1 Introduction to Chemistry

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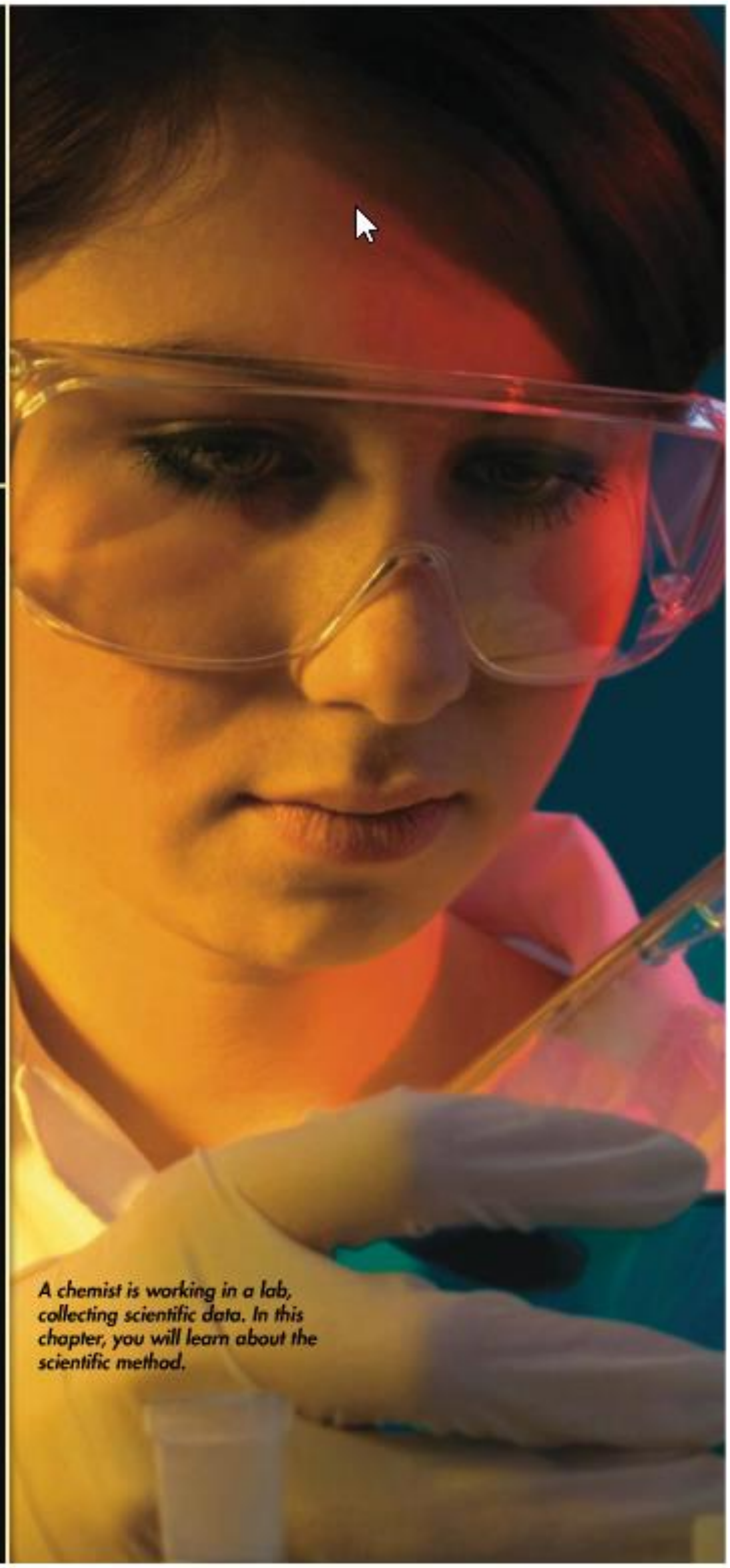


A chemist is working in a lab, collecting scientific data. In this chapter, you will learn about the scientific method.

1.1 The Scope of Chemistry

CHEMISTRY & YOU

Q: *Why might this creature interest you if you were a chemist?* Fugu, also known as puffer fish, is a sushi delicacy that can also be lethal. Puffer fish contain a powerful toxin that can kill an adult a few hours after ingestion. Sushi chefs who prepare fugu must be specially trained because any contamination of the toxin-free areas of the fish can be deadly. Recently this toxin has been put to good use, as scientists have discovered that a purified form of it can treat severe pain in cancer patients.

Key Questions

Why is the scope of chemistry so vast?

What are five traditional areas of study in chemistry?

What are the central themes of chemistry?

Vocabulary

- matter
- chemistry
- organic chemistry
- inorganic chemistry
- biochemistry
- analytical chemistry
- physical chemistry
- pure chemistry
- applied chemistry

What Is Chemistry?

Why is the scope of chemistry so vast?

Look around you. This book you are reading, the chair you sit in, and the computer you use are all made of matter. Matter is the general term for all the things that can be described as materials, or "stuff." **Matter** is anything that has mass and occupies space. The trees, the water, and the buildings you see in Figure 1.1 are all examples of matter. However, you don't have to be able to see something for it to qualify as matter. The air you breathe is an example of matter that you cannot see with the naked eye.

Have you ever wondered how some creatures can survive deep in the ocean where there is no light? Why some foods taste sweet and some taste bitter? Chemistry answers these questions and the many other questions you may have about the world you live in. **Chemistry** is the study of the composition of matter and the changes that matter undergoes. **Chemistry affects all aspects of life and most natural events because all living and nonliving things are made of matter.** Chemistry is also known as the central science, because it is fundamental to the understanding of the other sciences.

Areas of Study

What are five traditional areas of study in chemistry?

The scope of chemistry is vast, so individual chemists tend to focus on one area of study. **Five traditional areas of study are organic chemistry, inorganic chemistry, biochemistry, analytical chemistry, and physical chemistry.**

Figure 1.1 Matter Around You
Everything around you is made of matter. Chemistry is the study of matter and the changes that matter undergoes.
Infer *What changes in matter do you think are happening in this photo?*

Learn more about the areas of chemistry online.

