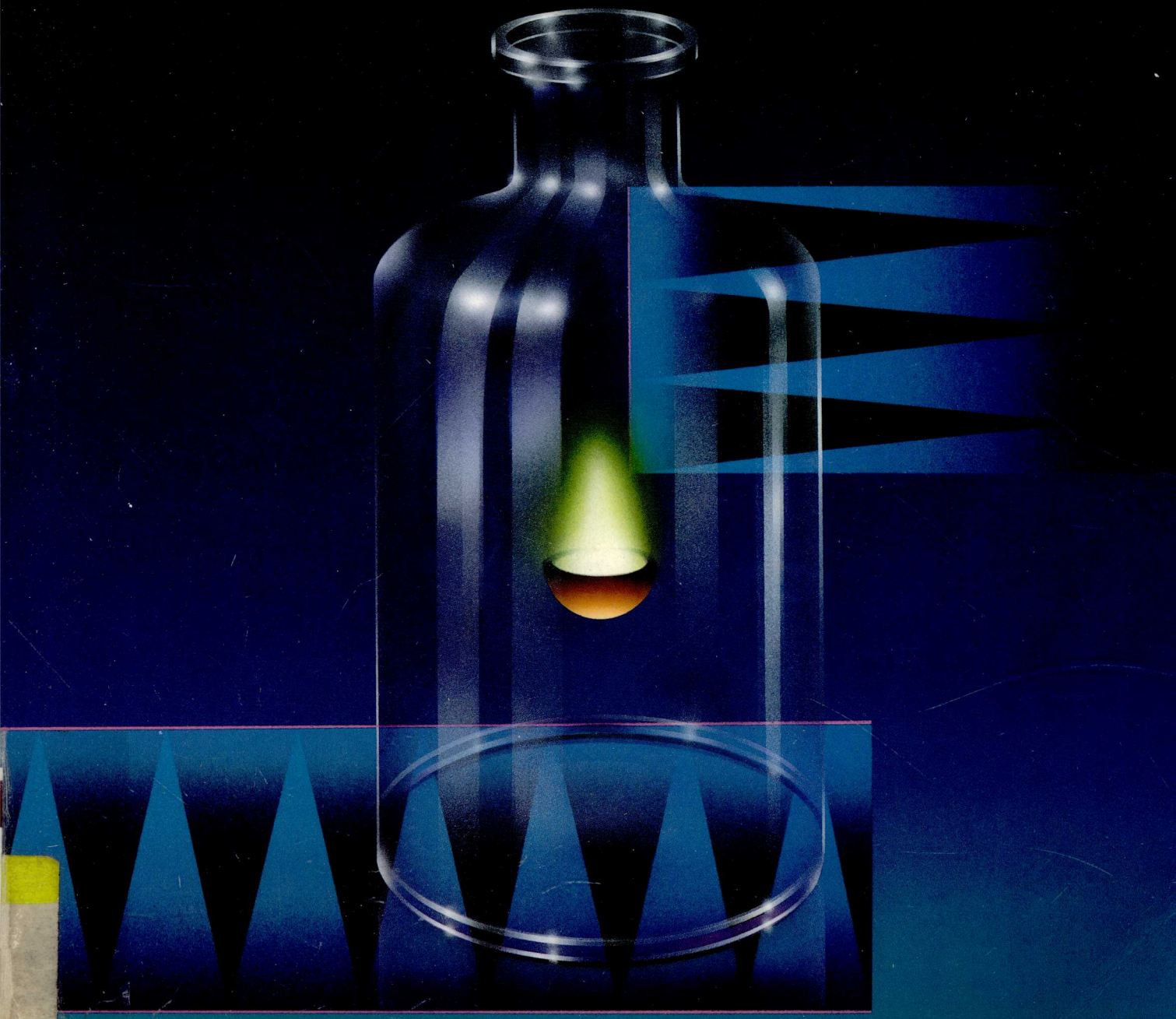
STUDY GUIDE

CHEMISTRY

The Study of Matter and Its Changes



JAMES E. BRADY ♦ JOHN R. HOLUM

STUDY GUII

TO ACCOMPANY

CHEMISTRY

The Study of Matter and Its Changes

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PREFACE

Our goal in preparing this Study Guide was to provide the student with a structured review of important concepts and problem solving approaches. We begin with a preliminary chapter that introduces students to the text and to the study guide. Here we explain how to use the text and study guide together most effectively, and we explain the importance of regular class attendance and how to develop proper study habits. One of the principal features of the textbook is the organized approach to problem solving employing the chemical toolbox analogy. Because this approach is likely to be new to the student, we discuss in some detail how this analogy can help students expand their problem solving skills.

