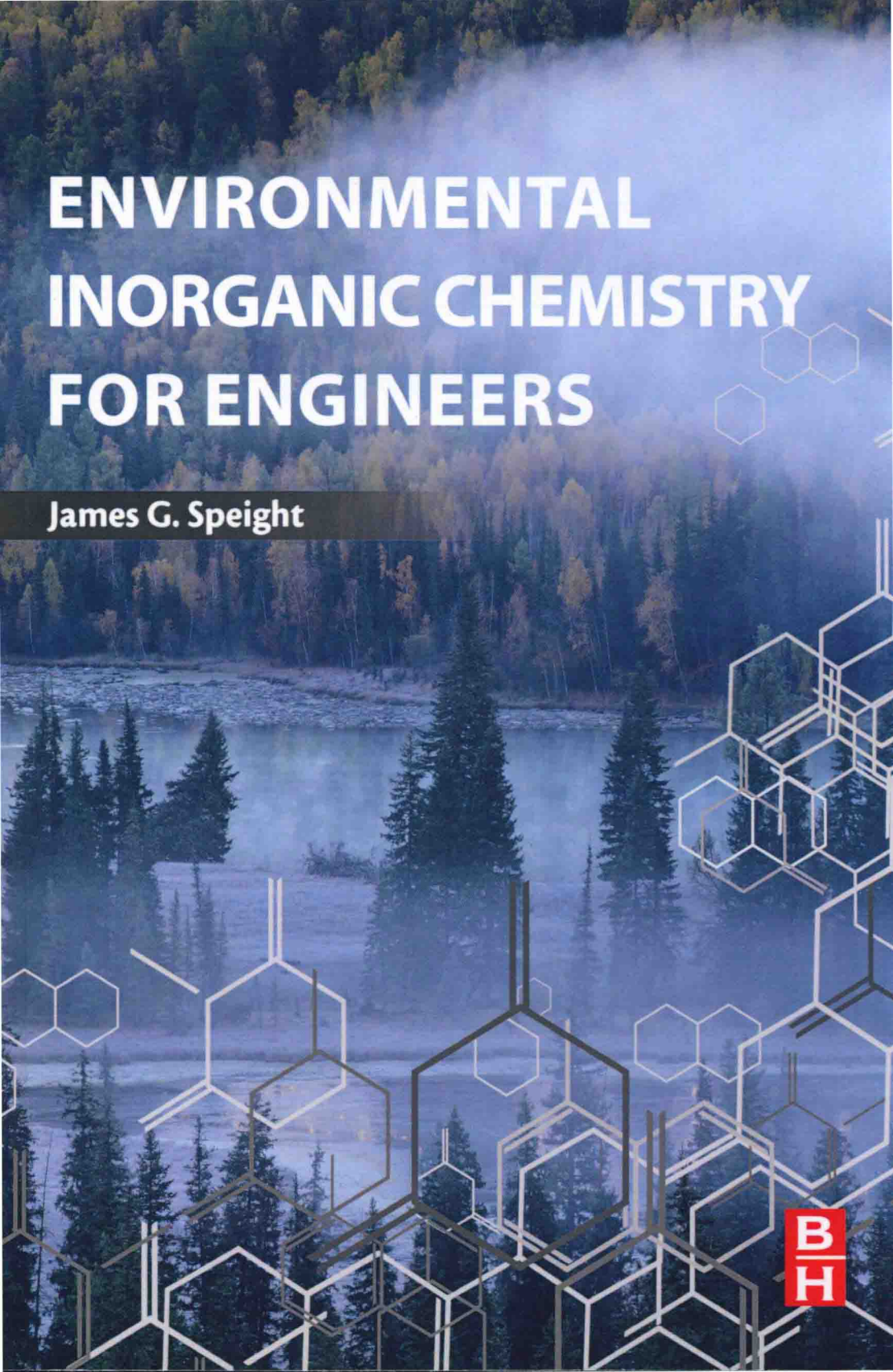
ENVIRONMENTAL INORGANIC CHEMISTRY FOR ENGINEERS

James G. Speight



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This book provides a valuable source for better understanding of the interaction between inorganic compounds:

- Clearly explains the principles of inorganic contaminant behavior to better explore available remediation technologies.
- Provides the design, operation, and advantages or disadvantages of the various remediation technologies available.
- Includes a clear exposition of metals including topics such as preparations, structures, and bonding, reaction, and properties and complex formation and sequestering.

Environmental Inorganic Chemistry for Engineers explains the principles of inorganic contaminant behavior and then moves on to apply these principles to explore available remediation technologies. The author provides the design, operation, and advantages or disadvantages of the various remediation technologies. Written for environmental engineers and researchers, this reference provides the tools and methods that are imperative to protect and improve the environment.

