Section 3.3

1 FOCUS

Objectives

3.3.1 **Describe** phase changes.
3.3.2 **Explain** how temperature can be used to recognize a phase change.
3.3.3 **Explain** what happens to the motion, arrangement, and average kinetic energy of water molecules during phase changes.
3.3.4 **Describe** each of the six phase changes.
3.3.5 **Identify** phase changes as endothermic or exothermic.

Reading Focus

Build Vocabulary L2

Word-Part Analysis List on the board the following word parts and meanings: *-ion*, "the act of" or "the result of an action"; *-ic,* "related to or characterized by"; *endo-,* "inside"; *exo-*, "outside"; *therm,* "heat"; *-ize,* "to become." Have students identify these word parts in the vocabulary terms. Discuss the terms' meanings with students.

Reading Strategy L2

a. Liquid **b.** Liquid **c.** Gas **d.** Liquid **e.** Gas **f.** Gas

2 INSTRUCT

Characteristics of Phase Changes

Use Visuals L1

Figure 15 Note that water is one of the few substances that exist naturally as a solid, liquid, and gas under ordinary conditions. Have students look at the figure and read the caption. Ask, **Which two phases of water are visible in the photograph?** *(Solid and liquid)* **Where would the third phase most likely be found?** *(In the air)*
Visual, Logical

3.3 Phase Changes

Reading Focus

Key Concepts

- What are six common phase changes?
- What happens to a substance's temperature and a system's energy during a phase change?
- How does the arrangement of water molecules change during melting and freezing?
- How are evaporation and boiling different?

Vocabulary

- phase change
- endothermic
- heat of fusion
- exothermic
- vaporization
- heat of vaporization
- evaporation
- vapor pressure
- condensation
- sublimation
- deposition

Reading Strategy

Summarizing Copy the diagram. As you read, complete the description of energy flow during phase changes.

Endothermic		Exothermic	
Solid →	Liquid	a. ? →	Solid
b. ? →	c. ?	Gas →	d. ?
Solid →	e. ?	f. ? →	Solid

Massive chunks of frozen water called icebergs are a common sight off the continent of Antarctica. A large iceberg like the one in Figure 15 contains enough fresh water to supply millions of people with water for a year. During the summer in southern Australia, fresh water is a scarce resource. People have proposed towing icebergs to Australia from Antarctica. The plan has not been implemented because the trip could take months to complete and much of the iceberg would melt along the way. In this section, you will find out what happens when a substance, such as water, changes from one state to another.

Characteristics of Phase Changes

When at least two states of the same substance are present, scientists describe each different state as a phase. For example, if an iceberg is floating in the ocean, there are two phases of water present—a solid phase and a liquid phase. A **phase change** is the reversible physical change that occurs when a substance changes from one state of matter to another.

Figure 15 The solid and liquid phases of water are visible in this photograph of an iceberg in the Amundsen Sea near Antarctica.

Section Resources

Print
- ***Laboratory Manual,*** Investigation 3A
- ***Reading and Study Workbook With Math Support,*** Section 3.3
Transparencies, Section 3.3

Technology
- ***Probeware Lab Manual,*** Lab 1
- ***Interactive Textbook,*** Section 3.3
- ***Presentation Pro CD-ROM,*** Section 3.3
- ***Go Online,*** NSTA SciLinks, Phases of matter; PHSchool.com, Data sharing

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In Figure 16, a state of matter is listed at each corner of the triangle. Each arrow in the diagram represents a different phase change. Each pair of arrows represents a set of reversible changes. For example, the arrow starting at the solid phase and ending at the liquid phase represents melting. The arrow starting at the liquid phase and ending at the solid phase represents freezing.

Melting, freezing, vaporization, condensation, sublimation, and deposition are six common phase changes. All phase changes share certain characteristics related to energy and temperature.

Temperature and Phase Changes One way to recognize a phase change is by measuring the temperature of a substance as it is heated or cooled. **The temperature of a substance does not change during a phase change.**

Naphthalene (NAF thuh leen) is a compound that is sometimes used in mothballs. Figure 17 is a graph of the data collected when a solid piece of naphthalene is slowly heated. Temperature readings are taken at regular intervals. At first the temperature rises as the solid naphthalene warms up. But at 80°C, the temperature of the naphthalene stops rising. The temperature remains at 80°C, which is the melting point of naphthalene, until melting is complete.

If liquid naphthalene is placed in an ice-water bath, the temperature of the liquid will drop until it reaches 80°C. It will remain at 80°C until all the liquid freezes. The temperature at which the substance freezes—its freezing point—is identical to the temperature at which it melts. The freezing and melting points of naphthalene are both 80°C.

If naphthalene is heated after it has completely melted, its temperature begins to rise again. The temperature keeps rising until it reaches 218°C, which is the boiling point of naphthalene. Until boiling is complete, the temperature remains at 218°C.

