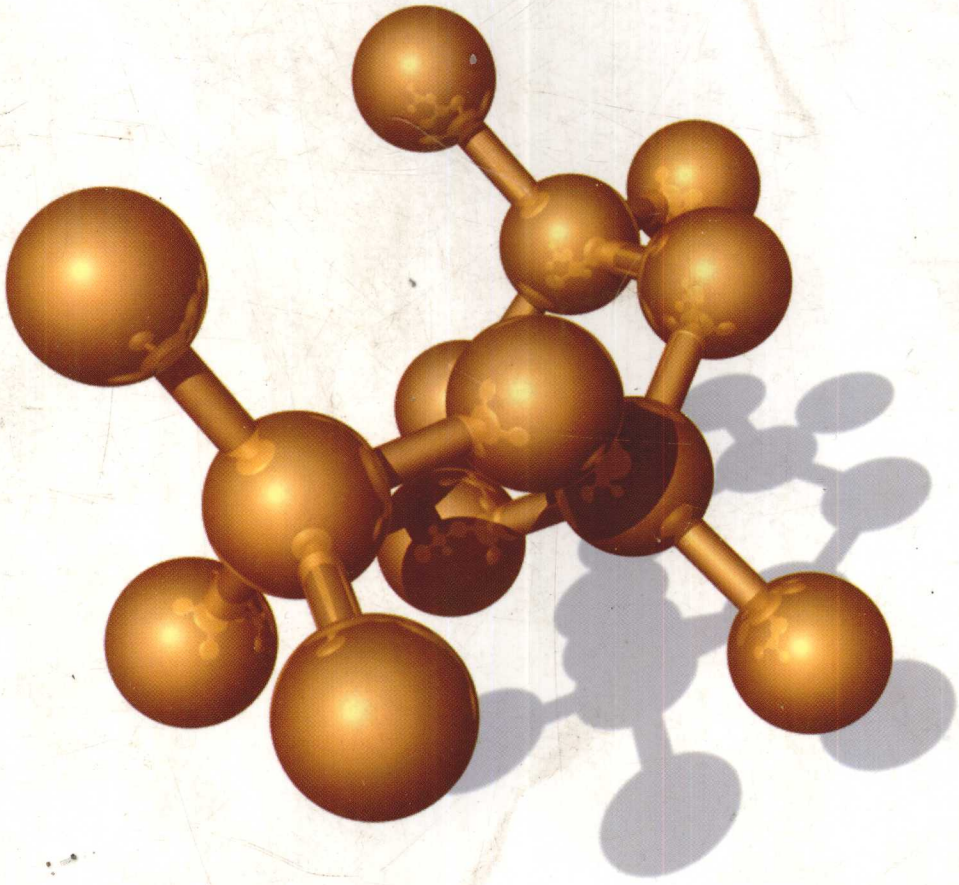
STUDENT'S GUIDE

JAMES C. HILL

SEVENTH EDITION

CHEMISTRY

THE CENTRAL SCIENCE



BROWN LEMAY BURSTEN

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JAMES C. HILL
CALIFORNIA STATE UNIVERSITY, SACRAMENTO

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To the Student

HOW TO USE THE *STUDENT'S GUIDE*

The seventh edition of the *Student's Guide* to the text *Chemistry: The Central Science* by T. Brown. G. LeMay and B. Bursten maintains the successful structure of the previous editions. Many aids are available to help you be successful: Learning goals for each chapter; suggested material to review; summaries of key ideas and concepts; sample exercises; end-of-chapter problems with detailed solutions; and sectional tests that check your understanding of material in several chapters. Topic summaries are designed with a "bullet" format wherein key or major points and ideas are identified by a • mark.

A new feature of this edition is the inclusion of integrative exercises in the Self-Study Exercises in most chapters and Sectional Tests. These questions are designed to have you integrate material from two or more chapters or to use several concepts in a chapter. They will be more challenging than "one concept" questions.

