SEPUP
Issue-Oriented Science

ISSUES AND
PHYSICAL SCIENCE

# Chemistry of Materials

THIRD EDITION

REDESIGNED FOR THE NGSS

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THIRD EDITION

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THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

LAB-AIDS®

**This book is part of SEPUP's *Issues and Science* course sequence. For more information about this sequence, see the SEPUP and Lab-Aids websites.**

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## A Letter to *Issues and Physical Science* Students

As you examine the activities in this book, you may wonder, "Why does this book look so different from other science books I've seen?" The reason is simple: it is a different kind of science program, and only some of what you will learn can be seen by leafing through this book!

*Issues and Physical Science* uses several kinds of activities to teach science. As you conduct these activities, you will engage in the same practices used by scientists to understand the natural world and by engineers to solve problems. For example, you will plan and carry out an experiment to investigate how water and sand heat up differently. You will analyze and interpret data on ocean temperatures and worldwide winds. And you will examine evidence for links between climate change, global warming, and human activity. A combination of laboratories, investigations, readings, models, scientific debates, role plays, and projects will help you develop your understanding of science and the relevance of physical science to your interests.

You will find that important scientific ideas come up again and again in different activities throughout the program. You will be expected to do more than just memorize these concepts: you will be asked to develop explanations and apply them to solve problems. In particular, you will improve your decision-making skills by using evidence to weigh outcomes and to decide what you think should be done about the scientific issues facing our society.

How do we know that this is a good way for you to learn? In general, research on science education supports it. In particular, many of the activities in this book were tested by hundreds of students and their teachers, and then modified on the basis of their feedback. New activities are based on what we learned in classrooms using the materials and on new research on science learning. In a sense, this entire book is the result of an investigation: we had people test our ideas, we interpreted the results, and we then revised our ideas! We believe the result will show you that learning more about science is important, enjoyable, and relevant to your life.

*SEPUP Staff*

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*Issues and Physical Science* is a revision of *Issues, Evidence, and You* (IEY). We are extremely grateful to the center directors and teachers who taught the original and revised program. These teachers and their students contributed significantly to improving the course. Since then, *Issues and Physical Science* has been used in many classrooms across the United States. This third edition is based on what we have learned from teachers and students in those classrooms. It also includes new data and information, so the issues included in the course remain fresh and up-to-date.

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# Contents

## *Chemistry of Materials*

# Chemistry of Materials

TERESA WAS RUNNING *late for soccer practice and knew her coach would make her run extra laps if she arrived even a minute late. She had 30 seconds to spare when she reached the field and tossed her backpack down next to her teammates' bags.*

*About half way through practice, they all stopped for a water break. Teresa pulled out her favorite bright pink reusable water bottle from her bag and drank deeply from it. Her friend Linea was drinking from an aluminum bottle. She looked at Teresa's bottle and said, "How can you stand that plastic bottle? Doesn't it make your water taste kind of funny?" Teresa replied, "I guess, a little, but I love the color and that it won't break. You know I'm always throwing my backpack around."*

*After practice, when Teresa got home, she was getting her water bottle out to fill it for the next day. Her dad was busy putting away groceries, including a package of bottled water that she knew was for her dad's lunches that he took to work. "Hey Dad," Teresa asked, "why don't you use a reusable water bottle like me and Mom?" Her dad said, "Well, you know how I often have meetings with clients at their offices or at different job sites? I don't want to worry that I'll forget a reusable water bottle and then have to go back and get it later. It's easier for me to just grab a disposable one and recycle it when I'm done with my water."*

*Later, Teresa was thinking about what her dad said. It made sense, but she wondered if her dad always had a spot to recycle his water bottles. And wouldn't it be less expensive to keep using the same bottle instead of always buying more? And what about her plastic bottle? It did kind of make the water taste funny. Teresa wondered if she and her dad were making the best choices.*

How do scientists and engineers decide which material is best to use to make things? What do they need to know about the materials to choose the best one? What are those materials made of and where do they come from? Do the materials react differently in different environments? What happens when the materials are no longer able to be used?

To investigate these questions, you will develop and use models to describe the composition of different materials and how those materials respond under various conditions. You will gather and make sense of information about where the materials come from and how scientists and engineers decide which material is best for making a product.

# 1 Exploring Materials

TALKING IT OVER

**CONSIDER THE WORLD** around you. The book in your hands, the floor underneath your feet—each is made from a type of material. The word material can have several meanings. To a scientist or engineer, a **material** is a type of solid matter used to make things. For example, clothing, homes, and computers are all made from different materials. Materials scientists and materials engineers study existing materials and design new ones. When they design these materials, here are some of the things they think about:

- How will they be used?
- What resources are needed to make them?
- What will happen to them when they are no longer useful?

For example, think about the materials used to make drink containers. Plastic was not used to make bottles until 1947. Until then, almost all drink containers in the United States were made of glass. Consumers would return glass milk and soft drink bottles and get their deposits paid back, and the drink bottling companies would clean and refill the bottles to sell again. Today, most drink containers are made mainly of aluminum, plastic, or glass. Each material has particular characteristics, or **properties**, that make it useful for holding drinks. Each material is made from specific resources and affects the environment when it is discarded or recycled.

In this unit, you will learn about some of the properties materials engineers investigate when deciding which material to use for a specific purpose. For this activity, you will be looking at materials used in making disposable drink containers.

*You are a materials scientist working for a bottling company. The president of the company has asked you which type of material to use to make containers for a new drink brand. You decide to look for a material that will both work well and have the fewest bad effects on the environment. Should it be aluminum, glass, or plastic? How will you decide? What evidence will you use?*

## GUIDING QUESTION

**What information would help you decide which material is best for making a single-use drink container?**

## PROCEDURE

### Part A: Comparing Properties of Materials

1. Prepare a data table for recording the advantages and disadvantages of each of the three materials—aluminum, glass, and plastic. Your table should fill an entire page in your science notebook. Give the table a title.

2. With your group,

    a. discuss and list the properties you already know of for each of the three materials—aluminum, glass, and plastic.

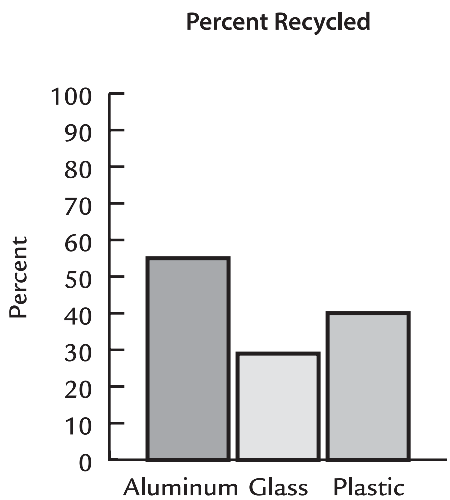
    b. decide whether each property is an advantage or disadvantage if you are using the material to make a drink container.

    c. record in your data table your decision from Step 2b.

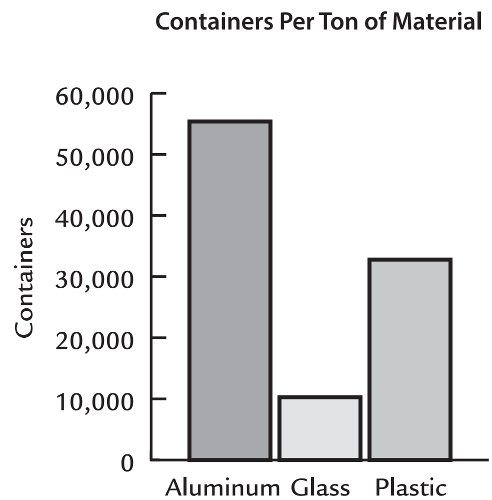
3. With your group, discuss what other questions you would like answered before deciding which of the three materials—aluminum, glass, or plastic—is the best choice for making a single-use drink container. Record your group's questions in your science notebook.

## Part B: Choosing a Material

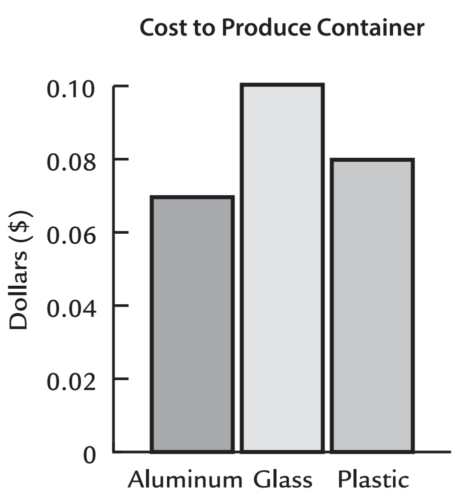
4. Review the information provided in the following graphs and descriptions. Complete the following with your group for each graph and description:
   a. Discuss what you think the data in the graph mean about each of the three materials—aluminum, glass, and plastic. Is it an advantage or disadvantage if you are using that material to make a single-use drink container?
   b. Record in your data table your decision from Step 4a.



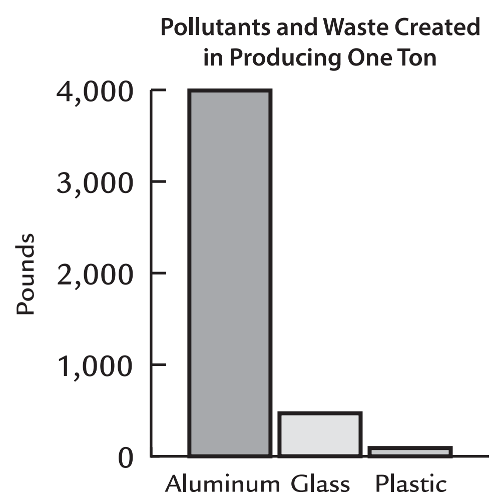

*This graph compares what percentage of the material is recycled.*




*This graph compares how many containers can be made out of 1 ton of each material.*




*This graph compares the cost (in U.S. dollars) of making one container out of each material.*




*This graph compares how many pounds of pollutants and waste are created during the process of manufacturing 1 ton of each material.*

5. With your group, discuss which material you think is the best choice for making a single-use drink container based on the evidence you have. Record your group's choice and your reasoning for that choice in your science notebook.

## ANALYSIS

1. Did the graphs of the data help you make a decision about the advantages and disadvantages of each material? Explain.

2. Imagine you are an environmentalist who is concerned with pollution, litter, and problems with a bottle's impact on the environment. Based on the information from this activity, which material would you claim is the best for making a single-use drink container?

   Write a letter from an environmentalist's viewpoint to the president of the drink company describing your recommendation at this time. Support your reasoning with evidence, and identify the trade-offs of your decision.

   *Hint*: To write a complete answer, first state your opinion. Provide two or more pieces of evidence that support your opinion. **Evidence** is factual information or data that support or refute a claim. Then consider all sides of the issue, and identify the trade-offs of your decision. A **trade-off** is an exchange of one outcome for another—giving up something that is a benefit or advantage in exchange for something that may be more desirable.

# 2 *Investigating Elements*

LABORATORY

**Chemicals are the** substances that make up all living and nonliving things (together known as **matter**). **Elements** are the simplest pure substances. They cannot be broken down into simpler substances. Elements are the building blocks for all other types of matter. Elements are made of a single type of atom. **Atoms** are the basic building blocks of matter. A sample of aluminum is made up of many aluminum atoms.

Scientists have assigned a chemical symbol to each element. Sometimes the symbol is one uppercase letter. For example, the symbol for carbon is C. Sometimes the symbol is one uppercase letter and one lowercase letter. For example, cobalt is Co. Sometimes the symbol is based on an element's Latin name. Copper's symbol is Cu—from cuprum, the Latin name for copper. The symbol CU would never be used for an element, because an element symbol can contain only one uppercase letter.

In this activity, you will investigate the physical properties of several elements: aluminum (Al), carbon (C), copper (Cu), germanium (Ge), iron (Fe), mercury (Hg), nitrogen (N), and sulfur (S). A **physical property** is one that you can identify without knowing if the material reacts with another substance.

*Carbon (C)*

*Cobalt (Co)*

*Copper (Cu)*

## GUIDING QUESTION

**How can scientists use physical properties to identify elements?**

## MATERIALS

*For each group of four students*

1 set of 4 elements
1 plastic cup (9-ounce)
1 stir stick
water
paper towels

*For each student*

1 Student Sheet 2.1, "Physical Properties of Elements"
1 pair of chemical splash goggles

## SAFETY

**Follow all safety rules. Pay close attention as your teacher demonstrates where to find and how to use classroom safety equipment. Wear safety eyewear. If a material does not bend easily, do not use more force because you could break or tear it. Watch out for sharp edges. Wash your hands after you complete the activity.**

## PROCEDURE

1. With your group, carefully observe the four element samples provided. Do not damage the element samples; other classes will use them, too.
2. Use the information in the "Testing Physical Properties" table that follows to guide you as you investigate the physical properties of each of the element samples. Record your observations of the elements in the data table on Student Sheet 2.1, "Physical Properties of Elements."

**Testing Physical Properties**

| PHYSICAL PROPERTIES | PROCEDURE | INTERPRETING TEST RESULTS |
|---|---|---|
| **State** at room temperature—whether the element is solid, liquid, or gas. | 1. Observe the sample of the element.<br>2. Record its state. | Describe your observations in detail. |
| **Appearance** | 1. Observe the sample of the element.<br>2. Record its color and whether it is shiny or dull. | Describe your observations in detail. |
| **Malleability**—whether the element is flexible and can be hammered or bent without breaking | 1. Try to bend the element gently.<br>2. Record how easily it bends. | If it does not bend, it is *not malleable*.<br>If it bends slightly, it is *somewhat malleable*.<br>If it bends easily, it is *very malleable*. |
| **Solubility** in water—whether the element **dissolves** (mixes evenly to form a clear mixture) in water | 1. Fill the plastic cup half full of water and place the material in the cup.<br>2. Leave the material in the water for at least 1 minute (min). Check to see if the material mixes with the water.<br>3. Once you have recorded your results, remove and dry the material. | If none of the material dissolves, it is *not soluble*.<br>If some of the material dissolves, it is *somewhat soluble*.<br>If all of the material dissolves, it is *very soluble*. |
| **Density**—how compact the matter is in the element | 1. Fill the plastic cup half full of water, and place the material in the cup.<br>2. Check to see if the material sinks or floats. With your stir stick, push underwater any material that floats, and see if it returns to the surface.<br>3. As soon as you have recorded results, remove and dry the material. | If it floats, it is *less dense* than water.<br>If it sinks, it is *more dense* than water. |

3. Examine the photos and information about four more elements in the "Properties of Four Elements" table that follows.

**Properties of Four Elements**

| SULFUR (S) | MERCURY (Hg) | GERMANIUM (Ge) | NITROGEN (N) |
|---|---|---|---|
|  |  |  |  |
| Sulfur is a brittle solid. It floats in water and does not dissolve. Many compounds with sulfur have an unpleasant smell. | Mercury is a liquid. It sinks in water and does not dissolve. | Germanium is a brittle solid. It sinks in water and does not dissolve. | Nitrogen is a gas. If mixed with water, it forms bubbles that rise to the surface. It does not dissolve. |

4. Add what you have learned about these four elements to the data table on Student Sheet 2.1.

## ANALYSIS

1. Why do you think it is important for scientists to observe multiple physical properties in order to identify an element? Use examples from the data you collected in this activity to support your ideas.

2. Copy the lists of words below:

| | | |
|---|---|---|
| element | gas | metal |
| iron | solid | property |
| carbon | liquid | malleable |
| water | metal | soluble |
| nitrogen | state | dense |

   a. Look for a relationship between the words in each list. Cross out the word that does not belong.

   b. Circle the word or phrase that includes all the other words.

   c. Explain how the word or phrase you circled is related to the other words in the list.

3. Based on the sample of eight elements you have observed so far, and assuming the rest of the elements fit the same pattern, would you expect most elements to be solid, liquid, or gas at room temperature? Explain.

4. When added to water at room temperature, most gases form bubbles that float to the top of the water and release into the air. What does this tell you about the density of gases?

5. Describe what you have learned about the physical properties of aluminum in this activity and the previous activity. What information, if any, from these activities would be helpful in deciding if aluminum would be a good choice for making a drink container?

6. In this activity, you recorded the appearance of each element you observed. Think of and explain two examples from this activity in which appearance does not help identify an element.

# 3 Physical and Chemical Properties of Materials

LABORATORY

**IN THE FIRST** activity, you compared aluminum, glass, and plastic—three materials that can be used to make drink containers. When designing a product, materials scientists and engineers consider the properties of materials to determine which is best to use. These properties can be grouped into two categories—physical and chemical. In the previous activity, you examined five physical properties—state, color, malleability, solubility, and density. A **chemical property** describes how a material reacts with another substance, such as an acid or oxygen.

In this activity, you will test both the physical and chemical properties of a variety of materials. You will investigate elements, **compounds** (substances made from more than one element chemically combined, such as plastic) and mixtures of compounds (glass). You will then use this information to consider how those materials could best be used to make products.

