Understanding CHEMISTRY

Chip Lovett
Raymond Chang

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Raymond Chang
Williams College

McGraw Hill Higher Education

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UNDERSTANDING CHEMISTRY

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In Memory of James F. Skinner (1940–1988)—
A Dedicated Chemical Educator and a Cherished Friend

Chip Lovett
Raymond Chang

About the Authors

Chip Lovett

Chip Lovett was born in Long Island, New York, and began his college career studying architecture. During a seven-year hiatus from college he worked as a portrait artist, musician, truck driver, and postal worker. He returned to school and took his first chemistry course at the age of 26. He received his B.S. and M.S. in chemistry from California State Polytechnic University at Pomona, and his Ph.D. in biochemistry from Cornell University.

In 1985 he joined the chemistry department at Williams College, where he teaches courses on introductory chemistry, biochemistry, and AIDS. His major research interest is understanding how protein molecules control the way genes are turned on and off. His research at Williams has involved more than 70 undergraduate students and has resulted in numerous scientific publications dealing with the control of DNA repair genes.

He has served as Director of the Science Center at Williams since 1993 and directs summer science programs for children, elementary-school teachers, and incoming college students.

For relaxation, Professor Lovett plays the guitar and the piano and enjoys skiing, motorcycling, and horseback riding.

Raymond Chang

Raymond Chang was born in Hong Kong and grew up in Shanghai and Hong Kong, China. He received his B.Sc. degree in chemistry from London University, England, and his Ph.D. in chemistry from Yale University. After doing postdoctoral research at Washington University and teaching for a year at Hunter College of the City University of New York, he joined the chemistry department at Williams College, where he has taught since 1968.

Professor Chang has served on the American Chemical Society Examination Committee, the National Chemistry Olympiad Examination Committee, and the Graduate Record Examination (GRE) Committee. He is an editor of *The Chemical Educator*. Professor Chang has written books on physical chemistry, industrial chemistry, and physical science. He has also coauthored books on the Chinese language, children's picture books, and a novel for juvenile readers.

For relaxation, Professor Chang maintains a forest garden; plays tennis, Ping-Pong, and the harmonica; and practices the violin.

Preface

We wrote *Understanding Chemistry* specially for students taking chemistry for the first time, either in high school or college. It is not a textbook in the conventional sense because it does not have the encyclopedic coverage of topics that you will find in a general chemistry text. We have carefully selected areas that we believe are essential for building a sound foundation for learning and understanding chemistry. Because students are often intimidated by chemistry and by chemistry textbooks, we have used a number of strategies to make this book readable, user friendly, and pedagogically effective: familiar analogies to help explain abstract ideas; cartoons (created and drawn by Chip Lovett) to help students visualize chemical processes at the molecular level and to provide some comic relief in the learning process; and portraits of scientists describing their important discoveries to add a personal touch and to serve as a useful tool for remembering facts and concepts.

Because problem-solving is a major part in learning chemistry, we have provided a number of worked examples in the text. To learn how to solve problems you must practice, so we have created a website (www.understandingchemistry.com) with many worked examples and problems, as well as further discussion of topics. You will also find numerous colored molecular models and animations on the Web that will help you visualize the three-dimensionality of molecules and chemical reactions.

We hope you will find that this book is just what you need to get the most out of your introductory chemistry course, to help you understand concepts and do well on tests, and finally, to appreciate what a fascinating subject chemistry really is.

Features

- Unique cartoons lend themselves to understanding the chemistry behind the concept they are representing. They act as visual tools to help commit a chemical concept into memory.
- Analogies are used freely throughout the text to help understand abstract concepts.
- Worked examples take you through a step-by-step process to build problem-solving skills.
- A summarizing problem at the end of most chapters will tie topics together. The problem takes you through strategizing and solving an inclusive problem.

Media

An easy-to-use website has been created to complement *Understanding Chemistry* as a companion to the text.

- Practicing problems is a necessary requirement for succeeding in and mastering chemistry. A multitude of various problem types are provided on the site for student practice.
- Answers to the questions posted in the text and on the website are provided.
- Molecular models and animations to enhance the understanding of chemical concepts are presented.
- A periodic table with historical background is provided to understand the naming conventions of the elements.
- A database of links to other sites is provided for further information.

