SECTION

4 Physical and Chemical Changes

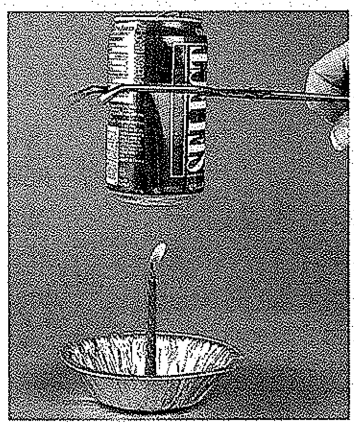
DISCOVER ACTIVITY

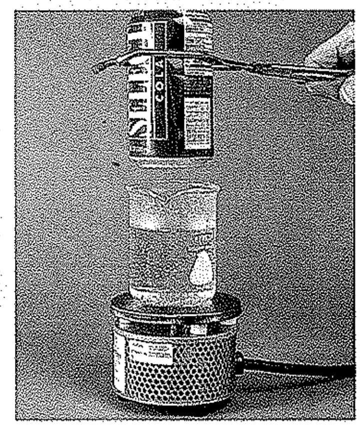
How Does a Burning Candle Differ From Boiling Water?

1. Put on your goggles.
2. Place a small beaker half-filled with water on a hot plate. Turn the hot plate to a medium-high setting so that the water will boil.
3. Add about half a cup of cold water to an empty soda can.
4. Use modeling clay to stand a candle in a small aluminum pie pan. Light the candle.
5. Use tongs to hold the can about 3 cm over the candle for about a minute.
6. Move the soda can away from the candle. When the soda can has cooled, examine its bottom side.
7. Blow out the candle. Repeat Steps 3, 5, and 6 with a different soda can, but hold the can over the boiling water.

Think It Over

Posing Questions Compare the substances that collected on the bottom of each soda can. Identify any changes in matter that you observed. What questions would you need to ask to determine whether each change was physical or chemical?





GUIDE FOR READING

- **How do physical and chemical changes differ?**
- **How do energy changes affect matter?**
- **What is a change of state?**

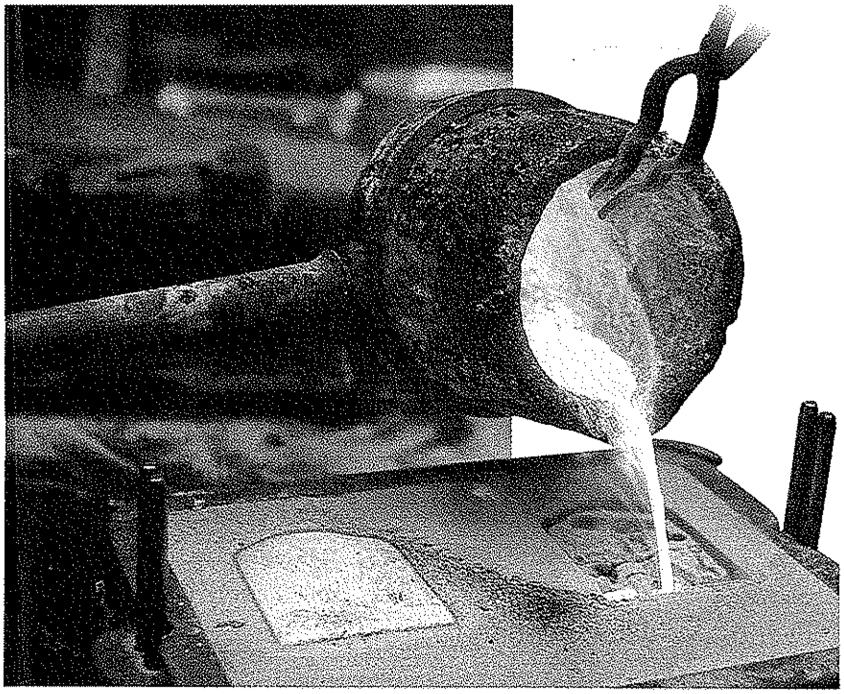
Reading Tip **As you read, compare and contrast the various physical and chemical changes.**

Your world depends on changing matter. Water changes from a liquid to solid ice in a freezer. Plants change raw materials from air and soil into stems and leaves. Cars and buses burn gasoline to move from place to place. If you look around, you can find lots of examples of substances changing shape, form, or identity.

