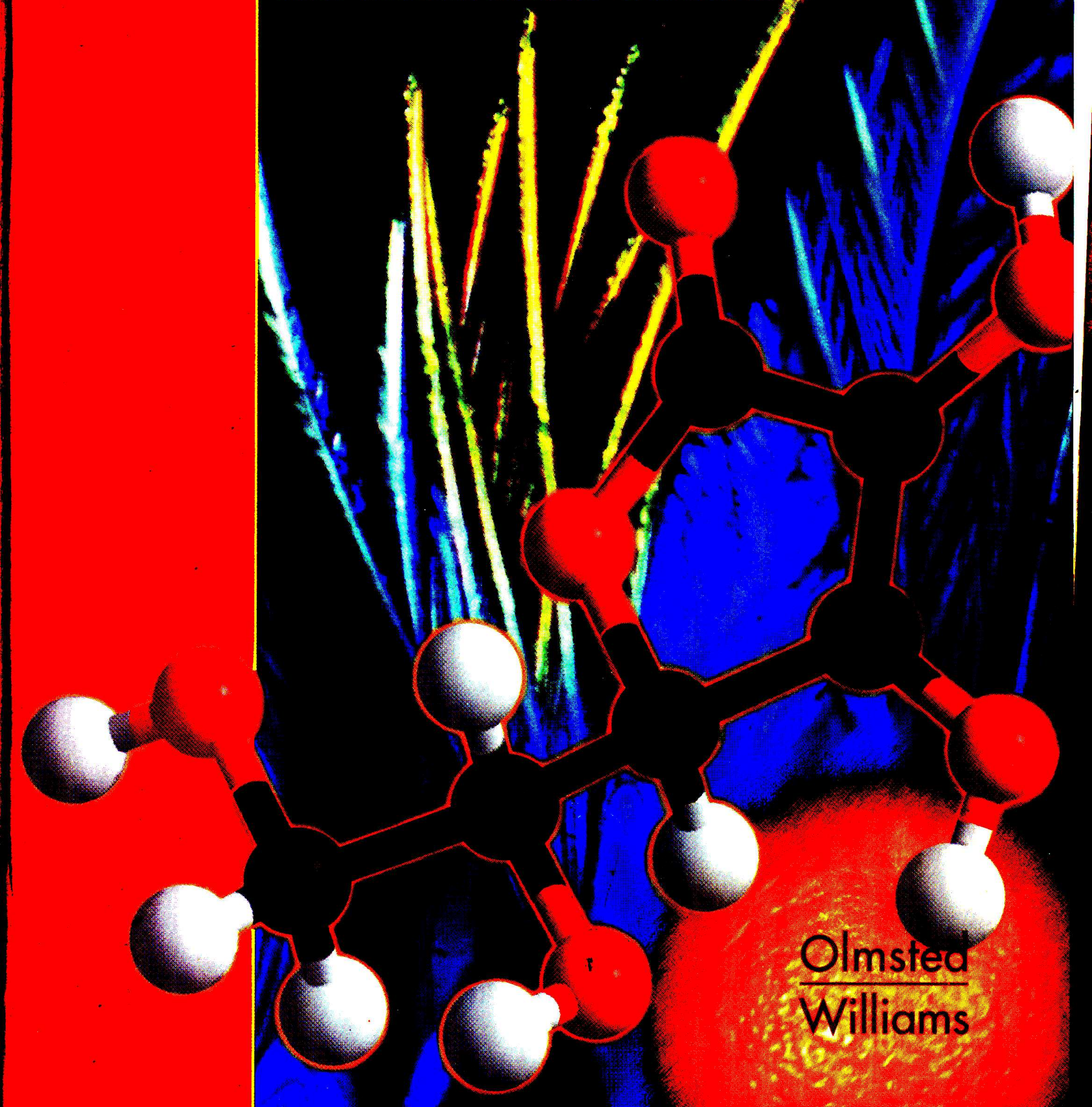
Chemistry

THE MOLECULAR SCIENCE



Olmsted
Williams

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To all those students whose determination to learn chemistry inspired us to write this book

PREFACE

You, our audience, are a diverse group because chemistry underlies fields extending from biology and geology, through medicine and pharmacy, to engineering and materials science. Consequently, a textbook must present general chemistry so that whatever your discipline, you can appreciate the elegance of chemistry and master its fundamental concepts. Regardless of where your interests lie, however, the important chemical properties and principles remain the same. These chemical properties and principles are the core of our presentation.

