Changes of State

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CHAPTER 1

Changes of State

Lesson Objectives

- Explain the role of energy in changes of state.
- Outline the processes of freezing and melting.
- Describe vaporization and condensation.
- Define sublimation and deposition.

Vocabulary

- condensation
- deposition
- evaporation
- freezing
- melting
- sublimation
- temperature
- vaporization

Introduction

Matter is always changing state. Look at the two pictures of Mount Rushmore in **Figure** 1.1. The picture on the left was taken on a sunny summer morning. In this picture, the sky is perfectly clear. The picture on the right was taken just a few hours later. In this picture, there are clouds in the sky. The clouds consist of tiny droplets of liquid water. Where did the water come from? It was there all along in the form of invisible water vapor.

Mount Rushmore: 7:00 AM Mount Rushmore: 10:00 AM

FIGURE 1.1

Both of these pictures of Mount Rushmore were taken on the same day just a few hours apart. Where did the clouds come from in the picture on the right?

Introduction to Changes of State

What causes clouds to form? And in general, how does matter change from one state to another? As you may have guessed, changes in energy are involved.

What Are Changes of State?

Changes of state are physical changes in matter. They are reversible changes that do not involve changes in matter's chemical makeup or chemical properties. Common changes of state include melting, freezing, sublimation, deposition, condensation, and vaporization. These changes are shown in **Figure** 1.2. Each is described in detail below.

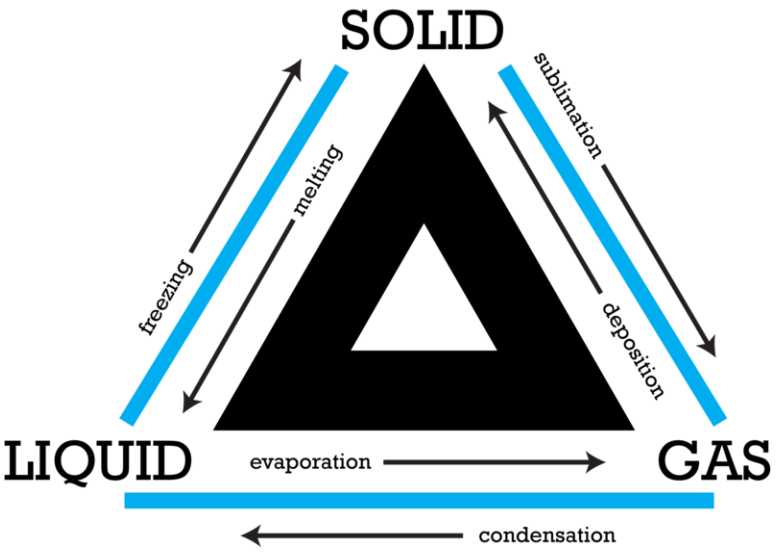

FIGURE 1.2

Which process changes a solid to a gas? Which process changes a gas to a solid?

Energy, Temperature, and Changes of State

Energy is always involved in changes of state. Matter either loses or absorbs energy when it changes from one state to another. For example, when matter changes from a liquid to a solid, it loses energy. The opposite happens when matter changes from a solid to a liquid. For a solid to change to a liquid, matter must absorb energy from its surroundings. The amount of energy in matter can be measured with a thermometer. That's because a thermometer measures temperature, and **temperature** is the average kinetic energy of the particles of matter. You can learn more about energy, temperature, and changes of state at this URL: http://hogan.chem.lsu.edu/matter/chap26/animate3/an26_035.mov .

Changes Between Liquids and Solids

Think about how you would make ice cubes in a tray. First you would fill the tray with water from a tap. Then you would place the tray in the freezer compartment of a refrigerator. The freezer is very cold. What happens next?

Freezing

The warmer water in the tray loses heat to the colder air in the freezer. The water cools until its particles no longer have enough energy to slide past each other. Instead, they remain in fixed positions, locked in place by the forces of attraction between them. The liquid water has changed to solid ice. Another example of liquid water changing to solid ice is pictured in **Figure** 1.3.

FIGURE 1.3

Water dripping from a gutter turned to ice as it fell toward the ground, forming icicles. Why did the liquid water change to a solid?

The process in which a liquid changes to a solid is called **freezing**. The temperature at which a liquid changes to a solid is its freezing point. The freezing point of water is 0°C (32°F). Other types of matter may have higher or lower freezing points. For example, the freezing point of iron is 1535°C. The freezing point of oxygen is -219°C.

Melting

If you took ice cubes out of a freezer and left them in a warm room, the ice would absorb energy from the warmer air around it. The energy would allow the particles of frozen water to overcome some of the forces of attraction holding them together. They would be able to slip out of the fixed positions they held as ice. In this way, the solid ice would turn to liquid water.