*Steel is a very durable substance that can be formed into many shapes. These properties make it an ideal material for external building supports and medical equipment.*

## GUIDING QUESTION

**How do the properties of materials determine their uses?**

## MATERIALS

*For each group of four students*

1 plastic cup (9-ounce)
1 plastic test tube
1 SEPUP tray
1 graduated cylinder (10-mL)
1 stir stick
1 dropper bottle of 1M hydrochloric acid (HCl)
1 strip of aluminum
1 strip of polypropylene plastic
1 strip of polystyrene plastic
1 glass rod
1 piece of limestone
1 dropper bottle of denatured alcohol
1 container of sodium chloride
1 container of calcium carbonate
water
paper towels

*For each student*

1 pair of chemical splash goggles
1 Student Sheet 3.1, "Physical and Chemical Properties of Materials"

## SAFETY

**Wear safety eyewear. If a material does not bend easily, do not use more force because you could break or tear it. Watch out for sharp edges. Be careful to avoid spills on skin or clothing. If hydrochloric acid gets on skin or clothing, immediately flush the area with running water and inform your teacher.**

## PROCEDURE

### Part A: Testing Physical and Chemical Properties

1. With your group, carefully observe the eight samples of materials provided. Do not damage the samples; other classes will use them, too.

2. Use the information in the "Testing Physical and Chemical Properties" table that follows to guide you as you investigate the

physical and chemical properties of each of the samples. Record your observations of the samples in the data table on Student Sheet 3.1, "Physical and Chemical Properties of Materials."

*Note*: You do not need to repeat any tests that you have already done on aluminum. You may copy your data from the previous activity.

### Testing Physical and Chemical Properties

| PHYSICAL PROPERTIES | | |
|---|---|---|
| **Properties** | **Procedure** | **Interpreting Test Results** |
| State— whether the element is solid, liquid, or gas. | 1. Observe the sample.<br>2. Record its state. | Describe your observations in detail. |
| Odor | 1. Hold the material about 15 cm in front of your face.<br>2. Use your hand to waft the air around the material toward your face, and inhale gently.<br>3. Record if there is any odor. | Describe any odor from the material, or if it has no odor. |
| Density—how compact the matter is in the substance | For solid materials:<br>1. Fill the plastic cup half full of water, and place the material in the cup.<br>2. Check to see if the material sinks or floats. With your stir stick, push underwater any material that floats, and see if it returns to the surface.<br>3. As soon as you have recorded results, remove and dry the material.<br><br>For powdered or crystal materials:<br>1. Fill the plastic cup half full of water.<br>2. Use the small scoop on the end of the stir stick to add 2 scoops of the material to the water.<br>3. Check to see if the material sinks or floats. With your stir stick, push underwater any material that floats, and see if it returns to the surface.<br>4. Record your results.<br><br>For liquid materials:<br>1. Fill the test tube half full of water.<br>2. Slowly pour 1 mL of the liquid down the inside of the test tube.<br>3. Check to see if the material sinks or floats.<br>4. Record your results. | If it floats, it is *less dense* than water.<br>If it sinks, it is *more dense* than water. |

| | | |
|---|---|---|
| Solubility in water—whether it dissolves (mixes evenly to form a clear mixture) in water | For solid materials:<br>1. Fill the plastic cup half full of water, and place the material in the cup.<br>2. Leave the material in the water for at least 1 min. Check to see if the material mixes with the water.<br>3. Once you have recorded your results, remove and dry the material.<br><br>For powdered or crystal materials:<br>1. Add 5 mL of water to a clean, large cup in the SEPUP tray.<br>2. Use the small scoop on the end of the stir stick to add 2 scoops of the material to the water.<br>3. Stir thoroughly and let the solution sit for 1 min. Check to see if the material mixes with the water.<br>4. Record your results.<br><br>For liquid materials:<br>1. Add 5 mL of water to a clean, large cup in the SEPUP tray.<br>2. Add 1 mL of the liquid to the water.<br>3. Stir thoroughly, and let the solution sit for 1 min. Check to see if the material mixes with the water. | If the material dissolves in water, it is *soluble*.<br>If the material does not dissolve in water, it is *not soluble*. |
| **CHEMICAL PROPERTIES** | | |
| **Properties** | **Procedure** | **Interpreting Test Results** |
| Reactivity to hydrochloric acid | For solid materials<br>1. Place 2 or 3 drops of 1M hydrochloric acid (HCl) on each material.<br>2. Observe and record the results.<br>3. As soon as you have recorded results, rinse the material in water and dry it.<br><br>For powdered or crystal materials<br>1. Use the small scoop on the end of the stir stick to add 2 scoops of the material to a small, clean cup in the SEPUP tray.<br>2. Add 2 or 3 drops of 1M HCl to the material.<br>3. Observe and record the results.<br><br>For liquid materials<br>1. Add 10 drops of the material to a clean, small cup in the SEPUP tray.<br>2. Add 10 drops of 1M HCl to the liquid in the cup.<br>3. Observe and record the results. | If the material does not bubble or change in any way, it does *not react* with HCl.<br>If the material bubbles or changes in any way, it *reacts* with HCl. |

## Part B: Analyzing Data on Properties of Materials

3. With your group, examine the data in the table that follows for melting point, boiling point, and flammability of the eight materials you investigated in Part A.

**Melting Point, Boiling Point, and Flammability Data**

| MATERIAL | MELTING POINT | BOILING POINT | FLAMMABILITY |
| --- | --- | --- | --- |
| Aluminum | 660°C | 2,470°C | Non-flammable |
| Calcium carbonate | 825°C | Decomposes at high temperatures | Non-flammable |
| Glass | 1,710°C | 2,230°C | Non-flammable |
| Denatured alcohol | –114°C | 78°C | Flammable |
| Limestone | 1,339°C | Decomposes at high temperatures | Non-flammable |
| Polypropylene plastic | 160°C | Decomposes at high temperatures | Non-flammable |
| Polystyrene plastic | 240°C | Decomposes at high temperatures | Flammable |
| Sodium chloride | 801°C | 1,413°C | Non-flammable |

4. Discuss with your group how the information on melting point, boiling point, and flammability might be useful to materials scientists.

5. With your group, make a list of other properties you observed for each material. Record them on your Student Sheet.

## ANALYSIS

1. Which of the physical and chemical properties that you examined in this activity do you think would be most helpful for identifying the materials? Which would be least helpful? Explain.

2. Which properties examined in this activity would be helpful in choosing a drink container material? Why?

3. Should the shape of a sample be considered a property of the material? Explain.

# 4 Determining Density

LABORATORY

**IN THE LAST** two activities, you investigated the density of several materials by testing if they float or sink in water. This tells you if a material is more or less dense than water. **Density** is the mass of a substance per unit of volume. You can measure a material's volume and mass and use that to calculate the material's density.

The density of water is 1 gram (g) per cubic centimeter ($cm^3$) or 1 $g/cm^3$, so if a material floats, it contains less than 1 $g/cm^3$ of matter. If it sinks, it contains more than 1 $g/cm^3$ of matter. Have you ever seen something really large and heavy, like an iceberg or a big log, floating in the water? Even though those objects are heavy, they float because they are less dense than water!

*This log floats in water because its density is less than 1 $g/cm^3$ of matter, so it is less dense than the water around it.*

If you want to determine the exact density of a material, it is necessary to measure the volume and mass of a sample of that material. **Volume** is the amount of space the sample takes up. **Mass** is the amount of matter—or stuff—in the sample. You can calculate the density of the material by using the following formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

To determine the volume, you can use two different methods—measurement and calculation, or water displacement. Mass is measured in grams or related units, such as kilograms (kg), and can be measured using a balance.

## GUIDING QUESTION

**How can you use the mass and volume of an object to calculate its density?**

## MATERIALS

*For each group of four students*

1 block of polypropylene (blue)
1 block of polyvinyl chloride (green)
1 block of high-density polyethylene (red)
1 block of polystyrene (yellow)
1 block of glass
1 block of aluminum
1 electronic balance
2 metric rulers
1 plastic cup (9-ounce)
water
paper towels

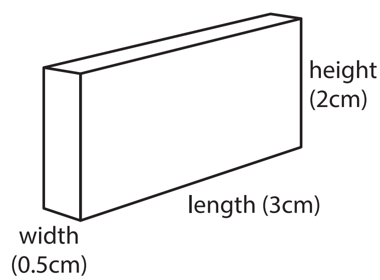
*For each student*

1 Student Sheet 4.1, "Density Data"

## PROCEDURE

### Part A: Measuring Mass and Volume

1. Obtain Student Sheet 4.1, "Density Data," from your teacher. Your teacher will show you how to identify each block.
2. Pick up and examine each of the six blocks. With your group, predict the order of the density of each of the six objects, from least to greatest density. Record your predicted order in your science notebook.
3. Watch your teacher demonstrate how to measure the dimensions and calculate the volume of the object, similar to the one shown below.




4. Divide the six blocks into two sets so that each pair in your group gets three blocks.
5. With your partner, measure and record the dimensions of one of your blocks. Then calculate the volume of the block.
6. Repeat Step 5 for the remaining two blocks.
7. Measure the mass of your block on the balance, as demonstrated by your teacher. Record the mass in the data table on Student Sheet 4.1.
8. Repeat Step 7 for the remaining two blocks.
9. Share your measurements with the other pair in your group so that you have data on all six blocks.

## Part B: Calculating Density

10. Calculate the density for each of the six blocks using the following formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Record the densities in your data table.

11. Based on your calculations, which of the materials do you think will sink and which will float? Test your predictions by doing the following:
    a. Fill the plastic cup about ¾ full of water.
    b. Carefully drop one of the rectangular blocks into the water. Observe what happens, and record it on your Student Sheet.
    c. Remove the block from the water, and dry it with the paper towels.
    d. Repeat Steps 11b and 11c with the other five blocks.
12. Compare your data to your predictions in Step 2.

# ANALYSIS

1. Each pure substance has specific properties that can be used to identify it. Which properties of the substances you have investigated so far do you think would be useful for identifying other materials? Explain your thinking.
2. Many plastics float in water. Do you think this is an advantage or disadvantage? Why?
3. One way in which scientists collect data on the world's oceans is by releasing floating plastic buoys containing scientific instruments. These buoys drift in the sea for 12–18 months and are exposed to rough seas, high winds, and long periods of sunlight. Which of the four plastics tested would you recommend using for ocean buoys? Explain your answer based on evidence from this activity. Recommend at least three other properties not examined in this activity that should be considered in choosing the best plastic for the buoy.

# 5 Evaluating Properties of Materials

TALKING IT OVER

*I*MAGINE YOU GET *an email with an advertisement for a reusable plastic water bottle on sale at your local sporting goods store. You wonder if that bottle is the best choice. The ad makes the bottle sound like a great deal, but you know that the company selling it might be* ***biased*** *(favoring their product over the others in an unfair way), so you decide to do a little more research to get information from other sources about the materials used to make water bottles.*

In this activity, you will evaluate information from three fictional sources, all of which have written reviews of what they think are the best reusable water bottles to buy. As you evaluate the reviews, keep in mind who wrote the reviews and if you think the authors might have a particular bias.

## GUIDING QUESTION

**How can information be evaluated for bias?**

## MATERIALS

*For each student*

1 Student Sheet 5.1, "Comparing Water Bottle Reviews"

1 Student Sheet 5.2, "Water Bottle Reviews"

## PROCEDURE

### Part A: Comparing Information

1. With your group, discuss features you think are important to consider when choosing a reusable water bottle. Examine the list of features shown in the left-hand column of Student Sheet 5.1, "Comparing Water Bottle Reviews." If any of your group's features are missing, add them to the blank rows on the Student Sheet.

2. With your group, read each review for reusable water bottles on Student Sheet 5.2, "Water Bottle Reviews." As you read, discuss which statements in the reviews might be biased, and what evidence from the reviews you think is accurate and not biased. Mark on Student Sheet 5.2 any statements that you think are biased.

   *Hint*: Biased statements are often based on opinion instead of facts or evidence, or they describe facts in a way that might change your opinion of the facts or evidence.

3. Add any evidence from the reviews to Student Sheet 5.1.

4. With your group, discuss what information you would still like to know about the three water bottle types. Write your list of questions in your science notebook.

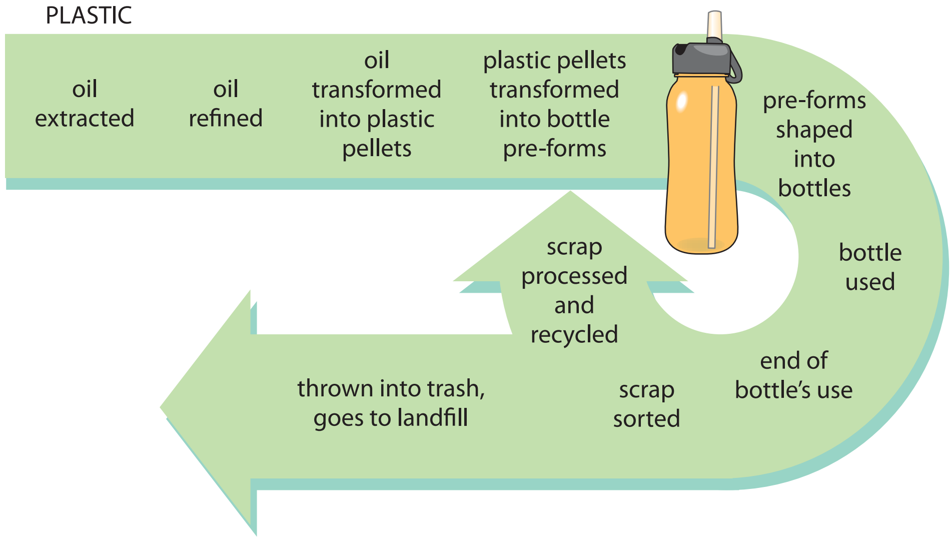
### Part B: Comparing Life Cycles

When materials scientists and engineers decide which material will be used to make a product like a reusable water bottle, they often consider what is needed to make the product, how it will be made, and what will happen to it when it is no longer being used (if it gets broken, etc.). All of these stages together are called the **life cycle** of a product. One way of illustrating each stage in the cycle is a

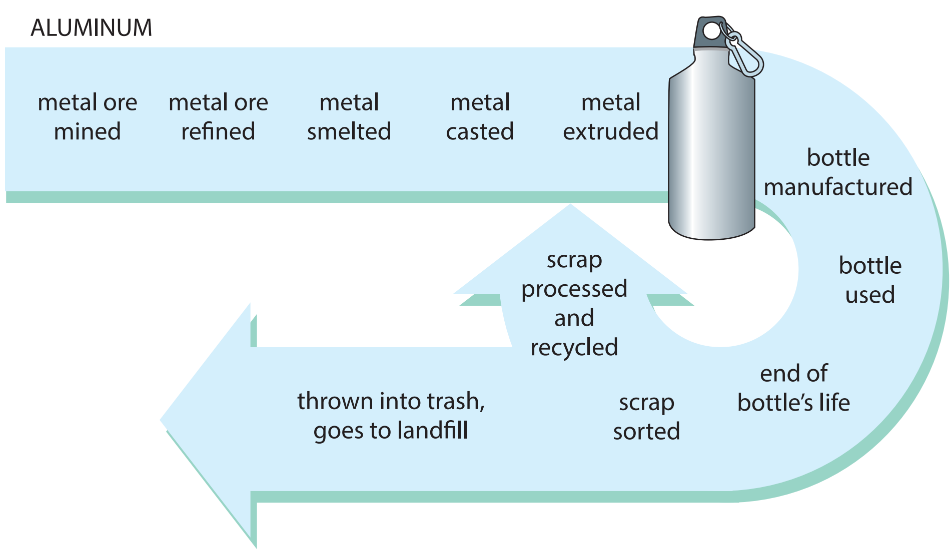
**life-cycle diagram**. These diagrams show how inputs and outputs from one stage relate to the inputs and outputs of other stages. Life-cycle diagrams can give you more information about how the reusable water bottle you are choosing can reduce the harm that manufacturing and eventually disposing of the bottle might cause to the environment.

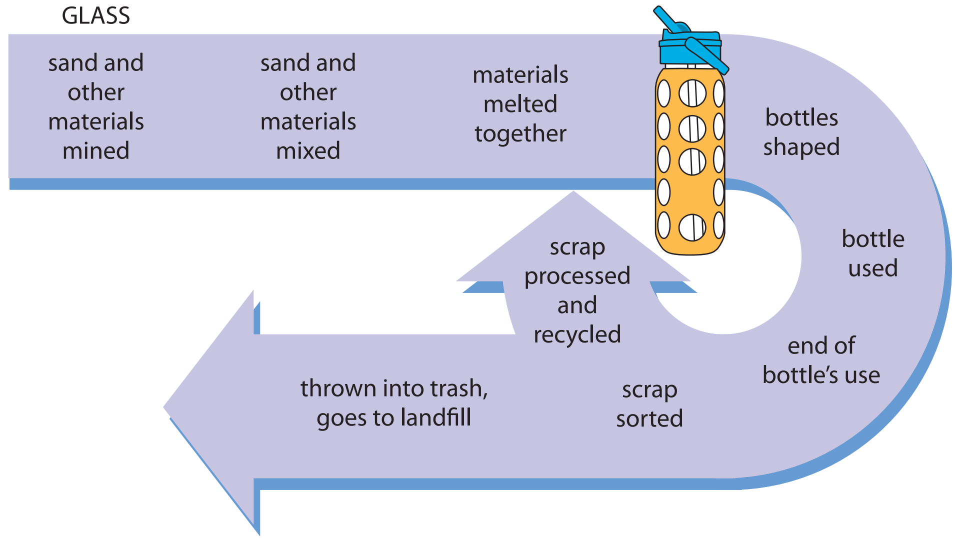
5. With your group, examine the three life-cycle diagrams that follow. On Student Sheet 5.1, write down any new information from the life-cycle diagrams that might be helpful for comparing the water bottles.

