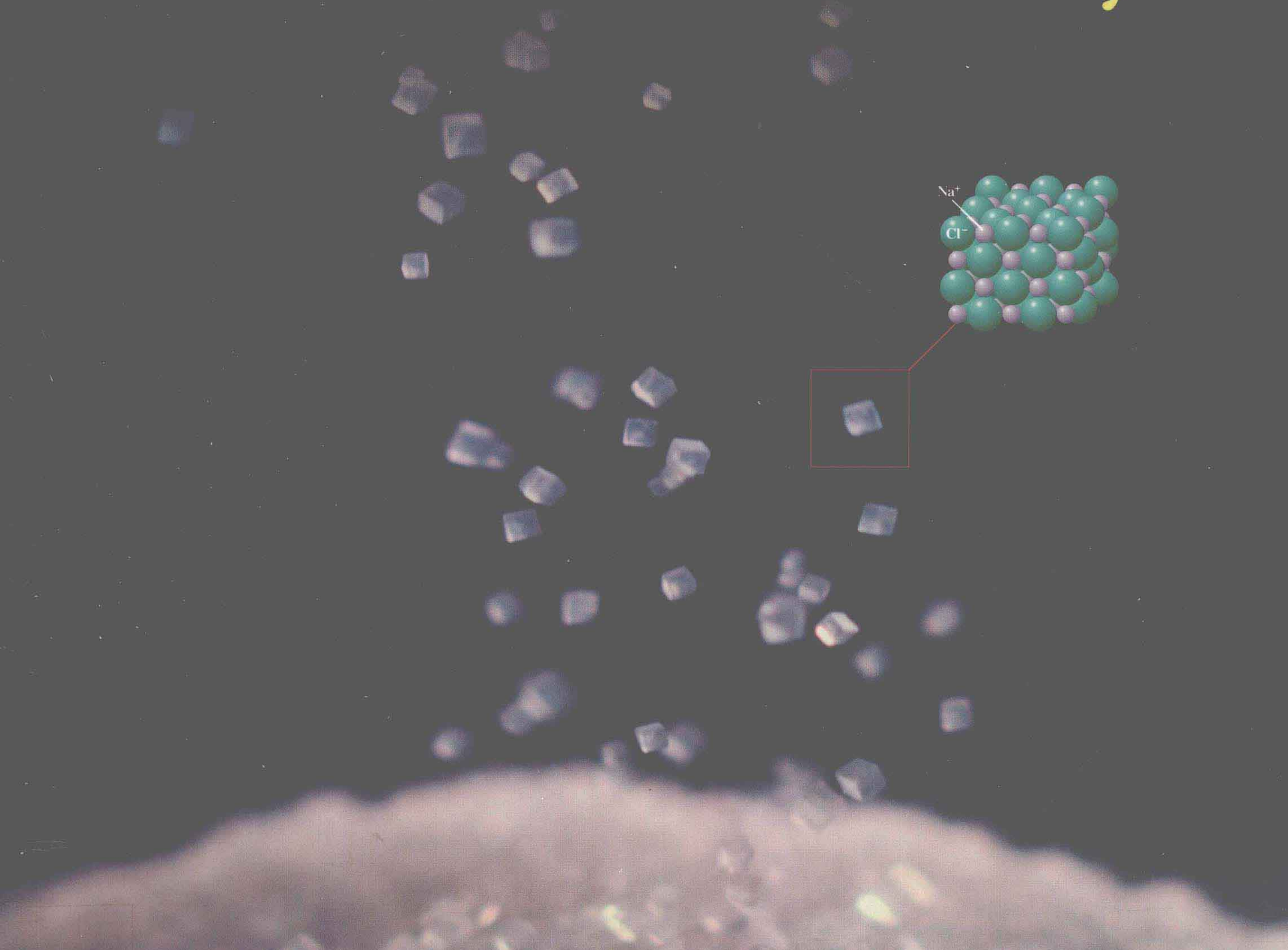
Essentials of
General Chemistry



EBBING | GAMMON | RAGSDALE

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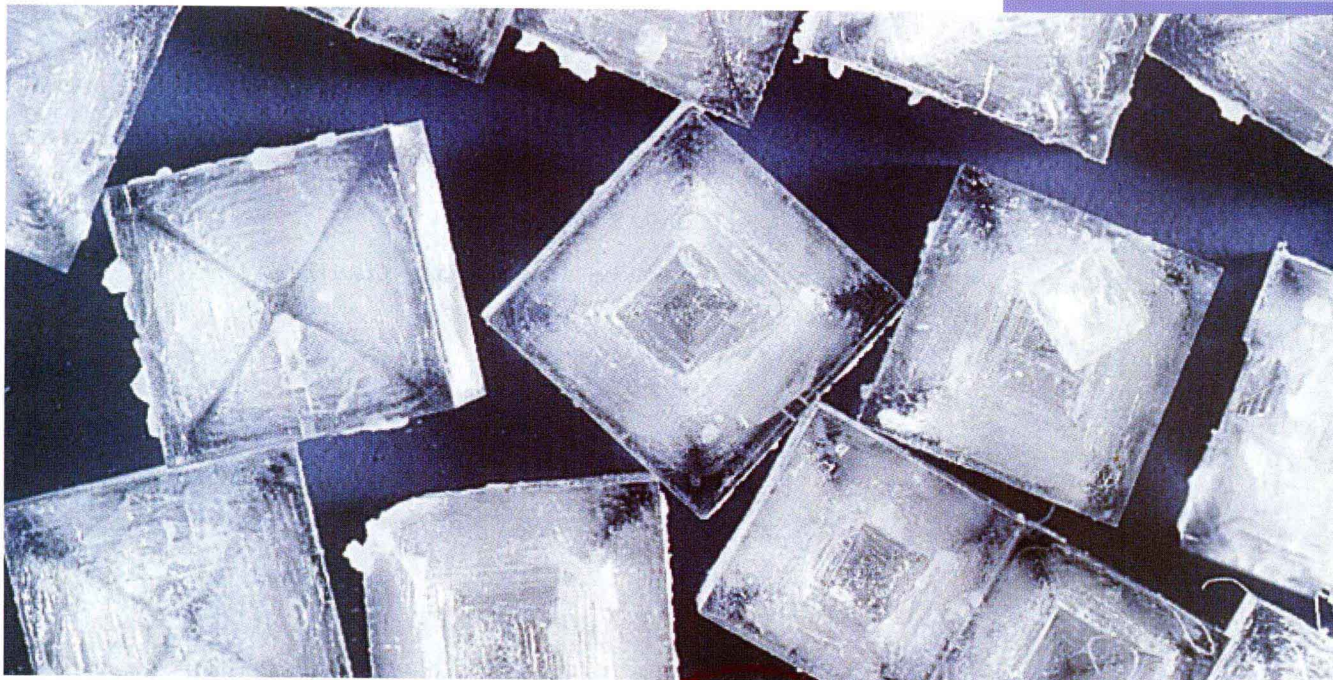

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Warning: This book contains descriptions of chemical reactions and photographs of experiments that are potentially dangerous and harmful if undertaken without proper supervision, equipment, and safety precautions. DO NOT attempt to perform these experiments relying solely on the information presented in this text.

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Essentials of
General Chemistry

Preface

To the Instructor

The Essentials of General Chemistry embodies the core and essence of Ebbing and Gammon's highly successful *General Chemistry*. There are several reasons for distilling a text as comprehensive as *General Chemistry* into an Essentials text. *The Essentials of General Chemistry* can be completely covered in two semesters without omitting any fundamental areas. It also facilitates the use of a common curriculum at large universities and colleges where there are many instructors and sections. This is a book for the students, and we must not forget that a textbook is the best place for a student to learn the concepts of chemistry. Students can read this shortened version in its entirety, and it is a first-rate book at a lower cost. *The Essentials of General Chemistry* offers the students a friendly, challenging, and stimulating environment for learning and developing the principles of chemistry.

Past users and prospective users will note that we have been able to maintain the spirit and vitality of the parent textbook, even though the text proper has been shortened by 325 pages. We have kept most of the essays that provided excitement and relevancy. The text still includes the lucid explanations that are a hallmark of all seven editions of *General Chemistry*.

