SECOND EDITION

CHEMISTRY: A FIRST COURSE

JACQUELINE I. KROSCHWITZ
Formerly of Kean College of New Jersey

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ABOUT THE AUTHORS

The authors bring a total of over 30 years of dedicated teaching and writing to their textbooks.

MEL WINOKUR was born and educated in New York City. After receiving his bachelor's degree from City College of New York, he went west to the California Institute of Technology where he obtained the Ph.D. in physical organic chemistry. Mel then returned to New York and taught at several branches of City University of New York, most notably at Bronx Community College. He moved to Bloomfield College and became full professor in 1984.

JACQUELINE KROSCHWITZ was born in Trenton, New Jersey, graduated from Ursinus College in Collegeville, Pennsylvania, and received the Ph.D. in physical organic chemistry from the University of Pennsylvania. Then she went west for a postdoctoral year at Caltech. Her first teaching post was at Barnard College, Columbia University. She has also taught in New York City community colleges and moved to Kean College of New Jersey in 1976.

Despite their different names, the authors are married and live in northern New Jersey with their wine cellar. Their avocation is traveling, especially among Michelin guide three-star restaurants.

PREFACE

"To teach is to learn." In writing our textbooks we have attempted to apply the valuable lessons which our students have generously supplied as we have tried (with some success we think) to teach them the fundamental concepts of chemistry. Perhaps the most valuable lesson we have learned is that beginning chemistry students simply do not possess certain knowledge and reasoning skills which their science instructors generally take for granted. In this text, aimed primarily at the preparatory-level chemistry course, we take nothing for granted, neither prior scientific knowledge nor prior experience in deduction.

As we approached each topic our aim was to offer complete, logical explanations which include all necessary steps in the deductive reasoning process, rather than assuming that the student already has the ability to make deductive leaps. This approach gives students the opportunity to glimpse the complete development of scientific thought, which is usually not their natural way of thinking, and to develop their own reasoning skills as they explore increasingly complex phenomena.

We hope that students might enjoy their study of chemistry despite the fact that many are captives of a science course requirement. To this end we have used a conversational tone, a few anthropomorphic explanations, and occasionally introduced humor into some illustrations. Also, we encourage student visualization of microscopic phenomena both because such imagery is a valuable scientific skill and because it is fun.

As a convenience and learning aid, and in order to reinforce concepts and encourage necessary review, we frequently refer students to previous sections needed as a foundation for understanding the topic at hand. Cross-referencing is also used to inform students of "coming attractions" in subsequent chapters. Other convenient features and learning aids are:

Sample Exercises are very carefully worked out in stepwise detail using the **Unit Conversion Method** wherever possible and appropriate. Sample Exercises are supplied copiously.

Problems frequently immediately follow Sample Exercises within the chapter so that the student can test his or her understanding of the concept explained. At the end of each chapter there are numerous problems at varying levels so that students can reach the limits of their own capacities. In this edition problems are arranged by subsection topics for the convenience of students and instructors.

Stepwise Procedural Rules or guidelines are provided for significant manipulations; for example, see "Guidelines for writing Lewis structures" in Section 6.13.

Tables are used extensively to organize and summarize information.

Illustrations are an integral part of the explanations.

Summaries of the major points addressed conclude each chapter.

Chapter Accomplishments provide the student with the learning objectives of each chapter.

Math skills are given the status and full treatment of a chapter.

The usefulness of the **periodic table** is stressed and reiterated.

An entire chapter is devoted to the **mole concept.**

Selected answers to problems appear in Appendix 4.

Defined words are **italicized** in the index for ready location.

More applications of chemistry to students' experience or interest are offered in this edition: for example, colligative properties in Chapter 13 and blood buffers in Chapter 15.

Student reception of the first edition of this text suggests we have succeeded in writing a truly student-oriented book. Students describe the text as "self-teaching." In short, preparatory level students are able to read and understand this book and many report enjoying it.

In order to provide an early explanation for compound formation and a logical basis for remembering ionic charges, we have altered the sequence of chapters in this new edition. Electronic structure and bonding are now covered before ionic formula and nomenclature.

Instructors who wish to follow the former sequence and introduce nomenclature, formula and equation writing, and stoichiometry early in their course should have no problem covering Chapters 1, 2, 3, 4, 7, 8, 9, and 10 before returning to electronic structure and bonding in Chapters 5 and 6. An Instructor's Manual is available and provides additional comments on each chapter, suggested accompanying laboratory experiments, answers to all problems, and sample examinations for each chapter. In our Laboratory Manual each experiment is related to a specific text section.