PLASTIC




ALUMINUM






6. Follow your teacher's instructions on how to hold a Walking Debate about which is the best choice of materials for a reusable drink container. You may want to review the information from the first activity, "Exploring Materials," and include that in your debate.

## ANALYSIS

1. Think about which position you ended up taking at the end of the Walking Debate.
   a. What physical and/or chemical properties of each material affected your decision? Explain.
   b. Which factors were the most important in making your decision? Explain.
2. Explain how a life-cycle diagram would or would not be a useful tool for
   a. the director of a drink company who wants to choose a single-use container for a new drink.
   b. a materials scientist working to reduce the negative impact a reusable drink container has on the environment.
   c. a person buying a bottle of sports drink in a store.
3. **Reflection:** Based on what you've learned in this activity, do you think that the life cycle of a product should be included on the label? Explain.

# 6 Modeling Molecules

MODELING

**YOU HAVE INVESTIGATED** the chemical properties of several examples of elements and compounds. Elements are made of a single type of atom, whereas compounds are made of two or more different types of atoms held together by chemical bonds. Two or more atoms held together by chemical bonds form a **molecule**. When the atoms in a molecule are identical, a molecule of an element forms. When the atoms are different, they form a molecule of a compound.

Most substances on Earth are not pure elements made up of a single type of atom. Atoms can combine with atoms of the same element, with atoms of another element, or even with atoms of several elements through chemical bonds. When the atoms of more than one element bond in specific, regular proportions, they form a compound. Water, for example, is a compound because its molecules are made from atoms of hydrogen and oxygen in exact proportions. These proportions (2:1) are shown in water's chemical formula, $H_2O$.

*The Atomium, a building modeled after the crystal structure of metal, was built in Brussels, Belgium, for the 1958 World's Fair.*

In this activity, you will use models to investigate how atoms combine to form molecules because we cannot see processes like that at a molecular scale. A **model** is a representation of a system, or its components, used to help understand and communicate how a system works. Here you are using plastic models of atoms and chemical bonds. The **scale** of a model is the ratio of its size to the real object. For example, a model car is usually built on a smaller scale than an actual car that someone can drive. A model of the moon would also be built on a smaller scale than our actual moon. However, molecules are so small that we cannot see them, so scientists use larger scale models to demonstrate what is happening between atoms that are forming molecules.

## GUIDING QUESTION

**How do atoms combine to form molecules?**

## MATERIALS

*For each pair of students*

1 molecular model set containing the following:
- 32 white "atoms"
- 18 black "atoms"
- 14 red "atoms"
- 4 blue "atoms"
- 54 white "bonds"

## PROCEDURE

1. Follow your teacher's directions to build a model of a molecule of water with 2 hydrogen (white) atoms and 1 oxygen (red) atom. Use the white bonds (tubes) to make the connections that represent chemical bonds between the atoms.

**Model Parts**

| COLOR | ELEMENT | SYMBOL |
|---|---|---|
| white | Hydrogen | H |
| black | Carbon | C |
| red | Oxygen | O |
| blue | Nitrogen | N |

2. Follow your teacher's directions to draw a diagram of this molecule in your science notebook.
3. Record the chemical formula for water next to your diagram.
4. Pull the model apart.

5. Every time you make a molecule, all of the bonding sites (the sticks on the atom models) must be connected to the sites on another atom. Using this bonding rule,
   a. make a model with one carbon and as many hydrogens as possible.
   b. draw a diagram of the molecule that you construct.
   c. record next to your diagram the chemical formula for the molecule.
   d. compare your model, diagram, and chemical formula with another pair of students. If your models are not the same, discuss how you made your models and come to agreement about which model best follows the bonding rule.
6. Repeat Step 5 to make models of molecules with
   a. 2 hydrogen atoms.
   b. 2 oxygen atoms.
   c. 1 nitrogen and as many hydrogen atoms as possible.
   d. 2 nitrogen atoms.
   e. 2 carbons and as many hydrogen atoms as possible.
7. Follow your teacher's directions to combine some of your models together to make a larger structure.
8. Take apart all the models, and return all the pieces to the set.

## ANALYSIS

1. How many different elements were you working with to create your models?
2. What was the role of the sticks on each atom model?
3. Was it possible for an atom to make more than one bond? Explain and give an example.
4. If you had 2 oxygen atoms and 1 hydrogen atom, could you form a molecule? Explain.
5. Make a labeled drawing to show the difference between an atom and a molecule. Write a short caption to go with your drawing.
6. Which model provides more information—a chemical formula or a sketch of the molecule?

# 7 Structure and Properties of Materials

READING

**I**N THE LAST activity, "Modeling Molecules," you developed models of very small structures that make up all matter, called **particles**. You modeled atoms, molecules, and other structures that make up various elements and compounds. Some substances are formed of individual atoms, whereas others are formed from molecules or another kind of structure called an extended structure. As you saw in the last activity, a molecule has a set number of each kind of atom; an **extended structure**, however, can have varied numbers of each kind of atom bonded together to form a very large structure. The structure of the particles in a substance determines its properties and the ways that the substance can be used.

## GUIDING QUESTION

**How do the structures of particles in substances vary?**

*Diamond*

*Sulfur*

*Iron*

## MATERIALS

*For each student*

1 Student Sheet 7.1, "Molecules and Extended Structures"

## PROCEDURE

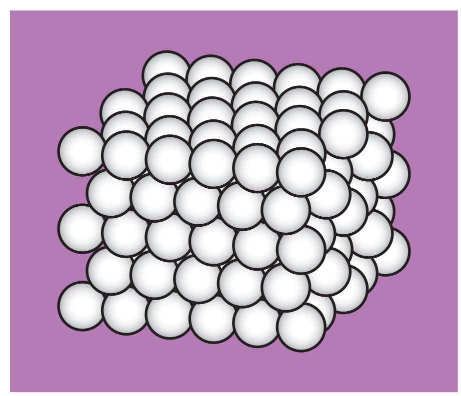
1. Read the text, and carefully examine the diagrams on the following pages.
2. Follow your teacher's directions for completing Student Sheet 7.1, "Molecules and Extended Structures."

## READING

### Elements Are Made of Just One Kind of Atom

Each element, whether a solid like iron, a liquid like mercury, or a gas like oxygen, is made of just one kind of atom. The properties of these atoms determine the properties of the element.

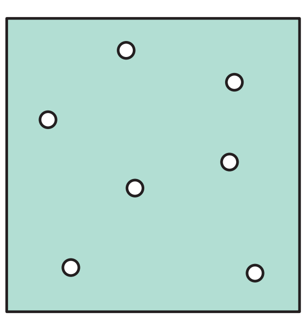
For example, the atoms in a metal tend to attract each other tightly, which is why most metals are solids at room temperature. The following diagram shows how the atoms are packed in many metals.



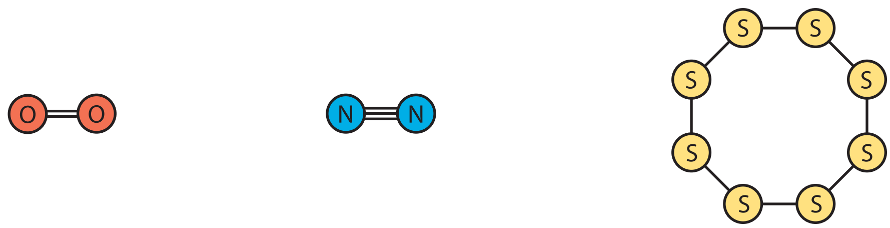
*Metal structure*

The structures of nonmetallic elements—all the elements that are not metals—vary. Some exist as individual atoms, some form small molecules, and some form large molecules or extended structures.

The gas neon, used in brightly colored neon electric signs, is one example of a nonmetal that does not form molecules. The atoms in neon interact so little that you would need to cool it to –246°C to turn it into a liquid. The atoms in helium gas, used in balloons, interact even less. Helium must be cooled to –269° C to turn it into a liquid. The following diagram shows how scientists model the atoms in neon or helium.



Several nonmetallic elements exist as small molecules. Oxygen and nitrogen are gases formed of molecules with only two atoms, as shown in the following diagram. You will notice that the bond in oxygen is a double bond, and the bond in nitrogen is a triple bond. More bonds generally cause stronger connections between atoms. Sulfur is a solid nonmetal formed of molecules with 8 sulfur atoms.



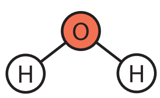

*oxygen* *nitrogen* *sulfur*

Carbon and silicon are nonmetals that form extended structures. Extended structures are composed of huge networks of atoms. For example, the following model of a carbon structure is for diamond, which is a very hard solid because of the strong interactions between many carbon atoms.

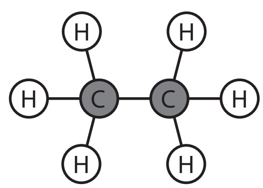
## Compounds Are Made of Two or More Kinds of Atoms

A compound is made of two or more kinds of atoms bonded together. The structures that form a compound might be small molecules of only two atoms or larger structures with thousands of atoms. Just as atoms determine the properties of elements, the atoms and structures that form a compound determine the compound's properties.

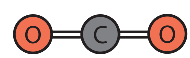
The atoms in a compound can combine in several ways. Sometimes the bonds between atoms form individual molecules. Water, carbon dioxide, and ethane are examples of substances made of small molecules with just a few atoms. A molecule of a substance always has a specific number of each kind of atom. For example, as you know, water always has exactly 1 oxygen and 2 hydrogen atoms. Water molecules attract each other, so water is liquid at room temperature. Carbon dioxide and ethane molecules do not attract each other, so they are both gases at room temperature.




*water molecule*



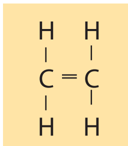

*ethane molecule*

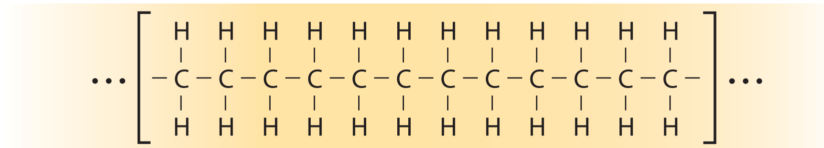



*carbon dioxide*

Some substances are made of chains of small molecules linked together to form long chains called polymers. These molecules can have thousands of atoms. The molecules that form proteins are one example. Each protein molecule is a polymer of a certain number and kind of smaller molecules. Every molecule of a protein has the exact same number and kind of smaller molecules as any other molecule of that protein.

Other substances can have varying numbers of small molecules linked together. In this case, there is no single molecule that forms the substance. You will learn more about this kind of substance in the "Making Polymers" activity. Most of these substances are synthetic, which means they are made by scientists and engineers. Polyethylene, shown in the following diagram, is one example. Polyethylene chains can have thousands of ethylene molecules linked together. The structure in the following diagram of a polyethylene model is shown continuing at both ends to represent the varying number of carbons possible. This structure might have anywhere from 1,000 to 10,000 carbons in the chain.

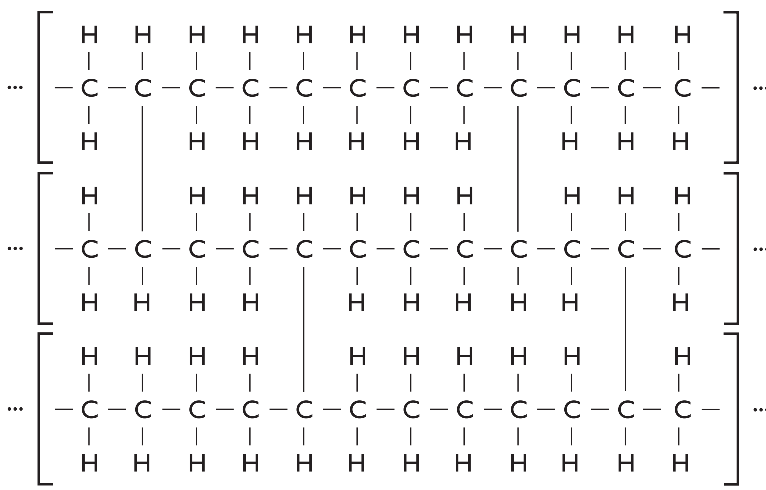




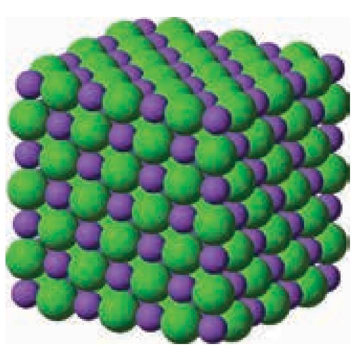
*ethylene*
- *single molecule*
- *monomer*

*polyethelene*
- *thousands of the same molecule linked together*
- *polymer*

These long polymer chains can be connected, or cross-linked, into huge networks, as shown below.



Common table salt is an example of a compound that forms an extended structure that is very similar to the structure of a metal. The sodium and chlorine atoms in salt interact strongly with each other to form a crystal structure, as shown below. This crystal is considered to be an extended structure because there are no separate molecules of sodium linked to one specific chlorine in the crystal. Instead, every sodium interacts with all the chlorines around it.



*The purple spheres represent sodium atoms.*
*The green spheres represent chlorine atoms.*

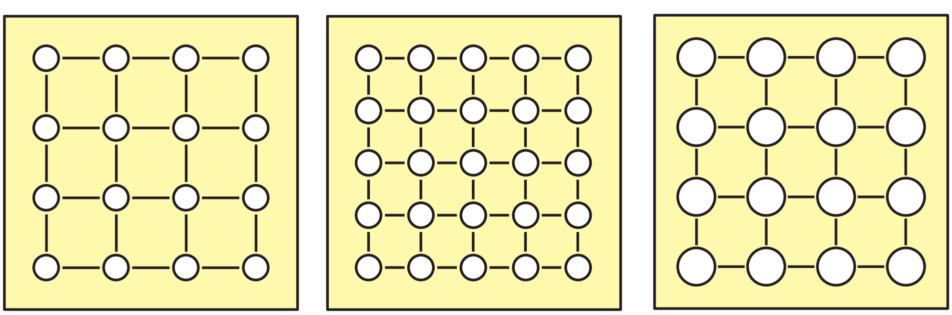
## The Structure of a Substance Determines its Properties

Atoms and molecules are extremely small. Any sample of an element or compound that is large enough for you to see has many billions of atoms or molecules. Even though atoms and molecules are much too small to see, the models of molecular and extended structures described above explain many of the properties of substances. And these properties determine how substances function in various products, from drink containers to computer circuits.

Their structures can explain why some substances boil at very low temperatures while other substances boil at very high temperatures. For example, neon has very little attraction between neon atoms, so it boils at very low temperatures. Other substances, like carbon or sodium chloride, form very large networks of atoms. These large networks of interconnected atoms must be heated to very high temperatures just to melt them. In general, very large molecular or extended structures tend to be solids at room temperature.

Differences in structures also explain why some substances, like sugar and salt, easily mix with and dissolve in water, whereas others, such as the network of tightly bonded carbon atoms in diamonds, do not dissolve.

Particle models can also help to explain density. Two factors that affect the density of a substance are the masses of the individual particles and how closely they are packed together. Compare the following diagrams of particles in three solids to see how a substance's particles affect its density.



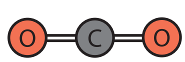
*A* *B* *C*

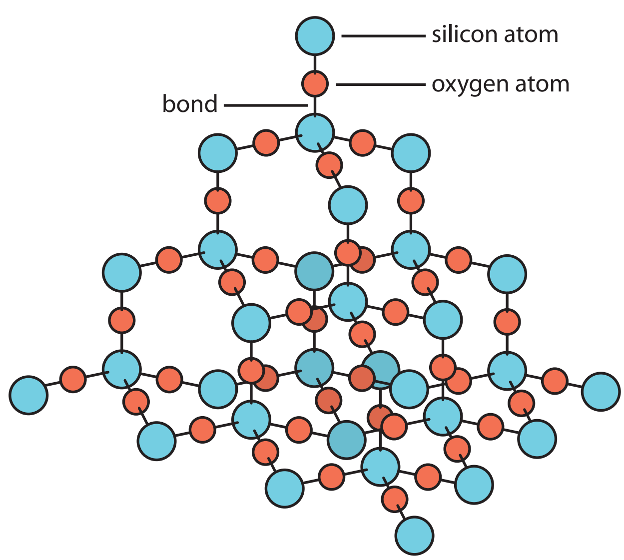
*B is more dense than A because more particles of the same mass are packed into the sample volume. C is more dense than A even though it has the same number of particles because each particle has a greater mass.*

In the next activity, you will look at how particles behave in solids, liquids, and gases.

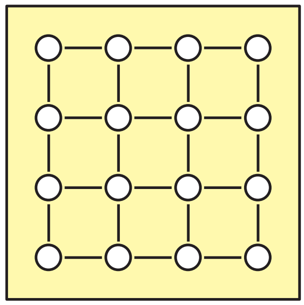
## ANALYSIS

1. Your friend says, "All substances made of molecules must be compounds because a molecule has more than one atom." Do you agree with your friend? Explain your answer.
2. How is an extended structure different from a molecule? Use an example of each to explain your answer. You may also use a diagram if you wish.
3. Carbon and sodium chloride are both extended structures. What are the main differences between these two kinds of extended structures?
   - Include a simple diagram of each structure to illustrate your answer.
   - Be sure to include some text or captions to describe what your diagrams show.
4. Compare the diagrams of the two substances shown below.
   a. Use your understanding of structure to predict which substance is a gas at room temperature and which is a hard solid at room temperature.
   b. Explain your answer using your understanding of the relationship between structure and properties of substances.