What has been cut? The Exercises that usually followed the Examples have been eliminated. (Many of these Exercises have been incorporated into the Lecture Outline for the Essentials book, which is a help for both professors and students.) The Examples are immediately followed by references to similar problems to be found at the end of the chapter. The Media Activities have been moved to the *Technology Guide*, and we have reduced the number of questions and problems at the end of each chapter. For instance, in the chapter on the gaseous state, these questions and problems are reduced from 134 to 80 in number. This will leave most instructors plenty of exercises to use in subsequent years without repeating an assignment. Many times we have eliminated additional explanations and examples of principles that have already been illustrated. The treatment of molecular orbital theory has been largely restricted to simple diatomic molecules. The discussion of colloids has been greatly curtailed, and the section on optical activity in coordination compounds has been omitted. Many professors did not cover Chapter 25 on biological chemistry in *General Chemistry*, so we have essentially dropped that chapter. We have included the section on synthetic polymers in Chapter 24, "Organic Chemistry."

We invite instructors to examine this new Essentials of *General Chemistry* textbook carefully. It is a beautifully illustrated and produced book that presents chemistry in a stimulating, meaningful, and coherent way.

Clear, Lucid Explanations of Chemical Concepts Just as in *General Chemistry*, we have placed the highest priority on writing clear explanations of chemical concepts. We have made every effort to relate abstract concepts to specific real-world events and have presented topics in a logical, yet flexible, order. By incorporating suggestions from instructors and students, we have refined the writing.

Concise Yet Comprehensive Treatment This shorter, less expansive text includes all of the important topics expected in a general chemistry text, but with substantial savings in length.

Coherent Problem-Solving Approach We teach problem solving by coupling worked-out Examples with corresponding end-of-chapter Problems. This approach has been one of the cornerstones of the larger *General Chemistry* text. In the present book, we have also included Problem Strategies to underscore how one thinks through the solution to a problem.

