Section 2
Changes of State

Key Concept A change of state, which is a physical change, occurs when matter changes from one physical state to another.

What You Will Learn
- A change of state is a physical process in which a material changes form with no chemical reaction.
- Changes of state include melting, freezing, evaporation, condensation, and sublimation and involve either gain or loss of energy by a material's particles.
- Every material has a characteristic melting point and freezing point.

Why It Matters
Learning about changes of state will help you understand changes you see every day, such as cooking and the weather.

It can be tricky to eat a frozen juice bar outside on a hot day. In just minutes, the juice bar will start to melt. Soon, the solid juice bar becomes a liquid mess. As the juice bar melts, it goes through a change of state. In this section, you will learn about the four changes of state shown in **Figure 1** as well as a fifth change of state called *sublimation* (SUHB luh MAY shuhn).

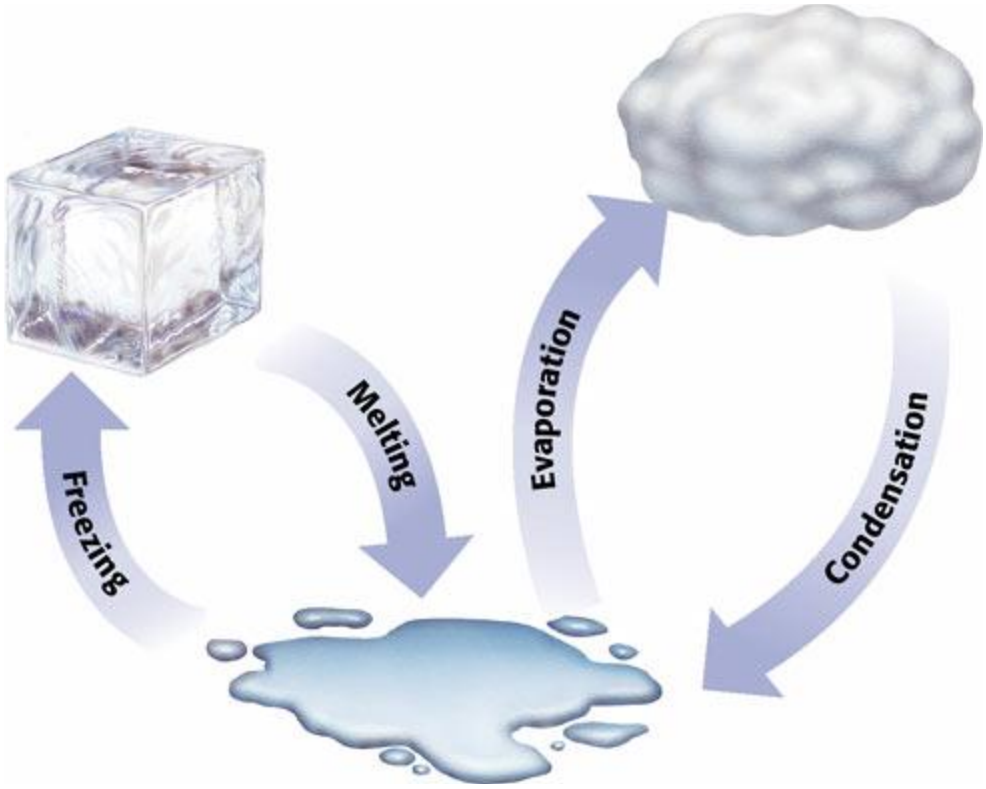


Figure 1 Changes of state involving water are shown here. **What two steps would the solid need to go through to change into a gas?**

Energy and Changes 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 rather than chemical changes. In a physical change, the identity of a substance does not change. In **Figure 1,** the ice, liquid water, and steam are all the same substance—water.

The particles of a substance move differently depending on the state of the substance. The particles 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. To change a substance from one state to another, you must add or remove energy.

Standards Check In terms of energy, what must happen to the particles of a substance for it to change state?

Melting: Solid to Liquid

One change of state that happens when you add energy to a substance is melting. **Melting** is the change of state from a solid to a liquid. This change of state is what happens when ice melts.

Melting Point

As the temperature of a solid increases, the particles of the solid move faster. 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,* or melting temperature, of the substance. Melting point is a physical property that is characteristic of the material. For example, gallium melts at about 30°C. Because your normal body temperature is about 37°C, gallium will melt in your hand! This is shown in **Figure 2.** Table salt, however, has a melting point of 801°C, so it will not melt in your hand. Melting points and other physical properties reflect the chemical composition of the material and can be used to classify substances.

Figure 2 Gallium is a metal that can melt in your hand. Even though gallium is a metal, it would not be very useful as jewelry!

Standards Check What is melting point, and what does it reflect about a substance?