Energy and Change

As you know, there are two kinds of changes in matter: physical changes and chemical changes. Some examples of physical change include tearing a piece of paper, bending a nail, or spinning wool into yarn. **A physical change alters the form of a substance, but does not change it to another substance.**

Matter can also change by means of a chemical change. Burning wood is a good example. **When a substance undergoes a chemical change, it is changed into a different substance with different properties.** The wood is changed into completely different substances, such as carbon dioxide gas and solid ash.



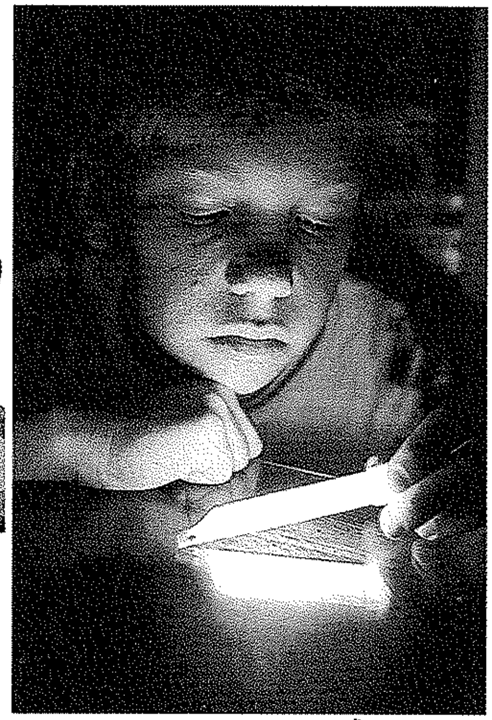


Figure 22 A jeweler melts silver before pouring it into a mold. The glow stick gives off a greenish glow. *Classifying* *Which of these examples is most likely a physical change? Which example may be a chemical change?*

INTEGRATING PHYSICS To explain changes in matter, scientists talk about the effects of energy. It's not easy to define "energy." You can give examples: Light and motion are two types of energy. Every substance also contains energy from the movement of its particles, called **thermal energy.** The higher the temperature of a substance, the greater its thermal energy. Another form of energy comes from the chemical bonds within matter. This form of energy is called **chemical energy.**

Any substance can either gain energy or lose energy. In either case, the substance changes in some way. **Matter changes whenever energy is added or taken away.** When something is heated, it gains thermal energy. When something cools, it loses thermal energy to its surroundings. Many physical and chemical changes involve heating or cooling. In order for pancakes to brown on a griddle, the chemical changes require heating. When a mixture of milk, cream, sugar, and flavors becomes ice cream, the physical change requires cooling.

In every physical change and chemical change, the total amount of energy stays the same, a principle which is called the **law of conservation of energy.** The word *conservation* comes from *conserve,* which means "to protect from loss." Energy can change from one form to another, but energy can never be lost.

For example, an unlit match contains chemical energy. When the match is lit, the chemical energy changes into light energy and thermal energy. The total amount of energy produced is equal to the amount of chemical energy in the unlit match. No energy is lost. It only changes from one form to another.

☑ *Checkpoint* *What is chemical energy?*

Changes Between Liquid and Solid

Remember that the common states of matter are solid, liquid, and gas. **Under certain conditions, a substance can change from any one state of matter to any other.**

Melting The change in state from a solid to a liquid is **melting.** In most pure substances, melting occurs at a specific temperature, called the melting point. The melting point of a substance depends on how strongly its particles attract one another.

Think of a melting ice cube. The energy to melt comes from the air in the room. At first, the added thermal energy makes the water molecules vibrate faster, which raises their temperature.

Eventually, when the temperature of the ice reaches 0°C, the water molecules are vibrating so fast that they break free from their positions in ice crystals. When this happens, the temperature of the ice stops increasing. Instead, the added energy changes the arrangement of the water molecules from ice crystals into liquid water. This is the process you observe as melting.

