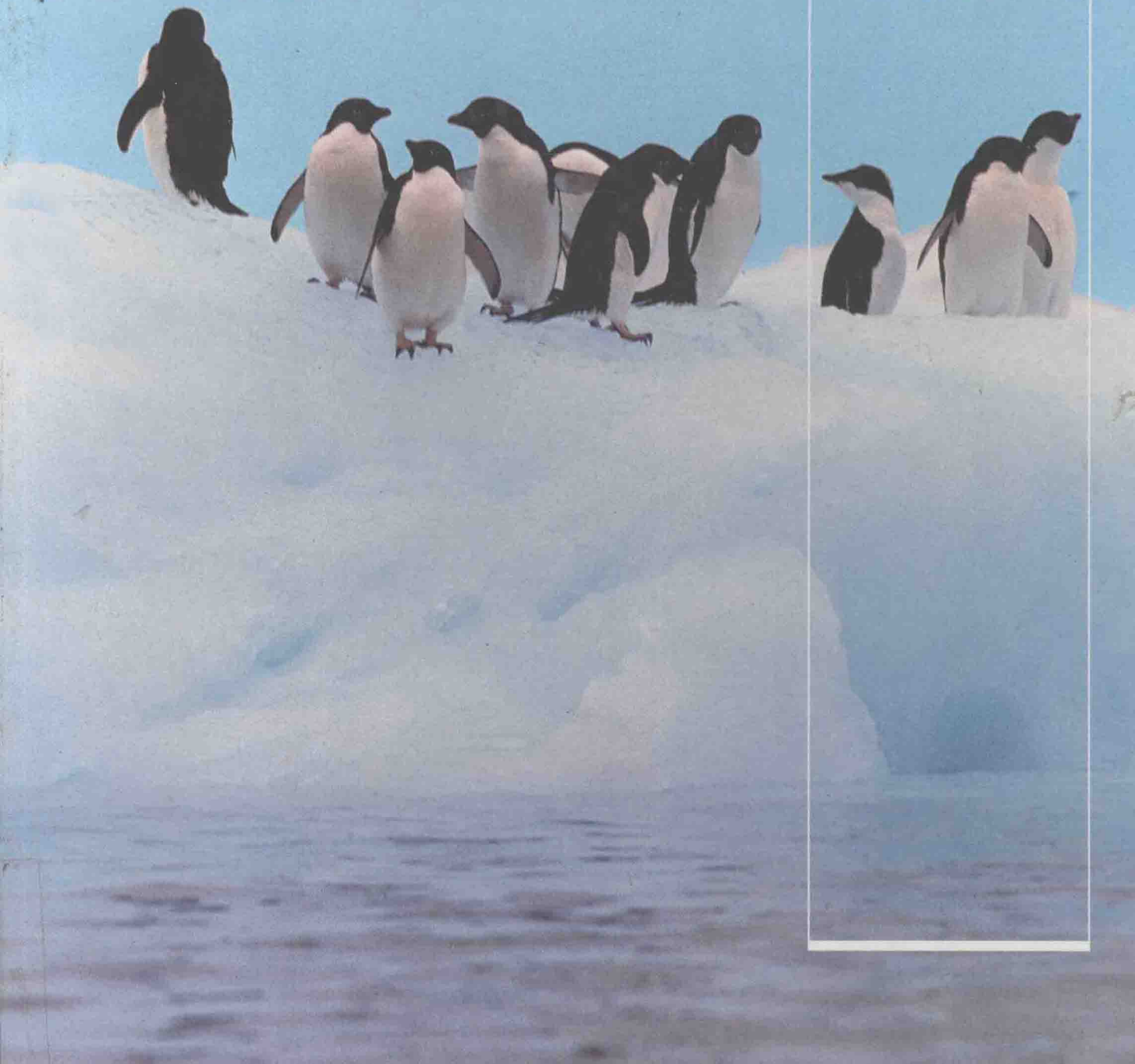
Foundations of College Chemistry

8th EDITION

HEIN • ARENA



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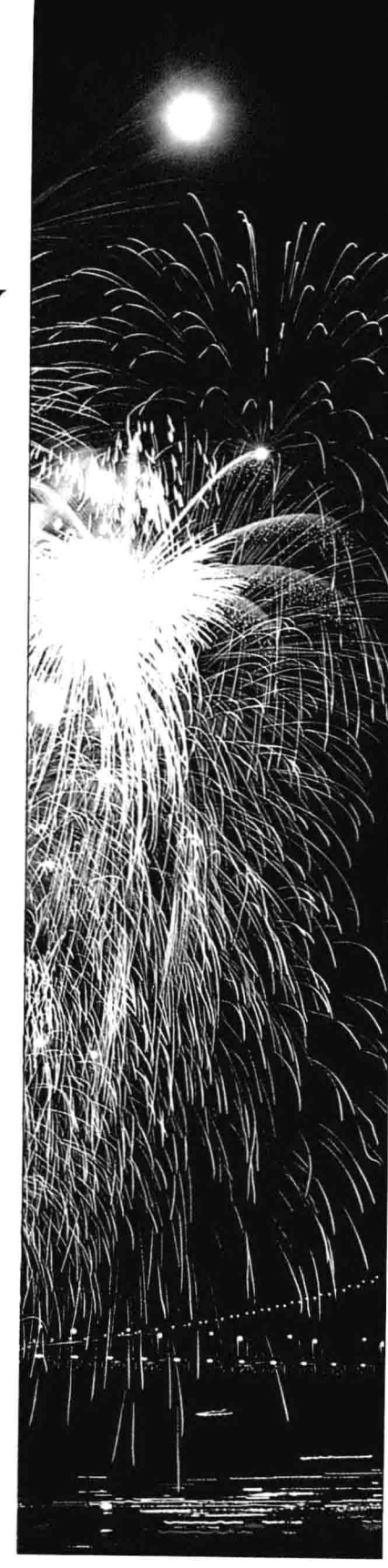
EIGHTH EDITION

MORRIS HEIN
SUSAN ARENA

MOUNT SAN ANTONIO COLLEGE



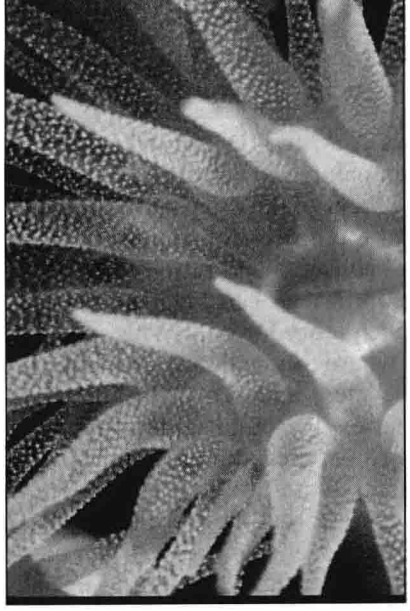
BROOKS/COLE PUBLISHING COMPANY
PACIFIC GROVE, CALIFORNIA

Sponsoring Editors: Maureen A. Allaire, Harvey C. Pantzis
Editorial Assistant: Beth Wilbur
Print Buyer: Vena M. Dyer
Production: Julie Kranhold, Ex Libris; Joan Marsh
Manuscript Editor: Andrew Alden
Interior Design: Nancy Benedict
Interior Illustration: Nancy Benedict, Lotus, Pat Rogondino
Photo Researcher: Stuart Kenter
Typesetting: Polyglot Pte. Ltd. Compositors
Cover Printing: The Lehigh Press
Printing and Binding: Arcata Graphics, Hawkins County Plant
Cover Design: Vernon T. Boes
Cover Photo: Frans Lanting, Allstock, Inc.
Photo credits are listed after the index.

Brooks/Cole Publishing Company
A Division of Wadsworth, Inc.

Printed in the United States of America
10 9 8 7 6 5 4

Library of Congress Cataloging-in-Publication Data
Hein, Morris.
Foundations of college chemistry/Morris Hein, Susan Arena.
p. cm.
Includes index.
ISBN 0-534-20004-4
1. Chemistry. I. Arena, Susan, 1951- . II. Title.
QD33.H45 1993
540—dc20 92-33078
CIP



Preface

The aim of *Foundations of College Chemistry, 8th Edition* is to introduce chemistry to students who have little or no background in mathematics or chemistry. To accomplish this effectively we have presented it in a manner that is both interesting and understandable. In this edition we have made the book more inviting and focused on "real" world applications.