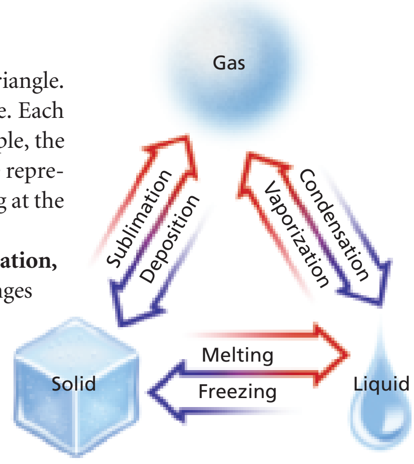


Figure 16 This diagram lists six physical changes that can occur among the solid, liquid, and gaseous phases of a substance. **Interpreting Diagrams** ***Explain why the changes are grouped into the pairs shown on the diagram.***

Go Online NSTA SCiLINKS

For: Links on phase diagrams
Visit: www.SciLinks.org
Web Code: ccn-1030

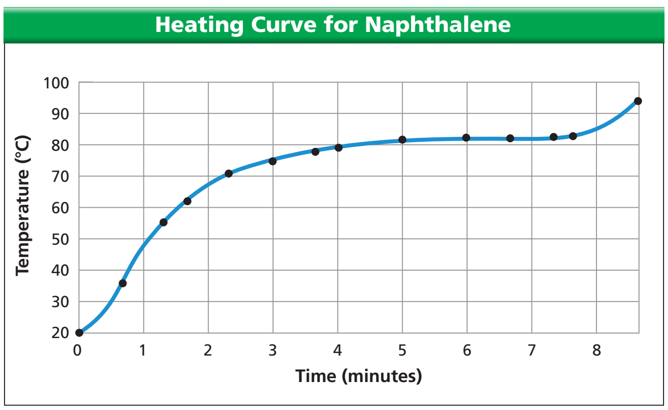


Figure 17 This graph shows what happens to the temperature of a solid sample of naphthalene as the sample is slowly heated. **Using Graphs** ***What happened to the temperature in the interval between four and seven minutes?***

Build Reading Literacy L1

Relate Text and Visuals Refer to page **190D** in **Chapter 7**, which provides the guidelines for relating text and visuals.

As students read the section, have them refer to Figure 17. Ask, **In what state is the naphthalene at 20°C? In what state is the naphthalene at 90°C?** *(Solid, liquid)* **What are the melting and freezing points of naphthalene?** *(Both are 80°C.)* **What would the heating curve for naphthalene look like if the graph were extended beyond a temperature of 100°C?** *(The heating curve would rise until it reached the boiling point of naphthalene, which is 218°C.)*
Visual, Logical

FYI

The plateau on the graph in Figure 17 is not completely flat as it should be while a substance melts. This graph represents actual data collected in a lab. It is likely that there were some impurities in the naphthalene sample, which caused some minor fluctuation in the melting point.

Go Online NSTA SCiLINKS

Download a worksheet on phase diagrams for students to complete, and find additional teacher support from NSTA SciLinks.

Customize for English Language Learners

Build a Science Glossary
Direct students to Figure 16. Before they read, have them use the figure to make a list of the six terms in the arrows for a glossary. Students should add definitions for the terms to the glossary as they read the section. Encourage students to include examples of the six phase changes along with the definitions.

Answer to . . .

Figure 16 *The groupings represent pairs of reversible changes.*

Figure 17 *The temperature remained fairly constant.*

Integrate Biology L2

One of the main causes of frost damage in crops is ice-nucleating bacteria. These bacteria provide a nucleus around which ice can form. When ice forms on plants, it pierces their cell walls and causes the cells to desiccate, or dry out because water escapes from the cells. Have students search the Internet for information on ice-nucleating bacteria. Have students present what they learn in a pamphlet that offers suggestions on how to prevent frost damage from bacteria.
Verbal

Teacher Demo

Energy Transfer L2

Purpose Students observe that the phase change from ice to water is endothermic.

Materials tray of ice cubes

Procedure Place a tray of ice cubes on a counter at the beginning of class. As the ice begins to melt, ask students where the energy to melt the ice comes from.

Expected Outcome Students will observe that the ice melts. They will infer that the energy to melt the ice comes from the air and the counter because these materials are warmer than the ice.
Visual

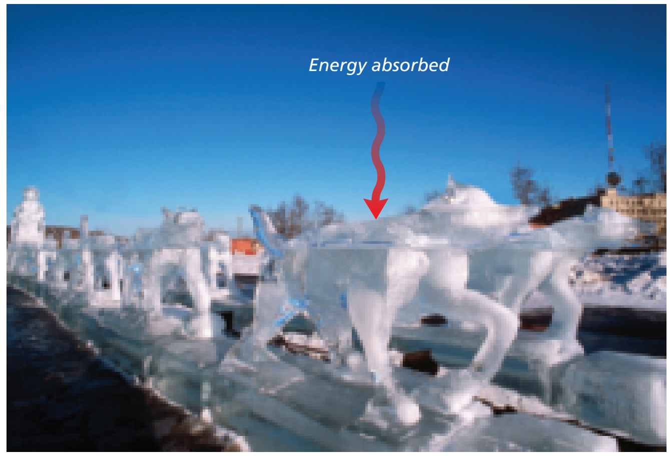


Figure 18 This ice sculpture of a dog sled was carved at a winter fair in Fairbanks, Alaska. The ice sculpture will start to melt if the temperature rises above 0°C or sunlight shines directly on the ice.

