CHAPTER 1

Introduction to Chemistry

BIG Idea **Chemistry is a science that is central to our lives.**

1.1 A Story of Two Substances

MAIN Idea Chemistry is the study of everything around us.

1.2 Chemistry and Matter

MAIN Idea Branches of chemistry involve the study of different kinds of matter.

1.3 Scientific Methods

MAIN Idea Scientists use scientific methods to systematically pose and test solutions to questions and assess the results of the tests.

1.4 Scientific Research

MAIN Idea Some scientific investigations result in the development of technology that can improve our lives and the world around us.

ChemFacts

- Many of the processes that occur around you are the result of chemistry in action.
- Chemists study chemical reactions, such as why heat and light are given off when a log burns.
- The rusting of a nail, or other iron object, is another example of a chemical process that chemists might study.

Start-Up Activities

LAUNCH Lab

Where did the mass go?

When an object burns, the mass of what remains is less than the original object. What happens to the mass of the object?

Procedure

1. Read and complete the lab safety form.
2. Use a **laboratory balance** to measure the mass of a **candle.** Record this measurement, and record detailed observations about the candle.
3. Place the candle on a burn-resistant surface, such as a lab table. Carefully strike a **match** and light the candle. Use a **stopwatch** or a **clock with a second hand** to measure the time. Allow the candle to burn for 5 min. Then, blow out the flame. Record your observations.
   WARNING: ***Do not place matches in the sink.***
4. Allow the candle to cool. Measure and record the mass of the extinguished candle.
5. Place the extinguished candle in a container designated by your instructor.

Analysis

1. **Summarize** your observations of the candle as it was burning and after the flame was extinguished.
2. **Evaluate** Where is the matter that appears to have been lost?

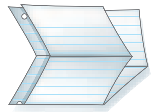
Inquiry Can the amount of matter "lost" vary? Plan an investigation to determine what factors might contribute to a different outcome.

FOLDABLES™ Study Organizer

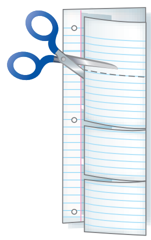
Scientific Methods Make the following Foldable to help you organize information about scientific methods.

STEP 1 Fold a sheet of paper in half lengthwise. Make the back edge about 2 cm longer than the front edge.

STEP 2 Fold in half and then in half again.



STEP 3 Unfold and cut along the folds of the top flap to make four tabs.



STEP 4 Label the tabs as follows: *Observation*, *Hypothesis*, *Experiments*, and *Conclusion*.

FOLDABLES Use this Foldable with Sections 1.2, 1.3, and 1.4. As you read these sections, summarize what you learn about scientific methods under the appropriate tabs. Include information about the two substances featured in the sections.

Chemistry Online

Visit glencoe.com to:

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Section 1.1

Objectives

- **Define** substance.
- **Explain** the formation and importance of ozone.
- **Describe** the development of chlorofluorocarbons.

Review Vocabulary

matter: anything that has mass and takes up space

New Vocabulary

chemistry
substance

A Story of Two Substances

MAIN Idea **Chemistry is the study of everything around us.**

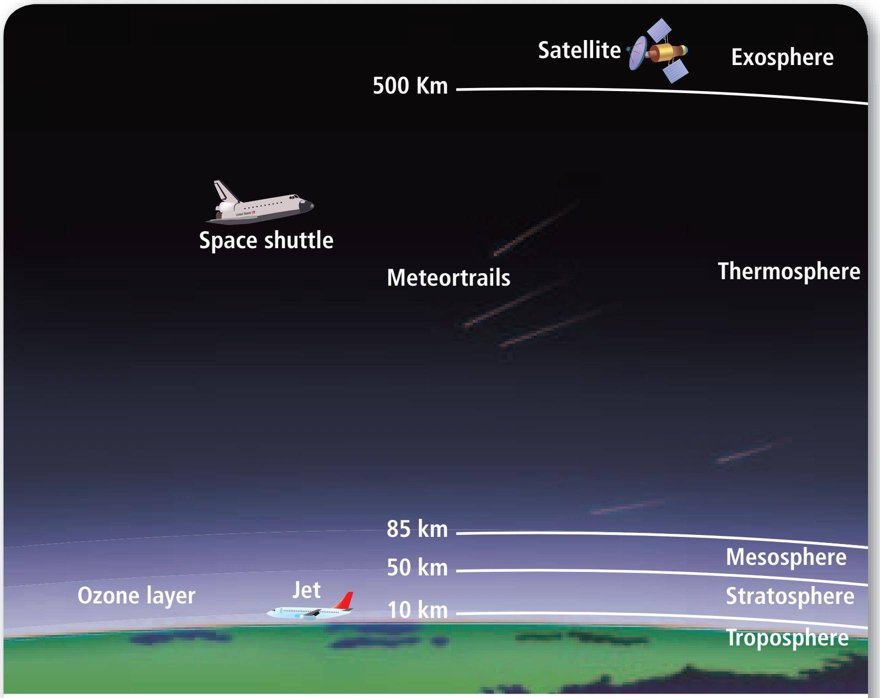
Real-World Reading Link Have you ever moved a piece of furniture to a new location, only to discover that the new location won't work? Sometimes, moving furniture creates a new problem, such as a door will not open all the way or an electric cord will not reach an outlet. Solving a problem only to find that the solution creates a new problem also occurs in science.

Why study chemistry?

Take a moment to observe your surroundings and **Figure 1.1.** Where did all the "stuff" come from? All the stuff in the universe, including everything in the photos, is made from building blocks formed in stars. Scientists call these building blocks and the "stuff" made from these building blocks *matter*.

As you begin your study of **chemistry**—the study of matter and the changes that it undergoes—you are probably asking yourself, "Why is chemistry important to me?" The answer to this question can be illustrated by real-life events that involve two discoveries. One discovery involves something that you probably use every day—refrigeration. If you go to school in an air-conditioned building or if you protect your food from spoilage by using a refrigerator, this discovery is important to you. The other discovery involves energy from the Sun. Because you eat food and spend time outdoors, this discovery is also important to you. These two seemingly unrelated discoveries became intertwined in an unexpected way—as you will soon learn.

Figure 1.1 Everything in the universe, including particles in space and things around you, is composed of matter.



■ **Figure 1.2** Earth's atmosphere consists of several layers. The protective ozone layer is located in the stratosphere.

The Ozone Layer

If you have ever had a sunburn, you have experienced the damaging effects of ultraviolet radiation from the Sun. Overexposure to ultraviolet radiation is harmful to both plants and animals. Increased levels of a type of ultraviolet radiation called UVB can cause cataracts and skin cancer in humans, lower crop yields in agriculture, and disrupted food chains in nature.

Living organisms have evolved in the presence of UVB, and cells have some ability to repair themselves when exposed to low levels of UVB. However, some scientists believe that when UVB levels reach a certain point, the cells of living organisms will no longer be able to cope, and many organisms will die.

Earth's atmosphere Living organisms on Earth exist because they are protected from high levels of UVB by ozone. Ozone, which is made up of oxygen, is a substance in the atmosphere that absorbs most harmful radiation before it reaches Earth's surface. A **substance,** which is also known as a chemical, is matter that has a definite and uniform composition.

About 90% of Earth's ozone is spread out in a layer that surrounds and protects our planet. As you can see in **Figure 1.2,** Earth's atmosphere consists of several layers. The lowest layer is called the troposphere and contains the air we breathe. The troposphere is where clouds occur and where airplanes fly. All of Earth's weather occurs in the troposphere. The stratosphere is the layer above the troposphere. It extends from about 10 to 50 kilometers (km) above Earth's surface. The ozone layer that protects Earth is located in the stratosphere.

Reading Check **Explain** the benefits of ozone in the atmosphere.

Real-World Chemistry
The Ozone Layer

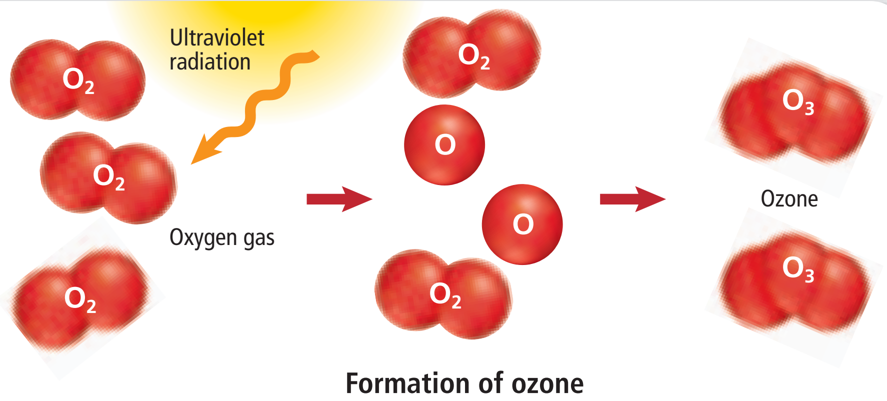
Sunscreen To offer some protection from harmful UV radiation, sunscreen can be applied to the skin. Sunscreen helps prevent sunburn and skin cancer. Health professionals recommend the use of sunscreen anytime that you are outdoors and exposed to the Sun's ultraviolet radiation.