Environmental Inorganic Chemistry for Engineers' three-part treatment starts with a clear and rigorous exposition of metals including topics such as preparations, structures, and bonding, reaction, and properties and complex formation and sequestering. This is followed by a self-contained section concerning complex formation and sequestering and organometallics, including hydrides and carbonyls. Finally, nonmetals provide an overview of chemical periodicity and the fundamentals of the structure and properties. Preparations, structures, reactions, and properties of representative compounds and materials are also covered in this section.

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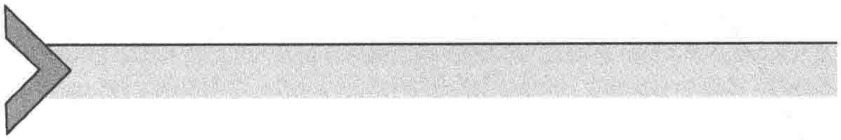

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DR. JAMES G. SPEIGHT
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AUTHOR BIOGRAPHY

Dr. James G. Speight CChem., FRSC, FCIC, and FACS earned his BSc and PhD degrees from the University of Manchester, England; he also holds a DSc in geologic sciences and a PhD in petroleum engineering. Dr. Speight is the author of more than 70 books in fossil fuel and engineering and environmental sciences. Now, being an independent consultant, he was formerly the CEO of the Western Research and has served as adjunct professor in the Department of Chemical and Fuels Engineering at the University of Utah and in the Departments of Chemistry and Chemical and Petroleum Engineering at the University of Wyoming. In addition, he has also been a visiting professor in chemical engineering at the following universities: the University of Missouri-Columbia, the Technical University of Denmark, and the University of Trinidad and Tobago.

Dr. Speight was elected to the Russian Academy of Sciences in 1996 and awarded the gold Medal of Honor that same year for the outstanding contributions to the field of petroleum sciences. He has also received the Scientists without Borders Medal of Honor of the Russian Academy of Sciences. In 2001, the academy also awarded Dr. Speight the Einstein medal for the outstanding contributions and service in the field of geologic sciences.

PREFACE

The latter part of the 20th century saw the realization arise that all chemicals can act as environmental pollutants, and in addition, there came the realization that emissions of inorganic chemicals such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) to the atmosphere and a host of other inorganic chemicals to water systems and to land systems had either a direct or indirect impacts on the various floral and faunal systems. As a result, unprecedented efforts have been made to reduce all global emissions and chemicals disposal in order to maintain a *green perspective*. Furthermore, operations have been designed to reduce the direct emissions of inorganic chemical products (such as carbon dioxide, sulfur oxides, and nitrogen oxides) into the air (*the atmosphere*), inorganic chemicals into water systems (*the aquasphere*), and inorganic chemicals on to the soil (*the terrestrial biosphere*). This has been accompanied by efforts to recycle and to reuse as much of these chemicals and chemical waste as possible.

The primary purpose of this book is to focus on the various issues related to the production and use of inorganic chemical issues that are the focus of any environmental chemistry program. In the context of inorganic chemistry, the book also presents an understanding of information on environmentally important physiochemical properties of inorganic chemicals for use by engineers and managers as well as any nonchemists. This book is a companion text to a book (Environmental Organic Chemistry for Engineers, James G. Speight, Elsevier, 2017) previously prepared for environmentally important effects and properties of organic chemicals. Like the "organics" book, this "inorganics" book describes available information that relates to the properties of inorganic chemicals and the effects of these chemicals on the environment. This information supports the primary objective of the book, which is to assist environmental engineers and managers (many of whom may not have a detailed knowledge or understanding of inorganic environmental chemistry) in overcoming the common problem of property data gaps and developing timely responses to environmental problems. This "inorganics" book presents not only generic discussion of these properties but also a summary of environmentally important data for the most common elements and pollutants.

The topics covered in this book are the basis topics that serve to introduce the reader to not only inorganic chemistry but also the effect of

inorganic chemicals on various ecosystems. Basic rules of nomenclature are presented. Understanding the mechanism of how a reaction takes place is particularly crucial in this and of necessity; the book brings a logic and simplicity to the reactions of the different functional groups. This in turn transforms a list of apparently unrelated facts into a sensible theme. Thus, this chapter will serve as an introduction to the physicochemical properties of inorganic chemicals and their effect on the floral and faunal environments.

The book will serve as an information source the engineers in presenting details of the various aspects of inorganic chemicals as they pertain to pollution of the environment. To accomplish this goal, the initial section (Chapters 1–4) presents an introduction to and a description of the nomenclature of inorganic compounds and the properties of these materials. The remaining part of the book (Chapters 5–9) presents information relevant to the sources of inorganic contaminants, the behavior of inorganic chemicals, the fate and consequences of chemicals in the environment, and cleanup of the environment.