Chemistry is a mature science in the sense that the atomic theory, its primary unifying theme, is nearly 300 years old. Yet it is a surprisingly young science bursting with the excitement of new discoveries such as buckminsterfullerene, taxol, and superconductivity as well as new challenges such as the causes and control of the ozone hole and new drugs to combat AIDS. An introductory chemistry textbook must focus on basic concepts whose validity is well established, and we do this. At the same time, however, the vibrancy and excitement of chemistry centers on what is newly discovered and as yet imperfectly understood. We try to capture this by introducing some of the "cutting edge" developments that chemists were exploring while we were writing this textbook.

ORGANIZATION AND EMPHASES

The title of this book, *Chemistry: The Molecular Science*, reveals our primary unifying theme. This book emphasizes the molecular view of chemical principles because practicing chemists visualize chemical processes at the molecular level. A chemist sees a pot of boiling water and thinks instinctively of water molecules moving from the liquid phase to the gas phase. In every chapter, you will find molecular descriptions and molecular pictures, and you will be asked to visualize how molecules behave and to draw molecular pictures.

Chemistry is molecular, but at the same time it is quantitative. For this reason, a second main thread running through our text is the presentation and use of the quantitative equations of basic chemistry. Qualitative concepts always underlie quantitative equations, however, so our presentation always seeks to buttress quantitative ideas with their conceptual foundations.

The power of quantitative relationships lies in their applications. In presenting equations, therefore, we not only outline their underlying logic, but also illustrate how they are applied to chemical problems. Sample Problems describe these applications and illuminate the conceptual approaches to problem solving and its mechanical aspects. Even though we set them off from the narrative text, we expect you to read the Sample Problems as part of the flow of the chapter.

The various topics within general chemistry present a rich tapestry in which each topic connects with many others. The linear presentation of a textbook cannot show the full richness of these connections, and there is no sequence of topics that avoids cross-references, both forward and backward. Our sequence starts with the molecular composition of matter and a description of chemical reactions and builds an understanding of a variety of chemical topics on those fundamental ideas.

Throughout this development, we describe how substances behave in the context of the concepts presented. This interweaving of concepts and descriptions presents chemistry as chemists understand it, a blend of principles and properties that illuminate and reinforce each other. As we present chemical principles, we also describe some of their practical applications. Because instructors differ in their beliefs about the importance of the descriptive aspects of chemistry, your instructor may place greater or lesser emphasis on these descriptive features. We have tried to write the text in a way that supports both a strong emphasis on principles and a strong emphasis on practice.

General chemistry introduces principles and properties common to all facets of the subject. To emphasize this, we use examples from inorganic, organic, industrial, and biological chemistry to illustrate underlying principles. Rather than introduce these branches of chemistry as separate topics, we weave them into our discussion wherever it seems appropriate. We hope that this approach provides insights into the close relationships among all facets of chemistry.

COVERAGE

Although there is a common core to a 1-year course in general chemistry, beyond that core is a number of topics from which each instructor makes a selection. Consequently, we present somewhat more material in this book than is likely to be covered in the usual course. Your instructor will choose to emphasize some topics beyond the core while omitting others. Several chapters contain sections that can be omitted without a loss of continuity. Chapters 10 and 18, in particular, include such optional material. In addition, Chapters 11 and 19 cover topics that, although central to the interface between chemistry and modern society, lie somewhat outside the mainstream of coverage in traditional general chemistry.

In general, our chapters begin with introductions that establish the context for the subject matter to be covered. These are followed by sequential developments of major concepts and techniques, developed using practical examples and illustrated, as much as possible, through molecular pictures. Many chapters end with sections that illustrate some important practical consequences of abstract chemical concepts. Examples are in Chapters 5 (The Earth's Atmosphere), 9 (Band Theory of Solids), 13 (Bioenergetics), 14 (Catalysis), and 17 (Metallurgy).

MASTERING CHEMISTRY

Success in general chemistry requires a blend of ingredients. It requires a clearly presented body of information; we hope you will find that in this textbook. It requires lucid instruction from a committed teacher; we hope that our text facilitates such instruction. Finally, success in chemistry requires commitment and hard work from the student. We have tried to structure the text so that it encourages that commitment and directs the work along productive lines.

Although no single formula is guaranteed to work for every type of student, there are strategies that successful students consistently recommend. Foremost among these is a focus on understanding concepts, because memorization without understanding leads to frustration, not to success. We explain principles using logical underpinnings that can make them easier to understand.

Much of chemistry is concerned with the applications of concepts to practical problems. Our text is laced with Sample Problems, Section Exercises, and chapter Problems designed to help you learn such applications. Each Sample Problem includes a brief explanation of the method, which outlines how the problem should be approached. Following the method is a step-by-step description of the solution.

