INTRODUCTORY CHEMISTRY

Nivaldo J. Tro

Custom Edition for California State University, Northridge

INTRODUCTORY CHEMISTRY

Nivaldo J. Tro

Custom Edition for California State University, Northridge

Taken from:
Introductory Chemistry, Second Edition
by Nivaldo J. Tro

PEARSON Custom Publishing
PEARSON Prentice Hall

Taken from:

Introductory Chemistry, Second Edition
by Nivaldo J. Tro

Published by Prentice Hall
Upper Saddle River, NJ 07458

This special edition published in cooperation with Pearson Custom Publishing.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-536-94384-2

2005180093

MT

Please visit our web site at *www.pearsoncustom.com*

PEARSON
Custom Publishing

PEARSON CUSTOM PUBLISHING
75 Arlington Street, Suite 300, Boston, MA 02116
A Pearson Education Company

TO THE STUDENT

This book is for *you*, and every text feature has you in mind. I have two main goals for you in this course: to see chemistry as you never have before, and to develop the problem-solving skills you need to succeed in chemistry.

I want you to experience chemistry in a new way. Each chapter of this book is written to show you that chemistry is not just something that happens in a laboratory; chemistry surrounds you at every moment. I have worked with several outstanding artists to develop photographs and art that will help you visualize the molecular world. From the opening example to the closing chapter, you will *see* chemistry. I hope that when you finish this course, you think differently about your world because you understand the molecular interactions that underlie everything around you.

I also want you to develop problem-solving skills. No one succeeds in chemistry—or in life, really—without the ability to solve problems. I can't give you a formula for problem solving, but I can give you strategies that will help you develop the *chemical intuition* you need to understand chemical reasoning. Look for several recurring structures throughout this book designed to help you master problem solving. The most important ones are (1) the solution map, a visual aid that helps you navigate your way through a problem; (2) the two-column Examples, in which the left column explains in clear and simple language the purpose of each step of the solution shown in the right column; and (3) the three-column Examples, which describe a problem-solving procedure while demonstrating how it is applied to two different Examples.

Lastly, know that chemistry is not reserved only for those with some special talent or special capability. With the right amount of effort and some clear guidance, anyone can master chemistry, including you.

Sincerely,

Nivaldo J. Tro
tro@westmont.edu

TO THE INSTRUCTOR

I thank all of you who used the first edition of *Introductory Chemistry*—you made this book a success from its first year of publication. The preparation of the second edition has enabled me to further refine and strengthen the text to even better fulfill its foundational mission: teaching chemical skills in the context of relevance.

Introductory Chemistry is designed for a one-semester, college-level, introductory or preparatory chemistry course. Students taking this course need to develop problem-solving skills—but they also must see *why* these skills are important to them and to their world. *Introductory Chemistry* extends chemistry from the laboratory to the student's world. It motivates students to learn chemistry by demonstrating how it plays out in their daily lives.

This is a visual book. Today's students often learn by seeing, so wherever possible, I have used images to help communicate the subject. In developing chemical principles, for example, I worked with several artists to develop multipart images that show the connection between everyday processes visible to the eye and the molecular interactions responsible for those processes. This art has been further refined and improved in the second edition, making the visual impact sharper and more targeted to student learning.

For the same reason, in teaching problem-solving skills, I use a *solution map* to help students see the general logic of working through a multistep problem. Extensive flow charts are also incorporated throughout the book, allowing students to visualize the organization of chemical ideas and concepts. In this edition, I have reworked the color scheme of both the solution maps and the flow charts to increase their pedagogical value, making them more intuitive and more consistent throughout the text. Thus, the solution maps now utilize the colors of the visible spectrum—always in the same order, from violet to red.

At key points throughout this book, I use a *three-column* layout, in which students learn a general procedure for solving problems of a particular type as they see it applied to two worked Examples simultaneously. In this format, the *explanation* of how to solve a problem is placed directly beside the actual steps in the *solution* of the problem. Your positive comments about the pedagogical benefits of this approach in the first edition prompted me to carry the strategy one step further and convert many of the *single-column* worked Examples to a *two-column* format for the second edition. In these Examples, one column describes how the problem is solved and explains the rationale for each step, while the other column shows the actual steps. Many of you said that you use a similar technique in lecture and office hours.

I have also added a new feature entitled *Conceptual Checkpoints* to this edition. These checkpoints are short questions that students can use to test their mastery of key concepts as they read through a chapter. Emphasizing understanding rather than calculation, they are designed to be easy to answer if the student has grasped the essential concept but difficult if he or she has not. The answers to these checkpoints, like the answers to the *Skillbuilder* exercises that follow each worked Example, are given at the end of each chapter.

Some significant improvements have been made to key content areas as well. These include:

- an enhanced discussion of the scientific method in Chapter 1
- a new section on physical separation methods in Chapter 3
- a more intuitive explanation of the mole, focusing on the underlying logic of the concept, in Chapter 6
- a clearer organization of the solubility rules for compounds in Chapter 7

Finally, the real-world relevance of the text has been further strengthened by the addition of half a dozen new interest boxes, dealing with such topics as ion size and nerve impulse transmission, artificial sweeteners, and Kevlar.

The media package that accompanies this book has been greatly enhanced for the second edition. To help both you and your students achieve your goals, we have provided innovative, book-specific, interactive media elements for all of your major instructional needs:

- classroom presentation
- student tutorial
- online assessment and course management

Marginal icons in the text now identify the Student Tutorials, interactive Live Examples, and manipulable 3-dimensional molecular images available to students in OneKey, the Accelerator CD, and the Companion Website that accompany the book. These components (as well as other available supplements) are fully described in the Print and Media Resources section of the Preface that follows.

To help you prepare your lectures more efficiently and teach most effectively, this text is now available in an *Annotated Instructor's Edition*. In addition to the entire student text, the *AIE* includes marginal annotations containing teaching tips, suggestions for dealing with common student misconceptions, ideas for classroom demonstrations, icons that identify the art and tables reproduced as color acetates in the Transparency Pack, and references to relevant instructional articles on a wide range of chemical topics.

I hope this book and the changes in the second edition support you in your mission of teaching students chemistry. Ours is a worthwhile cause, even though it requires constant effort. Please feel free to email me with any questions or comments you might have. I look forward to hearing from you as you use this book in your course.

Sincerely,

Nivaldo J. Tro
tro@westmont.edu

PREFACE

The design and features of this text have been conceived to work together as an integrated whole with a single purpose: to help students understand chemical principles and master problem-solving skills in a context of relevance. Students must not only be able to grasp chemical concepts and solve chemical problems, but also understand how those concepts and problem-solving skills are relevant to their other courses, their eventual career paths, and their daily lives.