As you begin your adventure into the chemical world, you will find it necessary to study certain abstract concepts and learn new problem-solving techniques in order to understand chemical phenomena. To use your time more efficiently when studying chemistry and to maximize your learning of ideas and skills, you should develop a strategy for learning chemistry in a classroom situation.

The following is a suggested method for using this book in conjunction with the Brown, LeMay and Bursten text:

1. In the *Student's Guide,* each chapter corresponds to a chapter in the text and is divided into three sections: Overview of the Chapter, Topic Summaries and Exercises, and Self-Study Exercises. By appropriately using these sections, you can facilitate your learning of chemical concepts, theories, facts, and problem-solving techniques.
2. Before attending the first lecture on a particular chapter in the text and before reading the chapter, read the corresponding Overview of the Chapter in the *Student's Guide.* By doing this first, you will gain familiarity with the key topics found in that chapter of the text. This is important because it will help you to keep the major topics in mind while you are reading the more minute details, such as facts, theories, and skills development. Also, the subject matter in each chapter of the text can be learned more easily if you study small segments of interrelated material. In addition to identifying key topics, the overview lists

the sections in which a topic is covered; it also lists learning objectives that will guide you in your study and suggests material that should be reviewed to prepare you for the chapter.

3. After reading the Overview of the Chapter in the *Student's Guide,* you should read the appropriate chapter in the text so that you will be prepared for your instructor's lecture; you will also be equipped to ask appropriate and thoughtful questions.
4. During the lecture, take detailed notes. In most chemistry classes, an instructor chooses to emphasize certain key topics and ideas within a chapter, and the instructor will test your knowledge and your problem-solving skills primarily in those areas. Detailed lecture notes will provide you with a complete record of the material covered in class. Often an instructor will also identify the key points. Be sure to note these for later reference. If you have the time, rewrite your lecture notes later that day. This allows you to carefully reorganize the information given in the lecture and to fill in some missing material that you didn't have time to record during the lecture; it also reinforces what you learned that day. To understand a concept thoroughly and retain it in your memory, you will need to reinforce material through repeated learning.
5. Once your instructor has begun to discuss a topic, you should study the text coverage of it in detail. At the same time, use the Topic Summaries and Exercises section in the *Student's Guide.* This section contains a summary of the key concepts, theories, and facts associated with each topic listed in the Overview of the Chapter. Further explanations of key material are also included. After each topic summary, there are exercises with detailed solutions; these are similar in style to the sample exercises found in the text. The solutions to the sample exercises often include further explanations of important or difficult material. Attempt the sample exercises after looking at the sample problems in the text. When doing the sample exercises, cover up the solutions and try to solve the problems. The more you work with pencil and paper, and the less you just read a solution, the better and faster you will learn chemistry and how to solve chemical problems.
6. You can check your understanding by answering questions provided in the Self-Study Exercises. Because instructors may use a variety of question formats on tests, the *Student's Guide* provides questions using three of the most common testing formats: true-false questions, problems and short-answer questions, and multiple-choice questions. The latter two question formats check your understanding and knowledge of material in the entire chapter. The true-false questions focus on your familiarity with the key terms listed in each chapter in the text. Chemistry has a language of its own, a language in which you must become proficient. Without an understanding of the key terms listed in each chapter of the text, you will have difficulty mastering chemistry.
7. *Sectional Tests:* Tests covering several chapters are provided to help you check your readiness to take an examination over the chapters. Take each test as if you were in a classroom. Tear out the test, find a quiet spot to work, and do the questions without referring to the text, unless specifically directed. Grade the test after you are finished. Each question has the appropriate section in the Brown, LeMay and Bursten text referenced; therefore, if you miss a question, study the section noted. Spend your valuable time studying material you don't know, not what

you firmly understand. The sectional tests may not cover the specific chapters on an examination you are taking. If this is the case, design your own sectional test by using questions with section references in the Brown, LeMay and Bursten text on which you are being tested. Cut-up the questions and paste them together to form a sample test appropriate for your situation.