5. Draw a model that shows the particles in a substance that is less dense than the one shown below. Include a written description of your model and how it compares with the diagram provided.



6. How does the crosscutting concept of scale, proportion, and quantity help scientists explain why one substance is denser than another?

   *Hint*: To answer this question, think about what you learned about density at a scale you can measure and what you have learned about density at the scale of particles (atoms and molecules).

# 8 What's in a State?

TALKING IT OVER

**SO FAR, YOU** have learned about how materials are made of atoms and how the types and arrangements of the atoms influences the properties and functions of materials. Materials are most commonly found in one of three states—solid, liquid, or gas. In the following activities, you will investigate how atoms or molecules are arranged in the three states of matter. You will also develop models to explain how the arrangements and interactions of atoms or molecules within substances determines their state.

*Water can exist in a solid, liquid, or gas state.*

## GUIDING QUESTION

**How does the particle structure of matter explain the different properties of solids, liquids, and gases?**

## MATERIALS

*For each group of four students*

1 syringe full of air
1 syringe full of water
1 syringe full of clay
3 syringe stoppers

*For each pair of students*

access to the Internet

*For each student*

1 Student Sheet 8.1, "Talking Drawing: Particles in Different States"

## PROCEDURE

Use Student Sheet 8.1, "Talking Drawing: Particles in Different States," to prepare you for the following activity.

### Part A: Different States of Matter

1. Create a table in your science notebook to record ideas about each state—solid, liquid, and gas—and its properties.
2. In your group, discuss what you know about the three states of matter. Include what you know about the properties common to all materials in each state. List these properties in your table. Things you might want to discuss include the following:
   - Does each state have a specific shape?
   - Does each state have a specific volume?
   - What properties have you studied in the previous activities that might relate to the different states?
3. Look at the three syringes provided by your teacher. Each contains a material in a different state of matter—a gas, a liquid, and a solid.
4. With your group, predict whether you think you can press the plunger down into the syringe. Record your predictions in your science notebook.

5. Remove the stopper from the syringe containing the gas. Take turns so that each person in your group presses the plunger down to expel the air. After the last person has done this, refill the syringe with air and replace the stopper.

6. Make sure the syringe stoppers are securely attached to all three syringes before you begin Step 7.

7. Using the same amount of force that it took to expel the air in Step 5, take turns trying to press the plunger down in each syringe. Discuss with your group whether your results match your predictions.

8. Return to Student Sheet 8.1. Revise your diagrams on the Student Sheet if you would like to change or include any new information based on your observations and discussions in this part of the activity.

## Part B: A Closer Look at the Different States

9. Go to the *SEPUP Third Edition Chemistry of Materials* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition*, and click on the link for the States of Matter simulation.

10. Start with "Collect Data I" to look at gases at the molecular scale. As you investigate the three states, be sure to record your observations in your science notebook.
    a. Begin with Gas 1. You may need to click on the box that says "Click here to start interaction" to begin. Make sure "Show interactions" is selected, and press play.
    b. What do you notice about the particles?
    c. After a few seconds, press pause. The dotted lines between particles indicate that those particles are interacting or touching at that point in time. Are all of the particles interacting or touching?
    d. Select "Randomly pick an atom and show its trajectory," and press play. The yellow dotted line shows the movement of one of the particles. How would you describe its motion and interactions with other particles?
    e. Now look at Gas 2, which is an example of a gas composed of molecules. Repeat Steps 10a–d. Does this gas behave the same way as Gas 1?

11. Move to "Collect Data II" to look at two liquids at the molecular scale. Repeat Steps 10a–e with Liquid 1 and Liquid 2.
12. Move to "Collect Data III" to investigate two solids at the molecular scale. Repeat Steps 10a–e with Solid 1 and Solid 2.
13. Return to your Student Sheet, and complete the final part.

## ANALYSIS

1. Use your observations of the particle models in the simulation to develop a short explanation for how particles interact in a
   a. gas.
   b. liquid.
   c. solid.
2. Explain how the shape of a substance is determined by its state. Use your explanation from Analysis item 1 to help you.
3. **Kinetic energy** is the energy an object has because of its motion. Which state of matter do you think has the greatest kinetic energy and why?
4. Consider your discussions and the table you completed in Part A. What do you think can cause a substance to change from one state to another?

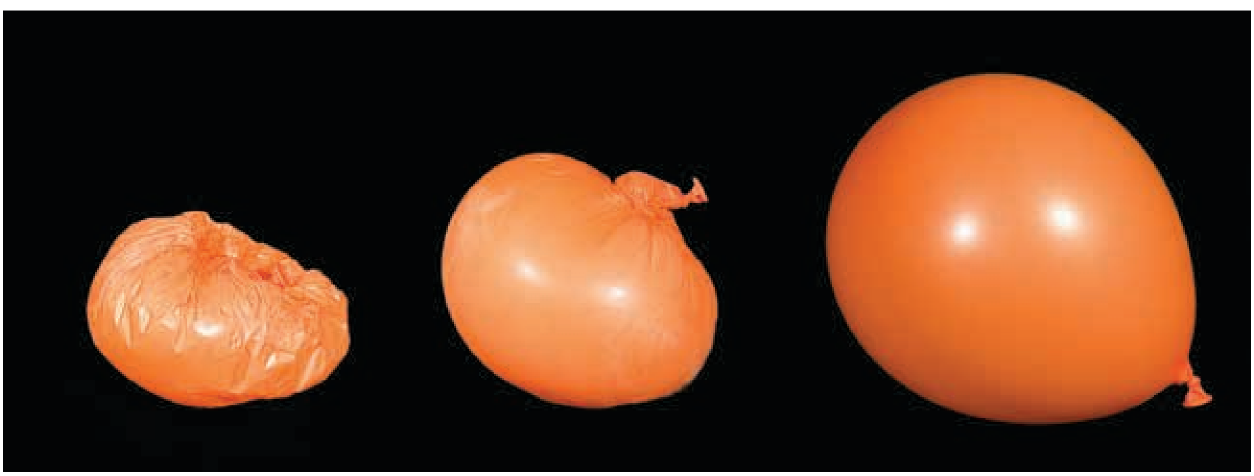
# 9 Energy and Particle Movement

LABORATORY

**IN THE STATES** of Matter simulation in the "What's in a State?" activity, you may have noticed that the particles in the three states were all moving in some way or another. And you learned that the energy due to this movement is called kinetic energy. The temperature of a substance measures the average kinetic energy of the particles. In this activity, you are going to investigate how changes in temperature can affect a gas—in this case, air.

## GUIDING QUESTION

**What happens when gas particles are heated or cooled?**



*How did the change in temperature cause the changes to these balloons?*

## MATERIALS

*For each pair of students*

1 plastic test tube
1 small plastic cup with dish soap
2 plastic cups (9-ounce)
1 syringe (6-mL)
dropper bottle of food coloring
1 stir stick
1 thermometer
3 plastic beakers (400-mL)
hot water
ice water
room-temperature water
1 timer or clock

*For each student*

1 Student Sheet 9.1, "Syringe Investigation Results"

## SAFETY

**Use care when handling hot water. In the event of a spill on skin, flush the area with cold water for about 5 min, and notify your teacher.**

## PROCEDURE

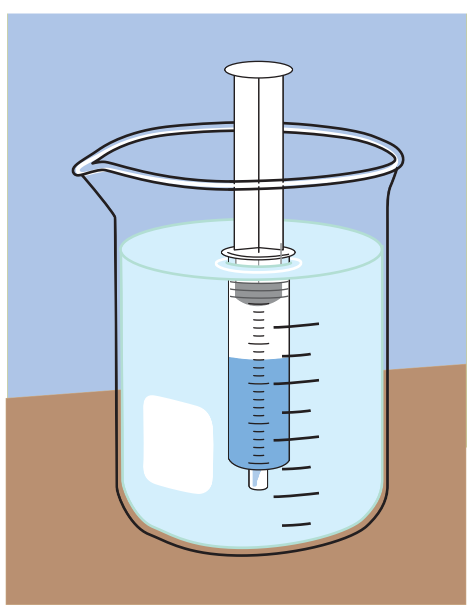
### Part A: Soap Bubbles

1. Fill one 9-ounce plastic cup two-thirds full with hot tap water.
2. Fill the other 9-ounce plastic cup two-thirds full with ice water.
3. Dip the opening of the empty test tube into the dish soap so that a thin layer of soap film covers the opening. You do not need a large amount of soap.
4. Holding the test tube upright, submerge the bottom of the test tube into the cup of hot water. Observe what happens to the soap film.
5. Carefully, without popping the soap film, transfer the test tube into your cup of ice water. Observe what happens to the soap film.
6. With your partner, discuss possible explanations for what you observed.
7. Clean up these materials as instructed by your teacher before moving to Part B.

## Part B: Syringe Investigation

8. Use Student Sheet 9.1, "Syringe Investigation Results," to keep track of your data in this part of the activity.
9. Fill three beakers three-quarters full of water—one with room-temperature water, one with ice water, and one with hot water.
10. Add 15 drops of food coloring to your room-temperature beaker and stir. Use your thermometer to measure the temperature of your colored water, and record this value in your Student Sheet table for the initial temperature.
11. Pull the plunger of your syringe so that about one-third (2 mL) of the barrel is full of room-temperature air. Record this volume in your table in the initial row.

    *Note*: When reading the volumes on the syringe, always hold the syringe upright with the plunger extending from the top, even though the numbers will be upside down.
12. Submerge the syringe into the colored room-temperature water, and draw up the colored water until the plunger is at the maximum volume marker on the syringe. Record this volume in your table in the initial row.
13. Holding the syringe upright, submerge the barrel of the syringe in the beaker of hot water for 3 min. Make sure the entire barrel is submerged in the water, as shown in the diagram.



14. While waiting for the 3 min to pass,
    a. the partner not holding the syringe should measure the temperature of the water in the beaker.
    b. both partners should make observations about what is happening to the water and air inside the syringe.
15. After 3 min have passed, carefully pull the syringe out of the water, continuing to hold it upright. Record in your table the final volumes of water and air and the temperature of the water in the beaker.
16. Submerge the syringe into the beaker of room-temperature water for 3 min and make observations. After 3 min, record the temperature and final volumes in your table.
17. Submerge the syringe into the beaker of ice water for 3 min and make observations. After 3 min, record the temperature and final volumes in your table.

## ANALYSIS

1. Scientists search for the cause-and-effect relationships that help to explain phenomena. One phenomenon you observed in Part A was the expansion (increase in size) or contraction (decrease in size) of a soap film.
    a. What cause-and effect relationships did you observe with the soap film investigation?
    b. Use what you know about particles to write an explanation for this relationship.
2. In both Part A and Part B of this activity, you investigated the effects of temperature on gas particle movement. The following are two possible explanations for the effects you observed:
    - The number of air particles inside the test tube (and syringe) increased with an increase in temperature, and the number of air particles decreased with a decrease in temperature.
    - The number of air particles inside the test tube (and syringe) stayed the same, but they took up more space when the temperature increased and took up less space when the temperature decreased.

Which explanation do you agree with? Create an argument using evidence from your investigation to support your decision.

3. In the "What's in a State?" activity, you made a labeled diagram of the particles in different states. This diagram can also be called a model. Return to your model of water vapor. Add to this model to show what happens to gas particles when the temperature changes.

# 10 Modeling State Changes

LABORATORY

In the "What's in a State?" activity, you worked with models of the particles in a gas, a liquid, and a solid. In the last activity, you learned that adding or removing thermal energy causes changes in the motion of gas particles. Thermal energy, which is a type of kinetic energy, is what people commonly refer to as heat. **Thermal energy** is the energy of the motion of the particles in a substance. Adding thermal energy to a gas increases particle movement, and removing thermal energy from a gas decreases particle movement. In this activity, you will investigate what happens if you add or remove enough thermal energy from a substance for it to change state.

*These melting ice cubes are an example of how water can change from a solid state to a liquid state.*

## GUIDING QUESTION

**What happens to the particles and temperature of a substance as it changes state?**

## MATERIALS

*For each pair of students*

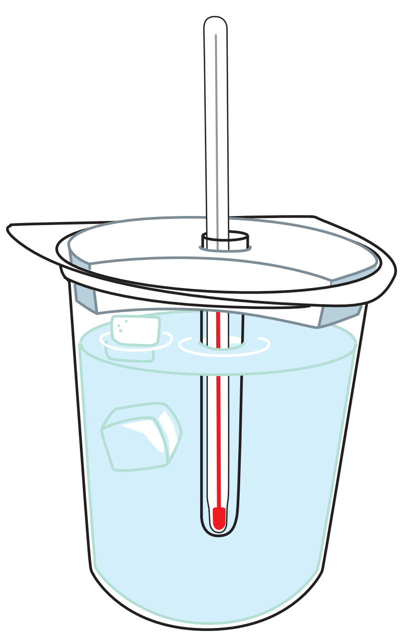
1 foam test tube holder for beaker
2 plastic beakers (400-mL)
1 plastic test tube
1 graduated cylinder (50-mL)
salt
ice cubes
water
1 plastic spoon
1 thermometer

*For each student*

1 Student Sheet 10.1, "Freezing and Melting Water"

## PROCEDURE

1. Use a graduated cylinder to measure 100 mL of water and put it into one of the beakers.
2. Add six ice cubes to the beaker.
3. Insert the test tube into the foam test tube holder. Put 2 mL of water into the test tube.



4. Place the thermometer into the test tube and record the starting temperature of the water in the “Freezing Temperatures” table on Student Sheet 10.1, “Freezing and Melting Water.”
5. Place the foam holder and test tube inside the beaker of ice water as shown in the diagram. The water in the test tube should be submerged below the ice water.
6. Immediately after lowering the test tube, add 5 level spoons of salt into the ice water through the opening in the foam test tube holder. One partner should carefully stir the salt and ice water continuously with the spoon for 15 min. Add more ice cubes as they start to melt.
7. The other partner should record the temperature of the water in the test tube in the “Freezing Temperatures” table every minute for 15 min.
8. During the first 10 min, gently move the thermometer in the test tube, keeping the bulb below the surface of the water in the tube. After 10 min, stop moving the thermometer and allow it to freeze in the ice.
9. After 15 min, leave the test tube submerged in your ice water.
10. Record the temperature of the test tube in the “Melting Temperatures” table on your Student Sheet.
11. Transfer the foam holder and test tube into an empty beaker, and begin recording the temperature every minute.
12. Dispose of the ice water as instructed by your teacher.
13. After 10 min have passed since moving the test tube, use the graduated cylinder to add 250 mL warm water to the beaker through the opening in the foam test tube holder.
14. Continue recording temperatures every minute for the next 5 min.
15. Clean up your experimental setup as instructed by your teacher.
16. Using the temperatures recorded on your Student Sheet, draw a line graph that plots temperature vs. time. You and your partner will each draw a graph—one for the freezing temperatures and one for the melting temperatures.
17. Answer Analysis items 1–3.
18. Follow your teacher’s instructions for exploring the effects of pressure on particles and state changes.

## ANALYSIS

1. Review the temperatures you recorded in the "Freezing Temperatures" table and the graph you or your partner drew on your Student Sheet. Use this information to help you answer the following:

   a. What is the freezing temperature of water? How did you determine this value?

   b. Freezing is an example of a state change—when a liquid becomes a solid. Explain what you think happened to the water molecules during this state change.

2. Review the temperatures you recorded in the "Melting Temperatures" table and the graph you or your partner drew on your Student Sheet. Use this information to help you answer the following:

   a. What is the melting temperature of ice? How did you determine this value?

   b. Ice melting is an example of another state change—when solid ice becomes liquid water. Explain what you think happened to the water molecules during this state change.

3. Develop a model that shows water molecules in all three states—solid, liquid, and gas—and the relationship between these states. Your model should include the following:

   - particle motion in each state
   - how particles interact within each state
   - the cause-and-effect relationship between addition or removal of thermal energy, particle movement, and state changes

   *Hint*: Think about the models you created in the last two activities and how you can add any new ideas from this activity to your models.

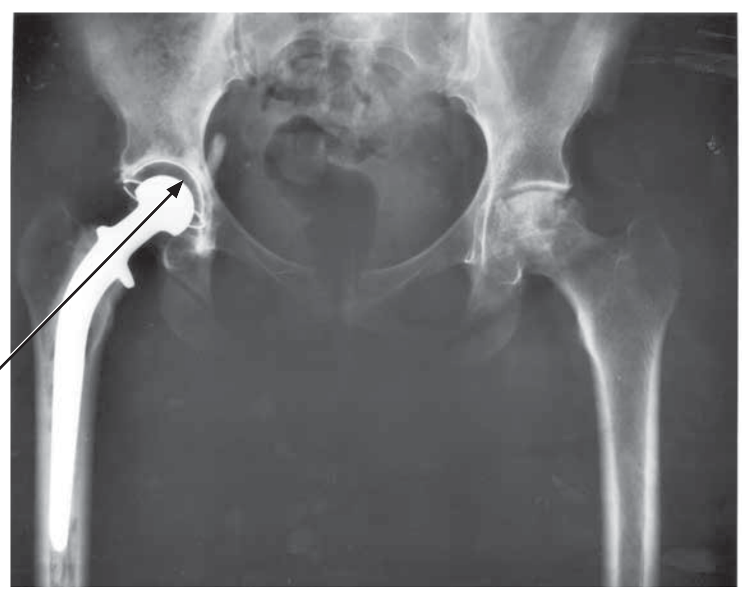
# 11 Making Polymers

LABORATORY

IN THE ACTIVITIES "Physical and Chemical Properties of Materials" and "Determining Density," you observed that each kind of plastic has characteristic properties. These properties can be used to identify the plastic, and they also determine how the plastic can be used. For example, the polypropylene used in flip-top lids for drink containers is fairly flexible, but the polystyrene used to make plastic eating utensils and clear plastic containers is not flexible. Their properties differ because they have different structures.