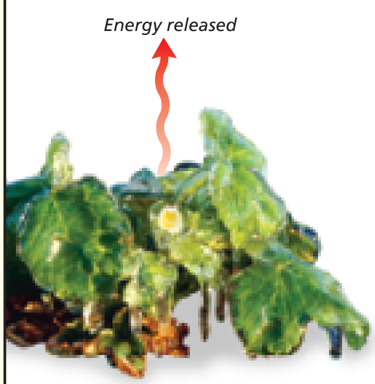


Figure 19 Energy released as ice forms on these strawberry plants keeps the plants from freezing at temperatures slightly below 0°C.
Applying Concepts ***Explain why a farmer would need to keep spraying the plants with water while the temperature remains below freezing.***

Energy and Phase Changes During a phase change, energy is transferred between a substance and its surroundings. The direction of the transfer depends on the type of phase change. **Energy is either absorbed or released during a phase change.**

The ice sculpture in Figure 18 isn't going to last forever. When the temperature of the air rises above 0°C or when sunlight shines directly on the ice, an ice sculpture begins to melt. Melting is an example of an endothermic change. During an **endothermic** change, the system absorbs energy from its surroundings.

The amount of energy absorbed depends on the substance. For example, one gram of ice absorbs 334 joules (J) of energy as it melts. This amount of energy is the **heat of fusion** for water. Fusion is another term for melting. The heat of fusion varies from substance to substance.

One gram of water releases 334 joules of energy to its surroundings as it freezes, the same amount of energy that is absorbed when one gram of ice melts. Farmers use this release of energy to protect their crops. When farmers expect temperatures to drop slightly below 0°C, they spray the crops with water as shown in Figure 19. As water freezes, it releases heat. The flow of heat slows the drop in temperature and helps protect the crops from damage. Freezing is an example of an exothermic change. During an **exothermic** change, the system releases energy to its surroundings.

An understanding of phase changes can be useful in many situations. The How It Works box explains how the design of an ice rink in Utah allows the manager of the rink to control the hardness of the ice.

Reading Checkpoint ***How much energy does one gram of ice absorb as it melts?***

Facts and Figures

Preventing Frost Damage For a frost control system to work, a farmer needs to start the sprinklers just before the temperature at ground level reaches 0°C. Placing a shallow pan of water in the lowest part of the field is an easy way to monitor the temperature. As soon as ice begins to form around the edge of the pan, the sprinklers should be turned on. The sprinklers should stay on until the temperature rises enough to start melting the ice.

This method of frost control is effective for strawberry plants down to about −6.6°C. When strawberries are in bloom, sprinklers are best started at 1.1°C. Blueberries with open blooms are safe from damage at temperatures as low as 0°C. Because of the cost of installation and operation, frost control systems are generally used for crops that can demand high unit prices, such as oranges, strawberries, Blueberries, and asparagus.