We have incorporated two additional study aids that have met with an enthusiastic response in *General Chemistry*: Concept Checks and Conceptual Problems. We have written these problems to encourage students to think about the chemical concepts involved, rather than focusing narrowly on just obtaining a numerical result. Many of these problems include artwork to help students visualize the key concepts.

Chapter Essays Showcasing Chemistry as a Modern Science Our "A Chemist Looks At..." essays highlight applications of chemistry to medicine and health, to frontiers of science, to the environment, and to everyday life. Students immediately see how the material is related to their future careers, their world, and their lives. The essays are designed to engage students' interest, while at the same time showcasing the chemistry involved. Most of the topics concern contemporary research demonstrating how chemistry is a vibrant, constantly changing science that is acutely relevant to our modern world. The essay "Removing Caffeine from Coffee," for example, describes the removal of caffeine from coffee via supercritical carbon dioxide instead of environmentally problematic organic solvents. Among the other essays are "Nitric Oxide and Biological Signaling," which describes the importance of a simple chemical compound in human biology, and "Scanning Tunnel Microscopy," which discusses a tool that makes it possible to view chemistry at the molecular level.

An Enhanced Illustration Program with an Emphasis on Molecular Concepts Most of us are strongly visual in our learning. When we see something, we tend to remember it. Much of the art for this text comes from *General Chemistry*, where it has been constantly refined and improved. In particular, the art focuses on presenting chemistry at the molecular level. We start building the molecular "story" in Chapter 1, and by Chapter 2 we have developed the molecular view and have integrated it into the problem-solving apparatus as well as into the text discussions. We continue in the subsequent chapters to use the molecular view to enhance the presentation of chemical concepts. In Chapter 3, on stoichiometry, for example, a Concept Check asks the student to visualize the concept of limiting reactant in terms of molecular models.

A Chapter on Materials Chapter 13, "Materials of Technology," traces cutting-edge developments in this important area. For example, it includes information on nonmetals, discussing the fullerenes and nanotechnology, ceramics, and composites.

To the Student

You are about to embark on a fascinating intellectual adventure. You are surrounded by chemical materials and substances that play vital roles in your life. How can you gain an understanding and an appreciation of the chemistry that takes place?

Of course, any new subject has concepts and ways of looking at things that at first may seem strange. Chemistry, dealing as it does with all the materials of the universe, from living things to the objects of the heavens, is a complex field. But its central concept is simple: Everything is composed of a selection from about one hundred different kinds of atoms, chemically combined as molecules or other clumps of matter. As abstract as such objects might seem, chemists now have supermicroscopes that can "see" these atoms and molecules.

Having studied and taught chemistry for years, your authors are well aware of the problems that students encounter in their study of chemistry. In writing this book, we have constantly attempted to relate the chemical concepts to specific things in the real world. And we have included an abundance of instructional aids to help you thoroughly understand the ideas presented.

Features of This Book

Each individual learns in a different way. For that reason, we have incorporated a number of different learning aids into the text to help you master the subject. We hope that by becoming familiar with these features, which are listed below, you will be able to tailor-make a study program that meets your particular needs.

Chapter Theme Each chapter begins with a theme—something specific that reveals the real-world relevance of the chapter topic. For example, Chapter 2 ("Atoms, Molecules, and Ions") opens with a discussion of sodium, chlorine, and sodium chloride. This chapter theme then leads naturally into a series of questions (such as "How do we explain the differences in the properties of different forms of matter?") that we answer later in the chapter.

Vocabulary Chemists use words in a precise way, and it is important for your "chemistry vocabulary" to include all the terms you will need in order to read and communicate about the subject effectively. When an important new word is introduced in the text, we have flagged it by putting it in ***boldface*** type. The definition of that word will generally follow, in the same sentence, in *italic* type. All of these key words are collected at the end of the chapter in the list of Important Terms. They also appear, along with a few other words, in the Glossary at the end of the book. In addition, on the student web site, you can use the *Flashcard* program or print them out to practice learning these terms.

Concept Checks and Conceptual Problems Many of the questions that you encounter daily start out "What do you think will happen if...?" or "Why is this choice the better one?" These questions are not asking for a numerical answer; rather, they are asking you to apply your conceptual knowledge to a problem. To answer this type of question, you need to think critically and to apply a variety of chemical concepts and ideas. Merely knowing a set of formulas and memorizing a series of steps to solve a problem will not help you obtain the answer. In many cases, your conceptual understanding of chemistry will be what you remember and apply later in life.

To help you master the concepts presented in this text, we have placed Concept Checks in the body of every chapter and a section of Conceptual Problems at the end of each chapter. Answers to the Concept Checks and the odd-numbered Conceptual Problems are provided at the end of the book. More detailed discussions of the Concept Checks are included on the student web site.

Problem-Solving Program Problem solving is an important part of chemistry. By solving problems yourself, you become involved with the subject, and by being involved with the subject, you will learn it. But problem solving is like learning to swim or to play a musical instrument; it becomes easy only with practice. In chemistry, one concept builds upon another, and fact upon fact. The secret of problem solving in chemistry is to know what you learned earlier so well that when you approach a new problem, it is easy to see how to put the pieces together.

