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Chemistry: An Introduction

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● Chemistry deals with the natural world.
(Dr. John Brackenbury/Science Photo Library/Photo Researchers, Inc.)



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Did you ever see a fireworks display on July Fourth and wonder how it's possible to produce those beautiful, intricate designs in the air? Have you read about dinosaurs—how they ruled the earth for millions of years and then suddenly disappeared? Although the extinction happened 65 million years ago and may seem unimportant, could the same thing happen to us? Have you ever wondered why an ice cube (pure water) floats in a glass of water (also pure water)? Did you know that the “lead”

in your pencil is made of the same substance (carbon) as the diamond in an engagement ring? Did you ever wonder how a corn plant or a palm tree grows seemingly by magic, or why leaves turn beautiful colors in autumn? Do you know how the battery works to start your car or run your calculator? Surely some of these things and many others in the world around you have intrigued you. The fact is that we can explain all of these things in convincing ways using the models of chemistry and the related physical and life sciences.



Fireworks are a beautiful illustration of chemistry in action.

1.1 Chemistry: An Introduction

OBJECTIVE: To understand the importance of learning chemistry.

Although chemistry might seem to have little to do with dinosaurs, knowledge of chemistry was the tool that enabled paleontologist Luis W. Alvarez and his coworkers from the University of California at Berkeley to “crack the case” of the disappearing dinosaurs. The key was the relatively high level of iridium found in the sediment that represents the boundary between the earth’s Cretaceous (K) and Tertiary (T) periods—the time when the dinosaurs disappeared virtually overnight (on the geological scale). The Berkeley researchers knew that meteorites also have unusually high iridium content (relative to the earth’s composition), which led them to suggest that a large meteorite impacted the earth 65 million years ago, causing the climatic changes that wiped out the dinosaurs.

A knowledge of chemistry is useful to almost everyone—chemistry occurs all around us all of the time, and an understanding of chemistry is useful to doctors, lawyers, mechanics, business people, firefighters, and poets among others. Chemistry is important—there is no doubt about that. It lies at the heart of our efforts to produce new materials that make our lives safer and easier, to produce new sources of energy that are abundant and nonpolluting, and to understand and control the many diseases that threaten us and our food supplies. Even if your future career does not require the daily use of chemical principles, your life will be greatly influenced by chemistry.

A strong case can be made that the use of chemistry has greatly enriched all of our lives. However, it is important to understand that the principles of chemistry are inherently neither good nor bad—it's what we do with this knowledge that really matters. Although humans are clever, resourceful, and concerned about others, they also can be greedy, selfish, and ignorant. In addition, we tend to be shortsighted; we concentrate too much on the present and do not think enough about the long-range implications of our actions. This type of thinking has already caused us a great deal of trouble—severe environmental damage has occurred on many fronts. We cannot place all the responsibility on the chemical companies, because everyone has contributed to these problems. However, it is less important to lay blame than to figure out how to solve these problems. An important part of the answer must rely on chemistry.

One of the “hottest” fields in the chemical sciences is environmental chemistry—an area that involves studying our environmental ills and finding creative ways to address them. For example, meet Bart Eklund, who works in the atmospheric chemistry field for Radian Corporation in Austin, Texas. Bart's interest in a career in environmental science was fostered by two environmental chemistry courses and two ecology courses he took as an undergraduate. His original plan to gain several years of industrial experience and then to return to school for a graduate degree changed when he discovered that professional advancement with a B.S. degree was possible in the environmental research field. The multidisciplinary nature of environmental problems has allowed Bart to pursue his interest in several fields at the same time. You might say that he specializes in being a generalist.

The environmental consulting field appeals to Bart for a number of reasons: the chance to define and solve a number of research problems; the simultaneous work on a number of diverse projects; the mix of desk, field, and laboratory work; the travel; and the opportunity to perform rewarding work that has a positive effect on people's lives.

Among his career highlights are the following:

- Spending a winter month doing air sampling in the Grand Tetons, where he also met his wife and learned to ski;
- Driving sampling pipes by hand into the rocky ground of Death Valley Monument in California;
- Working regularly with experts in their fields and with people who enjoy what they do;
- Doing vigorous work in 100 °F weather while wearing a rubberized suit, double gloves, and a respirator; and
- Getting to work in and see Alaska, Yosemite Park, Niagara Falls, Hong Kong, the People's Republic of China, Mesa Verde, New York City, and dozens of other interesting places.