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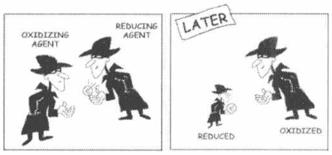
Chip Lovett
Raymond Chang

A Student Walk-Through

***U**nderstanding Chemistry* is not a textbook in the conventional sense because it does not have the encyclopedic coverage of topics that you will find in a general chemistry text. Carefully selected areas are presented that are essential for building a sound foundation for learning and understanding chemistry.

Major Types of Chemical Reactions 41



This reaction is an example of a redox reaction. The sodium metal, which has lost an electron, is said to be *oxidized*, and the chlorine molecules, which accept electrons, are said to be *reduced*. For this reason, Na is also called a **reducing agent** (because it reduces Cl_2 molecules), and Cl_2 is called an **oxidizing agent** (because it oxidizes the Na metal). This may seem confusing, but it's simply the result of the definitions of oxidation and reduction previously given. A useful mnemonic for redox reactions is OILRIG: **O**xidation **I**s **L**oss (of electrons) and **R**eduction **I**s **G**ain (of electrons).

There are many examples of redox reactions. Calcium metal reacts with oxygen to form calcium oxide (CaO):

$$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$$

In terms of half-reactions, we write

$$2Ca \longrightarrow 2Ca^{2+} + 4e^- \qquad \text{oxidation}$$
$$O_2 + 4e^- \longrightarrow 2O^{2-} \qquad \text{reduction}$$

(Recall that Ca is a Group 2A element, so we expect each Ca atom to lose two electrons to form the Ca^{2+} ion.) Here, Ca is the reducing agent because it loses electrons, and O_2 is the oxidizing agent because it accepts electrons.

When we add zinc metal to a copper sulfate ($CuSO_4$) solution, we observe the disappearance of the blue color (due to Cu^{2+} ions in water) as a result of the reaction

$$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$$

or, in terms of net ionic equation

$$Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$$

Note that SO_4^{2-} is a spectator in this reaction. The electron-transfer process can be represented by the half-reactions

$$Zn \longrightarrow Zn^{2+} + 2e^-$$
$$Cu^{2+} + 2e^- \longrightarrow Cu$$

So far so good. However, it turns out that the vast majority of redox reactions do not involve the *complete* transfer of electrons. Consider, for example, the reaction between hydrogen and chlorine gases:

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

Unique Cartoons

Cartoons lend themselves to understanding the chemistry behind the concept they are representing. They act as visual tools to help commit a chemical concept into memory.

Analogies

Used freely throughout the text, analogies are another source of learning and retaining chemical knowledge.

28 CHAPTER 2 *Building a Foundation*

mass number, 11	nonmetal, 14	proton, 9
metal, 14	nucleus, 9	representative element, 21
metalloid, 14	oxoacid, 23	solubility, 25
molecular compound, 20	oxoanion, 23	solute, 25
molecule, 15	period, 13	solution, 25
monatomic, 18	periodic table, 12	solvent, 25
monoprotic acid, 24	physical property, 25	transition metal, 22
neutron, 10	polar molecule, 26	triporotic acid, 24
noble gas, 15	polyatomic anion, 18	
nonelectrolyte, 25	polyatomic molecules, 16	

CONCEPTS

Explain in your own words:

- The structure of an atom.
- The difference between metals and nonmetals.
- The difference between molecules and ionic compounds and how to distinguish between the two based on their chemical formulas.
- The physical properties of boiling point, melting point, and solubility and how these properties differ among molecular and ionic compounds.

UNDERSTANDING CHEMISTRY

To test your overall understanding of the material in this chapter, use what you have learned to answer this question: What comes to mind when you look at a chemical formula? For example, consider the chemical formula Na_2CO_3.

You should immediately note that the compound is made of a metal and two nonmetals so it is probably ionic (and named accordingly). Each of the Na atoms would have lost an electron to become a sodium ion, a cation, and the rest of the compound must be the anion. You should recognize the anion as carbonate with a charge of −2. Thus, the name of this ionic compound is sodium carbonate. Because it's ionic, it must be a solid at room temperature and have a high melting point and boiling point. You might also expect it to dissolve in a polar solvent such as water. If all this comes to mind when you read Na_2CO_3, you are understanding chemistry. A useful mental exercise to aid in your understanding of chemistry would be to go through a similar analysis whenever you look at a chemical formula. This will help you think about chemicals in terms of their structure and properties and not just as an abstract string of letters.

