chemistry

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Chemistry

A Study of Matter
Third Edition

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A Study of Matter

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The past few years have seen a decided upswing in the desire of students to understand the major forces that control their lives. More and more, students are recognizing the importance of comprehending and appreciating the forces of nature and the nature of the material world. With this has come an impatience with learning that has no obvious use outside the learning situation and a willingness to struggle with difficult concepts that have important bearing on life and living. The general chemistry course, dealing as it does with the fabric and the dynamics of the material world, holds great fascination and promise for large numbers of students. Most expect to be challenged by this course; most will work diligently to learn, provided they see how this learning will benefit them.

In writing this text, and in revising it for the second and third editions, we have sought to provide both a reliable guide and resource for helping students understand the chemistry that is taking place around them, and a vehicle to illustrate how such knowledge is obtained, how it can be used, and how new ideas evolve and are examined.

The third edition begins with a somewhat more deliberate pace than earlier editions. Every effort is made to help students develop study and mathematics skills as they learn chemistry. In addition, even greater emphasis is placed on showing how and where the chemistry being discussed becomes important in the life of the individual, in the economy or in the society. Industrial, ecological, and health-related applications are included whenever possible.

An important feature of the third edition is an early (Chapter 4) overview of structural variety among chemical substances illustrated by commonly occurring materials ranging from ionic and small molecule covalent substances such as table salt and carbon dioxide to the chainlike molecules found in gasoline, plastics, and fibers, and the network structures present in certain rocks and minerals. Guidelines are provided in this chapter to enable students to predict the state and certain other properties of a substance simply by looking at its formula.

preface

To avoid overwhelming students by presenting most or all of the great unifying concepts in the first weeks of the course without providing adequate time to assimilate and use these ideas in examining actual chemical systems, we have organized the text for the early introduction of only one or two major themes. These are studied in detail, and this knowledge illustrated and applied in appropriate chemical systems. The next major theme is then presented, studied in detail, and once again illustrated and applied; however, this time the applications require students to use not only the major concepts currently under study but all those that were studied previously. A few concepts such as atomic structure and chemical equilibrium are introduced early and used in simple applications. Later, after students have acquired greater insight and range, they are presented in depth.

Questions and problems that enable students to check their understanding of what they have just read are inserted at appropriate points in each chapter; detailed answers and solutions are given at the end of the chapter. Specially designed quantitative units have been placed at the ends of Chapters 1, 2, 4, and 5 to help students improve their math skills before undertaking the chapter on stoichiometry. These are titled: (1) Units of Measurement; Problems of Conversion; (2) Exponential Numbers; Significant Figures; (3) Measurement in Chemistry: Formulas and the Mole; and (4) Writing Chemical Equations. The quantitative units can be assigned at any time or omitted as appropriate. Each chapter includes a two or three page essay giving examples of how the material studied in the chapter is used or has relevance in life or in the culture.

The major theme of the first six chapters is chemical substances, their properties and composition. Included in these chapters are introductions to atomic structure and chemical bonding, guidelines for predicting certain properties of substances, a brief look at chemical reactivity, and stoichiometry. The theme of the next six chapters is structure and reactivity patterns. These chapters include topics such as electrons in atoms, covalent bonding and the shapes of molecules, and acids–bases and an introduction to chemical equilibrium. The principles developed in these chapters are illustrated and applied in correlating the behavior of two families of representative metals and a family of nonmetals. This is followed by a chapter on the periodic table and the chemistry of noble gases. In Chapters 13 to 16, the major themes are molecules in motion, energy absorption by molecules, and the nature of solutions and of solids. These concepts, along with those developed in the first eight chapters, are applied in examining the chemistry of *p*-block elements, Chapters 17 to 19. In Chapters 20 to 25, chemical equilibrium, introductory thermodynamics, electrochemistry, and kinetics are presented. This is followed by units titled nuclear chemistry and coordination chemistry. Two chapters on organic chemistry, emphasizing principles and practical applications including polymers, drugs, and foods, and a chapter on biochemistry, giving an overview of the chemistry of living cells, complete the text.

