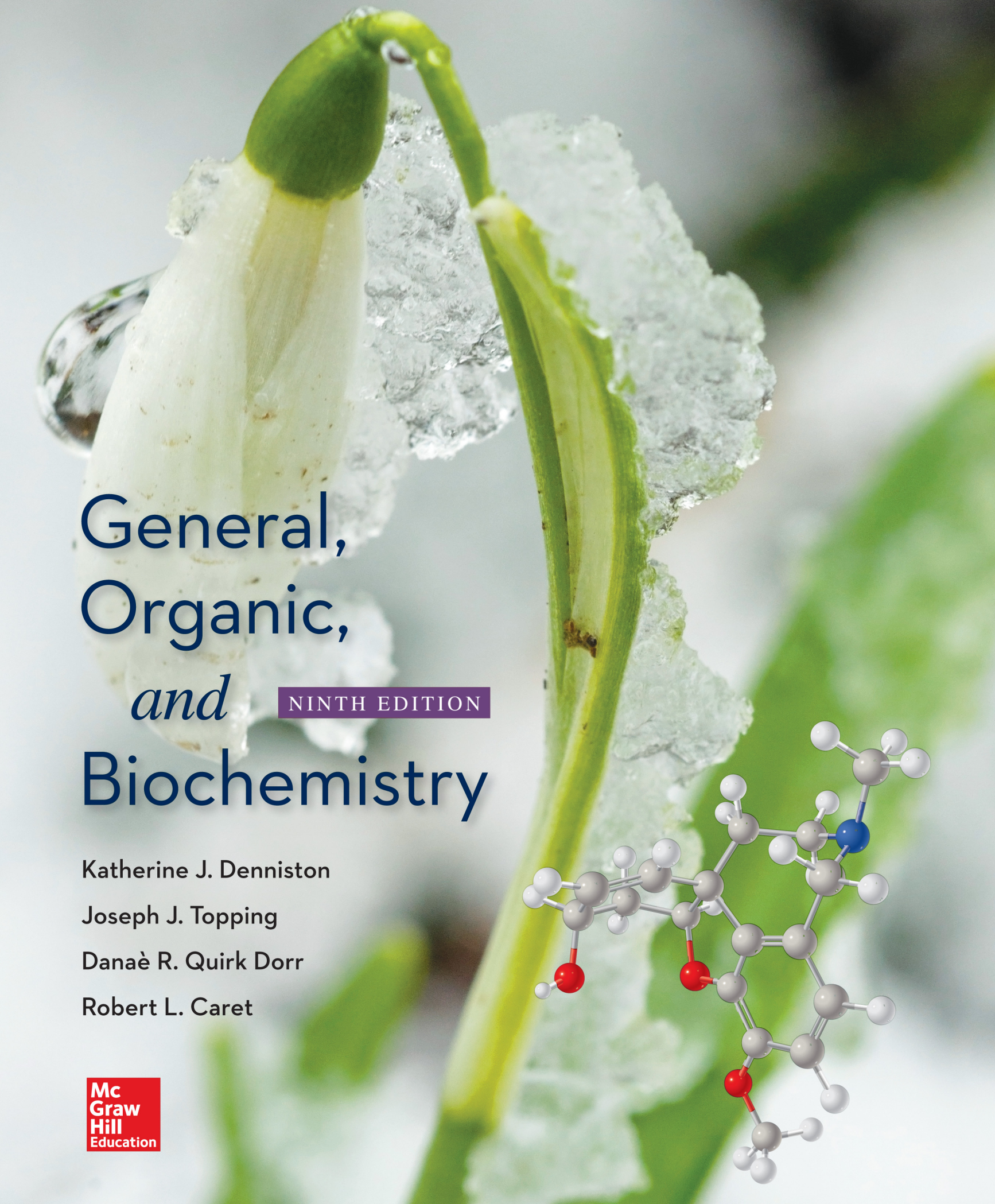

General, Organic, *and* Biochemistry

NINTH EDITION

Katherine J. Denniston
Joseph J. Topping
Danaè R. Quirk Dorr
Robert L. Caret

Mc Graw Hill Education

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GENERAL, ORGANIC, AND BIOCHEMISTRY, NINTH EDITION

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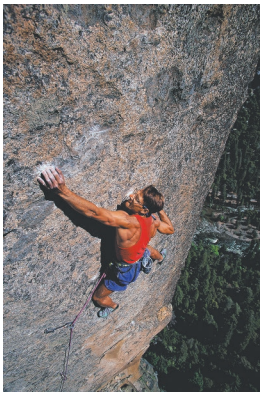

Perspectives

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Preface

To Our Students

Just as some researchers study chemical change, others study learning. The two are related: there are measurable changes in the brain as learning occurs. While the research on brain chemistry and learning continues, the research on learning has taught us some very successful strategies for teaching and learning chemistry. For instance, we now know that building long-term memory requires "repetitions." When you exercise to build muscle strength, you perform some number of "reps" of each exercise for each muscle that you wish to build. That is exactly what you need to do to build your long-term memory and understanding. The Center for Academic Success at the Louisiana State University has devised study tools that have allowed students to improve their performance by a full letter grade, or higher. The following is the Study Cycle with five stages that provide the "reps" needed to perform well in any course:

1. ***Preview*** the chapter *before* class. Either the evening before or the day of class, skim the material; pay attention to the end-of-chapter summary with boldfaced key terms, chapter map, the learning goals, and headings. Think of questions you would like the instructor to answer. Think of this 10 minutes as your "warm up."
2. ***Attend*** class! Be an active participant in the class, asking and answering questions and taking thoughtful, meaningful notes. Class time is much more meaningful if you have already familiarized yourself with the organization and key concepts to be discussed.
3. ***Review*** your notes as soon as possible after class. Fill in any gaps that exist and note any additional questions that arise. This also takes about 10 minutes; think of it as your "cool down" period.
4. ***Study.*** Since repetition is the key to success, The Center for Academic Success recommends 3–5 short, but intense, study sessions each day. These intense study sessions should have a very structured organization. In the first 2–5 minutes, establish your goal for the session. Spend the next 30–50 minutes studying with focus and action. Organize the material, make flash cards to help you review, draw concept maps to define the relationship among ideas, and practice problem solving. Then reward yourself with a 5–10 minute break. Call a friend, play Angry Birds, or do anything you find enjoyable. Then take 5 minutes to review the material. Finally, about once a week, perhaps on the weekend, review all of the material that you have been studying throughout the week.
5. ***Assess*** your progress. Are you able to solve the questions and problems at the end of the chapter? Can you explain the concepts to others? The assessment will affirm what you know well and reveal what you need to study further.