Recognizing the importance of problem solving in chemistry, we felt that the burden could be much reduced if we established and followed a consistent problem-solving program. Accordingly, we introduce each problem-solving skill with an Example, in which you are led through the reasoning involved in working out a particular type of problem. Many of these examples include a Problem Strategy that underscores the thinking process involved in solving the problem. At the end of the Example is a list of corresponding end-of-chapter Practice Problems. Solving them will provide immediate reinforcement! Try some of these to gain mastery of each problem-solving skill. Answers to odd-numbered problems appear at the end of the book.

Checklist for Review When it comes to reviewing, students generally develop their own techniques. We have tried to accommodate these differences by presenting various review possibilities. For example, you may find that the list of Important Terms is useful not only because it is a list of new words but also because, as you look over those words, you see the structure of the chapter. As you mentally note this structure, try to recall the ideas associated with the words. You may also choose to use the *Flashcard* program on the web site to review these terms. Many chapters also introduce one or more mathematical equations to be used in problem solving. In the chapter, these are shaded in color; then, in the Checklist for Review, they are listed as Key Equations. The Summary of Facts and Concepts presents a verbal overview of the chapter. Study this, and as you go over each statement, try to flesh out the main points. Finally, we present a list of Operational Skills. This is a summary of the problem-solving skills introduced or developed in that chapter. Each entry in this extremely useful section tells you what information is needed, and what is to be solved for, in a given type of problem. Each operational skill also cites a numbered Example that illustrates the application of that problem-solving skill.

End-of-Chapter Questions and Problems This section begins with Review Questions. These have been designed to test your understanding of the ideas introduced in the chapter. Generally, they can be answered by straightforward recall or by simple extension of the chapter material. Following these questions, we have added a section of more in-depth Conceptual Problems. After these problems you will find several sections of problems to help you hone your problem-solving skills. The Practice Problems are keyed to particular topics; the General Problems are not. The Cumulative-Skills Problems give you an opportunity to combine several skills, including skills that you developed in previous chapters.

Complete Instructional Package

This text is complemented by a complete package of print and electronic ancillaries.

For Students and Instructors

Student web site (http://college.hmco.com/, select "chemistry"). Password required. Includes Houghton Mifflin's ACE self-quizzing, interactive molecules, movies, flashcards of key terms and concepts, and links to other useful sites.

Student Technology Package This package is available on request at an **additional charge** with all new texts. It is also available for sale separately. The package includes

Technology Guide A handy guide to the technology resources available to accompany *The Essentials of General Chemistry*. This booklet includes Media Activities, which guide students in using the technology resources provided to explore topics and concepts and to solve problems.

***General Chemistry Interactive 5.0* Student CD.** A highly interactive CD-ROM that helps students visualize molecular behavior, explore important concepts, and practice working problems. The CD runs on both Macintosh and Windows platforms.

Passkey. A unique 13-digit code that gives students access to web site materials. The passkey is valid for 12 months from sign-up.

Smarthinking™ online tutoring. Passkey required. Web-based tutoring by qualified e-structors at Smarthinking.com.

Houghton Mifflin's Eduspace™ Online homework system. Passkey required. The online homework system provides students with questions that are keyed directly to the text content. Individual student progress is tracked and may be viewed, managed, and downloaded by instructors.

Experiments in General Chemistry, R. A. D. Wentworth, Indiana University. Forty experiments parallel the material found in the textbook. Each lab exercise has a pre-lab assignment, background information, clear instructions for performing the experiment, and a convenient section for reporting results and observations. An instructor's resource manual is also available. Several experiments in this edition incorporate the use of computers and the Internet.

Student Solutions Manual, David Bookin, Mount San Jacinto College; Darrell D. Ebbing, Wayne State University; and Steven D. Gammon, University of Idaho. This manual contains detailed solutions to all the odd-numbered problems in the text (in-chapter exercises, end-of-chapter problems, General Problems, and Cumulative-Skills Problems). It also contains answers to the Review Questions, Concept Checks, and Conceptual Problems.

Study Guide for *The Essentials of General Chemistry,* Larry K. Krannich, University of Alabama at Birmingham. Each chapter of this study guide reinforces the students' understanding of concepts and operational skills presented in the text. It includes the following features for each chapter: a list of key terms and their definitions, a diagnostic test with answers, a summary of major concepts and operational skills, additional practice problems and their solutions, and a chapter post-test with answers.

Qualitative Analysis and Ionic Equilibrium, George H. Schenk, Wayne State University. This laboratory manual presents a traditional qualitative analysis scheme that can be used with the text or can stand alone. It stresses the chemistry of metal ions and anions. Each exercise has a preliminary report and a final report for pre-lab and post-lab activities.

Workbook Lecture Outline, Ron Ragsdale, University of Utah. Students can use the outline as a platform to take organized notes on in-class lectures or as a guide to help them process important concepts that they encounter in their own reading. Each outline is set up as a skeleton of the corresponding chapter with enough room to take notes. Students can fill in some of the outline before class so that they can listen more attentively during lecture. Instructors may find the outlines useful in organizing their own lectures as well.