More material is included in this book than can be covered reasonably in one semester. The core curriculum as preparation for general chemistry would be Chapters 1–11. If time permits, the instructor then has the freedom to choose additional topics based on personal preference. Chapters 12, 13, 14, 17, and 18 stand independently of one another. Chapter 15 (Acids and Bases) relies on material in Chapter 13 (Solutions) and Chapter 14 (Chemical Equilibrium). Chapter 16 presupposes coverage of Chapter 13.

We earnestly invite your comments and suggestions toward the improvement of this textbook as a learning device.

ACKNOWLEDGMENT

We would like to acknowledge and thank the many individuals who helped and encouraged us as we developed this text. First of all, there are the C.U.N.Y. community college students who were our original inspiration and the many Chemistry 110 students at Bloomfield College who have sustained the inspiration. They have used the first edition thoughtfully and offered useful suggestions for improvement.

Reviewers of our text have been very thorough and helpful, and we thank them: Ron Backus, American River Community College; Boyd Earle, University of Nevada, Las Vegas; Nancy Howard, Philadelphia College of Textile and Science; William B. Huggins, Pensacola Junior College; E. J. Kremnitz, University of Nebraska, Omaha; Steven Murov, Modesto Junior College; Raymond O'Connor, Santa Barbara City College; Donald B. Phillips, Eastern Michigan University; Gordon Parker, University of Toledo; and Ray F. Wilson, Texas Southern University.

We also thank the editors and other production staff at McGraw-Hill, who gave such careful attention to all details as the manuscript became a book.

Jacqueline I. Kroschwitz
Melvin Winokur

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THE MOLE CONCEPT

CLASSIFICATION OF MATTER

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H
Hydrogen
1.008

INTRODUCTION

1.1 Chemistry is the study of matter, which is everything you see around you, this book, your hand, a pencil, water a tree, and invisible things such as air. 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. That is, you probably perceive the world around you as boasting an unlimited number of different forms of matter. As it turns out, we can actually classify matter into a surprisingly small number of categories. Discovering useful classifications of matter will be our first task in this text, as it was for the earliest investigators of matter.

CLASSIFICATION OF MATTER BY PHYSICAL STATE

1.2 As citizens of the twentieth century, you have a decided advantage over the 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 of matter and think about how you might group the samples into three categories based on characteristics of the samples that you have observed.

Samples of Matter (See Figure 1.1)

Steam	Iron
Gasoline	Ice
Table salt	Oxygen
Water	Carbon dioxide
Mercury	Alcohol

A useful classification system that you may have chosen involves identifying these samples as **solids, liquids,** or **gases.**

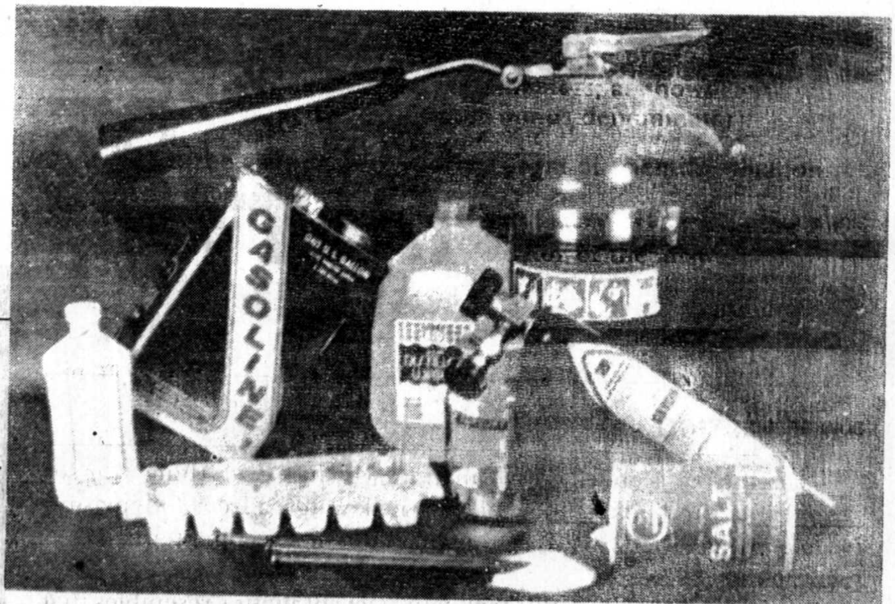


FIGURE 1.1

Matter is everything you see around you. Here are some familiar examples classified in Section 1.2. Most samples are labeled. The nails are iron, and the fire extinguisher contains carbon dioxide. Steam is not shown because of its elusiveness. (*Photograph by Bryan Lees*)