Courtesy, Bart Eklund

Bart Eklund checking air quality at a hazardous waste site.

Bart Eklund's career demonstrates how chemists are helping to solve our environmental problems. It is how we use our chemical knowledge that makes all the difference.

An example that shows how technical knowledge can be a "double-edged sword" is the case of chlorofluorocarbons (CFCs). When the compound CCl_2F_2 (originally called Freon-12) was first synthesized, it was hailed as a near-miracle substance. Because of its noncorrosive nature and its unusual ability to resist decomposition, Freon-12 was rapidly applied in refrigeration and air-conditioning systems, cleaning applications, the blowing of foams used for insulation and packing materials, and many other ways. For years everything seemed fine—the CFCs actually replaced more dangerous materials, such as the ammonia formerly used in refrigeration systems. The CFCs were definitely viewed as "good guys." But then a problem was discovered—the ozone in the upper atmosphere that protects us from the high-energy radiation of the sun began to decline. What was happening to cause the destruction of the vital ozone?

Much to everyone's amazement, the culprits turned out to be the seemingly beneficial CFCs. Inevitably, large quantities of CFCs had leaked into the atmosphere but nobody was very worried about this development because these compounds seemed totally benign. In fact, the great stability of the CFCs (a tremendous advantage for their various applications) was in the end a great disadvantage when they were released into the environment. Professor F. S. Rowland and his colleagues at the University of California at Irvine demonstrated that the CFCs eventually drifted to high altitudes in the atmosphere, where the energy of the sun stripped off chlorine atoms. These chlorine atoms in turn promoted the decomposition of the ozone in the upper atmosphere. (We will discuss this in more detail in Chapter 13.) Thus a substance that possessed many advantages in earth-bound applications turned against us in the atmosphere. Who could have guessed it would turn out this way?

The good news is that the U.S. chemical industry is leading the way to find environmentally safe alternatives to CFCs, and the levels of CFCs in the atmosphere are already dropping.

The saga of the CFCs demonstrates that we can respond relatively quickly to a serious environmental problem if we decide to do so. Also, it is important to understand that chemical manufacturers have a new attitude about the environment—they are now among the leaders in finding ways to address our environmental ills. The industries that apply the chemical sciences are now determined to be part of the solution rather than part of the problem.

As you can see, learning chemistry is both interesting and important. A chemistry course can do more than simply help you learn the principles of chemistry, however. A major by-product of your study of chemistry is that you will become a better problem solver. One reason chemistry has the reputation of being "tough" is that it often deals with rather complicated systems that require some effort to figure out. Although this might at first seem like a disadvantage, you can turn it to your advantage if you have the right attitude. Recruiters for companies of all types maintain that one of the first things they look for in a prospective employee is the ability to solve problems. We will spend a good deal of time solving various types of problems in this book by using a systematic, logical approach that will serve you well in solving any kind of problem in any field. Keep this broader goal in mind as you learn to solve the specific problems connected with chemistry.

Although learning chemistry is often not easy, it's never impossible. In fact, anyone who is interested, patient, and willing to work can learn



A chemist in the laboratory.

Dr. Ruth—Cotton Hero



AP Photo/Ric Ricberg

Ruth Benerito, the inventor of easy-care cotton.

Dr. Ruth Rogan Benerito may have saved the cotton industry in the United States. In the 1960s, synthetic fibers posed a serious competitive threat to cotton, primarily because of wrinkling. Synthetic fibers such as polyester can be formulated to be highly resistant to wrinkles both in the laundering process and in wearing. On the other hand, 1960s' cotton fabrics wrinkled easily—white cotton shirts had to be ironed to look good. This requirement put cotton at a serious disadvantage and endangered an industry very important to the economic health of the South.

During the 1960s Ruth Benerito worked as a scientist for the Department of Agriculture, where she was instrumental in developing the

chemical treatment of cotton to make it wrinkle resistant. In so doing she enabled cotton to remain a preeminent fiber in the market—a place it continues to hold today. She was honored with the Lemelson–MIT Lifetime Achievement Award for Inventions in 2002 when she was 86 years old.

Dr. Benerito, who holds 55 patents, including the one for wrinkle-free cotton awarded in 1969, began her career when women were not expected to enter scientific fields. However, her mother, who was an artist, adamantly encouraged her to be anything she wanted to be.