Freezing Now suppose you put the liquid water from the melted ice cube into a freezer. After an hour or so, the water will freeze back into ice. **Freezing** is the change of state from liquid to solid—just the reverse of melting.

When you put liquid water into the freezer compartment of a refrigerator, the water loses energy to the cold air in the freezer. At first, the water molecules move more slowly. This means that the temperature of the water drops. When the temperature reaches 0°C, the molecules are moving so slowly that they form regular patterns. These patterns are the crystals that form ice.

When water freezes, the temperature stays at 0°C until freezing is complete. (This is the same temperature at which ice melts.) The energy loss during freezing changes the arrangement of the molecules, from liquid water into ice crystals.

Social Studies CONNECTION

In the United States, home refrigerators became common in the 1920s. Before then, people relied on ice to keep food cold. In the winter, blocks of ice were cut from frozen lakes, as in the photo below, and stored in buildings called ice houses. Many people earned their livings by supplying ice to homes and businesses.

In Your Journal

Imagine the time is about 80 years ago. For years, your family has earned a comfortable living in the ice business. You have just heard about a new product called a refrigerator. Write a letter in which you describe your opinions of this product. How will it change your life?

Figure 23 In this photo taken in New England about 1890, you can see the pond ice was cut into large blocks. The blocks were stored in the icehouse.

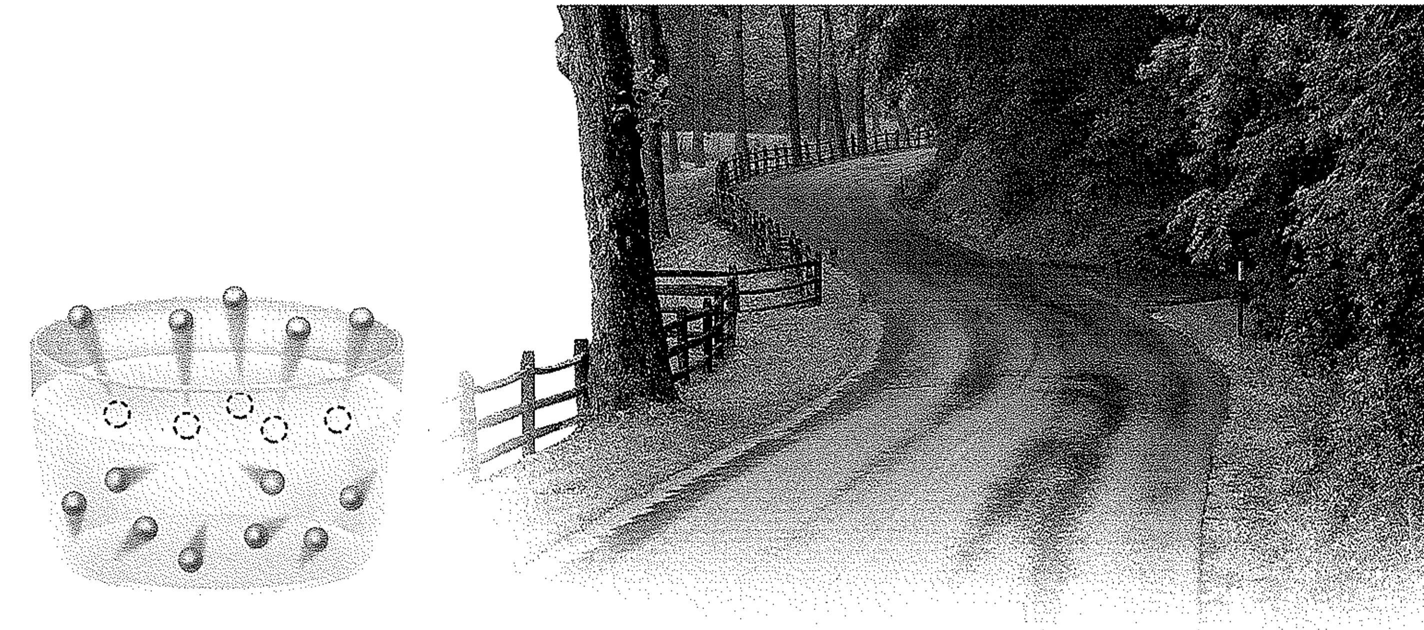


Figure 24 Water evaporates from the surface of a wet road.
Making Generalizations What happens to water molecules when they evaporate?