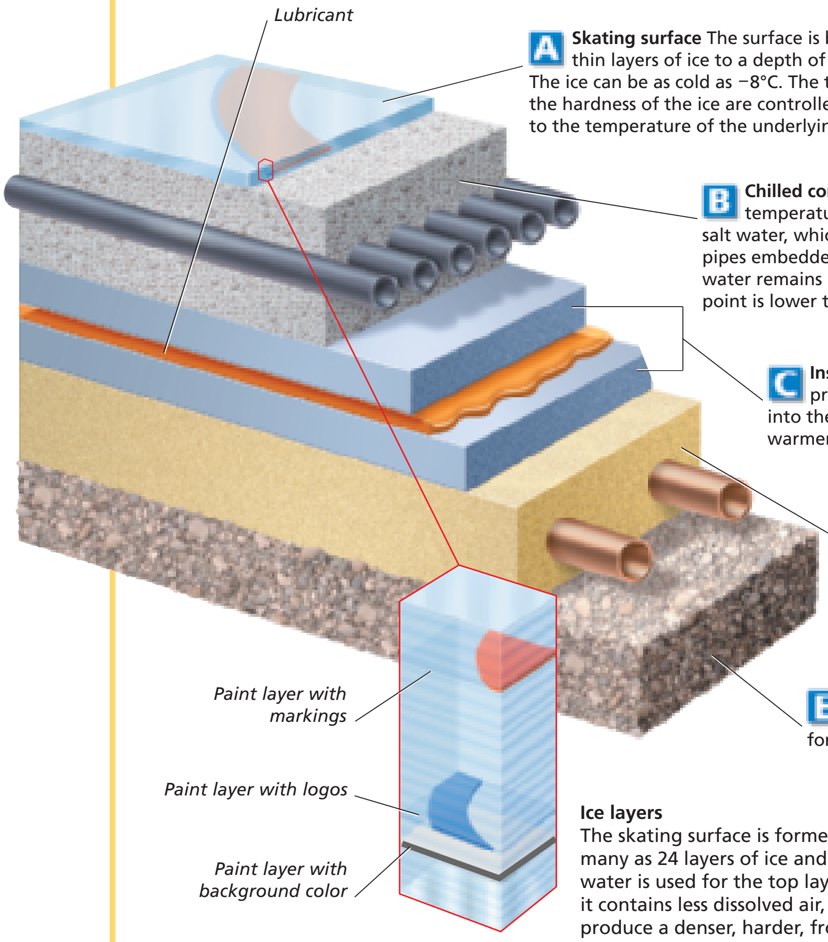
DK HOW It Works

Custom-Tailored Ice

At the Utah Olympic Oval the hardness of the ice can be controlled. The ice must be cold and hard for long speed-skating races, where the length of a skater's glide is important. For shorter races, the skaters need more traction, so the ice is made a little warmer and softer.

Interpreting Diagrams ***What is the purpose of the sand layer?***

Speed Skater
This skater is racing at the Utah Olympic Oval, one of the world's most technically advanced ice rinks.



A Skating surface The surface is built up from thin layers of ice to a depth of less than 2 cm. The ice can be as cold as −8°C. The temperature and the hardness of the ice are controlled by tiny changes to the temperature of the underlying concrete layer.

B Chilled concrete slab The temperature is controlled by cold salt water, which is pumped through pipes embedded in the slab. The salt water remains liquid because its freezing point is lower than that of pure water.

C Insulating layers These layers prevent heat from rising up into the concrete slab from the warmer sand layer underneath.

D Sand layer To prevent the gravel layer from freezing, which could damage the rink structure, the sand layer is kept at a temperature above 0°C.

E Gravel layer This layer provides the foundation for the rink.

Ice layers
The skating surface is formed with as many as 24 layers of ice and paint. Warm water is used for the top layers because it contains less dissolved air, and can produce a denser, harder, frozen surface.

DK HOW It Works

Custom-Tailored Ice **L2**

Skaters traveling at speeds up to 80 km/h will be slowed by a surface that is not smooth, level, and uniformly hard. The conditions of the ice at the Utah Olympic Oval, which was constructed for the 2000 Winter Olympics, can be changed overnight. For sprinters, the ice is softer so that their traction, or ability to grip the ice, is greater. A harder surface allows long-distance skaters to glide more easily across the ice.

Controlling the indoor climate is also important in maintaining the ice surface. The Utah Olympic Oval has two air-filtering systems and a dehumidifier that can reduce humidity to 3%. The air temperature varies only 3°C from the ice to the ceiling. Controlling the conditions above and below the ice allows for precise control of the ice surface.

Interpreting Diagrams The sand layer prevents the gravel layer from freezing and damaging the rink structure.
Visual, Logical

For Enrichment **L3**

Have students research playing surfaces used in other sports, such as football, tennis, and golf. Explain that different surfaces affect an athlete's performance. Students could compare the advantages and disadvantages of artificial turf and grass football fields; or cement, clay, and grass tennis courts. They could also find out how the length of grass affects shots at different locations on a golf course.
Logical

Answer to . . .

Figure 19 *Until the temperature rises above freezing, the farmer must continue to provide energy to keep the plants from freezing.*

Reading Checkpoint *334 joules*

Melting and Freezing

Use Visuals L1

Figure 20 Keeping food cool requires the transfer of energy. Ask, **What change occurs in the evaporator? Is this change exothermic or endothermic?** *(Liquid to gas; the change is endothermic because energy is absorbed from the food compartment)* **What change occurs in the condenser? Is this change exothermic or endothermic?** *(Gas is liquid; the change is exothermic because energy is released to the surroundings)* **Visual**

FYI

Refrigeration is also discussed in Chapter 16, where the focus is on the need for work to be done for heat to flow from an area of lower temperature to an area at higher temperature. In this chapter, the focus is on the endothermic and exothermic phase changes.

Vaporization and Condensation

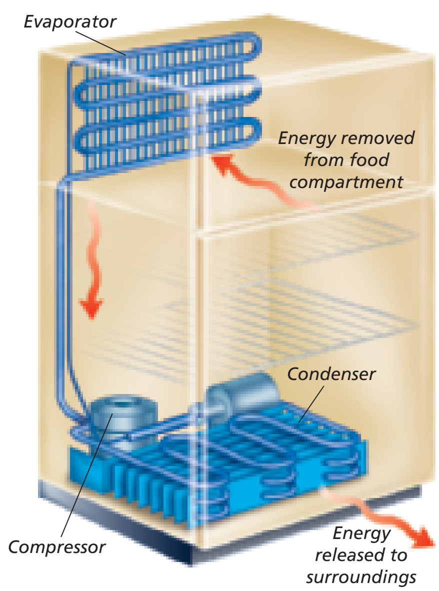
Use Community Resources L2

Invite an appliance repairperson to come to the class and speak about compounds used in air conditioner and refrigerator cooling coils. Suggest that the speaker describe the types of compounds used, how the compounds have changed over time, and whether there are any problems with the replacement compounds. **Interpersonal**

Download a worksheet on phases of matter for students to complete, and find additional teacher support from NSTA SciLinks.