Dr. Benerito graduated from high school at 14 and attended Newcomb College, the women's college associated with Tulane University. She majored in chemistry with minors in physics and math. At that time she was one of only two women allowed to take the physical chemistry course at Tulane. She earned her B.S. degree in 1935 at age 19 and subsequently earned a master's degree at Tulane and a Ph.D. at the University of Chicago.

In 1953 Dr. Benerito began working in the Agriculture Department's Southern Regional Research Center in New Orleans, where she mainly worked on cotton and cotton-related products. She also invented a special method for intravenous feeding in long-term medical patients.

Since her retirement in 1986, she has continued to tutor science students to keep busy. Everyone who knows Dr. Benerito describes her as a class act.

the fundamentals of chemistry. In this book we will try very hard to help you understand what chemistry is and how it works and to point out how chemistry applies to the things going on in your life.

Our sincere hope is that this text will motivate you to learn chemistry, make its concepts understandable to you, and demonstrate how interesting and vital the study of chemistry is.

1.2

What Is Chemistry?

OBJECTIVE: To define chemistry.

Chemical and physical changes will be discussed in Chapter 3.

Chemistry can be defined as *the science that deals with the materials of the universe and the changes that these materials undergo*. Chemists are involved in activities as diverse as examining the fundamental particles of matter,



The launch of the space shuttle gives clear indications that chemical reactions are occurring.

looking for molecules in space, synthesizing and formulating new materials of all types, using bacteria to produce such chemicals as insulin, and inventing new diagnostic methods for early detection of disease.

Chemistry is often called the central science—and with good reason. Most of the phenomena that occur in the world around us involve chemical changes, changes where one or more substances become different substances. Here are some examples of chemical changes:

- Wood burns in air, forming water, carbon dioxide, and other substances.
- A plant grows by assembling simple substances into more complex substances.
- The steel in a car rusts.
- Eggs, flour, sugar, and baking powder are mixed and baked to yield a cake.
- The definition of the term *chemistry* is learned and stored in the brain.
- Emissions from a power plant lead to the formation of acid rain.

As we proceed, you will see how the concepts of chemistry allow us to understand the nature of these and other changes and thus help us manipulate natural materials to our benefit.

1.3 Solving Problems Using a Scientific Approach

OBJECTIVE: To understand scientific thinking.

One of the most important things we do in everyday life is solve problems. In fact, most of the decisions you make each day can be described as solving problems.

It's 8:30 A.M. on Friday. Which is the best way to drive to school to avoid traffic congestion?

You have two tests on Monday. Should you divide your study time equally or allot more time to one than to the other?

Your car stalls at a busy intersection and your little brother is with you. What should you do next?

These are everyday problems of the type we all face. What process do we use to solve them? You may not have thought about it before, but there are several steps that almost everyone uses to solve problems:

1. Recognize the problem and state it clearly. Some information becomes known, or something happens that requires action. In science we call this step *making an observation*.
2. Propose *possible* solutions to the problem or *possible* explanations for the observation. In scientific language, suggesting such a possibility is called *formulating a hypothesis*.

A Mystifying Problem

To illustrate how science helps us solve problems, consider a true story about two people, David and Susan (not their real names). Several years ago David and Susan were healthy 40-year-olds living in California, where David was serving in the Air Force. Gradually Susan became quite ill, showing flu-like symptoms including nausea and severe muscle pains. Even her personality changed: she became uncharacteristically grumpy. She seemed like a totally different person from the healthy, happy woman of a few months earlier. Following her doctor's orders, she rested and drank a lot of fluids, including large quantities of coffee and orange juice from her favorite mug, part of a 200-piece set of pottery dishes recently purchased in Italy. However, she just got sicker, developing extreme abdominal cramps and severe anemia.

During this time David also became ill and exhibited symptoms much like Susan's: weight loss, excruciating pain in his back and arms, and uncharacteristic fits of temper. The disease became so debilitating that he retired early from the Air Force and the couple moved to Seattle. For a short time their health improved, but after they unpacked all their belongings (including those pottery dishes), their health began to deteriorate again. Susan's body became so sensitive that she could not tolerate the weight of a blanket. She was near death. What was wrong? The doctors didn't know, but one suggested she might have porphyria, a rare blood disease.

Desperate, David began to search the medical literature himself. One day while he was reading about porphyria, a phrase jumped off the page: "Lead poisoning can sometimes be confused with porphyria." Could the problem be lead poisoning?

