An Introduction to CHEMISTRY

Mark Bishop

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MARK BISHOP

Benjamin Cummings

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Preface

To the Instructor

An Introduction to Chemistry is intended for use in beginning chemistry courses that have no chemistry prerequisite. It was written for students who want to prepare themselves for general college chemistry, for students seeking to satisfy a science requirement, and for students in health-related or other programs that require a one-semester introduction to general chemistry. No matter what your students' goals, this book will help them to learn the basics of chemistry.

I have taught introductory chemistry for over 25 years, and for much of that time I have considered writing my own text. One reason was that the existing textbooks struck me as disjointed. They read more like a list of skills to master than like a coherent story of the nature of chemistry. I thought it should be possible to organize the fundamentals of chemistry so that each would flow smoothly into the next, but it wasn't until I made some changes in my course that I began to take the prospect of writing a new textbook seriously.

The first change I tried was to move the description of unit conversions from the beginning of the course to the middle. I decided that one reason why the course felt disjointed was that I kept jumping back and forth between the description of the basic concepts of chemistry and the explanation of unit conversions. Postponing the mathematics enabled me to focus on chemistry in the first part of the course. Moreover, as a result of this change, my students develop far stronger computational skills than I was able to give them before. (The reasons for this are described below.) While I recommend this change, I know it is not an option in all courses. Therefore, I designed this text so that unit conversions can be either introduced at the start of the course or postponed (as I prefer) until later.

The second change I made was to put more emphasis on developing my students' ability to visualize the particle nature of matter. Students too often view chemistry as a set of rules for manipulating numbers, symbols, and abbreviations, never really connecting these rules to a physical reality. They can balance equations and do chemical calculations, but they cannot answer questions about what is happening on the particle level when an acid reacts with a base. Thus, whenever appropriate, I enhance the standard topics covered in introductory chemistry with corresponding descriptions of events from the particles' "point of view."

The final factor that led to the creation of this text and its supplements is that I learned to create computer-based tools myself, and it occurred to me that a package whose text and computer-based ancillaries were all produced by the same person would offer real benefits. The Web-based tools that accompany this text include animations, glossary quizzes for each chapter, tutorials to consolidate and enhance important skills, and Web pages that provide extra information. Because I have created both the tools and the text, I think you will find that they fit together seamlessly.

Read on for a more detailed discussion of how these changes have been incorporated into *An Introduction to Chemistry* and its supplements. Each innovation has been developed with the ultimate goal of making it easier for you to give your students a coherent understanding of chemistry, a positive attitude toward chemistry (and toward you and your course), and a solid foundation on which to build, should they decide to continue their chemistry studies.

Flexible Order of Math-Related Topics

Do you spend a lot of time in the first week or two of your course teaching unit conversions and significant figures? If so, do many students lose interest or even drop the course because they find the math-related topics boring and perhaps intimidating?

The single most beneficial change I have made in my prep-chem course has been to shift the coverage of unit conversions from the beginning to the middle of the semester. As detailed below, this book can be used to support either that approach or a more traditional one. Delaying the coverage of unit conversions enables me to describe elements, compounds, and chemical reactions earlier than usual and, I believe, to give my students a much better understanding of what chemistry really is. Students emerge from the first lectures with a better attitude toward the course and with more confidence in their abilities—which, in my experience, has translated into significantly lower drop rates. One of the most important by-products of this change, in my assessment, is that my students end up *better* equipped with math-related skills than would otherwise be the case (see "More Emphasis on Math-Related Topics," below). Immediately after I teach them the technique of dimensional analysis, they begin using it in mole calculations. Thus, instead of learning the technique at the start of the course, and then largely forgetting it, and then trying to relearn it in haste, the students learn it well and then immediately consolidate their knowledge.

Because not everyone will choose to restructure their course in this way, I organized this book to allow several approaches to teaching unit conversions. The optional Inter-Chapter 1A, located between Chapters 1 and 2, gives a brief introduction to dimensional analysis and metric–metric conversions. Chapter 8, which covers dimensional analysis comprehensively, can be used either in its current position or early in the course.

- An instructor who wishes to introduce unit conversions briefly at an early point in the course (perhaps to prepare the students for labs), while postponing a comprehensive treatment of the topic, can use the text in its current order.
- An instructor who wishes to teach unit conversions in detail early in the course can skip Inter-Chapter 1A and instead cover Chapter 8 immediately after Chapter 1. Chapter 8 is written so that students can read it without confusion before reading Chapters 2 through 7.
- An instructor who, like myself, wishes to delay the discussion of unit conversions until the middle of the course can skip Inter-Chapter 1A and cover the remaining chapters in their current order. Chapter 8 is located

so that it teaches unit analysis immediately before the students need the technique for mole calculations.

Early Introduction to Chemical Reactions

Are you ever frustrated that it takes so long to get to describing interesting chemical changes?

Most prep-chem texts don't describe chemical reactions until midway through the text or even later, thereby reinforcing students' expectations that chemistry will be boring and irrelevant. In this text, chemical reactions are described in Chapters 4 through 6.

More Emphasis on Math-Related Topics

Do you ever wish that you could cover unit conversions in more detail but resist doing so because it would further postpone the introduction of the description of elements, compounds, and chemical changes?

Although I postpone the math-related topics in my prep-chem courses, I think they are extremely important. Therefore, I have devoted three full chapters to them. Chapter 8 teaches unit conversions using dimensional analysis, Chapter 9 describes chemical calculations and chemical formulas, and Chapter 10 covers chemical calculations and chemical equations.

