STUDY GUIDE

CHEMISTRY

The Study of Matter and Its Changes

Second Edition

BRADY
HOLUM

Study Guide

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The Study of Matter and Its Changes

Second Edition

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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. The contents of the Study Guide cover both the text and the supplement, *Descriptive Chemistry of the Elements*. The latter book contains a discussion of the descriptive chemistry of the metals and nonmetals which had appeared within the main text in the previous edition.

We begin the Study Guide 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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CONTENTS

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,* Second Edition, and a supplement to the text entitled *Descriptive Chemistry of the Elements*. Each chapter of the Study Guide 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 "Student Guide" 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*.

C*hemical 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 a T-shaped icon in the margin when they are introduced. (To see what the icon looks like, refer to the "Student Guide" message at the beginning of the textbook.) 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 the problem. 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 many 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. These are given in the table below, which continues at the top of the next page.

Tools that apply to stoichiometry:

Tool	*Function*
Atomic mass	to convert between grams and moles for element
Formula mass (molecular mass)	to convert between grams and moles for compound

Tool	*Function*
Chemical formula	gives the atom ratio in a compound gives the mole ratio in a compound
Chemical equation	gives mole ratios between the various substances in a reaction
Avogadro's number	to convert between number of particles and moles
Molarity	to convert 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 $\boxed{\text{grams of Al}}$ that will react with $\boxed{\text{900 molecules of } O_2}$ to form $\boxed{Al_2O_3}$ 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 to the quantities in the problem.

Quantity in question	**Tool related to it**	**Relationship**
$\boxed{\text{grams of Al}}$	atomic mass	27 g Al = 1 mol Al
$\boxed{\text{900 molecules of } O_2}$	Avogadro's number	6.02×10^{23} molecules O_2 = 1 mol O_2
$\boxed{Al_2O_3}$ $\boxed{O_2}$	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

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

As you can see, 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 arithmetic.

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 answers. 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

Building a Foundation

This first chapter introduces you to some basic concepts which you will need to understand future discussions in class and the textbook. You will also need them to function effectively in the laboratory part of your course.

If you've had a prior course in chemistry, much of what we discuss in this chapter will seem familiar. Nevertheless, be sure you really understand all of 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 set off by light-blue lines, such as the statement near the bottom of page 12. Important equations are summarized at the end of this Study Guide chapter.

We begin the chapter by explaining why chemistry is important to you. You will learn what chemistry is about, namely, chemicals and chemical reactions. You will also learn about the scientific method, which describes how scientists learn about nature.

A key requirement for progress for any science is measurement, and in Section 1.3 you will study the modern version of the metric system and the units used for common measurements in the laboratory. We will also introduce you to the concept of significant figures and you will learn a useful tool for setting up the correct arithmetic in calculations.

In the second half of the chapter we bring our focus to the principal subjects of our study—matter and energy. You will learn about properties of matter and how two of them, density and specific gravity, illustrate how measurement and calculation combine to give us useful, quantitative properties. We end the chapter by discussing how substances are identified by the properties they exhibit.

Learning Objectives

As you study 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 units used for expressing measurements in the sciences and how to convert among differently sized units.

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

5 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.

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

7 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.

8 To learn the relationship between temperature and the kinetic energy of atoms and other small particles that make up matter, and how heat is transferred between objects.

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

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

1.1 Chemistry: Where It Fits Among the Sciences

Review

The central theme of this section is that chemistry is a science that all physical and biological scientists must know something about. All the sciences study the same natural world; only their perspectives differ. Chemistry is unique, however, in that it seeks to provide an understanding of the chemical substances that serve as the subjects of all the other sciences.

If you are not a chemistry major, you might ponder for a moment why it is that you are required to take chemistry as part of the requirements for your major.

1.2 Chemistry as a Science

Review

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.

The Scientific Method

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

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?

____

____

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.

chemistry	scientific method	data
chemical reaction	law	hypothesis
natural science	empirical facts	theory

1.3 Chemistry in the Laboratory

Review

Quantitative measurements (observations involving numbers) are necessary in the sciences in order to make meaningful progress. Numbers that come from measurement must be expressed in some sort of units. A metric-based system has the advantage that converting among units is accomplished by just moving the decimal point.