We have described a very serious problem with life-or-death implications. What should David

do next? Overlooking for a moment the obvious response of calling the couple's doctor immediately to discuss the possibility of lead poisoning, could David solve the problem via scientific thinking? Let's use the three steps described in Section 1.3 to attack the problem one part at a time. This is important: usually we solve complex problems by breaking them down into manageable parts. We can then assemble the solution to the overall problem from the answers we have found "piece-meal."

In this case there are many parts to the overall problem:

What is the disease?

Where is it coming from?

Can it be cured?

Let's attack "What is the disease?" first.

Observation: David and Susan are ill with the symptoms described. Is the disease lead poisoning?

Hypothesis: The disease is lead poisoning.

Experiment: If the disease is lead poisoning, the symptoms must match those known to characterize lead poisoning. Look up the symptoms of lead poisoning. David did this and found that they matched the couple's symptoms almost exactly.

This discovery points to lead poisoning as the source of their problem, but David needed more evidence.

Observation: Lead poisoning results from high levels of lead in the bloodstream.

Hypothesis: The couple have high levels of lead in their blood.

Experiment: Perform a blood analysis. Susan arranged for such an analysis, and the results showed high lead levels for both David and Susan.

- Decide which of the solutions is the best or decide whether the explanation proposed is reasonable. To do this we search our memory for any pertinent information or we seek new information. In science we call searching for new information *performing an experiment*.



Italian pottery.

This confirms that lead poisoning is probably the cause of the trouble, but the overall problem is still not solved. David and Susan are likely to die unless they find out where the lead is coming from.

Observation: There is lead in the couple's blood.

Hypothesis: The lead is in their food or drink when they buy it.

Experiment: Find out whether anyone else who shopped at the same store was getting sick (no one was). Also note that moving to a new area did not solve the problem.

Observation: The food they buy is free of lead.

Hypothesis: The dishes they use are the source of the lead poisoning.

Experiment: Find out whether their dishes contain lead. David and Susan learned that lead compounds are often used to put a shiny finish on pottery objects. And laboratory analysis of their Italian pottery dishes showed that lead was present in the glaze.

Observation: Lead is present in their dishes, so the dishes are a possible source of their lead poisoning.

Hypothesis: The lead is leaching into their food.

Experiment: Place a beverage, such as orange juice, in one of the cups and then analyze the beverage for lead. The results showed high levels of lead in drinks that had been in contact with the pottery cups.

After many applications of the scientific method, the problem is solved. We can summarize the answer to the problem (David and Susan's illness) as follows: the Italian pottery they used for everyday dishes contained a lead glaze that contaminated their food and drink with lead. This lead accumulated in their bodies to the point where it interfered seriously with normal functions and produced severe symptoms. This overall explanation, which summarizes the hypotheses that agree with the experimental results, is called a *theory* in science. This explanation accounts for the results of all the experiments performed.*

We could continue to use the scientific method to study other aspects of this problem, such as

What types of food or drink leach the most lead from the dishes?

Do all pottery dishes with lead glazes produce lead poisoning?

As we answer questions using the scientific method, other questions naturally arise. By repeating the three steps over and over, we can come to understand a given phenomenon thoroughly.

*"David" and "Susan" recovered from their lead poisoning and are now publicizing the dangers of using lead-glazed pottery. This happy outcome is the answer to the third part of their overall problem, "Can the disease be cured?" They simply stopped eating from that pottery!

As we will discover in the next section, scientists use these same procedures to study what happens in the world around us. The important point here is that scientific thinking can help you in all parts of your life. It's worthwhile to learn how to think scientifically—whether you want to be a scientist, an auto mechanic, a doctor, a politician, or a poet!

1.4 The Scientific Method

OBJECTIVE: To describe the method scientists use to study nature.

In the last section we began to see how the methods of science are used to solve problems. In this section we will further examine this approach.

Science is a framework for gaining and organizing knowledge. Science is not simply a set of facts but also a plan of action—a *procedure* for processing and understanding certain types of information. Although scientific thinking is useful in all aspects of life, in this text we will use it to understand how the natural world operates. The process that lies at the center of scientific inquiry is called the **scientific method**. As we saw in the previous section, it consists of the following steps:

Steps in the Scientific Method

1. *State the problem and collect data (make observations).* Observations may be *qualitative* (the sky is blue; water is a liquid) or *quantitative* (water boils at 100 °C; a certain chemistry book weighs 4.5 pounds). A qualitative observation does not involve a number. A quantitative observation is called a **measurement** and does involve a number (and a unit, such as pounds or inches). We will discuss measurements in detail in Chapter 2.
2. *Formulate hypotheses.* A hypothesis is a *possible* explanation for the observation.
3. *Perform experiments.* An experiment is something we do to test the hypothesis. We gather new information that allows us to decide whether the hypothesis is supported by the new information we have learned from the experiment. Experiments always produce new observations, and this brings us back to the beginning of the process again.