Each of the remaining chapters in the Study Guide begins with a brief overview of the chapter contents, followed by a list of Learning Objectives. Because students tend to study one section at a time, we divide each chapter in the Study Guide into sections that match one-for-one the sections in the text. Each section provides a review of the topics covered in the text. Here we call to students' attention key concepts and important facts. In many places, additional explanations of difficult topics are provided, and where students often find particular difficulty, additional worked examples are given.

In keeping with our aim of providing students with frequent opportunities to hone their skills and test their knowledge, almost all sections of the Study Guide include a brief Self-Test that consists of questions and problems that supplement those in the text. The answers to all the Self-Test exercises appear at the ends of the chapters. Many sections also contain a Thinking It Through question of the type found in the textbook, and for each there is a worked-out answer at the end of the chapter.

Following the Self-Test there is a list of new terms introduced in the section. As an exercise, the student is encouraged to write out the definitions of these terms in their notebook.

As an additional aid in problem solving, tables listing the Chemical Tools and their functions as well as summaries of important equations and other useful information are found on separate tear-out pages at the ends of chapters. The aim is to provide the student with another means to reinforce the key problem solving concepts.

James E. Brady
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Before You Begin...

Before you begin your general chemistry course, read the next several pages. They're designed to tell you how to use this study guide and to give you a few tips on improving your study habits.

How to Use the Study Guide

This book has been written to parallel the topics covered in your text, *Chemistry: The Study of Matter and Its Changes*. Each chapter begins with a very brief overview of the chapter contents followed by a list of learning objectives. Read these before beginning a chapter, and then read them again after you've finished to be sure you have met the goals described. For each section in the textbook, you will find a corresponding section in the Study Guide. In the Study Guide, the sections are divided into **Review, Thinking It Through, Self-Test** and **New Terms**.

After you've read a section in the text, turn to the study guide and read the **Review**. This will point out specific ideas that you should be sure you have learned. Sometimes you will be referred back to the text to review topics there. Sometimes there will be additional worked-out sample problems. Work with the Review and the text together to be sure you have mastered the material before going on.

In some sections you will find questions titled **Thinking It Through**. The goal of these questions is to allow you to test you ability in figuring out *how* to solve problems. The emphasis is on the *method*, not the *answer*. (We will have more to say about this later.) In most sections you will also find a short **Self-Test** to enable you to test your knowledge and problem-solving ability. The answers to all of the Thinking It Through and Self-Test questions are located at the ends of the chapters in the Study Guide. However, you should try to answer the Thinking It Through and Self-Test questions without looking up the answers. A space is left after each Self-Test question so that you can write in your answers and then check them all after you've finished.

Chemical Vocabulary

An important aspect of learning chemistry is becoming familiar with the language. There are many cases where lack of understanding can be traced to a lack of familiarity with some of the terms used in a discussion or a problem. A great deal of effort was made in your textbook to adequately define terms before using them in discussions. Once a term has been defined, however, it is normally used with the assumption that you've learned its meaning. It's important, therefore, to learn new terms as they appear, and for that reason, most of them are set in boldface type in the text. At the end of each section of the study

guide there is a list of these **New Terms**. To test your knowledge of them, you are asked to write out their meanings. This will help you review them later when you prepare for quizzes or examinations. At the end of the textbook there is a Glossary which you can use to be sure you understand the meanings of the new terms.