8. How does one take a test? Every student seems to develop his or her own approach; some approaches to test taking are successful, and others are not. Let me suggest a few ideas based on my own teaching experiences. First, try to study the material being covered on a test early so that you do not have to study late into the night immediately before the test. A tired and foggy mind cannot do its best. Second, organize beforehand the materials you will need to bring with you for the test—pencils, pens, paper, and calculator (don't forget to bring spare batteries or to charge the calculator before the test begins)—and don't forget to bring them. Third, find a place in the testing room that is comfortable and not too hot and that has sufficient light. Finally, when taking the test, read the instructions carefully, read over the questions quickly, and do the questions that are easy for you first. By answering the easy questions first, you will gain confidence and become more relaxed. After you finish the easy questions, begin the harder ones. If you find that you are stumped by a problem, stop working on it and go on to the next one instead of wasting time worrying about it. Later in the test you may remember how to do the problems that you could not complete earlier.

I would like to make a comment about the need for careful use of modern calculators. The numbers you obtain from a calculator often have six or eight digits, usually more digits than there are in any single number used in a calculation. In Chapter 1 of the text, you will learn that you cannot always report all the digits that a calculator shows. It is also easy to make an error entering a number into the calculator. Always check the final answer to see if it is a reasonable one. Is the answer too large or too small? Is the exponent of 10 reasonable? Sometimes a quick and rough hand calculation will tell you if the answer derived using a calculator is correct. Also, remember that a calculator is only a tool; it cannot provide the logic for solving a problem. Only you can do that.

These suggestions for learning chemistry and doing well in your chemistry course are only that—suggestions. You may already have your own strategy for studying, and if it is successful, by all means use it. Or, you may want to adapt some of the suggested study tactics so that they complement your own learning methods. The key to being a successful student and learner is to have a consistent study plan and use it!

Acknowledgements

The form and content of the seventh edition reflects the significant input of hundreds of students, reviewers of prior editions, the editorial staff at Prentice-Hall through many years and my ideas as to what makes a successful study guide. To those who inspired me, gave me ideas or noted errors I thank you. I also acknowledge Ms. Mary Hornby, Associate Science Editor, and her staff for their assistance in the preparation of this edition. Professor Julia Burdge, Department of Chemistry, University of Arkon, had a key role in checking problems and the manuscript.

A family plays an important role in writing a book. They can help create an environment that is supportive and be understanding when neglected. Without the love, understanding and patience of my wife, Jan, and my children, Jason and Jeanina, this book would have been far more difficult to prepare.

If you have comments please send them to me:

Professor James C, Hill
Department of Chemistry
California State University, Sacramento
6000 J Street
Sacramento CA 95819

Chemistry and the Internet

The telecommunication/computer age has brought a wonderful new resource to students who have a computer and modem to connect to an Internet account. The World Wide Wed, also known as the Web, is part of the Internet and is a pathway to sites which contain a wide variety of information. The challenge is to find the "nuggets" that are actually useful to you. Fortunately software exists which permits Web searches. This section of the *Student's Guide* suggests some uses of the Web for students in chemistry.

You will need an Internet account to access the Web. Your university may provide this service free or for a low fee. Alternatively there are many local internet providers which advertise in newspapers and magazines. Online services such as AOL, Compuserve and Prodigy also offer access to the Web. You will also need software to navigate the Web. Usually when you sign up for an Internet account Web navigator software is provided, often free.

Each Web site has its own unique address, called a URL (Uniform Resource Locator). The normal format for the URL is http://www.name.server/path. For example, a site that lists may other chemistry sites is http://www.chem.ucla.edu/. This site at UCLA has many hyperlinks to other universities, chemical companies and other points of interest, all accessible by pointing with a mouse and clicking.

Suppose you want to find some information about a particular university or college, for example Occidental College. How do you find the URL for the Web site of Occidental College? There are thousands of URL's! Fortunately software exists for searching the Web for URL sites. The Web navigator software provided by your Internet provider usually has a search function. Yahoo is a provider of a popular search engine and is available in the software provided by some Internet providers. Each search engine has its own unique features and some focus on certain types of URL sites. There is a very useful site called "The All-in-One Search Page" and is a compilation of a large number of Internet search engines. I use it extensively. The URL is http://www.albany.net/allinone/. Each search engine gives you instructions on how to construct a search.