Quantitative observations involve a number. Qualitative ones do not.

To explain the behavior of a given part of nature, we repeat these steps many times. Gradually we accumulate the knowledge necessary to understand what is going on.

Once we have a set of hypotheses that agrees with our various observations, we assemble them into a theory that is often called a *model*. A **theory (model)** is a set of tested hypotheses that gives an overall explanation of some part of nature (see Figure 1.1).

It is important to distinguish between observations and theories. An observation is something that is witnessed and can be recorded. A theory is an *interpretation*—a possible explanation of *why* nature behaves in a particular way. Theories inevitably change as more information becomes available. For example, the motions of the sun and stars have remained virtually the same over the thousands of years during which humans have been observing them, but our explanations—our theories—have changed greatly since ancient times.

The point is that we don't stop asking questions just because we have devised a theory that seems to account satisfactorily for some aspect of natural behavior. We continue doing experiments to refine our theories. We generally do this by using the theory to make a prediction and then doing an experiment (making a new observation) to see whether the results bear out this prediction.

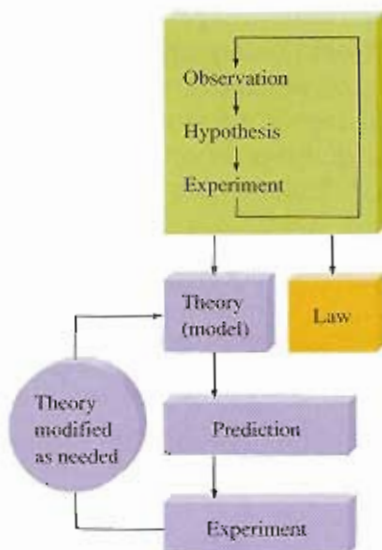


Figure 1.1

The various parts of the scientific method.

Law: A summary of observed behavior.

Theory: An explanation of behavior.

Always remember that theories (models) are human inventions. They represent our attempts to explain observed natural behavior in terms of our human experiences. We must continue to do experiments and refine our theories to be consistent with new knowledge if we hope to approach a more nearly complete understanding of nature.

As we observe nature, we often see that the same observation applies to many different systems. For example, studies of innumerable chemical changes have shown that the total mass of the materials involved is the same before and after the change. We often formulate such generally observed behavior into a statement called a **natural law**. The observation that the total mass of materials is not affected by a chemical change in those materials is called the law of conservation of mass.

You must recognize the difference between a law and a theory. A law is a summary of observed (measurable) behavior, whereas a theory is an explanation of behavior. *A law tells what happens; a theory (model) is our attempt to explain why it happens.*

In this section, we have described the scientific method (which is summarized in Figure 1.1) as it might ideally be applied. However, it is important to remember that science does not always progress smoothly and efficiently. Scientists are human. They have prejudices; they misinterpret data; they can become emotionally attached to their theories and thus lose objectivity; and they play politics. Science is affected by profit motives, budgets, fads, wars, and religious beliefs. Galileo, for example, was forced to recant his astronomical observations in the face of strong religious resistance. Lavoisier, the father of modern chemistry, was beheaded because of his political affiliations. And great progress in the chemistry of nitrogen fertilizers resulted from the desire to produce explosives to fight wars. The progress of science is often slowed more by the frailties of humans and their institutions than by the limitations of scientific measuring devices. The scientific method is only as effective as the humans using it. It does not automatically lead to progress.

1.5 Learning Chemistry

OBJECTIVE: To develop successful strategies for learning chemistry.

Chemistry courses have a universal reputation for being difficult. There are some good reasons for this. For one thing, the language of chemistry is unfamiliar in the beginning; many terms and definitions need to be memorized. As with any language, *you must know the vocabulary* before you can communicate effectively. We will try to help you by pointing out those things that need to be memorized.

But memorization is only the beginning. Don't stop there or your experience with chemistry will be frustrating. Be willing to do some thinking, and learn to trust yourself to figure things out. To solve a typical chemistry problem, you must sort through the given information and decide what is really crucial.