Changes Between Liquid and Gas

For other examples of matter changing state, look up at the sky. Have you ever wondered how clouds form, or why rain falls from clouds? And after a rain shower, why do puddles dry up in the sunshine? To answer each of these questions, you need to look at the ways that water changes between the liquid and gas states.

Vaporization Liquid water changing into water vapor is an example of **vaporization** (vay puhr ih ZAY shuhn). Vaporization occurs when a liquid gains enough energy to become a gas.

There are two main types of vaporization. When vaporization takes place only on the surface of the liquid, the process is called **evaporation** (ee vap uh RAY shuhn). A puddle drying up after a rain shower is one example of evaporation. As the water in the puddle gains energy from the ground, the air, or the sun, the molecules on the surface of the puddle gradually escape into the atmosphere. You also can observe evaporation whenever you sweat. Beads of sweat evaporate into the air as they gain energy from your skin. Because your skin is losing energy, sweating helps keep you cool on a hot day or when you exercise.

When vaporization takes place inside a liquid as well as at the surface, the process is called **boiling.** Each liquid boils only at a certain temperature. That temperature is called its boiling point. Like the melting point of a solid, the boiling point of a liquid depends on how strongly the particles attract one other.

Boiling Point and Air Pressure Boiling point also depends on the pressure of the air above a liquid.

INTEGRATING EARTH SCIENCE

The lower the air pressure above the liquid, the less energy that liquid molecules need to escape into the air. As you go up in elevation, air pressure decreases. At the air pressure in places close to sea level, the boiling point of water is 100°C. In the mountains, however, air pressure is lower and so is the boiling point of water.

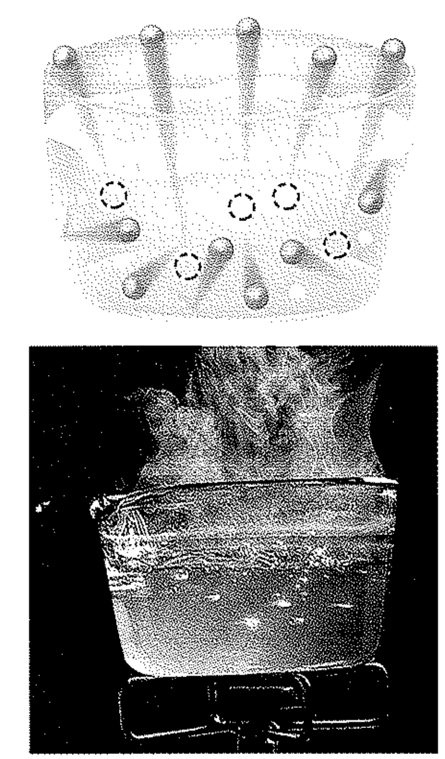


Figure 25 A pot on the stove boils when water inside reaches its boiling point.

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Figure 24 Water evaporates from the surface of a wet road. ***Making Generalizations*** *What happens to water molecules when they evaporate?*

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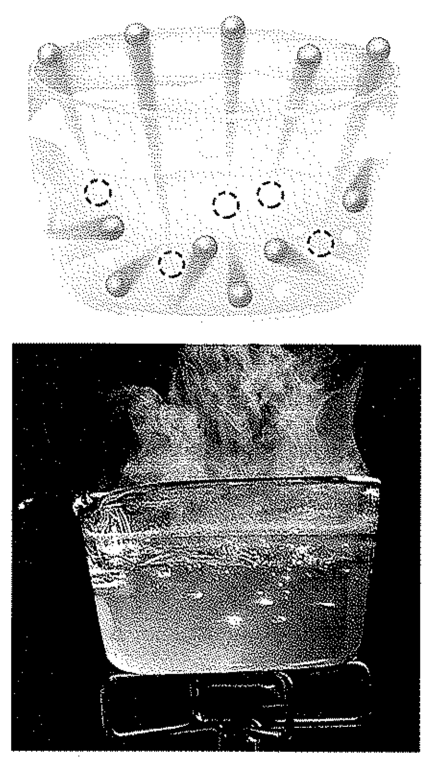