Teaching Principles

The development of basic chemical principles—such as those of atomic structure, chemical bonding, chemical reactions, and the gas laws—is one of the main goals of this text. Students must acquire a firm grasp of these principles in order to succeed in the general chemistry sequence or the chemistry courses that support the allied health curriculum. To that end, the book integrates qualitative and quantitative material, and proceeds from concrete concepts to more abstract ones.

Organization of the Text

The main divergence in topic ordering among instructors teaching introductory and preparatory chemistry courses is the placement of electronic structure and chemical bonding. Should these topics come early, at the point where models for the atom are being discussed? Or should they come later, after the student has been exposed to chemical compounds and chemical reactions? Early placement gives students a theoretical framework within which they can understand compounds and reactions. However, it also presents students with abstract models before they understand why they are necessary. I have chosen a later placement for the following reasons:

1. *A later placement seems more flexible.* An instructor who wants to cover atomic theory and bonding earlier can simply cover Chapters 9 and 10 after Chapter 4. However, if atomic theory and bonding were placed earlier, it would be more difficult for the instructor to skip these chapters and come back to them later.
2. *A later placement allows earlier coverage of topics that students can more easily visualize.* Coverage of abstract topics too early in a course can lose some students. Chemical compounds and chemical reactions are more tangible than atomic orbitals, and the relevance of these is easier to demonstrate to the beginning student.
3. *A later placement gives students a reason to learn an abstract theory.* Once students learn about compounds and reactions, they are more easily motivated to learn a theory that explains them in terms of underlying causes.
4. *A later placement follows the scientific method.* In science, we normally make observations, form laws, *and then* build models or theories that explain our observations and laws. A later placement follows this ordering.

Nonetheless, I know that every course is unique and that each instructor chooses to cover topics in his or her own way. Consequently, I have written each chapter for maximum flexibility in topic ordering. In addition, the book is offered in two formats. The full version, *Introductory Chemistry*, contains 19 chapters, including organic chemistry and biochemistry. The shorter version, *Introductory Chemistry Essentials*, contains 17 chapters and omits these topics.

Improving Conceptual Understanding

Students often have difficulty in developing a true understanding of the concepts that underlie chemical behavior. These concepts are important not only as the foundation for problem solving but also as the basis for insight into how the chemical world works. To address this need, we have incorporated a new set of questions at the end of appropriate sections that encourage students to test their grasp of the key principles in the section.

NEW Conceptual Checkpoints

These strategically located conceptual questions

- enhance understanding of chemical principles,
- encourage students to stop and think about the ideas just presented before going on to new material, and
- provide a tool for self-assessment.

Presented in multiple-choice format, the questions are designed so that an attentive student can answer them quickly, with little or no calculation.
Answers to Conceptual Checkpoints are given at the end of each chapter, along with explanations of the reasoning involved.

✔ **CONCEPTUAL CHECKPOINT 6.1**

Which of these statements is *always* true for samples of atomic elements, regardless of the type of element present in the samples?

(a) If two samples of different elements contain the same number of atoms, they must contain the same number of moles.
(b) If two samples of different elements have the same mass, they must contain the same number of moles.
(c) If two samples of different elements have the same mass, they must contain the same number of atoms.

Answers to Conceptual Checkpoints are given at the end of each chapter, along with explanations of the reasoning involved.

Answers to Conceptual Checkpoints

6.1 (a) The mole is a counting unit; it represents a definite number (Avogadro's number, 6.02×10^{23}). Therefore, a given number of atoms always represents a precise number of moles, regardless of what atom is involved. Atoms of different elements have different masses, so if samples of different elements have the same mass, they *cannot* contain the same number of atoms or moles.

6.2 (a) Avogadro's number was defined so as to make the molar mass of a compound (the mass of one mole, or Avogadro's number of molecules or formula units), *in grams*, numerically equal to the formula mass of the compound in amu. In order for the molar mass *in kilograms* to be numerically equal to the formula mass in amu, we would need 1000 times as many molecules or formula units in a mole. In other words, Avogadro's number would have to be 1000 times larger, or 6.02×10^{26}.

6.3 (b) This compound has the highest ratio of oxygen atoms to chromium atoms, and so must have the greatest mass percent of oxygen.

Developing Problem-Solving Skills

The development of problem-solving skills is the main goal of the text. To this end, *Introductory Chemistry* develops a systematic approach in which problem-solving skills are

- emphasized throughout each chapter,
- developed through many in-chapter Examples,
- reinforced with *Skillbuilder* exercises immediately following each Example,
- reviewed in unique chapter summaries, and
- practiced and synthesized in end-of-chapter exercises.

Starting with the simplest problems involving unit conversions, the text presents students with a basic procedure for solving most chemical problems. This procedure and the Examples that demonstrate its use have a number of special pedagogical features, designed to help students master problem-solving skills through understanding rather than mechanical repetition.

UNIQUE Solution Maps

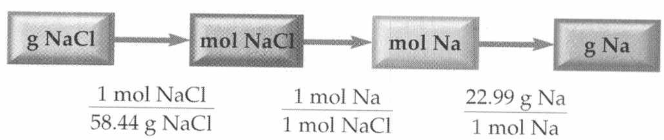
Many of the Examples employ a unique visual approach in which students are shown how to draw a *solution map* for the problem. They are taught to outline the steps—using conversion factors and equations—needed to get from the information they are given to the information they are trying to find. This technique encourages students to think through the problem and formulate a solution strategy, and helps them see the relationship between the big picture and the individual steps. In response to requests from users of the text, there is a more consistent use of color for the buttons in the solution maps in this edition.

Converting between Grams of a Compound and Grams of a Constituent Element

Now, we have everything we need to solve our sodium problem. Suppose we want to know how many grams of sodium there are in 15 g of NaCl. The chemical formula gives us the relationship between moles of Na and moles of NaCl:

$$1 \text{ mol Na} \equiv 1 \text{ mol NaCl}$$

To use this relationship, we need *mol* NaCl. But, we have *g* NaCl. We can, however, use the *molar mass* of NaCl to convert from g NaCl to mol NaCl. Then we use the conversion factor from the chemical formula to convert to mol Na. Finally, we use the molar mass of Na to convert to g Na. The solution map is:



Notice that we must convert from g NaCl to mol NaCl *before* we can use the chemical formula as a conversion factor.