CHEMICAL CONNECTIONS

Foundations of College Chemistry emphasizes the connection between chemistry and the lives of the students. Each chapter opens with a color photo relating the chapter to daily life. A "Chapter Preview" assists the students in seeing the overall concepts in the chapter, and an introductory paragraph further connects the chapter to aspects of our highly technical culture. Each chapter contains a special section titled "Chemistry in Action," which shows the impact of chemistry in a variety of chemical applications. These essays and photos cover such topics as superconductors, food additives, photogray sunglasses, scuba diving, and the restoration of the Statue of Liberty. We chose the cover of the text to illustrate these connections as well. Here, the ice, water, and water vapor in the atmosphere show the three phases of matter. The penguins illustrate the potential environmental effects associated with the enlarging hole in the ozone layer. The hole results in an increase in the ultraviolet radiation reaching the surface, which is believed to have a detrimental effect on the vision of the penguins.

The entire book has been redesigned to captivate students' imagination to enjoy the applications and color associated with chemical reactions and

concepts. The new four-color format shows consistent use of color to highlight atoms and molecules. Line art has been painted to highlight the connection to real equipment and to emphasize the focus of the drawing. Flow charts have been added to increase visualization of the process of chemistry and to assist students in thinking through chemical concepts and problems.

We have continued to stress the less theoretical aspects of chemistry early in the book, leaving the more abstract atomic theory for later. This sequence seems especially appropriate in a course where students are encountering chemistry for the first time. Atoms, molecules, and reactions are all an integral part of the chemical nature of matter. A sound understanding of these topics will allow the student to develop an appreciation for fundamental chemical properties and vocabulary. Students therefore gain confidence in their own ability to identify and work with chemicals in the laboratory before tackling the abstract theories of matter. We as practicing chemists can easily connect the theory to the chemical property it explains. Students, especially those with no prior chemistry background, may not share this ability to connect the abstract and the practical. Reactions, models, and demonstrations spark the imagination and draw the student into the study of chemistry.

We continue to present new material at a level appropriate for the beginning student by accentuating nomenclature, composition of compounds, and reactions (Chapter 6–9) before moving into the details of atomic structure (Chapter 10–12). For those instructors who find it necessary to cover modern atomic theory and bonding early in the course, these chapters (10–12) can be covered immediately following Chapter 5.

Because the connection between molecular shape and function is becoming more important in the design and use of chemicals in our lives, we have reorganized Chapter 11 (Periodic Table) and Chapter 12 (Chemical Bonding) in order to clarify and simplify the relationship between structure and reactivity. And, we have introduced two new sections in Chapter 12 to illustrate the use of simple VSEPR theory to predict the shape of molecules.

PROBLEM-SOLVING SKILLS

More and more, students need to develop real skills in solving problems. Thus, we continue to show examples beginning with simple substitutions into algorithms and moving toward more complex algebraic problems. The examples show how to incorporate fundamental mathematical skills, scientific notation, and significant figures by following the rules consistently. Painstaking care has been taken to show each step in the problem-solving process, and to give alternative methods for solution where appropriate. In this edition we have used four significant figures for atomic and molar masses for consistency and for rounding of answers appropriately. We have added new end-of-chapter exercises to incorporate the applications in the "Chemistry in Action" features. Practice problems follow many examples to provide an immediate opportunity for the student to reinforce the skill developed in the example.

Learning Aids

To help the beginning student gain the confidence necessary to master technical material we have developed and refined a series of learning aids.

- A list of "Concepts in Review" given at the end of each chapter guides the students in determining the most important concepts in the chapter.
- Important terms are set off in bold face where they are defined and are printed in color in the margin.
- A "Glossary-Index" is provided to help students locate key terms and find the definition in context.
- Answers to the mathematical problems are given in Appendix V.
- Review Exercises for each chapter have been compiled at the end of the book with convenient gray-banded pages to help students prepare for examinations.