For: Links on phases of matter
Visit: www.SciLinks.org
Web Code: ccn-1033

Figure 20 In a refrigerator, a pair of phase changes keep the food cold. Energy from inside the food compartment is used to change a liquid to a gas in the evaporator. This energy is released when the compressed gas changes back to a liquid in the condenser.



Melting and Freezing

In water, hydrogen and oxygen atoms are combined in small units called molecules. Each water molecule contains two hydrogen atoms and one oxygen atom. **The arrangement of molecules in water becomes less orderly as water melts and more orderly as water freezes.**

Melting In ice, attractions between water molecules keep the molecules in fixed positions. When ice cubes are removed from a freezer and placed in an empty glass, heat flows from the air to the ice. As the ice gains energy, the molecules vibrate more quickly. At the melting point of water, 0°C, some molecules gain enough energy to overcome the attractions and move from their fixed positions. When all the molecules have enough energy to move, melting is complete. Any energy gained by the water after the phase change increases the average kinetic energy of the molecules, and the temperature rises.

Freezing When liquid water is placed in a freezer, energy flows from the water to the air in the freezer, and the water cools down. As the average kinetic energy of its molecules decreases, they move more slowly. At the freezing point of water, some molecules move slowly enough for the attractions between molecules to have an effect. When all the molecules have been drawn into an orderly arrangement, freezing is complete. Any energy removed from the ice after the phase change decreases the average kinetic energy of the molecules, and the temperature of the ice drops.

Often, people think of cold temperatures when they hear the term *freezing.* But substances that are solids at room temperature can freeze at temperatures that are quite high. For example, silicon freezes at 1412°C (2574°F). As a comparison, you can bake cookies at 177°C (350°F).

Vaporization and Condensation

Figure 20 shows how food cools and stays cold in a refrigerator. The process depends on a substance that changes from a liquid to a gas to a liquid over and over again. During these phase changes, energy flows from the inside of the refrigerator to the outside.

The phase change in which a substance changes from a liquid into a gas is **vaporization.** Vaporization is an endothermic process. That is, a substance must absorb energy in order to change from a liquid to a gas. One gram of water gains 2258 joules of energy when it vaporizes at 100°C. This amount of energy is the **heat of vaporization** for water. The heat of vaporization varies from substance to substance.

Facts and Figures

Chlorofluorocarbons Under the Clean Air Act, which became effective in November of 1995, it became illegal to release into the air compounds that harm Earth's ozone layer. Chlorofluorocarbons (CFCs) are among the banned substances. CFCs were used as refrigerants in cooling devices, such as refrigerators and air conditioners.

Because CFCs do not dissolve easily in water and are generally not very reactive, they tend to stay in the atmosphere once they are released. In the lower atmosphere, their presence causes few problems. However, these compounds move into the stratosphere where they are exposed to high energy radiation. This radiation causes the CFCs to react and release chlorine atoms. These chlorine atoms react with oxygen to form chlorine monoxide, which causes the ozone to decompose into oxygen. Hydrogen fluorocarbons (HFCs) have replaced CFCs in many cooling devices.

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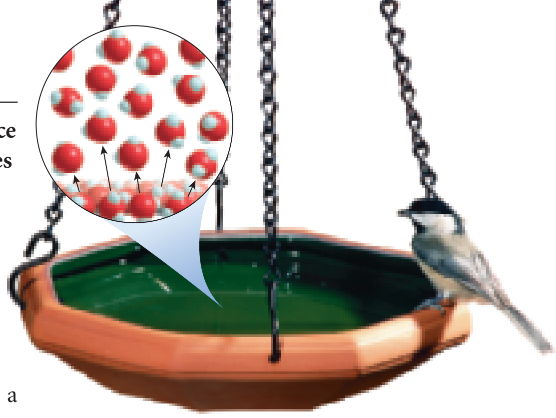
Scientists distinguish two vaporization processes—boiling and evaporation. **Evaporation takes place at the surface of a liquid and occurs at temperatures below the boiling point.**



Evaporation If you go outside after a rain shower on a sunny, warm day, you may notice puddles of water. If you return to the same location after a few hours, the puddles may be gone. This disappearance of the puddles is due to evaporation. **Evaporation** is the process that changes a substance from a liquid to a gas at temperatures below the substance's boiling point.

Figure 21 Evaporation takes place at the surface of a liquid.

Figure 21 shows what is happening as water evaporates from a small, shallow container. Some molecules near the surface are moving fast enough to escape the liquid and become water vapor. (A vapor is the gaseous phase of a substance that is normally a solid or liquid at room temperature.) The greater the surface area of the container, the faster the water evaporates.