EXAMPLE 6.7 **Chemical Formulas as Conversion Factors—Converting between Grams of a Compound and Grams of a Constituent Element**

Carvone ($C_{10}H_{14}O$) is the main component of spearmint oil. It has a pleasant aroma and mint flavor. Carvone is often added to chewing gum, liqueurs, soaps, and perfumes. Find the mass of carbon in 55.4 g of carvone.

Extract the important information from the problem in the normal way. You are given the mass of carvone and asked to find the mass of one of its constituent elements.

Given: 55.4 g $C_{10}H_{14}O$

Find: g C

MOLECULE Carvone

Conversion Factors:

You need three conversion factors. The first is the molar mass of carvone.

$$\text{Molar mass} = 10(12.01) + 14(1.01) + 1(16.00) = 120.1 + 14.14 + 16.00 = 150.2 \text{ g/mol}$$

The second conversion factor is the relationship between moles of C and moles of carvone from the molecular formula.

$$10 \text{ mol C} \equiv 1 \text{ mol } C_{10}H_{14}O$$

The third conversion factor is the molar mass of carbon.

$$1 \text{ mol C} = 12.01 \text{ g}$$

The solution map is based on Grams ⟶ Mole ⟶ Mole ⟶ Grams

Solution Map:

g $C_{10}H_{14}O$ → mol $C_{10}H_{14}O$ → mol C → g C

$$\frac{1 \text{ mol } C_{10}H_{14}O}{150.2 \text{ g } C_{10}H_{14}O} \quad \frac{10 \text{ mol C}}{1 \text{ mol } C_{10}H_{14}O} \quad \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

Remember, the conversion factor obtained from the chemical formula (10 mol C ≡ 1 mol $C_{10}H_{14}O$) applies only to moles; since we are given grams of carvone, we must first convert from g to mol.

Follow the solution map to solve the problem, beginning with g $C_{10}H_{14}O$ and multiplying by the appropriate conversion factors to arrive at g C.

Solution:

$$55.4 \text{ g } C_{10}H_{14}O \times \frac{1 \text{ mol } C_{10}H_{14}O}{150.2 \text{ g } C_{10}H_{14}O} \times \frac{10 \text{ mol C}}{1 \text{ mol } C_{10}H_{14}O} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 44.3 \text{ g C}$$

SKILLBUILDER 6.7 **Chemical Formulas as Conversion Factors—Converting between Grams of a Compound and Grams of a Constituent Element**

Determine the mass of oxygen in a 5.8-g sample of sodium bicarbonate ($NaHCO_3$).

SKILLBUILDER PLUS

Determine the mass of oxygen in a 7.20-g sample of $Al_2(SO_4)_3$.

NEW Two-Column Examples

In this edition, all but the simplest Examples are presented in a unique two-column format. The left column explains each step, while the right column shows how the step is executed. This format encourages students to think about the reason for each step in the solution and to fit the steps together in the context of an overall plan.

UNIQUE *Skillbuilder* Exercises

Every worked Example in *Introductory Chemistry* is followed by at least one similar but unworked *Skillbuilder* problem, allowing students to make an immediate test of the problem-solving techniques they have just learned. Many important Examples also have an additional *Skillbuilder Plus* problem, affording students further opportunity for practice. For immediate reinforcement, answers to all *Skillbuilder* and *Skillbuilder Plus* problems are given at the end of each chapter.

UNIQUE Three-Column Problem-Solving Procedures

Among the distinctive features of this book are the numerous specific procedures for solving particular types of problems, presented in a unique three-column format. The first column outlines the problem-solving procedure and explains the reasoning that underlies each step. The second and third columns show how the steps are implemented for two typical Examples. Seeing the method applied to solve two related but slightly different problems helps students understand the general procedure in a way that no single Example could convey.

Obtaining an Empirical Formula from Experimental Data	EXAMPLE 6.10	EXAMPLE 6.11
	A compound containing nitrogen and oxygen is decomposed in the laboratory and produces 24.5 g of nitrogen and 70.0 g of oxygen. Calculate the empirical formula of the compound.	A laboratory analysis of aspirin determined the following mass percent composition: C 60.00%, H 4.48%, O 35.53%. Find the empirical formula.
1. Write down (or compute) as given the masses of each element present in a sample of the compound. If you are given mass percent composition, assume a 100-g sample and compute the masses of each element from the given percentages.	**Given:** 24.5 g N, 70.0 g O **Find:** empirical formula	**Given:** In a 100-g sample: 60.00 g C, 4.48 g H, 35.53 g O **Find:** empirical formula
2. Convert each of the masses in Step 1 to moles by using the appropriate molar mass for each element as a conversion factor.	**Solution:** $24.5 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 1.75 \text{ mol N}$ $70.0 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 4.38 \text{ mol O}$	**Solution:** $60.00 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.996 \text{ mol C}$ $4.48 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 4.44 \text{ mol H}$ $35.53 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.221 \text{ mol O}$
3. Write down a pseudoformula for the compound, using the moles of each element (from Step 2) as subscripts.	$N_{1.75}O_{4.38}$	$C_{4.996}H_{4.44}O_{2.221}$
4. Divide all the subscripts in the formula by the smallest subscript.	$N_{\frac{1.75}{1.75}}O_{\frac{4.38}{1.75}} \longrightarrow N_1O_{2.5}$	$C_{\frac{4.996}{2.221}}H_{\frac{4.44}{2.221}}O_{\frac{2.221}{2.221}} \longrightarrow C_{2.25}H_2O_1$
5. If the subscripts are not whole numbers, multiply all the subscripts by a small whole number (see the following table) to get whole-number subscripts.	$N_1O_{2.5} \times 2 \longrightarrow N_2O_5$ The correct empirical formula is N_2O_5.	$C_{2.25}H_2O_1 \times 4 \longrightarrow C_9H_8O_4$ The correct empirical formula is $C_9H_8O_4$.

Fractional Subscript	Multiply by this Number to Get Whole-Number Subscripts
_.10	10
_.20	5
_.25	4
_.33	3
_.50	2
_.66	3
_.75	4

SKILLBUILDER 6.10

A sample of a compound is decomposed in the laboratory and produces 165 g of carbon, 27.8 g of hydrogen, and 220.2 g O. Calculate the empirical formula of the compound.

