SECTION 2

READING WARM-UP

Terms to Learn

change of state	boiling
melting	evaporation
freezing	condensation
vaporization	sublimation

What You'll Do

- Describe how substances change from state to state.
- Explain the difference between an exothermic change and an endothermic change.
- Compare the changes of state.

Changes of State

It can be tricky to eat an ice-cream cone outside on a hot day. In just minutes, the ice cream will start to melt. Soon, the solid ice cream will become a liquid mess!

When solid ice cream melts and becomes liquid, it goes through a change of state. A **change of state** is the change of a substance from one physical form to another. All changes of state are physical changes. In a physical change, the identity of a substance does not change. In **Figure 11,** the ice, liquid water, and steam are all the same substance—water. In this section, you will learn about the four changes of state shown in Figure 11. You will also learn about a fifth change of state called sublimation (SUHB luh MAY shuhn).

Energy and Changes of State

You have learned that the particles of a substance move differently depending on the state of the substance. The particles of a substance also have different amounts of energy when the substance is in different states. For example, particles in liquid water have more energy than particles in ice. Particles in steam have even more energy than the particles in liquid water.

During a change of state, a substance changes from one state to another. When a change of state happens, the energy of the particles of the substance changes. So, to change a substance from one state to another, you must add or remove energy.

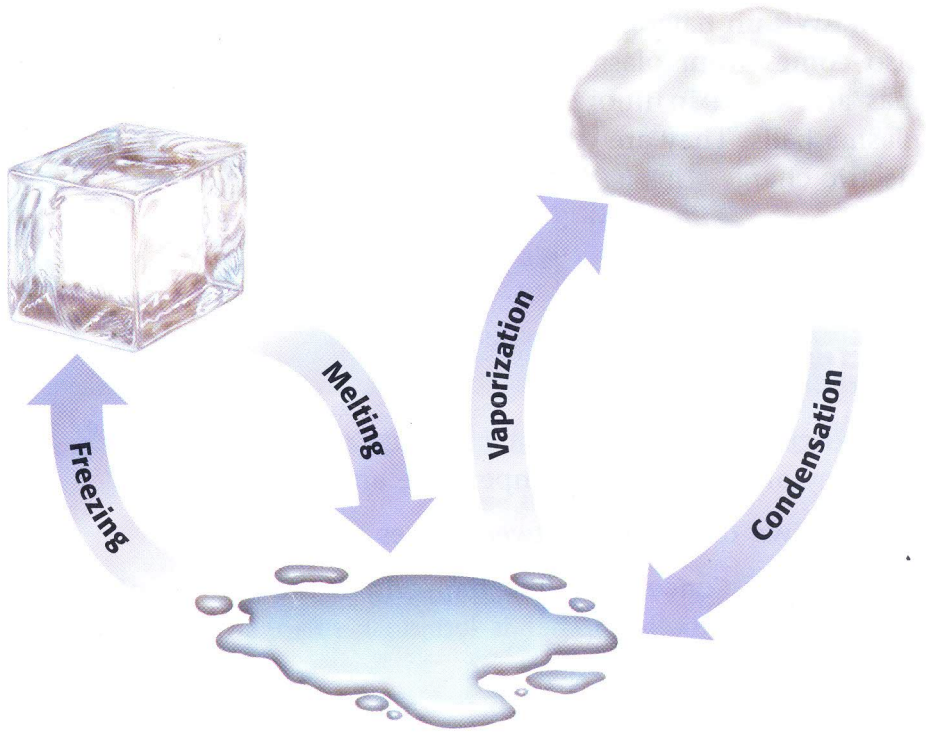


Figure 11 *The terms in the arrows are changes of state. Water can go through the changes of state shown here.*

Melting: Solids to Liquids

One change of state that happens when you add energy is melting. **Melting** is the change of state from a solid to a liquid. This change of state is what happens when ice melts. You must add energy to a solid to increase the temperature of the solid. As the temperature increases, the particles of the solid speed up. However, when a certain temperature is reached, the solid will melt.

The temperature at which a substance changes from a solid to a liquid is the *melting point* of the substance. Melting point is a physical property. Different substances have different melting points. **Figure 12** shows the metal gallium melting. The melting point of gallium is 30°C. Because your normal body temperature is about 37°C, gallium will melt right in your hand! Table salt, however, has a melting point of 801°C. Most substances have a unique melting point that can be used with other properties to identify substances. The melting point of a substance is always the same no matter how much of the substance is present. For this reason, melting point is called a *characteristic property* of a substance.

