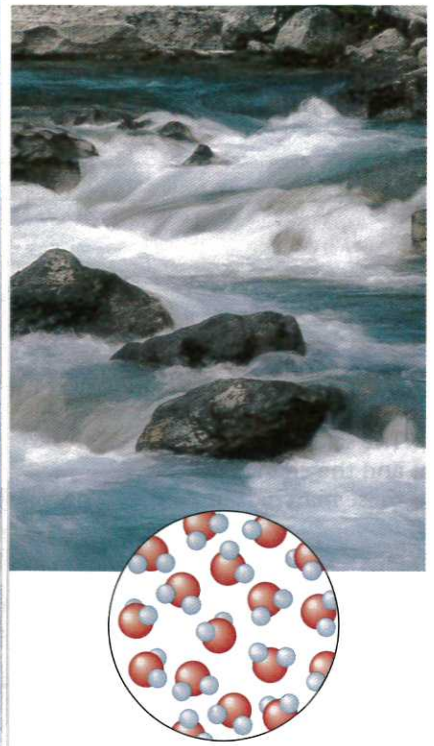
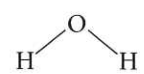


The macroscopic view of water (the mountain stream) and the microscopic view (the individual water molecules)

then to a red or golden color in the fall? To answer these questions, we need a microscope. As we examine the leaf under a microscope, we see cells and motion. Because we don't "live" in this *microscopic* world, the commonplace leaf becomes fascinating and mysterious.

When we speak of "motion" in the macroscopic world, we refer to the swaying of the tree and the rustling of the leaves. In the microscopic world, "motion" refers to the cells acting as tiny machines that absorb energy from the sun and nutrients from the air and the soil. We are now in the microscopic world, but as chemists, we want to go even further. What are the building blocks of the cells and what are the components of the water that contains the dissolved nutrients?

Think about water, a very familiar substance. In the macroscopic world, it flows and splashes over rocks in mountain streams and freezes on ponds in the winter. What is the microscopic nature of water? As you may know already, water is composed of tiny molecules that we can represent as

 or 

Here H represents a hydrogen atom and O represents an oxygen atom. We often write this molecule as H_2O because it contains two hydrogens (H) and one oxygen (O).

This is the microscopic world of the chemist—a world of molecules and atoms. This is the world we will explore in this book. One of our main goals is to connect the macroscopic world in which you live to the microscopic world that makes it all work. We think you will enjoy the trip!

Active Reading Question

What are some examples of chemistry that you see in everyday life?

SECTION 1.1 REVIEW QUESTIONS

1. How do CFC's illustrate that technical advances can be a "double-edged" sword?
2. Why is chemistry often called a central science?
3. What is the difference between a *microscopic* picture and a *macroscopic* picture?
4. What is chemistry?
5. Name three activities that a chemist may do.

RESEARCH LINKS
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SECTION 1.2

Using Science to Solve Problems

Key Terms

- Scientific method
- Theory
- Natural law
- Measurement

Objectives

- *To understand scientific thinking*
- *To illustrate scientific thinking*
- *To describe the method scientists use to study nature*

A. Solving Everyday Problems

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.**
3. 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.**

As we will see, citizens as well as 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!

B. Using Scientific Thinking to Solve a 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 flulike 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 plenty of fluids, including large quantities of orange juice from her favorite mug, part of a 200-piece set of pottery dishes recently purchased in Italy. However, she just became 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 serious 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 of them suggested that 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 statement 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 by scientific thinking? Let's use the three steps of the scientific approach 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 "from the parts."

CHEMISTRY IN YOUR WORLD

Science, Technology, and Society

Land Mine Buzzers

An estimated 100 million plastic land mines are scattered throughout the earth on former battlefields. Every day, these hidden mines kill or maim 60 people. Finding these mines is very difficult—they were designed to resist detection. Scientists are now enthusiastic about a new way to identify the mines—with honeybees. Previous work has shown that bees foraging in chemically contaminated areas carry these substances back to their hives. The hope is that bees searching for food in mined areas will bring back traces of the explosives from "leaky" mines, alerting people to nearby danger. Scientists also plan to train bees to seek out explosives by associating the scents of the explosive compounds with food. The researchers will keep track of the bees' movements by fitting electronic identification tags (about the size of a grain of rice) on the bees' backs.