Vocabulary

Word origin

Ozone
comes from the Greek word *ozōn*, which means *to smell*

Figure 1.3 Ultraviolet radiation from the Sun causes some oxygen gas (O_2) to break into individual particles of oxygen (O). These individual particles combine with oxygen gas (O_2) to form ozone (O_3).
Explain *why there is a balance between oxygen gas and ozone levels in the stratosphere.*

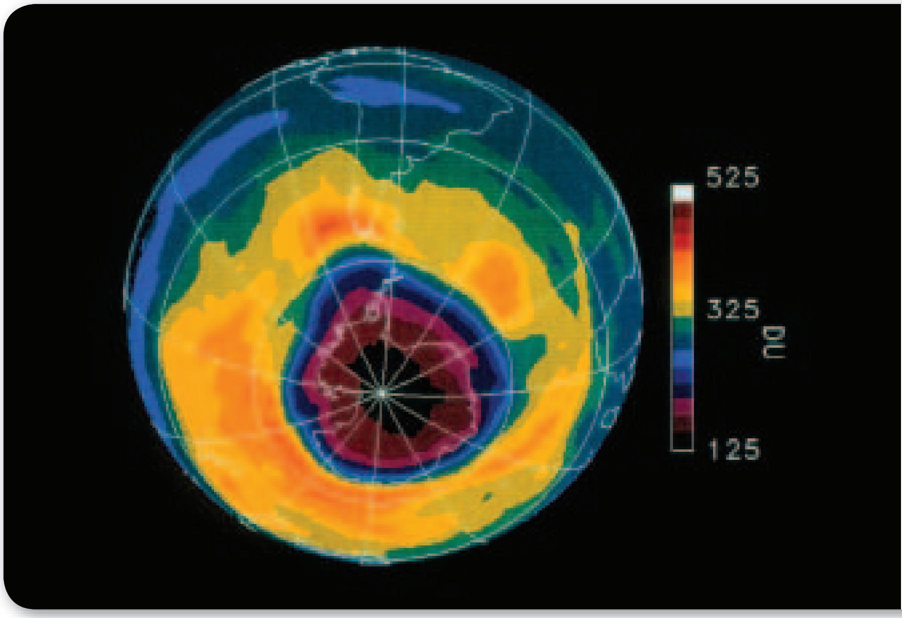


Ozone formation How does ozone enter the stratosphere? When oxygen gas (O_2) is exposed to ultraviolet radiation in the upper regions of the stratosphere, ozone (O_3) is formed. Molecules of oxygen gas are made of two smaller oxygen particles. The energy of the radiation breaks the oxygen gas into individual oxygen particles (O), which then interact with O_2 to form O_3. **Figure 1.3** illustrates this process. Ozone can also absorb radiation and break apart to reform oxygen gas. Thus, there tends to be a balance between oxygen gas and ozone levels in the stratosphere.

Ozone was first identified and measured in the late 1800s, so its presence has been studied for a long time. It was of interest to scientists because air currents in the stratosphere move ozone around Earth. Ozone forms over the equator, where the rays of sunlight are the strongest, and then flows toward the poles. Thus, ozone makes a convenient marker to follow the flow of air in the stratosphere.

In the 1920s, British scientist G.M.B. Dobson (1889–1976) began measuring the amount of ozone in the atmosphere. Although ozone is formed in the higher regions of the stratosphere, most of it is stored in the lower stratosphere. Ozone can be measured in the lower stratosphere by instruments on the ground or in balloons, satellites, and rockets. Dobson's measurements helped scientists determine the normal amount of ozone that should be in the stratosphere. Three hundred Dobson units (DU) is considered the normal amount of ozone in the stratosphere. Instruments, like those shown in **Figure 1.4,** monitor the amount of ozone present in the stratosphere today.

Figure 1.4 Scientists use a variety of equipment, including this Brewer spectrometer, to take ozone measurements.



■ **Figure 1.5** Satellite photos confirmed the British Antarctic Survey team's measurements that the ozone layer was thinning over Antarctica. On this satellite map, the area over Antarctica appears pink, purple, and black. The color-key on the right indicates that the ozone level ranges from 125 to about 200 Dobson Units, which is well below the normal level of 300 Dobson units.

Between 1981 and 1983, a research group from the British Antarctic Survey was monitoring the atmosphere above Antarctica. They measured surprisingly low levels of ozone—readings as low as 160 DU—especially during the Antarctic spring in October. They checked their instruments and repeated their measurements. In October 1985, they reported a confirmed decrease in the amount of ozone in the stratosphere and concluded that the ozone layer was thinning. **Figure 1.5** shows how the thinning ozone layer looked in October 1990.

Although the thinning of the ozone layer is often called the ozone hole, it is not a hole. The ozone is still present in the atmosphere. However, the protective layer is much thinner than normal. This fact has alarmed scientists, who never expected to find such low levels. Measurements made from balloons, high-altitude planes, and satellites have supported the measurements made from the ground. What could be causing the ozone hole?

Chlorofluorocarbons

The story of the second substance in this chapter begins in the 1920s. Large-scale production of refrigerators, which at first used toxic gases such as ammonia as coolants, was just beginning. Because ammonia fumes could escape from the refrigerator and harm the members of a household, chemists began to search for safer coolants. Thomas Midgley, Jr. synthesized the first chlorofluorocarbons in 1928. A chlorofluorocarbon (CFC) is a substance that consists of chlorine, fluorine, and carbon. Several different substances are classified as CFCs. They are all made in the laboratory and do not occur naturally. CFCs are nontoxic and stable—they do not readily react with other substances. At the time, they seemed to be ideal coolants for refrigerators. By 1935, the first self-contained home air-conditioning units and eight million new refrigerators in the United States used CFCs as coolants. In addition to their use as refrigerants, CFCs were also used in plastic foams and as propellants in spray cans.

Reading Check **Explain** why scientists thought CFCs were safe for the environment.

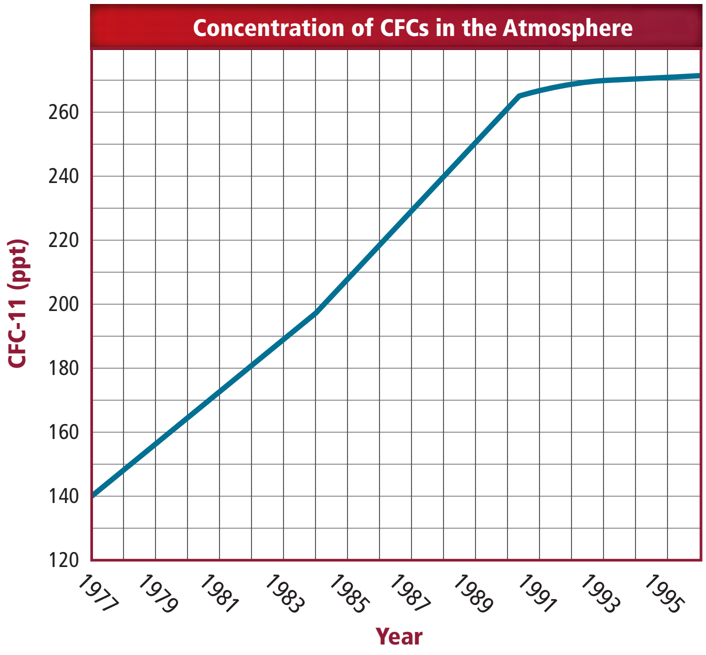
CAREERS IN CHEMISTRY

Environmental Chemist An environmental chemist uses tools from chemistry and other sciences to study how chemicals interact with the physical and biological environment. This includes identifying the sources of pollutants such as ozone and their effects on living organisms. For more information on chemistry careers, visit glencoe.com.

■ **Figure 1.6** Scientists collected data on the global use of CFCs and the accumulation of CFCs over Antarctica. CFC-11 is one particular type of CFC.

Graph Check

Describe the trend in the data from 1977 through 1995.



Scientists first began to detect the presence of CFCs in the atmosphere in the 1970s. They decided to measure the amount of CFCs in the stratosphere and found that quantities in the stratosphere increased year after year. By 1990, the concentration of CFCs had reached an all-time high, as shown in **Figure 1.6.** However, it was widely thought that CFCs did not pose a threat to the environment because they are so stable, and consequently many scientists were not alarmed.

Scientists had noticed and measured two separate phenomena: the protective ozone layer in the atmosphere was thinning, and increasingly large quantities of CFCs were drifting into the atmosphere. Could there be a connection between the two occurrences? Before you learn the answer to this question, you need to understand some of the basic ideas of chemistry and know how chemists—and most scientists—solve scientific problems.

Section 1.1 Assessment

Section Summary

- Chemistry is the study of matter.
- Chemicals are also known as substances.
- Ozone is a substance that forms a protective layer in Earth's atmosphere.
- CFCs are synthetic substances made of chlorine, fluorine, and carbon that are thinning the ozone layer.

1. **MAIN Idea** **Explain** why the study of chemistry should be important to everyone.
2. **Define** *substance* and give two examples of things that are substances.
3. **Describe** how the ozone layer forms and why it is important.
4. **Explain** why chlorofluorocarbons were developed and how they are used.
5. **Explain** If cells have the ability to repair themselves after exposure to UVB, why do the increasing levels of UVB in the atmosphere concern scientists?
6. **Explain** why the concentration of CFCs increased in the atmosphere.
7. **Evaluate** why it was important for Dobson's data to be confirmed by satellite photos.

ChemistryOnline **Self-Check Quiz** glencoe.com

Section 1.2

Objectives

- **Compare and contrast** mass and weight.
- **Explain** why chemists are interested in a submicroscopic description of matter.
- **Identify** the area of emphasis for various branches of chemistry.

Review Vocabulary

technology: a practical application of scientific information

New Vocabulary

mass
weight
model

Chemistry and Matter

MAIN Idea Branches of chemistry involve the study of different kinds of matter.

Real-World Reading Link If you consider that everything around you is matter, you will realize that chemists study a huge variety of things.

Matter and its Characteristics

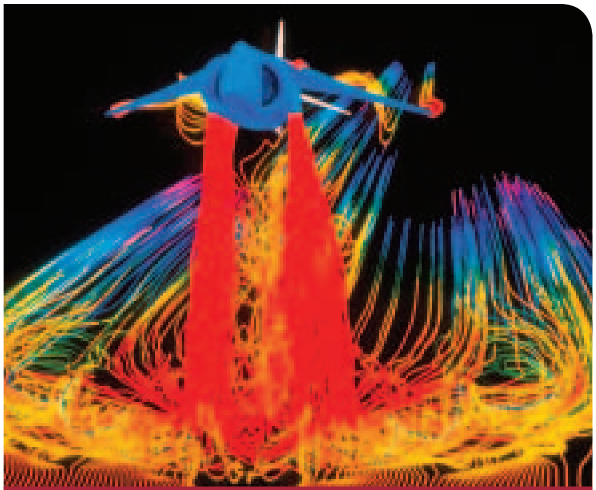
Matter, the stuff of the universe, has many different forms. Everything around you, like the things in **Figure 1.7,** is matter. Some matter occurs naturally, such as ozone, and other substances are not natural, such as CFCs, which you read about in Section 1.1.

You might realize that everyday objects are composed of matter, but how do you define matter? Recall that matter is anything that has mass and takes up space. Also recall that **mass** is a measurement that reflects the amount of matter. You know that your textbook has mass and takes up space, but is air matter? You cannot see it and you cannot always feel it. However, when you inflate a balloon, it expands to make room for the air. The balloon gets heavier. Thus, air must be matter. Is everything matter? The thoughts and ideas that "fill" your head are not matter; neither are heat, light, radio waves, nor magnetic fields. What else can you name that is not matter?

Mass and weight Have you ever used a bathroom scale to measure your weight? **Weight** is a measure not only of the amount of matter but also of the effect of Earth's gravitational pull on that matter. This force is not exactly the same everywhere on Earth and actually becomes less as you move away from Earth's surface at sea level. You might not notice a difference in your weight from one place to another, but subtle differences do exist.

Figure 1.7 Everything in this photo is matter and has mass and weight.
Compare and contrast *mass and weight.*

Office building model



Airplane model

■ **Figure 1.8** Scientists use models to visualize complex ideas, such as the materials and structure used to build office buildings. They also use models to test a concept, such as a new airplane design, before it is mass produced.

Infer ***why chemists use models to study atoms.***

It might seem more convenient for scientists to simply use weight instead of mass. Why is it so important to think of matter in terms of mass? Scientists need to be able to compare the measurements that they make in different parts of the world. They could identify the gravitational force every time they weigh something, but that would not be practical or convenient. They use mass as a way to measure matter independently of gravitational force.

Structure and observable characteristics What can you observe about the outside of your school building? You know that there is more to the building than what you can observe from the outside. Among other things, there are beams inside the walls that give the building structure, stability, and function. Consider another example. When you bend your arm at the elbow, you observe that your arm moves, but what you cannot see is that muscles under the skin contract and relax to move your arm.

Much of matter and its behavior is macroscopic; that is, you do not need a microscope to observe it. You will learn in Chapter 3 that the tremendous variety of stuff around you can be broken down into more than a hundred types of matter called elements, and that elements are made up of particles called atoms. Atoms are so tiny that they cannot be seen even with optical microscopes. Thus, atoms are submicroscopic. They are so small that one trillion atoms could fit onto the period at the end of this sentence. The structure, composition, and behavior of all matter can be explained on a submicroscopic level—or the atomic level. All that we observe about matter depends on atoms and the changes they undergo.

Chemistry seeks to explain the submicroscopic events that lead to macroscopic observations. One way this can be done is by making a model. A **model** is a visual, verbal, or mathematical explanation of experimental data. Scientists use many types of models to represent things that are hard to visualize, such as the structure and materials used in the construction of a building and the computer model of the airplane shown in **Figure 1.8.** Chemists also use several different types of models to represent matter, as you will soon learn.

Reading Check **Identify** two additional types of models that are used by scientists.

FOLDABLES
Incorporate information from this section into your Foldable.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Weight

Science usage: the measure of the amount of matter in and the gravitational force exerted on an object

The weight of an object is the product of its mass and the local acceleration of gravity.

Common usage: the relative heaviness of an object

The puppy grew so quickly it doubled its weight in a matter of weeks.

Concepts In Motion

Interactive Table Explore branches of chemistry at glencoe.com.

Table 1.1	Some Branches of Chemistry	
Branch	Area of Emphasis	Examples of Emphasis
Organic chemistry	most carbon-containing chemicals	pharmaceuticals, plastics
Inorganic chemistry	in general, matter that does not contain carbon	minerals, metals and nonmetals, semiconductors
Physical chemistry	the behavior and changes of matter and the related energy changes	reaction rates, reaction mechanisms
Analytical chemistry	components and composition of substances	food nutrients, quality control
Biochemistry	matter and processes of living organisms	metabolism, fermentation
Environmental chemistry	matter and the environment	pollution, biochemical cycles
Industrial chemistry	chemical processes in industry	paints, coatings
Polymer chemistry	polymers and plastics	textiles, coatings, plastics
Theoretical chemistry	chemical interactions	many areas of emphasis
Thermochemistry	heat involved in chemical processes	heat of reaction

Chemistry: The Central Science

Recall from Section 1.1 that chemistry is the study of matter and the changes that it undergoes. A basic understanding of chemistry is central to all sciences—biology, physics, Earth science, ecology, and others. Because there are so many types of matter, there are many areas of study in the field of chemistry. Chemistry is traditionally broken down into branches that focus on specific areas, such as those listed in **Table 1.1.** Although chemistry is divided into specific areas of study, many of the areas overlap. For example, as you can see from **Table 1.1,** an organic chemist might study plastics, but an industrial chemist or a polymer chemist could also focus on plastics.

ChemistryOnline

Personal Tutor For an online tutorial on mass and weight relationships, visit glencoe.com.

Section 1.2 Assessment

Section Summary

- Models are tools that scientists, including chemists, use.
- Macroscopic observations of matter reflect the actions of atoms on a submicroscopic scale.
- There are several branches of chemistry, including organic chemistry, inorganic chemistry, physical chemistry, analytical chemistry, and biochemistry.

8. MAIN Idea **Explain** why there are different branches of chemistry.
9. **Explain** why scientists use mass instead of weight for their measurements.
10. **Summarize** why it is important for chemists to study changes in the world at a submicroscopic level.
11. **Infer** why chemists use models to study submicroscopic matter.
12. **Identify** three models that scientists use, and explain why each model is useful.
13. **Evaluate** How would your mass and weight differ on the Moon? The gravitational force of the Moon is one-sixth the gravitational force on Earth.
14. **Evaluate** If you put a scale in an elevator and weigh yourself as you ascend and then descend, does the scale have the same reading in both instances? Explain your answer.

Section 1.3

Objectives

- **Identify** the common steps of scientific methods.
- **Compare and contrast** types of data.
- **Identify** types of variables.
- **Describe** the difference between a theory and a scientific law.

Review Vocabulary

systematic approach: an organized method of solving a problem

New Vocabulary

scientific method
qualitative data
quantitative data
hypothesis
experiment
independent variable
dependent variable
control
conclusion
theory
scientific law

Scientific Methods

MAIN Idea Scientists use scientific methods to systematically pose and test solutions to questions and assess the results of the tests.

Real-World Reading Link When packing for a long trip, how do you start? Do you throw all of your clothes in a suitcase, or do you plan what you are going to wear? Usually, it is most effective to make a plan. Similarly, scientists develop and follow a plan that helps them investigate the world.

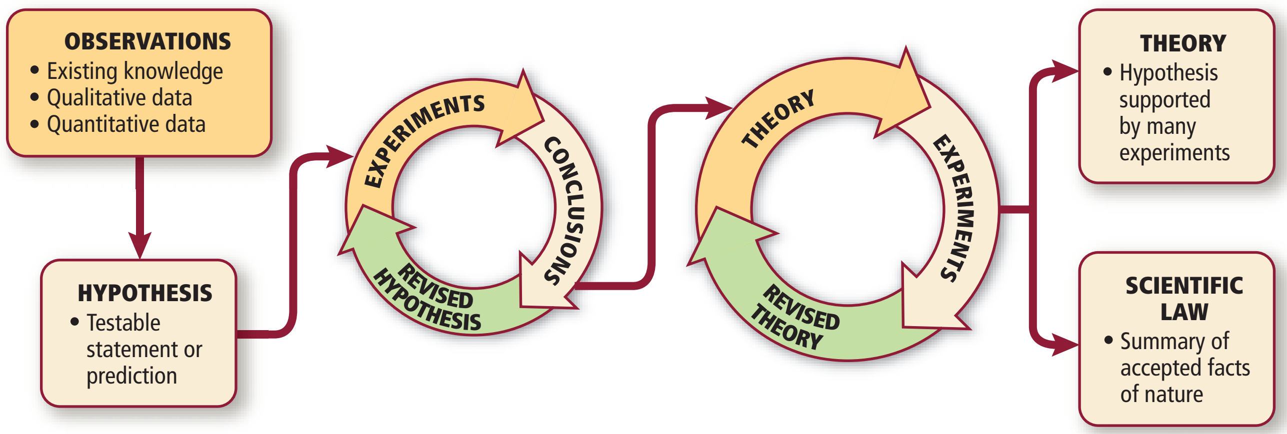
A Systematic Approach

You might have worked with a group on an experiment in the laboratory in a previous science course. If so, you know that each person in the group probably has a different idea about how to do the lab. Having many different ideas about how to do the lab is one of the benefits of many people working together. However, communicating ideas effectively to one another and combining individual contributions to form a solution can be difficult in group work.

Scientists approach their work in a similar way. Each scientist tries to understand his or her world based on a personal point of view and individual creativity. Often, the work of many scientists is combined in order to gain new insight. It is helpful if all scientists use common procedures as they conduct their experiments.

A **scientific method** is a systematic approach used in scientific study, whether it is chemistry, biology, physics, or another science. It is an organized process used by scientists to do research, and it provides a method for scientists to verify the work of others. An overview of the typical steps of a scientific method is shown in **Figure 1.9.** The steps are not meant to be used as a checklist, or to be done in the same order each time. Therefore, scientists must describe their methods when they report their results. If other scientists cannot confirm the results after repeating the method, then doubt arises over the validity of the results.

Figure 1.9 The steps in a scientific method are repeated until a hypothesis is supported or discarded.



MiniLab

Develop Observation Skills

Why are observation skills important in chemistry? Observations are often used to make inferences. An inference is an explanation or interpretation of observations.

Procedure

1. Read and complete the lab safety form.
2. Add **water** to a **petri dish** to a height of 0.5 cm. Use a **graduated cylinder** to measure 1 mL of **vegetable oil,** then add it to the petri dish.
3. Dip the end of a **toothpick** into **liquid dishwashing detergent.**
4. Touch the tip of the toothpick to the water at the center of the petri dish. Record your detailed observations.
5. Add **whole milk** to a **second petri dish** to a height of 0.5 cm.
6. Place one drop each of **four different food colorings** in four different locations on the surface of the milk. Do not put a drop of food coloring in the center.
7. Repeat Steps 3 and 4.

Analysis

1. **Describe** what you observed in Step 4.
2. **Describe** what you observed in Step 7.
3. **Infer** Oil, the fat in milk, and grease belong to a class of substances called lipids. What can you infer about the addition of detergent to dishwater?
4. **Explain** why observations skills were important in this chemistry lab.

Observation You make observations throughout your day in order to make decisions. Scientific study usually begins with simple observation. An observation is the act of gathering information. Often, the types of observations scientists make first are **qualitative data**—information that describes color, odor, shape, or some other physical characteristic. In general, anything that relates to the five senses is qualitative: how something looks, feels, sounds, tastes, or smells.

Chemists frequently gather another type of data. For example, they can measure temperature, pressure, volume, the quantity of a chemical formed, or how much of a chemical is used up in a reaction. This numerical information is called **quantitative data.** It tells how much, how little, how big, how tall, or how fast. What kind of qualitative and quantitative data can you gather from **Figure 1.10?**

Hypothesis Recall the stories of the two substances that you read about in Section 1.1. Even before quantitative data showed that ozone levels were decreasing in the stratosphere, scientists observed CFCs there. Chemists Mario Molina and F. Sherwood Rowland were curious about how long CFCs could exist in the atmosphere.

Molina and Rowland examined the interactions that can occur among various chemicals in the troposphere. They determined that CFCs were stable there for long periods of time, but they also knew that CFCs drift upward into the stratosphere. They formed a hypothesis that CFCs break down in the stratosphere due to interactions with ultraviolet light from the Sun. In addition, the calculations they made led them to hypothesize that chlorine produced by this interaction would break down ozone.

A **hypothesis** is a tentative explanation for what has been observed. Molina and Rowland's hypothesis stated what they believed to be happening, even though there was no formal evidence at that point to support the statement.

Reading Check **Infer** why a hypothesis is tentative.

Figure 1.10 Quantitative data are numerical information. Qualitative data are observations made by using the human senses.
Identify *the quantitative and qualitative data in the photo.*

■ **Figure 1.11** These materials can be used to determine the effect of temperature on the rate at which table salt dissolves.

Experiments A hypothesis is meaningless unless there are data to support it. Thus, forming a hypothesis helps the scientist focus on the next step in a scientific method—the experiment. An **experiment** is a set of controlled observations that test the hypothesis. The scientist must carefully plan and set up one or more laboratory experiments in order to change and test one variable at a time. A variable is a quantity or condition that can have more than one value.

Suppose your chemistry teacher asks your class to use the materials shown in **Figure 1.11** to design an experiment to test the hypothesis that table salt dissolves faster in hot water than in water at room temperature (20°C). Because temperature is the variable that you plan to change, it is an **independent variable.** Your group determines that a given quantity of salt completely dissolves within 1 min at 40°C, but that the same quantity of salt dissolves after 3 min at 20°C. Thus, temperature affects the rate at which the salt dissolves. This rate is called a **dependent variable** because its value changes in response to a change in the independent variable. Although your group can determine the way in which the independent variable changes, it has no control over the way the dependent variable changes.

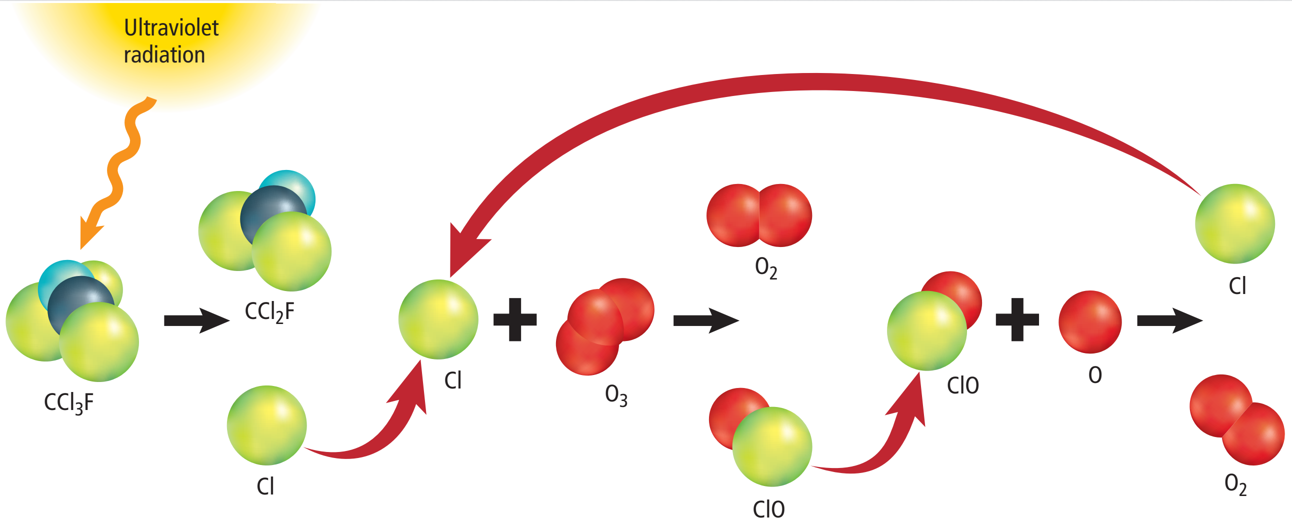
Reading Check **Explain** the difference between a dependent and an independent variable.

Other factors What other factors could you vary in your experiment? Would the amount of salt you try to dissolve make a difference? The amount of water you use? Would stirring the mixture affect your results? The answer to all of these questions might be yes. You must plan your experiment so that these variables are the same at each temperature, or you will not be able to tell clearly what caused your results. In a well-planned experiment, the independent variable should be the only condition that affects the experiment's outcome. A constant is a factor that is not allowed to change during the experiment. The amount of salt, water, and stirring must be constant at each temperature.

In many experiments, it is valuable to have a **control,** that is, a standard for comparison. In the above experiment, the room-temperature water is the control. **Figure 1.12** shows a different type of control. A chemical indicator has been added to each of three test tubes. An acidic solution is in the test tube on the left, and the indicator turns red. The test tube in the middle contains water and the indicator is yellow. The test tube on the right contains a basic solution and the indicator turns blue.

■ **Figure 1.12** Because the acidity of the solutions in these test tubes is known, these solutions can be used as controls in an experiment.

Infer *If the same chemical indicator were added to a solution of unknown acidity, how could you determine if it was acidic, neutral, or basic?*



Molina and Rowland's model predicted that ultraviolet radiation causes chlorine (Cl) to split off from a CFC (CCl_3F).

The chlorine then destroys the ozone by combining with it to form oxygen gas (O_2) and chlorine monoxide (ClO).

A free oxygen (O) combines with the chlorine monoxide (ClO) to form oxygen gas (O_2) and a chlorine (Cl). Then, the chlorine is free to combine with another ozone. The process begins again.

■ **Figure 1.13** Molina and Rowland's model showed how CFCs could destroy ozone.

Concepts In Motion

Interactive Figure To see an animation of ozone depletion, visit glencoe.com.

Controlling variables The interactions described between CFCs and ozone in Molina and Rowland's hypothesis take place high overhead. Many variables are involved. For example, there are several gases present in the stratosphere. Thus, it would be difficult to determine which gases, or if all gases, are causing decreasing ozone levels. Winds, variations in ultraviolet light, and other factors could change the outcome of any experiment on any given day, making comparisons difficult. Sometimes, it is easier to simulate conditions in a laboratory, where the variables can be more easily controlled.

Conclusion An experiment might generate a large amount of data. Scientists take the data, analyze it, and check it against the hypothesis to form a conclusion. A **conclusion** is a judgment based on the information obtained. A hypothesis can never be proven. Therefore, when the data support a hypothesis, this only indicates that the hypothesis might be true. If further evidence does not support it, then the hypothesis must be discarded or modified. The majority of hypotheses are not supported, but the data might still yield new and useful information.

Molina and Rowland formed a hypothesis about the stability of CFCs in the stratosphere. They gathered data that supported their hypothesis and developed a model in which the chlorine formed by the breakdown of CFCs would react over and over again with ozone.

A model can be tested and used to make predictions. Molina and Rowland's model predicted the formation of chlorine and the depletion of ozone, as shown in **Figure 1.13.** Another research group found evidence of interactions between ozone and chlorine when taking measurements in the stratosphere, but they did not know the source of the chlorine. Molina and Rowland's model predicted a source of the chlorine. They came to the conclusion that ozone in the stratosphere could be destroyed by CFCs, and they had enough support for their hypothesis to publish their discovery. They won the Nobel Prize in 1995.

FOLDABLES
Incorporate information from this section into your Foldable.

■ **Figure 1.14** It does not matter how many times skydivers leap from a plane; Newton's law of universal gravitation applies every time.

Theory and Scientific Law

A **theory** is an explanation of a natural phenomenon based on many observations and investigations over time. You might have heard of Einstein's theory of relativity or the atomic theory. A theory states a broad principle of nature that has been supported over time. All theories are still subject to new experimental data and can be modified. Also, theories often lead to new conclusions. A theory is considered successful if it can be used to make predictions that are true.

Sometimes, many scientists come to the same conclusion about certain relationships in nature and they find no exceptions to these relationships. For example, you know that no matter how many times skydivers, like those shown in **Figure 1.14,** leap from a plane, they always return to Earth's surface. Sir Isaac Newton was so certain that an attractive force exists between all objects that he proposed his law of universal gravitation. Newton's law is a **scientific law**—a relationship in nature that is supported by many experiments. It is up to scientists to develop further hypotheses and experiments to explain why these relationships exist.

Section 1.3 Assessment

Section Summary

- Scientific methods are systematic approaches to problem solving.
- Qualitative data describe an observation; quantitative data use numbers.
- Independent variables are changed in an experiment. Dependent variables change in response to the independent variable.
- A theory is a hypothesis that is supported by many experiments.

15. MAIN Idea **Explain** why scientists do not use a standard set of steps for every investigation they conduct.
16. **Differentiate** Give an example of quantitative and qualitative data.
17. **Evaluate** You are asked to study the effect of temperature on the volume of a balloon. The balloon's size increases as it is warmed. What is the independent variable? The dependent variable? What factor is held constant? How would you construct a control?
18. **Distinguish** Jacques Charles described the direct relationship between temperature and volume of all gases at constant pressure. Should this be called Charles's law or Charles's theory? Explain.
19. **Explain** Good scientific models can be tested and used to make predictions. What did Molina and Rowland's model of the interactions of CFCs and ozone in the atmosphere predict would happen to the amount of ozone in the stratosphere as the level of CFCs increased?

Chemistry Online **Self-Check Quiz** glencoe.com

Section 1.4

Objectives

- **Compare and contrast** pure research, applied research, and technology.
- **Apply** knowledge of laboratory safety.

Review Vocabulary

synthetic: something that is human-made and does not necessarily occur in nature

New Vocabulary

pure research
applied research

Scientific Research

MAIN Idea Some scientific investigations result in the development of technology that can improve our lives and the world around us.

Real-World Reading Link Much of the information that scientists obtain through basic research is used to solve a specific problem or need. For example, X rays were discovered by scientists who were conducting basic research on electrical discharge through gases. Later, it was discovered that X rays could be used to diagnose medical problems.

Types of Scientific Investigations

Every day in the media—through TV, newspapers, magazines, or the Internet—the public is bombarded with the results of scientific investigations. Many deal with the environment, medicine, or health. As a consumer, you are asked to evaluate the results of scientific research and development. How do scientists use qualitative and quantitative data to solve different types of scientific problems?

Scientists conduct **pure research** to gain knowledge for the sake of knowledge itself. Molina and Rowland were motivated by curiosity and, thus, conducted research on CFCs and their interactions with ozone as pure research. No environmental evidence at the time indicated that there was a correlation to their model in the stratosphere. Their research showed only that CFCs could speed the breakdown of ozone in a laboratory setting.

By the time the ozone hole was reported in 1985, scientists had made measurements of CFC levels in the stratosphere that supported the hypothesis that CFCs could be responsible for the depletion of ozone. The early pure research done only for the sake of knowledge became applied research. **Applied research** is research undertaken to solve a specific problem. Scientists continue to monitor the amount of CFCs in the atmosphere and the annual changes in the amount of ozone in the stratosphere, as shown in **Figure 1.15.** Applied research is also being conducted to find replacement chemicals for the CFCs that are now banned.

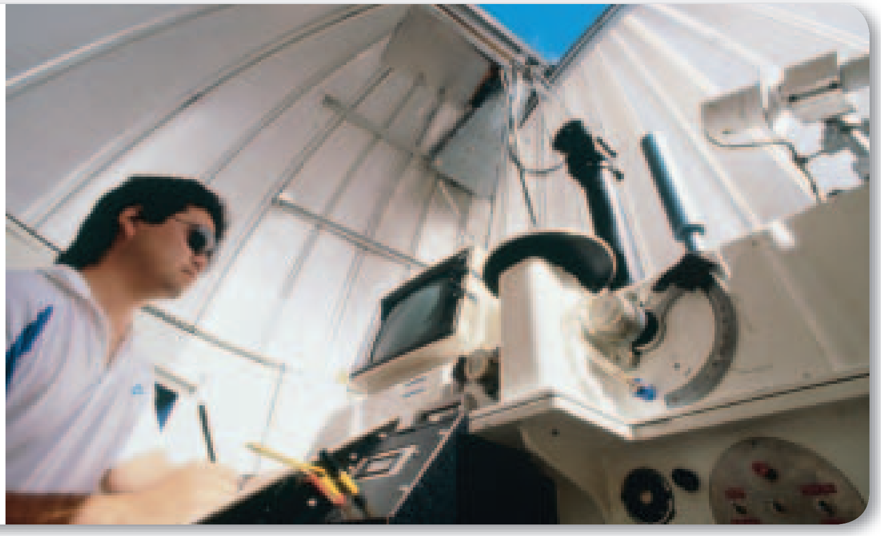
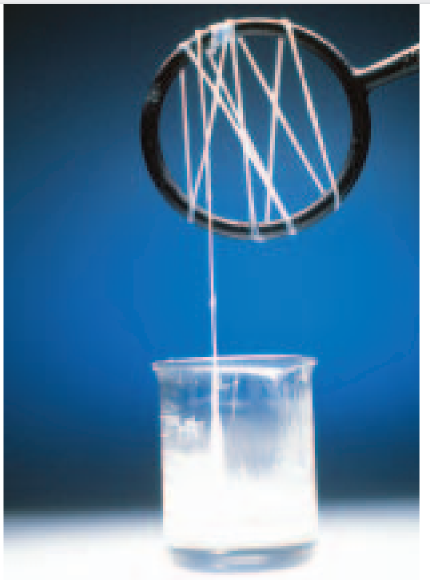


Figure 1.15 This UV-visible spectrometer (UVIZ) is used to measure ozone and other stratospheric gases during the dark winter months in Antarctica.

■ **Figure 1.16** After its discovery, nylon was used mainly for war materials and was unavailable for home use until after World War II. Today it is used in a variety of products.



Strands of nylon can be pulled from the top layer of solution.

Nylon fibers are used to make hook-and-loop fastener tape.

Chance discoveries Often, a scientist conducts experiments and reaches a conclusion that is far different from what was predicted. Some truly wonderful discoveries in science have been made unexpectedly. You might be familiar with the two examples described below.

Connection to Biology Alexander Fleming is famous for making several accidental discoveries. In one accidential discovery, Fleming found that one of his plates of *Staphylococcus* bacteria had been contaminated by a greenish mold, later identified as *Penicillium*. He observed it carefully and saw a clear area around the mold where the bacteria had died. In this case, a chemical in the mold—penicillin—was responsible for killing the bacteria.

The discovery of nylon is another example of an accidental discovery. In 1930, Julian Hill, an employee of E.I. DuPont de Nemours and Company, dipped a hot glass rod in a mixture of solutions and unexpectedly pulled out long fibers similar to those shown in **Figure 1.16.** Hill and his colleagues pursued the development of these fibers as a synthetic silk that could withstand high temperatures. They eventually developed nylon in 1934. During World War II, nylon was used as a replacement for silk in parachutes. Today, nylon is used extensively in textiles and some kinds of plastics. It is also used to make hook-and-loop tape, as shown in **Figure 1.16.**

Students in the Laboratory

In your study of chemistry, you will learn many facts about matter. You will also do investigations and experiments in which you will be able to form and test hypotheses, gather and analyze data, and draw conclusions.

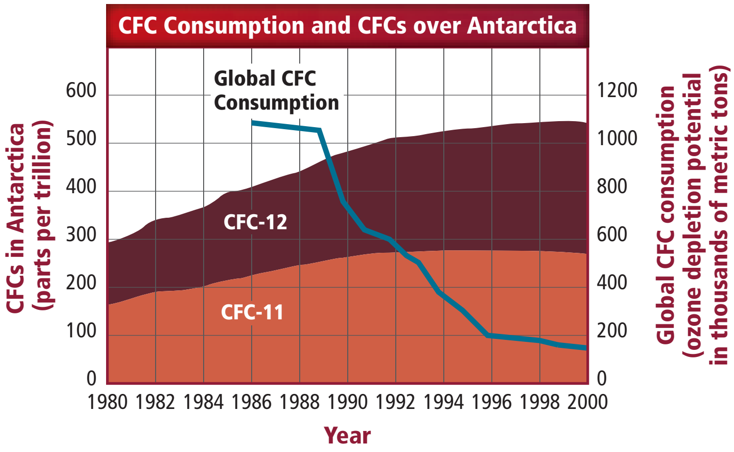
When you work in the chemistry laboratory, you are responsible for your safety and the safety of people working nearby. Often, many people are working in a small space during a lab, so it is important that everyone practice safe laboratory procedures. **Table 1.2** lists some safety rules that you should follow each time you enter the lab. Chemists and all other scientists use these safety rules as well.

Table 1.2 Safety in the Laboratory

1. Study your lab assignment before you come to the lab. If you have any questions, ask your teacher for help.
2. Do not perform experiments without your teacher's permission. Never work alone in the laboratory. Know how to contact help, if necessary.
3. Use the table on the inside front cover of this textbook to understand the safety symbols. Read and adhere to all **WARNING** statements.
4. Wear safety goggles and a laboratory apron whenever you are in the lab. Wear gloves whenever you use chemicals that cause irritations or can be absorbed through the skin. If you have long hair, you must tie it back.
5. Do not wear contact lenses in the lab, even under goggles. Lenses can absorb vapors and are difficult to remove during an emergency.
6. Avoid wearing loose, draping clothing and dangling jewelry. Wear only closed-toe shoes in the lab.
7. Keep food, beverages, and chewing gum out of the lab. Never eat in the lab.
8. Know where to find and how to use the fire extinguisher, safety shower, fire blanket, first-aid kit, and gas and electrical power shutoffs.
9. Immediately clean up spills on the floor and keep all walkways clear of objects, such as backpacks, to prevent accidental falls or tripping. Report any accident, injury, incorrect procedure, or damaged equipment to your teacher.
10. If chemicals come in contact with your eyes or skin, flush the area immediately with large quantities of water. Immediately inform your teacher of the nature of the spill.
11. Handle all chemicals carefully. Check the labels of all bottles before removing the contents. Read the label three times: before you pick up the container, when the container is in your hand, and when you put the bottle back.
12. Do not take reagent bottles to your work area unless instructed to do so. Use test tubes, paper, or beakers to obtain your chemicals. Take only small amounts. It is easier to get more than to dispose of excess.
13. Do not return unused chemicals to the stock bottle.
14. Do not insert droppers into reagent bottles. Pour a small amount of the chemical into a beaker.
15. Never taste any chemicals. Never draw any chemicals into a pipette with your mouth.
16. Keep combustible materials away from open flames.
17. Handle toxic and combustible gases only under the direction of your teacher. Use the fume hood when such materials are present.
18. When heating a substance in a test tube, be careful not to point the mouth of the test tube at another person or yourself. Never look down into the mouth of a test tube.
19. Do not heat graduated cylinders, burettes, or pipettes with a laboratory burner.
20. Use caution and proper equipment when handling a hot apparatus or glassware. Hot glass looks the same as cool glass.
21. Dispose of broken glass, unused chemicals, and products of reactions only as directed by your teacher.
22. Know the correct procedure for preparing acid solutions. Always add the acid to the water slowly.
23. Keep the balance area clean. Never place chemicals directly on the pan of a balance.
24. After completing an experiment, clean and put away your equipment. Clean your work area. Make sure the gas and water are turned off. Wash your hands with soap and water before you leave the lab.

Matt Meadows

Figure 1.17 This graph shows the concentration of two common CFCs in the atmosphere over Antarctica and the global consumption of CFCs from 1980 to 2000.



The Story Continues

Now, back to the two substances that you have been reading about. A lot has happened since the 1970s, when Molina and Rowland hypothesized that CFCs broke down stratospheric ozone. The National Oceanic and Atmospheric Administration (NOAA) and many other groups are actively collecting historic and current data on CFCs in the atmosphere and ozone concentrations in the stratosphere. Through applied research, scientists determined that not only do CFCs react with ozone, but a few other substances react as well. Carbon tetrachloride and methyl chloroform are two additional substances that harm the ozone, as well as substances that contain bromine.

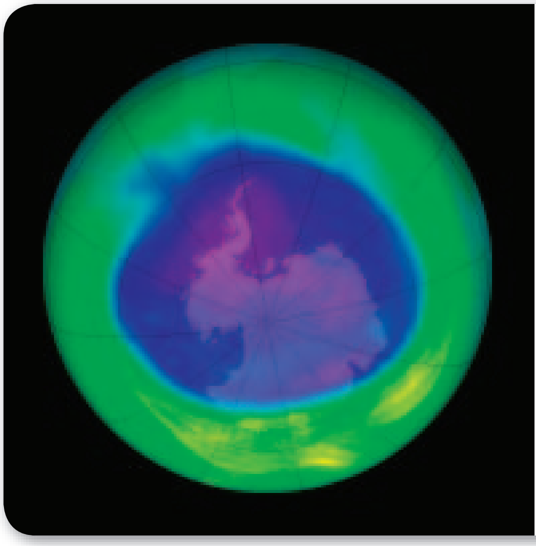
FOLDABLES Incorporate information from this section into your Foldable.

The Montreal Protocol Because ozone depletion is an international concern, nations have banned together to try to solve this problem. In 1987, leaders from many nations met in Montreal, Canada, and signed the Montreal Protocol. By signing this agreement, nations agreed to phase out the use of these compounds and place restrictions on how they should be used in the future. As you can see from **Figure 1.17,** the global use of CFCs began to decline after the Montreal Protocol was signed. However, the graph shows that the amount of CFCs measured over Antarctica did not decline immediately.

Graph Check **Identify** when CFCs in Antarctica began to level off after national leaders signed the Montreal Protocol.

The ozone hole today Scientists have also learned that the ozone hole forms each year over Antarctica during the spring. Stratospheric ice clouds form over Antarctica when temperatures there drop below −78°C. These clouds produce changes that promote the production of chemically active chlorine and bromine. When temperatures begin to warm in the spring, this chemically active chlorine and bromine react with ozone, causing ozone depletion. This ozone depletion causes the ozone hole to form over Antarctica. Some ozone depletion also occurs over the Arctic, but temperatures do not remain low for as long, which means less ozone depletion in the Arctic.

Reading Check **Explain** what triggers the formation of the ozone hole over Antarctica.



■ **Figure 1.18** The ozone hole over Antarctica reached its maximum level of thinning in September 2005. The color-key below shows what the colors represent in this colorized satellite image.

Compare *How do these ozone levels compare with what is considered normal?*

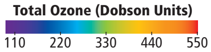


Figure 1.18 shows the ozone hole over Antarctica in September 2005. The ozone thinning over Antarctica reached its maximum for the year during this month. If you compare the color-coded key to the satellite image, you can see that the ozone level is between 110 and 200 DU. Notice the area surrounding the ozone hole. Much of this area has ozone levels around 300 DU, which is considered normal.

Scientists are not sure when the ozone layer will begin to recover. Originally, scientists predicted that it would begin to recover in 2050. However, new computer models predict that it will not begin to recover until 2068. The exact date of its recovery is not as important as the fact that it will recover given time.

VOCABULARY

ACADEMIC VOCABULARY

Recover
to bring back to normal
It takes several days to recover from the flu.

DATA ANALYSIS LAB

Based on Real Data*

Interpret Graphs

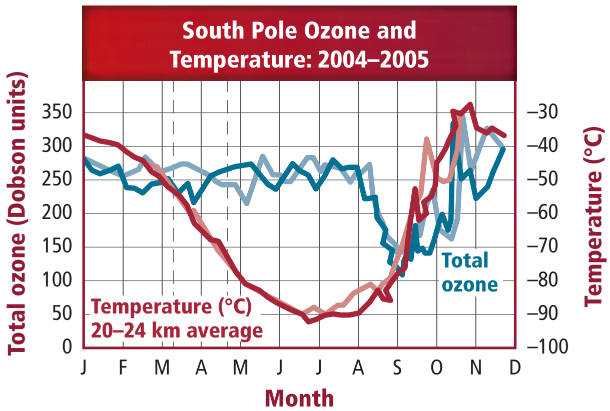
How do ozone levels vary throughout the year in Antarctica? The National Oceanic and Atmospheric Administration (NOAA) continues to monitor the concentration of ozone in the stratosphere over Antarctica.

Think Critically

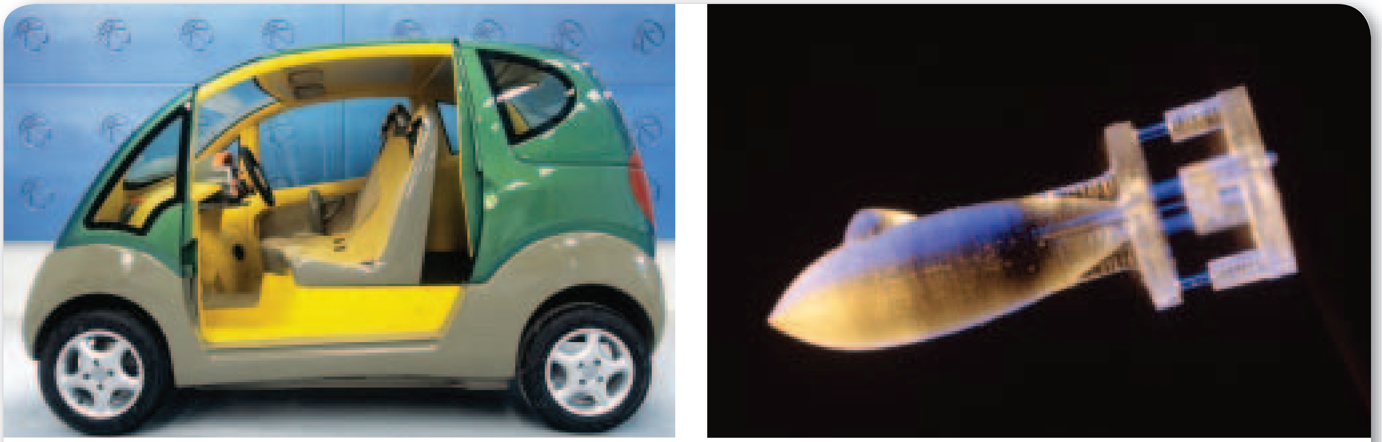
1. **Describe** the trend in the data for total ozone and temperature at the 20–24 km layer.
2. **Evaluate** how the 2004 data compare with the 2005 data.
3. **Identify** the month during which the ozone levels were the lowest.
4. **Assess** Do these data points back up what you learned in this chapter about ozone depletion? Explain your answer.

Data and Observations

This graph displays data that the NOAA collected in 2004 and 2005 over Antarctica. The darker lines represent 2005 data.



*Data obtained from: Shein, K.A., editor et al. 2005. State of the Climate in 2005. NOAA/NESDIS/NCDC & American Meteorological Society. S55.



■ **Figure 1.19** This car, which is powered by compressed air, and this tiny submarine, which is only 4 mm long, are examples of technology that are possible by the study of matter.

The Benefits of Chemistry

Chemists are an important part of the team of scientists that solve many of the problems or issues that we face today. Chemists are not only involved in resolving the ozone depletion problem. They are also involved in finding cures or vaccines for diseases, such as AIDS and influenza. Almost every situation that you can imagine involves a chemist, because everything in the universe is made of matter.

Figure 1.19 shows some of the advances in technology that are possible because of the study of matter. The car on the left is powered by compressed air. When the compressed air is allowed to expand, it pushes the pistons that move the car. Because the car is powered by compressed air, no pollutants are released. The photo on the right shows a tiny submarine that is made by computer-aided lasers. This submarine, which is only 4 mm long, might be used for detecting and repairing defects in the human body.

Section 1.4 Assessment

Section Summary

- Scientific methods can be used in pure research or in applied research.
- Some scientific discoveries are accidental, and some are the result of diligent research in response to a need.
- Laboratory safety is the responsibility of everyone in the laboratory.
- Many of the conveniences we enjoy today are technological applications of chemistry.

20. MAIN Idea **Name** three technological products that have improved our lives or the world around us.
21. **Compare and contrast** pure research and applied research.
22. **Classify** Is technology a product of pure research or applied research? Explain.
23. **Summarize** the reason behind each of the following.
    a. Wear goggles and an apron in the lab even if you are only an observer.
    b. Do not return unused chemicals to the stock bottle.
    c. Do not wear contact lenses in the laboratory.
    d. Avoid wearing loose, draping clothing and dangling jewelry.
24. **Interpret Scientific Diagrams** What safety precautions should you take when the following safety symbols are listed?

Chemistry Online Self-Check Quiz glencoe.com

In the Field

Career: Art Restorer

Painting Restoration

Art does not last forever. It is damaged by events such as people sneezing on it, touching it, or by smoke during a fire. The repair of damage to artwork is the job of art restorers. Art repair is not always an easy task, because the materials used to correct the damage can also damage the artwork.

Help from above Oxygen makes up 21% of Earth's atmosphere. Near the ground, almost all the oxygen exists as oxygen gas (O_2). However, high in the atmosphere, ultraviolet light from the Sun splits oxygen gas into atomic oxygen (O). While oxygen gas is chemically reactive, atomic oxygen is even more reactive. It can damage spacecraft in orbit, which is why NASA actively studies the reactions between atomic oxygen and other substances.

Oxygen and art Atomic oxygen is especially reactive with the element carbon—the main substance found in soot from a fire. When NASA scientists treated the soot-damaged painting shown in **Figure 1** with atomic oxygen, the carbon in the soot reacted with oxygen to produce gases that floated away.

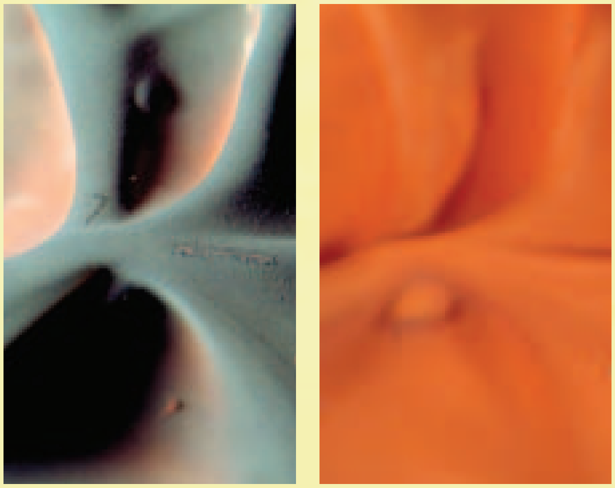


Figure 1 The photo on the left shows soot damage to an oil painting. The photo on the right shows the painting after oxygen treatment. Removal of a small amount of glossy binder was the only damage to the painting during the treatment.