2 Chapter 1 • Lesson 1

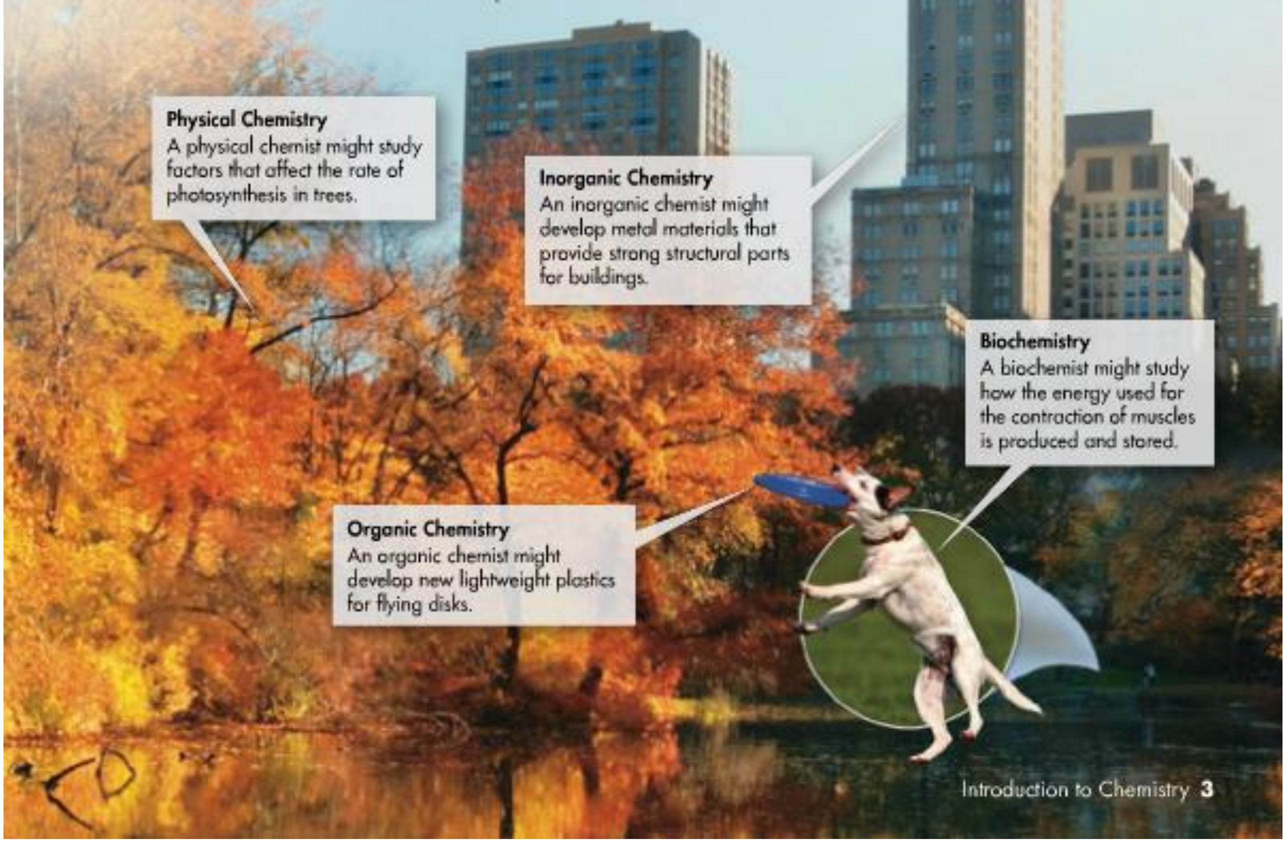
Most chemicals found in organisms contain carbon. Therefore, organic chemistry was originally defined as the study of the carbon-based chemicals found in organisms. Today, with few exceptions, **organic chemistry** is defined as the study of all chemicals containing carbon. The study of chemicals that, in general, do not contain carbon is called **inorganic chemistry.** Many inorganic chemicals are found in non-living things, such as rocks. The study of processes that take place in living organisms is **biochemistry.** These processes include muscle contraction and digestion. The area of study that focuses on the composition of matter is **analytical chemistry.** A task that would fall into this area of chemistry is measuring the level of carbon dioxide in the atmosphere. **Physical chemistry** is the area that deals with the mechanism, rate, and energy transfer that occurs when matter undergoes a change.

The boundaries between the five areas are not firm. A chemist is likely to be working in more than one area of chemistry at any given time. For example, an organic chemist uses analytical chemistry to determine the composition of an organic chemical. Figure 1.1 shows examples of the types of research different chemists do.

Some chemists do research on fundamental aspects of chemistry. This type of research is sometimes called pure chemistry. **Pure chemistry** is the pursuit of chemical knowledge for its own sake. The chemist doesn't expect that there will be any immediate practical use for the knowledge. However, most chemists do research that is designed to answer a specific question. **Applied chemistry** is research that is directed toward a practical goal or application. In practice, pure chemistry and applied chemistry are often linked. Pure research can lead directly to an application, but an application can exist before research is done to explain how it works.

CHEMISTRY & YOU

Q: *Why would you study a puffer fish if you were a biochemist? If you were an organic chemist?*



Introduction to Chemistry **3**

Big Ideas in Chemistry

What are the central themes of chemistry?

This book contains many ideas in the science of chemistry. One of the goals of your course in chemistry is to help you understand these ideas so you can use them to explain real situations that you may encounter in your life, such as the one shown in Figure 1.2. Fortunately, most of the topics of interest in chemistry are connected by a relatively few organizing principles, or "big ideas." **Some of chemistry's big ideas are as follows: chemistry as the central science, electrons and the structure of atoms, bonding and interactions, reactions, kinetic theory, the mole and quantifying matter, matter and energy, and carbon chemistry.**

BIGIDEA Chemistry As the Central Science Chemistry overlaps with all of the other sciences. Many physicists, biologists, astronomers, geologists, environmental scientists, and others use chemistry in their work.

BIGIDEA Electrons and the Structure of Atoms Carbon, oxygen, and copper are all examples of elements. Elements are composed of particles called atoms, and every atom contains a nucleus and one or more electrons. The type of products obtained in a chemical reaction is largely determined by the electrons in the reacting chemicals.

BIGIDEA Bonding and Interactions Most elements exist in chemical compounds, which are collections of two or more elements held together by relatively strong attractive forces. These forces, called chemical bonds, greatly influence the properties of compounds. Weak bonds between the particles of an element or compound can also contribute to the properties of the material.

Figure 1.2 Big Ideas
The big ideas in chemistry can help you understand the world around you. For example, all matter is made up of atoms, which are held together in compounds by chemical bonds. The fire is a result of a chemical reaction between the carbon-containing compounds in the wood and the oxygen in the air. The fire gives off energy in the form of heat and light. The gas particles in the air around the fire begin to move faster as the air heats up.
Predict *Marshmallows are made up of mostly sugar, a carbon-containing compound. What do you think happens when the sugar is heated by the fire?*

BIGIDEA Reactions Chemical reactions involve processes in which reactants produce products. When you strike a match, the compounds in the head of the match combine with oxygen in the air to produce a flame. New compounds, along with light and heat, are formed. The compounds in the match head and oxygen are the reactants, and the new compounds are the products. Chemical reactions are important to the chemistry of living and nonliving things.