Figure 12 *Even though gallium is a metal, it would not be very useful as jewelry!*

Adding Energy

For a solid to melt, particles must overcome some of their attractions to each other. When a solid is at its melting point, any energy added to it is used to overcome the attractions that hold the particles in place. Melting is an *endothermic* change because energy is gained by the substance as it changes state.

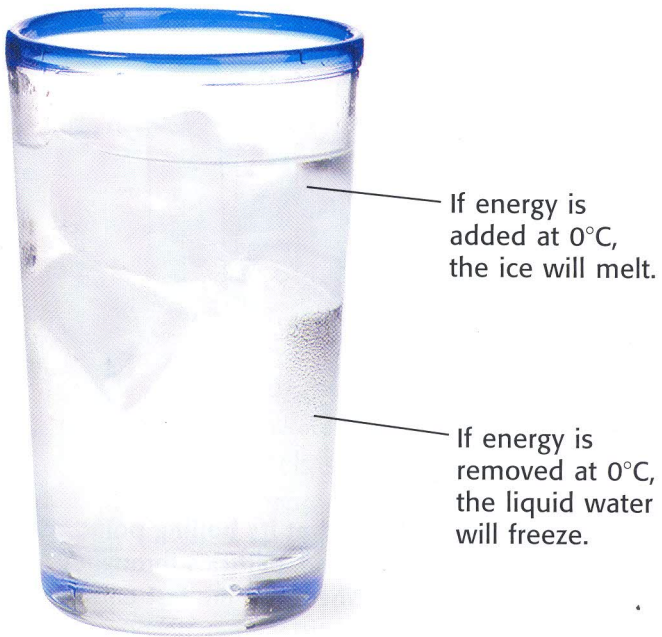
Freezing: Liquids to Solids

The change of state from a liquid to a solid is called **freezing.** The temperature at which a liquid changes into a solid is the *freezing point*. Freezing is melting in reverse. This means that freezing and melting happen at the same temperature, as shown in **Figure 13.**

Removing Energy

For a liquid to freeze, the attractions between the particles must overcome the motion of the particles. Imagine that a liquid is at its freezing point. Removing more energy will cause the particles to begin locking into place. Freezing is an *exothermic* change because energy is removed from, or taken out of, the substance as it changes state.

Figure 13 *Liquid water freezes at the same temperature that ice melts—0°C.*



Self-Check

Is the vaporization of water an endothermic or exothermic change? Explain your answer. *(See page 640 to check your answer.)*

Vaporization: Liquids to Gases

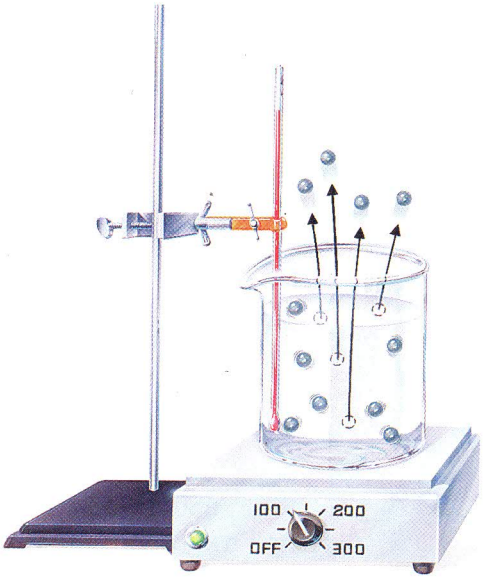
One way to see vaporization (VAY puhr i ZAY shuhn) is to iron a shirt using a steam iron. You will notice steam coming up from the iron as the wrinkles disappear. This steam comes from the vaporization of liquid water by the iron. **Vaporization** is the change of state from a liquid to a gas. **Figure 14** shows two kinds of vaporization.

Vaporization that takes place throughout a liquid is called **boiling.** The temperature at which a liquid boils is called the *boiling point*. Boiling point is a physical property. Like the melting point, the boiling point is also a characteristic property of a substance. The boiling point of water is 100°C. The boiling point of liquid mercury is 357°C.