EXAMPLE 3.2

Write a balanced equation to represent the reaction between sodium metal (Na) and water to form sodium hydroxide (NaOH) and hydrogen gas (H_2).

Answer *First we write*

$$Na + H_2O \longrightarrow NaOH + H_2$$

We see that both the Na and O atoms are balanced, but the H atoms are not. Because the H atoms will always be even on the left of the arrow, we multiply NaOH by 2 so that the H atoms are also even on the right of the arrow and obtain

$$Na + H_2O \longrightarrow 2NaOH + H_2$$

All that is left is to add a "2" to both Na and H_2O to arrive at the final equation:

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

The final tally shows that there are two Na atoms, four H atoms, and two O atoms on both sides of the arrow.

Visit the website for more problems on balancing chemical equations.

Worked Examples

Worked examples take you through a step-by-step process to guide you through similar problems.

Synopsis Problems

A synopsis problem at the end of most chapters tie the chapter together. The problem takes you through strategizing and solving an inclusive problem.

Media Walk-Through

An easy-to-use website has been created to complement *Understanding Chemistry* as a companion to the text.

Practice Problems

Practicing problems is a necessary requirement for succeeding and mastering chemistry. A multitude of various problem types are provided on the site for student practice.

Answers to the questions posted in the text and on the website are provided.

Example 3.16 Titanium is a strong, lightweight, corrosion-resistant metal that is used in rockets, aircraft, jet engines, and bicycle frames. It is prepared by the reaction of titanium(IV) chloride with molten magnesium between 950°C and 1150°C:

$$TiCl_4(g) + 2Mg(l) \longrightarrow Ti(s) + 2MgCl_2(l)$$

In a certain industrial operation 3.54×10^7 g of $TiCl_4$ are reacted with 1.13×10^7 g of Mg. (a) Calculate the theoretical yield of Ti in grams. (b) Calculate the percent yield if 7.91×10^6 g of Ti are actually obtained.

Reasoning and Solution We follow the procedure in Example 3.15 to find out which of the two reactants is the limiting agent. This knowledge will enable us to calculate the theoretical yield. The percent yield can then be obtained by applying Equation (3.4).

(a) First we calculate the number of moles of $TiCl_4$ and Mg initially present:

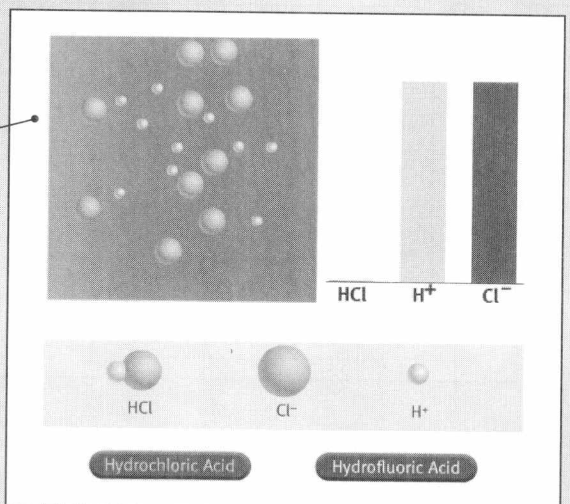
$$\text{moles of } TiCl_4 = 3.54 \times 10^7 \text{ g } TiCl_4 \times \frac{1 \text{ mol } TiCl_4}{189.7 \text{ g } TiCl_4} = 1.87 \times 10^5 \text{ mol } TiCl_4$$

$$\text{moles of Mg} = 1.13 \times 10^7 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}} = 4.65 \times 10^5 \text{ mol Mg}$$

Next, we must determine which of the two substances is the limiting reagent. From the balanced equation we see that 1 mol $TiCl_4 \simeq$ 2 mol Mg; therefore, the number of moles of Mg needed to react with 1.87×10^5 moles of $TiCl_4$ is

Molecular Models/Animations

Molecular models and animations to enhance the understanding of chemical concepts are presented.



Contents

In the Beginning

Read this first!