Solids	Liquids	Gases
Table salt	Gasoline	Steam
Iron	Water	Oxygen
Ice	Mercury	Carbon dioxide
	Alcohol	

This is the classification of matter according to **physical state**. Because you have long been aware of the characteristics of the three physical states, you now recognize solids, liquids, and gases without realizing that you are examining the definiteness of the shape and volume of the sample when you make your classification. Table 1.1 summarizes the shape and volume characteristics of the three physical states.

Usually we talk about the physical state of matter at room temperature. This is so because the physical state may change as temperature changes, and the samples we consider are usually at room temperature. For example, water is a liquid at room temperature (20°C), a solid (ice) below the freezing temperature (0°C), and a gas (steam) above the boiling temperature (100°C).

CHANGES IN STATE

1.3 **Melting** is the name applied to the change between the solid and liquid physical states. Other familiar changes of state are liquids **freezing** to solids, liquids **evaporating** to gases, and gases **condensing** to liquids. Liquid-solid changes (melting or freezing) and liquid-gas changes

SHAPE AND VOLUME CHARACTERISTICS OF THE THREE PHYSICAL STATES **TABLE 1.1**

Physical State	Shape	Volume
Solid	*Definite*—does *not* depend on the shape of the container	*Definite*—has a fixed volume (A gold bar occupies a clearly defined amount of space.)
Liquid	*In*definite—takes on the shape of its container	*Definite*—has a fixed volume (A glass of milk spilled on the floor spreads out, but not forever.)
Gas*	*In*definite—takes on the shape of its container	*In*definite—has no fixed volume (A small vial of gas opened in a large auditorium spreads to fill the entire room.)

* Because you are probably less familiar with this state since it is usually invisible, a whole chapter (Chapter 11) is devoted to gases. The more familiar liquids and solids are discussed in Chapter 12.
Note: Some substances, such as chocolate pudding, ice cream, etc., may not be so easily classified.

(evaporation or condensation) are the most familiar, but direct changes between the solid and gaseous states are also possible. Conversion of a solid directly into a gas is called **sublimation.** The water in wet laundry that is hung on a clothesline on a freezing winter day freezes to ice. The clothes become dry when the ice sublimes into the gaseous state and goes off into the air (see Figure 1.2).

We can summarize changes in state by the diagram below. The arrows represent the processes named, and the arrowheads indicate the direction of the change between states.

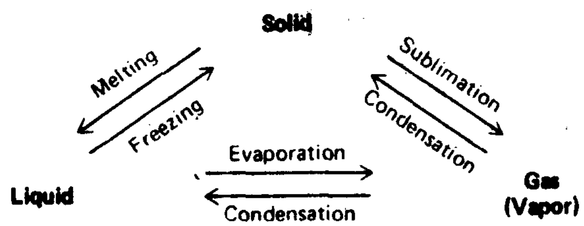
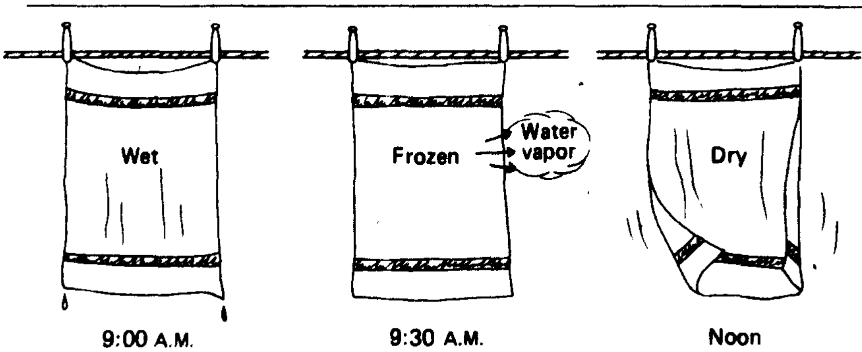


FIGURE 1.2



How your laundry dries on a cold winter day. Water in the towel freezes into ice; the ice sublimes into water vapor, and your towel is dry.