Plastics are members of a group of chemicals known as polymers. **Polymers** are compounds made of long chains of smaller repeating molecular subunits. The prefix "poly" means many, and the word polymer means many parts. The word for a single subunit within a polymer is **monomer,** or one part of a larger molecule, because "mono'" means one. So a polymer is made of many monomers. For example, the polypropylene you investigated is made of many propylene monomers. The polystyrene you investigated is made of many styrene monomers.

By changing the monomers that make up a plastic, chemical engineers can change the properties of the plastics they produce. But there are other ways to change the properties of plastics. You will explore one of these ways in this activity.



*The socket of this replacement hip joint is made of plastic.*

## GUIDING QUESTION

**How are plastics engineered for various uses?**

## MATERIALS

*For each group of four students*

1 bottle of polyvinyl alcohol (PVA) solution
1 bottle of sodium borate solution

*For each pair of students*

2 graduated cups (30-mL)
1 plastic dish or cup containing the following from the molecular model set:
- 4 white hydrogen "atoms"
- 2 black carbon "atoms"
- 1 red oxygen "atom"
- 7 white plastic "bonds"

1 plastic spoon
1 stir stick
paper towels
warm soapy water

*For each student*

1 pair of chemical splash goggles

## SAFETY

**Wear chemical splash goggles at all times during this lab. Do not allow the PVA and sodium borate solutions to touch your skin or clothing. Clean up any spills immediately. If accidental contact occurs, inform your teacher and rinse exposed areas.**

## PROCEDURE

### Part A: Making a Cross-Linked Polymer

1. Follow your teacher's instructions to create a model of a monomer and a polymer using your molecular model set.
2. In your science notebook, create a table to record your observations of the substances before the reaction and the results after the reaction is completed.

   *Hint:* Read through the entire Procedure before making your table so you know what you will need to record.

3. Pour 10 mL of polyvinyl alcohol (PVA) into an empty 30-mL graduated cup. As you pour, be sure to observe the PVA and then record in your table its color, how well it pours, whether it can be stirred, and if it appears sticky.
4. Pour 2.5 mL of sodium borate into the other graduated cup. As you pour, be sure to observe its properties and record them in your table.
5. One partner should slowly add all of the sodium borate to the PVA while the other stirs constantly with the stir stick. Observe the changes, and keep stirring until nothing further happens. Record all changes that occurred as you stirred.
6. Observe the properties of the substance that results. Record your observations in your data table.
7. Transfer your product from the cup onto a paper towel using the spoon. Immediately wash the cups. Then investigate and describe additional properties, such as the following:
   - Stickiness: Does it stick to your hands? to the desk? to the paper towel?
   - Stretchiness: What happens when you pull it slowly? when you pull it quickly?
   - Bounciness: Try bouncing a small piece.

8. In your table, summarize the properties of the substance you produced.
9. Follow your teacher's directions for cleanup.

## Part B: Plastic Pros and Cons

10. Read each of the following statements about plastics.

### POSITION 1

***Plastics: An Ideal Material***

Plastics are everywhere, in food packaging and toys, sports equipment, water pipes, computers, and medical devices. By varying the type of monomer and amount of cross-linking in a polymer, materials engineers can produce a nearly unlimited range of plastic products with whatever properties are desired. A strong plastic fiber is used to make bulletproof vests, whereas thin flexible plastics are used in artificial skin for burn victims. Plastics can be transparent or opaque, colorless or colored, and high or low in density and melting point. Most plastics are durable, lasting for many years. There are many products people depend on, such as certain medical devices, that can only be made of plastics. Today, it's hard to imagine life without this important and inexpensive class of materials.

### POSITION 2

***Plastics: An Environmental Disaster***

Plastics are one of the most damaging materials ever developed. Both the petroleum resources used to make them and their final disposal when they are no longer needed cause serious problems. They are made from oil, and obtaining the oil and using it to produce plastics creates pollution. Because they are so resistant to breaking down, most plastics last for many years. Think of all the plastic litter along the roads of America! And that isn't all. When plastic enters the ocean, it chokes wildlife and breaks into tiny pieces. Rotating ocean currents called gyres concentrate these tiny pieces of plastic in certain areas of the oceans. Although the pieces of plastic in these "garbage patches" are usually so small you can't see them, they are a serious problem. Finally, some plastics release chemicals that are toxic to humans and wildlife.

11. Make a list of the advantages and disadvantages of plastics based on the two statements about plastics.
12. The two statements give a very different view of plastics. Answer the following questions in your science notebook:
    a. Do you think there is any false or misleading information in the statements? Explain.
    b. Do you think there is any bias in the statements? Explain.

## ANALYSIS

1. How do the physical properties of the final substance you made in Part A compare with the properties of
    a. PVA, one of the starting substances?
    b. sodium borate, the second starting substance, which you added to the PVA?
2. Do you think you created a new substance in Part A? Use evidence to support your answer.
3. Plastics are a category of materials. Compare the plastics that you worked with in this activity to the properties of the plastics you investigated in the activities "Physical and Chemical Properties of Materials" and "Determining Density." From these investigations, what can you say about the properties of plastics?
4. What are two ways that materials engineers can vary the plastics they produce?
5. **Reflection**: What is your opinion of plastics? Do you tend to agree with Position 1 or Position 2, or are you somewhere in between? Explain your thinking.

## EXTENSION

Visit the *SEPUP Third Edition Chemistry of Materials* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition* and go to the links to information about plastics. Use the information you find to evaluate the accuracy of Position 1 and Position 2 in Part B of this activity.

# 12 Modeling Polymers

MODELING

**IN THIS ACTIVITY,** you will construct several kinds of models to help you understand how the structures of polymers determine their properties. Scientists use models to help explain things they cannot see. But keep in mind that a scientific model, like the particle and molecular models you have worked with, does not have to look like the real thing—it just has to act like it in one or more important ways. Also, models can be made at various scales. A model of a polymer might show every single atom, or it might only show the monomers in the polymer. Models at these two different scales can help explain different aspects of polymer properties.

You will model a monomer, a polymer, and a cross-linked polymer. A **cross-linked polymer** has small molecules that link together the polymer chains, the way the sodium borate in the last activity linked together the PVA chains.


*Models of buildings can help architects and engineers create and revise their designs.*

## GUIDING QUESTION

**How do the structures of plastics relate to their varied properties?**

## MATERIALS

*For each group of four students*

1 wide-mouthed plastic bottle (60-mL)
48 silver paper clips
6 colored paper clips
2 clear plastic cups (9-ounce)
1 plastic spoon

*For each student*

1 Student Sheet 12.2, "Comparing Models"

## PROCEDURE

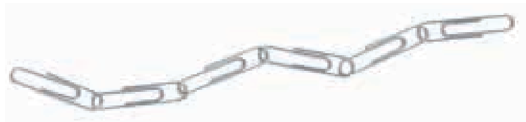
### Part A: Examining a Monomer

1. In your science notebook, create a table to record how well a monomer, a polymer, and a cross-linked polymer can be poured, stirred, and pulled, as shown by the models you will make. Read through the entire Procedure before constructing the table so you will know what data you will need to record.
2. Work with your group to investigate the properties of the model monomers. Put 24 unconnected silver paper clips in the wide-mouthed bottle. Each paper clip represents one monomer.
3. Slowly pour the monomers from the bottle into the plastic cup. (If necessary, gently shake the bottle.) Repeat this two or three times. Describe how quickly the clips come out of the bottle. Record your observations in your data table.
4. Use the plastic spoon to stir the monomers in the cup. Record your observations.
5. Reach into the cup and pull out a single monomer. Record in your data table your observations about pulling out the monomer.

### Part B: Forming a Polymer

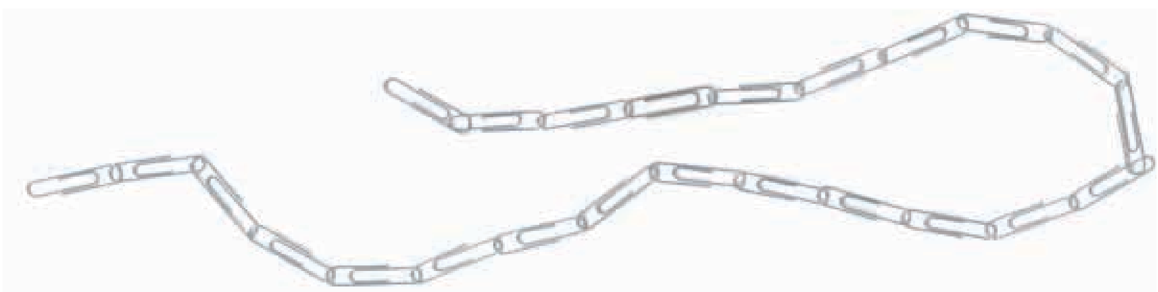
6. Each member of your group will now link six paper clips from the remaining 24 clips into a straight chain, as shown in the diagram on the following page.

**Model of a Polymer**



7. Link your four chains together to make one long chain of 24 paper clips. You have just made a model of a polymer like the PVA you used in the "Making Polymers" activity. (You would need thousands of paper-clip monomers to make a realistic paper-clip polymer.)

**Model of a Longer Polymer Molecule**

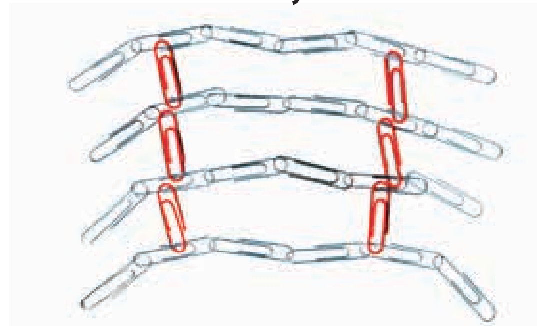


8. Put your polymer in the wide-mouthed bottle. Leave one or two paper clips hanging out of the top. Now pour the polymer into a plastic cup two or three times. Record your observations.
9. Use the plastic spoon to stir the polymer in the cup. Record your observations.
10. Reach into the cup, and pull out a single paper clip. Record your observations.

## Part C: Cross-Linking a Polymer

11. Separate the polymer back into four chains of six paper clips each. Each part represents individual polymer molecules. Place the chains in four parallel rows as shown in the diagram below.
12. Use two colored paper clips to connect, or cross-link, the first and second chains. Continue to do this with all four of the chains, as shown in the diagram at right. You have just made a model of a cross-linked polymer, like cross-linked PVA. You have constructed a model of a chemical reaction that chemically

**Model of a Cross-Linked Polymer**



bonds polymers together into cross-linked polymers. The colored paper clips represent the sodium borate molecules that linked the PVA polymer chains together in the last activity.

13. Test how well your cross-linked model polymer can be poured, stirred, and pulled. Record your observations in your data table.
14. Separate all of the paper clips, and put the 24 silver paper clips back in the plastic cup.
15. Follow your teacher's instructions for creating another kind of model of a cross-linked polymer. Sketch your ideas in your science notebook.

## ANALYSIS

1. Models provide ways to represent complex systems. In the last activity, "Making Polymers," and this activity, you made a total of three models of polymers at different scales. Use Student Sheet 12.2, "Comparing Models," to analyze each of the following models:
   a. atomic/molecular models
   b. paper-clip models
   c. human-chain models
2. Compare the models you built in this activity. Which was the most helpful in analyzing the physical properties of a polymer?
3. Using models from this and the last activity, explain the relationships between a monomer, a polymer, and a cross-linked polymer. Be sure to
   - include a sketch of the models that illustrate your explanation.
   - label examples of atoms, bonds, a monomer, a polymer, a cross-linked polymer, and a molecule.
4. How does cross-linking affect the properties of a polymer?

# 13 The Impact of Plastics on Society

TALKING IT OVER

**IN THIS UNIT,** you have learned about the properties of different types of materials, especially plastics. In the 1940s and 1950s, when manufacturing improved enough to allow for plastics to be manufactured easily and on a large scale, materials scientists and engineers began to come up with many new types of and uses for plastics. Now plastics are used every day in many different ways—including things as significant as life-saving medical devices and as "everyday" as packaging for snacks. In fact, many of the products we use on a regular basis would not be possible without plastics. But how often do we think about the impact these plastics have on society overall? In this activity, you will investigate four different types of plastics—Teflon, Kevlar, compostable polymers, and polyester. All four of these plastics are widely used and have different benefits and trade-offs.

*These objects are all made of different types of plastics.*

## GUIDING QUESTION

**What are the benefits and trade-offs of different plastics?**

## MATERIALS

*For each student*

1 Student Sheet 13.1, "Comparing Plastics"

## PROCEDURE

1. As you read the following text, complete Student Sheet 13.1, "Comparing Plastics," according to your teacher's instructions.

### Teflon

*This pan is nonstick because it has been coated with Teflon.*

Most people know Teflon (polytetrafluoroethylene—PTFE) from its use as a nonstick coating in kitchen pots and pans, but it has many other uses. Teflon is used in space suits for astronauts and heat shields on space ships. Teflon is nonreactive, so it can be used as a coating in containers and pipes that come into contact with acids and other chemicals. Teflon is also used as a lubricant in all kinds of machinery. Teflon is even used as a coating on some medical devices because it interferes with the ability of bacteria to attach to surfaces, therefore helping to prevent bacterial infections.

The production of Teflon uses a lot of energy (including a lot of heat) and water. Most of the water used in Teflon production is contaminated after use and must be treated or properly disposed of. Several types of strong acids are also used in the production of Teflon. Teflon production also creates byproducts, which are additional or unintended products made during the production process. Some of these byproducts are toxic (like hydrofluoric acid and carbon dioxide), but some of the debris and the contaminated water from production can be cleaned and reused.

Teflon can be recycled, but recycled Teflon is not good for long-term use. Teflon cannot be incinerated because burning releases highly corrosive vapors. Teflon does not biodegrade—or naturally decompose—at regular temperatures, so it persists in the environment. Some research shows it may be a health hazard to humans. Teflon breaks down if heated above 260°C (500°F), and the byproducts it releases can be deadly to birds and cause flu-like symptoms in humans.

## Kevlar

Kevlar's most well-known use is in bulletproof vests and body armor, but did you know it is also used in motorcycle safety gear and other protective clothing? Kevlar (polyparaphenylene terephthalamide) is five times stronger than steel, but it also can protect against cuts, abrasions, and burns. It's even used in brake pads in cars and other vehicles. Unlike many plastics, when Kevlar gets cold it maintains its strength and does not become brittle or crack. However, it does slowly degrade with ultraviolet (UV) light—like sunlight—so it often has to be combined with another material or coating. It also degrades in high heat (over 160°C [320°F]).

*This canoe is made with Kevlar.*

Kevlar is produced from several monomers. Making Kevlar produces hydrochloric acid as a byproduct, and some of the solutions used in the production process are hazardous. For example, concentrated sulfuric acid is used during one stage of the production. Recycling of Kevlar is becoming more common, but it often ends up in landfills where it does not degrade.

## Polylactic Acid

Polylactic acid (PLA) is one of the most widely used compostable polymers manufactured today. It is used in many of the ways that noncompostable plastics are used. You may have seen PLA used for compostable forks, knives, spoons, and food containers. It is also used in 3-D printers. Some temporary medical implants, like the pins and plates that can help to set badly broken bones, are made of PLA. The PLA breaks down in the body within 6 months to 2 years, so the patient does not need another surgery to have the pin or plate removed.

*This biodegradable plastic bag is made from PLA so it can be disposed of in the compost pile instead of a landfill.*

Making PLA (and many other compostable polymers) uses less energy than the production of noncompostable plastics. Unlike other polymers, which are made from petroleum products, PLA is made from products that are derived from corn and other starches. However, the production of PLA does use a lot of water.

PLA can be recycled, but not with other noncompostable plastics. (It can contaminate other plastics, so it has to be carefully separated.) PLA can also biodegrade, but it will not break down quickly in landfills. Some people are concerned that the corn used in PLA is taking up farmland that could be used to grow food instead. PLA can be used in place of many noncompostable plastics but not for long-term use because it will break down over time.

## Polyester

Polyester (polyethylene terephthalate—PET) is one of the most common human-made polymers used today. The word polyester actually refers to a whole category of polymers, used in everything from clothing and upholstery to insulation and plastic bottles. Polyester can be blended easily with natural fibers, and a lot of clothing is made from "cotton–poly" blends or mixtures of polyester and other fibers. Polyester and polyester-blended fabrics are wrinkle- and tear-resistant.