The International System of Units (the SI) is founded on a set of carefully defined base units, which are given in Table 1.1 of the textbook. Quantities other than mass, length, time, etc. are obtained from these base quantities by mathematical operations, and their units (called derived units) are obtained from the base units by the same operations. For example, volume is a product of three length units

$$\text{length} \times \text{width} \times \text{height} = \text{volume}$$

The unit for volume is the product of the units for length, width, and height.

$$\text{meter} \times \text{meter} \times \text{meter} = \text{meter}^3$$

$$\text{m} \times \text{m} \times \text{m} = \text{m}^3$$

Similarly, speed is expressed as a ratio of distance divided by time. The SI base unit for distance is the meter and the base unit for time is the second. Therefore

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{\text{meter}}{\text{second}} = \frac{\text{m}}{\text{s}}$$

Often, the base units (or the derived units that come from them) are too large or too small to be used conveniently. For example, if we were to use cubic meters to express the volumes of liquids that we measure in the laboratory, we would find ourselves using very small numbers such as 0.000025 m^3 or 0.000050 m^3. Because they have so many zeros, these values are difficult to comprehend. To make life easier for us, the SI has a simple way of making larger or smaller units out of the basic ones. This is done with the decimal multipliers and SI prefixes given in Table 1.2 on page 6. Be sure you learn the ones in the table at the bottom of this page. (These are the ones in bold type in Table 1.2.)

The SI prefixes are tools we can use to scale units to convenient sizes and to translate between differently sized units. You will see how this is done in Section 1.4. Notice that each prefix stands for a particular decimal multiplier. Thus *kilo* means "× 1000" or "× 10^3." This lets us translate a quantity into the value that it has when expressed in terms of the base units. For example, suppose we wanted to know how many meters are in 25 kilometers (25 km). Since kilo (k) means "× 1000," then

$$\begin{aligned} 25 \text{ km} &= 25 \times 1000 \text{ m} \\ &= 25{,}000 \text{ m} \end{aligned}$$

Similarly, a length of 25 millimeters (25 mm) would be

$$\begin{aligned} 25 \text{ mm} &= 25 \times 0.001 \text{ m} \\ &= 0.025 \text{ m} \end{aligned}$$

Units for Laboratory Measurements

Length, volume, mass, and temperature are four commonly measured quantities in the lab. The units we usually use for length are millimeters and centimeters. Remember that 10 mm = 1 cm. It is also useful to remember one crossover relationship between the metric and English units for length. For example,

1 in. = 2.54 cm

The liter, which is the traditional metric unit of volume, is a bit too large to be convenient for most of the laboratory measurements that you will encounter. That's why most laboratory glassware is marked in

SI Prefixes and Decimal Multipliers

Prefix	Symbol	Multiplication Factor
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	m	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

units of milliliters (mL). Remember:

$$1000 \text{ mL} = 1 \text{ L}$$

$$1 \text{ cm}^3 = 1 \text{ mL}$$

Be sure to practice converting between milliliters and liters; it is an operation you will have to perform frequently throughout the course.

Mass is normally measured in grams. The SI base unit is 1000 g (1 kilogram). The apparatus used to measure mass is called a balance.

Temperature is measured with a thermometer, and in the sciences it is measured in units of degrees Celsius (°C). The Celsius and Fahrenheit degree units are of different sizes; five degree units on the Celsius scale correspond to nine degree units on the Fahrenheit scale. Equation 1.1 on page 10 enables you to make conversions between °C and °F.

The SI unit of temperature is the kelvin (K). Zero on the Kelvin scale corresponds to –273 °C (rounded to the nearest degree) and is called absolute zero, because it is the coldest temperature. (Notice that the name of the *temperature scale* is capitalized; the name of the *unit* measured on that scale, the kelvin, is not capitalized.) The kelvin and Celsius degree are the same size, so a *temperature change* of 10 K, for example, is the same as a temperature change of 10 °C. Be sure you can convert from °C to K (Equation 1.3 usually, but Equation 1.2 when more precision is required), because when the temperature is needed in a calculation, it nearly always must be expressed in kelvins. In mathematical equations, the capital letter T is used to stand for the Kelvin temperature.