The Center for Academic Success has many other suggestions to help students learn how to learn. You can find their online tutorials and workshops at www.cas.lsu.edu.

To the Instructor

The ninth edition of *General, Organic, and Biochemistry,* like our earlier editions, has been designed to help undergraduate majors in health-related fields understand key concepts and appreciate significant connections among chemistry, health, and the treatment of disease. We have tried to strike a balance between theoretical and practical chemistry, while emphasizing material that is unique to health-related studies. We have written at a level intended for students whose professional goals do not include a mastery of chemistry, but for whom an understanding of the principles and practice of chemistry is a necessity.

Although our emphasis is the importance of chemistry to the health-related professions, we wanted this book to be appropriate for all students who need a one- or two-semester introduction to chemistry. Students learn best when they are engaged. One way to foster that engagement is to help them see clear relationships between the subject and real life. For these reasons, we have included perspectives and essays that focus on medicine and the function of the human body, as well as the environment, forensic science, and even culinary arts.

We begin that engagement with the book cover. Students may wonder why the cover has a photo of the Caucasian snowdrop (*Galanthus caucasicus*). What does this flower have to do with the study of chemistry or the practice of medicine? They will learn that Russian scientists extracted the drug galantamine from this plant in the early 1950s and others found that it was useful in treating nerve pain and poliomyelitis. More recently, it has been discovered that the drug is a reversible, competitive inhibitor of the enzyme acetylcholinesterase and that it can cross the blood-brain barrier. These characteristics have made it a useful drug for the treatment of mild to moderate Alzheimer's Disease. By inhibiting the enzyme, galantamine increases the amount of acetylcholine in the brain; this, in turn, enhances brain function, memory, and the ability to think more clearly.

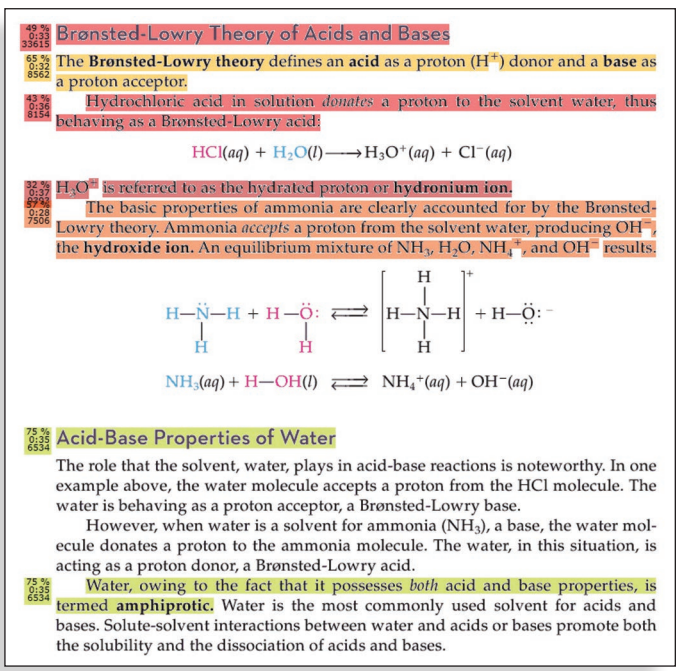
The cover sets the theme for the book: chemistry is not an abstract study, but one that has an immediate impact on our lives. We try to spark student interest with an art program that uses relevant photography, clear and focused figures, and perspectives and essays that bring life to abstract ideas. We reinforce key concepts by explaining them in a clear and concise way and encouraging students to apply the concept to solve problems. We provide guidance through the inclusion of a large number of in-chapter examples that are solved in a stepwise fashion and that provide students the opportunity to test their understanding through the practice problems that follow and the suggested end-of-chapter questions and problems that apply the same concepts.

Foundations for Our Revisions

In the preparation of each edition, we have been guided by the collective wisdom of reviewers who are expert chemists and excellent teachers. They represent experience in community colleges, liberal arts colleges, comprehensive institutions, and research universities. We have followed their recommendations, while remaining true to our overriding goal of writing a readable, student-centered text. This edition has also been designed to be amenable to a variety of teaching styles. Each feature incorporated into this edition has been carefully considered with regard to how it may be used to support student learning in both the traditional classroom and the flipped learning environment.

Also for this edition, we are very pleased to have been able to incorporate real student data points and input, derived from thousands of our LearnSmart users, to help guide our revision. LearnSmart Heat Maps provided a quick visual snapshot of usage of portions of the text and the relative difficulty students experienced in mastering the content. With these data, we were able to hone not only our text content but also the LearnSmart probes.

- If the data indicated that the subject covered was more difficult than other parts of the book, as evidenced by a high proportion of students responding incorrectly, we substantively revised or reorganized the content to be as clear and illustrative as possible.
- In some sections, the data showed that a smaller percentage of the students had difficulty learning the material. In those cases, we revised the *text* to provide a clearer presentation by rewriting the section, providing additional examples to strengthen student problem-solving skills, designing new text art or figures to assist visual learners, etc.
- In other cases, one or more of the LearnSmart probes for a section was not as clear as it might be or did not appropriately reflect the content. In these cases, the *probe,* rather than the text, was edited.



Brønsted-Lowry Theory of Acids and Bases

The **Brønsted-Lowry theory** defines an **acid** as a proton (H^+) donor and a **base** as a proton acceptor.

Hydrochloric acid in solution *donates* a proton to the solvent water, thus behaving as a Brønsted-Lowry acid:

$$HCl(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + Cl^-(aq)$$

H_3O^+ is referred to as the hydrated proton or **hydronium ion.**

The basic properties of ammonia are clearly accounted for by the Brønsted-Lowry theory. Ammonia *accepts* a proton from the solvent water, producing OH^-, the **hydroxide ion.** An equilibrium mixture of NH_3, H_2O, NH_4^+, and OH^- results.

Acid-Base Properties of Water

The role that the solvent, water, plays in acid-base reactions is noteworthy. In one example above, the water molecule accepts a proton from the HCl molecule. The water is behaving as a proton acceptor, a Brønsted-Lowry base.

However, when water is a solvent for ammonia (NH_3), a base, the water molecule donates a proton to the ammonia molecule. The water, in this situation, is acting as a proton donor, a Brønsted-Lowry acid.

Water, owing to the fact that it possesses *both* acid and base properties, is termed **amphiprotic.** Water is the most commonly used solvent for acids and bases. Solute-solvent interactions between water and acids or bases promote both the solubility and the dissociation of acids and bases.

The previous image is an example of one of the heat maps from Chapter 8 that was particularly useful in guiding our revisions. The highlighted sections indicate the various levels of difficulty students experienced in learning the material. This evidence informed all of the revisions described in the "New in This Edition" section of this preface.

