third edition

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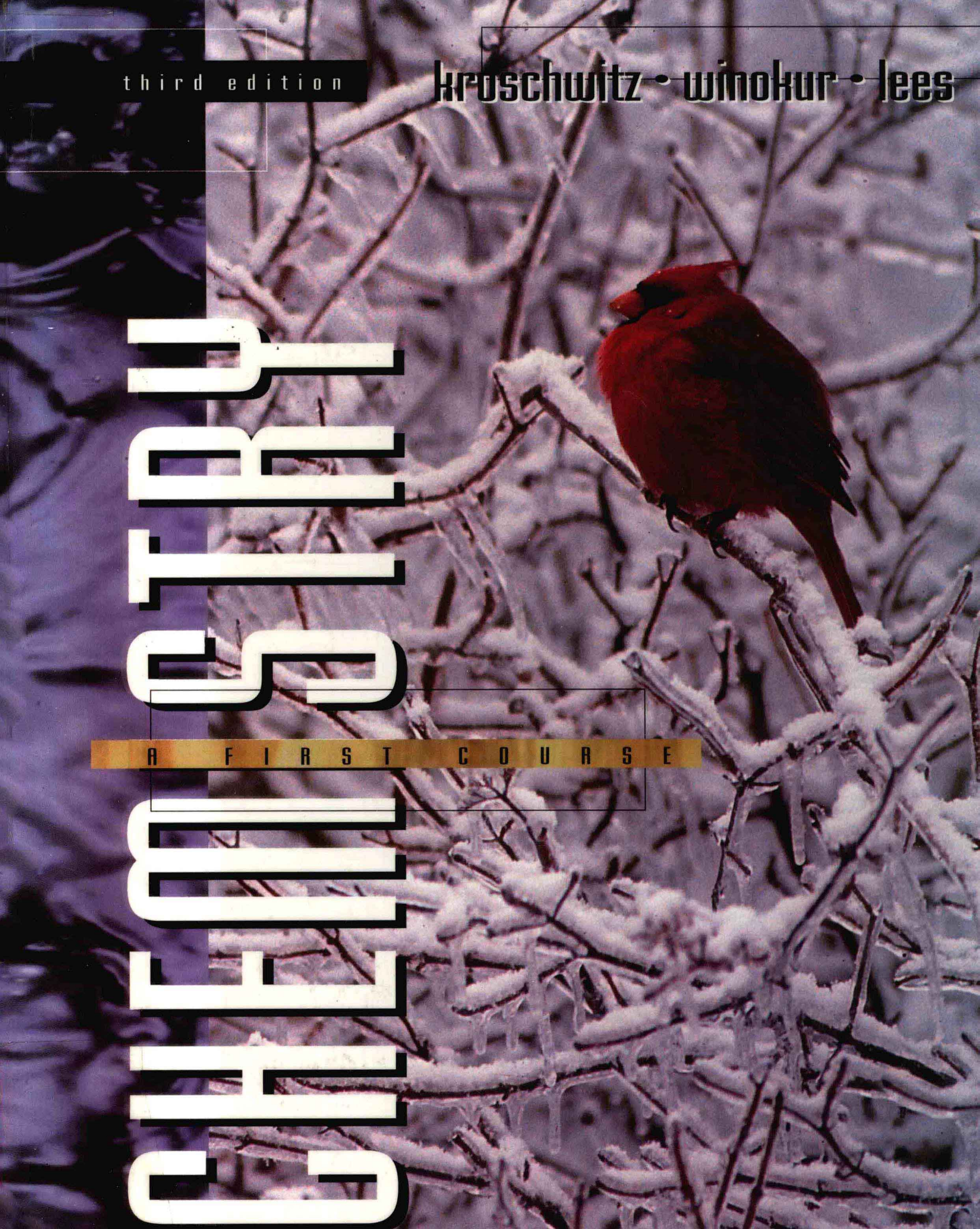
CHEMISTRY

A FIRST COURSE



third edition

CHEMISTRY

A FIRST COURSE

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preface

Chemistry is the science that deals with matter and the transformations that it undergoes. To the student who has not previously taken a chemistry course this may be an intimidating topic. Therefore, *Chemistry: A First Course* was developed as a one-semester, preparatory textbook for students with a non-chemistry background. This book will be a foundation on which to build a successful progression into future two-semester General Chemistry courses. We will present chemistry to the student as an interdisciplinary subject with broad points of interest for people in all walks of life, integrating the function and uses of chemicals and chemistry in the everyday world.