Choices for Coverage

For the convenience of instructors and to accommodate the various lengths of terms, two versions of this book are available. *Foundations of College Chemistry 8th Edition*, includes 21 chapters covering all basic material as well as introductions to organic and biochemistry. *Foundations of College Chemistry, 5th Alternative Edition*, provides a shorter versions of the same material without the nuclear, organic, and biochemical material, in a soft-back cover binding.

Supplements

The following comprehensive teaching package accompanies these books:

- *Study Guide*, by Peter C. Scott of Linn-Benton Community College includes a self-evaluation section and a recap section for each chapter.
- *Instructor's Supplement* includes answers to all review exercises, a copy of the test questions in EXP Test, and answers to the test questions.
- *Solutions Manual* includes answers and solutions to all end-of-chapter exercises.
- *Foundations of College Chemistry in the Laboratory*, by Morris Hein, Leo R. Best, and Robert L. Miner includes twenty-eight experiments for a laboratory program that may accompany the lecture course. Also included are study aids and exercises.
- *Instructor's Manual for the Laboratory* includes information on the management of the lab, evaluation of experiments, notes for individual experiments, a list of reagents needed, and answer keys to each report form and exercise.

- *EXP Test*, Version 5.0, is a test generation system from Brooks/Cole for IBM PCs or compatibles.
- *Transparencies* include a number of the tables and figures from the book enlarged for use in the classroom.
- *Computer Software*

We have worked hard to make the entire package of books and supplements interesting and accurate. We would appreciate any comments that would help us clarify the material and make it more useful to students and faculty.

ACKNOWLEDGMENTS

Books are always the result of a collaborative effort of many talented and dedicated people. We deeply appreciate the support and enthusiasm of Edna Hein and Frank Arena. Both of them provided constant good humor, emotional support, and understanding during the many hours of writing, proofing, and consultation. Maureen Allaire provided the spark needed to keep things moving and her energy, great attitude, and strong desire to make this the best revision possible were constant during some very difficult times. Harvey Pantzis provided the initial catalyst for the edition, supported us through the revision, and guided the project to completion. Joan Marsh managed the production of the book and held us together during the trying process of moving from two colors to four colors. Her ability to know when help was needed and to provide just the right emotional and technical support is evident everywhere in this edition. Julie Kranhold, of *Ex Libris*, was absolutely amazing in her ability to keep track of all the details, and to translate our ideas for art and photos into reality. Rita Amaya was exceptionally patient in taking many of the laboratory photos. Special thanks to Nancy Benedict for the inviting design of the book and to Vernon Boes for finding a way to connect chemistry and penguins for our cover.

We are grateful to Bill Roberts for his ability to hire the best people for producing books, and for his insistence that we move forward into new areas. Our thanks also to Lisa Moller for her enthusiasm for this book and her understanding of a constantly changing marketplace. We would also like to thank all of the Wadsworth Brooks/Cole "book reps" for their interest and enthusiasm in the field and for the fun we've enjoyed over the last several meetings.

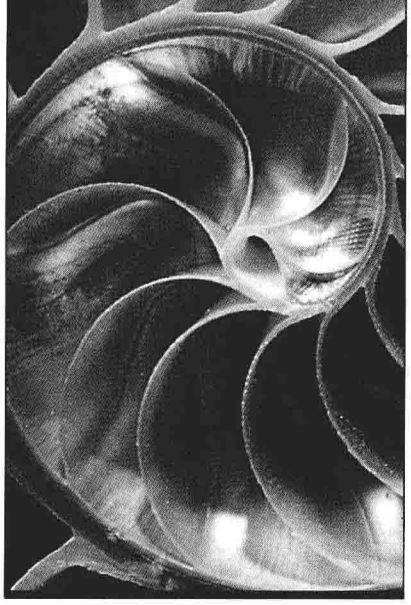
Our sincere appreciation goes to the following reviewers who were kind enough to read and give their professional comments:

Robert Fremland, San Diego Mesa College; John Goodenow, Lawrence Technical University; Laurel Heyman, Owens Technical College; Christine Kerr, Montgomery College; and William Nickels, Schoolcraft College.