The following is a summary of the additions and refinements that we have included in this edition.

New in This Edition

- Chapters 4 and 8 were completely reorganized for better integration and discussion of acid-base and oxidation-reduction reactions.
- **Two new Kitchen Chemistry boxes and eight new Perspective boxes** have been added to the ninth edition to help students see the connections between chemistry and their daily lives and future careers.
- **Each of the following sections was either rewritten or significantly revised for enhanced clarity and student understanding:** 1.1, 1.2, 1.4, and 1.5; 2.1, 2.2, and 2.3; 4.4 and 4.5–4.8 (new to the chapter and revised); 5.1; 6.4; 7.4; 8.1; 9.7; 10.1, 10.2, 10.4, and 10.5; 11.5; 12.1 and 12.3–12.5; 13.1, 13.2, and 13.4; 14.1–14.4; 15.1 and 15.3; 16.2–16.4; 17.3; 18.4–18.5 and 18.7; 19.3, 19.4, and 19.6–19.8; 20.2, 20.8, and 20.10; 21.1–21.5; 23.1, 23.4, and 23.6.

Chapter 1 We have revised or added eight new learning goals to help the student identify the key concepts in the chapter. As with the last edition, each goal is used to label relevant sections and examples. Recognizing the importance of visual learning, we have revised six figures and introduced four new photos. Each of the tables, important devices for summarizing information, has also been revised. We recognize that students learn by doing and, to that end, we have paid special attention to the worked examples, with thirteen new or revised examples included. We challenge the student with in-chapter and end-of-chapter problems, forty-one of which are new or revised. The first chapter of the textbook develops fundamental skills that will be needed throughout the book, and we have revised or rewritten four of these critical sections, 1.1, 1.2, 1.4, and 1.5. Organizing and summarizing concepts is an important aspect of learning; for this reason, we have revised both the Summary and Chapter Map.

Chapter 2 We continued our focus on helping students identify key concepts by adding or revising nine learning goals focusing on the structure of the atom and the periodic table. In addition, all ten of the examples are either new or modified with reworked solutions to enhance clarity. Three of the new examples, *Determining Ion Proton and Electron Composition, Writing Shorthand Electron Configurations for Ions,* and *Determining Isoelectronic Ions and Atoms* help students understand the octet rule and ion formation. The introduction and sections featuring isotopes and electromagnetic radiation have been rewritten. Six figures and two tables are new or revised.

Chapter 3 We have introduced three new learning goals and revised four others. Figure 3.2 has been revised in order to help clarify the concept of covalent bonding. Bonding is fundamentally important to gaining a real understanding of chemistry; for that reason, we have paid special attention to Section 3.1,

Chemical Bonding, rewriting and revising where necessary, to provide a strong foundation for subsequent topics. Students must also learn to apply the concepts of bonding, structure, and the properties of ions and molecules. For that reason, we have added 30 new or revised in-chapter or end-of-chapter problems and questions. Both the Chapter Map and Summary have been revised to reflect changes in the chapter material.

Chapter 4 Chemical changes have been further developed in this chapter in conjunction with calculations and the chemical equation. Significant emphasis has been placed on problem solving beginning with the introduction of nine new and two revised learning goals, nineteen new or revised examples and forty-six new or revised questions and problems. Section 4.4, Balancing Chemical Equations, has been revised, and Sections 4.5–4.8 are new to this chapter. These sections include precipitation reactions, net-ionic equations, acid-base reactions, and oxidation-reduction reactions. Four new pictures and five figures have been added or modified, including Figure 4.10, an illustration supporting the limiting reactant concept. The Summary and Chapter Map have been revised to be consistent with the topics and learning goals of the chapter.

Chapter 5 Four new or revised learning goals have been introduced in the ninth edition to help students focus on key concepts. A comprehensive art program is critical to teaching and learning properties of gases, liquids, and solids. We have introduced five new or revised figures and nine new or revised figure captions, as well as three new photos to illustrate the effects of temperature and pressure on the behavior of the states of matter and the conversion between solids, liquids, and gases. Section 5.1, discussing the properties of gases and the ideal gas laws, has been revised to enhance clarity. Two revised examples and thirteen new or revised questions and problems were used to enhance problem-solving skills. The medical perspective, *Blood Gases and Respiration* has been moved to Chapter 6, where it accompanies the discussion of Henry's law. The Summary and Chapter Map were revised to assist students in organizing concepts as well as seeing the relationships that exist between the concepts discussed in the chapter.

Chapter 6 Several learning goals have been added or revised. Eight of the chapter examples have been modified with reworked solutions in order to enhance clarity. The discussion pertaining to osmosis, osmotic pressure, and osmolarity has been amended. Twenty new or revised questions and problems have been added to correlate to the new and revised material within the chapter. The Summary and Chapter Map have been improved for better alignment with the discussions pertaining to concentration and concentration-dependent properties.

Chapter 7 As in other chapters, we have paid special attention to the learning goals and introduction, revising where appropriate, to lead the students to understand three topics: thermodynamics, kinetics, and equilibrium. These topics are a critical part of any discussion of chemical and physical change. Opportunities for visual learning have been enhanced with three new or revised figures, six new or revised figure captions, and six new photographs. Section 7.4, dealing with equilibrium, was revised to enhance clarity. Eight new or revised questions and problems have been added to provide greater opportunity for students to learn by doing. The Summary and Chapter Map have been revised to reflect changes in the chapter material.

Chapter 8 The emphasis of this chapter has been changed to focus primarily on acids and bases. Oxidation and reduction content has been moved to Chapter 4. Ten new learning goals have been added to correlate to the new and revised content. The Introduction and Section 8.1, Acids and Bases, have been rewritten to incorporate acids and bases commonly used in organic chemistry. Topics revised include acid and base theories, the amphiprotic nature of water, conjugate acid-base pairs, acid and base strength, self-ionization of water, and K_w. The revision includes new figures and images. Five new or revised examples, two new practice problems, and thirty-six new or revised questions and problems provide students with an opportunity to practice solving problems correlating to the learning goals emphasized. The Summary and Chapter Map have been revised in alignment with the changes to the chapter content.

Chapter 9 Two new learning goals have been added to help students identify essential concepts. The topic of nuclear chemistry can be difficult for students to conceptualize. To help overcome this problem, we have introduced three new or revised figures, twelve new or revised figure captions, and eleven new photos. Section 9.7 has been updated, including additional radiation measurement units. Thirteen new or revised questions and problems have been added, as well as four revised examples, reflecting an increased emphasis on improving the student's problem-solving skills. Both the Summary and Chapter Map have been revised to help students understand the basic concepts and their interrelationships.