More Logical Sequence of Topics

In many texts, Chapter 1 or 2 asks the reader to classify substances as elements, compounds, or mixtures and to classify changes as chemical or physical. Do you find it difficult to describe compounds before your students have a clear understanding of atoms and elements? Do you find it hard to describe chemical changes before your students know about chemical bonds and chemical compounds?

In the first week of class, I used to ask my students to classify substances as elements, compounds, or mixtures. That required me to introduce the concept of an element long before any significant discussion of atoms and to describe compounds without first presenting a clear depiction of elements. I was equally uncomfortable asking students to classify changes as chemical or physical before they had any clear definition of chemical bonds. Now I move smoothly from the kinetic molecular theory to a description of atoms and elements (Chapter 2). This flows into a description of chemical bonds and chemical compounds (Chapter 3), which in turn forms the basis for an understanding of the nature of solutions and the processes of chemical changes (Chapters 4, 5, and 6). The introductory discussions that felt so disjointed to me in the past now seem to follow a logical progression—a story, really—that flows from simple to more complex.

Emphasis on the Development of Visualization Skills

Do you ever worry that your students can write balanced chemical equations but do not have a clear mental image of the events that occur during a chemical reaction?

I think it is extremely important for students to develop the ability to visualize the models that chemists use for describing the structure and behavior of matter. I want them to be able to connect a chemical equation with a visual image of what is happening in the reaction. Throughout the text, I emphasize the development of a mental image of the structure of matter and the changes it undergoes. I start with a more comprehensive description of the kinetic molecular theory than is found in most books, and I build on that description in the sections on elements, compounds, and chemical changes. To help the student visualize structures and processes, I provide the colorful and detailed illustrations that are a prominent feature of the book. Moreover, the book's Web site provides animations based on key illustrations.

Identification of Skills to Review

When your students have trouble with a task, is it ever because they have not completely mastered some of the lessons presented in earlier chapters?

The Review Skills section at the start of each chapter lists skills from earlier chapters that will be needed in the present chapter. The students can test their mastery of each skill by working the problems in the Review Questions section at the end of each chapter.

Instructors who wish to teach chapters in a different order than the one in the book can use these sections to identify topics that may require supplementation. The Instructor's Manual contains a list of various possible chapter orders, with suggested detours to ensure that the students always have the skills they need.

Sample Study Sheets

Are the best-organized students in your class often the most successful? Do you ever wish that the text you were using helped students get more organized?

In an introductory chemistry course, it really pays to be organized. This text helps students get organized by providing Sample Study Sheets for many of the tasks they will be expected to do on exams. Each study sheet describes how to recognize a specific kind of task ("Tip-off") and then breaks the task down into general steps. Each study sheet is accompanied by at least one worked example.

Extensive Lists of Learning Objectives

Do your students ever complain that they do not know what they are supposed to be able to do after studying a chapter in the text?

The learning objectives listed at the end of each chapter are more comprehensive than the objectives in other texts. They list all the key skills taught in the chapter, thus helping students to focus on the most critical material. Objective references in the margins of the chapter denote the paragraphs that pertain to each objective, so that a student who has trouble with a particular objective can easily find the relevant text discussion. Many of the end-of-chapter problems are similarly referenced, so that students can see how each objective might be covered on an exam.

Chapter Glossaries and Glossary Quizzes

Do you wish your text did more to help students learn the language of chemistry?

Learning the language of science is an important goal of the courses for which this text is designed. Most books have a glossary at the back, but I suspect that students rarely refer to it. In addition to a glossary at the back of the book, this text also has a list of new terms at the end of each chapter, where it can serve as a chapter review. Glossary quizzes for each chapter can be found on the book's Web site.

More Real-World Examples

Do your students feel that what they read in their textbook is far removed from the real world?

This text is full of real-world examples, both in the chapter narrative and in the problems. For instance, after introducing the idea of limiting reactants, Section 10.2 explains why chemists design procedures for chemical reactions in such a way that some substances are limiting and others are in excess. Chapter 9 problems mention vitamins, cold medicines, throat lozenges, antacids, gemstones, asphalt roofing, fireworks, stain and rust removers, dental polishing agents, metal extraction from natural ores, explosives, mouthwashes, Alar on apples, nicotine, pesticides, heart drugs, Agent Orange, thalidomide, and more. The chemical reactions used in problems often represent actual industrial processes. Several of the Special Topics scattered throughout the book describe the achievements of "green chemistry."

Key Ideas Questions

Have you ever wondered whether the chapter reviews in many textbooks are useful to students?

After the Review Questions section at the end of each chapter is a section titled Key Ideas. Students are given a list of numbers, words, and phrases that they use to fill in the blanks in a series of statements that follows the list. The statements summarize the most important ideas from the chapter—that is, they add up to a chapter review. Because this review is a game of sorts, the students get more actively involved and are more interested in recalling key ideas than they do when reading a chapter summary.

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If you have any questions about the text that you would like to ask me, I'd be happy to have the opportunity to answer them. Your Benjamin Cummings sales representative can provide you with my email address. I hope that your teaching experience using this book (or any other text) will be a satisfying and pleasurable experience.