Adding Energy

For a solid to melt, particles must absorb energy to overcome some of their attractions to each other. The particles acquire enough energy to

slide past one another so that the material, which has melted and become a liquid, can flow.

Freezing: Liquid to Solid

The change of state from a liquid to a solid is called *freezing.* For a liquid to freeze, the attractions between a liquid's particles must overcome the motion of the particles. Then, the particles will become closely locked in position.

Removing Energy

The temperature at which a liquid changes into a solid is the liquid's *freezing point.* Freezing is the reverse process of melting. Thus, freezing and melting happen at the same temperature, as shown in **Figure 3.**

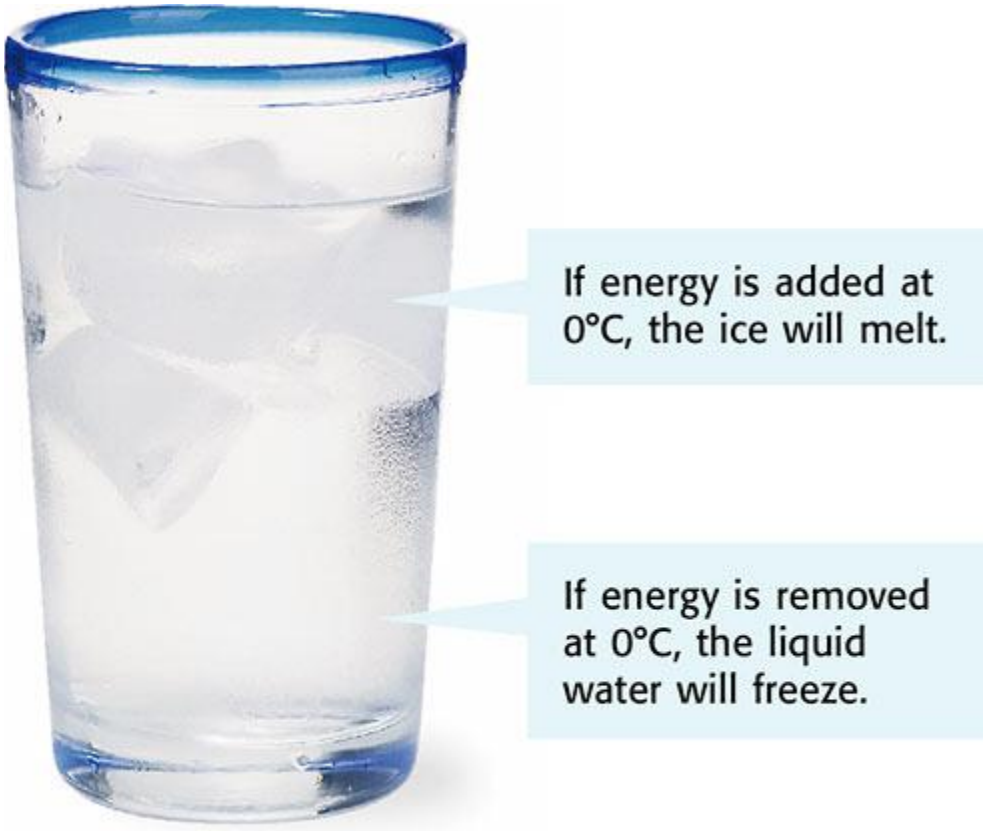


Figure 3 Liquid water freezes at the same temperature at which ice melts: 0°C.

Evaporation: Liquid to Gas

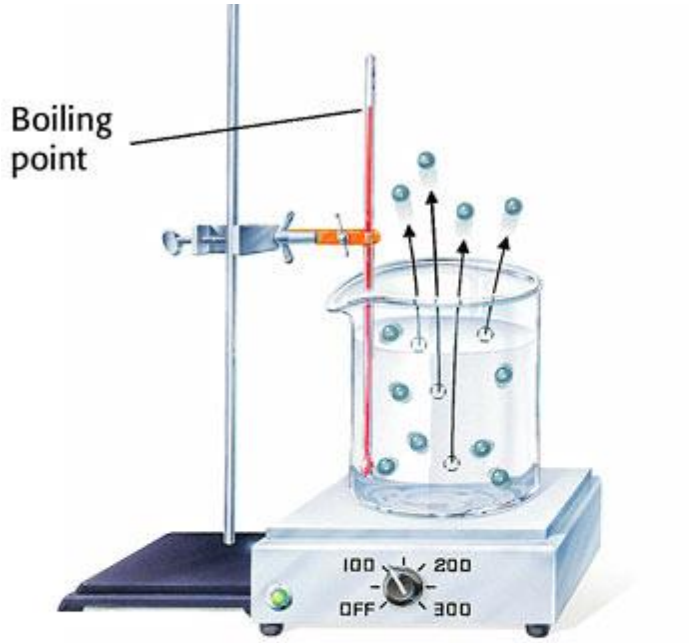
One way to make evaporation happen is to iron a shirt by using a steam iron. Steam comes up from the iron as the wrinkles disappear. This steam forms when the liquid water in the iron becomes hot and changes to gas.