CHAPTER 1

In the beginning there were **atoms,**[1] **molecules,** and **ions.** After years of thinking about the world around them, people from every corner of Earth began to explore and discover the properties of the stuff we call matter. From these discoveries sprung chemistry—the science of matter. The first chemical experiments (performed thousands of years ago) probably involved testing the properties of different metals to make better weapons or testing the ability of plant extracts to treat illness. Priorities haven't changed much since then. With the eventual discovery of atoms and **compounds,** it seemed that it would be possible to actually understand why the material components of life and Earth behave the way they do. As scientists became intent on understanding the properties of substances, chemical experiments became more focused on testing hypotheses about the nature of matter. Scientists and students alike were excited about the subject of chemistry. Along the way, an enormous amount of knowledge about the structure and properties of atoms, molecules, and ions was acquired. To communicate this newfound knowledge, new words had to be invented to describe previously unknown substances and their behavior. Using this new chemical language, scientists began describing in textbooks the knowledge gleaned from countless experiments—and the textbooks kept growing in size. Textbooks for introductory chemistry are now so full of information that it would be practically impossible for anyone to learn it all in a year. This situation presents a challenge for chemistry teachers because students can't discern what information is essential to understanding chemistry and what information is not as important. To *understand* chemistry, a student needs to learn only a handful of concepts and principles that form the foundation for the science of matter—living and nonliving alike.

We designed this book for students taking chemistry for the first time, either in high school or college. It's also for students who have studied some chemistry but feel they really don't understand it. It's especially for students who find chemistry formidable, intimidating, scary, difficult, or just plain impenetrable. As chemistry teachers, we've encountered too many students who believe they really can't understand chemistry—students who take the introductory course like a bitter pill, hoping to come out of it with a decent grade. Of course, many students avoid the subject altogether. (This wasn't possible 100 years ago when all college students had to take chemistry!) We wrote this book because we honestly believe that everyone can understand chemistry at the introductory level and because we want to help students

1. Words in boldface are defined in the glossary and described in later chapters.

appreciate a subject that provides the basis for understanding everything that deals with matter.

The Three Objectives of This Book

This book was written with three objectives in mind: (1) to focus only on those topics that are *essential* to really understand chemistry, (2) to help the readers through the usual *hurdles* in a beginning chemistry course in ways that will make sense to them, and (3) to present the subject in a way that the readers *understand, remember, and enjoy*. We believe these are the most important objectives for helping everyone who uses this book to master all of the material that we describe, to do well in his or her chemistry course, and to be on solid ground for more advanced topics.

The Essentials

Chemistry is the study of atoms, molecules, and ions—that is, what they look like (or their structure) and how they behave. Understanding chemistry means having a working knowledge of the structure of these elementary particles and how (and why) they interact with one another. The good news is that both the structure and behavior of atoms, molecules, and ions are logical and in most cases predictable, and we will do our best to convince you of this fact. In this book, we have chosen to present only the information that we think is absolutely essential for you to acquire this knowledge.

The Hurdles

Chemistry deals with a world so tiny that it's invisible to the casual observer. Although chemists have devised equipment and techniques to observe the atoms and molecules that make up this tiny world, most people are still not comfortable thinking about things that they can't see. The first hurdle you must overcome in understanding chemistry is to learn to visualize these tiny particles—to think of them as objects with shapes and sizes (all small, of course). This is particularly important because it will help you deal with the assortment of abstract symbols, formulas, and equations—all couched in a foreign language. Without imagining what molecules look like, chemistry students can only associate unfamiliar words with an unfamiliar collection of symbols, formulas, and equations. Understanding chemistry on these terms would be extremely difficult and definitely no fun. You have to associate the language of chemistry and the symbols, formulas, and equations with the images of atoms and molecules themselves. Imagine trying to learn the word for "apple" in a foreign language if you have never seen (or eaten) an apple; the word would have little meaning because you wouldn't know what an apple is.

Another hurdle you must overcome is looking for and focusing on the common conceptual themes that relate all of chemistry. There is so much information in general chemistry textbooks that it's really hard for the beginning student to sort out what's essential for understanding the subject and what are merely details, trivia, and exceptional cases. Textbook authors are obliged to provide all of the information relevant to an introduction to chemistry (and we're glad they do), but you don't have to know it all to understand chemistry. Despite the best efforts of textbook authors and chemistry teachers, students often view all this information as an enormous collection of unrelated facts. In fact, there are only a few underlying themes that form the basis of chemistry, and once you understand them, the rest is relatively easy to add to the foundation of this knowledge. You may even find the details, trivia, and exceptional cases pretty interesting (as we do).