Mark Bishop
Monterey, California

Features of This Book

CHAPTER 4

An Introduction to Chemical Reactions

NOW THAT YOU UNDERSTAND THE BASIC STRUCTURAL DIFFERENCES between different kinds of substances, you are ready to begin learning about the chemical changes that take place as one substance is converted into another. Chemical changes are chemists' primary concern. They want to know what, if anything, happens when one substance encounters another. Do the substances change? How and why? Can the conditions be altered so as to speed the changes up, slow them down, or perhaps reverse them? Once chemists understand the nature of one chemical change, they begin to explore the possibilities that arise from

... an old house *as is*, with the water turned off. ... it will go, and all you get is a slow drip, drip, ... to ruin ... ity that ... ining, you ... our trou- ... change ... ventually ... 5, you ... ve that ... on your ... tooth- ... that can help fight cavities.

Many of the chapters begin with a short introduction that describes how the topics in the chapter relate to the reader's daily life.

A chemical reaction causes solids to form in hot water pipes.

Chemical changes, like the ones mentioned above, are described ... chapter begins with a discussion of how to interpret and write chemica...

Review Skills

The presentation of information in this chapter assumes that you can a... listed below. You can test your readiness to proceed by answering the R... the chapter. This might also be a good time to read the Chapter Objecti... Questions.

- Write the formulas for the diatomic elements.. (Section 2.5)
- Predict whether a bond between 2 atoms of different elements would be covalent or ionic. (Section 3.2)
- Desc...
- Conv... binary covalent compounds, and ionic compounds. (Sections 3.3–3.5)

The Review Skills section instructs the reader to review specific skills from earlier chapters that are necessary for success in the present chapter.

Salt towers rise from the water in Mono Lake, California.

Photographs give the reader visual reminders that chemistry is important in their world.

Students can test themselves on the review skills by working the problems in the Review Questions section found at the end of each chapter.

The Key Ideas section gives the reader an opportunity to review the most important ideas from the chapter.

174 Chapter 4 | An Introduction to Chemical Reactions

Review Questions

1. Write the formulas for all of the diatomic elements.
2. Predict whether atoms of each of the following pairs of elements would be expected to form ionic or covalent bonds.
   a. Mg and F c. Fe and O
   b. O and H d. N and Cl
3. Describe the structure of liquid water, including a description of water molecules and the attractions between them.
4. Write formulas that correspond to the following names.
   a. ammonia c. propane
   b. methane d. water
5. Write formulas that correspond to the following names.
   a. nitrogen dioxide c. dibromine monoxide
   b. carbon tetrabromide d. nitrogen monoxide
6. Write formulas that correspond to the following names.
   a. lithium fluoride d. sodium carbonate
   b. lead(II) hydroxide e. chromium(III) chloride
   c. potassium oxide f. sodium hydrogen phosphate

Key Ideas

Complete the following statements by writing one of these words or phrases in each blank.

above	minor
charge	negative
chemical bonds	none
coefficients	organized, repeating
complete formula	partial charges
continuous	positive
converted into	precipitate
created	precipitates
delta, Δ	precipitation
destroyed	same proportions
equal to	separate ions
gas	shorthand description
homogeneous mixture	solute
left out	solvent
liquid	subscripts
major	very low

222 Chapter 5 ▌ Acids, Bases, and Acid–Base Reactions

Chapter Objectives

The goal of this chapter is to teach you to do the following.

1. Define all of the terms in the Chapter Glossary.

Section 5.1 Acids

2. Identify
3. Describe ... added to water.
4. Identify ... and
... acetic
... id, is

The comprehensive list of **Chapter Objectives** at the end of each chapter identifies the key skills taught within the chapter (in the same logical order as in the chapter) so that students can concentrate on learning the most important material. The number of each objective appears in the margin next to the text where that objective is described. Many of the end-of-chapter problems are also accompanied by references to the corresponding objectives.

In-chapter **Examples** provide the reader with models for how to complete important problems.

Chapter 5 ▌ Acids, Bases, and Acid–Base Reactions

EXAMPLE 5.8 Brønsted–Lowry Acids and Bases

OBJECTIVE 31

Identify the Brønsted–Lowry acid and base for the forward reaction in each of the following equations.

a. $HClO_2(aq) + NaIO(aq) \rightarrow HIO(aq) + NaClO_2(aq)$

b. $HS^-(aq) + HF(aq) \rightarrow H_2S(aq) + F^-(aq)$

c. $HS^-(aq) + OH^-(aq) \rightarrow S^{2-}(aq) + H_2O(l)$

d. $H_3AsO_4(aq) + 3NaOH(aq) \rightarrow Na_3AsO_4(aq) + 3H_2O(l)$

Solution

a. The $HClO_2$ loses an H^+ ion, so it is the Brønsted–Lowry acid. The IO^- in the NaIO gains the H^+ ion, so the NaIO is the Brønsted–Lowry base.

b. The HF loses an H^+ ion, so it is the Brønsted–Lowry acid. The HS^- gains the H^+ ion, so it is the Brønsted–Lowry base.

c. The HS^- loses an H^+ ion, so it is the Brønsted–Lowry acid. The OH^- gains the H^+ ion, so it is the Brønsted–Lowry base.

d. The H_3AsO_4 loses three H^+ ions, so it is the Brønsted–Lowry acid. Each OH^- in NaOH gains an H^+ ion, so the NaOH is the Brønsted–Lowry base.

... duce fewer H_3O^+ ions in water than strong ... umbers of acid molecules are added to equal

... ng monoprotic acids: HCl and HNO_3.
... protic strong acid.
... sulfuric acid is added to water.
... any acid, identify it as a strong or a weak acid.

... and formulas for binary acids and oxyacids.

... **Nomenclature**

... rmula, tell whether it represents a binary ionic ... nd with polyatomic ion(s), a binary covalent ... an oxyacid.

... and chemical formulas for binary ionic ... ds with polyatomic ion(s), binary covalent

EXERCISE 5.10 Brønsted–Lowry Acids and Bases

OBJECTIVE 31

Identify the Brønsted–Lowry acid and base in each of the following equations.

a. $HNO_2(aq) + NaBrO(aq) \rightarrow HBrO(aq) + NaNO_2(aq)$

b. $H_2AsO_4^-(aq) + HNO_2(aq) \rightleftharpoons H_3AsO_4(aq) + NO_2^-(aq)$

c. $H_2AsO_4^-(aq) + 2OH^-(aq) \rightarrow AsO_4^{3-}(aq) + 2H_2O(l)$

The Examples are followed by similar **Exercises** that provide the reader with an opportunity to test their skills. The answers for these Exercises are in the back of the book, and the complete solutions are in the Student Study Guide.

Chapter Glossary

Hydronium ion H_3O^+.

Arrhenius acid According to the Arrhenius theory, any substance that generates hydronium ions, H_3O^+, when added to water.

Acidic solution A solution with a significant concentration of hydronium ions, H_3O^+.

A **Chapter Glossary** of new terms at the end of each chapter makes it easy for the reader to learn these terms and provides a brief review of the chapter information.

622 Chapter 14 ▌ Liquids: Condensation, Evaporation, and Dynamic Equilibrium

Chapter Problems

Section 14.1 Change from Gas to Liquid and from Liquid to Gas—An Introduction to Dynamic Equilibrium

OBJECTIVE 2

39. A batch of corn whiskey is being made in a backwoods still. The ingredients are mixed and heated, and because the ethyl alcohol, C_2H_5OH, evaporates more rapidly than the other ... mixture is enriched in C_2H_5... the liquid it forms has a hig... mixture. Describe the subm... C_2H_5OH is converted into a... from a high-temperature ga...

40. Why is dew more likely to ... the changes that take place ...

41. Acetone, CH_3COCH_3, is a l... nail polish remover.

OBJECTIVE 3 a. Describe the submicros... liquid acetone when it e...

OBJECTIVE 4 b. Do all of the acetone m... liquid escape? If not, w... molecule to escape fron... phase?

OBJECTIVE 5 c. If you spill some nail p... feel cold. Why?

OBJECTIVE 7 d. If you spill some aceton... rapidly than the same a...

OBJECTIVE 9 e. If you spill acetone on a ... more quickly than the same amount of acetone spilled on the cooler lab bench. Why?

42. Consider two test tubes, each containing the same amount of liquid acetone. A student leaves one of the test tubes open overnight and covers the other one with a balloon so that gas cannot escape. When the student returns to the lab the next day, all of the acetone is gone from the open test tube, but most of it remains in the covered tube.

a. Explain why the acetone is gone from one test tube and not from the other.

b. Was the initial rate at which liquid changed to gas (the rate of evaporation) greater in one test tube than in the other? Explain your answer.

c. Consider the system after 30 minutes, with liquid remaining in both test tubes. Is condensation (vapor to liquid) taking place in both test tubes? Is the rate of condensation the same in both test tubes? Explain your answer.

OBJECTIVE 10 d. Describe the submicroscopic changes in the covered test tube that lead to a constant amount of liquid and vapor.

OBJECTIVE 12 e. The balloon expands slightly after it is placed over the test tube, suggesting an initial increase in pressure in the space above the liquid. Why?

This text is full of real-world examples, both in the chapter narrative and in the problems. The **Chapter Problems** not only test readers on specific skills, but they also teach them how chemicals are made, how substances are used, and some of the issues that relate to chemicals.

Special Topics in each chapter describe important issues relating to chemistry, including environmental issues and health-related applications. Several of these Special Topics describe the achievements of "green chemistry" (or environmentally benign chemistry), which has as its goal the development of new ways to produce, process, and use chemicals so as to reduce the risks to humans and to the environment.

564 Chapter 13 | Gases

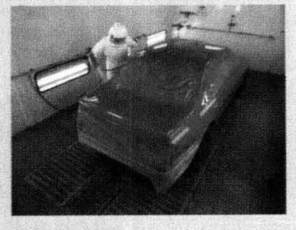
Special Topic 13.1 A Greener Way to Spray Paint

United States industries use an estimated 1.5 billion liters of paints and other coatings per year, and much of this is applied by spraying. Each liter sprayed from a canister releases an average of 550 grams of volatile organic compounds (VOCs), including hydrocarbons, alcohols, esters, and ketones. Some of these VOCs are hazardous air pollutants.

The mixture that comes out of the spray can has two kinds of components: (1) the solids being deposited on the surface as a coating and (2) a solvent blend that allows the solids to be sprayed and to spread evenly. The solvent blend must dissolve the coatings into a mixture that is thin enough in consistency to be easily sprayed. But a mixture that is thin enough to be easily sprayed will be too runny to remain in place when deposited on a surface. Therefore, the solvent blend contains additional components so volatile that they will evaporate from the spray droplets between the time the spray leaves the spray nozzle and the time the spray hits the surface. Still other, slower-evaporating components do not evaporate until after the spray hits the surface. They remain in the coating mixture long enough to cause it to spread out evenly. Because the more volatile solvents have escaped, the mixture that hits the surface is thick enough not to run or sag.

The Clean Air Act has set strict limitations on the emission of certain VOCs, so safer solvents are needed to replace them. One new spray system has been developed that yields a high-quality coating while emitting as much as 80% fewer VOCs of all types and none of the VOCs that are considered hazardous air pollutants. This system is called the *supercritical fluid spray process.* The solvent mixture for this process still contains some of the slowly evaporating solvents that allow the coating to spread evenly, but it replaces the rapidly-evaporating solvents with high-pressure CO_2.

Some gases can be converted into liquids at room temperature by being compressed into a smaller volume, but for each gas, there is a temperature above which ...



By taking advantage of the properties of gases at high temperatures and pressures, scientists have invented a new, environmentally friendly spray-painting process.

The critical temperature of CO_2 is 31 °C. Ab... temperature, carbon dioxide can be compresse... very high-pressure and relatively high-density... critical fluid. Like a liquid, the supercritical ca... ide will mix with or dissolve the blend of coat... low-volatility solvent to form a product that is... enough to be sprayed easily, in very small dro... supercritical CO_2 has a very high volatility, so... rates from the droplets almost immediately af... are emitted from the spray nozzle, leaving a m... that is thick enough not to run or sag when it ... surface. The mixture is sprayed at temperature... 50 °C and a pressure of 100 atm (about 100 tim... room pressure).

Because carbon dioxide is much less toxic t... VOCs it replaces and because it is nonflammab... relatively inert, it is much safer to use in the w... It is also far less expensive. Moreover, the CO_2... obtained from the production of other chemic... new process does not lead to an increase in ca... ide in the atmosphere. In fact, because the VO...

Many features of the book help students develop the ability to visualize the models that chemists use for describing the structure and behavior of matter. The reader is continually encouraged, with the aid of colorful and detailed illustrations, to visualize particle movements and particle interactions that accompany chemical changes.

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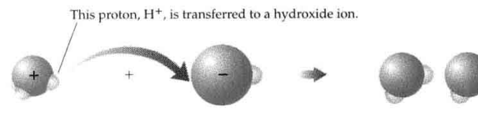
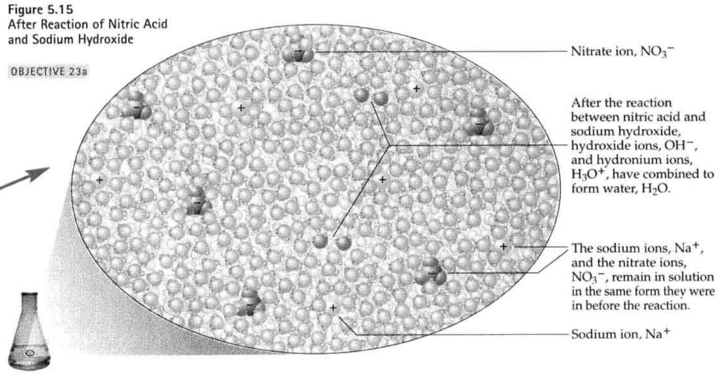
Figure 5.14
Hydronium and Hydroxide Ions



$$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$$

Figure 5.15
After Reaction of Nitric Acid and Sodium Hydroxide

OBJECTIVE 23a



...d not actively participate in the reaction. In other ...ns, so they are left out of the net ionic chemical ...ation for the reaction is therefore

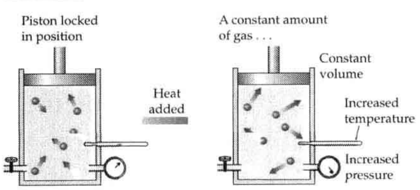
$\rightarrow 2H_2O(l)$

...bit of describing reactions such as this in terms ...en though hydrogen ions do not exist in a water ... that sodium ions do. When an acid loses a ... proton immediately forms a covalent bond to ... it forms a covalent bond to a water molecule to ...on. Although H_3O^+ is a better description of

13.1 Gases and Their Properties 537

Figure 13.4
Relationship Between Temperature and Pressure
Increased temperature leads to increased pressure if the moles of gas and the volume are constant.

OBJECTIVE 10b



Increased temperature
↓
Increased average velocity of the gas particles
↓ ↓
Increased number of collisions with the walls | Increased force per collision
↓
Increased total force of collisions
↓
Increased $\frac{\text{force due to collisions}}{\text{area of wall}}$
↓
Increased gas pressure

The Relationship Between Volume and Temperature

Consider the system shown in Figure 13.5 on the next page. To demonstrate the relationship between temperature and volume of gas, we must keep the moles of gas and the gas pressure constant. If our valve is closed and our system has no leaks, the moles of gas are constant. We keep the gas pressure constant by allowing the piston to move freely throughout our experiment, because then it will adjust to keep the pressure pushing on it from the inside equal to the atmospheric pressure pushing on it from the outside. The atmospheric pressure is the pressure in the air outside the container, which acts on the top of the piston because of the force of collisions between particles in the air and the surface of the piston. We can assume that it is constant throughout our experiment. OBJECTIVE 10c

If we increase the temperature, the piston in our apparatus moves up, increasing the volume occupied by the gas. A decrease in temperature leads to a decrease in volume.

Increased temperature → Increased volume OBJECTIVE 10c

Decreased temperature → Decreased volume

The increase in temperature of the gas leads to an increase in the average velocity of the gas particles, which leads in turn to more collisions with the walls of the container and a greater force per collision. This greater force acting on the walls of the container leads to an *initial* increase in the gas pressure. Thus, the increased temperature of our gas creates an internal pressure, acting on the bottom of the piston, that is greater than the external pressure acting on the top of the piston. The greater internal pressure causes the piston to move up, increasing the volume of the chamber. The OBJECTIVE 10c

Figures throughout the text illustrate important ideas and act as constant reminders of the particle nature of matter. Key concepts are often summarized with logic sequences that show how one component of an explanation leads logically to the next.

A variety of art, combining photos and illustrations, highlight the key concepts.

like the situation depicted in Figure 16.6, where a rolling ball rolls back down the same side of a hill it started up.

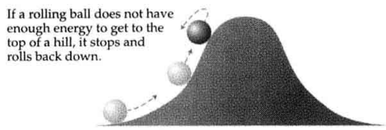
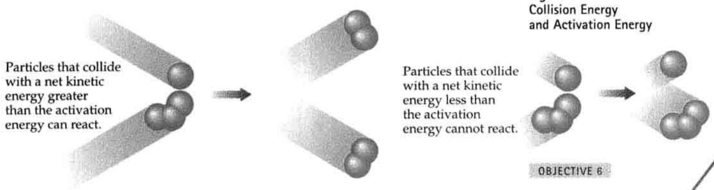


Figure 16.6
Not Enough Kinetic Energy to Get Over the Hill

OBJECTIVE 6

The activation energy for the oxygen–ozone reaction is 17 kJ/mole O_3. If the collision between reactants yields a net kinetic energy equal to or greater than the activation energy, the reaction can proceed to products (Figure 16.7). This is like a ball rolling up a hill with enough kinetic energy to reach the top of the hill, from which it can roll down the other side (Figure 16.8).

Figure 16.7
Collision Energy and Activation Energy



OBJECTIVE 6

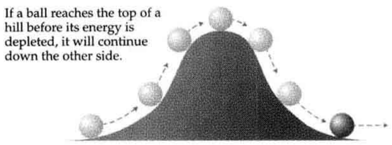
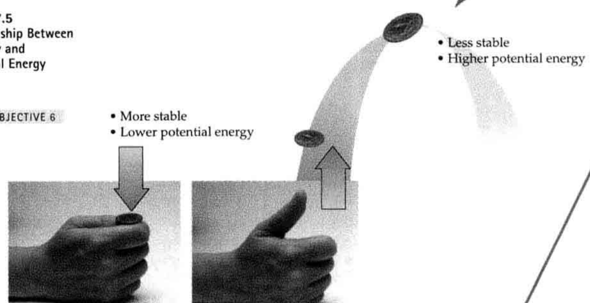


Figure 16.8
Ball with Enough Kinetic Energy to Get Over the Hill

The bonds between oxygen atoms in O_2 molecules are stronger and more stable than the bonds between atoms in the ozone molecules, so more energy is released in the formation of the new bonds than is

Figure 7.5
Relationship Between Stability and Potential Energy

OBJECTIVE 6

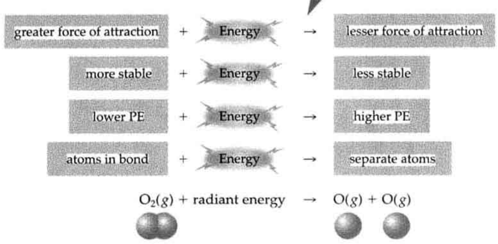


the more stable atoms in the bond. For example, the first step in the formation of ozone in the earth's atmosphere is the breaking of the oxygen–oxygen covalent bonds in more stable oxygen molecules, O_2, to form less stable separate oxygen atoms. This change could not occur without an input of considerable energy—in this case, radiant energy from the sun. We call changes that absorb energy **endergonic** (or endogonic) changes (Figure 7.6).

OBJECTIVE 7

Figure 7.6
Endergonic Change

OBJECTIVE 5



The attraction between the separated atoms makes it possible that they will change from their less stable separated state to the more stable bonded state. As they move together, they may bump into and move something (such as another atom), so the separated atoms have a greater capacity to

represent the combustion reactions for methane, the primary component of natural gas, and hexane, which is found in gasoline.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

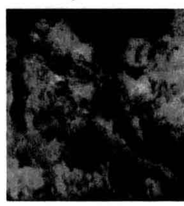
$$2C_6H_{14}(l) + 19O_2(g) \rightarrow 12CO_2(g) + 14H_2O(l)$$

The complete combustion of a substance, such as ethanol, C_2H_5OH, that contains carbon, hydrogen, and oxygen also yields carbon dioxide and water.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

When any substance that contains sulfur burns completely, the sulfur forms sulfur dioxide. For example, when methanethiol, CH_3SH, burns completely, it forms carbon dioxide, water, and sulfur dioxide. Small amounts of this strong-smelling substance are added to natural gas to give the otherwise odorless gas a smell that can be detected if a leak occurs (Figure 6.3).

$$CH_3SH(g) + 3O_2(g) \rightarrow CO_2(g) + 2H_2O(l) + SO_2(g)$$



Combustion reactions include oxygen as a reactant and are accompanied by heat and usually light.

OBJECTIVE 8

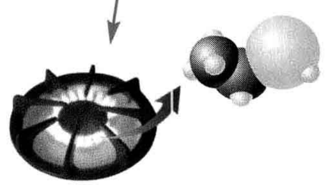


Figure 6.3
Odor to Natural Gas
The methanethiol added to natural gas warns us when there is a leak.

The following sample study sheet lists the steps for writing equations for combustion reactions.

SAMPLE STUDY SHEET 6.2
Writing Equations for Combustion Reactions

OBJECTIVE 8

TIP-OFF You are asked to write an equation for the complete combustion of a substance composed of one or more of the elements carbon, hydrogen, oxygen, and sulfur.

GENERAL STEPS

STEP 1 Write the formula for the substance combusted.
STEP 2 Write $O_2(g)$ for the second reactant.

SAMPLE STUDY SHEET 9.1

Converting Between Mass of Element and Mass of Compound Containing the Element

OBJECTIVE 15

TIP-OFF When you analyze the type of unit you have and the type of unit you want, you recognize that you are converting between a unit associated with an element and a unit associated with a compound containing that element.

GENERAL STEPS The following general procedure is summarized in Figure 9.3.

- **Convert the given unit into moles of the first substance.**

  This step often requires converting the given unit into grams, after which the grams can be converted into moles using the molar mass of the substance.
- **Convert moles of the first substance into moles of the second substance using the molar ratio derived from the formula for the compound.**

  You convert either from moles of element into moles of compound or from moles of compound into moles of element.
- **Convert moles of the second substance into the desired units of the second substance.**

  This step requires converting moles of the second substance into grams of the second substance using the molar mass of the second substance, after which the grams can be converted into the specific units that you want.

EXAMPLE See Example 9.6.

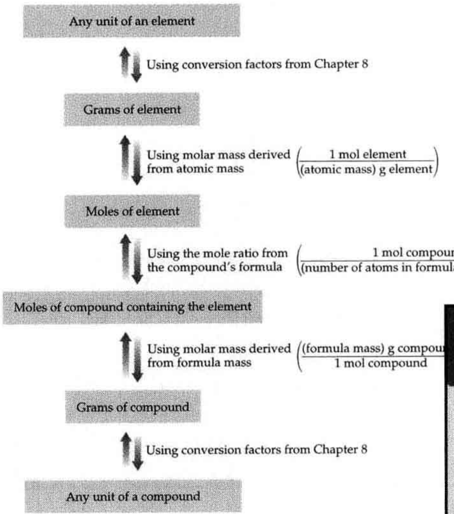


Figure 9.3
General Steps for Converting Between the Mass of an Element and the Mass of a Compound Containing the Element
The calculation can be set up to convert from the mass of an element to the mass of a compound (top to bottom) or from the mass of a compound to the mass of an element (bottom to top).

OBJECTIVE 15

This text helps students get organized by providing Sample Study Sheets for many of the tasks they will be expected to do on exams. Each study sheet describes how to recognize a specific kind of task ("Tip-off") and breaks the task down into general steps.

INTER-CHAPTER 1A

A Brief Introduction to Unit Conversions

8 BOTH DESCRIBE THE PROCEDURES for doing a useful in chemistry, but the inter-chapter does so aps you are wondering why the inter-chapter is here y ways to teach introductory chemistry. This text has rse begins the coverage of chemical principles right topics until mid-semester. Although many chemistry nstructors believe in covering the math-related topics or each approach. The flexible organization of this text e course topics in the way that they believe is best. ble approaches to learning chemistry's math-related uss unit conversions until the middle of the course, ncepts first. These teachers will tell you not to read a brief introduction to unit conversions early in the unit conversions in early laboratory sessions, while t of the subject until later. If your instructor falls into text, including this inter-chapter, in the order in ts a broader coverage of the math-related topics early re to Chapter 8, which describes unit conversions in . Chapter 8 was written in such a way that you can ters 2 through 7. (4) Some instructors will ask their e or two of the sections in Chapter 8 before proceed- structor t

r assumes ceed by a read the

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CHAPTER 8

Unit Conversions

[M]athematics . . . is the easiest of sciences, a fact which is obvious in that no one's brain rejects it . . .

ROGER BACON (C. 1214–C. 1294)
ENGLISH PHILOSOPHER AND SCIENTIST

Stand firm in your refusal to remain conscious during algebra. In real life, I assure you, there is no such thing as algebra.

FRAN LEBOWITZ (B. 1951)
AMERICAN JOURNALIST

YOU MAY AGREE WITH ROGER BACON THAT MATHEMATICS IS THE EASIEST OF SCIENCES, but many beginning chemistry students would not. Because they have found mathematics challenging, they wish it were not so important for learning chemistry—or for answering so many of the questions that arise in everyday life. They can better relate to Fran Lebowitz's advice in the second quotation. If you are one of the latter group, it will please you to know that even though there *is* some algebra in chemistry, this chapter teaches a technique for doing chemical calculations (and many other calculations) without it. The technique is called dimensional analysis. You will be using it throughout the rest of this book, in future chemistry and science courses, and any time you want to calculate the number of nails you need to build a fence or the number of rolls of paper necessary to cover the kitchen shelves.

Dimensional analysis, the technique for doing unit conversions that is described in this chapter, can be used for a lot more than chemical calculations.

Review Skills

The presentation of information in this chapter assumes that you can already perform the tasks listed below. You can test your readiness to proceed by answering the Review Questions at the end of the chapter. This might also be a good time to read the Chapter Objectives, which precede the Review Questions.