For Instructors

Instructor's Resource Manual with Printed Test Bank, Ron Ragsdale, University of Utah. This manual offers information about chapter essays, suggestions for alternative sequencing of topics, short chapter descriptions, a master list of operational skills, correlation of Cumulative-Skills Problems with text topics, alternative examples for lectures, suggested lecture demonstrations, and a list of overhead transparencies. The printed test bank contains more than 2000 multiple-choice test questions organized by chapter.

HMClassPrep™ Package. This instructor CD-ROM has everything that instructors will need to develop their lectures. It includes PowerPoint slides of text figures, photos, concept checks, and lecture outlines, along with videos, animations, and an online *Instructor's Resource Manual*. The assets can be accessed from the CD-ROM by chapter or asset type. They can be customized to help instructors create lectures and in-class activities in a flexible manner.

HMTesting Computerized Testing System. This flexible test-editing program and comprehensive grade book make it easy to administer tests and to track students' progress. Instructors can administer tests via a network server or the Web. The HMTesting database contains a wealth of algorithmically generated questions and can produce multiple-choice or free-response tests. Instructors can customize questions on the basis of chapter, question format, and/or specific topics.

Transparencies. Numerous two-color and four-color transparencies of figures, tables, and photographs selected from the text are provided.

Instructor web site at college.hmco.com. This web site, created exclusively for instructors, allows access to all student web site resources plus downloadable PowerPoint slides, an on-line version of the *Instructor's Resource Manual*, additional instructor and classroom resources, animations, and relevant links.

Complete Solutions Manual, David Bookin, Mount San Jacinto College; Darrell D. Ebbing, Wayne State University; and Steven D. Gammon, University of Idaho. This complete solutions manual contains worked-out answers to *all* of the problems that appear in *The Essentials of General Chemistry*. This includes detailed, step-by-step solutions for all the Practice Problems, General Problems, and Cumulative-Skills Problems that appear at the end of the chapters. Also provided are answers to all the Review Questions, Concept Checks, and Conceptual Problems. This supplement is intended for the instructor's convenience and for those who want their students to have solutions to all problems.

Instructor's Resource Manual to the Lab Manual, R. A. D. Wentworth, Indiana University. This manual provides instructors with sample results for all pre- and post-lab activities in *Experiments in General Chemistry*.

Content for Course Management Software is available through *WebCT* and *Blackboard.com*. These two distributed learning systems enable you to create a virtual classroom without any knowledge of HTML. Features include assessment tools and a grade book, online file exchange between you and your students, and online syllabi and course descriptions. The customized cartridges for *General Chemistry* feature quizzes, study materials, and exercises related to the text and can be used in conjunction with *The Essentials of General Chemistry*.

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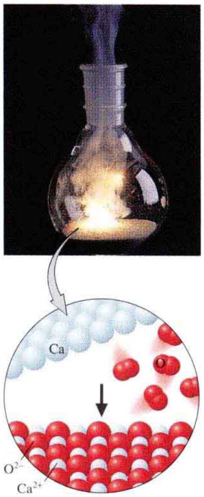
Features of *Essentials of General Chemistry*

Essentials of General Chemistry focuses on the importance of teaching quantitative **problem solving**—a quality complemented by features that focus on key themes of **visualization** and **conceptual understanding**.

VISUALIZATION



ion gains two electrons to form a copper atom in the metal. The net effect is that two electrons are transferred from each iron atom in the metal to each copper(II) ion.

The concept of *oxidation numbers* was developed as a simple way of keeping track of electrons in a reaction. Using oxidation numbers, you can determine whether or not electrons have been transferred from one atom to another. If electrons have been transferred, an oxidation–reduction reaction has occurred.

Oxidation Numbers

We define the **oxidation number** (or **oxidation state**) of an atom in a substance as *the actual charge of the atom if it exists as a monatomic ion, or a hypothetical charge assigned to the atom in the substance by simple rules*. An oxidation–reduction reaction is one in which one or more atoms change oxidation number, implying that there has been a transfer of electrons.

Consider the combustion of calcium metal in oxygen gas (Figure 4.11).

$$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$$

This is an oxidation–reduction reaction. To see this, you assign oxidation numbers to the atoms in the equation and then note that the atoms change oxidation number during the reaction.

Since the oxidation number of an atom in an element is always zero, Ca and O in O_2 have oxidation numbers of zero. Another rule follows from the definition of oxidation number: The oxidation number of an atom that exists in a substance as a monatomic ion equals the charge on that ion. So the oxidation number of Ca in CaO