Chapter 10 A new perspective, *Kitchen Chemistry: Alkanes in our Food,* including two For Further Understanding questions, has been added to the revised Chapter 10. Six new margin notes, many with associated art, have been added to help students understand line formulas, alkyl groups, the classification of carbon atoms, identification and numbering of parent carbon chains in nomenclature, and placement of substituents above and below a cycloalkane ring. A new figure has been added to facilitate student comprehension of the variety of bonding patterns in organic molecules. Several topics have been rewritten to provide students with a deeper understanding of the content. These include the discussion of families of organic compounds, functional groups, physical properties of hydrocarbons, classification of carbon atoms and alkyl groups, nomenclature, free rotation around a bond, and halogenation. Six new problems have been added to accompany the revised content.

Chapter 11 A new perspective, *Kitchen Chemistry: Pumpkin Pie Spice: An Autumn Tradition,* including two For Further Understanding questions, has been added to the revised Chapter 11. A new Example, *Writing Equations for the Hydrogenation of a Cycloalkane,* has been added, along with a set of practice problems and a set of recommended practice problems to help students master the concept. Two new problems have been added to accompany the revisions in the text. The revisions, along with new margin notes and text art, are intended to enhance student

learning and understanding. Topics revised include physical characteristics, nomenclature, geometric isomers, and parts of the section on the reactions of alkenes and alkynes. A new table, and accompanying text, on saturated and unsaturated fatty acids has been added to help students recognize the practical applications of the chemistry being studied.

Chapter 12 A new Example, *Using the Common System of Nomenclature to Name Alcohols,* has been added, along with a set of practice problems and a set of recommended practice problems to help students master the concept. The *Medical Perspective: Fetal Alcohol Syndrome,* has been updated to reflect the more recently described Fetal Alcohol Spectrum Disorder. New text art has been designed to help students understand the physical properties of alcohols and the nature of intramolecular hydrogen bonding. Revision of the discussion of intramolecular hydrogen bonding, along with the new text art, provides students with a clear idea of the importance of hydrogen bonding in biological systems. The information on general anesthetics has been updated, and sections on physical properties, dehydration reactions, and oxidation of alcohols have been revised for greater clarity.

Chapter 13 A new *Human Perspective: Powerful Weak Attractions,* including two For Further Understanding questions, has been added to the revised Chapter 13. New text art has been added to the discussion of the common names of ketones and to clarify oxidation products of aldehydes under acidic or basic conditions. Other new text art clarifies the structure of hemiacetals and acetals. Three examples have been modified to include a structure of practical interest or to clarify the principle being applied. Revisions to the text included a reorganization of the discussion of structure and physical properties and additional details to clarify the IUPAC nomenclature of ketones.

Chapter 14 A new *Medical Perspective: Esters for Appetite Control,* including two For Further Understanding questions, has been added. Five new text art diagrams have been added to support the revisions of the text with regard to the structure and physical properties of carboxylic acids and esters, as well as the action of soaps and the significance of phosphoester compounds in nature. Other revisions in the text include the preparation of carboxylic acids, the properties and nomenclature of carboxylic acid salts, and the structure, physical properties, and nomenclature of esters. Unnecessary content regarding acid anhydrides has been deleted.

Chapter 15 New text art, with the associated text revisions, has been designed to assist student understanding of the physical properties and nomenclature of amines, the nomenclature of alkylammonium salts, neutralization reactions, and preparation of amides from acid chlorides. Along with revision of the nature of neutralization reactions, hydrolysis of amides, and nomenclature of amides, the synthesis and structure of primary, secondary, and tertiary amides is introduced in this edition. To complement these changes, the chapter map has been revised and three new key terms have been introduced. Four new problems have been added to allow students to test their understanding of the new materials.

Chapter 16 A new *Medical Perspective: Human Milk Oligosaccharides,* including two For Further Understanding questions, has been added. A new Example, *Identifying a Chiral Compound,* has been added, along with a set of practice problems and a set of recommended practice problems to allow students to test their mastery of the concept. A new figure (16.13) shows the action of the enzymes α-amylase, β-amylase, and maltase. The section on meso compounds has been revised completely and two new problems have been included.

Chapter 17 Section 17.2 has been reorganized so that ω-fatty acids are discussed prior to the section on prostaglandins. The reactions of fatty acids and glycerides has also been reorganized and revised for greater clarity. All text art in the section on sphingolipids has been redesigned as line formulas to enhance student understanding of the structures.

Chapter 18 Two new perspectives have been added to Chapter 18: *A Medical Perspective: Medications from Venoms* and *A Human Perspective: The New Protein.* Sections 18.4, 18.5, and 18.7 have been revised to streamline the text and clarify concepts.

Chapter 19 *A Medical Perspective: HIV Protease Inhibitors and Pharmaceutical Drug Design* has been updated to reflect the variety of new drugs available to treat the infection in adults and children. The discussion of transferases has been rewritten and new text art designed to provide students with an example that they will study later in the chapters on metabolism. Text revisions include Section 19.3 and passages in Sections 19.4, 19.6, 19.7, and 19.8. In all cases, the revisions streamline and simplify concepts to promote more effective student learning.

Chapter 20 A new *Medical Perspective: Epigenomics,* including two For Further Understanding questions, has been added. The more recently described non-invasive prenatal testing procedure has been included in *A Medical Perspective: Molecular Genetics and Detection of Human Genetic Disorders.* The sections on the chemical composition of DNA and RNA and on chromatin structure have been revised for clarity. Section 20.8, Recombinant DNA, has been rewritten to reduce some of the historical methodologies so that students will focus on the potential of more recent advances.

Chapter 21 *A Medical Perspective: High Fructose Corn Syrup* has been updated with information on the recent studies demonstrating the impact of glucose and fructose on the hypothalamus of humans. In each of Sections 21.1–21.6, the text has been revised to simplify concepts. Section 21.7 has been reorganized for greater clarity.

Chapter 22 A new *Medical Perspective, Babies with Three Parents,* including two For Further Understanding questions, has been added. Throughout the chapter, the text has been revised to streamline the writing and clarify the concepts.

Chapter 23 Section 23.5 has been revised extensively to avoid redundancy with information presented in earlier chapters. Six new problems have been added to this chapter.

Applications

Each chapter contains applications that present short stories about real-world situations involving one or more topics students will encounter within the chapter. There are over 100 applications throughout the text, so students are sure to find many topics that spark their interest. Global climate change,

DNA fingerprinting, the benefits of garlic, and gemstones are just a few examples of application topics.