What can you find in the Internet that relates to Chemistry? A few possibilities are:

Chemistry courses
Information about universities
Safety in chemistry
Employment information
Tips on resume preparation
Software for chemistry
New chemical products
Fax numbers
Course handouts—see what other courses require
Undergraduate lecture material

Here are some Web sites that you might want to explore:

http://www.shef.ac.uk/uni/academic/A-C/chem/chemistry-www-sites.html [A resource pointer to other gateways in the Web]

http://www.indiana.edu:80/~cheminfo/[A resource pointer to other gateways in the Web]

http://www.yahoo.com/Science/Chemistry [Edited collection of chemistry highlights]

http://www.ch.ic.ac.uk/GIC/ [Global instructional chemistry-teaching resources]

http://www.acs.org [Web site of the American Chemical Society]

http://www-hpcc.astro.washington.edu/scied/chemistry.html [Resources for chemical education]

http://www.shef.ac.uk:80/web-elements [WebElements periodic table]

http://www.chem.vt,edu/chem-ed/vt-chem-ed.html [Chemistry hypermedia project at Virginia Tech]

http://www.science.widener.edu/~svanbram [General chemistry handouts, bookmarks, links to other chemistry sites]

http://www.nas.edu/1/nap/online/obas [Information on being a responsible, ethical scientist]

http://www.halcyon.com/cairns/chemistry.html [A reference source for chemistry instructors]

http://www.edie.cprost.sfu.ca/~rhlogan/index.html [A list of sites with distance education]

http://www.enc.org [Eisenhower National Clearinghouse: a source for science teachers]

http://www.host.cc.utexas.edu/world/lecture/ [Links to a variety of undergraduate lecture materials]

http://www-hpcc.astro.washinton.edu/scied/chemistry.html [Chemical education resources]

http://www.chem.ucla.edu/chempointers.html [WWW chemistry sites]

news:sci.chem [A forum for discussing topics related to chemistry. There are a variety of News Groups available through the Internet]

A disclaimer: URL sites are subject to change or may disappear and the content advertised may change.

Contents

Introduction: Matter and Measurement 1

OVERVIEW OF THE CHAPTER

1.1, 1.2, 1.3 MATTER: ELEMENTS, COMPOUNDS, AND MIXTURES

Learning Goals: You should be able to:

1. Distinguish between physical and chemical properties and also between simple physical and chemical changes.
2. Differentiate between the three states of matter.
3. Distinguish between elements, compounds, and mixtures.
4. Give the symbols for the elements discussed in this chapter.

1.4 PHYSICAL QUANTITIES AND UNITS

Review: Concept of fraction; exponential notation (see text: Appendix A).

Learning Goal: You should be able to list the basic SI units and the common metric prefixes and their meanings.

1.5 UNCERTAINTY IN MEASUREMENTS: SIGNIFICANT FIGURES

Review: Exponential notation (see text Appendix A).

Learning Goals: You should be able to:

1. Determine the number of significant figures in a measured quantity.
2. Express the result of a calculation with the proper number of significant figures.

1.4 TEMPERATURE AND DENSITY: INTENSIVE PROPERTIES

Learning Goals: You should be able to:

1. Convert temperatures among the Fahrenheit, Celsius, and Kelvin scales.
2. Perform calculations involving density.

1.6 DIMENSIONAL ANALYSIS

Review: Concepts of fraction and ratio.

Learning Goal: You should be able to interconvert metric and English-system measurements by using dimensional analysis.

TOPIC SUMMARIES AND EXERCISES

MATTER: ELEMENTS, COMPOUNDS, AND MIXTURES

Matter is any material that occupies space and has mass. Three phases (states) of matter exist: gas, liquid, and solid. Check your knowledge of their characteristics by doing Exercise 1.