It is important to realize that chemical systems tend to be complicated—there are typically many components—and we must make approximations in describing them. Therefore, trial and error play a major role in solving chemical problems. In tackling a complicated system, a practicing chemist really does not expect to be right the first time he or she analyzes the problem. The usual practice is to make several simplifying assumptions and then give it a try. If the answer obtained doesn't make sense, the chemist adjusts the assumptions, using feedback from the first attempt, and tries

Chemistry: An Important Component of Your Education

What is the purpose of education? Because you are spending considerable time, energy, and money to pursue an education, this is an important question.

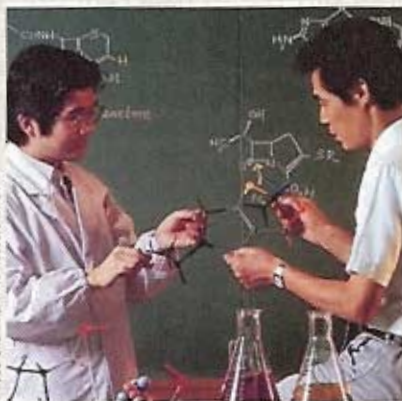
Some people seem to equate education with the storage of facts in the brain. These people apparently believe that education simply means memorizing the answers to all of life's present and future problems. Although this is clearly unreasonable, many students seem to behave as though this were their guiding principle. These students want to memorize lists of facts and to reproduce them on tests. They regard as unfair any exam questions that require some original thought or some processing of information. Indeed, it might be tempting to reduce education to a simple filling up with facts, because that approach can produce short-term satisfaction for both student and teacher. And of course, storing facts in the brain is important. You cannot function without knowing that red means stop, electricity is hazardous, ice is slippery, and so on.

However, mere recall of abstract information, without the ability to process it, makes you little better than a talking encyclopedia. Former students always seem to bring the same message

when they return to campus. The characteristics that are most important to their success are a knowledge of the fundamentals of their fields, the ability to recognize and solve problems, and the ability to communicate effectively. They also emphasize the importance of a high level of motivation.

How does studying chemistry help you achieve these characteristics? The fact that chemical systems are complicated is really a blessing, though one that is well disguised. Studying chemistry will not by itself make you a good problem solver, but it can help you develop a positive, aggressive attitude toward problem solving and can help boost your confidence. Learning to "think like a chemist" can be valuable to anyone in any field. In fact, the chemical industry is heavily populated at all levels and in all areas by chemists and chemical engineers. People who were trained as chemical professionals often excel not only in

chemical research and production but also in the areas of personnel, marketing, sales, development, finance, and management. The point is that much of what you learn in this course can be applied to any field of endeavor. So be careful not to take too narrow a view of this course. Try to look beyond short-term frustration to long-term benefits. It may not be easy to learn to be a good problem solver, but it's well worth the effort.



Students pondering the structure of a molecule.

again. The point is this: in dealing with chemical systems, do not expect to understand immediately everything that is going on. In fact, it is typical (even for an experienced chemist) *not* to understand at first. Make an attempt to solve the problem and then analyze the feedback. *It is no disaster to make a mistake as long as you learn from it.*

The only way to develop your confidence as a problem solver is to practice solving problems. To help you, this book contains examples worked out in detail. Follow these through carefully, making sure you understand each step. These examples are usually followed by a similar exercise (called a self-check exercise) that you should try on your own (detailed solutions of the self-check exercises are given at the end of each chapter). Use the self-check exercises to test whether you are understanding the material as you go along.

There are questions and problems at the end of each chapter. The questions review the basic concepts of the chapter and give you an opportunity to check whether you properly understand the vocabulary introduced. Some of the problems are really just exercises that are very similar to examples done in the chapter. If you understand the material in the chapter, you should be able to do these exercises in a straightforward way. Other problems require more creativity. These contain a knowledge gap—some unfamiliar territory that you must cross—and call for thought and patience on your part. For this course to be really useful to you, it is important to go beyond the questions and exercises. Life offers us many exercises, routine events that we deal with rather automatically, but the real challenges in life are true problems. This course can help you become a more creative problem solver.

As you do homework, be sure to use the problems correctly. If you cannot do a particular problem, do not immediately look at the solution. Review the relevant material in the text and then try the problem again. Don't be afraid to struggle with a problem. Looking at the solution as soon as you get stuck short-circuits the learning process.