It is for the students who seek a broad base of knowledge that we have written the present text. As you will later note, the text has undergone a great deal of scrutiny to assure the accuracy and versatility of this book. New supplements and pedagogical features have been added to aid the students and to utilize the wide range of benefits that other technologies have to offer.

new features in this edition

Highlighted Regions: To help the student in organizing material, the authors have included shaded summary areas. These shaded summaries include rules, tables, charts, etc.

ChemLab: Chemistry progress in the real world is accomplished through curiosity and experimentation. We have included in each chapter a laboratory exercise that introduces the student to a potentially hands-on experience. These laboratory exercises are closely tied to the material in the chapter, making them relevant to understanding the lecture material.

ChemQuest: These essays are located throughout the text to help the student make connections between the text and everyday applications. These essays lead the student to a series of questions that may form the basis of a term paper or group project.

Full-Color Art Program: Color is another way to reinforce learning and we have used color consistently throughout the text. Lavender is used for electrons, green for nuclei, blue for bases, red for acids, and so on. This consistent use of color not only improves the asthetics of the textbook, but also supports student comprehension.

Design: Essential to this edition is a new design. With a large trim size, we were better able to use white space and larger, clearer visuals effectively, providing the student with a textbook that is clear, inviting, and well-organized.

Features retained and improved from earlier editions include:

In-Chapter Exercises, Solutions, and Problems: Because problem-solving is most easily learned by example and practice, we have included throughout the text a number of examples that show the student, step-by-step, precisely how to determine the correct answer. Whenever possible, exercises are included with each example to build student self-confidence. The student will find the answers to the odd-numbered problems in the back of the book.

End-of-Chapter Accomplishments: This feature is a combination of chapter outline, student comprehension checklist, and chapter summary. This review of chapter content is an elemental tool used to help the student organize and categorize material that often appears foreign and overwhelming. By simply going through this detailed checklist the students will be able to assess their own understanding.

Key Terms: Key Terms appear in boldface when they are introduced within the text and are immediately defined in context. All key terms are also defined in the glossary.

The End-of-Chapter Problems: There are a wide variety and number of problems located at the end of each chapter. There are two different types of problems that require the students to think a little harder, testing their understanding. Furthermore, since students learn by various means, the problems at the end of the chapter contain not only the traditional mathematically based problems but problems that ask the student to explain, identify, predict, arrange, state evidence, etc. The students are encouraged to explore a new dimension of their understanding of the chapter material. All of this leads to students who are better prepared for any chemistry that they must take in the future.

End of Book Glossary of Key Terms: All new terms are in boldface and each term is defined in the alphabetized glossary at the end of the textbook.

ancillaries

An extensive supplemental package has been designed to support this text. It includes the following elements.