Study Habits

You say you want to get an A in chemistry? That's not as impossible as you may have been led to believe, but it's going to take some work. Chemistry is not an easy subject—it involves a mix of memorizing facts, understanding theory, and solving problems. There is a lot of material to be covered, but it won't overwhelm you if you ***stay up to date***. Don't fall behind, because if you do, you are likely to find that you can't catch up. Your key to success, then, is *efficient* study, so your precious study time isn't wasted.

Efficient study requires a regular routine, not hard study one night and nothing the next. At first, it's difficult to train yourself, but after a short time you will be surprised to find that your study routine has become a study habit, and your chances of success in chemistry, or any other subject, will be greatly improved.

To help you get more out of class, try to devote a few minutes the evening before to reading, in the text, the topics that you will cover the next day. Read the material quickly just to get a feel for what the topics are about. Don't worry if you don't understand everything; the idea at this stage is to be aware of what your teacher will be talking about.

Your lecture instructor and your textbook serve to complement one another; they provide you with two views of the same subject. Try to attend lecture regularly and take notes during class. These should include not only those things your teacher writes on the blackboard, but also the important points he or she makes verbally. If you pay attention carefully to what your teacher is saying in class, your notes will probably be somewhat sketchy. They should, however, give an indication of the major ideas. After class, when you have a few minutes, look over your notes and try to fill in the bare spots while the lecture is still fresh in your mind. This will save you a lot time later when you finally get around to studying your notes in detail.

In the evening (or whatever part of the day you close yourself off from the rest of the world to really study intensely) review your class notes once again. Use the text and study guide as directed above and really try to learn the material presented to you that day. If you have prepared before class and briefly reviewed the notes afterward, you'll be surprised at how quickly and how well your concentrated study time will progress. You may even find yourself enjoying chemistry!

As you study, continue to fill in the bare spots in your class notes. Write out the definitions of new terms in your notebook. In this way, when it comes time for an exam you should be able to review for it simply from your notes.

At this point you're probably thinking that there isn't enough time to do all the things described above. Actually, the preparation before class and brief review of the notes shortly after class takes very little time and will probably save more time than they consume.

Well, you're on your way to an A. There are a few other things that can help you get there. If you possibly can, spend about 30 minutes to an hour at the end of a week to review the week's work. Psychologists have found that a few brief exposures to a subject are more effective at fixing them in the mind than a "cram" session before an exam. The brief time spent at the end of a week can save you hours just before an exam (efficiency!). Try it (you'll like it); it works.

There are some people (you may be one of them) who still have difficulty with chemistry even though they do follow good study habits. Often this is because of weaknesses in their earlier education. If, after following intensive study, you are still fuzzy about something, speak to your teacher about it. Try to clear up these problems before they get worse. Sometimes, by having study sessions with fellow classmates you can help each other over stumbling blocks. Group study is very effective, because if you find you can explain something to someone else, you really know the subject. But if you can't explain a topic, then it requires more study.

Problem Solving—Using Chemical Tools

Your course in chemistry provides a unique opportunity for you to develop and sharpen your problem solving skills. Just as in life outside the classroom, the problems you will encounter in chemistry are not only numerical ones. In chemistry, you will also find problems related to theory and the application of concepts. The techniques that we apply to these various kinds of problems do not differ much, and one of the goals of your textbook and this Study Guide is to provide a framework within which you can learn to solve all sorts of problems effectively.

If you've read the "To The Student" message at the beginning of the textbook, you learned that we view solving a chemistry problem as not much different than solving a problem in auto repair. Both involve the application of specific tools that accomplish specific tasks. A mechanic uses tools such as screwdrivers and wrenches; you will learn to use a different set of tools—ones that we might call *chemical tools*.

Chemical tools are the simple one-step tasks that you will learn how to do, such as changing units from feet to meters, or degrees Fahrenheit to degrees Celsius. Solving more complex problems just involves combining simple tools

in various ways. The secret to solving complex problems, therefore, is learning how to choose the chemical tools that must be used.

Building a Chemical Toolbox

Our first goal is to clearly identify the tools you will have at your disposal. As you study the text, the concepts you will need to solve problems are marked by an icon in the margin when they are introduced. (To see what the icon looks like, refer to the "To The Student" message in the text.) The chemical tools are summarized at the end of a textbook chapter in a section titled *Tools You Have Learned* and they are also collected in table form at the end of each of the chapters in this Study Guide.