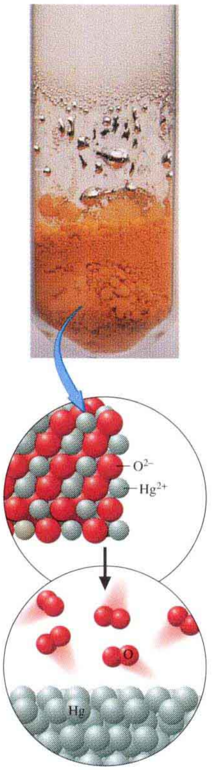


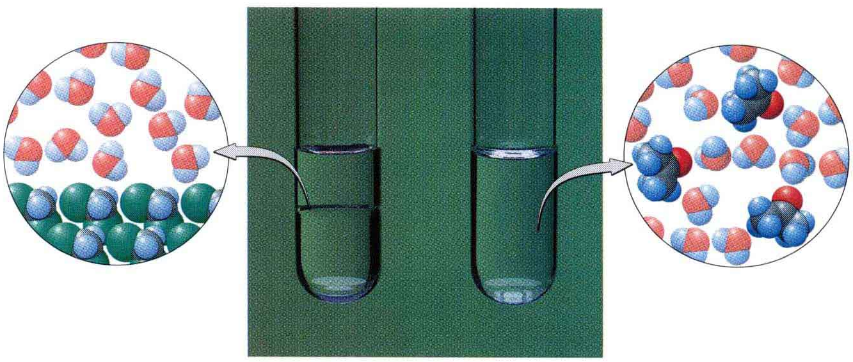
Figure 4.14
Decomposition reaction. The decomposition reaction of mercury(II) oxide into its elements, mercury and oxygen.

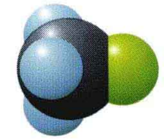
Molecular blowups help students connect the macroscopic to the molecular level.

Figure 12.1
Immiscible and miscible liquids. *Left:* Water and methylene chloride are immiscible and form two layers. *Right:* Acetone and water are miscible liquids; that is, the two substances dissolve in each other in all proportions.

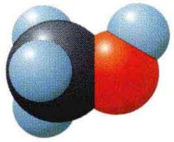
Liquid Solutions

Most liquid solutions are obtained by dissolving a gas, liquid, or solid in some liquid. Soda water, for example, consists of a solution of carbon dioxide in water. Acetone in water is an example of a liquid–liquid solution. (Immiscible and miscible liquids are shown in Figure 12.1.) Seawater contains both dissolved gases (from air) and solids (mostly sodium chloride).





CH_3F



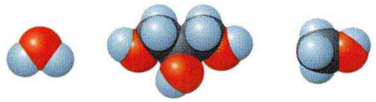
CH_3OH

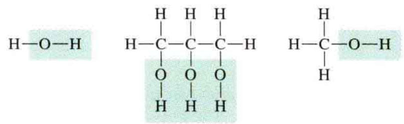
Figure 11.17
Fluoromethane and methanol. Space-filling molecular models.

Hydrogen Bonding

It is interesting to compare fluoromethane, CH_3F, and methanol, CH_3OH (Figure 11.17). They have about the same molecular weight (34 for CH_3F and 32 for CH_3OH) and about the same dipole moment (1.81 D for CH_3F and 1.70 D for CH_3OH). You might expect these substances to have about the same intermolecular attractive forces and therefore about the same boiling points. In fact, the boiling points are quite different. Fluoromethane boils at $-78°C$ and is a gas under normal conditions. Methanol boils at 65°C and is normally a liquid. Why?

We have already seen that the properties of water and glycerol cannot be explained in terms of van der Waals forces alone. What water, glycerol, and methanol have in common is one or more —OH groups.





water glycerol methanol

Many chemical structures are depicted in multiple ways to help students make the leap from symbolic to visual representations.

$$\Delta H = H_f - H_i = (U_f + PV_f) - (U_i + PV_i)$$

Collecting the internal-energy terms and the pressure-volume terms, you can rewrite this as

$$\Delta H = (U_f - U_i) + P(V_f - V_i) = \Delta U + P\Delta V$$

You write ΔU for $U_f - U_i$ and ΔV for $V_f - V_i$ and rearrange this as follows:

$$\Delta U = \Delta H - P\Delta V$$

The equation says that the internal energy of the system changes in two ways. It changes because energy leaves or enters the system as heat (ΔH), and it changes because the system increases or decreases in volume against the constant pressure of the atmosphere (which requires energy $-P\Delta V$).

Consider a specific reaction. When 2 mol of sodium and 2 mol of water react in a beaker, 1 mol of hydrogen forms and heat evolves.

Because hydrogen gas forms during the reaction, the volume of the system increases. To expand, the system must push back the atmosphere, and this requires energy equal to the pressure–volume work. It may be easier to see this pressure–volume work if you replace the constant pressure of the atmosphere by an equivalent pressure from a piston-and-weight assembly, as in Figure 6.7. When hydrogen is released during the reaction, it pushes upward on the piston and raises the weight. It requires energy to lift a weight upward in a gravitational field. If you calculate this pressure–volume work at 25°C and 1.00 atm pressure, you find that it is $-P\Delta V = -2.5$ kJ.

In the sodium–water reaction, the internal energy changes by -367.5 kJ because heat evolves and changes by -2.5 kJ because pressure–volume work is done. The total change of internal energy is

$$\Delta U = \Delta H - P\Delta V = -367.5 \text{ kJ} - 2.5 \text{ kJ} = -370.0 \text{ kJ}$$

As you can see, ΔU does not differ a great deal from ΔH. This is the case in most reactions.