SKILLBUILDER 6.11

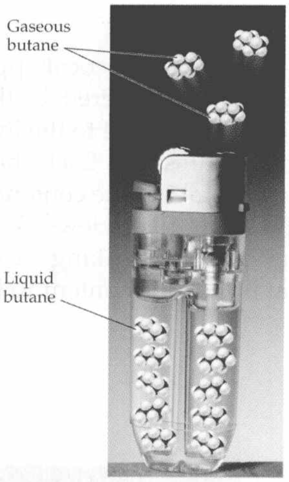
Ibuprofen, an aspirin substitute, has the following mass percent composition: C 75.69%; H 8.80%; O 15.51%. Calculate the empirical formula of the compound.

Visualization: Connecting the Macroscopic and Microscopic Worlds

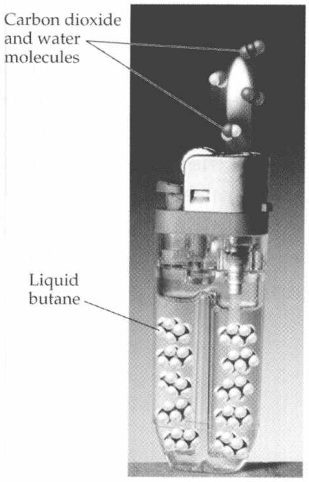
Today's students often absorb information best when it is presented in graphic form or accompanied by some visual reinforcement. While pictures cannot replace clear explanations, they can supplement them in crucial ways. The art program of this book was expressly conceived to help students visualize connections between molecular processes and the behavior of macroscopic objects.

◀ Many concepts are illustrated using a two-part visual image: a photograph of a real-world object or process, and a depiction of what is taking place on the molecular level, either superimposed or shown as a magnified breakout.

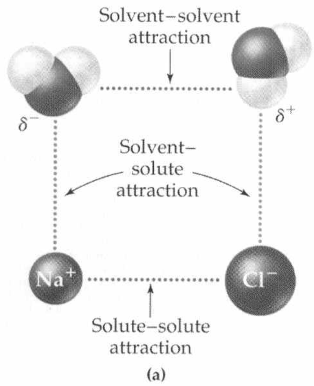
▼ Many molecular formulas in the text are depicted not only with structural formulas, but also with space-filling drawings of the molecules for greater clarity and vividness.

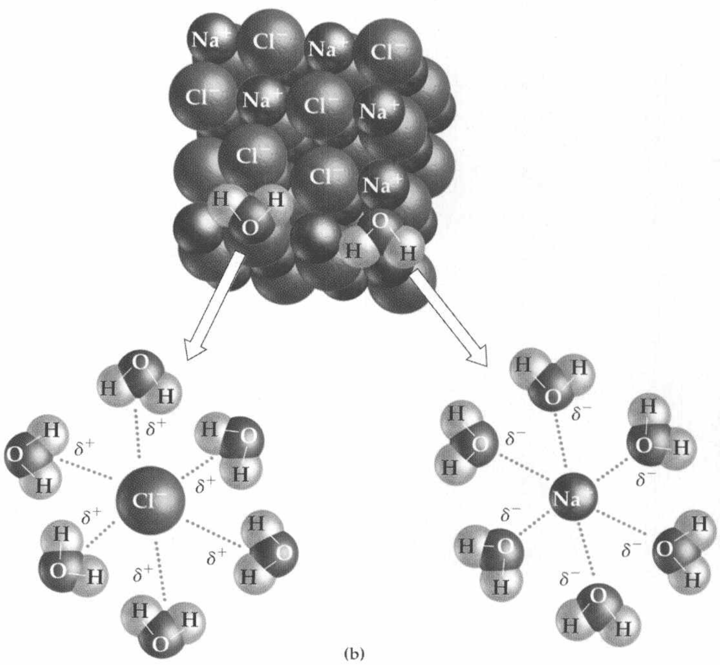


▲ **Figure 3.11 Vaporization: a physical change** If you push the button on a lighter without turning the flint, some of the liquid butane vaporizes to gaseous butane. Since the liquid butane and the gaseous butane are both composed of butane molecules, this is a physical change.



▲ **Figure 3.12 Burning: a chemical change** If you push the button *and* turn the flint to create a spark, you produce a flame. The butane molecules react with oxygen molecules in air to form new molecules, carbon dioxide and water. This is a chemical change.





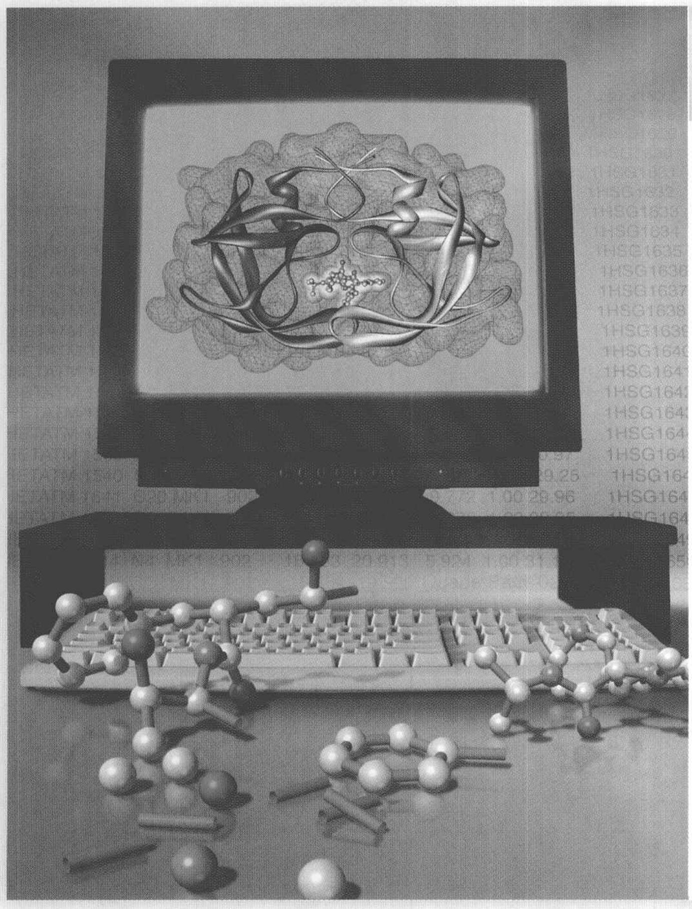
▲ **Figure 13.1 How a solid dissolves in water** **(a)** When NaCl is put into water, the attraction between water molecules and Na^+ and Cl^- ions (solvent–solute attraction) overcomes the attraction between Na^+ and Cl^- ions (solute–solute attraction). **(b)** The positive ends of the water dipoles are attracted to the negatively charged Cl^- ions and the negative ends of the water dipoles are attracted to the positively charged Na^+ ions. The result is that water molecules surround the ions of NaCl and disperse them in the solution.