Evaporation (ee VAP uh RAY shuhn) is vaporization that occurs at the surface of a liquid below the liquid's boiling point. When you sweat, your body is cooled through evaporation. Your sweat is mostly water. Water absorbs energy from your skin as it evaporates. You feel cooler because your body transfers energy to the water. Evaporation also explains why water in a glass on a table disappears after several days.

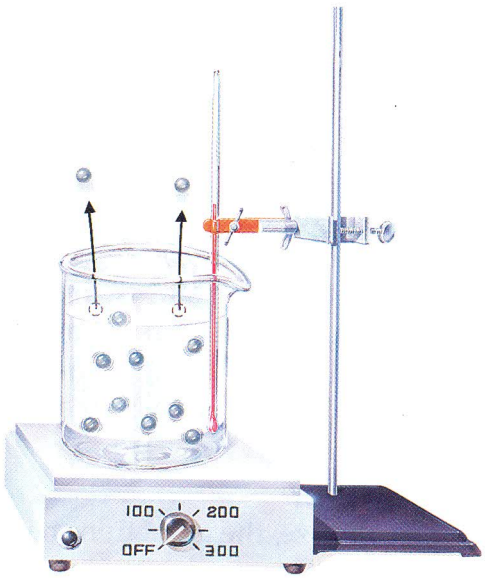
Figure 14 Two Kinds of Vaporization

Boiling



Boiling happens in a **liquid at its boiling point.** As energy is added to the liquid, particles throughout the liquid move faster. When they are fast enough to break away from other particles, they become a gas.

Evaporation



Evaporation happens in a **liquid below its boiling point.** Some particles at the surface of the liquid move fast enough to break away from the particles around them and become a gas.

Pressure Affects Boiling Point

Earlier you learned that water boils at 100°C. In fact, water boils at 100°C only at sea level because of atmospheric pressure. Atmospheric pressure is caused by the weight of the gases that make up the atmosphere.

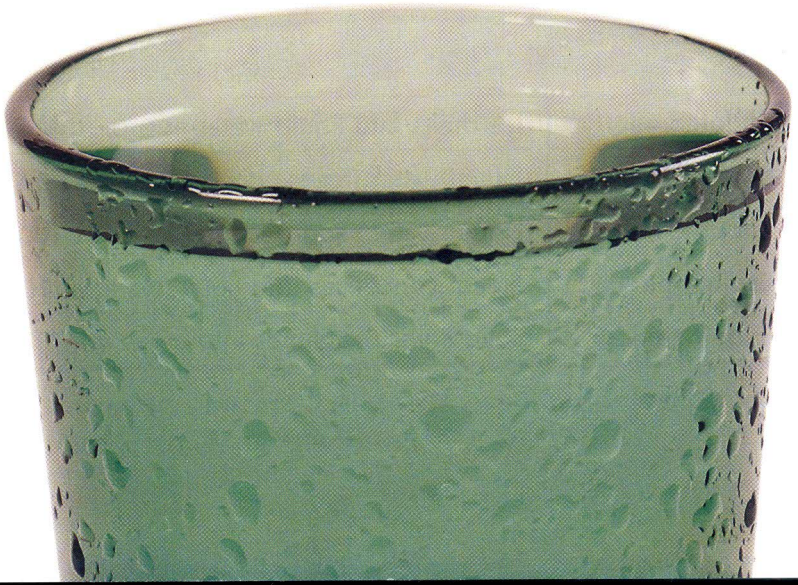
Atmospheric pressure varies depending on where you are in relation to sea level. Atmospheric pressure is lower at higher elevations. The higher you go above sea level, the less air there is above you and the lower the atmospheric pressure is. Imagine boiling water at the top of a mountain. The boiling point would be lower than 100°C. For example, Denver, Colorado, is 1.6 km (1 mi) above sea level. In Denver, water boils at about 95°C. You can make water boil at an even lower temperature by doing the QuickLab at right.

Condensation: Gases to Liquids

Look at the cool glass of water in **Figure 15.** Notice the beads of water on the outside of the glass. These beads do not come from the water in the glass. They form because of condensation of gaseous water in the air. **Condensation** is the change of state from a gas to a liquid. The *condensation point* of a substance is the temperature at which the gas becomes a liquid. The condensation point of a substance is the same temperature as its boiling point at a given pressure. So, at sea level, steam condenses to form water at 100°C. This temperature is the same temperature at which water boils.