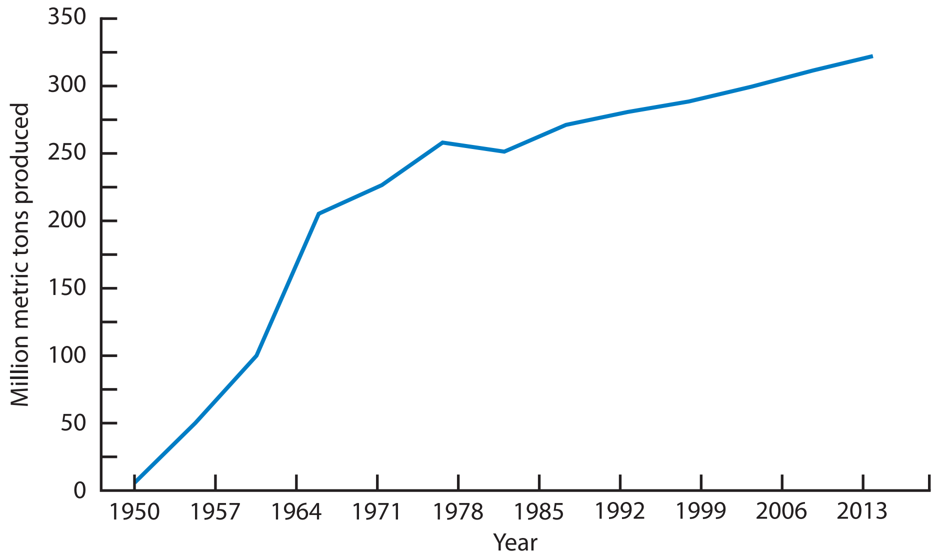
*This bottle is made from one type of polyester.*

Polyester is made from petroleum products. The production process uses a lot of energy and water, and can release dangerous substances. However, many of the chemicals used in producing polyester can be used over and over again, helping to minimize the hazardous waste produced. In general, polyester does not biodegrade (there are a few natural ones that do), but it can be recycled.

## Impacts of Plastics Now and in the Future

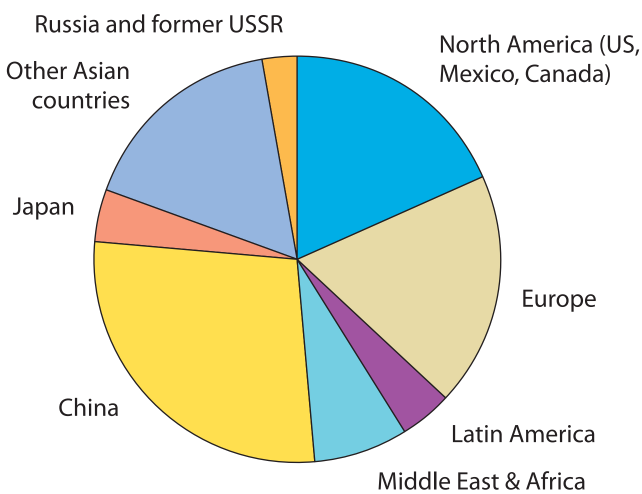
Plastics have been used throughout the world for many years, but it was not until the 1940s and 1950s that technology allowed for mass production of plastics for general use. As you can see in the following graph, the global production of plastics has increased since then.

**Global Production of Plastics**



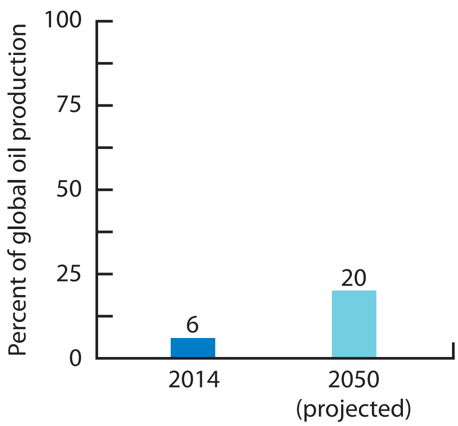

Scientists estimate that the production of plastics will continue to grow. One estimate is that by 2050 the world will be producing over 1,100 million metric tons of plastic. Plastics are produced and used throughout the world, with the highest percentage of plastic production currently based in China.

**Plastic Production by Region/Country**



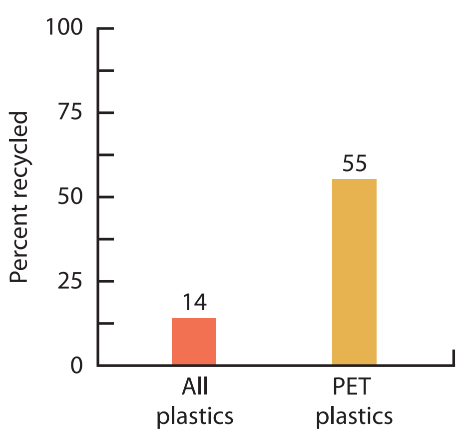
Much of this plastic production requires the use of petroleum, a nonrenewable resource that we also use to produce things like transportation fuels.

**Percent of Global Oil Consumption Due to Plastic Production**




Many plastics can be recycled, but only if recycling facilities are available and if people use those facilities. There also has to be a market for using the plastic once it has been recycled. Some plastics, like PET bottles, are recycled fairly often. However, global rates of recycling plastics still remain very low.

**Percent of Plastic Packaging Recycled**




Some countries, such as Switzerland and Germany, have landfill bans, meaning it is illegal to send plastic to the landfill, and it must be recycled whenever possible. In general, countries where bans like this have been introduced have had significant increases in the amount of material recycled and have reduced their overall landfill use.

Plastics have allowed for many new technologies to be developed, leading to important industries that we rely on today. Plastics are used in everything from cars to cellular phones to industrial machinery. However, many plastics are made from petroleum products, and all plastics require large amounts of resources, such as energy, chemicals, and water, to be manufactured. Plastics have many benefits for society, but they also have a lot of trade-offs.

2. Imagine that your community is trying to reduce the amount of plastics it uses. The following proposals are being voted on by the city council:

   - It is prohibited to sell or provide disposable plastic products (no plastic drink containers, no plastic utensils, no plastic bags) to customers.
   - Only compostable plastics can be sold or used for disposable products.
   - Disposable plastic products can only be used when there is no other disposable alternative.
   - Disposable plastic products can be sold or provided, but recycling programs will be improved to make it easier to recycle some plastics.

   Follow your teacher's instructions to conduct a Walking Debate about the four proposals.

## ANALYSIS

1. Choose one of the four plastics discussed in this activity. Explain how the properties of that plastic determine what type of products it can and cannot be used for.
2. Prepare a short speech explaining which proposal from the Walking Debate you support and why. Include the benefits and trade-offs of the proposal you have chosen and the evidence that supports them. You do not have to choose the same proposal you chose to support in the Walking Debate. You may use convincing statements in your explanation as long as they are accurate.

# *Chemistry of Materials*

UNIT SUMMARY

## How Do a Material's Properties Affect its Uses?

All materials are made from a limited number of elements. Each of these elements has characteristic properties such as color, solubility, density, and melting and boiling point. Physical properties are observed, measured, or calculated and do not involve reactions with another material. For example, a substance's density can be calculated from the mass and volume of a sample. Chemical properties describe the reaction of the material with another material, such as an acid or oxygen. The properties of materials are used to identify materials and to determine appropriate uses for materials.

## Why Do Materials Have Unique Properties?

Substances have specific structures based on what elements they are made of and how those elements bond together. These structures can be modeled to help explain the properties of materials, such as density and solubility. Some substances form small structures with only a few atoms bonded together. Other substances form larger structures with many atoms bonded together to form large molecules or extended structures.

## States of Matter

Substances mostly exist in one of three different states—solid, liquid, or gas. Particle models help explain the differences between these states. Particle models can show the distance between particles, particle motion (kinetic energy), and particle interactions. Solids tend to have less particle motion and less distance between particles, whereas gases tend to have more particle motion and more distance between particles. Particles in liquids tend to be intermediate in motion and are almost as closely packed as in solids.

Adding thermal energy either increases the temperature and kinetic energy of particles or causes a phase change from solid to liquid or liquid to gas. Removing thermal energy either decreases particles' temperature and kinetic energy or causes a state change from gas to liquid or liquid to solid. Transfer of thermal energy to a substance increases the substance's average kinetic energy except during a state change.

## Materials and Society

Some large molecules and structures are made of small, repeating subunits (monomers). Hundreds to thousands of these monomers can bond together to form polymers, such as different types of plastics. Some polymer chains can connect to form cross-linked polymers.

Plastics are a type of polymer. They have specific properties that materials scientists and engineers consider when determining the best material for a product. Polymers have also allowed scientists and engineers to determine the limitations of technologies and how to adapt them for individual and societal needs, desires, and values. There are benefits and trade-offs to using all materials, including plastics. Plastics, and other synthetic materials, are made from natural resources and have many impacts, both positive and negative, on human health and the environment.

## Essential Scientific Terms

atom

bias

chemical property

compound

density

element

extended structure

kinetic energy

life cycle

mass

material

model

molecule

physical property

polymer

scale

state

thermal energy

volume

APPENDIX

# A Science and Engineering

## THE NATURE OF SCIENCE AND ENGINEERING

**IF SOMEONE ASKED** you the question, "What is science?" how would you answer?

You might reply that it is knowledge of such subjects as biology, chemistry, Earth science, and physics. That would be only partly correct. Although science is certainly related to the accumulation and advancement of knowledge, it is much more than that. Science is a way of exploring and understanding the natural world.

According to the American Association for the Advancement of Science (AAAS), two of the most fundamental aspects of science are that the world is understandable and that scientific ideas are subject to change.

Scientists believe that the world is understandable because things happen in consistent patterns that we can eventually understand through careful study. Observations must be made and data collected for us to discover the patterns that exist in the universe. At times scientists have to invent the instruments that allow them to collect this data. Eventually, they develop theories to explain the observations and patterns. The principles on which a theory is based apply throughout the universe.

When new knowledge becomes available, it is sometimes necessary to change theories. This most often means making small adjustments, but on rare occasions it means completely revising a theory. Although scientists can never be 100% certain about a theory, as knowledge about the universe becomes more sophisticated most theories become more refined and more widely accepted. You will see examples of this process as you study the history of scientists' understanding of such topics as elements and the periodic table, the cellular basis of life, genetics, plate tectonics, the solar system, and the universe in this middle school science program.

While the main goal of science is to understand phenomena, the main goal of engineering is to solve problems. Like science, engineering involves both knowledge and a set of practices common across a range of engineering problems. Just as scientists start by asking questions, engineers start by defining problems. Just as scientists search for explanations for phenomena, engineers search for solutions to problems.

Science and engineering often build on each other. For example, scientists use instruments developed by engineers to study the natural world. And engineers use scientific principles when designing solutions to problems.

## Scientific Inquiry

Inquiry is at the heart of science, and an important component of inquiry is scientific investigation, including experimentation. Although scientists do not necessarily follow a series of fixed steps when conducting investigations, they share common understandings about the characteristics of a scientifically valid investigation. For example, scientists obtain evidence from observations and measurements. They repeat and confirm observations and ask other scientists to review their results. It is important for scientists to avoid bias in designing, conducting, and reporting their investigations and to have other unbiased scientists duplicate their results. Some types of investigations allow scientists to set up controls and vary just one condition at a time. They formulate and test hypotheses, sometimes collecting data that lead them to develop theories.

When scientists develop theories they are constructing models and explanations of the patterns and relationships they observe in natural phenomena. These explanations must be logically consistent with the evidence they have gathered and with evidence other scientists have gathered. Hypotheses and theories allow scientists to make predictions. If testing turns out to not support a prediction, scientists may have to look at revising the hypothesis or theory on which the prediction was based.

## Engineering Design

An engineer uses science and technology to build a product or design a process that solves a problem or makes the world better. Engineering design refers to the process engineers use to design, test, and improve solutions to problems. Like scientists, engineers design investigations to test their ideas, use mathematics, analyze their data, and develop models.

Since most solutions in the real world are not perfect, engineers work to develop the best solutions they can, while balancing such factors as the function, cost, safety, and usability of their solutions. The factors engineers identify as important for solutions to a problem are called criteria and constraints. Most engineering solutions have one or more trade-offs—desired features that must be given up in order to gain other more desirable features.

## *References*

American Association for the Advancement of Science (AAAS). (1990). *Project 2061: Science for all Americans*. New York, NY: Oxford University Press.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K–12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

APPENDIX

# B Science Safety

## SCIENCE SAFETY GUIDELINES

YOU ARE RESPONSIBLE for your own safety and for the safety of others. Be sure you understand the following guidelines and follow your teacher's instructions for all laboratory and field activities.

### Before the Investigation

- Listen carefully to your teacher's instructions, and follow any steps recommended when preparing for the activity.
- Know the location and proper use of emergency safety equipment, such as the safety eye-and-face wash, fire blanket, and fire extinguisher.
- Know the location of exits and the procedures for an emergency.
- Dress appropriately for lab work. Tie back long hair and avoid wearing dangling or bulky jewelry or clothing. Do not wear open-toed shoes. Avoid wearing synthetic fingernails—they are a fire hazard and can tear protective gloves.
- Tell your teacher if you wear contact lenses, have allergies to latex, food, or other items, or have any medical condition that may affect your ability to perform the lab safely.
- Make sure the worksurface and floor in your work area are clear of books, backpacks, purses, or other unnecessary materials.
- Ask questions if you do not understand the procedure or safety recommendations for an activity.
- Review, understand, and sign the Safety Agreement, and obtain the signature of a parent or guardian.

## During the Investigation

- Carefully read and follow the activity procedure and safety recommendations.
- Follow any additional written and spoken instructions provided by your teacher.
- Use only those activities and materials approved by your teacher and needed for the investigation.
- Don't eat, drink, chew gum, or apply cosmetics in the lab area.
- Wear personal protective equipment (chemical splash goggles, lab aprons, and protective gloves) appropriate for the activity.
- Do not wear contact lenses when using chemicals. If your doctor says you must wear them, notify your teacher before conducting any activity that uses chemicals.
- Read all labels on chemicals, and be sure you are using the correct chemical.
- Keep chemical containers closed when not in use.
- Do not touch, taste, or smell any chemical unless you are instructed to do so by your teacher.
- Mix chemicals only as directed.
- Use caution when working with hot plates, hot liquids, electrical equipment, and glassware.
- Follow all directions when working with live organisms or microbial cultures.
- Be mature and cautious, and don't engage in horseplay.
- Report any unsafe situations, accidents, or chemical spills to your teacher immediately.
- If you spill chemicals on your skin, wash it for 15 minutes with large amounts of water. Remove any contaminated clothing and continue to rinse. Ask your teacher if you should take other steps, including seeking medical attention.
- Respect and take care of all equipment.

## After the Investigation

- Dispose of all chemical and biological materials as instructed by your teacher.
- Clean up your work area, replace bottle caps securely, and follow any special instructions.
- Return equipment to its proper location.
- Wash your hands with soap and warm water for at least 20 seconds after any laboratory activity, even if you wore protective gloves.

*Your teacher will give you an agreement similar to the one below to sign.*

## Science Safety Agreement

### STUDENT

I, ________________________, have read the attached Science Safety Guidelines for students and have discussed them in my classroom. I understand my responsibilities for maintaining safety in the science classroom. I agree to follow these guidelines and any additional rules provided by the school district or my teacher.

Student Signature________________________________________________________

Date____________________

### PARENT OR GUARDIAN

Please review with your student the attached Science Safety Guidelines, which include the safety responsibilities and expectations for all students. It is important that all students follow these guidelines in order to protect themselves, their classmates, and their teachers from accidents. Please contact the school if you have any questions about these guidelines.

I, ________________________, have read the attached guidelines and discussed them with my child. I understand that my student is responsible for following these guidelines and any additional instructions at all times.

Parent or Guardian Signature______________________________________________

Date____________________

APPENDIX

# C Science Skills

THE FOLLOWING PAGES include instructional sheets that you can use to review important science skills:

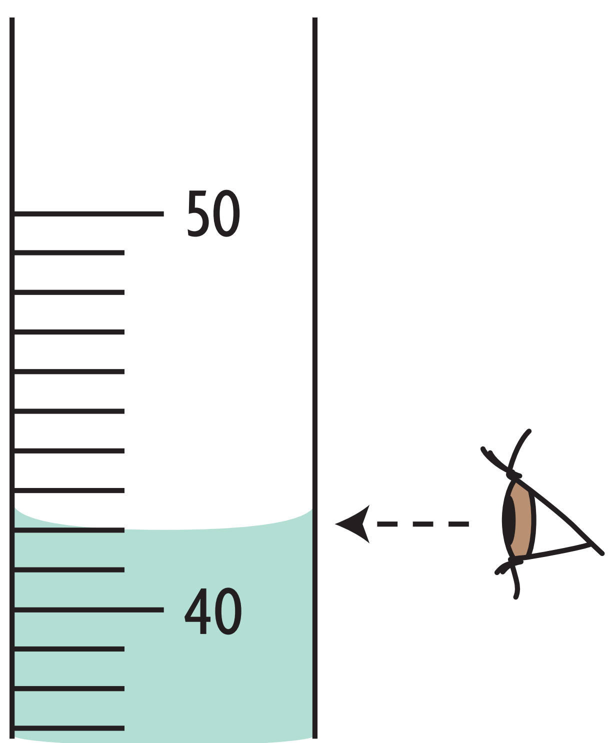
- Reading a Graduated Cylinder
- Using a Dropper Bottle
- Bar Graphing Checklist
- Scatterplot and Line Graphing Checklist
- Interpreting Graphs
- Elements of Good Experimental Design
- Using Microscopes

## READING A GRADUATED CYLINDER

A graduated cylinder measures the volume of a liquid, usually in milliliters (mL). To measure correctly with a graduated cylinder:

1. Determine what measurement each unmarked line on the graduated cylinder represents.
2. Set the graduated cylinder on a flat surface and pour in the liquid to be measured.
3. Bring your eyes to the level of the fluid's surface. (You will need to bend down!)
4. Read the graduated cylinder at the lowest point of the liquid's curve (called the *meniscus*).
5. If the curve falls between marks, estimate the volume to the closest milliliter.