1. **Instructor's Manual** The Instructor's Manual contains the printed test item file, answers to the text's even-numbered problems and exercises, detailed solutions to the text's odd-numbered problems and exercises, and a list of the transparencies. Written by the authors, this unique ancillary also contains suggestions for organizing lectures, additional "Perspectives," and a list of each chapter's key problems and concepts.
2. **Student Study Guide/ Solutions Manual** A separate Student Study Guide/Solutions Manual is available for the students. It contains the answers and solutions for the half of the chapter problems found in the Instructor's Manual. It also offers students a variety of exercises and keys for testing their comprehension of basic, as well as difficult, concepts.
3. **Transparencies** A set of over 100 transparencies is available to help the instructor coordinate the lecture with the key illustrations from the text.
4. **Customized Transparency Service** For those adopters interested in receiving acetates of text figures not included in the standard transparency package, a select number of acetates will be custom-made upon request. Contact your local Wm. C. Brown Publishers sales representative for more information.
5. **Microtest** This computerized classroom management system/service includes a database of test questions, reproducible student self-quizzes, and a grade-recording program. Disks are available for IBM and Macintosh computers, and require no programming experience.
6. **Laboratory Manual** Written by Kathy Dodds Tyner of Southwest College. *Lab Exercises for Preparatory Chemistry* features 63 class-tested experiments. The manual can easily be customized to suit an instructor's individual needs. The instructor can delete experiments, add his or her own experiments, or change the arrangement to create a custom manual to fit specific class needs.
7. ***Is Your Math Ready for Chemistry?*** Developed by Walter Gleason of Bridgewater State College, this unique booklet provides a diagnostic test that measures your students' math ability. Part II of the booklet provides helpful hints on the necessary math skills needed to successfully complete a chemistry course.
8. ***Problem Solving Guide to General Chemistry*** Written by Ronald DeLorenzo of Middle Georgia College, this exceptional supplement provides your students with over 2,500 problems and questions. The guide holds students' interests by integrating the solution of chemistry problems with real-life applications, analogies, and anecdotes.
9. ***How to Study Science*** Written by Fred Drewes of Suffolk County Community College, this excellent workbook offers students helpful suggestions for meeting the considerable challenges of a science course. It offers tips on how to take notes and how to overcome science anxiety. The book's unique design helps to stir critical thinking skills, while facilitating careful note taking on the part of the student.
10. **Exploring Chemistry Videotapes** Narrated by Ken Hughes of the University of Wisconsin-Oshkosh, the tapes provide six hours of laboratory demonstrations. Many of the demonstrations are of high-interest experiments, too expensive or dangerous to be performed in the typical freshman laboratory. Contact your local Wm. C. Brown Publishers sales representative for more details.
11. **Doing Chemistry Videodisc** This critically acclaimed image database contains 136 experiments and demonstrations. It can be used as a prelab demonstration of equipment setups, laboratory techniques, and safety precautions. It may also be used as a substitute for lab experiences for which time or equipment is not available. Contact your local Wm. C. Brown Publishers sales representative for more details.
12. **ChemTALK Lecture Presentation Software** This unique presentation software contains lecture outlines and numerous color illustrations and animations designed to bring concepts of chemistry to life. Three software programs have been developed to be used in a variety of introductory courses including general chemistry, preparatory

chemistry, and allied health chemistry. The programs are available on both Windows and Macintosh formats.

Less cumbersome than writing on a blackboard, this software will allow you to present material to your students at the pace that you choose, while integrating full-color illustrations and animations into your lecture.

Students may purchase the corresponding lecture notebook which contains all the material from the software. Using the notebook to follow the lecture, students will spend more time listening and absorbing information.

13. **Student Study Art Notebook** Free with each new text, the Student Study Art Notebook contains all of the full-color art included in the transparency set. The notebook allows the student to focus on the lecture rather than trying to recopy art being displayed in class.

acknowledgments

We would like to acknowledge the may individuals who helped and encouraged us as we developed this text, including CUNY, Bloomfield College, and Kean College students who provided the original and sustaining inspiration and the many students who used the first two editions and provided us with their comments.

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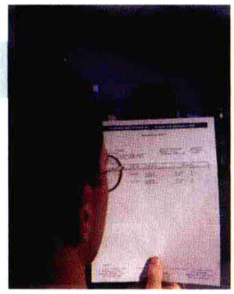

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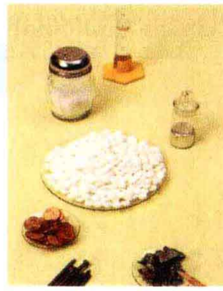

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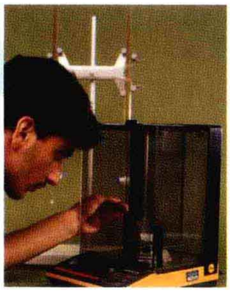