For a gas to become a liquid, large numbers of particles must clump together. Particles will clump together when the attraction between them overcomes their motion. For this to happen, energy must be removed from the gas to slow the particles down. So, condensation is an exothermic change.

Figure 15 *Gaseous water in the air will become liquid when it touches a cool surface.*



QuickLab

Boiling Water Is Cool

1. Remove the cap from a **syringe.**
2. Place the tip of the syringe in the **warm water** provided by your teacher. Pull the plunger out until you have 10 mL of water in the syringe.
3. Tightly cap the syringe.
4. Hold the syringe. Slowly pull the plunger out.
5. Observe any changes you see in the water. Record your observations in your ScienceLog.
6. Why would you not be burned by the boiling water in the syringe?

TEKS

Meteorology CONNECTION

The amount of gaseous water that air can hold gets smaller as the temperature of the air gets lower. As air cools, some of the gaseous water condenses to form small drops of liquid water. These drops form clouds in the sky and fog near the ground.

Sublimation: Solids to Gases

Look at the solids shown in **Figure 16.** The solid on the left is ice. Notice the drops of liquid collecting as the ice melts. On the right, you see carbon dioxide in the solid state, also called dry ice. It is called dry ice because instead of melting into a liquid, it goes through a change of state called sublimation. **Sublimation** is the change of state from a solid directly to a gas. Dry ice is colder than ice. Unlike ice, dry ice doesn't melt into a puddle of liquid. It is often used to keep food, medicine, and other materials cold without getting them wet.

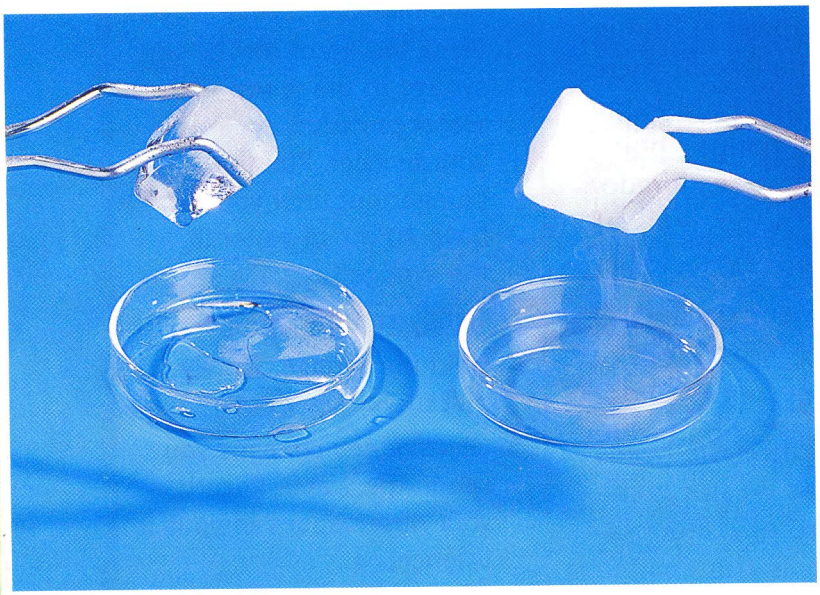


Figure 16 *Ice (left) melts, but dry ice (right) turns directly into a gas.*

For a solid to change directly into a gas, the particles must move from being very tightly packed to being very spread apart. The attractions between the particles must be completely overcome. The substance must gain energy for the particles to overcome their attractions. So, sublimation is an endothermic change.

Comparing Changes of State

As you learned in Section 1, the state of a substance depends on how fast its particles move. It also depends on how strongly the particles are attracted to each other. A substance may change from one state to another by an endothermic change if energy is added. A substance goes through an exothermic change if energy is removed. The table below shows the differences between the changes of state described in this section.