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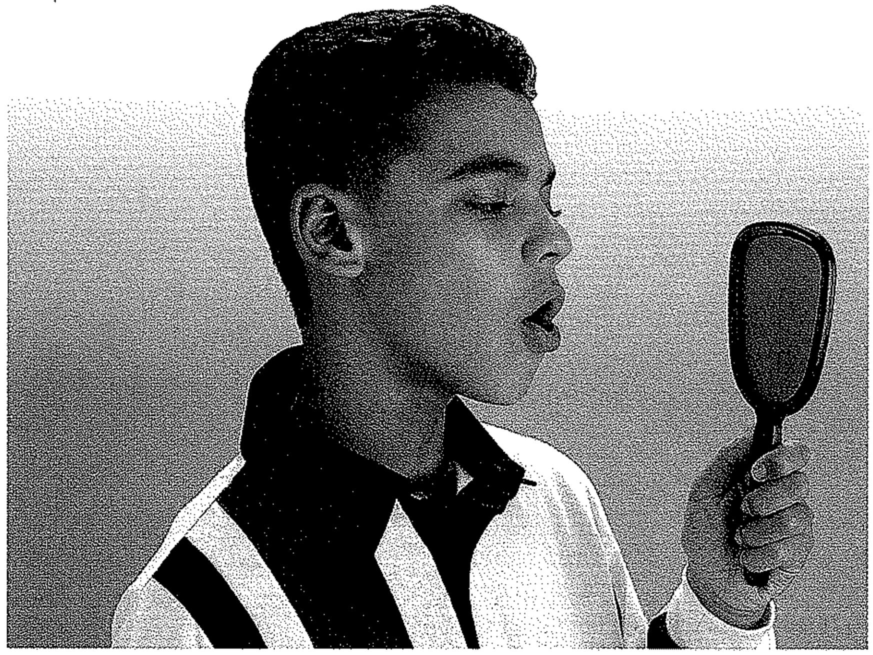


Figure 26 The water vapor in your warm breath condenses on the cool surface of the mirror. ***Classifying*** *What state of matter is the condensation on the glass?*

For example, the city of Denver, Colorado, is 1,600 meters above sea level. At this elevation, the boiling point of water is 95°C. Cooks in Denver have to be careful when a recipe calls for boiling water. Food doesn't cook as quickly at 95°C as it does at 100°C.

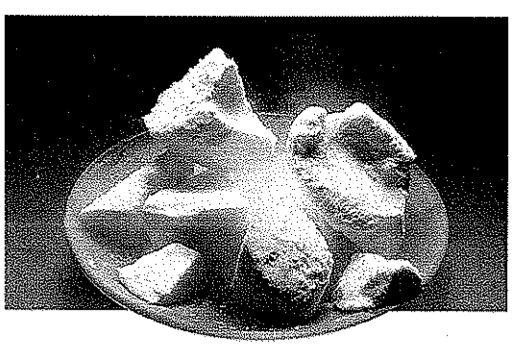
Condensation The opposite of vaporization is called condensation. **Condensation** occurs when a gas loses enough thermal energy to become a liquid. Clouds typically form when water vapor in the atmosphere condenses into liquid droplets. When the droplets get heavy enough, they fall to the ground as rain.

You can observe condensation by breathing onto a mirror. When warm water vapor in your breath reaches the cooler surface of the mirror, the water vapor condenses into liquid droplets. The droplets then evaporate into water vapor again.

When you observe vaporization and condensation, remember that you cannot see water vapor. Water vapor is a clear gas, and is impossible to see. The steam you see above a boiling kettle is not water vapor, and neither are clouds or fog. Instead, what you see in each of them is tiny droplets of liquid water suspended in the air.