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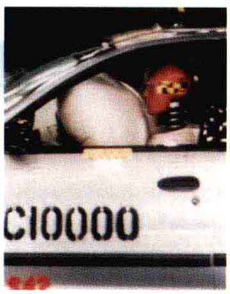

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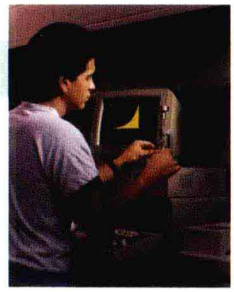

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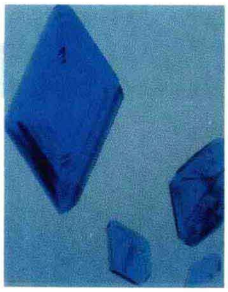

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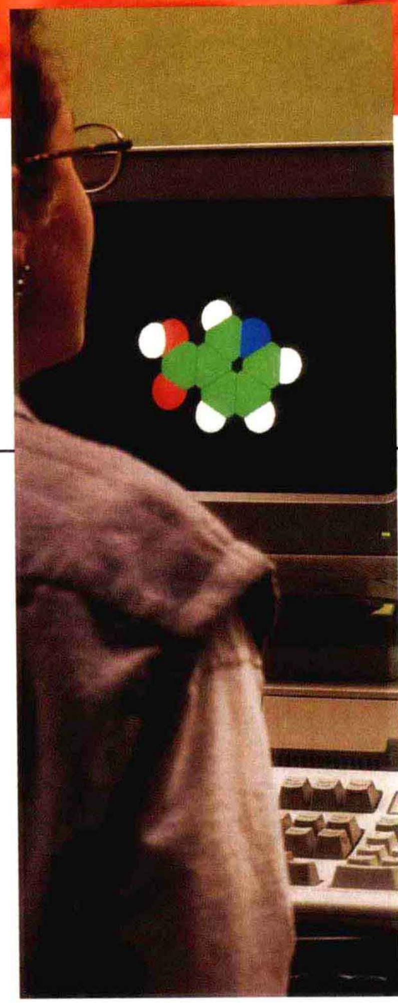
chapter 1

classification of matter



A modern chemistry student is using a desktop computer to access a chemical database containing the properties of more than 10 million known compounds. Any chemist may use this information to help identify an unknown material or to verify that he or she may have prepared a new material with properties different from materials previously registered.

1.1 introduction

We invite you to explore with us some of the questions, beauty, and helpful results that have arisen from the study of chemistry and the efforts of chemists throughout the ages. As we proceed, you will discover some of the concerns of chemists, how they think, how they design experiments to answer their questions, and how they attempt to make new materials that are useful in improving our lives.

The basic aim of chemists is to understand the behavior of the 109 known elements and how those elements combine or may be combined in the laboratory to make new materials and to prepare known materials in a more useful and efficient manner.

Studying how and why atoms from different elements combine into new materials, how quickly they combine, and how much material is formed increases the chemist's ability to predict the behavior of elements without further experiment. It is amazing also to consider how the modern chemist is able to build, or synthesize, chemically complex materials from simpler or more readily available materials. Sometimes the new materials may become a useful drug, fiber, or fuel.

The number of materials catalogued in the Chemical Abstracts Service (CAS) Registry at present is more than 10 million, and a large number of those have been synthesized, that is, built to order in the laboratory. With so many materials sufficiently understood to the extent of being "laboratory prepared," you can appreciate the powerful scientific principles that chemists must have developed to guide them in their work. Those principles will form the basis of each of the chapters in this text.

Fortunately, chemists have organized materials into relatively few groups, so that we can all work with such enormous diversity in a systematic way. That organization or classification of materials will be our starting point in Chapter 1.

Chemistry is the study of matter and changes in matter, which includes everything you see around you. This book, your hand, a pencil, water, a tree, and invisible things such as air are all examples of matter. Two characteristics define **matter**: matter occupies space and has mass.