- **Medical Perspectives** relate chemistry to a health concern or a diagnostic application.
- **Green Chemistry** explores environmental topics, including the impact of chemistry on the ecosystem and how these environmental changes affect human health.
- **Human Perspectives** delve into chemistry and society and include such topics as gender issues in science and historical viewpoints.
- **Chemistry at the Crime Scene** focuses on forensic chemistry, applying the principles of chemistry to help solve crimes.
- **Kitchen Chemistry** discusses the chemistry associated with everyday foods and cooking methods.

Learning Tools

In designing the original learning system we asked ourselves: "If we were students, what would help us organize and understand the material covered in this chapter?" Based on the feedback of reviewers and users of our text, we include a variety of learning tools:

- **Chapter Overview** pages begin each chapter, listing learning goals and the chapter outline. Both students and professor can see, all in one place, the plan for the chapter.
- **Learning Goal Icons** mark the sections and examples in the chapter that focus on each learning goal.
- **Chapter Cross-References** help students locate pertinent background material. These references to previous chapters, sections, and perspectives are noted in the margins of the text. Marginal cross references also alert students to upcoming topics related to the information currently being studied.
- **End-of-Chapter Questions and Problems** are arranged according to the headings in the chapter outline, with further subdivision into Foundations (basic concepts) and Applications.
- **Chapter Maps** are included just before the End-of-Chapter Summaries to provide students with an overview of the chapter—showing connections among topics, how concepts are related, and outlining the chapter hierarchy.
- **Chapter Summaries** are now a bulleted list format of chapter concepts by major sections, with the integrated bold-faced **Key Terms** appearing in context. This more succinct format helps students to quickly identify and review important chapter concepts and to make connections with the incorporated Key Terms. Each Key Term is defined and listed alphabetically in the **Glossary** at the end of the book.
- **Answers to Practice Problems** are supplied at the end of each chapter so that students can quickly check their understanding of important problem-solving skills and chapter concepts.
- **Summary of Reactions** in the organic chemistry chapters highlight each major reaction type on a tan background. Major chemical reactions are summarized by equations at the end of the chapter, facilitating review.

Problem Solving and Critical Thinking

Perhaps the best preparation for a successful and productive career is the development of problem-solving and critical thinking skills. To this end, we created a variety of problems that require recall, fundamental calculations, and complex reasoning. In this edition, we have used suggestions from our reviewers, as well as from our own experience, to enhance our 2300 problems. This edition includes new problems and hundreds of example problems with step-by-step solutions.

- **In-Chapter Examples, Solutions, and Practice Problems:** Each chapter includes examples that show the student, step-by-step, how to properly reach the correct solution to model problems. Each example contains a practice problem, as well as a referral to further practice questions. These questions allow students to test their mastery of information and to build self-confidence. The answers to the practice problems can be found at the end of each chapter so students can check their understanding.
- **Color-Coding System for In-Chapter Examples:** In this edition, we also introduced a color-coding and label system to help alleviate the confusion that students frequently have when trying to keep track of unit conversions. Introduced in Chapter 1, this color coding system has been used throughout the problem-solving chapters.

$$3.01 \cancel{\text{ mol S}} \times \frac{32.06 \text{ g S}}{1 \cancel{\text{ mol S}}} = 96.5 \text{ g S}$$

Data Given × Conversion Factor = Desired Result

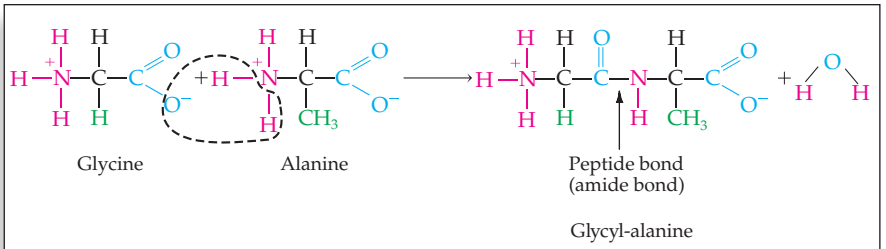
- **In-Chapter and End-of-Chapter Questions and Problems:** We have created a wide variety of paired concept problems. The answers to the odd-numbered questions are found in the back of the book as reinforcement for students as they develop problem-solving skills. However, students must then be able to apply the same principles to the related even-numbered problems.
- **Challenge Problems:** Each chapter includes a set of challenge problems. These problems are intended to engage students to integrate concepts to solve more complex problems. They make a perfect complement to the classroom lecture because they provide an opportunity for in-class discussion of complex problems dealing with daily life and the health care sciences.

Over the course of the last nine editions, hundreds of reviewers have shared their knowledge and wisdom with us, as well as the reactions of their students to elements of this book. Their contributions, as well as our own continuing experience in the area of teaching and learning science, have resulted in a text that we are confident will provide a strong foundation in chemistry, while enhancing the learning experience of students.

The Art Program

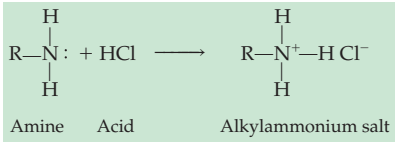
Today's students are much more visually oriented than previous generations. We have built upon this observation through the use of color, figures, and three-dimensional computer-generated models. This art program enhances the readability of the text and provides alternative pathways to learning.

- **Dynamic Illustrations:** Each chapter is amply illustrated using figures, tables, and chemical formulas. All of these illustrations are carefully annotated for clarity. To help students better understand difficult concepts, there are approximately 350 illustrations and 250 photos in the ninth edition.
- **Color-Coding Scheme:** We have color-coded equations so that chemical groups being added or removed in a reaction can be quickly recognized.
  1. **Red print** is used in chemical equations or formulas to draw the reader's eye to key elements or properties in a reaction or structure.
  2. **Blue print** is used when additional features must be highlighted.
  3. **Green background** screens denote generalized chemical and mathematical equations. In the organic chemistry chapters, the Summary of Reactions at the end of the chapter is also highlighted for ease of recognition.
  4. Yellow backgrounds illustrate energy, stored either in electrons or groups of atoms, in the general and biochemistry sections of the text. In the organic chemistry section of the text, yellow background screens also reveal the parent chain of an organic compound.
  5. There are situations in which it is necessary to adopt a unique color convention tailored to the material in a particular chapter. For example, in Chapter 18, the structures of amino acids require three colors to draw attention to key features of these molecules. For consistency, blue is used to denote the acid portion of an amino acid and red is used to denote the basic portion of an amino acid. Green print is used to denote the R groups, and a yellow background screen directs the eye to the α-carbon.
- **Computer-Generated Models:** The ability of students to understand the geometry and three-dimensional structure of molecules is essential to the understanding of organic and biochemical reactions. Computer-generated models are used throughout the text because they are both accurate and easily visualized.