Evaporation and Boiling

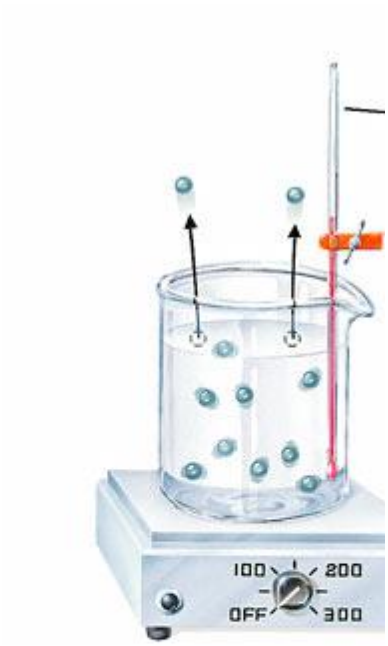
Evaporation is the change of state from a liquid to a gas. Evaporation can happen at the surface of a liquid. For example, when you sweat, your body is cooled through evaporation. Your sweat is mostly water. Water absorbs energy from your skin as the water evaporates. You feel cooler because your body transfers energy to the water.

Figure 4 explains the difference between boiling and evaporation. **Boiling** is the change of a liquid to a vapor, or gas, throughout the liquid. The temperature at which this change happens is the boiling point of the liquid. When liquid water is heated to temperatures of 100°C, molecular motion increases until large groups of water molecules overcome the attractive forces between them. Bubbles of water vapor escape from the liquid water as the water boils.

Figure 4 Boiling and Evaporation



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



Evaporation can happe
its boiling point. Some
face of the liquid move
away from the particles
become a gas.

Standards Check What happens to the particles of a liquid as the liquid boils?

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Effects of Pressure on Boiling Point

Earlier, you learned that water boils at 100°C. In fact, this is true only

at sea level. The reason is that atmospheric pressure varies depending on where you are in relation to sea level. Atmospheric pressure is caused by the weight of the gases that make up the atmosphere.

Atmospheric pressure is lower at higher elevations. The higher you go above sea level, the fewer air particles there are above you. So, the atmospheric pressure is lower. Think about boiling water at the top of a mountain. The boiling point would be lower than 100°C, because water boils more easily if the atmospheric pressure is lower. For example, Denver, Colorado, is 1.6 km above sea level. In Denver, water boils at about 95°C.

Condensation: Gas to Liquid

Look at the spider web in **Figure 5.** Notice the beads of water that have formed on it. They form because of condensation of gaseous water in the air. **Condensation** is the change of state from a gas to a liquid. Condensation and evaporation are the reverse of each other. The *condensation point* of a substance is the temperature at which the gas becomes a liquid. The condensation point is the same temperature as the boiling point at a given pressure.

Figure 5 Beads of water form when water vapor in the air contacts a cool surface, such as this spider web.

For a gas to become a liquid, large numbers of particles must clump together. Particles clump together when the attraction between them overcomes their motion keeping them apart. For this to happen, energy must be removed from the gas to slow the movement of the particles.

Sublimation: Solid to Gas

The solid in **Figure 6** is dry ice. Dry ice is carbon dioxide in a solid state. It is called *dry ice* because it goes through sublimation instead of melting into a liquid. **Sublimation** is the change of state in which a solid changes directly to a gas.

Figure 6 Dry ice is a substance that will change directly from a solid to a gas at atmospheric pressure.

For a solid to change directly to a gas, the particles of the substance must go from being very tightly packed to being spread far apart. So, the attractions between the particles must be completely overcome. The substance must gain energy for the particles to overcome their attractions.