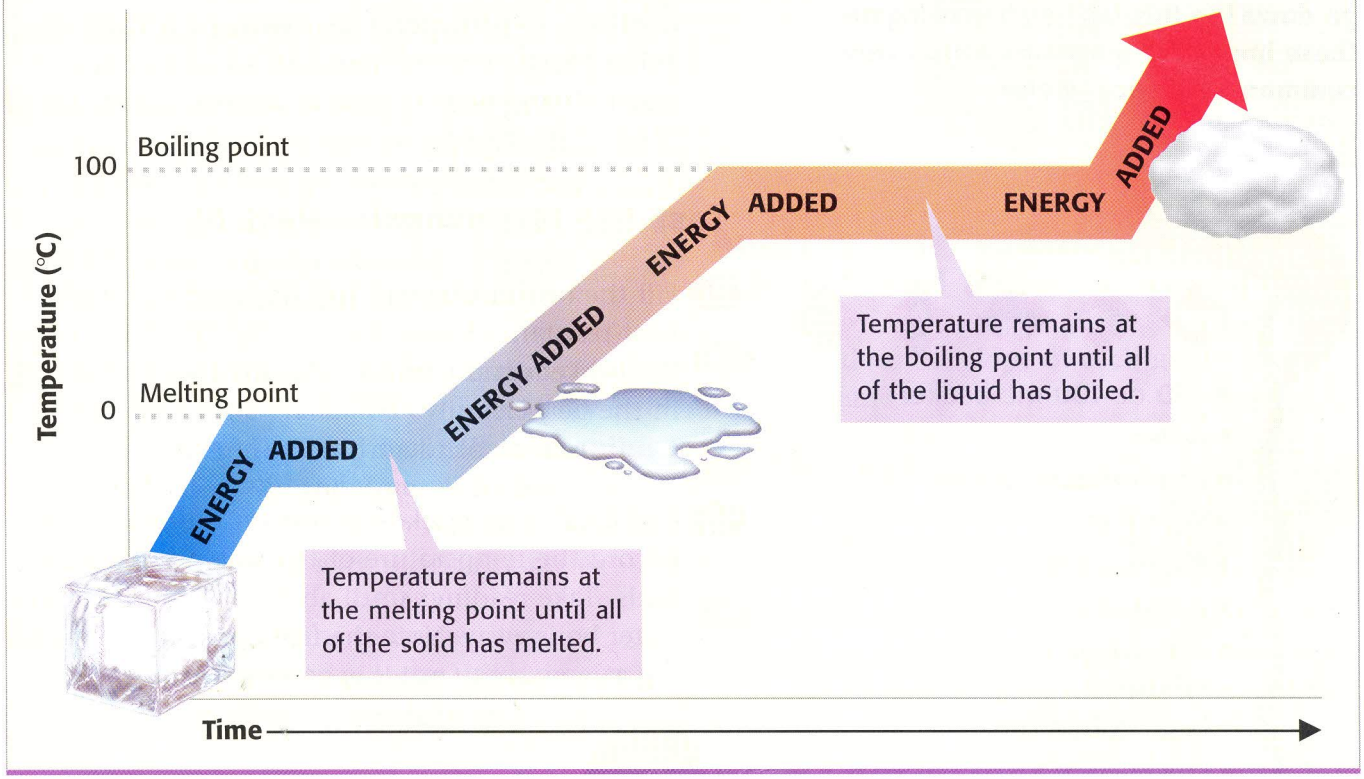
Summarizing the Changes of State

Change of state	Direction	Endothermic or exothermic	Example
Melting	Solid → liquid	Endothermic	Ice melts into liquid water at 0°C.
Freezing	Liquid → solid	Exothermic	Liquid water freezes into ice at 0°C.
Vaporization	Liquid → gas	Endothermic	Liquid water vaporizes into steam at 100°C.
Condensation	Gas → liquid	Exothermic	Steam condenses into liquid water at 100°C.
Sublimation	Solid → gas	Endothermic	Solid dry ice sublimes into a gas at −78°C.

Change in Temperature Versus Change of State

When most substances lose or gain energy, one of two things happens to the substance: its temperature changes or its state changes. The temperature of a substance is related to the speed of the particles. So, when the temperature of a substance changes, the speed of the particles changes. But while a substance changes state, its temperature does not change until the change of state is complete. In the chart below, you can see what happens to ice as energy is added.

Changing the State of Water



SECTION REVIEW

1. Compare endothermic and exothermic changes.
2. Classify each change of state (melting, freezing, vaporization, condensation, and sublimation) as endothermic or exothermic.
3. Describe how the motion and arrangement of particles change as a substance freezes.
4. **Comparing Concepts** How are evaporation and boiling similar? How are they different?

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