The chapters are written as essays on each topic building from the simple to the complex. Certain enriching material supplementing the text discussion appears throughout; this material includes historical developments, elaboration and refinement of definitions, extended descriptions of experiments and equipment, and some illustrative examples. Epigraphs at the beginning of the chapters commemorate important discoveries and people in the history of chemistry. Each chapter concludes with a summary, a list of important terms, a reading list, and a variety of questions and problems.

The essays at the ends of the chapters discuss such diverse topics as "Acid–Base Balance in Body Chemistry," "Molecular Structure and the Chemistry of Vision," "Measurement Standards and the Levels of Food Additives and Drugs," "Modern Ceramics," "Atmospheric Stability and Air Quality," "Sources of Energy", "Geochemical Cycles," "Time's Arrow and Entropy in Human Enterprise," and 22 others.

The text is arranged so that the teacher can select any of a variety of sequences of topics. For teachers wishing to emphasize introductory physical chemistry, the sequence of Chapters 1 to 16 and 20 to 26 is recommended; for those favoring a principles-oriented course in descriptive inorganic chemistry, the sequence of Chapters 1 to 22 and 27 is suggested; for those wishing to prepare students for more biologically directed curricula, the sequence of Chapters 1 to 15, 20 to 22, and 26 to 30 might be appropriate. Rarely would the entire book be covered in a single course.

The program is designed for students in the first course in college chemistry. A background in high school chemistry is assumed, but the diligent student should succeed without it. The book is written for all, including the best in the class. The authors have made a special effort in developing the difficult areas to keep the background and the intellectual maturity of the students in mind. The mathematics required is an elementary understanding of algebra and a sound, thorough comprehension of arithmetic.

We acknowledge with grateful appreciation assistance received from past and present colleagues, particularly those at The Ohio State University and The University of Arizona. We acknowledge also the suggestions and advice of those who read much or all of the manuscript, Professors Jon M. Bellama, David W. Brooks, John L. Burmeister, Lawrence E. Conroy, Donald R. Dimmel, Michael L. Gross, Leo E. Kallan, Gary J. Long, Gloria G. Lyle, Jack E. Powell, David M. Schrader, George D. Sturgeon, Walter E. Weibrecht, Jay A. Young, Jerold J. Zuckerman.

We invite you to join us in this venture of understanding and interpreting the material universe.

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contents

Chemical substances are the material constituents of everything we use, see, or are. They are as much the components of living cells, and hence of all living things, as they are the materials that constitute the rocks, liquids, and gases of the earth and the rest of the universe. Studies of the nature of chemical substances have advanced to such a point that today we can describe with considerable confidence the structures of not only tiny objects of the universe—molecules, atoms, and atomic nuclei—but also great, massive bodies, such as the planets and moons, the sun and other stars, and even galaxies (Figure 1.1). We can describe as well the changes in chemical substances that occur within us, around us, in our laboratories, and even in the farthest star in the most distant galaxy. Our accumulated information about the structure and composition of the stuff of the universe and our understanding of the changes in structure, composition, and energy of this stuff are an impressive part of our cultural heritage. But more than this, our information and understanding give us the power to build a better world—one in which famine, pestilence, and poverty are no longer the threats they were to our predecessors.

In this chapter, we shall describe the development of chemistry in its early years, review and summarize some of the terms and concepts used in chemistry (the language of chemistry), and describe some of the units of measurement that give quantitative meaning to chemical phenomena.

1.1 Historical perspective

Mankind's early attempts

Earliest history records human interest in many natural phenomena such as fire, lightning, and thunder, as well as concern with common things like air, water, and soil, and with the moon, sun, and stars. For thousands of years people struggled to find a way to describe such things in terms of simpler substances. In their early attempts, superstitions and black magic played a major role. Folklore and religious dictums often dominated. For hundreds of years many people lived under the beliefs that:

Chemistry An Approach to Interpreting the Material Universe

chapter one

Let us remember, please, that the search for the constitution of the world is one of the greatest and noblest problems presented by nature.
Galileo (1564–1642)

Figure 1.1
Range in sizes and distances of objects in the universe.