- A sample of matter is either a substance or a mixture.
- **Substances** are either elements or compounds. **Elements** can not be chemically decomposed into simpler new substances. **Compounds** consist of two or more elements chemically combined in a definite ratio. A compound can be chemically decomposed into its elements.
- **Mixtures** are combinations of two or more substances and are either homogeneous or heterogeneous. Note that a *heterogeneous* mixture exhibits more than one phase and possess a nonuniform distribution of substances. A *homogeneous* mixture consists of one phase and a uniform distribution of substances.
- Mixtures can be separated into substances by physical means.

Alterations in matter can involve chemical or physical changes.

- A **chemical change** involves a change in the composition of a substance. A **chemical property** describes the type of chemical change. For example, the property of wood burning is a chemical property.
- A **physical change** does not involve a change in composition but rather a change in a **physical property** such as temperature, volume, mass, pressure or state.

Check your understanding of the new terms you have learned by doing Exercises 2–5.

EXERCISE 1

Match the following characteristics to one or more of the three states of matter: (**a**) has no shape of its own; (**b**) definite shape; (**c**) occupies the total volume of a container; (**d**) partially takes on the shape of a container; (**e**) does not take on the shape of a container; (**f**) readily compressible; (**g**) slightly compressible; (**h**) essentially noncompressible.

SOLUTION: Gas—(**a**), (**c**), (**f**) Liquid—(**a**), (**d**), (**g**) Solid—(**b**), (**e**), (**h**)

EXERCISE 2

Match the term with the best identifying phrase:

Terms

1. Homogeneous mixture
2. Heterogeneous mixture
3. Mixture
4. Substance
5. Element
6. Compound

Phrases

a. Any kind of matter that is pure and has a fixed composition
b. Cannot be decomposed into simpler substances by chemical changes
c. A solution
d. Can be decomposed into simpler substances by chemical changes
e. Any kind of matter that can be separated into simpler substances by physical means
f. Nonuniform composition

SOLUTION: 1-**c**; 2-**f**; 3-**e**; 4-**a**; 5-**b**; 6-**d**

EXERCISE 3

With the help of the periodic table, write the name or the chemical symbol for each of the following elements: (**a**) F; (**b**) zinc; (**c**) potassium; (**d**) As; (**e**) Al; (**f**) iron; (**g**) helium; (**h**) barium; (**i**) Ne.

SOLUTION: (**a**) fluorine; (**b**) Zn; (**c**) K; (**d**) arsenic; (**e**) aluminum; (**f**) Fe; (**g**) He; (**h**) Ba; (**i**) neon

EXERCISE 4

Are the following changes physical or chemical: (**a**) the vaporization of solid carbon dioxide; (**b**) the explosion of TNT; (**c**) the aging of an egg with a resultant unpleasant smell; (**d**) the formation of a solid when honey is cooled?

SOLUTION: (**a**) A physical change. The form of carbon dioxide is changed from solid to gas. There is no change in its chemical composition. (**b**) A chemical change. The explosion results from a change in the chemical composition of TNT. (**c**) A chemical change. A change in the composition of the egg results in the formation of a gas (hydrogen sulfide) that has an unpleasant smell. (**d**) A physical change. The solid results from the crystallization of dissolved sugars; no change occurs in the chemical form of the sugars.

EXERCISE 5

Classify each of the following as an element, compound, or mixture: (**a**) a 100-percent silver bar; (**b**) wine; (**c**) gasoline; (**d**) carbon dioxide (CO_2).

SOLUTION: (**a**) Silver is an element and cannot be separated by either chemical or physical means into simpler substances. It is listed among the elements in Table 1.2 in the text. (You should know the symbols in Table 1.2.) (**b**) Wine is a mixture of alcohol, other components and water. The fact that wines contain varying percentages of alcohol attests to their having different compositions. (**c**) We know gasoline must be a mixture because it is available with different compositions and properties (no lead, regular, and different brands with different additives). (**d**) CO_2 is a compound because the ratio of carbon and oxygen atoms does not vary. The name also implies that it is a compound because we do not have such systematic names for mixtures.

PHYSICAL QUANTITIES AND UNITS

A property of a sample is measured by comparing it with a standard unit of that property. Measured quantities such as volume, length, mass and temperature require a number and a reference label, called the unit of measurement. Two systems of unit measurements are shown in Table 1.1.