Creating Interest in Chemistry

Students learn best when they feel that the material is interesting and relevant to their lives. Interest in the field of chemistry and in the topic under study is enhanced by means of two recurring features.

UNIQUE Chapter Openers

Every chapter opens with a description of an everyday situation or practical application that clearly demonstrates the importance of the material covered in that chapter. These openers often involve topics that are particularly relevant to the lives of students, such as health, consumer, environmental, or societal issues. Each chapter introductory narrative is accompanied by a piece of art portraying the content in a striking visual image that combines macroscopic and molecular views. Each chapter introductory narrative is accompanied by a unique and striking visual image, combining macroscopic and molecular views, that brings the content to life for the student.



CHAPTER 10

Chemical Bonding

"The fascination of a growing science lies in the work of the pioneers at the very borderland of the unknown, but to reach this frontier one must pass over well traveled roads . . ."

Gilbert N. Lewis (1875–1946)

10.1 Bonding Models and AIDS Drugs

In 1989, researchers discovered the structure of a molecule called HIV-protease. HIV-protease is a protein (a class of biological molecules) synthesized by the human immunodeficiency virus (HIV), which causes AIDS. HIV-protease is crucial to the virus's ability to replicate itself. Without HIV-protease, HIV could not spread in the human body because the virus could not copy itself, and AIDS would not develop.

Proteins are discussed in more detail in Chapter 19.

With knowledge of the HIV-protease structure, drug companies set out to design a molecule that would disable protease by sticking to the working part of the molecule (called the *active site*). To design such a molecule, researchers used **bonding theories**—models that predict how atoms bond together to form molecules—to simulate how potential drug molecules would interact with the protease molecule. By the early 1990s, these companies had developed several drug molecules that seemed to work. Since these molecules inhibit the action of HIV-protease, they are called *protease inhibitors*. In human trials, protease inhibitors in combination with other drugs have decreased the viral count in HIV-infected individuals to undetectable levels. Many AIDS patients are still alive today because of the development of these drugs.

Bonding theories are central to chemistry because they predict how atoms bond together to form compounds. They predict what combinations of atoms form compounds and what combinations do not. For example, bonding theories predict why salt is NaCl and not $NaCl_2$ and why water is H_2O and not H_3O. Bonding theories also explain the shapes of molecules, which in turn determine many of their physical and chemical properties. The bonding theory you will learn in this chapter is called **Lewis theory,** named after the American chemist who developed it, G. N. Lewis (1875–1946). It involves representing electrons as dots and drawing what are called *dot structures* or *Lewis structures* to represent molecules. These structures, which are fairly simple to draw, have tremendous predictive power. It takes just a few minutes to

◄ The gold-colored structure on the computer screen is a representation of HIV-protease. The molecule shown in the center is Indinavir, a protease inhibitor.

305

Interest Boxes

Introductory Chemistry has four types of interest boxes: Everyday Chemistry, Chemistry in the Media, Chemistry in the Environment, and Chemistry and Health.

EVERYDAY Chemistry

Antifreeze in Frogs

On the outside, wood frogs *(Rana sylvatica)* look like most other frogs. They are only a few inches long and have characteristic greenish-brown skin. However, wood frogs survive cold winters in a remarkable way—they partially freeze. In the frozen state, the frog has no heartbeat, no blood circulation, no breathing, and no brain activity. Within 1 to 2 hours of thawing, however, these vital functions return, and the frog hops off to find food. How is this possible?

Most cold-blooded animals cannot survive freezing temperatures because the water within their cells freezes. As we learned in Section 12.8, when water freezes, it expands, irreversibly damaging cells. When the wood frog hibernates for the winter, however, it secretes large amounts of glucose into its blood and into the interior of its cells. When the temperature drops below freezing, extracellular bodily fluids, such as those in the abdominal cavity, freeze solid. Fluids within cells, however, remain liquid because the high glucose concentration lowers their freezing point. In other words, the concentrated glucose solution within the frog's cells acts as antifreeze, preventing the water within the cells from freezing and allowing the frog to survive.

CAN YOU ANSWER THIS? *The wood frog can survive at body temperatures as low as −8.0 °C. Calculate the molality of a glucose solution ($C_6H_{12}O_6$) required to lower the freezing point of water to −8.0 °C.*

REFERENCE: Another interesting example is discussed in "Freeze-Proof Bugs," Donald DeLorenzo, *J. Chem. Educ.* 1981 58 788

◄ The wood frog survives cold winters by partially freezing. The fluids within the frog's cells, however, remain liquid to temperatures as low as −8 °C. These fluids are protected by a high concentration of glucose that acts as antifreeze, lowering their freezing point.

- *Everyday Chemistry* boxes describe in chemical terms what is happening on the atomic or molecular level in common, everyday processes, such as the bleaching of hair, and explain the properties of familiar materials, such as Kevlar.
- *Chemistry in the Media* boxes discuss chemical topics that have been in the news, such as the controversy over oxygenated fuels.
- *Chemistry in the Environment* boxes deal with environmental issues that are closely tied to chemistry, such as acid rain and the ozone hole.
- *Chemistry and Health* boxes focus on biomedical topics as well as those related to personal health and fitness, such as drug dosage, ulcers and antacids, and isoosmotic solutions for transfusions.

The interest boxes in *Introductory Chemistry* all contain questions that relate directly to the chapter material, helping students apply what they have just learned.

Review and Assessment

UNIQUE Chapter in Review

Each chapter ends with a review consisting of two sections, the first focusing on chemical principles and the second on chemical skills. Each section is itself divided into two columns.

CHAPTER IN REVIEW

Chemical Principles	Relevance
The Mole Concept: The mole is a specific number (6.022×10^{23}) that is defined so as to allow us to easily count atoms or molecules by weighing them. One mole of any element has a mass equivalent to its atomic mass in grams, and a mole of any compound has a mass equivalent to its formula mass in grams. The mass of 1 mol of an element or compound is called the molar mass.	**The Mole Concept:** The mole concept allows us to determine the number of atoms or molecules in a sample from its mass. Just as a hardware store customer wants to know the number of nails in a certain weight of nails, so we want to know the number of atoms in a certain mass of atoms. Since atoms are too small to count, we use their mass.

- In the Chemical Principles section, the left column summarizes the key principles while the right column tells why each is important.