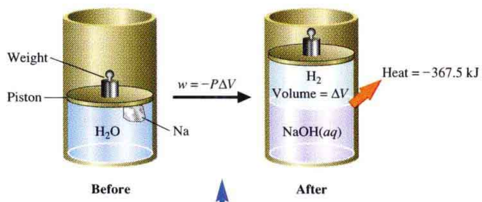


Figure 6.7
Pressure–volume work. In this experiment, we replace the pressure of the atmosphere by a piston-and-weight assembly of equal pressure. As sodium metal reacts with water, the hydrogen gas evolved pushes the piston and weight upward (compare *before* and *after*). It requires work to raise the piston and weight upward in a gravitational field.

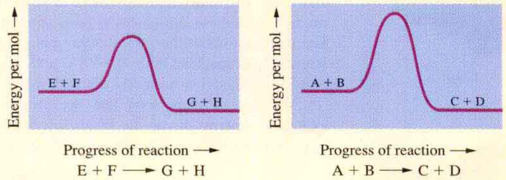
Revised diagrams convey chemical principles clearly and effectively.

CONCEPTUAL UNDERSTANDING

Concept Checks throughout the chapters challenge the student to learn the ideas underlying chemistry. An icon identifies conceptually focused material.

CONCEPT CHECK 14.4

Consider the following potential energy curves for two different reactions:



a. Which reaction has a higher activation energy for the forward reaction?

b. If both reactions were run at the same temperature and have the same orientation requirements to react, which one would have the larger rate constant?

c. Are these reactions exothermic or endothermic?

A Checklist for Review

Important Terms

acid-ionization constant (17.1)
degree of ionization (17.1)
base-ionization constant (17.3)
hydrolysis (17.4)
common-ion effect (17.5)
buffer (17.6)
Henderson–Hasselbalch equation (17.6)
acid–base titration curve (17.7)
equivalence point (17.7)

Key Equations

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

$$K_b = \frac{[HB^+][OH^-]}{[B]}$$

$$K_aK_b = K_w$$

$$pH = pK_a + \log\frac{[base]}{[acid]}$$

Summary of Facts and Concepts

When a weak acid dissolves in water, it ionizes to give hydronium ions and the conjugate base ions. The equilibrium constant for this *acid ionization* is $K_a = [H_3O^+][A^-]/[HA]$, where HA is the general formula for the acid. The constant K_a can be determined from the pH of an acid solution of known concentration. Once obtained, the acid-ionization constant can be used to find the concentrations of species in any solution of the acid. In the case of a *diprotic* acid, H_2A, the concentration of H_3O^+ and HA^- are calculated from K_{a1}, and the concentration of A^{2-} equals K_{a2}. Similar considerations apply to *base ionizations.*

Solutions of salts may be acidic or basic because of *hydrolysis* of the ions. The equilibrium constant for hydrolysis equals K_a for a cation or K_b for an anion. Calculation of the pH of a solution of a salt in which one ion hydrolyzes is fundamentally the same as calculation of the pH of a solution of an acid or base. However, K_a or K_b for an ion is usually obtained from the conjugate base or acid by applying the equation $K_aK_b = K_w$.

A *buffer* is a solution that can resist changes in pH when small amounts of acid or base are added to it. A buffer contains either a weak acid and its conjugate base or a weak base and its conjugate acid. The concentrations of acid and base conjugates are approximately equal. Different pH ranges are possible for acid–base conjugates, depending on their ionization constants.

An *acid–base titration curve* is a plot of the pH of the solution against the volume of reactant added. During the titration of a strong acid by a strong base, the pH changes slowly at first. Then, as the amount of base nears the *equivalence point,* the pH rises abruptly, changing by several units. The pH at the equivalence point is 7.0. A similar curve is obtained when a weak acid is titrated by a strong base. The pH at the equivalence point is greater than 7.0 because of hydrolysis of the salt produced. An indicator must be chosen that changes color within a pH range near the equivalence point.

A narrative **Summary of Facts and Concepts** at the end of each chapter recaps the important concepts in each chapter

Conceptual Problems at the end of each chapter reinforce principles by asking nonquantitative questions about the material.

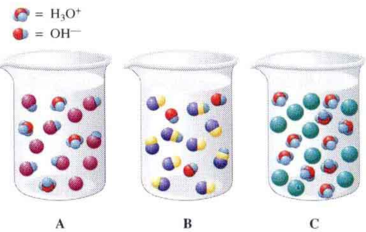
Conceptual Problems

4.11 You come across a beaker that contains water, aqueous ammonium acetate, and a precipitate of calcium phosphate.
a. Write the balanced molecular equation for a reaction between two solutions containing ions that could produce this solution.
b. Write the complete ionic equation for the reaction in part a.
c. Write the net ionic equation for the reaction in part a.

4.12 Three acid samples are prepared for titration by 0.01 *M* NaOH:
1. Sample 1 is prepared by dissolving 0.01 mol of HCl in 50 mL of water.
2. Sample 2 is prepared by dissolving 0.01 mol of HCl in 60 mL of water.
3. Sample 3 is prepared by dissolving 0.01 mol of HCl in 70 mL of water.
a. Without performing a formal calculation, compare the concentrations of the three acid samples (rank them from highest to lowest).
b. When performing the titration, which sample, if any, will require the largest volume of the 0.01 *M* NaOH for neutralization?