As you begin reading this text, your view of matter resembles that of the earliest chemists who set out to study matter. You probably perceive the world around you as boasting an unlimited number of different forms of matter (Figure 1.1). As it turns out, you can actually classify matter into a surprisingly small number of categories, which are, in fact, the focus of this chapter. By the time you finish reading Chapter 1, you will be familiar with the most fundamental categories for classifying matter and you will be able to use them to help you identify any of the millions of known materials. You will have begun to function as a modern chemist.

Classification of matter is the process of arranging materials systematically into a useful number of groups according to their **properties,** those characteristics that are distinct for each material and that help you to identify them. Classifying information is a process you do every day without consciously realizing it. You classify automobiles as those that you particularly like and those you don't, as those that have pizzazz and those that don't, and as those that are economical and dependable and those that aren't.

••• problem 1

Make a list of the categories you use when you think about food, clothes, friends, jobs, and courses you are taking (including this chemistry course).

Figure 1.1

All matter occupies space and has mass, including these hot air balloons, the gas within the balloons, the air around the balloons, the gondolas, and the grains of soil in the earth below.

If you compare the lists that you made for Problem 1 with those of a fellow student, you will find that some of your categories agree, but others do not. Each of you has made a list that is useful for your own needs. When scientists construct a list of categories for classifying matter, they are looking for categories that are as simple and as general as possible. Then these categories are likely to include all materials, yet serve the needs of everyone studying those materials or trying to identify them.

Discovering properties useful for the classification of matter will be our first task in this text, as it was for the earliest investigators of matter. By grouping materials according to similar properties, you will begin to understand the tremendous power and increased capability you attain by simply organizing the information you have on hand. In everyday language, classifying matter is just a way for you to "take charge." But "taking charge" of scientific information means that you will proceed in a critical manner so that your efforts will be as useful as possible to anyone who wants to build on your results.

1.2 classification of matter by physical state

As citizens of the late twentieth century, you have a decided advantage over early investigators because you have absorbed some of the compiled scientific knowledge of the last 200 years in your everyday experience. For example, consider the following list of samples and think about how you might group them into three categories based on properties of the samples you have observed.

Samples of matter (Figure 1.2)

Gasoline	Ice	Distilled water	Mercury
Table salt	Oxygen	Helium	
Iron	Carbon dioxide	Rubbing alcohol	

When you think about each of these materials, you usually visualize a particular form or **physical state** that each takes (Figure 1.2). For example, ice, iron, and table salt are **solids;** distilled water, gasoline, mercury, and rubbing alcohol are **liquids;** and carbon dioxide, helium, and oxygen are **gases.** So, a useful classification system that you may readily choose involves identifying these samples as solids, liquids, or gases. The grouping of these materials according to their physical state is shown below.

Solids	**Liquids**	**Gases**
Ice	Distilled water	Carbon dioxide
Iron	Gasoline	Helium
Table salt	Mercury	Oxygen
	Rubbing alcohol	

Because you have long been aware of the characteristics of the three physical states, you recognize solids, liquids, and gases without realizing that you are

Figure 1.2

Common examples of solids, liquids, and gases. Solids include ice (in the ice cubes), iron (in the nails), and table salt. Liquids include distilled water, gasoline, mercury, and rubbing alcohol. Gases include carbon dioxide (in the fire extinguisher), helium (in the balloons), and oxygen. Water has been shown in two of its three states—solid ice and liquid.