Converting between Grams of a Compound and Grams of a Constituent Element (Section 6.5)

To convert from grams of a compound to grams of a constituent element, first use the molar mass of the compound to convert from grams of the compound to moles of the compound. Then use the chemical formula to obtain a conversion factor to convert from moles of the compound to moles of the constituent element. Finally, use the molar mass of the constituent element to convert from moles of the element to grams of the element.

To convert from grams of a constituent element to grams of a compound, first use the molar mass of the constituent element to convert from grams of the element to moles of the element. Then use the chemical formula to obtain a conversion factor to convert from moles of the constituent element to moles of the compound. Finally, use the molar mass of the compound to convert from moles of the compound to grams of the compound.

EXAMPLE 6.17 Converting between Grams of a Compound and Grams of a Constituent Element

Find the grams of iron in 79.2 g of Fe_2O_3.

Given: 79.2 g Fe_2O_3

Find: g Fe

Conversion Factors:

Molar mass Fe_2O_3
$= 2(55.85) + 3(16.00)$
$= 159.70$ g/mol

2 mol Fe = 1 mol Fe_2O_3

Solution Map:

g Fe_2O_3 → mol Fe_2O_3 → mol Fe → g Fe

$$\frac{1 \text{ mol } Fe_2O_3}{159.70 \text{ g } Fe_2O_3} \qquad \frac{2 \text{ mol Fe}}{1 \text{ mol } Fe_2O_3} \qquad \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}}$$

Solution:

$$79.2 \text{ g } Fe_2O_3 \times \frac{1 \text{ mol } Fe_2O_3}{159.70 \text{ g } Fe_2O_3} \times \frac{2 \text{ mol Fe}}{1 \text{ mol } Fe_2O_3} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 55.4 \text{ g Fe}$$

- In the Chemical Skills section, the left column describes the key skills while the right column contains a worked Example illustrating each skill.

Student Exercises

All chapters contain exercises divided into four types: questions, problems, cumulative problems, and highlight problems. Many new exercises have been added in this edition to provide a full range of assessment opportunities.

Questions

1. Why is reaction stoichiometry important? Can you give some examples?
2. What does it mean to say that two quantities in a chemical reaction are equivalent?
3. Write conversion factors showing the relationships between moles of each of the reactants and products in the following reaction.

$$N_2(g) + 3\,H_2(g) \longrightarrow 2\,NH_3(g)$$

4. For the reaction in Problem 3, how many molecules of H_2 are required to completely react with two molecules of N_2? How many moles of H_2 are required to completely react with 2 mol of N_2?
5. Write the conversion factor that you would use to convert from moles of Cl_2 to moles of NaCl in the following reaction.

If you have 7 cups of noodles, 27 tomatoes, and 9 cloves of garlic, how many servings of pasta can you make? Which ingredient limits the amount of pasta that is possible?

9. In a chemical reaction, what is the limiting reactant?
10. In a chemical reaction, what is the theoretical yield?
11. In a chemical reaction, what are the actual yield and percent yield?
12. If you are given a chemical equation and specific amounts of each reactant in grams, how would you determine how much product can possibly be made?
13. Consider the following generic chemical reaction.

$$A + 2\,B \longrightarrow C + D$$

Suppose you have 12 g of A and 24 g of B. Which of the following statements are true?

◀ The *Questions* are qualitative, requiring the student to summarize important chapter concepts.

Mass Percent Composition

67. A 2.45-g sample of strontium completely reacts with oxygen to form 2.89 g of strontium oxide. Use this data to calculate the mass percent composition of strontium in strontium oxide.

68. A 4.78-g sample of aluminum completely reacts with oxygen to form 6.67 g of aluminum oxide. Use this data to calculate the mass percent composition of aluminum in aluminum oxide.

69. A 1.912-g sample of calcium chloride is decomposed into its constituent elements and found to contain 0.690 g Ca and 1.222 g Cl. Calculate the mass percent composition of Ca and Cl in calcium chloride.

70. A 0.45-g sample of aspirin is decomposed into its constituent elements and found to contain 0.27 g C, 0.020 g H, and 0.16 g O. Calculate the mass percent composition of C, H, and O in aspirin.

71. Copper(II) fluoride contains 37.42% F by mass. Use this percentage to calculate the mass of fluorine in grams contained in 28.5 g of copper(II) fluoride.

72. Silver chloride, often used in silver plating, contains 75.27% Ag. Calculate the mass of silver chloride in grams required to make 4.8 g of silver plating.

◀ The *Problems* are quantitative in nature. This section, the longest, is divided by headings into subsections dealing with the major topical areas of the chapter.

Cumulative Problems

97. A pure copper cube has an edge length of 1.42 cm. How many copper atoms does it contain? (volume of a cube = (edge length)^3; density of copper = 8.96 g/cm^3)

98. A pure silver sphere has a radius of 0.886 cm. How many silver atoms does it contain? (Volume of a sphere = $\frac{4}{3}\pi r^3$; density of silver = 10.5 g/cm^3)

99. A drop of water has a volume of approximately 0.05 mL. How many water molecules does it contain? (density of water = 1.0 g/cm^3).

100. Fingernail-polish remover is primarily acetone (C_3H_6O). How many acetone molecules are in a bottle of acetone with a volume of 325 mL? (density of acetone = 0.788 g/cm^3).

101. Complete the following table:

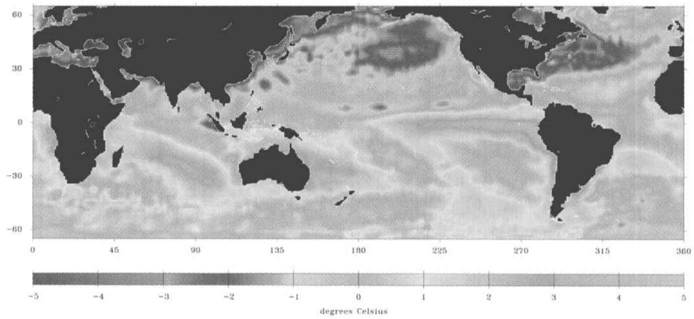
Substance	*Mass*	*Moles*	*Number of Particles (atoms or molecules)*
Ar	___	4.5×10^{-4}	___
NO_2	___	___	1.09×10^{20}
K	22.4 mg	___	___
C_8H_{18}	3.76 kg	___	___

102. Complete the following table:

Substance	*Mass*	*Moles*	*Number of Particles (atoms or molecules)*
$C_6H_{12}O_6$	15.8 g	___	___
Pb	___	___	9.04×10^{21}
CF_4	22.5 kg	___	___
C	___	0.0388	___

▶ *Cumulative Problems* require students to synthesize several of the skills they have learned in the chapter and in previous chapters.