Section Exercises appear at the end of each section and are designed to give you immediate practice in applying the concepts presented in the section. So that you can know whether or not you are reasoning correctly, we provide the answers to all Section Exercises at the end of each chapter.

At the end of each chapter, we provide material designed to engage you in active learning. For greatest effectiveness, use this material to guide the manner in which you study. A Chapter Summary provides a brief overview of the major themes of the chapter, and a list of Key Terms flags the words with which you must be familiar. Skills to Master reminds you what problem-solving techniques require your attention, whereas the Learning Exercises are qualitative questions designed to help you organize your ideas about the material in the chapter.

Proficiency in using chemical concepts comes only with practice. The chapter Problems are designed to give you the opportunity for such practice. About half of the chapter Problems are identified by the section to which they relate. One of the skills of problem solving, however, is the ability to identify the concepts underlying the problem. For this reason, we have included many problems that are not identified by section. These Additional Problems are not necessarily more difficult than those identified by section; however, by placing them randomly, we give you the opportunity to learn how to recognize problem types.

Two axioms characterize successful students, in our experience. The first is an attitude: **Be an active learner.** *Ask* questions, *seek* help from many sources, *form* study groups, *work* extra problems, and *prepare* chapter outlines. Try a combination of these and additional strategies until you find a set that works best for you. The second is a perspective: **Think molecules.** Every phenomenon in chemistry has an atomic/molecular basis that can make the phenomenon easier to understand. Ask yourself *what* the molecules are doing and *why.* Imagine yourself to be the size of a molecule and ask what you would see. Learn how to draw pictures showing what goes on at the molecular level. When you have mastered this perspective, you will have learned how to think like a chemist and will appreciate the unity of chemistry. You may even decide that you are a chemist.

ACKNOWLEDGMENTS

A textbook in general chemistry does not just happen. It is painstakingly developed over several years. Moreover, it is a team effort that consumes the attention and talents of many individuals. This text has come to fruition over a 5-year span, during which time many individuals have made essential contributions.

Our textbook began with our interactions with several generations of general chemistry students, with whom we have shared the frustrations of imperfect explanations and on whom we have tried out diverse methods of presenting elusive concepts. We have been encouraged time and again by students asking us when this book will appear and lamenting that its appearance follows their completion of the course. We are grateful to them for serving as the educational laboratory in which we improved our instructional skills.

Support and criticism from our talented editors shaped the scope, content, level, and language of our text throughout its development. Jim Smith, our executive editor, has provided unerring guidance as the text moved from a proposal through initial drafts to final product. John Murdzek, our developmental editor, kept our attention on the important details, including accuracy, continuity, and relevance. Carol Sullivan Wiseman, our project manager, and Pat Joiner, our senior production editor, converted our manuscript into the book you now hold in your hands. The beauty and readability of the page layout are due entirely to their editing and design skills. Kay Kramer, Jeanne Wolfgeher, and Betty Schulz created a book design that enhances the text without overpowering its purpose, which is to teach you chemistry.

Illustrations can powerfully assist learning, and we hope that the illustrations in this text make it easier for you to grasp chemical concepts. Several talented individuals are responsible for the quality of our illustrations. Patrick Watson took many of the photos and located sources for many of the others. Carolyn Duffy and Greg Holt, who are ArtScribe, Inc., and the artists at J/B Woolsey Associates created elegant four-color artwork from our crude black-and-white sketches.

Our writing has been tempered in the crucible of peer review and criticism. A legion of professors agreed to assist in this role, and they provided us with a wealth of insights that far surpassed our own. All of those listed below contributed to our endeavor, but we wish particularly to thank Allan Burkett, Donald Campbell, John Rund, Paul Hunter, Glenn Kuehn, and Larry Peck. These individuals reviewed our work repeatedly and in detail and always told us explicitly what they thought we were doing wrong while at the same time encouraging us to make things right.

Every student knows that writing is time intensive and that good writing requires focused concentration for blocks of time. In this regard, writing a textbook is no different from other writing. We owe an immense debt to those who permitted us to devote to this project the time required for its completion. Above all, we are indebted to our wives, Eileen and Trudy, who did not realize at the outset how extensive our time commitments would become but who have borne with us understandingly despite several years of long evenings and lost weekends.