The process in which a solid changes to a liquid is called **melting**. The melting point is the temperature at which a solid changes to a liquid. For a given type of matter, the melting point is the same as the freezing point. What is the melting point of ice? What is the melting point of iron, pictured in **Figure** 1.4?

Changes Between Liquids and Gases

If you fill a pot with cool tap water and place the pot on a hot stovetop, the water heats up. Heat energy travels from the stovetop to the pot, and the water absorbs the energy from the pot. What happens to the water next?

Vaporization

If water gets hot enough, it starts to boil. Bubbles of water vapor form in boiling water. This happens as particles of liquid water gain enough energy to completely overcome the force of attraction between them and change to the

FIGURE 1.4

Molten (melted) iron is poured into a mold at a foundry. It takes extremely high temperatures to change iron from a solid to the liquid shown here. That's because iron has a very high melting point.

gaseous state. The bubbles rise through the water and escape from the pot as steam.

The process in which a liquid boils and changes to a gas is called **vaporization**. The temperature at which a liquid boils is its boiling point. The boiling point of water is 100°C (212°F). Other types of matter may have higher or lower boiling points. For example, the boiling point of table salt is 1413°C. The boiling point of nitrogen is -196°C.

Evaporation

A liquid can also change to a gas without boiling. This process is called **evaporation**. It occurs when particles at the exposed surface of a liquid absorb just enough energy to pull away from the liquid and escape into the air. This happens faster at warmer temperatures. Look at the puddle in **Figure** 1.5. It formed in a pothole during a rain shower. The puddle will eventually evaporate. It will evaporate faster if the sun comes out and heats the water than if the sky remains cloudy.

Condensation

If you take a hot shower in a closed bathroom, the mirror is likely to "fog" up. The "fog" consists of tiny droplets of water that form on the cool surface of the mirror. Why does this happen? Some of the hot water from the shower evaporates, so the air in the bathroom contains a lot of water vapor. When the water vapor contacts cooler surfaces, such as the mirror, it cools and loses energy. The cooler water particles no longer have enough energy to overcome the forces of attraction between them. They come together and form droplets of liquid water.

The process in which a gas changes to a liquid is called **condensation**. Other examples of condensation are shown in **Figure** 1.6. A gas condenses when it is cooled below its boiling point. At what temperature does water vapor condense?

FIGURE 1.5

Evaporation of water occurs even at relatively low temperatures. The water trapped in this pothole will evaporate sooner or later.

FIGURE 1.6

Water vapor condenses to form liquid water in each of the examples pictured here.

Changes Between Solids and Gases

Solids that change to gases generally first pass through the liquid state. However, sometimes solids change directly to gases and skip the liquid state. The reverse can also occur. Sometimes gases change directly to solids.

Sublimation

The process in which a solid changes directly to a gas is called **sublimation**. It occurs when the particles of a solid absorb enough energy to completely overcome the force of attraction between them. Dry ice (solid carbon dioxide, CO_2) is an example of a solid that undergoes sublimation. **Figure** 1.7 shows a chunk of dry ice changing directly to carbon dioxide gas. Sometimes snow undergoes sublimation as well. This is most likely to occur on sunny winter days when the air is very dry. What gas does snow become?

FIGURE 1.7

Solid carbon dioxide changes directly to the gaseous state.

Deposition

The opposite of sublimation is **deposition**. This is the process in which a gas changes directly to a solid without going through the liquid state. It occurs when gas particles become very cold. For example, when water vapor in the air contacts a very cold windowpane, the water vapor may change to tiny ice crystals on the glass. The ice crystals are called frost. You can see an example in **Figure** 1.8.

Lesson Summary

- Changes of state are physical changes. They occur when matter absorbs or loses energy.
- Processes in which matter changes between liquid and solid states are freezing and melting.
- Processes in which matter changes between liquid and gaseous states are vaporization, evaporation, and condensation.
- Processes in which matter changes between solid and gaseous states are sublimation and deposition.

Lesson Review Questions

Recall

1. Identify the processes involved in changes of state between liquids and solids.

FIGURE 1.8

Frost is solid water that forms when water vapor undergoes deposition.

2. Define vaporization and evaporation. State how the two processes differ.
3. What is sublimation? Give an example.
4. Define deposition. When does it occur?

Apply Concepts

5. Cliff opened the oven door to check on the cake he was baking. As hot, moist air rushed out of the oven, his eyeglasses steamed up. Explain why.

Think Critically

6. Explain the role of energy in changes of state.
7. Form a hypothesis to explain why the melting points of different solids vary.

Points to Consider

In this chapter, you read that atoms and molecules of the same kind of matter have forces of attraction between them. Atoms consist of even smaller particles. These particles are held together by certain forces as well.

- What are the particles that make up atoms?
- What forces might hold them together?

References

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