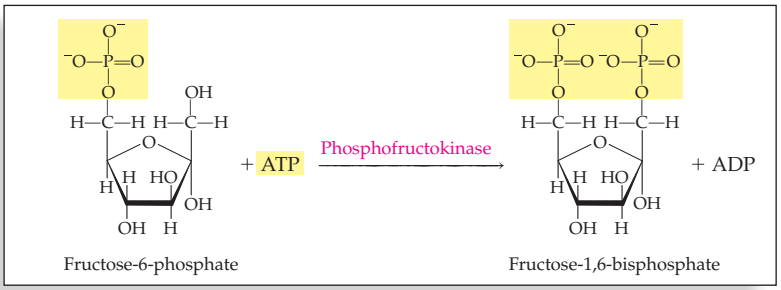


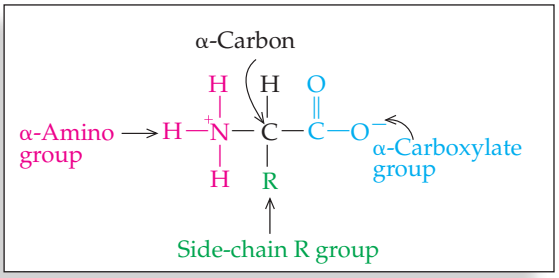
The molecule formed by condensing two amino acids is called a *dipeptide*. The amino acid with a free α-N^+H_3 group is known as the amino terminal, or sim-

Because amines are bases, they react with acids to form alkylammonium salts.



The reaction of methylamine with hydrochloric acid shown is typical of these reactions.





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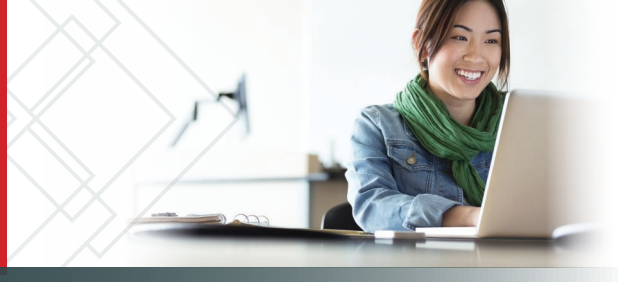

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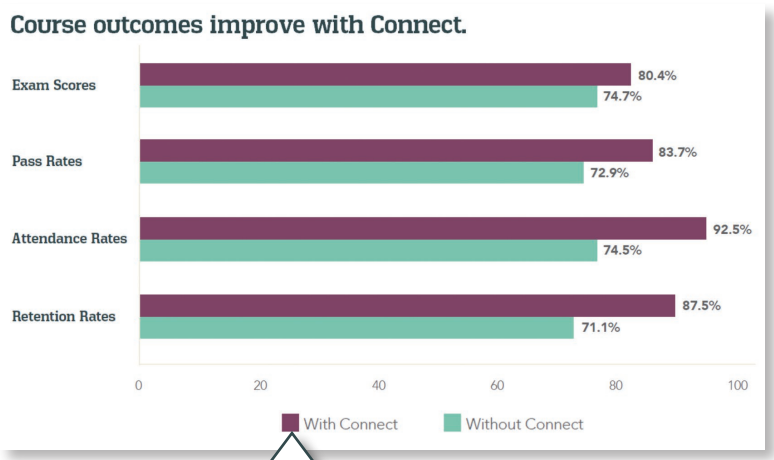

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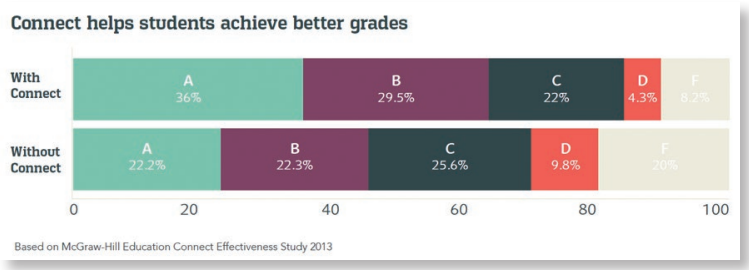

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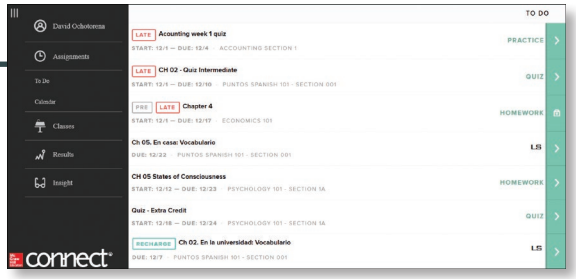

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For the Instructor

- **Instructor's Manual:** Written and developed for the ninth edition by the authors, this ancillary contains many useful suggestions for organizing flipped classrooms, lectures, instructional objectives, perspectives on readings from the text, answers to the even-numbered problems from the text, a list of each chapter's key problems and concepts, and more. The Instructor's Manual is available through the Instructor Resources in the Connect Library tab.
- **Laboratory Manual for General, Organic, and Biological Chemistry:** Authored by Applegate, Neely, and Sakuta to be the most current lab manual available for the GOB course, incorporating the most modern instrumentation and techniques. Illustrations and chemical structures were developed by the authors to conform to the most recent IUPAC conventions. A problem-solving methodology is also utilized throughout the laboratory exercises. There are two online virtual labs for Nuclear Chemistry and Gas Laws. This Laboratory Manual is also designed with flexibility in mind to meet the differing lengths of GOB courses and the variety of instrumentation available in GOB labs. Helpful instructor materials are also available on this companion website, including answers, solution recipes, best practices with common student issues and TA advice, sample syllabi, and a calculation sheet for the Density lab.
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- **More than 300 animations available through Connect:** They supplement the textbook material in much the same way as instructor demonstrations. However, they are only a few mouse-clicks away, any time, day or night. Because many students are visual learners and quite computer-literate, the animations add another dimension of learning; they bring a greater degree of reality to the written word.

For the Student

- **Student Study Guide/Solutions Manual:** A separate Student Study Guide/Solutions Manual, prepared by Danaè Quirk Dorr, is available. It contains the answers and complete solutions for the odd-numbered problems. It also offers students a variety of exercises and keys for testing their comprehension of basic, as well as difficult, concepts.
- **Schaum's Outline of General, Organic, and Biological Chemistry:** Written by George Odian and Ira Blei, this supplement provides students with more than 1 400 solved problems with complete solutions. It also teaches effective problem-solving techniques.