In both the text and the Study Guide there are worked examples that illustrated a wide variety of problems and their solutions. You will notice that in many of them there is a section titled *Analysis*. The Analysis section describes the thinking that goes into solving the problem and identifies the tools needed to do the job. Be sure to study the Examples thoroughly, and also be sure to work on the Practice Exercises that follow the Examples.

Solving Problems

You should always think of solving a problem as a two-step process. The first step is figuring out *how* to solve it. The second step is obtaining the answer. Of course, once you know how to solve the problem, obtaining the answer is easy. Therefore, let's look at a method you can use when working on a problem you haven't seen before—one for which the solution is not immediately obvious. To do this, we will look at a problem of the type you will encounter in Chapter 3. If you've had a previous course in chemistry, you will recognize much of the concepts presented. If they are unfamiliar, don't be concerned. The goal at this time is to illustrate how the chemical tools approach can be used to help find a solution to a problem.

Problem

Assemble all the information needed to determine the number of grams of Al that will react with 900 molecules of O_2 to form Al_2O_3, and then describe how the information can be used to find the answer.

The first step in solving the problem is determining what kind of problem it is. In this case, it is a problem dealing with a subject we call *stoichiometry*. (Don't worry, you will learn about all this later.)

Now that we have identified the *kind* of problem, we look over the tools that apply to stoichiometry problems. Here is a table that lists the tools.

Tools that apply to stoichiometry:

Tool	*Function*
Atomic mass	convert between grams and moles for element
Formula mass (molecular mass)	convert between grams and moles for compound
Chemical formula	gives atom ratio in a compound gives mole ratio in a compound
Chemical equation	gives mole ratios in a reaction
Avogadro's number	converts between number of particles and moles
Molarity	converts between moles and volume for a solution

Next, we examine the problem to identify the quantities that relate to the tools we have at hand. Notice that we've drawn boxes around the quantities.

> Assemble all the information needed to determine the number of [grams of Al] that will react with [900 molecules] of [O_2] to form [Al_2O_3] and then describe how the information can be used to find the answer.

Now we begin to assign specific numbers to quantities as we assemble the final set of tools we will use to solve the problem. We've collected the information in a table just to make it easier for you to follow. Notice that we have not used all the tools related to stoichiometry. Instead, we have selected just the tools that apply the the quantities in the problem.

Quantity in question	**Tool related to it**	**Relationship**
[grams of Al]	atomic mass	27 g Al = 1 mol Al
[900 molecules] [O_2]	Avogadro's number	6.02×10^{23} molecules O_2 = 1 mol O_2
[Al_2O_3] [O_2]	chemical formula	2 mol Al = 3 mol O 1 mol O_2 = 2 mol O

The information in the column at the right is what we use to obtain the answer. As you will learn, we can use a method called the factor label method to make sure the units of the answer work out correctly. The proper setup of the solution is

$$900 \text{ molecules } O_2 \times \frac{1 \text{ mole } O_2}{6.02 \times 10^{23} \text{molecules } O_2} \times \frac{2 \text{ mol O}}{1 \text{ molecule } O_2} \times \frac{2 \text{ mol Al}}{3 \text{ mole O}} \times \frac{27 \text{ g Al}}{1 \text{ mol Al}} = \text{answer}$$

Notice that we have not actually calculated the answer. Nevertheless, we really have *solved* the problem; we just haven't done the dirty work of doing the calculation. At the end of most chapters in the textbook, and in some of the sections in the Study Guide, you will find questions titled Thinking It Through. These questions ask you to figure out what you need to know to solve various problems, but not what the answers are. The goal is to make you *think* about how to solve the problems without having to worry out the answer. They are worthwhile exercises and you should be sure to work on them. As you will see, some are pretty difficult. But as they say, "No pain, no gain!"

We realize, of course, that many problems have more than one path to the answer. We understand that after correctly analyzing a problem and after recognizing what tools must be used, intermediate calculations and thought processes can validly follow more than one *order*. Therefore, you might choose a path in which the order of the steps is different from ours. This is why we provide answers to the thinking it through exercises, so that you can have the reinforcement (and the reward) of comparing answers when your method differs from ours.