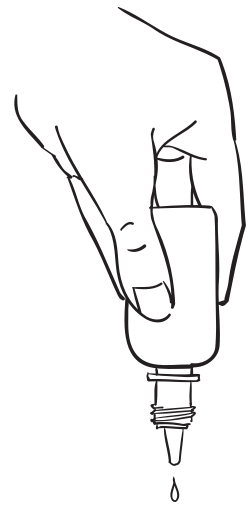
*The example below shows a plastic graduated cylinder that contains 42 mL of liquid.*



# USING A DROPPER BOTTLE

***Incorrect***

*Holding the dropper bottle at an angle creates drops that vary in size.*



***Correct***

*Holding the dropper bottle vertically creates drops that are more consistent in size.*

# BAR GRAPHING CHECKLIST

## Sample Graph

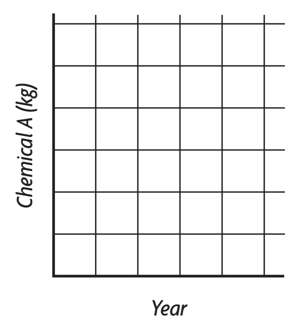
Follow the instructions below to make a sample bar graph.

- ☐ Start with a table of data. This table represents the amount of Chemical A that the Acme Company used each year from 2011 to 2015.

| *Year* | *Chemical A used (kg)* |
|---|---|
| *2011* | *100* |
| *2012* | *80* |
| *2013* | *110* |
| *2014* | *90* |
| *2015* | *105* |

- ☐ Determine whether a bar graph is the best way to represent the data.

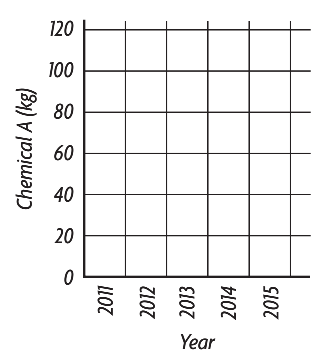
- ☐ If so, draw the axes. Label them with the names and units of the data.




- ☐ Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

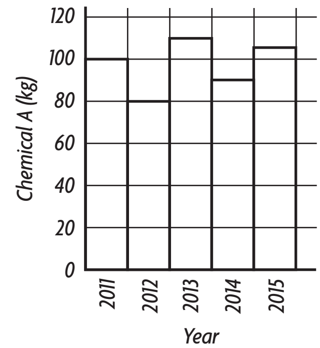
*Year axis: 1 block = 1 year*
*Chemical A axis: 1 block = 20 kilograms*

- ☐ Mark intervals on the graph, and label them clearly.

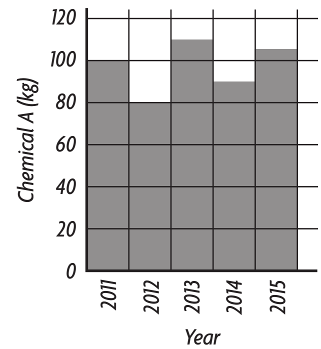


## BAR GRAPHING CHECKLIST (continued)

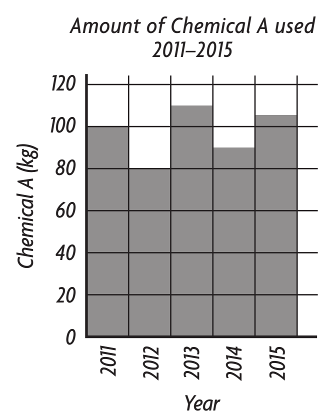
☐ Plot your data on the graph.




☐ Fill in the bars.




☐ Title your graph. The title should describe what the graph shows.



# SCATTERPLOT AND LINE GRAPHING CHECKLIST

## Sample Graph

Follow the instructions below to make a sample graph.

☐ Start with a table of data.

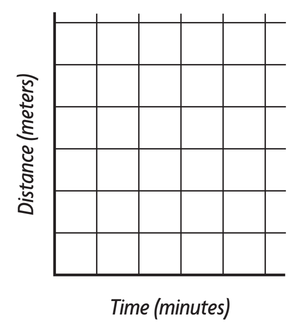
*MOTION OF A BALL*

| *Time (minutes)* | *Distance (meters)* |
|---|---|
| 0 | 0 |
| 1 | 5 |
| 2 | 9 |
| 3 | 16 |
| 4 | 20 |
| 5 | 27 |

☐ Determine whether a line graph or a scatterplot is the best way to represent the data.

*LINE GRAPH*

☐ Draw the axes. Label them with the names and units of the data.

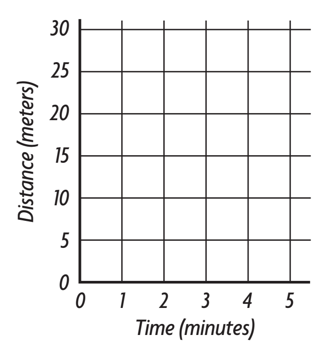



☐ Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

*Time axis:* *1 block = 1 minute*

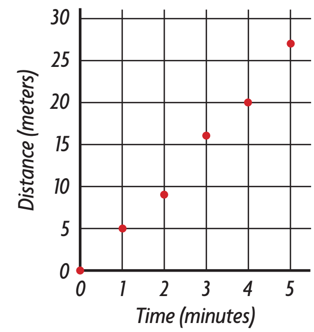
*Distance axis:* *1 block = 5 meters*

☐ Draw intervals on the graph, and label them clearly.



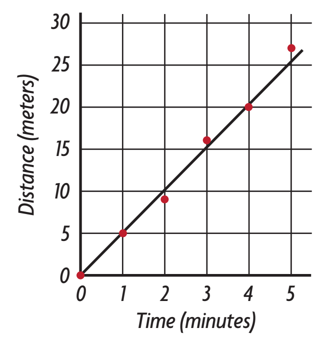
## SCATTERPLOT AND LINE GRAPHING CHECKLIST (continued)

☐ Plot your data on the graph.

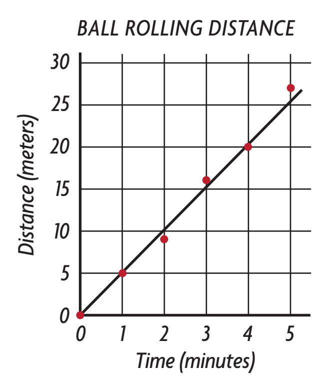



☐ For a scatterplot, leave the points unconnected.

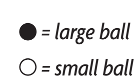
For a line graph, draw a smooth line or curve that follows the pattern indicated by the position of the points.




☐ Title your graph. The title should describe what the graph shows.

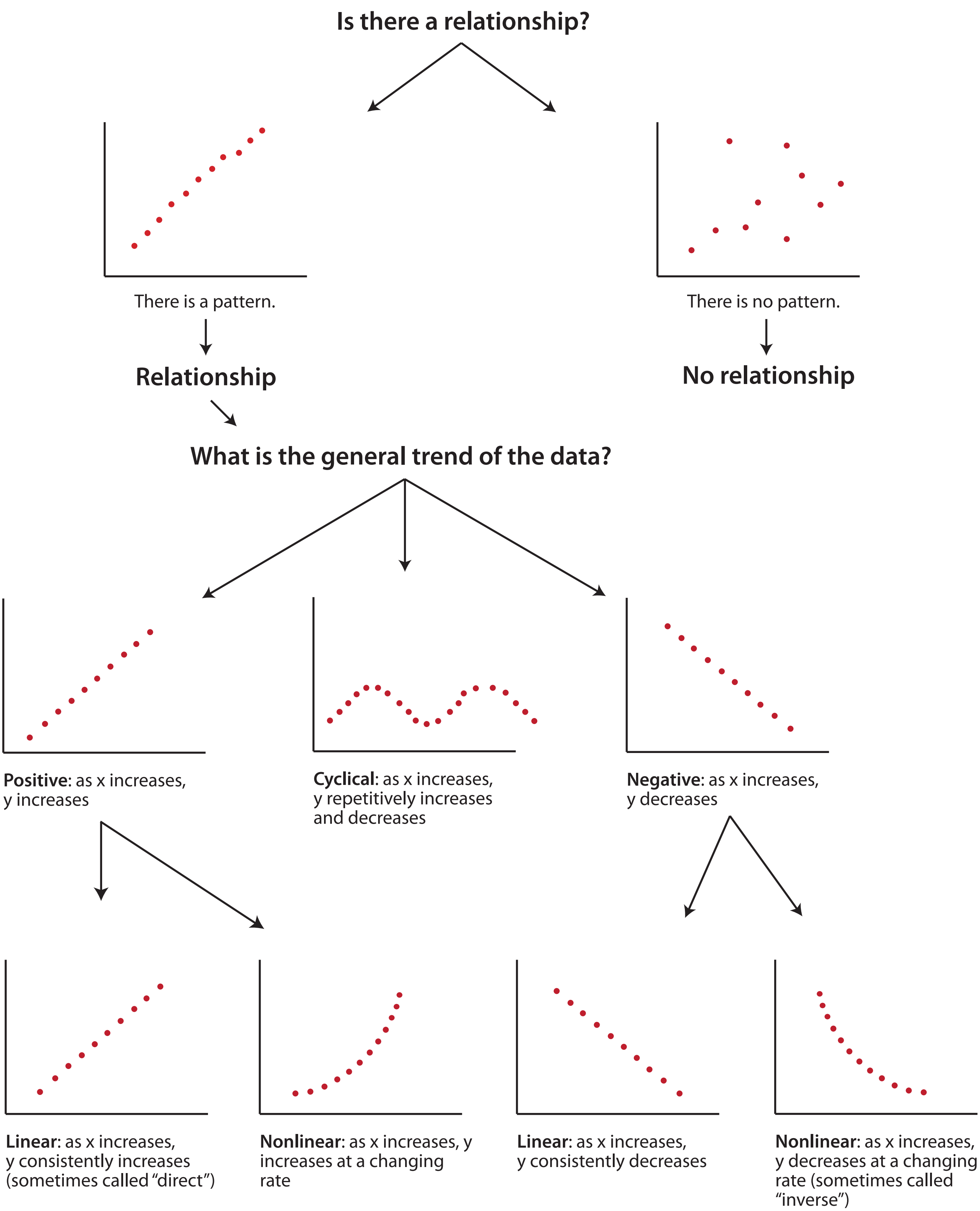



☐ If more than one data set has been plotted, include a key.



# INTERPRETING GRAPHS

## Determine the path that describes the data.



## INTERPRETING GRAPHS (continued)

### Define the components of the graph.

Things you can say:

"The title of the graph is …"

"The independent variable in this graph is …"

"The dependent variable in this graph is …"

"__________ is measured in ____________________"

### Create a description of what the graph reveals.

Things you can say:

"This graph shows that …"

"As the __________ increases, the …"

"The ______ has the highest …"

"__________ is different from ____________ because …"

"The___________ peaked at …"

"The rate of _______ increased from …"

### Describe how the graph relates to the topic.

Things you can say:

"This graph is important to understanding _________because …"

"This graph supports the claim that ______________ because …"

"This graph refutes the claim that ______________ because …"

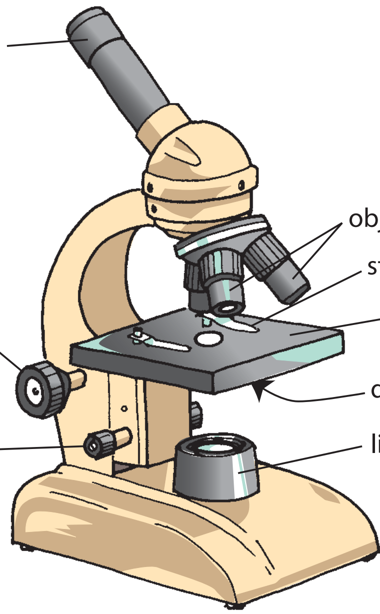
# ELEMENTS OF GOOD EXPERIMENTAL DESIGN

## An experiment that is well designed

- builds on previous research.
- is based on a question, observation, or hypothesis.
- describes all steps in a procedure clearly and completely.
- includes a control for comparison.
- keeps all variables—except the one being tested—the same.
- describes all data to be collected.
- includes precise measurements and all records of data collected during experiment.
- may require multiple trials.
- can be reproduced by other investigators.
- respects human and animal subjects.

*Note: Elements may vary depending on the problem being studied.*

# USING MICROSCOPES




## Focusing a Microscope

Be sure that your microscope is set on the lowest power before placing your slide onto the microscope stage. Place the slide on the microscope stage. Center the slide so that the sample is directly over the light opening, and adjust the microscope settings as necessary. If the microscope has stage clips, secure the slide in position so that it does not move.

- Observe the sample. Focus first with the coarse-focus knob, and then adjust the fine-focus knob.
- After switching to a higher power magnification, be careful to adjust the focus with the fine-focus knob only.
- Return to low power before removing the slide from the microscope stage.

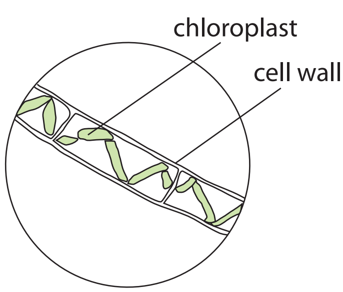
## Safety

Always carry a microscope properly with both hands—one hand underneath and one holding the microscope arm. When you are working with live organisms, be sure to wash your hands thoroughly after you finish the laboratory.

## Some Tips for Better Drawings

- Use a sharp pencil and have a good eraser available.
- Try to relax your eyes when looking through the eyepiece. You can cover one eye or learn to look with both eyes open. Try not to squint.
- Look through your microscope at the same time as you do your drawing. Look through the microscope more than you look at your paper.
- Don't draw every small thing on your slide. Just concentrate on one or two of the most common or interesting things.
- You can draw things larger than you actually see them. This helps you show all of the details you see.
- Keep written words outside the circle.
- Use a ruler to draw the lines for your labels. Keep lines parallel—do not cross one line over another.
- Remember to record the level of magnification next to your drawing.

*Spirogyra* (algae) x 400



APPENDIX

# D The International System of Units

MEASUREMENTS THAT APPEAR in this program are expressed in metric units from the International System of Units, otherwise known as *SI units* (from Système Internationale d'Unités), which was established by international agreement. Virtually all countries in the world mandate use of the metric system exclusively. The United States does not use the metric system for many measurements, although it has been the standard for the scientific community in the United States for more than 200 years. A U.S. government effort to convert from the United States customary system to metric measurements in all realms of life has yet to extend far beyond governmental agencies, the military, and some industries.

The reason that many countries have replaced their traditional measurement systems with the metric system is its ease of use and to improve international trade. There are far fewer units to understand in comparison to the system commonly used in the United States. The metric system has only one base unit for each quantity and larger or smaller units are expressed by adding a prefix. The table below shows the base units in the International System of Units.

| QUANTITY | BASE UNIT |
|---|---|
| Length | meter (m) |
| Mass | kilogram (kg) |
| Time | second (s) |
| Temperature | kelvin (K) |
| Electric current | ampere (A) |
| Luminous intensity | candela (cd) |
| Mole | mole (mol) |

Other international units appearing in SEPUP's *Issues and Science* units are shown in the table below:

| QUANTITY | UNIT | COMMON EXAMPLE |
|---|---|---|
| Temperature | Celsius (°C) | Room temperature is about 20° Celsius |
| Volume | liter (L) | A large soda bottle contains 2 liters. |
| Mass | gram (g) | A dollar bill has the mass of about 1 gram. |
| Wavelength | nanometer (nm) | Visible light is in the range of 400 to 780 nanometers |

The International System's prefixes change the magnitude of the units by factors of 1,000. Prefixes indicate which multiple of a thousand is applied. For example, the prefix *kilo-* means 1,000. Therefore, a kilometer is 1,000 meters and a kilogram is 1,000 grams. To convert a quantity from one unit to another in the metric system, the quantity needs only to be multiplied or divided by multiples of 1,000. The chart below shows the prefixes for the metric system in relation to the base units. *Note*: Although it is not a multiple of 1,000 the prefix *centi-* is commonly used, for example, in the unit centimeter. Centi- represents a factor of one 100th.

| METRIC PREFIX | FACTOR | FACTOR (NUMERICAL) |
|---|---|---|
| giga (G) | one billion | 1,000,000,000 |
| mega (M) | one million | 1,000,000 |
| kilo (k) | one thousand | 1,000 |
| [UNIT] | one | 1 |
| milli (m) | one one-thousandth | 1/1,000 |
| micro (μ) | one one-millionth | 1/1,000,000 |
| nano (n) | one one-billionth | 1/1,000,000,000 |

APPENDIX

# E Literacy Strategies

THE FOLLOWING PAGES include instructional sheets and templates for some of the literacy strategies that are used throughout this book. Use them for reference or to copy into your science notebook.

- Oral Presentations
- Reading Scientific Procedures
- Keeping a Science Notebook
- Writing a Formal Investigation Report
- Constructing a Concept Map
- Developing Communication Skills

## ORAL PRESENTATIONS

- Your presentation time is short. Focus your presentation on the most important ideas you need to communicate.
- Communicate clearly by planning your words in advance. When speaking, talk slowly and loudly, and look at your audience.
- Group members should ask for and give each other support if they need help expressing a key word or concept.
- Include graphs and maps when possible. Make sure the type or handwriting and the images are large enough for everyone in the audience to see them.
- While you have your own opinions on a topic, it is important that you present unbiased and complete information. Your audience can then make their own conclusions.
- All the members of a group must participate.
- Since any group member may be asked to answer questions from the class, all group members should fully understand the presentation.
- In a group presentation, you could all play the role of different experts when presenting your information. The class would represent the community members who might be making a decision on the issue.