What happens if the water is in a closed container? As the water evaporates, water vapor collects above the liquid. The pressure caused by the collisions of this vapor and the walls of the container is called **vapor pressure.** The vapor pressure of water increases as the temperature increases. At higher temperatures, more water molecules have enough kinetic energy to overcome the attractions of other molecules in the liquid.

Reading Checkpoint ***How does the surface area of a liquid affect the rate of evaporation?***

Boiling As you heat a pot of water, both the temperature and the vapor pressure of the water increase. When the vapor pressure becomes equal to atmospheric pressure, the water boils. The temperature at which this happens is the boiling point of water.

The kinetic theory explains what happens when water boils. As the temperature increases, water molecules move faster and faster. When the temperature reaches 100°C, some molecules below the surface of the liquid have enough kinetic energy to overcome the attraction of neighboring molecules. Figure 22 shows that bubbles of water vapor form within the liquid. Because water vapor is less dense than liquid water, the bubbles quickly rise to the surface. When they reach the surface, the bubbles burst and release water vapor into the air.

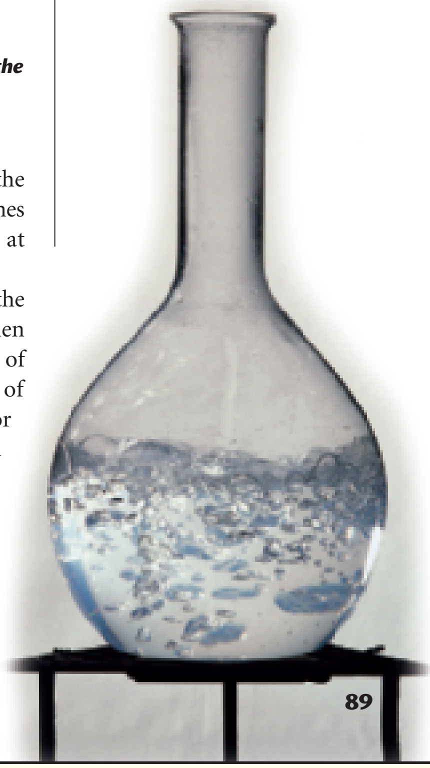


Figure 22 Boiling takes place throughout a liquid. Applying Concepts ***Explain why the temperature of water does not rise during boiling.***

Build Science Skills L2

Designing Experiments The rate of evaporation is affected by surface area. Ask students to design an experiment using water in a beaker with gradations to test this statement. Have students identify the variables that will need to be controlled (type of liquid, volume of liquid, temperature of liquid, time). Ask, **What will the manipulated variable be?** *(Surface area)* **What will the responding variable be?** *(Rate of evaporation)* **How will you measure the rate of evaporation?** *(One acceptable answer is measuring the liquid level after a specified interval of time.)* Allow students to conduct approved experiments and summarize their results in a report.
Verbal, Logical

Address Misconceptions L2

Students often think that atoms and molecules expand as the temperature rises. Use water's expansion when it freezes to challenge this misconception. Explain that the space between water molecules is greater in ice than in liquid water because of the arrangement of molecules in ice. When ice melts, the space between molecules decreases and the volume decreases.
Logical

FYI

Eventually, no more vapor can collect above the liquid in a closed container. The water continues to evaporate, but some of the vapor condenses in return. This is an example of a dynamic equilibrium. Chemical (and physical) equilibrium is introduced in Chapter 7.

Water, especially tap water, contains dissolved gases such as oxygen and nitrogen. When water is heated, the solubility of these gases in water decreases, which causes small bubbles to form in heated water before it begins to boil.

Answer to . . .

Figure 22 *Energy absorbed by the system during boiling is used to overcome attractions among water molecules.*

Reading Checkpoint *The greater the surface area, the faster the water evaporates.*

Quick Lab

Observing Phase Changes

L2

Objective
After completing this lab, students will be able to

- identify examples of condensation and sublimation.

Skills Focus **Observing**

Prep Time 15 minutes

Advance Prep Obtain dry ice from a local supplier or from a scientific supply house, ice cream wholesaler, or compressed gas dealer. Do not store dry ice in an airtight container. Leave a window open in your car if you have dry ice in the car. Use a hammer to carefully break the dry ice into pea-sized pieces.

Class Time 20 minutes

Safety Do not handle dry ice with bare hands. It damages skin tissue on contact. Wear safety goggles, a lab apron, and leather gloves when handling dry ice. Use forceps to dispense a pea-sized piece of dry ice into each flask. Caution students not to touch dry ice and to use care when handling glassware to avoid breakage. Provide only nonmercury thermometers.

Teaching Tips

- Do this lab after students have studied sublimation.
- If students are having trouble with Question 2, ask at what temperature water boils. If they are having trouble with Question 4, remind them that water vapor exists above the liquid.

Expected Outcome When dry ice is added to water, vigorous bubbling begins and a fog appears above the liquid.