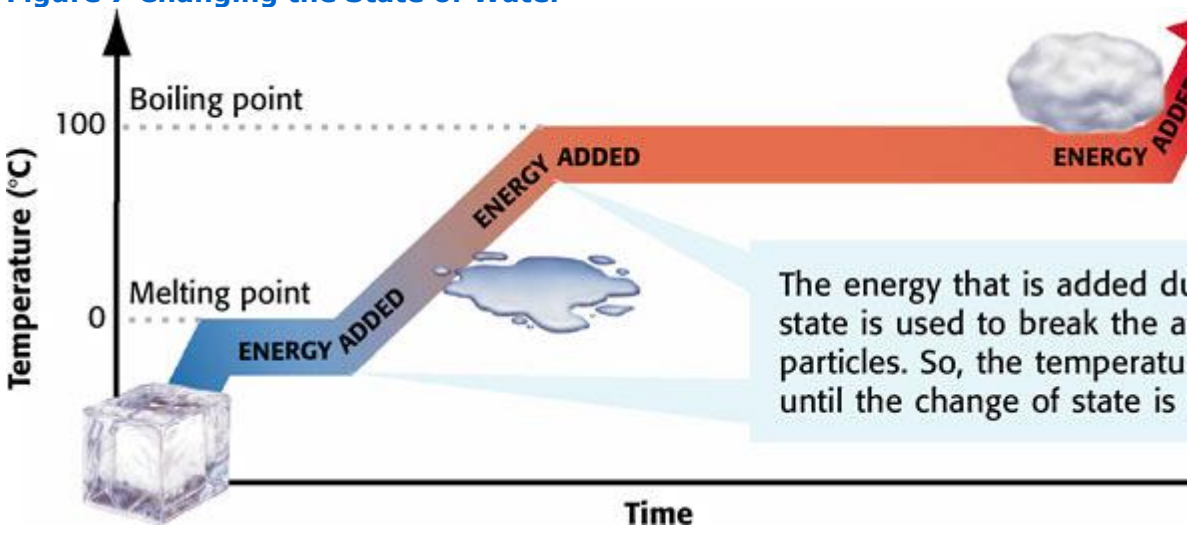
Standards Check What do the particles of a solid do when the solid

sublimes?

Temperature and Changes of State

When most substances lose or gain energy, one of two things happens to the substance: its temperature changes or its state changes. When temperature changes, the speed of the particles also changes. But when a substance is undergoing a change of state, its temperature does not change until the change of state is complete. For example, continued heating of a liquid at its boiling point will change the liquid entirely into vapor instead of raising its temperature. Only after all of the liquid is turned into gas will the temperature rise. **Figure 7** on the next page shows the effects of adding energy to ice.

Figure 7 Changing the State of Water



Section Summary

- A change of state is the conversion of a substance from one physical form to another.
- A change of state requires a loss or gain of energy by a substance's particles.
- Melting is the change from a solid to a liquid, and freezing is the change from a liquid to a solid.

- Both boiling and evaporation result in a liquid changing to a gas.
- Condensation is the change of a gas to a liquid. It is the reverse of evaporation.
- Sublimation changes a solid directly to a gas.
- The temperature of a substance does not change during a change of state.

Section Review

To answer questions online, click here.

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Chapter Summary

The Big Idea

Matter exists in various physical states, which are determined by the movement of that matter's particles.

Section 1

Four States of Matter

Key Concept Each state of matter has a characteristic way in which its particles interact.

- All matter is made of particles that are in constant motion.
- Each state of matter depends on the motion of its particles.
- In solids, particles can only vibrate; in liquids, particles can collide with and move past one another; in gases, particles are free to move independently, colliding frequently.
- In plasmas, particles move independently and are broken apart.

The three familiar states of matter are solid, liquid, and gas.

Section 2

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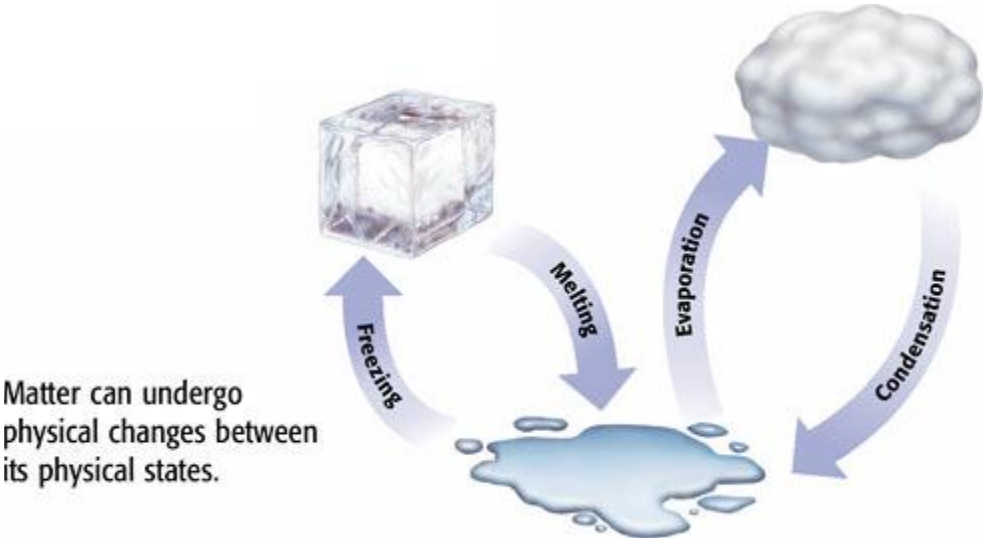

Matter can undergo physical changes between its physical states.