4.13 Would you expect a precipitation reaction between an ionic compound that is an electrolyte and an ionic compound that is a nonelectrolyte? Justify your answer.

4.14 Equal quantities of the hypothetical strong acid HX, weak acid HA, and weak base BZ are each added to a separate beaker of water, producing the solutions depicted in the drawings. In the drawings, the relative amounts of each substance present in the solution (neglecting the water) are shown. Identify the acid or base that was used to produce each of the solutions (HX, HA, or BZ).



3.3 Mass Percentages from the Formula

We define the **mass percentage** of *A* as *the parts of* A *per hundred parts of the total, by mass.* That is,

$$\text{Mass \% } A = \frac{\text{mass of } A \text{ in the whole}}{\text{mass of the whole}} \times 100\%$$

The next example will provide practice with the concept of mass percentage. In this example we will start with a compound (formaldehyde, CH_2O) whose formula is given and obtain the percentage composition.

EXAMPLE 3.7

Calculating the Percentage Composition from the Formula

Formaldehyde, CH_2O, is a toxic gas with a pungent odor. Large quantities are consumed in the manufacture of plastics, and a water solution of the compound is used to preserve biological specimens. Calculate the mass percentages of the elements in formaldehyde.

PROBLEM STRATEGY

Interpret the formula in molar terms and then convert moles to masses. Thus, 1 mol CH_2O has a mass of 30.0 g and contains 1 mol C (12.0 g), 2 mol H (2 × 1.01 g), and 1 mol O (16.0 g). Divide each mass of element by the molar mass, then multiply by 100.

SOLUTION

$$\% \text{ C} = \frac{12.0 \text{ g}}{30.0 \text{ g}} \times 100\% = \mathbf{40.0\%}$$

$$\% \text{ H} = \frac{2 \times 1.01 \text{ g}}{30.0 \text{ g}} \times 100\% = \mathbf{6.73\%}$$

You can calculate the percentage of O in the same way, but it can also be found by subtracting the percentages of C and H from 100%:

$$\% \text{ O} = 100\% - (40.0\% + 6.73\%) = \mathbf{53.3\%}$$

See Problems 3.35, 3.36, 3.37, and 3.38.

In-text **Examples** guide students through the logic of solving a type of problem.

Problem Strategies outline the thinking that underlies the numerical solution of the problem. The **Solution** then applies that thinking to a particular problem.

A **Reference to End-of-Chapter Problems** directs students to other problems of this type.

End-of-chapter **Practice Problems** are keyed to particular topics by a heading. In addition, there are **General Problems** and **Cumulative-Skills Problems**, which require students to combine several skills.

368 CHAPTER 11 States of Matter; Liquids and Solids

Practice Problems

Phase Transitions

11.21 Identify the phase transition occurring in each of the following.

a. The water level in an aquarium tank falls continuously (the tank has no leak).
b. A mixture of scrambled eggs placed in a cold vacuum chamber slowly turns to a powdery solid.
c. Chlorine gas is passed into a very cold test tube where it turns to a yellow liquid.
d. When carbon dioxide gas under pressure exits from a small orifice, it turns to a white "snow."

11.22 Identify the phase transition occurring in each of the following.

a. Mothballs slowly become smaller and eventually disappear.
b. Rubbing alcohol spilled on the palm of the hand feels cool as the volume of liquid decreases.
c. A black deposit of tungsten metal collects on the inside of a lightbulb whose filament is tungsten metal.
d. Raindrops hit a cold metal surface, which becomes covered with ice.

11.23 Use Figure 11.6 to estimate the boiling point of diethyl ether, $(C_2H_5)_2O$, under an external pressure of 350 mmHg.

11.24 Use Figure 11.6 to estimate the boiling point of carbon tetrachloride, CCl_4, under an external pressure of 350 mmHg.

of the water in the flask was raised to 83°C? The heat of vaporization of water at 100°C is 40.7 kJ/mol and the specific heat is 4.18 J/(g · °C).

11.29 Chloroform, $CHCl_3$, a volatile liquid, was once used as an anesthetic but has been replaced by safer compounds. Chloroform boils at 61.7°C and has a heat of vaporization of 31.4 kJ/mol. What is its vapor pressure at 33.0°C?

11.30 Methanol, CH_3OH, a colorless, volatile liquid, was formerly known as wood alcohol. It boils at 65.0°C and has a heat of vaporization of 37.4 kJ/mol. What is its vapor pressure at 22.0°C?

11.31 White phosphorus, P_4, is normally a white, waxy solid melting at 44°C to a colorless liquid. The liquid has a vapor pressure of 400.0 mmHg at 251.0°C and 760.0 mmHg at 280.0°C. What is the heat of vaporization of this substance?

11.32 Carbon disulfide, CS_2, is a volatile, flammable liquid. It has a vapor pressure of 400.0 mmHg at 28.0°C and 760.0 mmHg at 46.5°C. What is the heat of vaporization of this substance?

Phase Diagrams

11.33 Shown here is the phase diagram for compound Z. The triple point of Z is −5.1°C at 3.3 atm and the critical point is 51°C and 99.1 atm.