- List the metric base units and the corresponding abbreviations for length, mass, volume, energy, and gas pressure. (Section 1.4)
- State the numbers or fractions represented by the following metric prefixes, and write their abbreviations: giga, mega, kilo, centi, milli, micro, nano, and pico. (Section 1.4)
- Given a metric unit, write its abbreviation; given an abbreviation, write the full name of the unit. (Section 1.4)
- Describe the relationships between the metric units that do not have prefixes (such as meter, gram, and liter) and units derived from them by the addition of prefixes—for example, 1 km = 10^3 m. (Section 1.4)
- Define temperature and describe the Celsius, Fahrenheit, and Kelvin scales used to report its values. (Section 1.4)
- Given a value derived from a measurement, identify the range of possible values it represents, on the basis of the assumption that its uncertainty is ±1 in the last position reported. (For example, 8.0 mL says the value could be from 7.9 mL to 8.1 mL.) (Section 1.5)

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This text takes a flexible approach to the coverage of chemical calculations. Chapter 8 provides a comprehensive treatment of unit conversions immediately before these calculations are used in the chemical calculations described in Chapters 9 and 10. Inter-Chapter 1A provides a briefer introduction to dimensional analysis and unit conversions. See the section in the Preface titled Flexible Order of Math-Related Topics for a description of the options that these two chapters provide.

Supplements to This Book

Instructor's Supplements

Instructor's Manual and Complete Solutions (0-8053-3215-4)
The Instructor's Manual has complete solutions to all of the in-chapter exercises and all of the end-of-chapter problems. It also contains suggestions for using the book most efficiently, possible variations in the order of coverage, lists of topics that can be skipped without causing problems for the coverage of later topics, and lists of the available computer tools for each chapter.

Printed Test Bank (0-8053-3213-8)
This printed test bank includes over 1500 questions that correspond to the major topics in the text.

Computerized Test Bank (0-8053-3214-6)
This dual-platform CD-ROM includes over 1500 questions that correspond to the major topics in the text.

Benjamin Cummings Science Digital Library (0-8053-3209-X)
The CD-ROM provides instructors a wealth of illustrations for incorporation into lecture presentations, student materials, and tests.

Transparency Acetates (0-8053-3212-X)
Includes 125 full-color acetate transparencies.

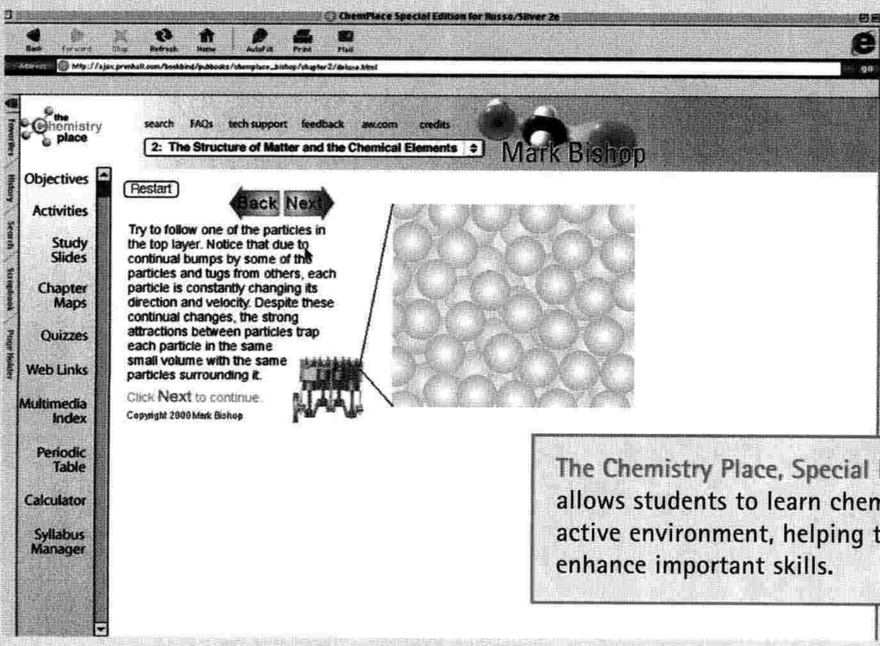
Instructor's Manual for Lab Manual (0-8053-3217-0)

Student's Supplements

Study Guide and Selected Solutions (0-8053-3211-1)
Each chapter in the Study Guide contains introductions to every section in the corresponding text chapter, a checklist to help students study efficiently, lists of important skills to master, a concept map to help students visualize the connections among the chapter topics, solutions to the in-chapter exercises, and solutions to selected end-of-chapter problems.

Laboratory Manual (0-8053-3217-0)
This introductory chemistry Laboratory Manual, written to accompany the Bishop text, contains 25 labs. It is designed to help students develop data acquisition, organization, and analysis skills while teaching basic techniques. Students learn to construct their own data tables, answer conceptual questions, and make predictions before performing experiments. They also have the opportunity to visualize and describe molecular level activity and explain the results.

Special Edition of The Chemistry Place
www.chemplace.com/college
This special edition of The Chemistry Place engages students in interactive exploration of chemistry concepts and provides a wealth of tutorial support. Tailored to the Bishop textbook, the site includes detailed objectives for each chapter of the text, interactive activities featuring simulations, animations, and 3D visualization tools, multiple-choice and glossary quizzes, and an extensive set of Web links. For instructors, a Syllabus Manager makes it easy to create an online syllabus complete with weekly assignments, projects, and test dates that students may access on the ChemPlace site.



The Chemistry Place, Special Edition for Bishop, allows students to learn chemistry in an interactive environment, helping to consolidate and enhance important skills.

Brief Contents