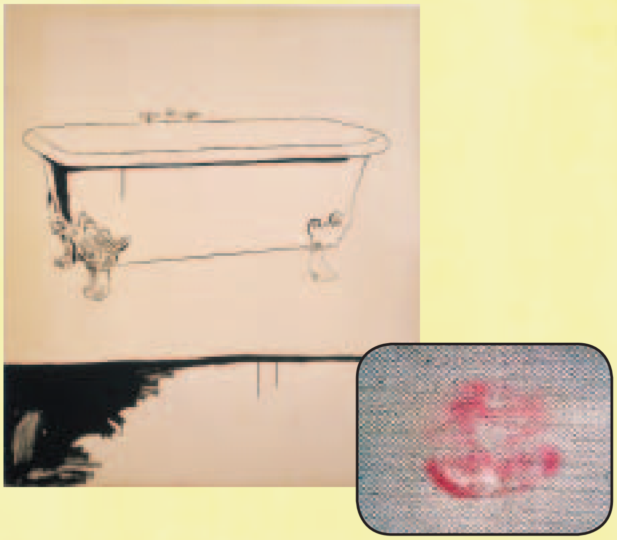


Figure 2 This lipstick stain could not be removed using conventional techniques. However, atomic oxygen removed the stain without damage to the painting.

On the surface Because atomic oxygen acts only on what it touches, paint layers below the soot or other surface impurities are unaffected. If you compare the image on the left with the image on the right in **Figure 1,** you will notice that the soot was removed, but the painting was not harmed. This is in contrast to more conventional treatments, in which organic solvents are used to remove the soot. These solvents often react with the paint as well as the soot.

The kiss Another successful restoration was the Andy Warhol painting called *The Bathtub.* It was damaged when a lipstick-wearing viewer kissed the canvas, as shown in **Figure 2.** Most conventional restoration techniques would have driven the lipstick deeper into the painting, leaving a permanent pink stain. When atomic oxygen was applied to the stain, the pink color vanished.

WRITING in Chemistry

Prepare a newspaper article explaining how atomic oxygen is used for art restoration. For more information about art restoration, visit glencoe.com.

CHEMLAB

FORENSICS: IDENTIFY THE WATER SOURCE

Chemistry Online
Probeware Alternate CBL instructions can be found at glencoe.com.

Background: The contents of tap water vary from community to community. Water is classified as hard or soft based on the amount of calcium or magnesium in the water, measured in milligrams per liter (mg/L). Imagine a forensics lab has two samples of water. One sample comes from Community A, which has soft water. The other sample comes from Community B, which has hard water.

Question: *From which community did each water sample originate?*

Materials

test tubes with stoppers (3)
test-tube rack
grease pencil
graduated cylinder (25-mL)
distilled water
dropper
beaker (250-mL)
Water sample 1
Water sample 2
dish detergent
metric ruler

Safety Precautions

Procedure

1. Read and complete the lab safety form.
2. Prepare a data table like the one shown. Then, use a grease pencil to label three large test tubes: *D* (for distilled water), *1* (for Sample 1), and *2* (for Sample 2).
3. Use a graduated cylinder to measure out 20 mL of distilled water. Pour the water into Test Tube D.
4. Place Test Tubes 1 and 2 next to Test Tube D and make a mark on each test tube that corresponds to the height of the water in Test Tube D.
5. Obtain 50 mL of Water Sample 1 in a beaker from your teacher. Slowly pour the water sample into Test Tube 1 until you reach the marked height.
6. Obtain 50 mL of Water Sample 2 in a beaker from your teacher. Slowly pour Water Sample 2 into Test Tube 2 until you reach the marked height.
7. Add one drop of dish detergent to each test tube. Stopper the tubes tightly. Then, shake each sample for 30 s to produce suds. Use a metric ruler to measure the height of the suds.
8. Use some of the soapy solutions to remove the grease marks from the test tubes.

Data Table

Sample	Height of Suds
D	
1	
2	

9. **Cleanup and Disposal** Rinse all of the liquids down the drain with tap water. Return all lab equipment to its designated location.

Analyze and Conclude

1. **Compare and Contrast** Which sample produced the most suds? Which sample produced the least amount of suds?
2. **Conclude** Soft water produces more suds than hard water. Use the table below to determine from which community each water sample originated.
3. **Calculate** If the 50 mL of hard water that you obtained contained 7.3 mg of magnesium, how hard would the water be according to the table below? (50 mL = 0.05 L)

Classification of Water Hardness

Classification	mg of Calcium or Magnesium /L
Soft	0–60
Moderate	61–120
Hard	121–180
Very hard	>180

4. **Apply Scientific Methods** Identify the independent and dependent variables in this lab. Was there a control in this lab? Explain. Did all your classmates have the same results as you? Why or why not?
5. **Error Analysis** Could the procedure be changed to make the results more quantitative? Explain.

INQUIRY EXTENSION

Investigate There are a number of products that claim to soften water. Visit a grocery store or home-improvement store to find these products and design an experiment to test their claims.

CHAPTER 1 # Study Guide

BIG Idea Chemistry is a science that is central to our lives.

Section 1.1 A Story of Two Substances

MAIN Idea Chemistry is the study of everything around us.

Vocabulary
- chemistry (p. 4)
- substance (p. 5)

Key Concepts
- Chemistry is the study of matter.
- Chemicals are also known as substances.
- Ozone is a substance that forms a protective layer in Earth's atmosphere.
- CFCs are synthetic substances made of chlorine, fluorine, and carbon that are thinning the ozone layer.

Section 1.2 Chemistry and Matter

MAIN Idea Branches of chemistry involve the study of different kinds of matter.

Vocabulary
- mass (p. 9)
- model (p. 10)
- weight (p. 9)

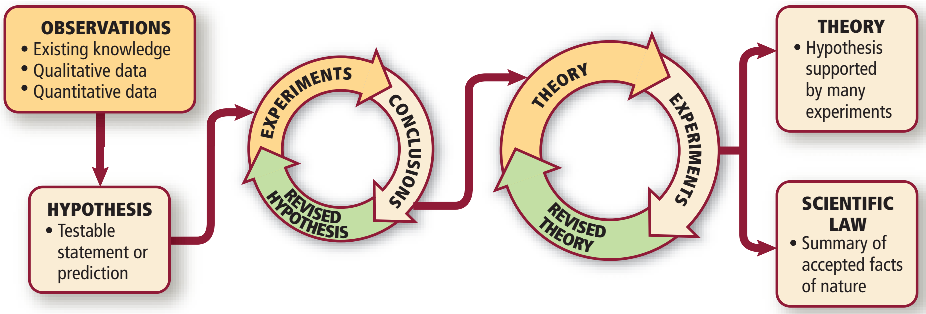
Key Concepts
- Models are tools that scientists, including chemists, use.
- Macroscopic observations of matter reflect the actions of atoms on a submicroscopic scale.
- There are several branches of chemistry, including organic chemistry, inorganic chemistry, physical chemistry, analytical chemistry, and biochemistry.

Section 1.3 Scientific Methods

MAIN Idea Scientists use scientific methods to systematically pose and test solutions to questions and assess the results of the tests.

Vocabulary
- conclusion (p. 15)
- control (p. 14)
- dependent variable (p. 14)
- experiment (p. 14)
- hypothesis (p. 13)
- independent variable (p. 14)
- qualitative data (p. 13)
- quantitative data (p. 13)
- scientific law (p. 16)
- scientific method (p. 12)
- theory (p. 16)

Key Concepts
- Scientific methods are systematic approaches to problem solving.
- Qualitative data describe an observation; quantitative data use numbers.
- Independent variables are changed in an experiment. Dependent variables change in response to the independent variable.
- A theory is a hypothesis that is supported by many experiments.



Section 1.4 Scientific Research

MAIN Idea Some scientific investigations result in the development of technology that can improve our lives and the world around us.

Vocabulary
- applied research (p. 17)
- pure research (p. 17)

Key Concepts
- Scientific methods can be used in pure research or in applied research.
- Some scientific discoveries are accidental, and some are the result of diligent research in response to a need.
- Laboratory safety is the responsibility of everyone in the laboratory.
- Many of the conveniences we enjoy today are technological applications of chemistry.

CHAPTER 1

Assessment

Section 1.1

Mastering Concepts

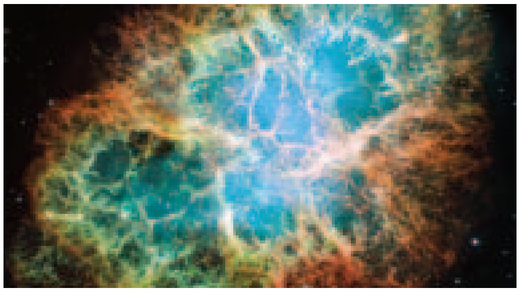
25. Define *substance* and *chemistry.*

26. Ozone Where is ozone located in Earth's atmosphere?

27. What three elements are found in chlorofluorocarbons?

28. CFCs What were common uses of CFCs?

29. Scientists noticed that the ozone layer was thinning. What was occurring at the same time?



■ **Figure 1.20**

30. Why do chemists study regions of the universe, such as the one shown in **Figure 1.20?**

Mastering Problems

31. If three oxygen particles are needed to form ozone, how many units of ozone could be formed from 6 oxygen particles? From 9? From 27?

32. Measuring Concentration **Figure 1.6** shows that the CFC level was measured at about 272 ppt (parts per thousand) in 1995. Because percent means *parts per hundred,* what percent is represented by 272 ppt?

Section 1.2

Mastering Concepts

33. Why is chemistry called the central science?

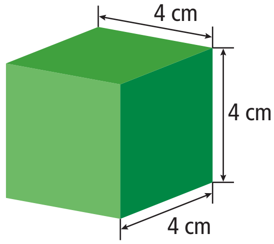
34. Which measurement depends on gravitational force—mass or weight? Explain.

35. Which branch of chemistry studies the composition of substances? The environmental impact of chemicals?

Mastering Problems

36. Predict whether your weight in the city of Denver, which has an altitude of 1.7 km above sea level, will be the same as, more than, or less than your weight in New Orleans, a city located at sea level.

37. The text tells you that, "1 trillion atoms could fit onto a period at the end of this sentence." Write out the number 1 trillion using the correct number of zeros.