For Enrichment

L3

Challenge students to propose a way to have solid, liquid, and gaseous water together in the same test tube. One way is to place ice in liquid water in a closed container. Water vapor will collect above the surface of the water.
Visual, Logical

Quick Lab

Observing Phase Changes

Materials
250-mL Erlenmeyer flask, graduated cylinder, thermometer, dry ice

Procedure

1. Pour 150 milliliters of water into a 250-mL Erlenmeyer flask. Place a thermometer in the flask. **CAUTION** *Wipe up any spilled water right away to avoid slips and falls.*
2. Observe what happens after your teacher adds a small piece of dry ice to the flask. (Dry ice is solid carbon dioxide.) **CAUTION** *Dry ice can damage skin on contact. Do not touch the dry ice.*
3. Record the temperature of the water just after the dry ice is added and again after it is no longer visible.

Analyze and Conclude

1. **Observing** What happened when the dry ice was added to the water?
2. **Analyzing Data** Did adding the dry ice cause the water to boil? Explain your answer.
3. **Inferring** What was the source of the bubbles in the water?
4. **Formulating Hypotheses** What caused a cloud to form above the flask?
5. **Applying Concepts** What phase changes occurred in the flask?

The boiling point of a substance depends on the atmospheric pressure. The normal boiling point of water at sea level is 100°C. At higher elevations, the atmospheric pressure is lower. Do you know that Denver, Colorado, is called the mile-high city? This nickname is based on Denver's location at one mile above sea level. In Denver, the vapor pressure of water will equal atmospheric pressure at temperatures below 100°C. The boiling point of water in Denver can be as low as 95°C. Food does not cook as quickly at 95°C as it does at 100°C. Pasta takes longer to cook in Denver than in New Orleans, Louisiana, a city that is located near sea level.

Condensation Have you ever come out of a shower to find your bathroom mirror clouded over? The "cloud" on the mirror is caused by water vapor that cooled as it came in contact with the mirror. The water vapor transferred heat to the mirror and condensed into liquid water. **Condensation** is the phase change in which a substance changes from a gas or vapor to a liquid. This process is also responsible for the morning dew on the blades of grass in Figure 23. Condensation is an exothermic process.

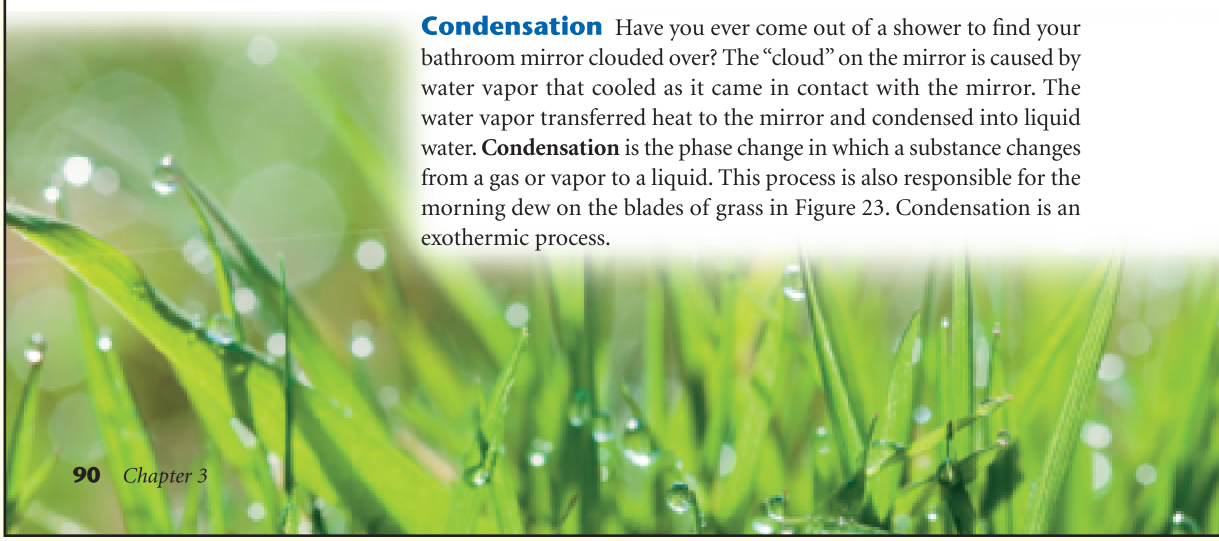


Figure 23 Water vapor from the air condensed into drops of liquid water on these blades of grass.

Analyze and Conclude
1. Bubbles formed in the water, and a fog formed above the water. The temperature of the water decreased.
2. No, because the water was not at 100°C when bubbles appeared.
3. Carbon dioxide gas from the dry ice
4. Cold carbon dioxide gas chilled the air above the water, causing water vapor to condense into tiny liquid droplets.
5. Sublimation of carbon dioxide and condensation of water occurred. Students may also mention vaporization of water.
Logical, Kinesthetic

Sublimation and Deposition

Directors of concerts and plays sometimes use dry ice to create a fog-like special effect. Dry ice is the common name for the solid form of carbon dioxide. At room temperature, dry ice can directly change from a solid to a colorless gas. **Sublimation** is the phase change in which a substance changes from a solid to a gas or vapor without changing to a liquid first. Sublimation is an endothermic change. As dry ice sublimes, the cold carbon dioxide vapor causes water vapor in the air to condense and form clouds.

Where does the name dry ice come from? Solid carbon dioxide does not form a liquid as its temperature rises. Suppose 100 steaks are shipped from Omaha, Nebraska, to a supermarket in Miami, Florida. The steaks will spoil unless they are kept cold during the trip. If regular ice is used, water collects in the shipping container as the ice melts. If the steaks are shipped in dry ice, the container and the steaks stay dry during the journey. Figure 24 shows another use of dry ice.

When a gas or vapor changes directly into a solid without first changing to a liquid, the phase change is called **deposition.** This exothermic phase change is the reverse of sublimation. Deposition causes frost to form on windows. When water vapor in the air comes in contact with cold window glass, the water vapor loses enough kinetic energy to change directly from a gas to a solid.

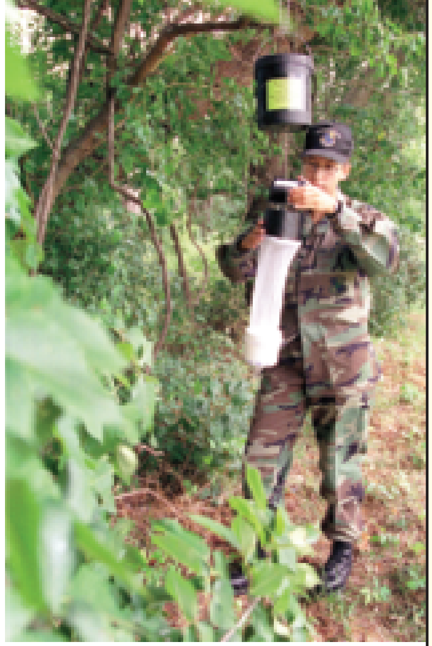


Figure 24 A technician at Tinker Air Force Base in Oklahoma hangs a mosquito trap. The trap is baited with dry ice because mosquitoes are attracted to carbon dioxide.

Section 3.3 Assessment

Reviewing Concepts

1. Name six common phase changes.
2. What happens to the temperature of a substance during a phase change?
3. How does the energy of a system change during a phase change?
4. What happens to the arrangement of water molecules as water melts and freezes?
5. What is the difference between evaporation and boiling?
6. Explain why sublimation and deposition are classified as physical changes.

Critical Thinking

7. **Applying Concepts** How can the mass of a pile of snow decrease on a sunny day when the air temperature does not rise above 0°C?
8. **Drawing Conclusions** At room temperature, table salt is a solid and acetone is a liquid. Acetone is the main ingredient in nail polish remover. What conclusion can you draw about the melting points of these materials?

Writing in Science

Steps in a Process Write a paragraph describing three steps that must occur for a water molecule to start on the surface of hot bath water and end up on the surface of a bathroom mirror. Note whether the phase changes that take place during the process are endothermic or exothermic. (*Hint:* Use words such as *first, next,* and *finally* to show the order of events.)

Section 3.3 Assessment

1. Melting, freezing, vaporization, condensation, sublimation, and deposition
2. The temperature of a substance does not change during a phase change.
3. Energy is either released or absorbed during a phase change.
4. The arrangement of molecules becomes less orderly as water melts and more orderly as water freezes.
5. Evaporation takes place at the surface of a liquid and occurs at temperatures below the boiling point.
6. A substance's identity does not change during sublimation or deposition.
7. When snow absorbs energy from sunlight, it either melts or sublimes.
8. Table salt must have a melting point above room temperature, and acetone must have a melting point below room temperature.

Sublimation and Deposition

Use Visuals L1

Figure 24 Have students examine Figure 24. Explain that the trap was hung as part of a study of West Nile virus, a mosquito-borne disease. Mosquitoes acquire the virus from infected birds and then transmit the virus to other animals and humans. Mosquitoes are collected and sent to a laboratory for identification by species and gender. Samples of similar female mosquitoes are blended and their RNA is analyzed for West Nile virus. Ask, **Why is dry ice used to bait the mosquito trap rather than gaseous carbon dioxide?** *(The large amount of carbon dioxide stored in dry ice is released slowly over time rather than all at once.)*
Logical

3 ASSESSMENT

Evaluate Understanding L2

Have students write the six terms that describe phase changes. Next to each term, students should describe the type of change. For example, for *melting*, students would indicate that the phase change is from a solid to a liquid. Tell students to include arrows pointing up to identify exothermic changes and arrows pointing down to identify exothermic changes.

Reteach L1

Use Figure 16 to review the six phase changes described in this section. Ask, **What do the phase changes with red arrows have in common?** *(They are all exothermic processes.)* **What do the phase changes with blue arrows have in common?** *(They are all endothermic processes.)*

Writing in Science

First, the water molecule on the surface of the bath water evaporates—an endothermic change. Next, random motion of the molecule carries it to the surface of the mirror. Finally, the molecule condenses on the mirror—an exothermic change.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 3.3.