Learning chemistry takes time. Use all the resources available to you and study on a regular basis. Don't expect too much of yourself too soon. You may not understand everything at first, and you may not be able to do many of the problems the first time you try them. This is normal. It doesn't mean you can't learn chemistry. Just remember to keep working and to keep learning from your mistakes, and you will make steady progress.

CHAPTER 1 REVIEW

Key Terms

chemistry (1.2)	theory (1.4)
scientific method (1.4)	natural law (1.4)

- F** directs you to the *Chemistry in Focus* feature in the chapter
- VP** indicates visual problems
- DWL** interactive versions of these problems are assignable in OWL

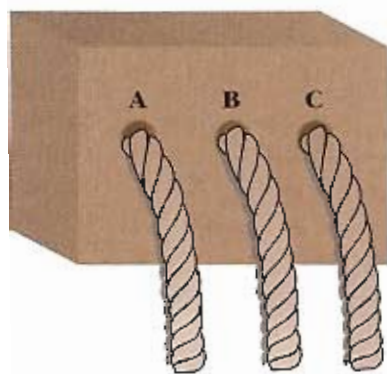
Active Learning Questions

These questions are designed to be considered by groups of students in class. Often these questions work well for introducing a particular topic in class.

- Discuss how a hypothesis can become a theory. Can a theory become a law? Explain.
- Make five qualitative and five quantitative observations about the room in which you now sit.
- List as many chemical reactions you can think of that are part of your everyday life. Explain.
- Differentiate between a "theory" and a "scientific theory."
- Describe three situations when you used the scientific method (outside of school) in the past month.
- Scientific models do not describe reality. They are simplifications and therefore incorrect at some level. So why are models useful?
- Theories should inspire questions. Discuss a scientific theory you know and the questions it brings up.
- Describe how you would set up an experiment to test the relationship between completion of assigned homework and the final grade you receive in the course.
- If all scientists use the scientific method to try to arrive at a better understanding of the world, why do so many debates arise among scientists?
- As stated in the text, there is no one scientific method. However, making observations, formulating hypotheses, and performing experiments are generally

components of “doing science.” Read the following passage, and list any observations, hypotheses, and experiments. Support your answer.

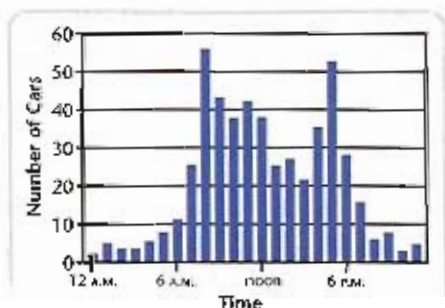
Joyce and Frank are eating raisins and drinking ginger ale. Frank accidentally drops a raisin into his ginger ale. They both notice that the raisin falls to the bottom of the glass. Soon, the raisin rises to the surface of the ginger ale, and then sinks. Within a couple of minutes, it rises and sinks again. Joyce asks, “I wonder why that happened?” Frank says, “I don’t know, but let’s see if it works in water.” Joyce fills a glass with water and drops the raisin into the glass. After a few minutes, Frank says, “No, it doesn’t go up and down in the water.” Joyce closely observes the raisins in the two glasses and states, “Look, there are bubbles on the raisins in the ginger ale but not on the raisins in the water.” Frank says, “It must be the bubbles that make the raisin rise.” Joyce asks, “OK, but then why do they sink again?”



*From Yoder, Suydam, and Snavelly, *Chemistry* (New York: Harcourt Brace Jovanovich, 1975), pp. 9–11.

11. In Section 1.3 the statement is made that it is worthwhile for scientists, auto mechanics, doctors, politicians, and poets to take a scientific approach to their professions. Discuss how each of these people could use a scientific approach in his or her profession.

- VP 12. As part of a science project, you study traffic patterns in your city at an intersection in the middle of downtown. You set up a device that counts the cars passing through this intersection for a 24-hour period during a weekday. The graph of hourly traffic looks like this.



- At what time(s) does the highest number of cars pass through the intersection?
 - At what time(s) does the lowest number of cars pass through the intersection?
 - Briefly describe the trend in numbers of cars over the course of the day.
 - Provide a hypothesis explaining the trend in numbers of cars over the course of the day.
 - Provide a possible experiment that could test your hypothesis.
- VP 13. Confronted with the box shown in the diagram, you wish to discover something about its internal workings. You have no tools and cannot open the box. You pull on rope B, and it moves rather freely. When you pull on rope A, rope C appears to be pulled slightly into the box. When you pull on rope C, rope A almost disappears into the box.*

- Based on these observations, construct a model for the interior mechanism of the box.
- What further experiments could you do to refine your model?