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1

METHODS AND MEASUREMENT

Chemistry

LEARNING GOALS

1. Explain the relationship between chemistry, matter, and energy.
2. Discuss the approach to science, the scientific method, and distinguish among the terms *hypothesis, theory,* and *scientific law.*
3. Distinguish between data and results.
4. Describe the properties of the solid, liquid, and gaseous states.
5. Classify matter according to its composition.
6. Provide specific examples of physical and chemical properties and physical and chemical changes.
7. Distinguish between intensive and extensive properties.
8. Identify the major units of measure in the English and metric systems.
9. Report data and calculate results using scientific notation and the proper number of significant figures.
10. Distinguish between *accuracy* and *precision* and their representations: *error* and *deviation.*
11. Convert between units of the English and metric systems.
12. Know the three common temperature scales, and convert values from one scale to another.
13. Use density, mass, and volume in problem solving, and calculate the specific gravity of a substance from its density.

Chemistry is the study of anything that has mass and occupies space.

OUTLINE

INTRODUCTION

Louis Pasteur, a chemist and microbiologist, said, "Chance favors the prepared mind." In the history of science and medicine, there are many examples in which individuals made important discoveries because they recognized the value of an unexpected observation.

One such example is the use of ultraviolet (UV) light to treat infant jaundice. Infant jaundice is a condition in which the skin and the whites of the eyes appear yellow because of high levels of the bile pigment bilirubin in the blood. Bilirubin is a breakdown product of the oxygen-carrying blood protein hemoglobin. If bilirubin accumulates in the body, it can cause brain damage and death. The immature liver of the baby cannot remove the bilirubin.

In 1956, an observant nurse in England noticed that when jaundiced babies were exposed to sunlight, the jaundice faded. Research based on her observation showed that the UV light changes the bilirubin into another substance, which can be excreted. To this day, jaundiced newborns undergoing phototherapy are treated with UV light. Historically, newborns were diagnosed with jaundice based only on their physical appearance. However, it has been determined that this method is not always accurate. Now, it is common to use either an instrument or a blood sample to measure the amount of bilirubin present in the serum.

In this first chapter of your study of chemistry, you will learn about the scientific method: the process of developing hypotheses to explain observations and the design of experiments to test those hypotheses.

You will also see that measurement of properties of matter, and careful observation and recording of data, are essential to scientific inquiry. So too is assessment of the precision and accuracy of measurements. Measurements (data) must be reported to allow others to determine their significance. Therefore, an understanding of significant figures, and the ability to represent data in the most meaningful units, enables other scientists to interpret data and results.

The goal of this chapter is to help you develop the skills needed to represent and communicate data and results from scientific inquiry.

1.1 The Discovery Process

Chemistry

LEARNING GOAL

1 Explain the relationship between chemistry, matter, and energy.

Chemistry is the study of matter, its chemical and physical properties, the chemical and physical changes it undergoes, and the energy changes that accompany those processes.

Matter is anything that has mass and occupies space. The air we breathe, our bodies, our planet earth, our universe; all are made up of an immense variety and quantity of particles, collectively termed matter. Matter undergoes change. Sometimes this change occurs naturally or we change matter when we make new substances (creating drugs in a pharmaceutical laboratory). All of these changes involve **energy,** the ability to do work to accomplish some change. Hence, we may describe chemistry as a study of matter and energy and their interrelationship.

Models In Chemistry, p. 4

Chemistry is an experimental science. A traditional image of a chemist is someone wearing a white coat and safety goggles while working in solitude in a laboratory. Although much chemistry is still accomplished in a traditional laboratory setting, over the last 40 years the boundaries of the laboratory have expanded to include the power of modern technology. For example, searching the scientific literature for information no longer involves a trip to the library as it is now done very quickly via the Internet. Computers are also invaluable in the laboratory because they control sophisticated instrumentation that measures, collects, processes, and interprets information. The behavior of matter can also be modeled using sophisticated computer programs.

Additionally, chemistry is a collaborative process. The solitary scientist, working in isolation, is a relic of the past. Complex problems dealing with topics such as the environment, disease, forensics, and DNA require input from other scientists and mathematicians who can bring a wide variety of expertise to problems that are chemical in nature.

The boundaries between the traditional sciences of chemistry, physics, and biology, as well as mathematics and computer science, have gradually faded. Medical practitioners, physicians, nurses, and medical technologists use therapies that contain elements of all these disciplines. The rapid expansion of the pharmaceutical industry is based on recognition of the relationship between the function of an organism and its basic chemical makeup. Function is a consequence of changes that chemical substances undergo.

For these reasons, an understanding of basic chemical principles is essential for anyone considering a medically related career; indeed, a worker in any science-related field will benefit from an understanding of the principles and applications of chemistry.

Investigating the causes of the rapid melting of glaciers is a global application of chemistry. How does this illustrate the interaction of matter and energy?

The Scientific Method

LEARNING GOAL

2 Discuss the approach to science, the scientific method, and distinguish among the terms *hypothesis*, *theory*, and *scientific law*.

The **scientific method** is a systematic approach to the discovery of new information. How do we learn about the properties of matter, the way it behaves in nature, and how it can be modified to make useful products? Chemists do this by using the scientific method to study the way in which matter changes under carefully controlled conditions.

The scientific method is not a "cookbook recipe" that, if followed faithfully, will yield new discoveries; rather, it is an organized approach to solving scientific problems. Every scientist brings his or her own curiosity, creativity, and imagination to scientific study. Yet, scientific inquiry does involve some of the "cookbook recipe" approach.

Characteristics of the scientific process include the following:

- *Observation.* The description of, for example, the color, taste, or odor of a substance is a result of observation. The measurement of the temperature of a liquid or the size or mass of a solid results from observation.
- *Formulation of a question.* Humankind's fundamental curiosity motivates questions of why and how things work.
- *Pattern recognition.* When a cause-and-effect relationship is found, it may be the basis of a generalized explanation of substances and their behavior.
- *Theory development.* When scientists observe a phenomenon, they want to explain it. The process of explaining observed behavior begins with a hypothesis. A **hypothesis** is simply an attempt to explain an observation, or series of observations. If many experiments support a hypothesis, it may attain the status of a theory. A **theory** is a hypothesis supported by extensive testing (experimentation) that explains scientific observations and data and can accurately predict new observations and data.
- *Experimentation.* Demonstrating the correctness of hypotheses and theories is at the heart of the scientific method. This is done by carrying out carefully designed experiments that will either support or disprove the hypothesis or theory. A scientific experiment produces **data.** Each piece of data is the individual result of a single measurement or observation.

  A **result** is the outcome of an experiment. Data and results may be identical, but more often, several related pieces of data are combined, and logic is used to produce a result.
- *Information summarization.* A **scientific law** is nothing more than the summary of a large quantity of information. For example, the law of conservation of matter states that matter cannot be created or destroyed, only converted from one form to another. This statement represents a massive body of chemical information gathered from experiments.