Time to Begin

As you begin your study of chemistry, we wish you well. Move on to the course now, and good luck on getting that A!

Chapter 1

INTRODUCTION

This chapter introduces you to some basic concepts which you will need to understand future discussions in class and the textbook, and to function effectively in the laboratory part of your course. We begin by explaining what chemistry is about—namely, chemicals and chemical reactions. You will also learn about the scientific method, which describes how scientists learn about nature. And you will learn about the subjects that will be the principal focus of our study—matter and energy.

In the second half of the chapter we examine the importance of measurements and the units used to express them. You will study the modern version of the metric system and learn the concept of significant figures. Finally, we discuss density and specific gravity to illustrate how measurement and calculation combine to give us useful, quantitative properties of matter.

If you've had a prior course in chemistry, much of what is discussed in this chapter will seem familiar. Nevertheless, be sure you really understand it fully and can do the assigned homework. In particular, be sure you've learned the meanings of the bold-faced terms in the text as well as equations and other relationships that are placed between thick light-blue lines, such as Equation 1.1 on page 6. Important equations are summarized at the end of this Study Guide chapter.

Learning Objectives

As you study of this chapter, keep in mind the following objectives:

1 To learn the meaning of a chemical reaction.

2 To learn how science develops through the application of the scientific method. In particular, you should learn the distinction between a law and a theory.

3. To learn the definitions of matter and energy, the difference between kinetic and potential energy, the law of conservation of energy, and the difference between heat and temperature.

4 To learn how matter is identified by its characteristics, or properties, and how properties are classified.

5 To learn the units used for expressing measurements in the sciences and how to convert among differently sized units.

6 To learn the kinds of measurements normally made in the laboratory, the apparatus used to obtain them, and the units used to express them.

7 To learn how the number of digits (significant figures) reported in a measurement relates to the reliability of the measurement. Be sure you know the difference between accuracy and precision.

8 To learn how to use the units associated with quantities as a tool for setting up the arithmetic in a problem.

9 To learn about density and specific gravity and to use them in calculations.

1.1 What is Chemistry?

Review

This section starts with a discussion of the way chemistry has affected our lives and the way chemists respond to studying this subject. To begin the course with the proper attitude, you might take a few moments to imagine what life would really be like if we had to do without the materials created through chemical research.

An important point made in this section is that when chemical changes (chemical reactions) occur, the characteristics (properties) of the substances involved change, often dramatically. This is because a chemical reaction transforms substances into new chemicals, which have properties that differ from the chemicals present initially. Observing such changes is what makes chemistry so fascinating, especially in the laboratory.

Self-Test

1. A simple experiment you can perform in your kitchen at home or in an apartment is to add a small amount of milk of magnesia to some vinegar in a glass. Stir the mixture and observe what happens. Then add some milk of magnesia to the same amount of water and stir. What evidence did *you* observe that suggests that there is a chemical reaction between the milk of magnesia and the vinegar?

_____

_____

2. Drop an Alka Seltzer tablet into a glass of water. Observe what happens. What evidence is there that a chemical reaction is taking place? _____

_____

New Terms

Write the definitions of the following terms, which were introduced in this section. If necessary, refer to the Glossary at the end of the text.

chemistry

chemical reaction

1.2 Chemistry and the Scientific Method

Review

The sequence of steps described by the scientific method is little more than a formal description of how people logically analyze any problem, scientific or otherwise. Observations are made in order to collect data (empirical facts), which are then analyzed in a search for generalizations. Generalizations often lead to laws, which are concise statements about the behavior of chemical or physical systems. Laws, however, offer no explanations about *why* nature behaves the way it does. Tentative explanations are called hypotheses; tested explanations are called theories. The scientific method consists of collecting data in experiments, formulating theories, and testing the theories by more experimentation. Based on the results of new experiments, the theories are refined, tested further, refined again, and so on.

Self-Test

3. Identify each of the following statements as either a law or a theory.

   (a) In general, what goes up must come down. _____

   (b) The ice ages resulted from the tilting of the earth's rotation axis which was caused by the earth being hit by very large meteors.