Bruce Ault
University of Cincinnati

Caroline Ayers
East Carolina University

George Baldwin
University of Manitoba

Jon M. Bellama
University of Maryland

Allan R. Burkett
Dillard University

Donald Campbell
University of Wisconsin–Eau Claire

John F. Cannon
Brigham Young University

Grover W. Everett
University of Kansas

Michael D. Fryzuk
University of British Columbia

Steven D. Gammon
University of Idaho

Michael F. Golde
University of Pittsburgh

Paul Hunter
Michigan State University

Richard F. Jordan
University of Iowa

Paul J. Karol
Carnegie Mellon University

Robert Kiser
University of Kentucky

Joseph W. Kolis
Clemson University

David Koster
Southern Illinois University at Carbondale

Glenn D. Kuehn
New Mexico State University

Richard S. Lumpkin
University of Alabama

John Luoma
Cleveland State University

Bruce Norcross
SUNY–Binghamton

Henry Offen
University of California, Santa Barbara

M. Larry Peck
Texas A & M University

John V. Rund
University of Arizona

Martha E. Russell
Iowa State University

Sanford Safron
Florida State University

Caesar V. Senoff
University of Guelph

Joanne Stewart
Hope College

Dwight A. Sweigart
Brown University

Wayne Tikkanen
California State University at Los Angeles

Charles Trapp
University of Louisville

D. Rodney Truax
University of Calgary

John Olmsted III
Gregory M. Williams

CONTENTS IN BRIEF

CHAPTER 1

THE SCIENCE OF CHEMISTRY

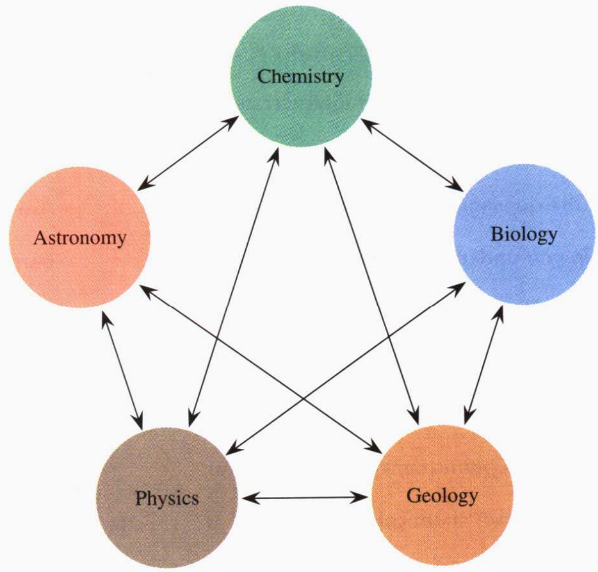


FIGURE 1-1
Schematic representation of the interrelationships among scientific disciplines.

Chemists explore the infinite variety of chemical behavior and use simplifications and generalizations to organize what they find. A common practice is to construct a theory in which a few principles describe how a system behaves. The theory can be used to predict what will happen to the system under different conditions. Chemists design and perform experiments that test whether or not a system behaves as theory predicts. If observations and experiments verify the predicted outcome, chemists become confident that the theories correctly describe how nature behaves.

In Chapter 2, we describe the atomic theory of matter, which underlies our understanding of chemical behavior.

According to the atomic theory, all matter is composed of tiny particles called *atoms*. The atomic theory was developed at the outset of the nineteenth century to explain the observations of early chemists. It was quickly found that new chemical discoveries were consistent with predictions based on the theory. Over the years the atomic theory has been expanded and refined as increasingly sophisticated chemical experiments revealed more detailed information about matter. We describe atomic theory and its applications in more depth in later chapters.

CHEMISTRY IS AN EXPERIMENTAL SCIENCE

This book describes fundamental chemical principles and chemical properties. Chemists learn about these properties and principles by designing and performing experiments that reveal how substances behave.

Chemists also construct theories to explain the results of their experiments. Some of these theories are presented in this book. Every theory is based on experimental observations, and the goal of a theory is to explain some set of experimental results. A useful theory also makes predictions about new phenomena that might be observed, and the test of any theory is whether its predictions match reality. Chemists continually test and refine chemical theories by designing and conducting new experiments.