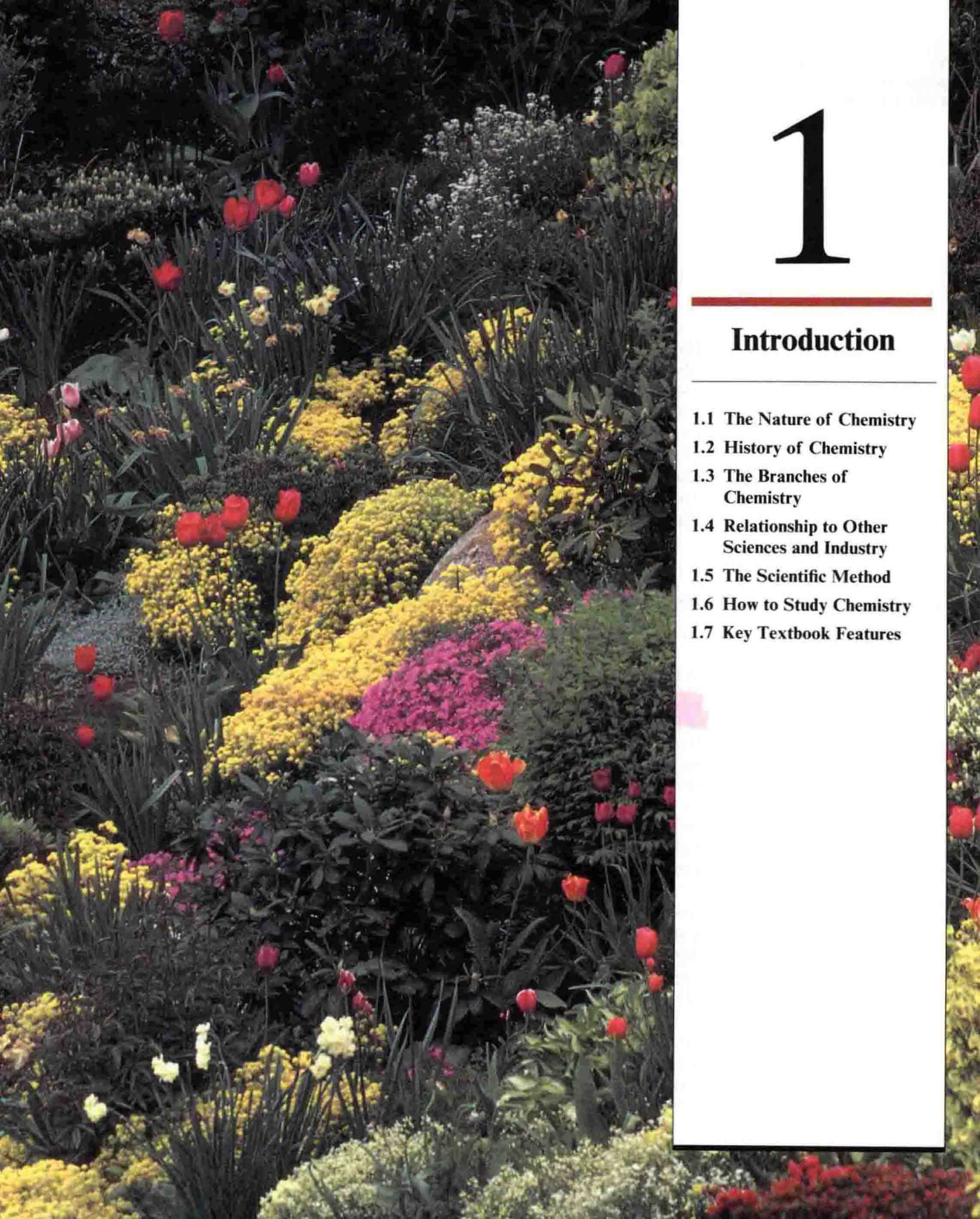
Morris Hein
Susan Arena

Chemistry in Action Boxes

Brief Contents



Detailed Contents



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Introduction

◀ CHAPTER OPENING PHOTO: The colors of this spring garden result from a series of chemical reactions.

Have you ever strolled through a spring garden and been amazed at the diversity of colors in the flowers? Or perhaps you have curled up in front of a winter fire and become fascinated watching the flames. And think of those times when you have dropped a beverage container on a hard floor, and were relieved to find that it was plastic instead of glass. All of these phenomena are the result of chemistry—not in the laboratory but rather in our everyday lives. Chemical changes can bring us beautiful colors, warmth and light, or new and exciting products. Chemists seek to understand, explain, and utilize the diversity of materials we find around us.