■ **Figure 1.21**

38. How much mass will the cube in **Figure 1.21** have if a 2-cm^3 cube of the same material has a mass of 4.0 g?

Section 1.3

Mastering Concepts

39. How does qualitative data differ from quantitative data? Give an example of each.

40. What is the function of a control in an experiment?

41. What is the difference between a hypothesis, a theory, and a law?

42. Laboratory Experiments You are asked to study how much table sugar can be mixed or dissolved in water at different temperatures. The amount of sugar that can dissolve in water goes up as the water's temperature goes up. What is the independent variable? Dependent variable? What factor is held constant?

43. Label each of the following pieces of data as qualitative or quantitative.
a. A beaker weighs 6.6 g.
b. Sugar crystals are white and shiny.
c. Fireworks are colorful.

44. If evidence you collect during an experiment does not support your hypothesis, what should happen to that hypothesis?

Mastering Problems

45. One carbon (C) and one ozone (O_3) react to form one carbon monoxide (CO) and one oxygen gas (O_2) particle. How many ozone particles are needed to form 24 particles of oxygen gas (O_2)?

Section 1.4

Mastering Concepts

46. Laboratory Safety Finish each statement about laboratory safety so that it correctly states a safety rule.
a. Study your lab assignment
b. Keep food, beverages, and
c. Know where to find and how to use the

Mastering Problems

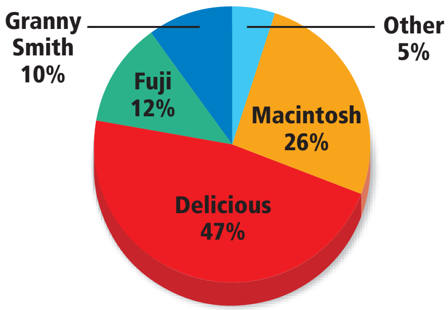
47. If your lab procedure instructs you to add two parts acid to each one part of water and you start with 25 mL of water, how much acid will you add, and how will you add it?

Think Critically

48. Compare and Contrast Match each of the following research topics with the branch of chemistry that would study it: water pollution, the digestion of food in the human body, the composition of a new textile fiber, metals to make new coins, and a treatment for AIDS.

49. Interpret Scientific Diagrams Decide whether each of the diagrams shown below is displaying qualitative or quantitative data.

a. Types of Apples Grown in Bioscience Greenhouse



■ **Figure 1.22**

b.

Data: Characteristics of Product Formed	
Color	white
Crystal Form	needles
Odor	none

50. Classify CFCs break down to form chemicals that react with ozone. Is this a macroscopic or a microscopic observation?

51. Infer A newscaster reports, "The air quality today is poor. Visibility is only 1.7 km. Pollutants in the air are expected to rise above 0.085 parts per million (ppm) in the next eight-hour average. Spend as little time outside today as possible if you suffer from asthma or other breathing problems." Which of these statements are qualitative and which are quantitative?

Cumulative Review

In Chapters 2 through 24, this heading will be followed by questions that review your understanding of previous chapters.

Additional Assessment

WRITING in Chemistry

52. Ozone Depletion Based on your knowledge of chemistry, describe the research into depletion of the ozone layer by CFCs in a timeline.

53. CFC Reduction Research the most recent measures taken by countries around the world to reduce CFCs in the atmosphere since the Montreal Protocol. Write a short report describing the Montreal Protocol and more recent environmental measures to reduce CFCs.

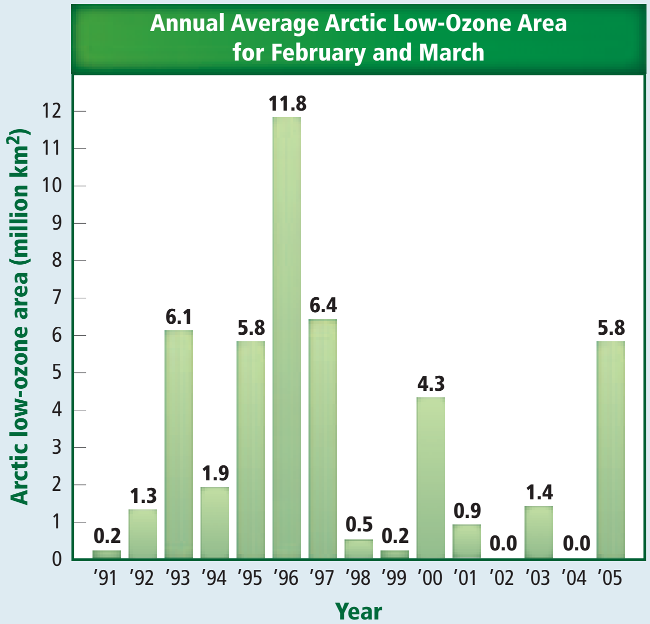
54. Technology Name a technological application of chemistry that you use everyday. Prepare a booklet about its discovery and development.

DBQ Document-Based Questions

Ozone Depletion *The area of low-ozone varies over the Arctic as well as over the Antarctic. NOAA collects data and monitors low-ozone area at both poles.*

Figure 1.23 *shows the average areas of unusually low ozone concentration in the north pole region from February to March of each year from 1991 to 2005.*

Data obtained from: Northern Hemisphere Winter Summary. April 2005. *National Oceanic and Atmospheric Administration.*



■ **Figure 1.23**

55. In what year or years was the low-ozone area the largest? The smallest?

56. What is the average area from 2000–2005? How does that compare to the average area from 1995–2000?

Cumulative

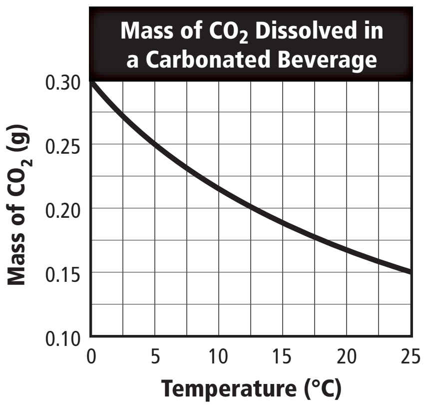
Standardized Test Practice

Multiple Choice

1. When working with chemicals in the laboratory, which is something you should NOT do?
   A. Read the label of chemical bottles before using their contents.
   B. Pour any unused chemicals back into their original bottles.
   C. Use lots of water to wash skin that has been splashed with chemicals.
   D. Take only as much as you need of shared chemicals.

Use the table and graph below to answer Questions 2–6.

Page From a Student's Laboratory Notebook	
Step	**Notes**
Observation	Carbonated beverages taste fizzier when they are warm than when they are cold. (Carbonated beverages are fizzy because they contain dissolved carbon dioxide gas.)
Hypothesis	At higher temperatures, greater amounts of carbon dioxide gas will dissolve in a liquid. This is the same relationship between temperature and solubility seen with solids.
Experiment	Measure the mass of carbon dioxide (CO_2) in different samples of the same carbonated beverage at different temperatures.
Data analysis	See graph below.
Conclusion	



2. What must be a constant during the experiment?
   A. temperature
   B. mass of CO_2 dissolved in each sample
   C. amount of beverage in each sample
   D. independent variable

3. Assuming that all of the experimental data are correct, what is a reasonable conclusion for this experiment?
   A. Greater amounts of CO_2 dissolve in a liquid at lower temperatures.
   B. The different samples of beverage contained the same amount of CO_2 at each temperature.
   C. The relationship between temperature and solubility seen with solids is the same as the one seen with CO_2.
   D. CO_2 dissolves better at higher temperatures.

4. The scientific method used by this student showed that
   A. the hypothesis is supported by the experimental data.
   B. the observation accurately describes what occurs in nature.
   C. the experiment is poorly planned.
   D. the hypothesis should be thrown out.

5. The independent variable in this experiment is
   A. the number of samples tested.
   B. the mass of CO_2 measured.
   C. the type of beverage used.
   D. the temperature of the beverage.

6. Which is an example of pure research?
   A. creating synthetic elements to study their properties
   B. producing heat-resistant plastics for use in household ovens
   C. finding ways to slow down the rusting of iron ships
   D. searching for fuels other than gasoline to power cars

Use the table below to answer Question 7.

What is the effect of drinking soda on heart rate?		
Student	**Cans of Soda**	**Heart Rate (beats per minute)**
1	0	73
2	1	84
3	2	89
4	4	96

7. In this experiment testing the effects of soda on students' heart rates, which student serves as the control?
   A. Student 1 **C.** Student 3
   B. Student 2 **D.** Student 4

Chemistry Online **Standardized Test Practice** glencoe.com

Short Answer

Use the table below to answer Questions 8 and 9.

Physical Properties of Three Elements				
Element	Symbol	Melting Point (°C)	Color	Density (g/cm^3)
Sodium	Na	897.4	Grey	0.986
Phosphorus	P	44.2	White	1.83
Copper	Cu	1085	orange	8.92

8. Give examples of qualitative data that are true for the element sodium.

9. Give examples of quantitative data that are true for the element copper.

10. A student in your class announces that he has a theory to explain why he scored poorly on a quiz. Is this a proper use of the term *theory*? Explain your answer.

Extended Response

11. Explain why scientists use mass for measuring the amount of a substance instead of using weight.

Consider the following experiment as you answer Questions 12 and 13.

A chemistry student is investigating how particle size affects the rate of dissolving. In her experiment, she adds a sugar cube, sugar crystals, or crushed sugar to each of three beakers of water, stirs the mixtures for 10 seconds, and records how long it takes the sugar to dissolve in each beaker.

12. Identify the independent and dependent variables in this experiment. How can they be distinguished?

13. Identify a feature of this experiment that should be kept constant. Explain why it is important to include keep this feature constant.

SAT Subject Test: Chemistry

14. A scientist from which field of chemistry investigates a new form of packaging material that breaks down rapidly in the environment?
A. biochemistry
B. theoretical chemistry
C. environmental chemistry
D. inorganic chemistry
E. physical chemistry

Use the safety symbols below to answer Questions 15–18. Some choices may be used more than once; others will not be used at all.

A. 

D. 

B. 

E. 

C. 

Select the symbol for the safety rule being described in each case.

15. Safety goggles should be worn whenever you are working in the lab.

16. Use chemicals in rooms with proper ventilation in case of strong fumes.

17. Wear proper protective clothing to prevent stains and burns.

18. Objects may be extremely hot or extremely cold; use hand protection.

19. Which statement is NOT true about mass?
A. It has the same value everywhere on Earth.
B. It is independent of gravitational forces.
C. It becomes less in outer space, farther from Earth.
D. It is a constant measure of the amount of matter.
E. It is found in all matter.

NEED EXTRA HELP?																			
If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Review Section . . .	1.2	1.2	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4