LEARNING GOAL

3 Distinguish between data and results.

LEARNING GOAL

3 Distinguish between data and results.

EXAMPLE 1.1 **Distinguishing Between Data and Results**

In many cases, a drug is less stable in the presence of moisture, and excess moisture can hasten the breakdown of the active ingredient, leading to loss of potency. Bupropion (Wellbutrin) is an antidepressant that is moisture sensitive. Describe an experiment that will allow for the determination of the quantity of water gained by a certain quantity of bupropion when it is exposed to air.

Solution

To do this experiment, we must first weigh the buproprion sample, and then expose it to the air for a period of time and reweigh it. The change in weight,

$$[\text{weight}_{\text{final}} - \text{weight}_{\text{initial}}] = \text{weight difference}$$

indicates the weight of water taken up by the drug formulation. The initial and final weights are individual bits of *data;* by themselves they do not answer the question, but they do provide the information necessary to calculate the answer: the results. The difference in weight and the conclusions based on the observed change in weight are the *results* of the experiment.

Note: This is actually not a very good experiment because many conditions were not measured. Measurement of the temperature, humidity of the atmosphere, and the length of time that the drug was exposed to the air would make the results less ambiguous.

Practice Problem 1.1

Describe an experiment that demonstrates that the boiling point of water changes when salt (sodium chloride) is added to the water.

▶ For Further Practice: **Questions 1.35 and 1.36.**

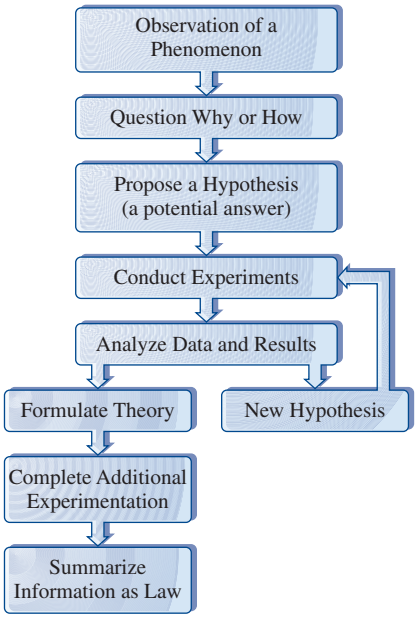


Figure 1.1 The scientific method is an organized way of doing science that incorporates a degree of trial and error. If the data analysis and results do not support the initial hypothesis, the cycle must begin again.

The scientific method involves the interactive use of hypotheses, development of theories, and thorough testing of theories using well-designed experiments. It is summarized in Figure 1.1.

Models in Chemistry

Hypotheses, theories, and laws are frequently expressed using mathematical equations. These equations may confuse all but the best of mathematicians. For this reason, a *model* of a chemical unit or system is often used to help illustrate an idea. A good model based on everyday experience, although imperfect, gives a great deal of information in a simple fashion.

Consider the fundamental unit of methane, the major component of natural gas, which is composed of one carbon (symbolized by C) atom and four hydrogen (symbolized by H) atoms.

A geometrically correct model of methane can be constructed from balls and sticks. The balls represent the individual atoms of hydrogen and carbon, and the sticks correspond to the attractive forces that hold the hydrogen and carbon together. The model consists of four balls representing hydrogen symmetrically arranged around a center ball representing carbon.

A Human Perspective

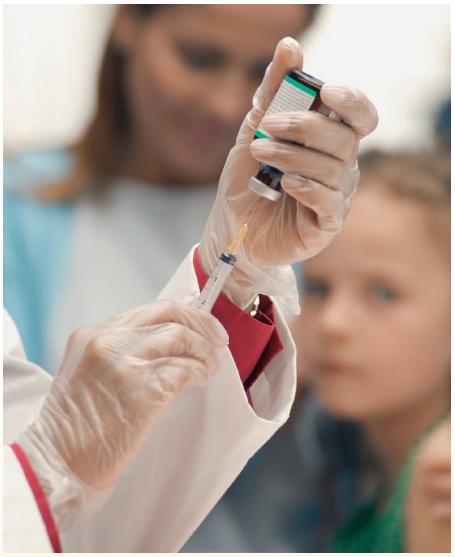
The Scientific Method

The discovery of penicillin by Alexander Fleming is an example of the scientific method at work. Fleming was studying the growth of bacteria. One day, his experiment was ruined because colonies of mold were growing on his plates. From this failed experiment, Fleming made an observation that would change the practice of medicine: Bacterial colonies could not grow in the area around the mold colonies. Fleming hypothesized that the mold was making a chemical compound that inhibited the growth of the bacteria. He performed a series of experiments designed to test this hypothesis.

The success of the scientific method is critically dependent upon carefully designed experiments that will either support or disprove the hypothesis. This is exactly what Fleming did.

In one experiment, he used two sets of tubes containing sterile nutrient broth. To one set he added mold cells. The second set (the control tubes) remained sterile. The mold was allowed to grow for several days. Then the broth from each of the tubes (experimental and control) was passed through a filter to remove any mold cells. Next, bacteria were placed in each tube. If Fleming's hypothesis was correct, the tubes in which the mold had grown would contain the chemical that inhibits growth, and the bacteria would not grow. On the other hand, the control tubes (which were never used to grow mold) would allow bacterial growth. This is exactly what Fleming observed.

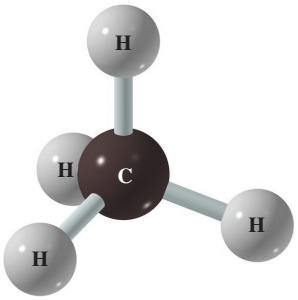
Within a few years this *antibiotic*, penicillin, was being used to treat bacterial infections in patients.



A nurse administers an injection of penicillin to a young patient.

For Further Understanding

- What is the purpose of the control tubes used in this experiment?
- Match the features of this article with the flowchart items in Figure 1.1.



Color-coding the balls distinguishes one type of atom from another; the geometrical form of the model, all of the angles and dimensions of a tetrahedron, are the same for each methane unit found in nature. Methane is certainly not a collection of balls and sticks, but such models are valuable because they help us understand the chemical behavior of methane and other more complex substances.

The structure-properties concept has advanced so far that compounds are designed and synthesized in the laboratory with the hope that they will perform very specific functions, such as curing diseases that have been resistant to other forms of treatment. Figure 1.2 shows some of the variety of modern technology that has its roots in scientific inquiry.

Chemists and physicists have used the observed properties of matter to develop models of the individual units of matter. These models collectively make up what we now know as the atomic theory of matter, which is discussed in detail in Chapter 2.