## READING SCIENTIFIC PROCEDURES

The purpose of reading a scientific procedure is to find out exactly what to do, when to do it and with what materials, in order to complete all the steps of an investigation.

If you read a step and are not sure what to do, try these strategies:

- Re-read the previous step.
- Re-read the step that confuses you. Sometimes re-reading clarifies the information.
- Ask your partner if he or she understands what the step says to do.
- Ask your partner if there are words you don't understand.
- Ask your partner to explain what the step says to do.
- Ask your partner to read the step aloud as you listen and try to do what your partner is describing.
- Re-read the purpose (Guiding Question) of the investigation.
- Try to say the purpose of the step out loud in your own words.
- Look at the clues in the pictures of the activity.
- Peek at other groups and listen to see if they are doing the step that confuses you.
- Tell your teacher exactly what you are confused about and why it doesn't make sense.

## KEEPING A SCIENCE NOTEBOOK

- Write in blue or black ink.
- Cross out mistakes or changes with a single line. Do not erase or use correction fluid.
- Write neatly.
- Record the date of each entry.
- For each new investigation, write down the following:

**Title:**

**Purpose:**
Re-write the Guiding Question in your own words.
*Hint*: What are you going to do? Why are you going to do it?

**Materials:**
Place a "√" here after you have collected the necessary materials.

**Procedure:**
Write down whether you understand the procedure.

**Data:**
Record observations, measurements, and other lab work.
Include data tables, charts, diagrams, and/or graphs when needed.
Be sure to label your work clearly.

- Sometimes, you may want to do the following:

**Make inferences or draw conclusions based on the data.**
*I think my results mean . . .*
*I think that this happened because . . .*

**Reflect on how the activity worked in your group.**
*This is what went well . . This is what did not go well . . .*
*If I could do this activity again, I would . . .*

**Think about what questions you still have.**
*I wonder if . . .*
*I'm not sure about . . .*

**Keep track of new vocabulary and ideas.**
*A key word I learned is . . .*
*I would like to find out what happens when . . .*
*One interesting thing to do would be to . . .*

## KEEPING A SCIENCE NOTEBOOK

The following is a guide to help you conduct investigations. However, depending on the investigation, you may not always use all of steps below or use them in the same order each time.

**Title:** Choose a title that describes the investigation.

**Purpose:** What am I looking for? Write what you are trying to find out in the form of a question.

**Background:** What do I know about the topic? Write a summary of background information you have on the topic that led to the purpose for the investigation.

**Hypothesis:** Write a statement about what you predict you will see as data in the experiment to answer the question in the "Purpose" and why you are making that prediction.

**Experimental Design:** How will you answer the question?

Describe the methods you will use (what you will do) to answer the question.

Use short numbered steps that are easy to follow in the lab.

Make a list of the materials you will use to answer the question.

Outline the variables:

- Independent variable (what is being changed)
- Dependent variable (what is being measured)
- Control (what will be used as baseline comparison)

**Data:** What did you find?

Record observations and measurements.

Use a data table where appropriate to organize the data.

Don't forget to include proper units and clear labels.

At the end of your investigation, do the following:

**Make inferences or draw conclusions about the data:**

*I think my results mean . . .*

*I think this happened because . . .*

**Think about any errors that occurred during the investigation:**

*What did not go as planned?*

*What steps were hard to follow while doing the investigation and why?*

**Think about questions you still have that could lead to new investigations:**

*I wonder if . . .*

*I'm not sure about . . .*

**Keep track of new vocabulary and new ideas that could lead to new investigations**

*I would like to find out what happens when . . .*

*One interesting thing to do would be to . . .*

**Reflect on how the activity worked in your group**

*This is what went well . . . This is what did not go well . . .*

*If I could do this investigation again, I would . . .*

## WRITING A FORMAL INVESTIGATION REPORT

Use the information from your science notebook to write a formal report on the investigation you performed.

**Title:**

Choose a title that describes the investigation.

**Abstract: What were you looking for in this investigation, and what did you find?**

Write a paragraph that summarizes what you already knew about the topic, your purpose, your hypothesis, and your results and conclusions.

**Experimental Design:**

Describe the materials and investigational methods you used to answer the question.

State what variables you worked with and any controls.

**Data: What did you find?**

Report observations and measurements. Include an organized data table if appropriate to help someone reviewing your report to easily see the results.

Don't forget to use proper units of measurement and write clear labels for your table columns.

**Data Analysis: Represent the data in a way that can be easily interpreted.**

Use graphs, diagrams, or charts where appropriate to help a reviewer interpret your data.

**Conclusion: What do the data mean?**

Summarize the data.

Discuss your conclusion based on the accuracy of your hypothesis and the data you collected.

Discuss any errors that occurred that may have interfered with the results.

Describe any changes that need to be made the next time the investigation is performed.

Describe any new questions to be investigated based on the results of this investigation.

## CONSTRUCTING A CONCEPT MAP

1. Work with your group to create a list of 15–20 words related to the topic.
2. If you are uncertain of the meaning of a word, look it up in the book or your notes or discuss it with your group.
3. Discuss with your group how all of the words on your list are related, and sort your list of words into three to five categories based on these relationships.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain to the rest of the group why you disagree.
4. Identify words that can be used to describe each category.
5. Work with your group to create a concept map on this topic. Follow these steps:
   a. Write the topic in the center of your paper, and circle it.
   b. Place the words describing each category around the topic. Circle each word.
   c. Draw a line between the topic and each category. On each line, explain the relationship between the topic and the category.
   d. Repeat Steps 5b and 5c as you continue to add all of the words on your list to your concept map.
   e. Add lines to connect other related words. Explain the relationship between the words on the line.
6. View the concept maps of other groups. As you look at their concept maps, observe similarities and differences between their maps and yours. Discuss your observations with your group members.

## DEVELOPING COMMUNICATION SKILLS

| COMMUNICATION | SENTENCE STARTERS |
|---|---|
| To better understand | One point that was not clear to me was . . .<br>Are you saying that . . .<br>Can you please clarify . . . |
| To share an idea | Another idea is to . . .<br>What if we tried . . .<br>I have an idea. We could try . . . |
| To disagree | I see your point, but what about . . .<br>Another way of looking at it is . . .<br>I'm still not convinced that . . . |
| To challenge | How did you reach the conclusion that . . .<br>What makes you think that . . .<br>How does it explain . . . |
| To look for feedback | What would help me improve . . .<br>Does it make sense, what I said about . . . |
| To provide positive feedback | One strength of your idea is . . .<br>Your idea is good because . . .<br>I have an idea. We coud try . . . |
| To provide constructive feedback | The argument would be stronger if . . .<br>Another way to do it would be . . .<br>What if you said it like this . . . |
| To discuss information presented in text and graphics | I'm not sure I completely understand this, but I think it may mean . . .<br>I know something about this from . . .<br>A question I have about this is . . .<br>If we look at the graphic, it shows . . . |

APPENDIX

# F Media Literacy

IMAGINE YOURSELF READING a magazine. A feature article summarizes recent studies on the effectiveness of vitamin supplements and concludes that taking vitamin pills and liquids is a waste of money. A few pages later, an advertisement from a vitamin company claims that one of its products will protect you from all sorts of diseases. Such wide differences in claims that you will see in the popular media are common, but how can you tell which one is correct? "Media literacy" is the term that encompasses the skills we need to develop to effectively analyze and evaluate the barrage of information we encounter every day. Media literacy also includes the ability to use various media to create and communicate our own messages.

A strong background in the process of science helps you build two important skills of media literacy: being able to identify valid and adequate evidence behind a claim and evaluating if the claim is a logical conclusion based on the evidence. The skills share much in common with the process of scientific inquiry, in which you learn to seek out information, assess the information, and come to a conclusion based on your findings.

## EVALUATING MEDIA MESSAGES

A "media message" is an electronic, digital, print, audible, or artistic visual message created to transmit information. Media messages can include newspaper articles, political advertisements, speeches, artwork, or even billboards. The following are some of the kinds of questions you might ask as you learn to critically analyze and evaluate messages from various kinds of media. On the next page are three examples of media messages, all related to a common theme. Use these three examples to analyze and evaluate the messages.


1. **Who created this message?**
   Is this person an expert in the content of the message? What credentials does this person have that would make them an expert in this topic? Does this person have any conflicts of interest that may make him or her biased in any way? Who sponsored (or paid for) the message? Does the source of funding have any conflicts of interest?

2. **What creative techniques in the message attract a person's attention?**
   Are there any sensational or emotional words, images, or sounds that grab the viewer's attention? Do any of these words, images, or sounds try to stir up emotions and influence the viewer's ideas?

3. **Does the message cite or mention appropriate sources of factual information?**
   Does the author cite first-person sources when reporting facts? Are the author's sources from credible organizations?

4. **Does the presented evidence completely support the claim?**
   Might there be other information that could support or discredit the message? Does the author make logical inferences and conclusions from the evidence presented in the article?

5. **Who is the target audience of this message?**
   How is this message directed at this particular audience?

6. **Is the message promoting certain values, lifestyles, positions, or ideas either directly or indirectly?**
   Are there any positions or ideas that are being promoted that are not explicit in the message?

## EVALUATING INTERNET SOURCES

Imagine that you want to search the Internet to find out about the effectiveness of vitamin supplements so that you can come to your own conclusion. When you are searching for information online, a search engine is searching from over one trillion websites.[1] Determining which websites and sources of information are reliable and which are biased is difficult. To make an informed decision about this topic, you will need to identify accurate and unbiased websites. Below is a suggested list of questions that will help you determine if a particular website is an accurate and unbiased source of information.

1. **Are the authors' names, contact information, and credentials clearly labeled on the website?**
   Accurate websites will usually contain information from knowledgeable authors who have their names, credentials, and contact information clearly labeled on the website. Some websites are managed by a collection of people or an organization, and information on the exact author may not be clearly stated. However,

1. Alpert, Jesse & Hajaj, Nissan. (July 25, 2008). We knew the Web was big. . . . *The Official Google Blog.* Retrieved August 2010 from http://googleblog.blogspot.om /2008/07/we-knew-web-was-big.html.

these organizations should state the names, contact information, and credentials somewhere on their website of the people who represent the organization.

2. **Is the information and the website up to date?**
   Some information that you may be seeking needs to be current. For example, if you were looking for the number of cars in the United States, you would want the most recent data. A study conducted in 1982 would not be helpful in this case. When seeking information that needs to be current, determine if the date the article or information was written is clearly indicated on the website so you can be sure you are accessing the most recent information. Credible websites will usually indicate the date the article or information was created or last updated. Also, the person or organization maintaining the website should be regularly updating the website, so that the majority of links to other websites work.

3. **Are sources of information clearly cited?**
   When factual information is stated in a website, is the source clearly cited so you can refer back to it?

4. **Are there links to more resources on this topic?**
   Authoritative websites will often provide links to further information from other sources that support their claim. Authors of websites that contain information that is biased or inaccurate usually do not provide additional information that supports their claims.

5. **What are other people saying about the author or the organization that produced this information?**
   If you come across information from an author or organization that you are unfamiliar with, perform a search for other information about the author or organization. What are experts writing about the author's or organization's other work?

6. **Why is this website on the Internet?**
   Was this information put on the Internet to inform or to persuade people? Is the author selling something? What is the author's motivation for providing this information?

**Further Resources**

Thier, M., & Daviss, B. (2002). The new science literacy. Portsmouth, NH: Heinemann.

Center for Media Literacy. http://www.medialit.org.

PBS Teachers. Media literacy. http://www.pbs.org/teachers/media_lit.

APPENDIX

# G Crosscutting Concepts

| | |
|---|---|
| **PATTERNS** | A pattern is a set of repeating things or events. Scientists observe patterns in their data. Patterns lead to questions about relationships and ideas about what causes these relationships. |
| **CAUSE AND EFFECT** | Events have causes. If "A" causes "B" to happen, they have a cause-and-effect relationship. A major activity of science is to explain how this happens. Sometime the causes are simple and sometimes they are complex. Sometimes both A and B occur, but one does not cause the other. |
| **SCALE, PROPORTION, AND QUANTITY** | Scientific phenomena occur at various scales of size, time, and energy. Phenomena observed at one scale may not be observable at another scale. Scientists use proportional relationships to compare measurements of objects and events. They often use mathematical expressions and equations to represent these relationships. |
| **SYSTEM AND SYSTEM MODELS** | A system is a group of interacting objects or processes. Describing a system, including its components, interactions and boundaries, and making models of that system helps scientists and engineers understand phenomena and test ideas. |
| **ENERGY AND MATTER** | Tracking changes of energy and matter into, out of, and within systems helps scientists understand the systems' possibilities and limitations. Many cause and effect relationships result from changes of energy and matter. |
| **STRUCTURE AND FUNCTION** | The structure (shape, composition, construction) of an object or living thing determines many of its properties and functions (what the structure can do). |
| **STABILITY AND CHANGE** | For natural and built systems alike, conditions are sometimes stable (the same or within a range), and sometimes they change. Scientists study what conditions lead to either stability or change. |

# Glossary

**advantage** A property that in your opinion, is favorable.

**analysis** (of experimental results) Making connections between the results of an experiment and the idea or question being investigated.

**atom** The basic building block of matter.

**benefit** An advantage, profit, or gain.

**bias** Favoring one thing over another in an unfair way.

**bond** *See* chemical bond**.**

**chemical bond** An electrical attraction between atoms.

**chemical property** Describes how a material reacts with another substance (e.g. reactivity with acid). *See* property.

**compound** A substance made from more than one element joined by a chemical bond.

**cross-linked polymer** A group of polymer chains that are linked together by small molecules to form a larger structure.

**data** Information gathered from an experiment or observations.

**density** Mass of a substance per unit of volume.

**disadvantage** A property that in your opinion, is not favorable.

**element** The simplest pure substances.

**energy** The ability to cause objects to change, move, or work.

**energy transfer** The movement of energy from one object to another.

**engineer** Someone who uses science and tools to build a product that solves a practical problem.

**evidence** Information that supports or refutes a claim.

**extended structure** A varied number of one or more kinds of atom bonded together to form a large network.

**gas** A state of matter with no fixed shape. A gas will expand to fill the space available. The particles in gas tend to have a lot of movement and not stay grouped together.

**kinetic energy** The energy an object has because of its motion.

**life cycle** The phases in the existence of a product, including what is needed to make the product, how it will be made, and what will happen to the product when it is no longer being used.

**life-cycle diagram** An illustration showing all stages of a life cycle. *See* life cycle.

**liquid** A state of matter with a specific volume but not a specific shape. Liquid particles tend to stay together and move less than gas particles but more than solid particles.

**liter (L)** A unit of volume in the metric system; 1 liter is equal to 1,000 milliliters. 1 mL is equal to 1 cubic centimeter ($cm^3$).

**malleability** The flexibility of a material.

**mass** The amount of matter in an object.

**material** A type of solid matter used to make things.

**matter** The stuff that makes up all living and nonliving objects.

**meter (m)** A unit of length in the metric system; 1 meter is equal to 100 centimeters or 1,000 millimeters.

**metric system** The worldwide measuring system used by scientists. Also known as the International System of Units (SI).

**model** Any representation of a system (or its components) used to help one understand and communicate how it works.

**molecule** Two or more atoms held together by chemical bonds.

**monomer** A single molecular subunit.

**observation** Any description or measurement gathered by the senses or instruments.

**particle** Small structures that make up all matter. *See* matter.

**pattern** Something that happens in a repeated and predictable way.

**physical property** A property that can be identified, observed, or measured and does not rely on testing if the material reacts with another substance (e.g., color). *See* property.

**property** Particular characteristics of a material such as the material's density, melting point, or color. A change in volume of the material does not change its properties.

**polymer** Compounds made of long chains of smaller repeating molecular subunits called monomers.

**reactivity** The tendency for a substance to react or combine chemically with other substances.

**scale** The ratio of the size of a real object and a model, map, diagram, or other representation of the object. Can also be used to refer to the general size of objects being referred to, for example molecular scale.

**science** The systematic study of the natural world.

**scientific method** A set of processes used when conducting investigations. These generally involve making observations, collecting and analyzing data, and drawing conclusions, especially when testing scientific hypotheses.

**scientific model** *See* model.

**scientist** Someone who pursues understanding of the natural world by using evidence to answer questions.

**simulation** The imitation of a real-world process or system over time.

**solid** A state of matter with relatively fixed volume and shape. Solid particles tend to stay close together and not move very much.

**solubility** The ability of a substance to dissolve in another substance.

**state** The physical form of matter - solid, liquid, or gas.

**structure** The parts of an object or system, including what they are made of, their shapes, and their arrangement. The type and arrangement of atoms and/or molecules that make up a substance.

**subunit** A distinct part of a larger unit.

**technology** Any product or process made by engineers and scientists.

**temperature** A measure of the average kinetic energy of a sample due to molecular motion, often using the Fahrenheit (°F) or Celsius (°C) scale.

**thermal energy** The total energy of motion of the particles in a sample of a substance, often referred to as heat in everyday use.

**trade-off** A desirable outcome given up to gain another desirable outcome.

**volume** The amount of space that an object or substance occupies.

**weight** The vertical force exerted by a mass as a result of gravity.

# *Index*

**Bold** page number indicates a definition. *Italic* page number indicates an illustration.

## Q



## R



## S



## T

# V



# W

# *Credits*

Abbreviations: t (top), m (middle), b (bottom), l (left), r (right), c (center)

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