☑ ***Checkpoint*** *How are vaporization and condensation related but different?*

Figure 27 Dry ice is solid carbon dioxide. It changes directly to gaseous carbon dioxide in the process of sublimation. The energy absorbed in this change of state cools the water vapor in the air, creating fog.



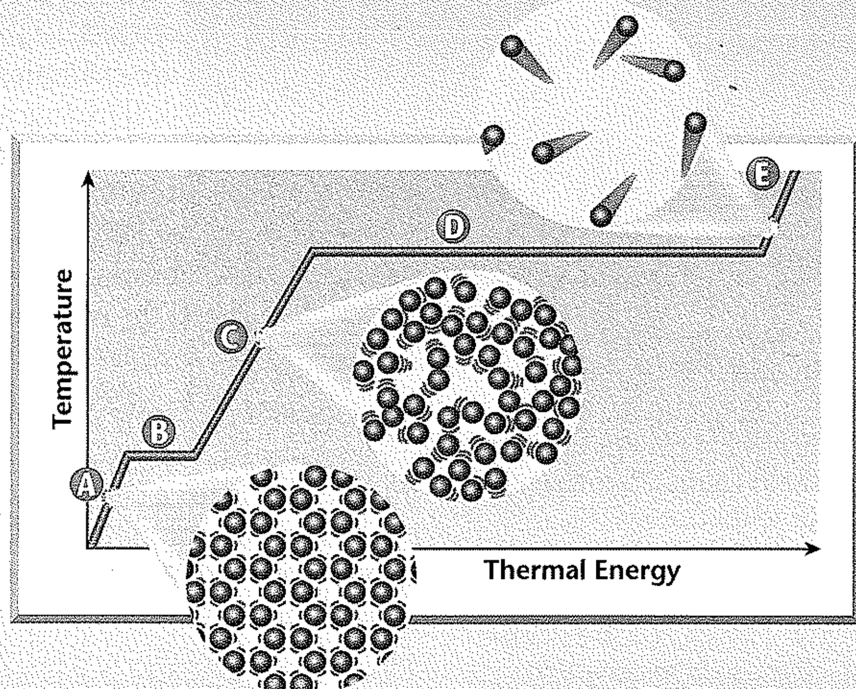
Changes Between Solid and Gas

If you live where the winters are cold, you may have noticed that snow seems to disappear even if the temperature stays well below freezing. This happens because of a process called sublimation. **Sublimation** occurs when the surface particles of a solid gain enough energy to become a gas. Particles do not pass through the liquid state at all.

One example of sublimation is the change that dry ice undergoes. Dry ice is the common name for solid carbon dioxide. At ordinary pressures, carbon dioxide cannot exist as a liquid. Instead of melting, solid carbon dioxide changes directly into a gas. Dry ice takes in thermal energy as it changes state, which keeps materials near it cold and dry. For this reason, dry ice is an excellent way to keep temperatures low when a refrigerator is not available. When dry ice becomes a gas, it cools water vapor in the nearby air. As a result, fog forms.

EXPLORING *Changes of State*

What changes occur as you slowly heat a beaker of ice from −10°C to 110°C?



A ***Solid***
Below 0°C, water exists in its solid state—ice. Although the water molecules in ice crystals stay in fixed positions, they do vibrate. As the molecules are heated, they vibrate faster and the temperature rises.

B ***Melting***
When more energy is added to ice at 0°C, the molecules overcome the forces that keep them in ice crystals. The ice melts or turns to liquid water. As ice melts, the molecules rearrange but do not move faster. Thus, the temperature of the ice stays at 0°C.

C ***Liquid***
Water must be liquid before its temperature can rise above 0°C. As liquid water is heated, the molecules move faster and the temperature rises again.

D ***Vaporization***
When more energy is added to liquid water at 100°C, molecules escape the liquid state and become a gas. This process is called boiling. When water boils, the molecules overcome the forces that hold them together as liquids, but they do not move faster. Thus, the temperature stays at 100°C.

E ***Gas***
Water must be in its gas state—called water vapor—before its temperature can rise above 100°C. As water vapor is heated, the molecules move faster and the temperature rises again.