Self-Test

5. Give the SI base unit and its abbreviation for

   (a) mass ____________________

   (b) length ____________________

   (c) time ____________________

   (d) electric current ____________________

   (e) temperature ____________________

6. Torque (pronounced "tork") is a quantity that describes a twisting force, such as that applied to a nut or a bolt by a wrench. It is a product of distance × force and in English units is normally given in foot pounds. The SI derived unit for force is the Newton (symbol, N). What is the SI derived unit for torque?

   Answer ____________________

7. Fill in the blanks with the correct prefixes.

   (a) 1 ____________ gram = 0.01 gram

   (b) 1 ____________ meter = 10^{-9} meter

   (c) 1 ____________ g = 0.001 g

   (d) 1 ____________ m = 1000 m

   (e) 1 pm = ____________ m

   (f) 1 μg = ____________ g

   (g) 1 dm = ____________ m

8. Fill in the blanks with the correct numbers.

(a) 63 dm = ____________ m

(b) 0.023 Mg = ____________ g

(c) 2450 nm = ____________ m

(d) 2487 cm = ____________ m

9. Fill in the blanks with the correct numbers.

(a) ____________ cm = 1.35 m

(b) ____________ mm = 22.4 cm

(c) ____________ cm = 32.6 mm

(d) ____________ mL = 1.250 L

(e) ____________ cm^3 = 246 mL

(f) ____________ L = 525 cm^3

(g) ____________ mL = 0.022 L

(h) ____________ L = 346 mL

(i) ____________ L = 2.41 mL

(j) ____________ K = 25 °C

(k) ____________ °C = 265 K

(l) ____________ °C = 300 K

10. (a) What Celsius temperature corresponds to 23 °F? ____________

(b) What Fahrenheit temperature equals 10 °C? ____________

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.

qualitative observation
quantitative observation
International System of Units
base unit
derived unit
decimal multiplier
meter (m)
centimeter (cm)
millimeter (mm)
cubic meter (m^3)
milliliter (mL)
balance
Fahrenheit Scale
Celsius scale
Kelvin temperature scale
kelvin (K)
absolute zero

1.6 Significant Figures and Scientific Calculations

Review

When a number is obtained by measurement, the digits in the number are called significant figures. They include all the digits known for sure *plus* the first digit that contains some uncertainty. Expressing a measurement to the correct number of significant figures allows us to express to someone else who sees that number how precise the measurement is. For example, a measured length of 32.47 cm has four significant figures. It tells us that the 3, 2, and 4 are known with certainty and the measuring instrument allowed the hundredths place to be *estimated* to be a 7. Since no digit is reported in the thousandths place, it is assumed that no estimate of that place could be obtained. In general, the larger the number of significant figures in a measurement, the greater is its precision.

In counting significant figures, zeros sometimes cause a problem. Note the statement on page 13, identified by the Tool Icon.

The rules given on page 14 are tools we use to correctly express the number of significant figures in a computed quantity.

Multiplication and Division

The answer cannot contain more significant figures than the factor that has the fewest number of significant figures. Study the example on page 14.

Addition and Subtraction

The answer is rounded to the same number of decimal places as the quantity with the fewest decimal places. See the example, also on page 14.

When using exact numbers in calculations, they can be considered to have as many significant figures as desired. They contain no uncertainty.

Example 1.1 Calculations Using Significant Figures

Assume that all of the numbers in the following expression come from measurement. Compute the answer to the correct number of significant figures.

$$(3.25 \times 10.46) + 2.44 = ?$$

Solution

When we perform the multiplication (which must, of course, be done first) we obtain 33.995. This should be rounded to three significant figures because that's how many there are in 3.25. The result is 34.0, which is then added to 2.44

34.0	one decimal place
+ 2.44	two decimal places
36.4	rounded to one decimal place

The correct answer, therefore, is 36.4

The Factor-Label Method

The factor label method is a tool we use to properly set up the arithmetic in numerical problems. It relies on the cancellation of units from the numerator and denominator of fractions. Relationships between units are used to form conversion factors by which the given quantity is multiplied. Successive conversion factors are used until the given units are converted to the units desired for the answer.

Sometimes, the factor label method helps us find the relationships we need to solve a problem. For example, to convert 65.0 gallons to liters we need a relationship between gallons and liters. In Table 1.3 (page 7) we find the following:

$$1 \text{ gal} = 3.786 \text{ L}$$

This can be used to form two different conversion factors.