101. A major event affecting global climate is the El Niño/La Niña cycle. In this cycle, equatorial Pacific Ocean waters warm by several degrees Celsius above normal (El Niño) and then cool by several degrees Celsius below normal (La Niña). This cycle affects weather not only in North and South America, but as far away as Africa. Why does a seemingly small change in ocean temperature have such a large impact on weather?



▲ Temperature anomaly plot of the world's oceans for December 23, 1997. The red section off the western coast of South America is the El Niño effect, a warming of the Pacific Ocean along the equator.

▶ *Highlight Problems* are set within a context that will be of particular interest to the student because of its timeliness, familiarity, or relevance to some important issue. Such problems often include photographs or art.

All Problems and Cumulative Problems are paired: A problem that is answered in the back of the book (identified by a blue number) is followed by a similar problem without an answer. All answers are available in the instructor's full *Solutions Manual*.

Print and Media Resources

For the Instructor

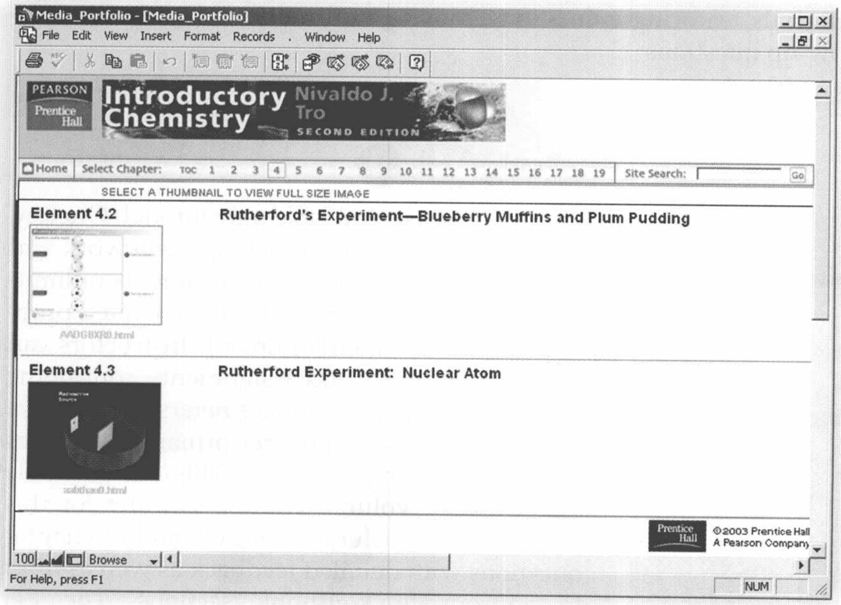
Annotated Instructor's Edition (0–13–149513–5) with annotations by Carl Hoeger, University of California, San Diego. This special edition contains the entire student text plus marginal annotations to aid instructors in preparing their lectures. Included are suggestions for classroom demonstrations, teaching tips, Transparency Pack icons, and references to articles on the effective presentation of many chemical topics.

Instructor's Resource and Full Solutions Manual (0–13–147062–0) by Mark Ott, Jackson Community College, and Matthew Johll, Illinois Valley Community College. This manual features lecture outlines with presentation suggestions, teaching tips, suggested in-class demonstrations, and topics for classroom discussion. It also contains full solutions to all the end-of-chapter problems from the text.

Test Item File (0–13–147064–7) by Kuruvilla Zachariah, Ohio University. This printed test bank includes more than 1300 questions. A computerized version of the test item file is available in the Instructor's Resource Center.

Transparency Pack (0–13–147069–8) This set contains 175 full-color transparencies from the text. Chosen specifically to put principles into visual perspective, it can save you time while you are preparing your lectures.

Instructor's Resource Center on CD/DVD (0–13–147063–9) This fully searchable and integrated collection of resources is designed to help you make efficient and effective use of your lecture preparation time as well as to enhance your classroom presentations and assessment efforts. This package features the following:



◀ Nearly all the art from the text, including tables, in JPG and PDF formats; movies; animations; interactive activities; and the *Instructor's Resource Manual* Word™ files.

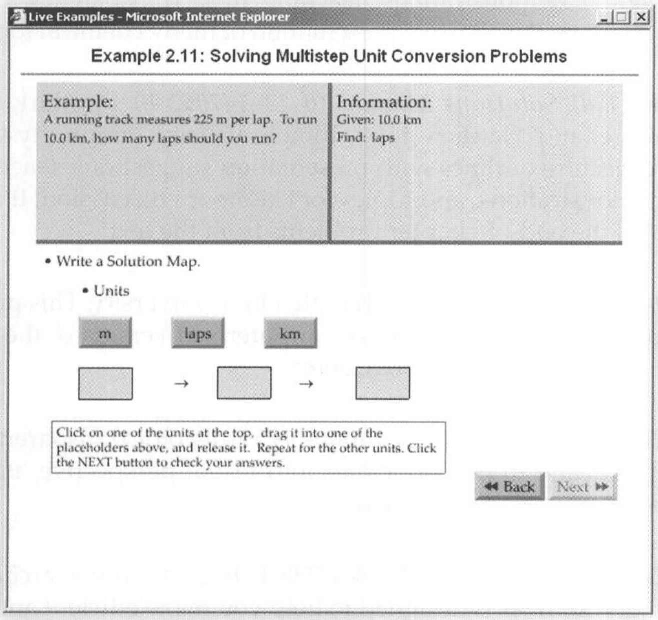
- Four PowerPoint™ presentations: (1) a lecture outline presentation for each chapter, (2) all the art from the text, (3) the worked Examples from the text, and (4) CRS (Classroom Response System) questions.
- A search engine tool that lets you find relevant resources via a number of different parameters, such as key terms, learning objectives, figure numbers, and resource type.
- The TestGen, a computerized version of the Test Item File that allows you to create and tailor exams to your needs.

ONEKEY (Access at http://chem.prenhall.com/tro)

OneKey offers the best teaching and learning resources all in one place.

- OneKey for *Introductory Chemistry, Second Edition*, is all your *students* need for access to your course materials anytime, anywhere.
- OneKey is all *you* need to plan and administer your course.

Conveniently organized by text chapter, these compiled resources help you save time and help your students reinforce and apply what they have learned in class.



Student Resources

- The new **WebBook**, a full electronic version of the text with embedded Live Examples, animations, movies, and molecules
- ◀ **Live Examples**, an interactive version of selected Examples from the text
- A **3-D Molecule Gallery** to help students visualize many important molecules introduced in the course
- **Quizzes** of multiple-choice and true/false questions featuring hints and answer-specific feedback
- More online resources such as **Research Navigator, Link Library,** and the **Math Tutorial**

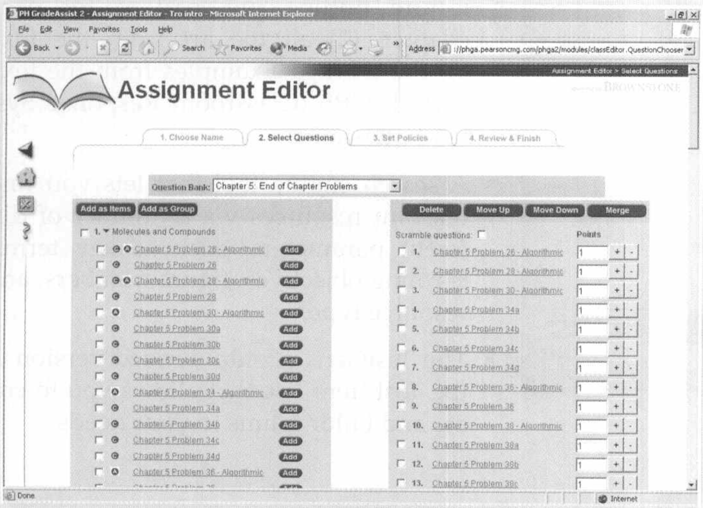
Instructor Resources

- Resources from the **Instructor's Resource Center on CD/DVD** (described on the previous page) are also included in OneKey.

Assessment Content

- Multiple choice **Quiz Questions** with hints and feedback
- **Student Tutorials** featuring animations, movies, and molecules with multiple-choice follow-up questions
- **Test Item File** questions

PHGradeAssist 2



◀ **PH GradeAssist** Available only through OneKey, PH GradeAssist is a timesaving homework and assessment system that allows students unlimited practice with algorithmically generated problems in an online environment. Instructors can administer quizzes and assignments, control the content and assignment parameters, and receive assignments and view performance statistics with the built-in gradebook. This customizable system has a volume built specifically for this text. Content includes selected end-of-chapter questions with detailed feedback as well as links to appropriate **WebBook** sections. The PH GradeAssist platform is going through continual, seamless upgrades, to offer instructors more options and to make the program easier for students to use.

With contributions by Roy Kennedy, Massachusetts Bay Community College; Mark E. Ott, Jackson Community College; Michael Hauser, St. Louis Community College–Meramec; Jeffrey Lehman, Grossmont College; Cary Willard, Grossmont College; and Bette Kreuz, University of Michigan–Dearborn.

COURSE MANAGEMENT

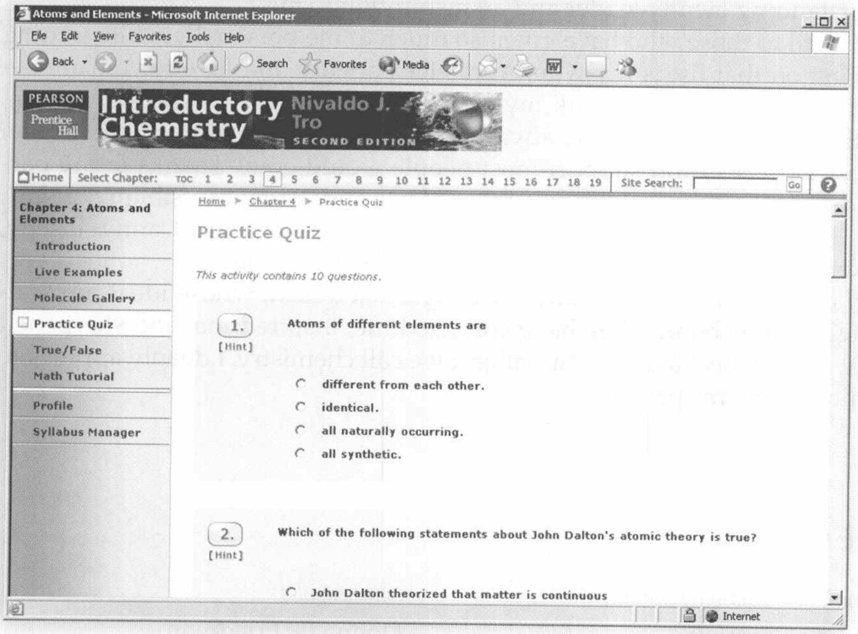
All of the content in **OneKey** is also available in **WebCT** and **Blackboard**. Prentice Hall offers content cartridges for these text-specific Classroom Management Systems. Visit **http://cms.prenhall.com** or contact your Prentice Hall sales representative for details. More basic courses, loaded with just the Test Item file, are also available.

For the Student

Study Guide (0–13–147071-X) by Donna Friedman, St. Louis Community College–Florissant Valley. This book assists students through the text material with chapter overviews and practice problems for each major concept in the text, followed by two or three self-tests with answers at the end of each chapter.

Selected Solutions Manual (0–13–147085–2) by Matthew Johll, Illinois Valley Community College. This book provides solutions only to those problems that have a short answer in the text's Answers section (problems numbered in blue in the text).

Math Review Toolkit (0–13–147066–3) by Gary L. Long, Virginia Tech. This print resource, free when packaged with the text, reinforces the skills necessary to succeed in chemistry. Keyed specifically to chapters in *Introductory Chemistry, Second Edition*, it includes additional mathematics review, problem-solving tools, and examples.



◀ ***Companion Website***
(Access at **http://chem.prenhall.com/tro**)
For students who wish to utilize a Website for additional practice, the Companion Website contains the **Chemical Principles**, **Live Examples**, **Molecule Gallery**, **Practice Quiz**, **True/False**, and **Math Tutorial** modules included in the Course Management Systems described previously.

Student Accelerator CD-ROM
This student CD—which contains animations, movies, and molecules from the Companion Website—accelerates the performance of the Website when students download high-bandwidth media, so that students are not restricted by slow connections. It can also be used apart from the Companion Website if a student doesn't have a live Internet connection. Many of the media elements available on the CD are referenced in the text by means of marginal icons and titles. The *Introductory Chemistry, Second Edition* Accelerator CD comes packaged with every new student textbook for no additional charge.