If this idea works, it would be an inexpensive, safe method for characterizing a minefield. These "mine buzzers" would be much safer than the current practice of prodding the soil with pokers.

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What Is the Disease?			
Observation	**Hypothesis**	**Experiment**	**Results**
David and Susan are ill with specific systems.	The disease is lead poisoning.	Look up symptoms of lead poisoning.	Symptoms match almost exactly.

Is It Lead Poisoning?			
Observation	**Hypothesis**	**Experiment**	**Results**
Lead poisoning results from high levels of lead in the blood.	David and Susan have high levels of lead in their blood.	Perform blood analysis.	High levels of lead in both people's blood.

Where Is the Lead Coming From?			
Observation	**Hypothesis**	**Experiment**	**Results**
There is lead in the couple's blood.	The lead is in their food and drink when they purchase it.	Determine whether anyone else shopping at the store has symptoms (no one does).	Moving to a new area (and new store) did not solve the problem.
The food they bought is free of lead.	The dishes they use at home are the source of the lead.	Determine whether the dishes contain lead.	Analysis of the pottery showed that lead was present in the glaze.
Lead is present in the dishes, so they could be a source of lead poisoning.	The lead is being leached into their food.	Place a beverage (such as orange juice) in one of the cups. Analyze the beverage for lead.	High levels of lead in the drink, so the dishes are the source of the lead poisoning.

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 at which 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 of the experiments performed.*

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

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 by using the scientific method, other questions naturally arise. By repeating the three steps again and again, 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 using that pottery for food and beverages.

C. The Scientific Method

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**, which consists of the following steps:

Scientific method
Systematic process for studying nature that involves observations, hypotheses, and experiments

Measurement
A quantitative observation

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 5.
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 these observations bring us back to the beginning of the process.

information

Quantitative observations involve a number. Qualitative observations do not.

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

When 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 1.2**).

Observations Are Not Theories

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.

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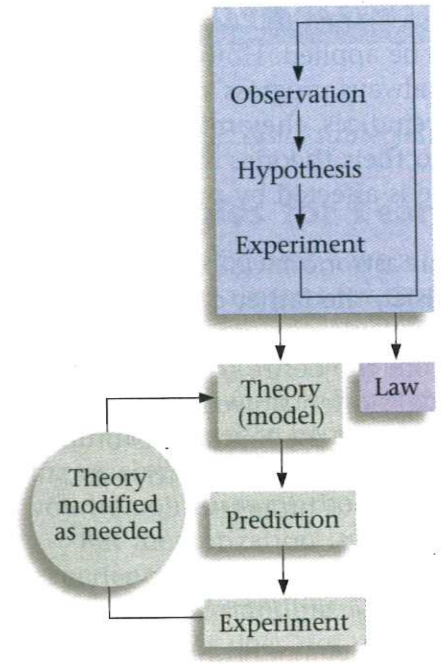

Figure 1.2
The various parts of the scientific method

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 do this by using the theory to make a prediction and then performing an experiment (making a new observation) to see whether the results match this prediction.

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.

Theories Do Not Become Laws

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 summarize 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.

Natural law Statement that summarizes generally observed behavior

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.

CRITICAL THINKING

What if everyone in the government used the scientific method to analyze and solve society's problems, and politics were never involved in the solutions?

Write a paragraph explaining how this approach would be different from the present situation, and whether it would be better or worse.

In this section, we have described the scientific method (which is summarized in **Figure 1.2**) 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 may play politics. Science is affected by profit motives, budgets, fads, wars, and religious beliefs.

Galileo, for example, was forced to deny his astronomical observations in the face of strong religious resistance. Lavoisier, the father of modern chemistry, was beheaded because of his politics. 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.

Active Reading Question

In what ways is using a scientific approach to solving a problem similar to approaches you have used in solving problems in everyday life? In what ways is it different?

SECTION 1.2 REVIEW QUESTIONS

1. Describe how you would set up an experiment to test the relationship between doing chemistry homework and the final grade in the course.

   Apply a scientific approach to solving this problem. Label each of your steps appropriately.

2. What is the difference between an observation and a theory? Give an example of each (different from the ones in your book!)

3. What are the steps in the scientific method?

4. Which is an interpretation—a law or a theory?

RESEARCH LINKS
CLASSZONE.COM