The third hurdle you must overcome is solving quantitative problems. Chemistry is an experimental science based in large part on drawing conclusions from measurements. Although general chemistry courses require some relatively straightforward calculations, students often see each problem as new and different. If this were the case, one would have to learn hundreds of different approaches to solve homework and exam problems. Again, chemistry would be an unreasonably difficult subject if this were the case. On the contrary, there are only a few different types of problems in general chemistry, but many variations of each type. So you need to learn only a few procedures (or approaches), but you also must learn to recognize the method needed to solve a particular problem.

Understanding, Remembering, and Enjoying Chemistry

The design of this book was inspired by our observation that students learn best when they enjoy the process and when they can engage themselves with the subject in a familiar and interesting context. We wanted it to be both an enjoyable read as well as a clear and friendly guide. To accomplish this goal, we have included pictures, some history, and many commonplace analogies to embellish the concepts.

Because chemistry deals mostly with things we can't normally see, the use of visual aids is especially important in understanding and remembering the subject. We have included many figures and cartoons to elaborate the formulas, equations, and text, and to add a human touch to the subject. These visual supplements will help you understand the concepts, and we hope they will also help you remember them. Another way to make chemistry memorable is to personalize it. Science is ultimately a very personal enterprise because scientists are people with their own individual pleasures, dreams, and biases. We have included information and pictures of some of the scientists who have pioneered the study of chemistry in the hope that this, too, will help you remember the concepts they helped develop.

There are many concepts in chemistry that are pretty abstract, and their development by scientists has often involved insights based on everyday experiences. Because it's always easier to understand something unfamiliar by relating it to something familiar, we have provided common analogies to illustrate the more abstract concepts. You may be surprised to learn that even the most brilliant scientists try to understand their work in the simplest terms. Many scientific discoveries might never have been made if scientists didn't try to reduce their results to the simplest possible explanation. The 14th-century scholastic monk William of Ockam has been cited by many generations of scientists for his insistence on economical explanations. He is often credited with saying, "If two theories explain the facts equally well, then the simpler theory is to be preferred." This principle, known as Ockam's razor, has inspired many scientists. In this book we have reduced introductory chemistry to the simplest explanation of the facts. We have also limited our focus on those facts that are essential to achieving a basic understanding of the structure and properties of atoms, molecules, and ions. Most of what you will learn is just variations on a few basic themes.

What Will You Have to Do to Understand Chemistry?

If you want to understand general chemistry (and do well on your exams), you will have to do the following:

- Learn to speak the language.
- Learn a handful of conceptual themes.
- Learn how to recognize and solve a few different types of quantitative problems.

The Language

Speaking the chemical language involves learning the names of chemicals and learning the terms used to describe fundamental processes and concepts.

Learning the names for chemicals turns out to be much easier than learning the names of your friends, acquaintances, and teachers. (Chemists use the term *nomenclature* for the naming system; it's from the Latin word *nomenclatura,* meaning "a list of names.") Learning the names of people is pure memorization—you have to memorize every individual's name because there are no rules that tell you a particular face should have a particular name (and it doesn't make it easier that some people have the same first name).

In chemistry there are simple rules for naming chemicals from a chemical formula (e.g., CO_2); without these rules, it would be impossible for anyone to learn the name of every chemical. You will have to memorize the rules, but there aren't very many. You will also have to memorize the names of a relatively small number of atoms and molecular species, and you may already know the names of some of these. The rules are given in Chapter 2, along with some useful tricks for memorizing the names of some molecular species. You can be sure that your first exam will have a question or two on nomenclature, and there is no good reason to lose any points on them, because it's not that hard.

You probably already know the names for some fundamental processes like melting, freezing, and boiling, as well as the names of some concepts like temperature, pressure, and heat. But you probably haven't thought about these concepts in terms of atoms and molecules (from which they ultimately derive their effects). Throughout this book, we will highlight all of the terms you should know and understand. These are words that can be found in the glossary of this book. Test yourself at the end of each chapter by trying to explain as much as you can about the highlighted words in the chapter.

The Conceptual Themes

Chemists are interested in understanding three fundamental properties of chemicals—their *structure,* their *physical behavior,* and their *chemical behavior.* Now that might sound rather dry, but to appreciate the relevance of what chemists do, you only have to realize that chemicals comprise everything—some chemists study water, some study DNA, some study drugs, and some study molecules that may someday run our computers. There are certain conceptual themes that underlie each of these three fundamental properties, and the structure and behavior of the millions of chemicals in the world are simply variations on these themes. Your mastery of general chemistry depends on learning these themes and how to recognize them in the chemical world. **An overarching theme is that for every substance the three fundamental properties are all interrelated.** A good exercise to practice throughout your study of chemistry is to ask how these properties are interrelated for specific substances. We will remind you of this point throughout the book.

Structure

What do molecules look like? The study of chemical structure in an introductory course mainly involves small molecules, but big molecules like antibiotics, proteins, and DNA are built with precisely the same structural features as for small molecules. Molecular structure is nothing more than simple geometry in which atoms are connected to each other by chemical bonds. There are essentially only five basic geometries that govern the construction of most molecules (and a majority of the molecules in the world use only three of them). The key to understanding structure is learning how atoms are connected to form a particular geometry. In general, we will be concerned with only a handful of different atoms. Moreover, this process is further simplified when you realize that atoms in the same vertical column in the **periodic table** usually form similar geometric structures when they combine with other atoms.

Physical Behavior

The physical behavior of chemicals includes everything that happens to a substance without changing its identity. As you will see later in this book, these are properties that don't involve breaking or making chemical bonds. For example, melting ice is physical behavior (or a **physical property**) because you start with water molecules in solid form and produce identical water molecules in the liquid state. Another physical property of water is its ability to dissolve sugar. A more elaborate example of a physical property is the interaction of a protein hormone with a site on DNA to turn on the expression of a particular gene. All of these examples, and many more, are based on one conceptual theme: **a positive charge attracts a negative charge**—like the opposite poles on a magnet. This electrostatic attraction underlies the forces that govern the physical behavior of matter, as well as the formation of the thousands of different ionic compounds.

Chemical Behavior

The chemical behavior (or **chemical property**) of substances is usually described in terms of **chemical reactions,** or what happens when one or more substances interact to produce other substances. In a chemical reaction, the bonds that hold atoms together in molecules are broken, and new bonds are formed. If you think of chemical reactions as processes that are accompanied by flames or explosions, you are already aware of a conceptual theme that is associated with every chemical reaction: **Energy is either produced or consumed in chemical reactions.**

To understand chemical reactions, it is especially important for you to realize that **most chemical reactions involve either the transfer of protons or the transfer of electrons**—those elementary particles that you may already be familiar with as the components of all atoms. (Chapters 2 and 6 describe these particles in the context of atomic structure.) Thus, we have two types of processes, proton transfer and electron transfer, that form the basis for nearly all chemical reactions.

An important concept inherent to both physical and chemical processes is **chemical equilibrium.** It applies to every chemical reaction that is reversible (and most of them are). A simple example of equilibrium is a closed container filled partially with water. Because the water molecules are constantly moving around, some at the surface will have enough energy to break away from the forces holding them in the bulk liquid. These free molecules become part of water vapor above the liquid, but the freed molecules can collide with the water and become part of the liquid again. Eventually, the number of water molecules in the vapor is sufficient to cause the rate of molecules returning to the water to equal the rate of molecules leaving the water. At this point, the number of water vapor molecules remains constant, and the system is at equilibrium. The situation is similar for a chemical reaction in which two molecules (the reactants) collide with one another to form two different molecules (the products). If the reaction is reversible, products can also collide with one another to form the same reactants. The difference between the evaporation and condensation of water and the chemical reaction is that the latter involves changing the identity of the molecule by breaking and making chemical bonds, while the former involves only breaking the forces that hold molecules together in the liquid or solid state. Every equilibrium situation involves one or the other or both—just variations on the same themes.

Thus, the conceptual themes that are important in general chemistry include the following:

1. Structure, physical properties, and chemical properties are interrelated.
2. Structure is simply geometry in which atoms are connected by chemical bonds.
3. A positive charge attracts a negative charge.
4. Energy is either produced or consumed in chemical reactions.
5. Most chemical reactions involve either the transfer of protons or the transfer of electrons.
6. Many chemical reactions reach equilibrium where the amounts of reactants and products remain constant.