1.1 THE NATURE OF CHEMISTRY

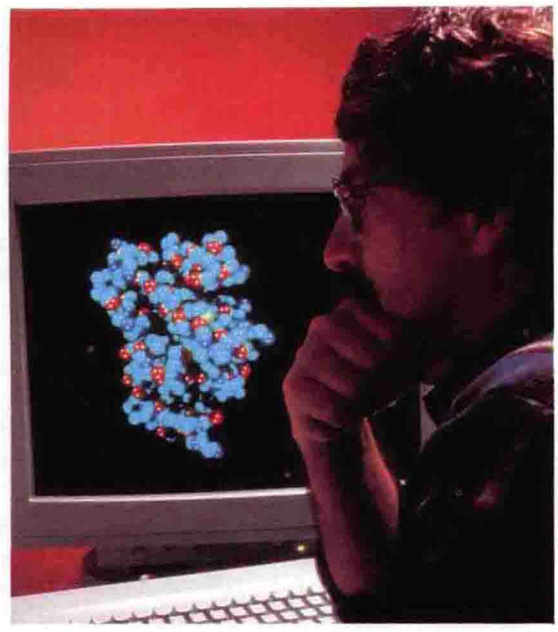
chemistry

What is chemistry? A popular dictionary gives this definition: **Chemistry** is the science of the composition, structure, properties, and reactions of matter, especially of atomic and molecular systems. Another, somewhat simpler dictionary definition is: Chemistry is the science dealing with the composition of *matter* and the changes in composition that matter undergoes. Neither of these definitions is entirely adequate. Chemistry, along with the closely related science of physics, is a fundamental branch of knowledge. Chemistry is also closely related to biology, not only because living organisms are made of material substances but also because life itself is essentially a complicated system of interrelated chemical processes.

The scope of chemistry is extremely broad: It includes the whole universe and everything, animate and inanimate, in it. Chemistry is concerned not only with the composition and changes in composition of matter, but also with the energy and energy changes associated with matter. Through chemistry we seek to learn and to understand the general principles that govern the behavior of all matter.

The chemist, like other scientists, observes nature and attempts to understand its secrets: What makes a rose red? Why is sugar sweet? What is occurring when iron rusts? Why is carbon monoxide poisonous? Why do people wither with age? Problems such as these—some of which have been solved, some of which are still to be solved—are part of what we call chemistry.

A chemist may interpret natural phenomena, devise experiments that will reveal the composition and structure of complex substances, study methods for



improving natural processes, or, sometimes, synthesize substances unknown in nature. Ultimately, the efforts of successful chemists advance the frontiers of knowledge and at the same time contribute to the well-being of humanity. Chemistry can help us to understand nature; however, one need not be a professional chemist or scientist to enjoy natural phenomena. Nature and its beauty, its simplicity within complexity, are for all to appreciate.

The body of chemical knowledge is so vast that no one can hope to master it all, even in a lifetime of study. However, many of the basic concepts can be learned in a relatively short period of time. These basic concepts have become part of the education required for many professionals, including agriculturists, biologists, dental hygienists, dentists, medical technologists, microbiologists, nurses, nutritionists, pharmacists, physicians, and veterinarians, to name a few.

1.2 The History of Chemistry

People have practiced empirical chemistry from the earliest times. Ancient civilizations were practicing the art of chemistry in such processes as wine-making, glass-making, pottery-making, dyeing, and elementary metallurgy. The early Egyptians, for example, had considerable knowledge of certain chemical processes. Excavations into ancient tombs dated about 3000 B.C. have uncovered workings of gold, silver, copper, and iron, pottery from clay, glass beads, and beautiful dyes and paints, as well as bodies of Egyptian kings in remarkably well-preserved states. Many other cultures made significant developments in chemistry. However, all these developments were empirical; that is, they were achieved by trial and error and did not rest on any valid theory of matter.

Philosophical ideas relating to the properties of matter (chemistry) did not develop as early as those relating to astronomy and mathematics. The Greek