BIGIDEA Kinetic Theory The particles in matter are in constant motion. The ways in which these motions vary with changes in temperature and pressure determine whether a substance will be a solid, liquid, or gas.

BIGIDEA The Mole and Quantifying Matter In many aspects of chemistry, it is vital to know the amount of material with which you are dealing. In conducting a chemical reaction, you would want to use just the right amount of the reacting material so none is wasted. This measurement is possible using the mole, the chemist's invaluable unit for specifying the amount of material. Other concepts in chemistry also rely on the mole unit.

BIGIDEA Matter and Energy Every chemical process uses or produces energy, often in the form of heat. The heat changes that occur in chemical reactions are easy to measure. Changes in a quantity called free energy allow you to predict whether a reaction will actually occur under the given conditions.

BIGIDEA Carbon Chemistry There are about 10 million carbon-containing compounds, with new ones being prepared each day. Many of these compounds, including plastics and synthetic fibers, are produced from petroleum. Carbon compounds are the basis of life in all living organisms.

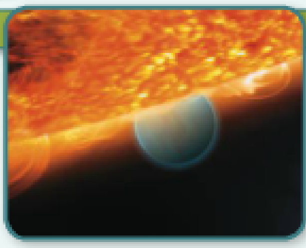
1.1 LessonCheck

1. **Explain** Why does chemistry affect all aspects of life and most natural events?
2. **List** Name the five traditional areas into which chemistry can be divided.
3. **Review** What are the "big ideas" of chemistry?
4. **Describe** What is the relationship between pure and applied chemistry?
5. **Infer** Why might a geologist ask an analytical chemist to help identify the minerals in a rock?
6. **Apply Concepts** Workers digging a tunnel through a city find some ancient pots decorated with geometric designs. Which of the following tasks might they ask a chemist to do? Explain.
   a. Determine the materials used to make the pots.
   b. Explain what the designs on the pots represent.
   c. Recommend how to store the pots to prevent further damage.

BIGIDEA CHEMISTRY AS THE CENTRAL SCIENCE

7. Why would a student who wants to be a doctor need to study chemistry?

1.2 Chemistry and You



CHEMISTRY & YOU

Q: *How is chemistry used to study worlds other than your own?* The Hubble Space Telescope has provided detailed views of celestial objects. Scientists who know chemistry have also used the telescope to discover water and compounds containing carbon on a planet located 63 light years from Earth. Such compounds are necessary for life on Earth. However, the planet, designated HD189733b, is much too hot to support life. Perhaps the Hubble Space Telescope or its successors will someday be used to find evidence of life on planets with atmospheres more like that of Earth.

Key Questions

What are three general reasons to study chemistry?

What are some outcomes of modern research in chemistry?

Vocabulary

- technology

Figure 1.3 Chemistry and Food
When cut apples are exposed to air, a chemical reaction takes place, which causes the color to change to brown.

Why Study Chemistry?

What are three general reasons to study chemistry?

You may not realize it, but chemistry can answer many questions you have about the world around you. Should you use hot water or cold water to remove a grass stain from a shirt? How could you prepare for a career in nursing, firefighting, or journalism? If your local government wanted to build a solid waste incinerator in your town, what questions would you ask about the project? **Chemistry can be useful in explaining the natural world, preparing people for career opportunities, and producing informed citizens.**

Explaining the Natural World You were born with a curiosity about your world. Chemistry can help you satisfy your natural desire to understand how things work. For example, chemistry can be seen in all aspects of food preparation. Chemistry can explain why cut apples, such as the one shown in Figure 1.3, turn brown upon exposure to air. It can explain why the texture of eggs changes from runny to firm as eggs are boiled. Chemistry can explain why water expands as it freezes, why sugar dissolves faster in hot water than in cold water, and why yeast makes bread dough rise. After you study this textbook, you will know the answers to these questions and many more.

Preparing for a Career Being a chemist can be rewarding. Chemists contribute to society in many ways. In this book, you will find features on careers that require knowledge of chemistry. Some of the choices may surprise you. You do not need to have the word *chemist* in your job title to benefit from understanding chemistry. For example, a reporter may be asked to interview a chemist to gather background for a story. Turf managers have the important task of keeping the grass on golf courses, lawns, and soccer fields, such as the one shown in Figure 1.4a, healthy. This job requires an understanding of soil chemistry. Figure 1.4b shows a firefighter, who must know which chemicals to use to fight different types of fires.

Figure 1.4 Careers
Many careers require a knowledge of chemistry. **a.** Turf managers must know how the soil and other conditions affect grass. **b.** Firefighters must choose the correct chemicals to extinguish different types of fires.
Infer ***What are some factors that may affect the health and appearance of the grass on a soccer field?***

Being an Informed Citizen Industry, private foundations, and the federal and state governments all provide funds for scientific research. The availability of funding can influence the direction of research. Those who distribute funds have to balance the importance of a goal against the cost. Areas of research often compete for funds because there is limited money available.

For example, space exploration research could not take place without federal funding. Critics argue that the money spent on space exploration would be better spent on programs such as cancer research. Those who support space exploration point out that NASA research has led to the development of many items used on Earth. These include smoke detectors, scratch-resistant plastic lenses, heart monitors, and flat-screen televisions. What if all the money spent on space exploration was used to find a cure for cancer? Are there enough valid avenues of research to take advantage of the extra funding? Would there be qualified scientists to do the research?

Like the citizen shown in Figure 1.5, you will need to make choices that will influence the direction of scientific research. You may vote directly on some issues through ballot initiatives or indirectly through the officials you elect. You may speak at a public hearing, write a letter to the editor, or sign a petition. When it comes to scientific research, there is no one correct answer. However, knowledge of chemistry and other sciences can help you evaluate the data presented, arrive at an informed opinion, and take appropriate action.

Figure 1.5 Voting
Through voting, citizens have a say in the decisions their government makes. Those decisions include how much money to provide for scientific research.

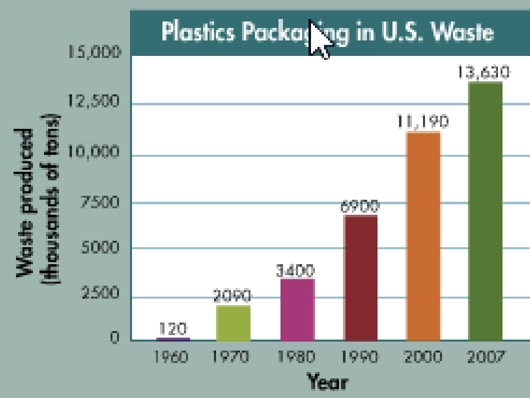
Interpret Graphs

Figure 1.6 Plastics packaging includes soft-drink and water bottles, milk and water jugs, and other plastic containers.