From the book, the reader will gain an understanding of the fundamental inorganic chemistry and chemical processes that are central to a range of important environmental problems and to utilize this knowledge in making critical evaluations of these problems. Specific knowledge will be in the area of (i) an understanding of the chemistry of the stratospheric ozone layer and of the important ozone depletion processes; (ii) an understanding of the chemistry of important tropospheric processes, including photochemical smog and acid precipitation; (iii) understanding of the basic physics of the greenhouse effect and of the sources and sinks of the family of greenhouse gases; (iv) an understanding of the nature, reactivity, and environmental fates of toxic inorganic chemicals; and (v) an understanding of societal implications of some environmental problems. An appendix contains a selection of tables that contain data relating to the properties and characterization of the elements and inorganic compounds, and a comprehensive glossary will help the reader to understand the common terms that are employed in this field of science and engineering.

Dr. James G. Speight
Laramie, Wyoming
Jan. 2017

CONTENTS

CHAPTER ONE

Inorganic Chemicals in the Environment

1.1 INTRODUCTION

Environmental chemistry focuses on environmental concerns about materials, energy, and production cycles and demonstrates how fundamental chemical principles and methodologies can protect the floral (plant) and faunal (animal, including human) species within the environment (Anastas and Kirchhoff, 2002). More specifically, the principles of chemistry can be used to develop how global sustainability can be supported and maintained. For this, future environmental chemists and environmental engineers must acquire the scientific and technical knowledge to design products and chemical processes. They must also acquire an increased awareness of the environmental impact of chemicals on the environment and develop an enhanced awareness of the importance of sustainable strategies in chemical research and the chemical industry, specifically in the context of this book the inorganic chemicals industry.

By way of introduction, although other classification systems have been published, a general classification of chemical pollutants is based on the chemical structure of the pollutant and includes (i) organic chemical pollutants and (ii) inorganic chemical pollutants. For the purposes of this text, organic chemical pollutants are those chemicals of organic origin or that could be produced by living organisms or are based of matter formed by living organisms (Speight, 2017a).

On the other hand, inorganic chemical pollutants are those chemicals of mineral origin in (not produced by living organisms). In general, substances of mineral origin (such as ceramics, metals, synthetic plastics, and water) as opposed to those of biological or botanical origin (such as crude oil, coal, wood, and food). In addition, minerals are the inorganic, crystalline solid

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that makes up rocks. With certain exceptions, inorganic substances do not contain carbon or its compounds. In scientific terms, no clear line divides organic and inorganic chemistry.

Inorganic chemistry focuses on the classification of inorganic compounds based on the properties of the compound(s) (Weller et al., 2014). Partly, the classification focuses on the position in the periodic table (Fig. 1.1) of the heaviest element (the element with the highest atomic weight) in the compound, partly by grouping compounds on the basis of structural similarities. Also, inorganic compounds are generally structured by ionic bonds and do not contain carbon chemically bound to hydrogen (hydrocarbons) or any of their derivatives that contain elements such as nitrogen, oxygen, sulfur, and metals. Examples of inorganic compounds include sodium chloride (NaCl) and calcium carbonate ($CaCO_3$) and pure elements (Cox, 1995).

Thus, this text relates to an introduction to the planned and unplanned effects of inorganic chemicals on the various environmental systems. Inorganic chemicals are an essential component of life, but some chemicals are extremely toxic and can severely damage the floral (plant life) and faunal (animal life) environment (Table 1.1).

As with organic chemicals (Speight, 2017a), contamination of the environment by inorganic chemicals is a global issue, and toxic inorganic chemicals are found practically in all ecosystems because, at the end of the various inorganic chemical life cycles, inorganic chemicals have been either recycled for further use or sent for disposal as chemical waste (Bodek et al., 1988). Current regulations do not permit the unmanaged disposal of chemical waste but, in the past (particularly in the first decades of the 20th century), the inappropriate management of chemical waste (e.g., through haphazard disposal and unregulated burning) has led to a series of negative and lingering impacts on the floral and faunal species that are part of the environment.

Briefly, inorganic chemistry deals with the synthesis and behavior of inorganic and organometallic compounds. The exception to the subdiscipline is the multitude of chemical compounds that fall within the subdiscipline of organic chemistry that covers the multitude of organic compounds (carbon-based compounds, usually containing C—H bonds). The distinction between the two subdisciplines is far from absolute, as there is much overlap within the subdiscipline of organometallic chemistry. Nevertheless, the principles of inorganic chemistry have application in every aspect of the chemical industry, including materials science, catalysis, surfactants, pigments, coatings, medications, fuels, and agriculture.