Questions and Problems

1.1 Chemistry: An Introduction

QUESTIONS

- Chemistry is an intimidating academic subject for many students. You are not alone if you are afraid of not doing well in this course! Why do you suppose the study of chemistry is so intimidating for many students? What about having to take a chemistry course bothers you? Make a list of your concerns and bring them to class for discussion with your fellow students and your instructor.
- The first paragraphs in this chapter ask you if you have ever wondered how and why various things in our everyday lives happen the way they do. For your next class meeting, make a list of five similar chemistry-related things for discussion with your instructor and the other students in your class.
- This section presents several ways our day-to-day lives have been enriched by chemistry. List three materials or processes involving chemistry that you feel have contributed to such an enrichment and explain your choices.
- The “Chemistry in Focus” segment titled *Dr. Ruth—Cotton Hero* discusses the enormous contribution of Dr. Ruth Rogan Benerito to the survival of the cotton fabric industry in the United States. In the discussion, it was mentioned that Dr. Benerito became a chemist when women were not expected to be interested in, or good at, scientific subjects. Has this attitude changed? Among your own friends, approximately how many of your female friends are studying a science? How many plan to pursue a career in science? Discuss.

1.2 What Is Chemistry?

QUESTIONS

- This textbook provides a specific definition of chemistry: the study of the materials of which the universe is made and the transformations that these materials undergo. Obviously, such a general definition has to be very broad and nonspecific. From your point of view at this time, how would you define chemistry? In your mind, what are "chemicals"? What do "chemists" do?
- We use chemical reactions in our everyday lives, too, not just in the science laboratory. Give at least five examples of chemical transformations that you use in your daily activities. Indicate what the "chemical" is in each of your examples and how you recognize that a chemical change has taken place.

1.3 Solving Problems Using a Scientific Approach

QUESTIONS

- Read the "Chemistry in Focus" segment *A Mystifying Problem* and discuss how David and Susan analyzed the situation, arriving at the theory that the lead glaze on the pottery was responsible for their symptoms.
- Being a scientist is very much like being a detective. Detectives such as Sherlock Holmes or Miss Marple perform a very systematic analysis of a crime to solve it, much like a scientist does when addressing a scientific investigation. What are the steps that scientists (or detectives) use to solve problems?

1.4 The Scientific Method

QUESTIONS

- Why does a scientist make repeated observations of phenomena? Is an observation the same as a theory? Why (or why not)? Is a hypothesis the same as a theory? When does a set of hypotheses become a theory?
- Observations may be either qualitative or quantitative. Quantitative observations are usually referred to as measurements. List five examples of qualitative observations you might make around your home or school. List five examples of measurements you might make in everyday life.
- Several words are used in this section that students sometimes may find hard to distinguish. Write your

own definitions of the following terms, and bring them to class for discussion with your instructor and fellow students: *theory*, *experiment*, *natural law*, *hypothesis*.

- Although, in general, science has advanced our standard of living tremendously, there is sometimes a "dark side" to science. Give an example of the misuse of science and explain how this has had an adverse effect on our lives.
- Although science *should* lead to solutions to problems that are completely independent of outside forces, very often in history scientific investigations have been influenced by prejudice, profit motives, fads, wars, religious beliefs, and other forces. Your textbook mentions the case of Galileo having to change his theories about astronomy based on intervention by religious authorities. Can you give three additional examples of how scientific investigations have been similarly influenced by nonscientific forces?

1.5 Learning Chemistry

QUESTIONS

- Although reviewing your lecture notes and reading your textbook are important, why does the study of chemistry depend so much on problem solving? Can you learn to solve problems yourself just by looking at the solved examples in your textbook or study guide? Discuss.
- Why is the ability to solve problems important in the study of chemistry? Why is it that the *method* used to attack a problem is as important as the answer to the problem itself?
- Students approaching the study of chemistry must learn certain basic facts (such as the names and symbols of the most common elements), but it is much more important that they learn to think critically and to go beyond the specific examples discussed in class or in the textbook. Explain how learning to do this might be helpful in any career, even one far removed from chemistry.
- The "Chemistry in Focus" segment *Chemistry: An Important Component of Your Education* discusses how studying chemistry can be beneficial not only in your chemistry courses but in your studies in general. What are some characteristics of a good student, and how does studying chemistry help achieve these characteristics?