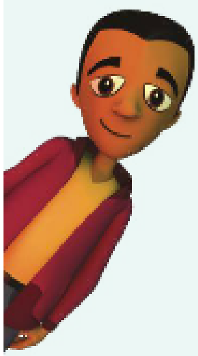
a. Read Graphs How much plastics packaging was in U.S. waste in 2007?

b. Calculate How much more plastics packaging was in U.S. waste in 2000 than in 1990?

c. Predict Do you think that the amount of plastics packaging in U.S. waste will increase or decrease in the next 10 years? Explain.



Note: The amount of plastics packaging in U.S. waste includes plastics packaging that is to be recycled.



Chemistry, Technology, and Society

What are some outcomes of modern research in chemistry?

You have probably heard the term *high tech* used when describing the latest gadgets and inventions, such as computers that are the size of your watch, or cars that can drive themselves. However, you may not realize that many of the basic items you use every day, such as the sneakers you wear or the cereal you eat, are products of technology. **Technology** is the means by which a society provides its members with those things needed and desired. Technology allows humans to do some things more quickly or with less effort. It also allows people to do things that would be otherwise impossible, such as traveling to the moon. **Modern research in chemistry can lead to technologies that aim to benefit the environment, conserve and produce energy, improve human life, and expand our knowledge of the universe.**

Materials and the Environment Chemists don't just study matter—they also use what they know about the structure and properties of matter to make new materials with different or improved properties. Take plastics, for example. If you have ever consumed bottled water, eaten a salad with a disposable fork, or put on your helmet before riding your bike, you have used plastics. Chemistry has played a large role in developing plastics for different uses.

Most plastics are made using petrochemicals, which are chemical products derived from petroleum. Although plastics are a part of most of our daily lives, there is concern that their use is taking a toll on the environment and on natural resources. The supply of petrochemicals is limited, and the manufacture of plastics uses large amounts of energy. Unrecycled plastics end up in landfills, where they remain for hundreds of years. Figure 1.6 shows the amount of plastics packaging in U.S. waste. Understandably, there has been a demand for plastics that are better for the environment. Figure 1.7 describes a new technology that offers an alternative to petroleum-based plastics.

Energy The needs of any modern society require energy to power homes, factories, and transportation. With population growth and more industrialization around the globe, the demand for energy is on the rise. There are only two ways to meet the demand for energy—conserve it or produce more of it. Chemistry plays an essential role in both of these options.

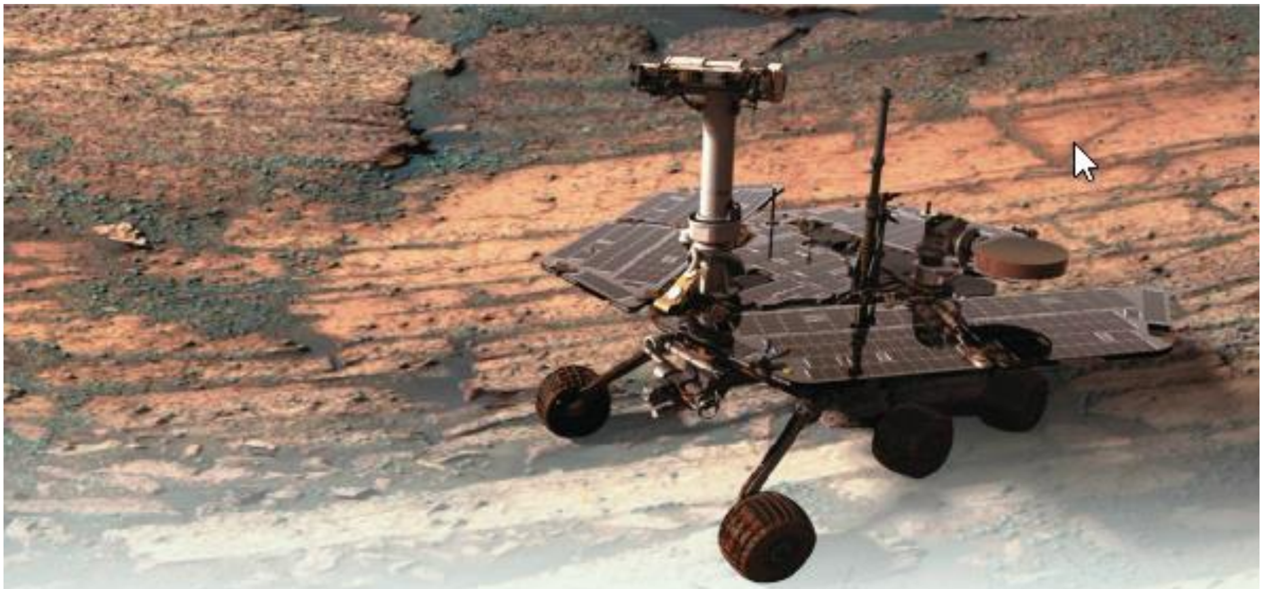
Gasoline-electric hybrid cars play a substantial role in the conservation of energy. They have greater fuel efficiencies than gasoline-powered vehicles. Hybrids use both a gasoline engine and a set of batteries to run the car. A knowledge of chemistry was necessary to develop these batteries. In an effort to produce more energy, sustainable energy sources are important to consider. Unlike fossil fuels, the sun is a renewable energy source. Chemists help design materials that collect energy from the sun that is then converted to electricity.

Medicine and Biotechnology Chemistry supplies the medicines, materials, and technology that doctors use to treat their patients. Biochemists work with biologists and doctors to understand the structure of matter found in the human body and the chemical changes that occur in cells.

There are more than 10,000 prescription drugs, which have been designed to treat various conditions including infections, high blood pressure, and depression. Other drugs, such as aspirin and antacids, can be sold without a prescription. Many drugs are effective because they interact in a specific way with chemicals in cells. Chemists who develop these drugs must have knowledge of the structure and function of these target chemicals in order to design safe and effective drugs. Chemistry can also develop materials to repair or replace body parts. Diseased arteries can be replaced with plastic tubes. Artificial hips and knees made from metals and plastics can replace worn-out joints and allow people to walk again without pain.

Figure 1.8a shows a model of a small piece of DNA. Segments of DNA, called genes, store the information that controls changes that take place in cells. Biotechnology applies science to the production of biological products or processes. It uses techniques that can alter the DNA in living organisms. It may depend on the transfer of genes from one organism to another. When genes from humans are inserted into bacteria, the bacteria act as factories that produce chemicals of importance to humans, such as insulin. Production takes place in large versions of the bioreactors shown in Figure 1.8b.

Figure 1.8 Biotechnology
The discovery of the structure of DNA led to the development of biotechnology. **a.** This computer graphics model shows a small segment of DNA. **b.** The conditions in a bioreactor are controlled so that the bacteria produce as much of the product as possible.



The Universe Scientists assume that the methods used to study Earth can be applied to other objects in the universe. To study the universe, chemists gather data from afar and analyze matter that is brought back to Earth.

In the early 1800s, scientists began to study the composition of stars by analyzing the light they transmitted to Earth. In 1868, Pierre Janssen discovered a gas on the sun's surface that was not known on Earth. Joseph Norman Lockyer named the gas helium from the Greek word *helios*, meaning "sun." In 1895, William Ramsay discovered helium on Earth.

The moon and the planets do not emit light, so scientists must use other methods to gather data about these objects. The methods used depend on matter brought back to Earth by astronauts or on probes that can analyze matter in space. Chemists have analyzed more than 850 pounds of moon rocks that were brought back to Earth. The rocks were similar to rocks formed by volcanoes on Earth, suggesting that vast oceans of molten lava once covered the moon's surface. Figure 1.9 is a drawing of the robotic vehicle *Opportunity*. The vehicle was designed to determine the chemical composition of rocks and soil on Mars. Data collected at the vehicle's landing site indicated that the site was once drenched with water.

Figure 1.9 Space Exploration With help from NASA, chemists study matter from other bodies in the solar system. This drawing shows the robotic vehicle *Opportunity* on the surface of Mars.

CHEMISTRY & YOU

Q: *How can chemistry be used to find evidence of life on other planets?*

1.2 LessonCheck

ONLINE PROBLEMS

8. **List** What are three reasons for studying chemistry?
9. **Review** How has modern research in chemistry impacted society?
10. **Describe** How do chemists study the universe?
11. **Form an Opinion** Do the advantages of substituting the bioplastic PLA for conventional plastics outweigh the disadvantages? Would you use products made out of PLA? Why or why not?
12. **Explain** How can a knowledge of chemistry help you be a more informed citizen?

BIGIDEA
CHEMISTRY AS THE CENTRAL SCIENCE

13. A friend tells you that she doesn't think it is important to learn chemistry. What would be your response?

1.3 Thinking Like a Scientist

CHEMISTRY & YOU

Q: *How do you think Alexander Fleming tested his hypothesis?* In 1928, Alexander Fleming, a Scottish scientist, noticed that a bacteria he was studying did not grow in the presence of a yellow-green mold. Other scientists had made the same observation, but Fleming was the first to recognize its importance. He assumed that the mold had released a chemical that prevented the growth of the bacteria. That chemical was penicillin, which can kill a wide range of harmful bacteria.

Key Questions

How did Lavoisier help to transform chemistry?

What are the steps in the scientific method?

What role do collaboration and communication play in science?

Vocabulary

- scientific method
- observation
- hypothesis
- experiment
- independent variable
- dependent variable
- model
- theory
- scientific law

An Experimental Approach to Science

How did Lavoisier help to transform chemistry?

The word *chemistry* comes from the word *alchemy*. Long before there were chemists, alchemists were studying matter. Alchemy arose independently in many regions of the world. It was practiced in China and India as early as 400 B.C. In the eighth century, Arabs brought alchemy to Spain, and from there it spread quickly to other parts of Europe.

You may have heard that alchemists were concerned with searching for a way to change other metals, such as lead, into gold. Although alchemists did not succeed with this quest, the work they did spurred the development of chemistry. Alchemists developed the tools and techniques for working with chemicals. For example, alchemists developed processes for separating mixtures and purifying chemicals. They designed equipment that is still used today, including beakers, flasks, tongs, funnels, and the mortar and pestle, which is shown in Figure 1.10. What they did not do was provide a logical set of explanations for the changes in matter that they observed. Chemists would accomplish that task many years later.

Figure 1.10 Mortar and Pestle
Pharmacists still use a bowl-shaped mortar and club-shaped pestle to mix drugs for patients. The mortar and pestle in this photograph are made of porcelain, which is a hard material.
Infer *What may be some other uses of a mortar and pestle?*

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By the 1500s in Europe, there was a shift from alchemy to science. Science flourished in Britain in the 1600s, partly because King Charles II was a supporter of the sciences. With his permission, some scientists formed the Royal Society of London for the Promotion of Natural Knowledge. The scientists met to discuss scientific topics and conduct experiments. The society's aim was to encourage scientists to base their conclusions about the natural world on experimental evidence, not on philosophical debates.

In France, Antoine-Laurent Lavoisier did work in the late 1700s that would revolutionize the science of chemistry. **Lavoisier helped to transform chemistry from a science of observation to the science of measurement that it is today.** To make careful measurements, Lavoisier designed a balance that could measure mass to the nearest 0.0005 gram.

One of the many things Lavoisier accomplished was to settle a long-standing debate about how materials burn. The accepted explanation was that materials burn because they contain phlogiston, which is released into the air as a material burns. To support this explanation, scientists had to ignore the evidence that metals can gain mass as they burn. By the time Lavoisier did his experiments, he knew that there were two main gases in air—oxygen and nitrogen. Lavoisier was able to show that oxygen is required for a material to burn. Lavoisier's wife Marie Anne, shown in Figure 1.11, helped with his scientific work. She made drawings of his experiments and translated scientific papers from English.

Figure 1.11 Antoine Lavoisier
This portrait of Antoine Lavoisier and his wife Marie Anne was painted by Jacques Louis David in 1788.

The Scientific Method

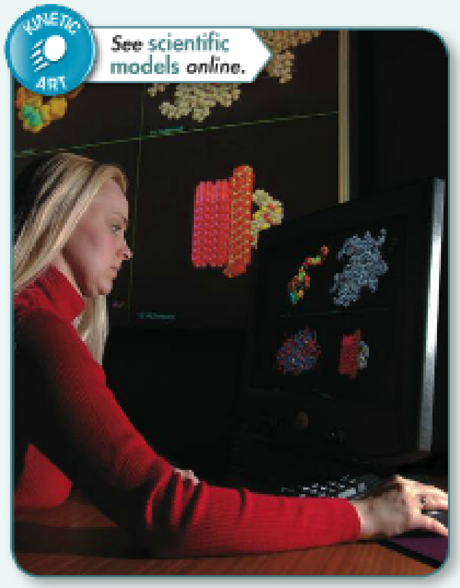
What are the steps in the scientific method?

Scientists have a powerful tool that they use to produce valuable results. Like all scientists, the biochemist shown in Figure 1.12 is using the scientific method to solve difficult problems. The **scientific method** is a logical, systematic approach to the solution of a scientific problem. **Steps in the scientific method include making observations, proposing and testing hypotheses, and developing theories.**

Making Observations The scientific method is useful for solving many kinds of problems. Suppose you try to turn on a flashlight and you notice that it does not light. When you use your senses to obtain information, you make an **observation.** An observation can lead to a question: What is wrong with the flashlight?

Figure 1.12 Observing With a Microscope
Observation is an essential step in the scientific method.

Figure 1.13 Computer Models
This scientist is using a computer to model complex molecules, which are difficult to study with experiments alone.



Testing Hypotheses If you guess that the batteries in the flashlight are dead, you are making a hypothesis. A **hypothesis** is a proposed explanation for an observation. You can test your hypothesis by putting new batteries in the flashlight. Replacing the batteries is an **experiment,** a procedure that is used to test a hypothesis. If the flashlight lights, you can be fairly certain that your hypothesis was true. What if the flashlight does not work after you replace the batteries? A hypothesis is useful only if it accounts for what is actually observed. When experimental data does not fit a hypothesis, the hypothesis must be changed. A new hypothesis might be that the light bulb is burnt out. An experiment to test this new hypothesis is to replace the bulb.

When you design experiments, you deal with variables, or factors that can change. The variable that you change during an experiment is the **independent variable,** also called the manipulated variable. The variable that is observed during the experiment is the **dependent variable,** also called the responding variable. If you keep other factors that can affect the experiment from changing during the experiment, you can relate any change in the dependent variable to changes in the independent variable. For the results of an experiment to be accepted, the experiment must produce the same result no matter how many times it is repeated, or by whom. This is why scientists are expected to publish a description of their procedures along with their results.

Sometimes the experiment a scientist must perform to test a hypothesis is difficult or impossible. For example, atoms and molecules, which are some of the smallest units of matter, cannot be easily seen. In these situations, scientists often turn to models to gain more understanding of a problem. A **model** is a representation of an object or event. Figure 1.13 shows a scientist working with computer models of complex biological molecules. Chemists may also use models to study chemical reactions and processes.

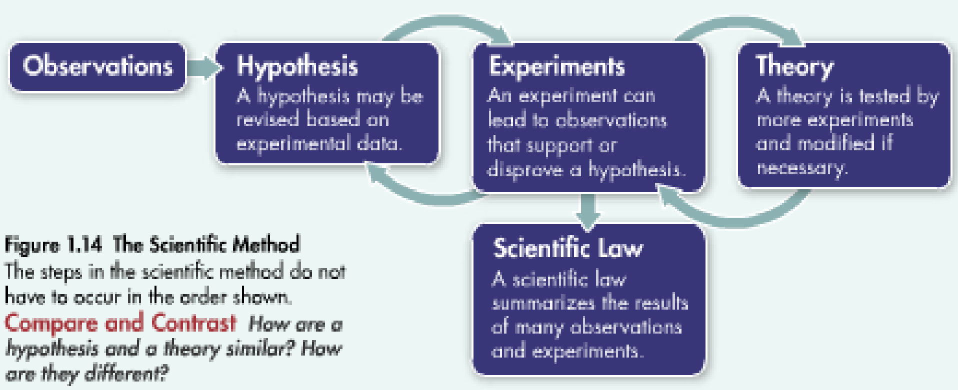


Figure 1.14 The Scientific Method
The steps in the scientific method do not have to occur in the order shown.
Compare and Contrast *How are a hypothesis and a theory similar? How are they different?*

Developing Theories Figure 1.14 shows how the steps of the scientific method fit together. Once a hypothesis meets the test of repeated experimentation, it may be raised to a higher level of ideas. It may become a theory. A **theory** is a well-tested explanation for a broad set of observations. Some of the theories in chemistry are very useful because they help you form mental pictures of objects or processes that cannot be seen. Other theories allow you to predict the behavior of matter.

When scientists say that a theory can never be proved, they are not saying that a theory is unreliable. They are simply leaving open the possibility that a theory may need to be changed at some point in the future to explain new observations or experimental results.

Scientific Laws Figure 1.14 shows how scientific experiments can lead to laws as well as theories. A **scientific law** is a concise statement that summarizes the results of many observations and experiments. In Chapter 14, you will study laws that describe how gases behave. One law describes the relationship between the volume of a gas in a container and its temperature. If all other variables are kept constant, the volume of the gas increases as the temperature increases. The law doesn't try to explain the relationship it describes. That explanation requires a theory.

CHEMISTRY & YOU

Q: *What was Alexander Fleming's hypothesis? How could he test his hypothesis?*

Quick Lab

Purpose To test the hypothesis that bubble making can be affected by adding sugar or salt to a bubble-blowing mixture

Materials

- 3 plastic drinking cups
- measuring cup and spoons
- liquid dish detergent
- water
- table sugar
- table salt
- drinking straw

Bubbles!

Procedure

1. Label three drinking cups 1, 2, and 3. Measure and add one teaspoon of liquid dish detergent to each cup.

2. Use the measuring cup to add two-thirds cup of water to each drinking cup. Then swirl the cups to form a clear mixture. CAUTION *Wipe up any spills immediately so that no one will slip and fall.*

3. Add a half teaspoon of table sugar to cup 2 and a half teaspoon of table salt to cup 3. Swirl each cup for one minute.

4. Dip the drinking straw into cup 1, remove it, and blow gently into the straw to make the largest bubble you can. Practice making bubbles until you feel you have reasonable control over your bubble production.

5. Repeat Step 4 with the mixtures in cups 2 and 3.

Analyze and Conclude

1. Observe Did you observe any differences in your ability to produce bubbles using the mixtures in cup 1 and cup 2?

2. Observe Did you observe any differences in your ability to produce bubbles using the mixtures in cup 1 and cup 3?

3. Draw Conclusions What can you conclude about the effects of table sugar and table salt on your ability to produce bubbles?

4. Design an Experiment Propose another hypothesis related to bubble making. Design an experiment to test your hypothesis.

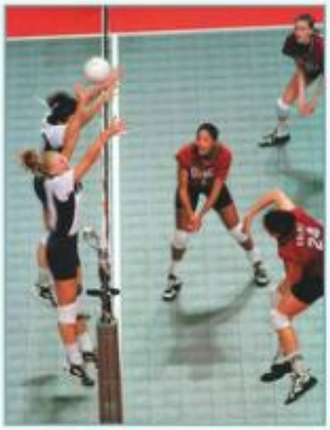


Figure 1.15 Teamwork
For a volleyball team to win, the players must work together.

Collaboration and Communication

What role do collaboration and communication play in science?

No matter how talented the players on a team may be, one player cannot ensure victory for the team. Individuals must collaborate, or work together, for the good of the team. Think about the volleyball players in Figure 1.15. In volleyball, the person who spikes the ball depends on the person who sets the ball. Unless the ball is set properly, the spiker will have limited success. Many sports recognize the importance of collaboration by keeping track of assists. During a volleyball game, the players also communicate with one another so it is clear who is going to do which task. Strategies that are successful in sports can work in other fields, such as science. **When scientists collaborate and communicate with one another, they increase the likelihood of a successful outcome.**

Collaboration Scientists choose to collaborate for different reasons. For example, some research problems are so complex that no one person could have all the knowledge, skills, and resources to solve the problem. It is often necessary to bring together individuals from different disciplines. Each scientist will typically bring different knowledge and, perhaps, a different approach to a problem. Just talking with a scientist from another discipline may provide insights that are helpful.

There may be a practical reason for collaboration. For example, an industry may give a university funding for pure research in an area of interest to the industry. Scientists at the university get the equipment and financing required to do the research. In exchange, the scientists provide ideas and expertise. The industry may profit from its investment by marketing applications based on the research.

Collaboration isn't always a smooth process. Conflicts can arise about use of resources, amount of work, who is to receive credit, and when and what to publish. Like the students in Figure 1.16, you will likely work in pairs or on a team in the laboratory. If so, you may face some challenges. However, you can also experience the benefits of a successful collaboration.

Figure 1.16 Lab Partners
Working in pairs or in a group can be challenging, but it can also be rewarding.
Apply Concepts *What steps in the scientific method are these students using?*

Communication The way scientists communicate with each other and with the public has changed over the centuries. In earlier centuries, scientists exchanged ideas through letters. They also formed societies to discuss the latest work of their members. When societies began to publish journals, scientists could use the journals to keep up with new discoveries.

Today, many scientists, like those in Figure 1.17, work as a team. They can communicate face to face. They also can exchange ideas with other scientists by e-mail, by phone, and at local and international conferences. Scientists still publish their results in scientific journals, which are the most reliable source of information about new discoveries. Most journals are now published online and are readily accessible. Articles are published only after being reviewed by experts in the author's field. Reviewers may find errors in experimental design or challenge the author's conclusions. This review process is good for science because work that is not well founded is usually not published.

The Internet is a major source of information. One advantage of the Internet is that anyone can get access to information. One disadvantage is that anyone can post information on the Internet without first having that information reviewed. To judge the reliability of information you find on the Internet, you have to consider the source. This same advice applies to articles in newspapers and magazines or the news you receive from television. If a media outlet has a reporter who specializes in science, chances are better that a report will be accurate.

Figure 1.17 Communication
Scientists often get together at professional meetings and workshops to discuss their findings and share ideas.

1.3 LessonCheck

14. **Review** How did Lavoisier revolutionize the science of chemistry?
15. **List** Name three steps in the scientific method.
16. **Explain** Why are collaboration and communication important in science?
17. **Describe** What did alchemists contribute to the development of chemistry?
18. **Explain** How did Lavoisier's wife help him to communicate the results of his experiments?
19. **Describe** What process takes place before an article is published in a scientific journal?
20. **Explain** Why is it important for scientists to publish a description of their procedures along with the results of their experiments?
21. **Infer** Why should a hypothesis be developed before experiments take place?
22. **Compare** What is the difference between a theory and a hypothesis?
23. **Classify** In Chapter 2, you will learn that matter is neither created nor destroyed in any chemical change. Is this statement a theory or a law? Explain your answer.

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24. Do the steps in the scientific method always need to be followed in order? Explain.

1.4 Problem Solving in Chemistry

CHEMISTRY & YOU

Q: *How does having a plan make solving problems easier?* Have you ever tried to solve a crossword puzzle? If so, you may have found it helpful to develop a strategy before you begin. For example, you may try to fill in all the "down" clues before attempting the "across" clues. Or, you may first try to complete the fill-in-the-blank clues before moving on to the more difficult clues. In chemistry, it is helpful to develop a strategy to solve both numeric and non-numeric problems.

Key Questions

What is a general approach to solving a problem?

What are the steps for solving numeric problems?

What are the steps for solving nonnumeric problems?

Skills Used in Solving Problems

What is a general approach to solving a problem?

Problem solving is a skill you use all the time. You are in a supermarket. Do you buy a name brand or the store brand of peanut butter? Do you buy the 1-liter bottle or the 2-liter bottle of a carbonated beverage? Do you choose the express line if there are five customers ahead of you or the non-express line with a single shopper who has a lot of items?

When you solve a problem, you may have a data table, a graph, or another type of visual to refer to. The shopper in Figure 1.18 is reading the label on a container while trying to decide whether to buy the item. She may need to avoid certain ingredients because of a food allergy. She may also want to know the number of Calories per serving.

The skills you use to solve a word problem in chemistry are not that different from those you use while shopping, cooking, or planning a party. **Effective problem solving always involves developing a plan and then implementing that plan.**

Figure 1.18 Problem Solving
A shopper must make many decisions. Some of those decisions are based on data, such as the information on a food label.

Solving Numeric Problems

What are the steps for solving numeric problems?

Most word problems in chemistry require math because measurement is such an important part of chemistry. The techniques used in this book to solve numeric problems are conveniently organized into a three-step, problem-solving approach. This approach has been shown to be very helpful and effective. We recommend that you follow this approach when working on numeric problems in this textbook. **The steps for solving a numeric word problem are analyze, calculate, and evaluate.** Figure 1.19 summarizes the three-step process, and Sample Problem 1.1 on the next page shows how the steps work in solving a numeric problem.

1 Analyze To solve a word problem, you must first determine where you are starting from (identify what is known) and where you are going (identify what is unknown). What is known may be a measurement or an equation that shows a relationship between measurements. If you expect the answer (the unknown) to be a number, you need to determine what unit(s) the answer should have before you do any calculations.

After you identify the known and the unknown, you need to make a plan for using what is known to arrive at the unknown. Planning is at the heart of successful problem solving. As part of planning, you might draw a diagram that helps you visualize a relationship between the known and the unknown. You might need to use a table or graph to identify data or to identify a relationship between a known quantity and the unknown. You may need to select an equation that you can use to calculate the unknown.

2 Calculate If you make an effective plan, doing the calculations is usually the easiest part of the process. For some problems, you will have to convert a measurement from one unit to another. For other problems, you may need to rearrange an equation before you can solve for an unknown. You will be taught these math skills as needed.

3 Evaluate After you calculate an answer, you should evaluate it. Is the answer reasonable? Does it make sense? If not, reread the word problem. Did you copy the data correctly? Did you choose the right equations?

Check that your answer has the correct unit(s) and the correct number of significant figures. You may need to use scientific notation in your answer. You will study significant figures and scientific notation in Chapter 3.