TABLE 1.1 Metric and SI Units

Physical quantity	Metric unit name	SI unit name[a]
Length	Meter (m)	Meter (m)
Volume	Cubic centimeter (cm^3)[b]	Cubic meter (m^3)
Mass	Gram (g)	Kilogram (kg)
Time	Second (s)	Second (s)
Energy	Calorie (cal)	Joule (J)
Pressure	Atmosphere (atm)	Newton per square meter (N/m^2)

[a]Systeme International d'Unites (SI) or International System of Units.

[b]Chemists commonly use the unit cubic centimeter when dealing with the volume of a solid, but they usually use the unit liter (L) when a substance is a liquid.

TABLE 1.2 Equivalence Relationships Between SI and Metric Units

Physical quantity	Metric unit name	SI unit name	Equivalence
Length	Meter	Meter	Same
Mass	Gram	Kilogram	1000 g = 1 kg
Time	Second	Second	Same
Energy	Calorie	Joule	1 cal = 4.184 J
Volume	Cubic centimeter	Cubic meter	1,000,000 cm^3 = 1 m^3
Volume	Liter	Cubic meter	1000 L = 1 m^3
Pressure	Atmosphere	Newton per squre meter	1 atm = 0.1754 N/m^2

The SI system of units is now the preferred one; however, you will find certain metric units still used. *You must become thoroughly familiar with the units in Table 1.1 before starting the next chapter.*

Another skill requiring proficiency is to change a number with a unit to one with a different unit. To do this, equivalence relationships exist between units. Tables 1.2 and 1.3 give some common equivalences that you will need in this chapter.

Prefixes are used with units to indicate decimal fractions (< 1) or multiples (> 1) of basic units.

- Example of a decimal fraction: The prefix centi- means 1/100 (= 0.01) of a basic unit; thus, 100 cm = 100 × 1/100 m = 1 m.
- Example of a multiple: The prefix kilo- means 10^3 (= 1000); thus, 1 km = 1 × 1000 m = 1000 m.

The commonly used prefixes that you must know are shown in Table 1.4. *Memorize them.*

EXERCISE 6

Which quantity of each pair is larger: (**a**) 1 nm or 1 micrometer; (**b**) 1 picogram or 1 cg; (**c**) 1 megagram or 1 milligram?

SOLUTION: Change the pairs so that each quantity is represented by either a numerical fraction or a multiple of the same basic metric unit. Then from their relative magnitudes you can determine which of the quantities is larger.

TABLE 1.3 Equivalence Relationships Between Metric and English Units

Physical quantity	English unit symbol	Metric unit symbol	Equivalence
Mass	lb (= 16 oz)	g	1 lb = 453.6 g
Length	ft (= 12 in.)	m	3.272 ft = 1 m
Length	in.	cm	1 in. = 2.54 cm
Length	mi (= 5280 ft)	m	1 mi = 1609 m
Volume	qt	L	1.057 qt = 1 L

TABLE 1.4 Commonly Used Prefixes for Scientific Measurement in Chemistry

Prefix	Fraction or multiple of base unit	Abbreviation
Deci -	$10^{-1}\left(\frac{1}{10}\right)$	d
Centi -	$10^{-2}\left(\frac{1}{100}\right)$	c
Milli -	$10^{-3}\left(\frac{1}{1000}\right)$	m
Micro -	$10^{-6}\left(\frac{1}{1,000,000}\right)$	μ
Nano -	$10^{-9}\left(\frac{1}{1,000,000,000}\right)$	n
Pico -	$10^{-12}\left(\frac{1}{1,000,000,000,000}\right)$	p
Kilo -	10^{3} (1000)	k
Mega -	10^{6} (1,000,000)	M
Giga -	10^{8} (1,000,000,000,000)	G

(a) $1\text{nm} = 1 \text{ nanometer} = 10^{-9} \text{ meter}$

$1 \text{ micrometer} = 1\ \mu\text{m} = 10^{-6} \text{ meter}$

One micrometer is larger in value than one nanometer because the fraction $10^{-6}\left(\frac{1}{1,000,000}\right)$ is larger in magnitude than the fraction $10^{-9}\left(\frac{1}{1,000,000,000}\right)$.