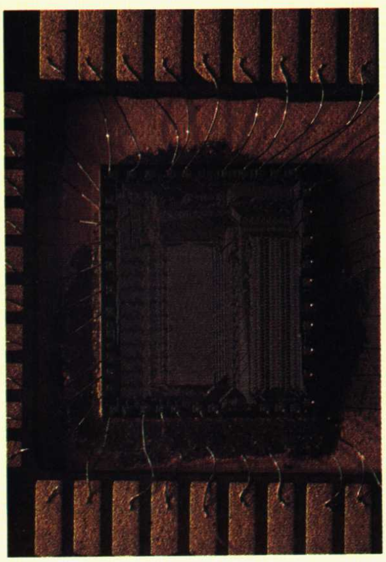
Sometimes experiments give surprising results. An event deemed impossible by a theory may occur. It can be exciting when experimental observations contradict theoretical predictions, but chemists proceed cautiously when this happens. First,

BOX 1-1

WHY STUDY CHEMISTRY?

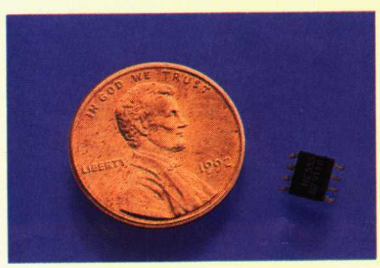
Most students who take an introductory course in chemistry are not chemistry majors. Their interests are in engineering, biology, physics, the health professions, geology, or agriculture. Why are you all expected to learn something about chemistry? The answer is that much of what occurs in nature has important chemical aspects. In fact, chemical principles play an important role in everything from weather patterns to brain functions to the operation of a computer. The following paragraphs give some specific examples.

For ages, farmers have known that fertilizers enhance crop yields spectacularly. Fertilizers are chemical substances that stimulate plant growth. From the chemical reactions involved in plant growth, botanists learned that all plants require nitrogen in the form of ammonia or nitrates in the soil. Further studies of plant chemistry have revealed that crops also need calcium, phosphorus, iron, and other chemical species. Gardening supply stores carry a variety of different fertilizers with different chemical compositions. The best fertilizer for a particular situation depends on the chemistry of the soil and the plant.



Oil exploration geologists study rock formations, looking for patterns that indicate where oil is likely to be found. Comparisons of the chemical constituents of rocks and petroleum deposits have revealed that characteristic chemical compounds are often found in the rock formations that surround oil deposits. By analyzing samples of rock for these telltale compounds, geologists can determine where oil is likely to be found in the Earth's crust.

A computer chip is a remarkable feat of electronic engineering. It is an equally remarkable feat of solid-state chemistry. Each chip is made of highly purified elemental silicon that has been chemically modified at the microscopic level. The modifications must be extremely precise in chemical composition and spatial organization. The quest for superminiaturized computer chips requires engineering technology to operate at the microscopic limits of chemistry.



Any disruption of the dynamic balance in an ecosystem may have far-reaching biological consequences. An ecosystem's response to change is governed by fundamental laws of chemical kinetics and thermodynamics. Kinetics describes how fast changes occur and how rates of change vary with the conditions. Thermodynamics, on the other hand, describes what is possible and impossible in any system where changes occur. To understand why an ecosystem responds to changes the way it does, a biologist must be aware of thermodynamic limits and kinetic constraints.

These examples illustrate why people who are not directly interested in chemistry must learn about the subject. The agriculturist who understands soil chemistry, the geologist who knows the chemical composition of petroleum, the engineer who is informed about solid-state chemistry, and the biologist who is knowledgeable about thermodynamics and kinetics are all at a distinct advantage as they try to master their own subjects.

they repeat the experiments to be sure that the original observations are reproducible. If the disagreement between prediction and experiment is verified, the theories must be modified. When theory and experiment disagree, the theory must be wrong. To give you some sense of the excitement that accompanies the ever-expanding field of chemistry, here are three recent developments that have affected how chemists view their subject.

Until the early 1960s the theories of chemical bonding, which describe how atoms can combine with one another, predicted that atoms of the elements known as the *rare gases* were incapable of combining with other atoms. In 1962, however, Neil Bartlett made a compound that contained xenon (one of the rare gases), fluorine, and platinum. Other chemists immediately tested Bartlett's results, and within a year at least 13 different chemical compounds containing xenon had been prepared. As a result, theories of how atoms bind together to make molecules had to be modified to take into account these experimental results.

The phenomenon of superconductivity, in which substances are able to conduct extremely high electrical currents without significant resistance, was discovered in 1911. Until recently, it was believed that superconductivity was possible only at temperatures below −250 °C. In 1986, however, several scientists discovered chemical substances with superconducting properties at temperatures up to about −200 °C. Since then, research has proceeded at a feverish pace as chemists and physicists try to synthesize chemical compounds that display superconductivity at higher and higher temperatures. They hope eventually to develop room-temperature superconductors. These would revolutionize the electrical industry by making it possible to transport electricity over long distances without significant losses caused by resistance. In addition, motors and magnets made with superconductors would be far superior to those that use standard electrical conductors. Figure 1-2 illustrates the remarkable power of superconducting magnets.

FIGURE 1-2
High-temperature superconductors make it possible to do some surprising things.

Exciting new discoveries sometimes are not verified on further study. In 1988 a pair of respected chemists reported that they had observed "cold fusion," the merging of nuclei of one form of hydrogen to form helium nuclei at room temperature. Because this was an immense departure from the predictions of theory and a potential source of unlimited, inexpensive energy, the entire world took immediate notice. Although cold fusion experiments are not difficult to perform, their results are quite difficult to interpret. Many laboratories tried to duplicate the first reports, with ambiguous and sometimes conflicting results. At publication, there has been no definite confirmation of the original reports. Research into cold fusion continues, but many scientists doubt that the original experiments were interpreted correctly. Cold fusion on a scale that would have practical applications has not been verified.

SECTION EXERCISES

1.1.1 List four ways that chemistry relates to cooking.

1.1.2 Describe how chemistry applies to the automobile industry.

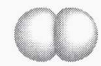
1.1.3 A planetary scientist announces a theory predicting that substances on Venus react differently than they do on Earth. Write a paragraph that describes ways to test whether or not this theory is valid.

1.2 THE MOLECULAR NATURE OF CHEMISTRY

The fundamental unit of a chemical substance is called an **atom.** The word is derived from the Greek *atomos,* meaning "uncuttable." An atom is the smallest possible particle of a substance. Atoms are made up of even smaller particles, which we describe in later chapters. For now, however, you should think of atoms simply as tiny, indivisible spheres of matter.

Atoms are extremely small. Measurements show that the diameter of a single carbon atom is approximately 0.0000000003 m. To give you some idea of just how small that is, a sample of carbon the size of the period at the end of this sentence would contain more atoms than there are stars in the Milky Way. Any sample of matter large enough for us to see, feel, smell, or taste is composed of an unfathomable number of atoms.

Two hydrogen atoms



One hydrogen molecule

FIGURE 1-3
A hydrogen molecule can be represented by connecting two spheres together, with each sphere representing a hydrogen atom.

MOLECULES

Atoms combine to make all substances in the world around us, but they do so in a very orderly fashion. Most substances that we encounter in our day-to-day lives are made up of small units called *molecules.* A **molecule** is a *combination* of two or more atoms held together in a *specific shape* by attractive forces. The simplest molecules contain just two atoms. For example, a molecule of hydrogen is made up of two hydrogen atoms. A molecule that contains two atoms is classified as a **diatomic molecule.** Figure 1-3 shows a representation of a diatomic hydrogen molecule as two spheres connected together.

We describe how atoms are held together in Chapters 8 and 9.

Because most chemistry deals with the behavior of molecules, this book emphasizes chemistry's molecular foundation. Throughout this book you will see many figures that represent molecules. These molecular pictures are scale models of real molecules in which each atom is represented by a colored sphere. Although 109 different types of atoms exist, only a handful are encountered frequently in our world. Many molecules described in this book are made up of just 10 different types of atoms: hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur, fluorine, chlorine, bromine, and iodine. Figure 1-4 shows the different color representations that we use for each type of atom. We introduce additional elements as the need arises. Figure 1-5 shows scale models of molecules of some substances, the names of which you may recognize.

Unfortunately the same name, *hydrogen,* is used for both atoms and molecules. To minimize confusion, we refer to *atomic hydrogen* when we mean hydrogen atoms and *molecular hydrogen* when we mean hydrogen molecules. This dual terminology also applies to fluorine, chlorine, bromine, iodine, nitrogen, and oxygen, all of which exist as diatomic molecules under most conditions.

FIGURE 1-4
Scale models of the 10 atoms encountered most frequently in this book.

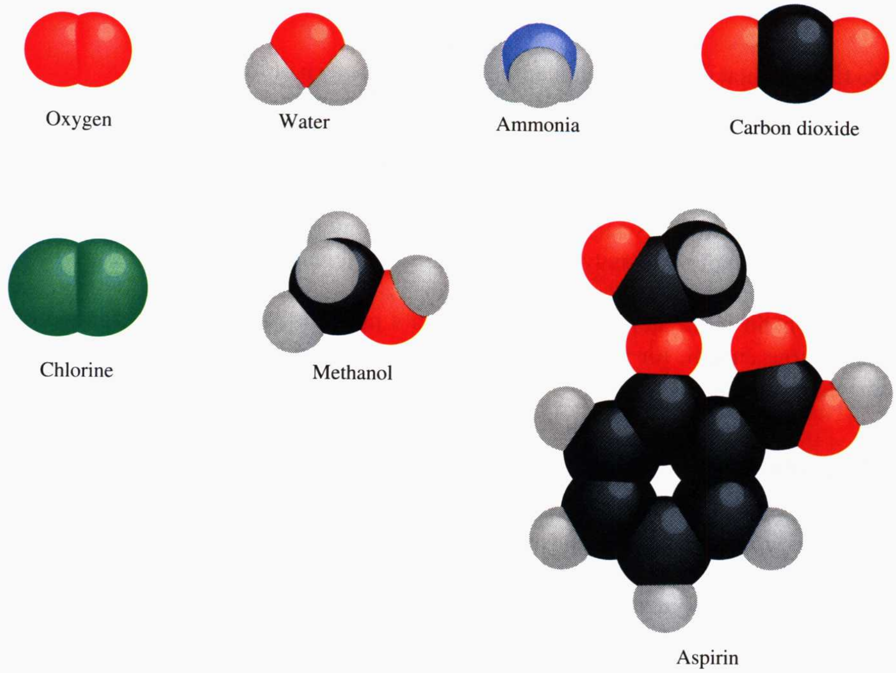


FIGURE 1-5
Scale models of oxygen, water, ammonia, carbon dioxide, chlorine, methanol, and aspirin.

We introduce the properties that give substances color in Chapter 6.

Although substances are colored, individual atoms do not have the colors shown in Figure 1-4. Individual nitrogen atoms are not blue, and oxygen atoms are not red. Elemental sulfur is yellow, but the color is a property of sulfur *molecules* in the sample. We use colored spheres because they provide a convenient way to distinguish different types of atoms in a molecular picture.

With a little practice, you can easily recognize simple molecules, such as carbon dioxide and water, just by looking at their models. The structures of larger molecules, such as aspirin, are too complex to be recognized at a glance. Consequently, chemists have created a shorthand language of symbols, formulas, and equations that convey information about atoms and molecules in a simple, straightforward manner. Symbols are used to designate each different type of atom. These symbols in turn are combined into formulas that describe the compositions of more complicated chemical substances. Formulas can then be used to write chemical equations that describe how molecules are changed in a chemical reaction.

SYMBOLS OF THE ELEMENTS

Each different type of atom is called a **chemical element.** A chemical element is distinguished by the simplicity of its atomic composition. When a sample of a chemical element is broken down into atoms, all the atoms are the same. Each chemical element has a unique name, such as hydrogen, carbon, oxygen, uranium, tantalum, and iron. (See Box 1-2 for an overview of how elements have been named.) Each element can be represented by a unique one- or two-letter symbol. For example, the symbol for hydrogen is H, oxygen's symbol is O, and nitrogen's symbol is N. The first letter of its English name serves as the symbol for nine other elements: B, C, F, I, P, S, U, V, and Y. When more than one element begins with the same English letter, a second letter is added to the symbol. For example, carbon is C, cobalt is Co, and chromium is Cr. To a chemist the symbol for an element is not just a letter or letters. Instead, a chemist sees the symbol Ni and immediately thinks of nickel *atoms.*

The artificial elements that have been made in recent years have three-letter symbols, as described in Box 1-2, but we do not deal with these elements.

BOX 1-2

NAMING ELEMENTS

Until recently the person who discovered an element named it. The name often referred to one of the element's properties. The Romans gave copper its name, *cuprum,* after the island Cyprus, where copper was mined during antiquity. Bromine, first isolated in 1826, received its name from the Greek word *bromos,* meaning "stench." If you ever work with bromine, you will understand the reason for its name.

When scientists began creating artificial elements, the naming process became somewhat more obscure. Technetium, the first element to be created in the laboratory, received its name from the Greek word for artificial, *technitos.* Neptunium and plutonium were named for planets because they were made from uranium, which is named for a planet as well. (It is uncertain why uranium is named for a planet.) The names of americium (element number 95), berkelium (97), and californium (98) honor the country, city, and state where the experiments that first manufactured them were performed. Curium (96), einsteinium (99), fermium (100), mendelevium (101), nobelium (102), and lawrencium (103) all honor famous scientists.

When elements after number 103 were created, a political impasse developed. The creations of some of these elements were reported virtually simultaneously in 1970 by scientists in what was then the Soviet Union and in the United States. Each group proposed different names. Perhaps because of the political antagonism between the two countries at that time, neither group would relinquish its "right" to name the new elements. Finally, the International Union of Pure and Applied Chemistry (IUPAC) decreed a compromise.

The IUPAC decided that the names of elements beyond number 103 should use the Latin words for their numbers: *nil-* for zero, *un-* for one, and so on. Thus element 104 becomes unnilquadium, 106 is unnilhexium, and so forth. The symbols for these elements are three letters derived from their names, so element 104 is symbolized Unq, element 106 is Unh, and so on.

Many scientists view this as an unfortunate compromise. The names are awkward to pronounce, the three-letter symbols break with tradition, and the symbols are easy to confuse because elements 104 to 109 all begin with *Un (unnil-).* Perhaps the very awkwardness of this scheme will encourage scientists to find a way to return to the tradition that gave us colorful, evocative elemental names such as xenon (from the Greek *xenos,* meaning "stranger") and rubidium (from Latin, meaning "dark red").

The elements listed in Table 1-1, most of which are metals, have symbols derived from their names in other languages. These elements were well known from early times, so their symbols reflect the Latin language that was dominant when they were named.

CHEMICAL FORMULAS

A chemical compound is a substance that contains more than one element. However, the relative amounts of each element in a particular compound do not change. Every molecule of a particular chemical substance contains a characteristic number of atoms of its constituent elements. Water molecules, for example, *always* contain two hydrogen atoms and one oxygen atom. To describe this atomic composition, chemists write the chemical formula for water as H_2O.

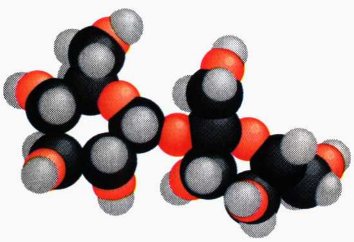
Not all chemical compounds exist as molecules. Some compounds are made up of chemical species called *ions.* We introduce and describe ions in Chapter 2.

TABLE 1-1 ELEMENTAL SYMBOLS WITH NON-ENGLISH ROOTS

NAME	SYMBOL	ROOT	LANGUAGE
Sodium	Na	Natrium	Latin
Potassium	K	Kalium	Latin
Iron	Fe	Ferrum	Latin
Copper	Cu	Cuprum	Latin
Silver	Ag	Argentum	Latin
Tin	Sn	Stannum	Latin
Antimony	Sb	Stibium	Latin
Tungsten	W	Wolfram	German
Gold	Au	Aurum	Latin
Mercury	Hg	Hydrargyum	Latin
Lead	Pb	Plumbum	Latin


Carbon monoxide


Methane


Sucrose

We explore chemical formulas in greater detail in Chapter 3.

The chemical formula for water illustrates how formulas are constructed. The formula lists the symbols of all elements found in the chemical compound, in this case H (hydrogen) and O (oxygen). A subscript number after the elemental symbol denotes how many atoms of that element are present in the molecule. The subscript 2 in the formula for water indicates that each molecule contains two hydrogen atoms. No subscript is used when only one atom is present, as is the case for the oxygen atom in a water molecule. Molecules always contain whole numbers of atoms because atoms are indivisible. Consequently, the subscripts in chemical formulas are always integers.

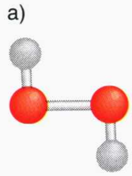
Molecules vary considerably in complexity. A carbon monoxide molecule is made of one atom of carbon and one atom of oxygen, so its chemical formula is CO. Methane, the major constituent of natural gas, is somewhat more complicated. Its molecules contain one carbon atom and four hydrogen atoms, so its formula is CH_4. Cane sugar, the chemical name of which is *sucrose,* is a still more complicated combination of carbon, hydrogen, and oxygen; its formula is $C_{12}H_{22}O_{11}$.

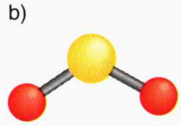
SECTION EXERCISES

1.2.1 What are the elemental symbols for cerium, cesium, copper, calcium, and carbon?

1.2.2 What are the names of the elements represented by the following symbols: Zr, Ni, Re, Sn, W, Se, Eu, Be, and Au?

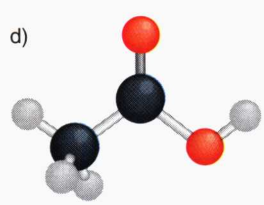
1.2.3 Molecular models of some common molecules are shown here. What are their formulas?

a)

Hydrogen peroxide (a common disinfectant and bleaching agent)

b)

Sulfur dioxide (a common air pollutant)

c)

Dinitrogen monoxide (laughing gas)

d)

Acetic acid (vinegar)