READING SUPPORT

Build Reading Skills: ***Main Ideas*** Under the heading Solving Numeric Problems, there are three main ideas presented as subheads. ***What are two details that support each main idea?***

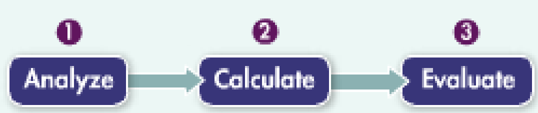

Figure 1.19 Solving Numeric Problems
This flowchart summarizes the steps for solving a numeric problem.
Identify *In which step do you make a plan for getting from what is known to what is unknown?*

SampleProblem 1.1

Estimating Walking Time

You are visiting Indianapolis for the first time. It is a nice day, so you decide to walk fro[m] the Indiana State Capital to the Murat Centre for an afternoon performance. According to the map in Figure 1.20 on the next page, the shortest route from the capital to the theater is eight blocks. How many minutes will the trip take if you can walk one mile in 20 minutes? Assume that ten blocks equals one mile.

1 Analyze List the knowns and the unknown.

This problem is an example of what is typically called a conversion problem. In a conversion problem, one unit of measure (in this case, blocks) must be expressed in a different unit (in this case, minutes).

Divide the distance to be traveled (in blocks) by the number of blocks in one mile to get the distance of the trip in miles. Then multiply the number of miles by the time it takes to walk one mile.

KNOWNS
distance to be traveled = 8 blocks
walking speed = 1 mile/20 minutes
1 mile = 10 blocks

UNKNOWN
time of trip = ? minutes

2 Calculate Solve for the unknown.

The relationship 1 mile = 10 blocks can be interpreted as "1 mile per 10 blocks."

Divide the number of blocks to be traveled by the number of blocks in one mile.

$$8\ \text{blocks} \times \frac{1\ \text{mile}}{10\ \text{blocks}} = 0.8\ \text{mile}$$

Multiply the number of miles by the time it takes to walk one mile.

$$0.8\ \text{mile} \times \frac{20\ \text{minutes}}{1\ \text{mile}} = 16\ \text{minutes}$$

Notice how the units cancel.

3 Evaluate Does the result make sense? The answer seems reasonable, 16 minutes to walk eight blocks. The answer has the correct unit. The relationships used are correct.

25. There is an ice cream shop six blocks north of your hotel. How many minutes will it take to walk there and back? Use the information in the sample problem.

In Problem 25, you must account for both the distance to and from the ice cream shop.

26. Using the information in the sample problem, how many blocks can be walked in 48 minutes?

In Problem 26, first determine how many miles can be walked in 48 minutes. Then, convert miles to blocks.

SampleProblem 1.2

Scheduling Classes

Manny needs to schedule his classes for next year. The school day is divided into seven periods, and he must take Algebra II, Art, Chemistry, English, History, and Physical Education. Using the information on the right, find a way for Manny to schedule all his classes.

- ✔ Algebra II is offered during either 1st or 2nd period.
- ✔ Art is offered during 2nd period only.
- ✔ Chemistry is offered during either 3rd or 6th period.
- ✔ English is offered during either 6th or 7th period.
- ✔ History is offered during either 4th or 7th period.
- ✔ Physical Education is offered during 4th period only.
- ✔ Lunch is scheduled for 5th period.

1 Analyze **Identify the relevant concepts.**
Manny must take lunch during 5th period. Art is only available during 2nd period. Physical Education is only available during 4th period.

2 Solve **Apply the concepts to this problem.**

Place lunch, Art, and Physical Education into Manny's schedule.

Manny's Schedule	
1st period	
2nd period	Art
3rd period	
4th period	P.E.
5th period	Lunch
6th period	
7th period	

Since Art is only available during 2nd period, Manny must take Algebra II during 1st period. Since P.E. is only available during 4th period, he must take History during 7th period.

Fit the remainder of the classes into Manny's schedule.

Manny's Schedule	
1st period	Algebra II
2nd period	Art
3rd period	Chemistry
4th period	P.E.
5th period	Lunch
6th period	English
7th period	History

27. How would Manny's schedule change if Art was available during 1st period, instead of 2nd period?

28. Would Manny's schedule change if Algebra II was available during 1st, 2nd, and 3rd periods? Explain.

1.4 LessonCheck

29. Review What are the two general steps in successful problem solving?

30. List What are the three steps for solving numeric problems?

31. List What are the two steps for solving nonnumeric problems?

32. Compare and Contrast How are the processes for solving numeric and nonnumeric problems similar? In what way are they different?

33. Calculate Read the following conversion problem, and then answer the questions. "There are 3600 seconds in an hour. How many seconds are there in one day?"

a. Identify the known and the unknown.

b. What relationship between the known and unknown do you need to solve the problem?

c. Calculate the answer to the problem.

d. Evaluate your answer and explain why your answer makes sense.

1 Study Guide

BIGIDEA
CHEMISTRY AS THE CENTRAL SCIENCE

It is important to study chemistry because chemistry is fundamental to the understanding of the other sciences. Chemistry is relevant to many professions. A knowledge of chemistry can help you become an informed citizen. Chemists use the scientific method to solve problems and develop theories about the natural world.

1.1 The Scope of Chemistry

Chemistry affects all aspects of life and most natural events because all living and nonliving things are made of matter.

Five traditional areas of study are organic chemistry, inorganic chemistry, biochemistry, analytical chemistry, and physical chemistry.

Some of chemistry's big ideas are as follows: chemistry as the central science, electrons and the structure of atoms, bonding and interactions, reactions, kinetic theory, the mole and quantifying matter, matter and energy, and carbon chemistry.

- matter (2)
- chemistry (2)
- organic chemistry (3)
- inorganic chemistry (3)
- biochemistry (3)
- analytical chemistry (3)
- physical chemistry (3)
- pure chemistry (3)
- applied chemistry (3)

1.2 Chemistry and You

Chemistry can be useful in explaining the natural world, preparing people for career opportunities, and producing informed citizens.

Modern research in chemistry can lead to technologies that aim to benefit the environment, conserve and produce energy, improve human life, and expand our knowledge of the universe.

- technology (8)

1.3 Thinking Like a Scientist

Lavoisier helped to transform chemistry from a science of observation to the science of measurement that it is today.

Steps in the scientific method include making observations, proposing and testing hypotheses, and developing theories.

When scientists collaborate and communicate with one another, they increase the likelihood of a successful outcome.

- scientific method (15)
- observation (15)
- hypothesis (16)
- experiment (16)
- independent variable (16)
- dependent variable (16)
- model (16)
- theory (17)
- scientific law (17)

1.4 Problem Solving in Chemistry

Effective problem solving always involves developing a plan and then implementing that plan.

The steps for solving a numeric word problem are analyze, calculate, and evaluate.

The steps for solving a nonnumeric problem are analyze and solve.