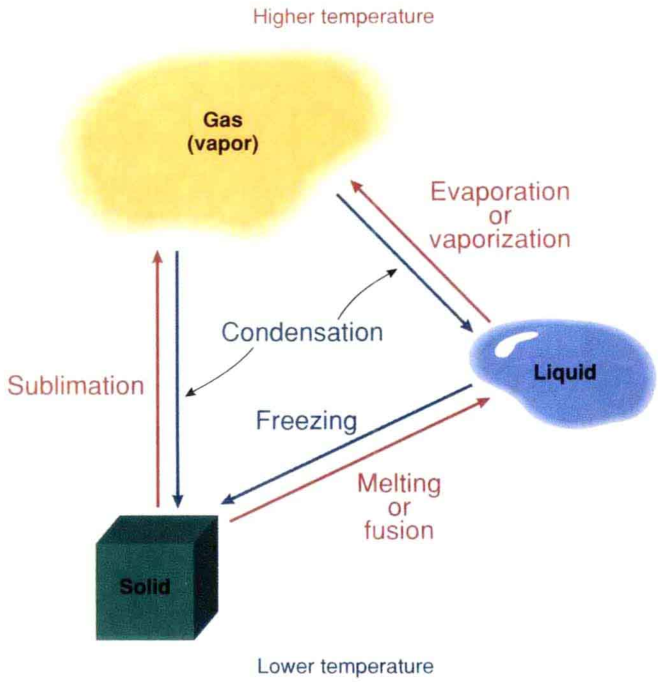
table 1.1 shape and volume characteristics of the three physical states

Physical state	Shape	Volume
Solid	Definite shape. The shape does not depend on the container; e.g., the shape of an iron bar is the same in a box or on the table.	Definite volume. The volume is fixed; e.g., an iron bar occupies a clearly defined amount of space.
Liquid	Indefinite shape. The liquid takes on the shape of its container; e.g., the same amount of water changes shape in a cup, glass, pan, or puddle.	Definite volume. The volume is fixed; e.g., a cup of water has the same volume in a glass, a pan, or spilled on the floor.
Gas	Indefinite shape. A gas takes the shape of its container; e.g., the same amount of natural gas can be contained in a pipe or in a room.	Indefinite volume. The volume is not fixed but changes with the size of the container; e.g., a small amount of natural gas that leaked from a pipe in a large auditorium spreads to fill the entire room.

examining whether the shape and volume of each sample are definite when you make your classification. Table 1.1 summarizes the shape and volume characteristics of the three physical states. Note that only solids have *both* a definite shape and a definite volume. Liquids have a definite volume only, not a definite shape, because their shape takes on the shape of their container. Gases have neither a definite shape nor a definite volume; they take on the shape of the container and spread throughout the container to fill it no matter how big it is.

Usually you refer to the physical state of all matter at room temperature as a standard for comparison. This is necessary because the physical state may change as temperature changes. While you visualized one physical state for each of the

Figure 1.3
Classification of changes in physical states.



materials in the classification example, each material may appear as either a solid, liquid, or gas depending on its temperature. For example, water, which is a liquid at room temperature (25°C), changes its state to a solid (ice) as the temperature drops to freezing (0°C); it also changes its state to a gas (steam) as the temperature rises to boiling (100°C).

1.3 changes in the physical state of matter

The processes for changing physical states are given in Figure 1.3. The arrows are labeled with the names of each process, and the arrowheads indicate the direction of the change between states. Here you can quickly see how the changes between physical states may be more easily remembered because the changes have been classified into three groups: between solid and liquid, between liquid and gas, and between solid and gas. Each of these groups of changes occurs at its own specific temperature for a given material and each may occur in either direction, depending on whether heat is being added or taken away.

Figure 1.4
Icicles melting on a sunny day.

changes between solid and liquid

Melting is the term applied to the change as solid turns into liquid (Figure 1.4). **Freezing** corresponds to the reverse process in which liquid turns into solid. Both processes occur at the same temperature, called the **melting point, freezing point,** or **temperature of fusion.** The melting point is measured when the solid and liquid states are both present, as shown in Figure 1.5 with a combination of solid ice and liquid water.

changes between liquid and gas

Evaporation and **vaporization** are terms applied to the change as liquid turns into gas. **Condensation** corresponds to the reverse process in which gas turns into liquid. The temperature at which bubbles form throughout a liquid and the liquid becomes a gas is called the **boiling point.** The boiling point is measured when liquid and gas states are both present, as shown in Figure 1.6 with a combination of water and steam. Bubbles forming within the body of the liquid distinguish boiling from evaporation. Below the boiling point, liquids still evaporate, but more slowly than at the boiling point. You can smell the "fumes" (vapor) of gasoline or the aroma of perfume at temperatures below their boiling points (Figure 1.7).