   _____

4. What does *empirical* mean? _____

   _____

New Terms

Write the definitions of the following terms, which were introduced in this section. If necessary, refer to the Glossary at the end of the text.

natural science empirical fact hypothesis
law data theory generalization
scientific method

1.3 Matter and Energy

Review

Matter has mass and occupies space. It includes all the tangible things we encounter. Mass and weight are not the same, although we often use the terms interchangeably. The mass of an object is constant, and refers to the amount of matter in an object. The weight of an object can vary depending on the force of gravity.

Energy is something an object has if it has the capability of performing work. There are two kinds of energy an object can have. Kinetic energy is energy of motion and can be calculated from the object's mass (m) and velocity (v) by the equation KE = 1/2 mv^2. Potential energy is stored energy, and the potential energy stored in chemicals, which can be released in chemical reactions, is sometimes called chemical energy. The law of conservation of energy states that energy cannot be destroyed, but only changed from one form to another.

Energy can be transferred between objects in a variety of ways, but we most commonly observe energy being transferred as heat. (You will learn later that heat is actually a kind of kinetic energy that the individual atoms of a substance possess.) Temperature is a measure of the intensity of heat, and heat always flow spontaneously from hot objects to cool ones.

Self-Test

5. How does the kinetic energy of a 1000-lb car traveling at 60 mph compare with the kinetic energy of a 4000-lb car traveling at the same speed? _____

   _____

6. How does the kinetic energy of a 2000-lb car moving at 20 mph compare with the kinetic energy of the same car traveling at 60 mph? _____

7. What is the difference between potential energy and chemical energy?

New Terms

Write the definitions of the following terms, which were introduced in this section. If necessary, refer to the Glossary at the end of the text.

matter	energy	chemical energy
mass	kinetic energy	temperature
weight	potential energy	

1.4 Properties of Matter

Review

In the text, we see that the properties of substances can be classified in two ways. One way is to divide them into either physical properties or chemical properties. The other is to divide them into intensive or extensive properties.

Chemical and Physical Properties

Physical properties are ones that can be observed without changing the chemical makeup of a substance. In general, physical properties can be specified without reference to another chemical substance. Examples are an object's mass, or the temperature at which it melts, or its volume. When we describe a chemical property of a substance, we describe how the substance reacts chemically with something else. Such a chemical reaction produces new chemical substances, so after observing a chemical reaction, the substance has changed into a different substance. A chemical property of iron, for example, is that it rusts when in contact with air and moisture. When we observe this property, the iron changes to rust.

Extensive and Intensive Properties

Extensive properties, such as mass or volume, depend on the size of the sample of matter being examined. Although extensive properties are important for a given sample, they are not especially useful for identifying substances. More useful are intensive properties, because all samples of a given substance have

identical values for its intensive properties. For example, if we were asked whether a sample of a liquid was water, we would examine its properties and compare them to those of a known sample of water. If we were to find that the mass of the liquid is 12.0 g, we still would not be any closer to knowing whether or not the sample is water. By itself, the mass is of no value, because different samples of water, or any other liquid, have different masses. However, if we further note that the liquid is clear, has no color, has no odor, and freezes at 0 °C, we would strongly suspect the sample to be water. This is because *all* samples of pure water are clear, colorless, odorless, and freeze at 0 °C.

Self-Test

8. Identify the following as chemical properties or physical properties.
   (a) Nitroglycerine explodes if it is heated. _____
   (b) Gold is a yellow metal. _____
9. Sodium is a soft, silvery metal that melts at 97.8 °C. It burns with a yellow light in the presence of chlorine gas to give the compound sodium chloride (table salt).
   (a) What are some physical properties of sodium? _____
   _____
   (b) Give a chemical property of sodium. _____
   _____
10. (a) Give two examples of intensive properties. _____
    _____
    (b) Give two examples of extensive properties. _____
    _____

New Terms

Write the definitions of the following terms, which were introduced in this section. If necessary, refer to the Glossary at the end of the text.

property
physical property
extensive property
intensive property
chemical property