The Problems

Chemistry is an experimental science that relies heavily on taking measurements at the macroscopic level to determine what's happening at the molecular level. Most of the problems you will have to solve in general chemistry involve converting macroscopic measurements into information about molecular details. The good news is that you will encounter only a few different types of problems, and we will show you how to systematically solve them using straightforward approaches. You will then need to learn to recognize only the particular type of problem.

There are three keys to problem solving: practice, practice, practice. You should keep at it until you are confident that you can solve any problem of each type. Your chemistry teacher will assign plenty of problems, and if you need more practice, we have provided lots of them on the website. To master problem solving in chemistry, you must realize and constantly remind yourself that these are all variations on a relatively small number of different problem types.

Students have trouble with chemistry problems because they either don't practice and/or they treat every problem they encounter as something requiring a new and totally different solution strategy.

Getting the Most Out of Your Chemistry Class

We assume that you are reading this book because you are taking a chemistry class. Although the expectations and testing methods may differ somewhat among chemistry classes, the following suggestions should maximize both your understanding of the course material and your performance on exams in any course.

Attend class. Get there for the start of the class when important announcements are made or handouts are distributed. It's also a good idea to sit in the front row. You will be less distracted by others in the class, and if for some reason your final grade ends up on the borderline between an A and a B, your teacher is more likely to look at your case favorably.

Take careful notes and be sure you understand them. Your understanding of the material introduced in class will be greatest if you take the time to read through your class notes on the same day of class, when the lecture (including any demonstrations) is still fresh in your mind. At that time you should note points of confusion and get them cleared up (preferably, with your teacher) before the next class period. **The best way to be sure that you understand the material is to try to explain it to someone else.** The old adage that you never really learn something until you teach it is often true with chemistry. Not only will explaining the material in your own words reinforce your understanding of it, you will easily identify the parts you don't understand.

Read assigned sections from the textbook before the class in which the topics will be discussed. Make notes in the margins of your text, especially for topics that you don't completely understand. Why do you think they put those big margins in chemistry textbooks? Throw away your highlighters and write extensively in your textbook. Making your own notes is a much more active process and will prime you for getting the most out of the lecture. You might find it helpful to refer to the text again after class to help clear up points discussed in lecture.

Do the assigned homework problems systematically as the material is covered in class. Promptly work on problems that relate to material just covered in a lecture. You should also refer to the relevant examples in your text when working on problems. It's often helpful to work on problems with your classmates, provided everyone is actively engaged in the process. This practice also gives you an opportunity to try your hand at explaining the material to someone else.

Don't confuse quantity of studying with quality of studying. Going into solitary confinement with your chemistry book for six hours or "pulling an all-nighter" is an extremely poor way to study (and a waste of time). Most people can't concentrate effectively on the same subject for more than two to three hours at one stretch. Studying chemistry for two hours on three successive days will likely result in a much better retention than putting in six hours on a single night (especially if the exam is the next day).

In reviewing homework problems prior to an exam, don't simply read through your answers to the problems. This method is very passive and teaches you little. Read the problem, cover your answer, and think logically through the steps you follow to answer the problem. In some cases, drawing a simple picture can help you organize your thoughts and better understand what is asked of you.

Review sessions with your classmates can be very helpful. While it is probably best to do much of your studying alone in a quiet place, review sessions with several students preparing for a quiz or an exam can be very effective. Students are usually more willing to expose their confusion to one another than to a teacher. And as we've said before, explaining a given point to another student is an excellent way to test and reinforce your own understanding of the subject.

Take advantage of your teacher's office hours. Your teacher is an extremely valuable resource. If you don't understand something, ask your teacher as soon as possible. The parts you don't understand will likely provide background for later material so don't wait to get it cleared up. Again, if for some reason your final grade ends up on the borderline between an A and a B, your teacher will be more likely to push it upward if you show up at office hours and demonstrate that you are serious about learning the material. Here's a useful hint: Before you appear in your teacher's office, make a list of the things that are unclear to you so you don't waste his or her time by flipping through pages of your textbook or notes, frantically trying to locate places that gave you trouble. Remember that the first step toward understanding a concept is being able to