(b) $1 \text{ picogram} = 1 \text{ pg} = 10^{-12} \text{ gram}$

$1 \text{ cg} = 1 \text{ centigram} = 10^{-2} \text{ gram}$

One centigram is larger in value than one picogram because the fraction $10^{-2}\left(\frac{1}{100}\right)$ is larger in magnitude than the fraction $10^{-12}\left(\frac{1}{1,000,000,000,000}\right)$.

(c) $1 \text{ megagram} = 1 \text{ Mg} = 10^{6} \text{ gram}$

$1 \text{ mg} = 1 \text{ milligram} = 10^{-3} \text{ gram}$

One megagram is larger in value than one milligram because the multiple 10^{6} (1,000,000) is larger in magnitude than the fraction $10^{-3}\left(\frac{1}{1,000}\right)$.

EXERCISE 7

With what types of measurements are the following units associated?

g, L, m, km, cm, Mg, pg, cm^3

SOLUTION: Mass (g, Mg, pg); volume (L, cm^3); length (m, km) Note that the prefixes such as M- and c- do not change the type of unit. However, the type of unit can be changed if it is raised to some power, as is the case for cm^3. The unit cm^3 means cm × cm × cm, which is a unit for volume (V = l × w × h).

EXERCISE 8

What is the advantage of the metric system in comparison to the English system?

SOLUTION: In the metric system, all quantities larger or smaller than the basic unit involve multiplication of the basic unit value by some power of 10 (for example, $10^3 = 1000$, $10^{-1} = \frac{1}{10}$, and so on). This is not true of the English system. Smaller or larger quantities of the basic unit in the English system are newly defined units. For example, 4000 qt equals 1000 gal, not 4 "kiloquarts." Many more conversion factors are required in the English unit system than in the metric unit system.

EXERCISE 9

Suggest a reason for the fact that 1 μkg (microkilogram) is not accepted as an appropriate SI mass unit expression.

SOLUTION: The expression 1 μkg involves two prefixes, micro- (μ) and kilo- (k), yielding a compound prefix. This can be confusing, particularly if three or four prefixes are used. Thus, we do not use more than one prefix when expressing numbers. Instead of 1 μkg (microkilogram), we write 1 mg (milligram).

UNCERTAINTY IN MEASUREMENT: SIGNIFICANT FIGURES

Quantities in chemistry are of two types:

- **Exact numbers:** These result from counting objects such as coins or occur as defined values (such as 2, which also means 2.0, 2.00, etc.).
- **Inexact numbers**: These are obtained from measurements and require judgment. Uncertainties exist in their values.

Measured quantities (inexact numbers) are reported so that the last digit is the first uncertain digit. All certain digits and the first uncertain digit are referred to as **significant figures.** For example:

- 2.86: 2 and 8 are certain and well known. The number 6 is the first that is subject to judgment and is uncertain. The first uncertain digit is assumed to have an uncertainty of ± 1: 2.86 ± 0.01. The number 2.86 has three significant figures.
- 0.0020: Zeroes to the left of the first nonzero digit are not significant. The first three zeroes are not significant because they are to the left of the 2 and also define the decimal point. The zero to the right of the 2 is significant. This number has only two significant figures.
- 100: Trailing zeroes that define a decimal point may or may not be significant. Unless stated, assume they are not significant. Therefore, 100 has one significant figure unless otherwise stated; if it is determined from counting objects, it has three significant figures.

Scientific notation removes the ambiguity of knowing how many significant figures a number possesses.

- The form of a number in scientific notation is A.BC $\times 10^x$. If $x < 1$, the number is less than 1. If $x > 1$, the number is greater than 1.
- Only significant digits are shown. The number 0.0020 becomes 2.0×10^{-3}.

Calculated numbers must show the correct number of significant figures. The rules for doing this are: