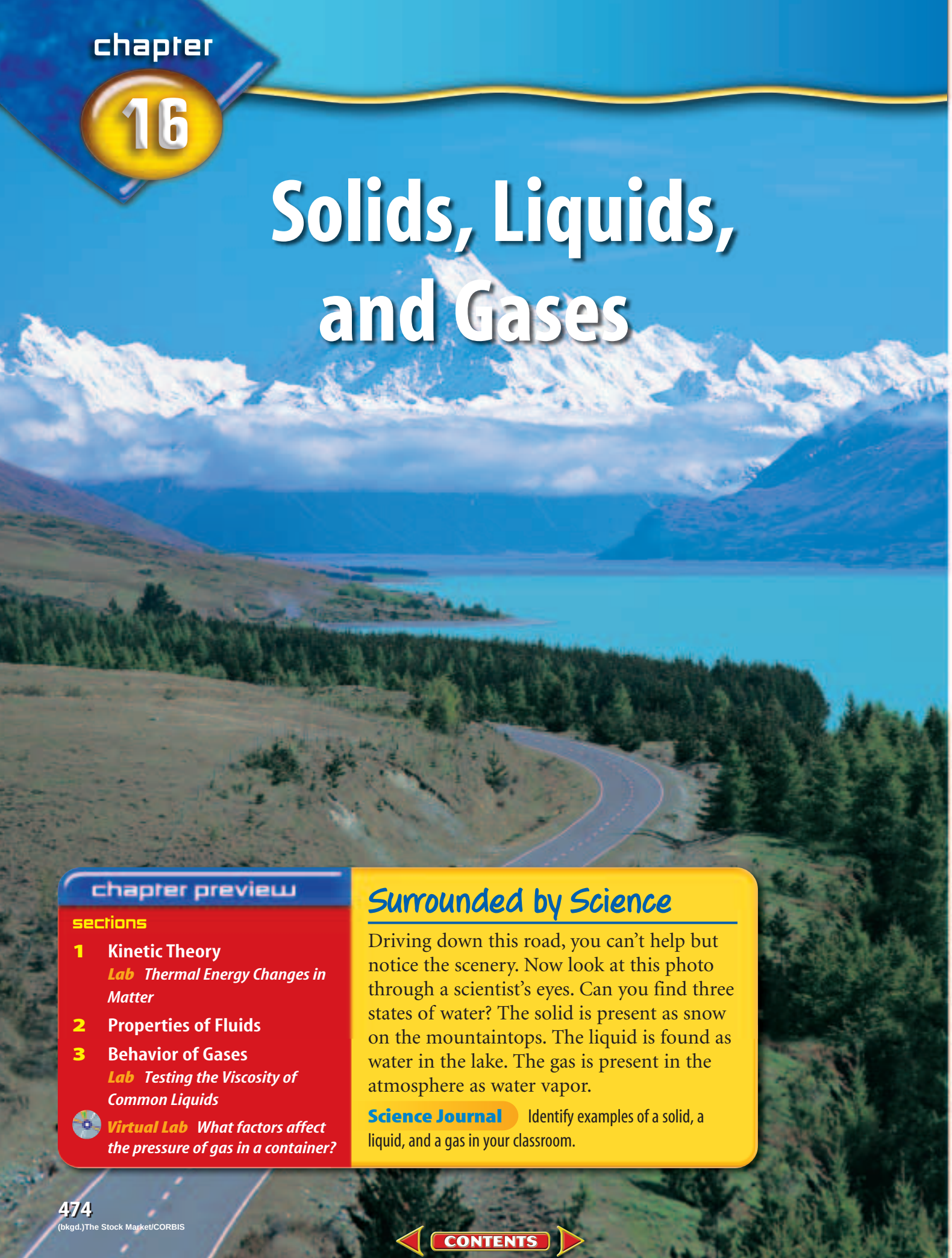
chapter 16

Solids, Liquids, and Gases



chapter preview

sections

Surrounded by Science

Driving down this road, you can't help but notice the scenery. Now look at this photo through a scientist's eyes. Can you find three states of water? The solid is present as snow on the mountaintops. The liquid is found as water in the lake. The gas is present in the atmosphere as water vapor.

Science Journal Identify examples of a solid, a liquid, and a gas in your classroom.

CONTENTS

Start-Up Activities

LAUNCH LAB

The Expansion of a Gas

Why does the mercury in a themometer rise? Why do sidewalks, streets, and bridges have cracks? Many substances expand when heated and contract when cooled, as you will see during this lab.

Observe the Expansion and Contraction of Air

1. Blow up a balloon until it is half filled. Use a tape measure to measure the circumference of the balloon.
2. Pour water into a large beaker until it is half full. Place the beaker on a hot plate and wait for the water to boil.
3. Set the balloon on the mouth of the beaker and observe for five minutes. Be careful not to allow the balloon to touch the hot plate. Measure the circumference of the balloon.
4. **Think Critically** Write a paragraph in your Science Journal describing the changing size of the balloon's circumference. Infer why the balloon's circumference changed.

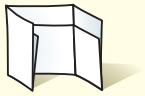
FOLDABLES™ Study Organizer

Solids, Liquids, and Gases

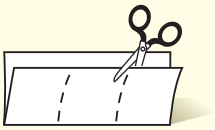
The matter that surrounds you is either a solid, liquid, or gas. Make the following Foldable to help you organize information about solids, liquids, and gases.

STEP 1 **Fold** a sheet of paper in half lengthwise. Make the back edge about 5 cm longer than the front edge.

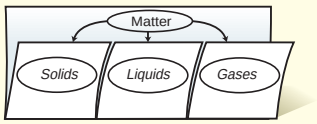
STEP 2 **Turn** the paper so the fold is on the bottom. Then **fold** it into thirds.



STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs.



STEP 4 **Label** the Foldable as shown.



Read for Main Ideas As you read the chapter, list the characteristics of solids, liquids, and gases under the appropriate tab. List some examples of each under the tab also.

Science Online

Preview this chapter's content and activities at gpscience.com

section 1

Kinetic Theory

Reading Guide

What You'll Learn

- **Explain** the kinetic theory of matter.
- **Describe** particle movement in the four states of matter.
- **Explain** particle behavior at the melting and boiling points.

Why It's Important

You can use energy that is lost or gained when a substance changes from one state to another.

Review Vocabulary

kinetic energy: energy in the form of motion

New Vocabulary

- kinetic theory
- melting point
- heat of fusion
- boiling point
- heat of vaporization
- diffusion
- plasma
- thermal expansion

Figure 1 Two states of water are visible in this photograph. **Identify** *Can you identify the solid and liquid states of water?*

States of Matter

You probably do not think of the states of matter as you do everyday activities. An everyday activity such as eating lunch may include solids, liquids, and gases. Look at **Figure 1.** Can you identify the states of matter present? The boiling soup on the stove and the visible steam above the boiling soup is in the liquid state. The ice cube dropped into the soup to cool it, is in the solid state. How are these states alike and different?

Kinetic Theory The **kinetic theory** is an explanation of how particles in matter behave. To explain the behavior of particles, it is necessary to make some basic assumptions. The three assumptions of the kinetic theory are as follows:

1. All matter is composed of small particles (atoms, molecules, and ions).
2. These particles are in constant, random motion.
3. These particles are colliding with each other and the walls of their container.

Particles lose some energy during collisions with other particles. But the amount of energy lost is very small and can be neglected in most cases.

To visualize the kinetic theory, think of each particle as a tiny table-tennis ball in constant motion. These balls are bouncing and colliding with each other. Mentally visualizing matter in this way can help you understand the movement of particles in matter.

Thermal Energy Think about the ice cube in the soup. Does the ice cube appear to be moving? How can a frozen, solid ice cube have motion? Remember to focus on the particles. Atoms in solids are held tightly in place by the attraction between the particles. This attraction between the particles gives solids a definite shape and volume. However, the thermal energy in the particles causes them to vibrate in place. Thermal energy is the total energy of a material's particles, including kinetic—vibrations and movement within and between the particles—and potential—resulting from forces that act within or between particles. When the temperature of the substance is lowered, the particles will have less thermal energy and will vibrate more slowly.

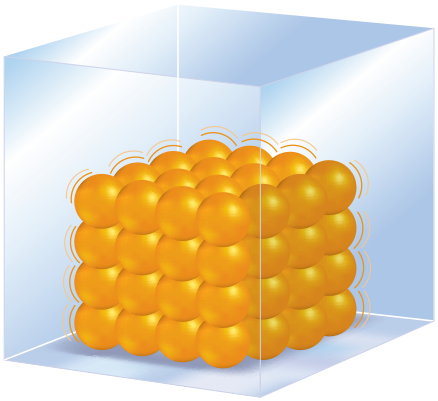


Figure 2 The particles in a solid are packed together tightly and are constantly vibrating in place.

Reading Check ***What is thermal energy?***

Average Kinetic Energy Temperature is the term used to explain how hot or cold an object is. In science, temperature means the average kinetic energy of particles in the substance, or how fast the particles are moving. On average, molecules of frozen water at 0°C will move slower than molecules of water at 100°C. Therefore, water molecules at 0°C have lower average kinetic energy than the molecules at 100°C. Molecules will have kinetic energy at all temperatures, including absolute zero. Scientists theorize that at absolute zero, or –273.15°C, particle motion is so slow that no additional thermal energy can be removed from a substance.

Reading Check ***How are kinetic energy and temperature related?***

Solid State An ice cube is an example of a solid. The particles of a solid are closely packed together, as shown in **Figure 2.** Most solid materials have a specific type of geometric arrangement in which they form when cooled. The type of geometric arrangement formed by a solid is important. Chemical and physical properties of solids often can be attributed to the type of geometric arrangement that the solid forms. **Figure 3** shows the geometric arrangement of solid water. Notice that the hydrogen and oxygen atoms are alternately spaced in the arrangement.

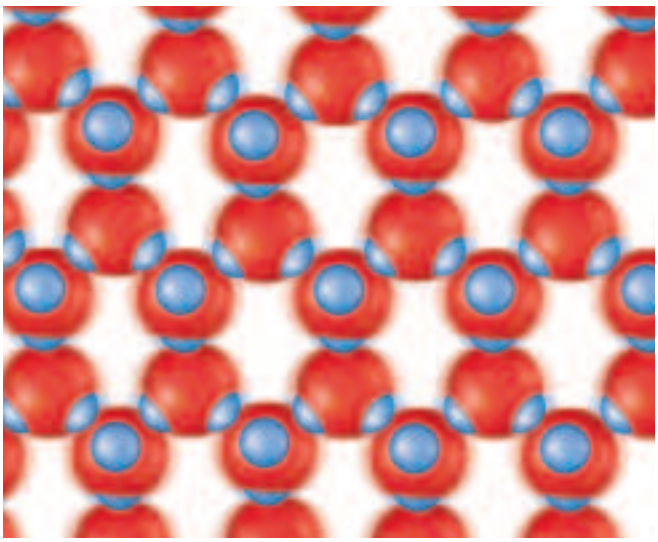
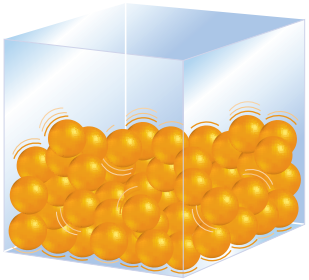


Figure 3 The particles in solid water align themselves in an ordered geometric pattern. Even though a solid ice cube doesn't look like it is moving, its molecules are vibrating in place.



Liquid

Figure 4 The particles in a liquid are moving more freely than the particles in a solid. They have enough kinetic energy to slip out of the ordered arrangement of a solid.

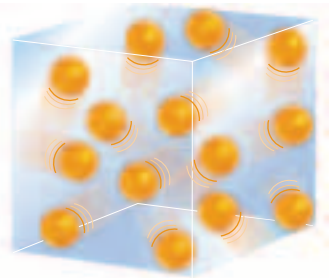
Liquid State What happens to a solid when thermal energy or heat is added to it? Think about the ice cube in the hot soup. The particles in the hot soup are moving fast and colliding with the vibrating particles in the ice cube. The collisions of the particles transfer energy from the soup to the ice cube. The particles on the surface of the ice cube vibrate faster. These particles collide with and transfer energy to other ice particles. Soon the particles of ice have enough kinetic energy to overcome the attractive forces. The particles of ice gain enough kinetic energy to slip out of their ordered arrangement and the ice melts. This is known as the **melting point,** or the temperature at which a solid begins to liquefy. Energy is required for the particles to slip out of the ordered arrangement. The amount of energy required to change a substance from the solid phase to the liquid phase at its melting point is known as the **heat of fusion.**

Reading Check ***What is heat of fusion?***

Liquids Flow Particles in a liquid, shown in **Figure 4,** have more kinetic energy than particles in a solid. This extra kinetic energy allows particles to partially overcome the attractions to other particles. Thus, the particles can slide past each other, allowing liquids to flow and take the shape of their container. However, the particles in a liquid have not completely overcome the attractive forces between them. This causes the particles to cling together, giving liquids a definite volume.

Reading Check ***Why do liquids flow?***

Gas State Particles in the gas state are shown in **Figure 5.** Gas particles have enough kinetic energy to overcome the attractions between them. Gases do not have a fixed volume or shape. Therefore, they can spread far apart or contract to fill the container that they are in. How does a liquid become a gas? The particles in a liquid are constantly moving. Some particles are moving faster and have more kinetic energy than others. The particles that are moving fast enough can escape the attractive forces of other particles and enter the gas state. This process is called vaporization. Vaporization can occur in two ways—evaporation and boiling. Evaporation is vaporization that occurs at the surface of a liquid and can occur at temperatures below the liquid's boiling point. To evaporate, particles must have enough kinetic energy to escape the attractive forces of the liquid. They must be at the liquid's surface and traveling away from the liquid.



Gas

Figure 5 In gases, the particles are far apart and the attractive forces between the particles are overcome. Gases do not have a definite volume or shape.

Figure 6 Boiling occurs throughout a liquid when the pressure of the vapor in the liquid equals the pressure of the vapor on the surface of the liquid. **Explain** *the difference between boiling and evaporation.*

Boiling Point A second way that a liquid can vaporize is by boiling. Unlike evaporation, boiling occurs throughout a liquid at a specific temperature depending on the pressure on the surface of the liquid. Boiling is shown in **Figure 6.** The **boiling point** of a liquid is the temperature at which the pressure of the vapor in the liquid is equal to the external pressure acting on the surface of the liquid. This external pressure is a force pushing down upon a liquid, keeping particles from escaping. Particles require energy to overcome this force. **Heat of vaporization** is the amount of energy required for the liquid at its boiling point to become a gas.

Reading Check ***How does external pressure affect the boiling point of a liquid?***

Gases Fill Their Container What happens to the attractive forces between the particles in a gas? The gas particles are moving so quickly and are so far apart that they have overcome the attractive forces between them. Because the attractive forces between them are overcome, gases do not have a definite shape or a definite volume. The movement of particles and the collisions between them cause gases to diffuse. **Diffusion** is the spreading of particles throughout a given volume until they are uniformly distributed. Diffusion occurs in solids and liquids but occurs most rapidly in gases. For example, if you spray air freshener in one corner of a room, it's not long before you smell the scent all over the room. The particles of gas have moved, collided, and "filled" their container—the room. The particles have diffused. Gases will fill the container that they are in even if the container is a room. The particles continue to move and collide in a random motion within their container.

Science Online

Topic: States of Matter
Visit gpscience.com for Web links to information about states of matter.

Activity Create a slide presentation about the states of matter using the computer and presentation software.

Doug Martin

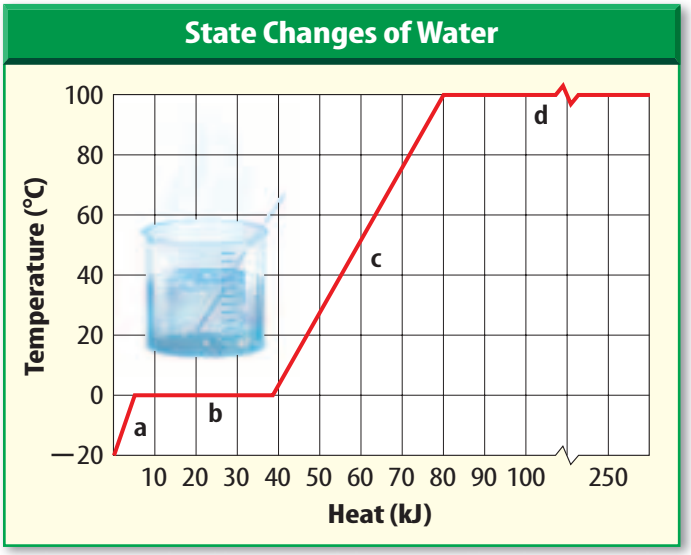


Figure 7 This graph shows the heating curve of water. At **a** and **c** the water is increasing in kinetic energy. At **b** and **d** the added energy is used to overcome the bonds between the particles.

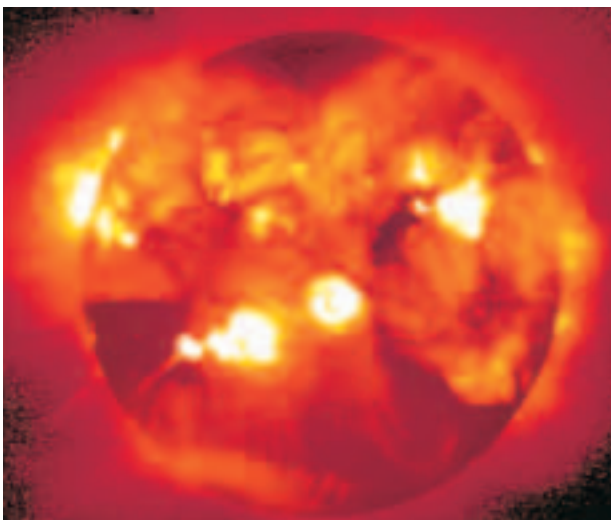
Heating Curve of a Liquid A graph of water being heated from –20°C to 100°C is shown in **Figure 7.** This type of graph is called a heating curve because it shows the temperature change of water as thermal energy, or heat, is added. Notice the two areas on the graph where the temperature does not change. At 0°C, ice is melting. All of the energy put into the ice at this temperature is used to overcome the attractive forces between the particles in the solid. The temperature remains constant during melting. After the attractive forces are overcome, particles move more freely and their average kinetic energy, or temperature, increases. At 100°C, water is boiling or vaporizing and the temperature remains constant again. All of the energy that is put into the water goes to overcoming the remaining attractive forces between the water particles. When all of the attractive forces in the water are overcome, the energy goes to increasing the temperature of the particles.

Reading Check *What is occurring at the two temperatures on the heat curve where the graph is a flat line?*

INTEGRATE Astronomy

Plasma State So far, you've learned about the three familiar states of matter—solids, liquids, and gases. But none of these is the most common state of matter in the universe. Scientists estimate that much of the matter in the universe is plasma. **Plasma** is matter consisting of positively and negatively charged particles. Although this matter contains positive and negative particles, its overall charge is neutral because equal numbers of both charges are present. Recall that on average, particles of matter move faster as the matter is heated to higher temperatures. The faster the particles move the greater the force is with which they collide. The forces produced from high-energy collisions are so great that electrons from the atom are stripped off. This state of matter is called plasma. All of the observed stars including the Sun, shown in **Figure 8,** consist of plasma. Plasma also is found in lightning bolts, neon and fluorescent tubes, and auroras.

Figure 8 Stars including the Sun contain matter that is in the plasma phase. Plasma exists where the temperature is extremely high. **Describe** *the plasma phase.*



Reading Check *What is plasma?*

JISAS/Lockheed/Science Photo Library/Photo Researchers

Thermal Expansion

You have learned how the kinetic theory is used to explain the behavior of particles in different states of matter. The kinetic theory also explains other characteristics of matter in the world around you. Have you noticed the seams in a concrete driveway or sidewalk? A gap often is left between the sections to clearly separate them. These separation lines are called expansion joints. When concrete absorbs heat, it expands. Then when it cools, it contracts. If expansion joints are not used, the concrete will crack when the temperature changes.

Figure 9 As the thermometer is heated, the column of liquid in the thermometer expands. As the temperature cools, the liquid in the thermometer contracts.

Expansion of Matter The kinetic theory can be used to explain this behavior in concrete. Recall that particles move faster and separate as the temperature rises. This separation of particles results in an expansion of the entire object, known as thermal expansion. **Thermal expansion** is an increase in the size of a substance when the temperature is increased. The kinetic theory can be used to explain the contraction in objects, too. When the temperature of an object is lowered, particles slow down. The attraction between the particles increases and the particles move closer together. The movements of the particles closer together result in an overall shrinking of the object, known as contraction.

Expansion in Liquids Expansion and contraction occur in most solids, liquids, and gases. A common example of expansion in liquids occurs in thermometers, as shown in **Figure 9.** The addition of energy causes the particles of the liquid in the thermometer to move faster. The particles in the liquid in the narrow thermometer tube start to move farther apart as their motion increases. The liquid has to expand only slightly to show a large change on the temperature scale.

Expansion in Gases An example of thermal expansion in gases is shown in **Figure 10.** Hot-air balloons are able to rise due to thermal expansion of air. The air in the balloon is heated, causing the distance between the particles in the air to increase. As the hot-air balloon expands, the number of particles per cubic centimeter decreases. This expansion results in a decreased density of the hot air. Because the density of the air in the hot-air balloon is lower than the density of the cooler air outside, the balloon will rise.

Figure 10 Heating the air in this hot-air balloon causes the particles in the air to move apart, creating a lower density inside the balloon.

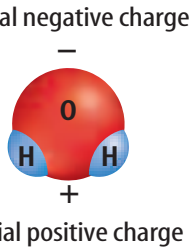


Figure 11 The positively and negatively charged regions on a water molecule interact to create empty spaces in the crystal lattice. These interactions cause water to expand when it is in the solid phase. **Explain** *why ice floats on water.*

The Strange Behavior of Water Normally, substances expand as the temperature rises, because the particles move farther apart. An exception to this rule, however, is water. Water molecules are unusual in that they have highly positive and highly negative areas. **Figure 11** is a diagram of the water molecule showing these charged regions. These charged regions affect the behavior of water. As the temperature of water drops, the particles move closer together. The unlike charges will be attracted to each other and line up so that only positive and negative zones are near each other. Because the water molecules orient themselves according to charge, empty spaces occur in the structure. These empty spaces are larger in ice than in liquid water, so water expands when going from a liquid to a solid state. Solid ice is less dense than liquid water. That is why ice floats on the top of lakes in the winter.

Solid or a Liquid?

Other substances also have unusual behavior when changing states. Amorphous solids and liquid crystals are two classes of materials that do not react as you would expect when they are changing states.

Amorphous Solids Ice melts at 0°C, gold melts at 1,064°C, and lead melts at 327°C. But not all solids have a definite temperature at which they change from solid to liquid. Some solids merely soften and gradually turn into a liquid over a temperature range. There is not an exact temperature like a boiling point where the phase change occurs. These solids lack the highly ordered structure found in crystals. They are known as amorphous solids from the Greek word for "without form."

You are familiar with two amorphous solids—glass and plastics. The particles that make up amorphous solids are typically long, chainlike structures that can get jumbled and twisted instead of being neatly stacked into geometric arrangements. Interactions between the particles occur along the chain, which gives amorphous solids some properties that are very different from crystalline solids.

Liquids do not have an orderly arrangement of particles. Some amorphous solids form when liquid matter changes to solid matter too quickly for an orderly structure to form. One example of this is obsidian—a volcanic glass. Obsidian forms when lava, made of molten rock, cools quickly, such as when it spills into water.

Reading Check *What are two examples of amorphous solids?*

INTEGRATE History

Understanding Unusual Behavior Pierre-Gilles de Gennes, a French physicist, was awarded the 1991 Nobel Prize for Physics for his discoveries about the behavior of molecules in liquid crystals and polymers (plastics). His discoveries led to a better understanding about the behavior and control of these substances.

Liquid Crystals Liquid crystals are another group of materials that do not change states in the usual manner. Normally, the ordered geometric arrangement of a solid is lost when the substance goes from the solid state to the liquid state. Liquid crystals start to flow during the melting phase similar to a liquid, but they do not lose their ordered arrangement completely, as most substances do. Liquid crystals will retain their geometric order in specific directions.

Liquid crystals are placed in classes depending upon the type of order they maintain when they liquefy. They are highly responsive to temperature changes and electric fields. Scientists use these unique properties of liquid crystals to make liquid crystal displays (LCD) in the displays of watches, clocks, and calculators, as shown in **Figure 12.**

Figure 12 Liquid crystals are used in the displays of watches, clocks, calculators, and some notebook computers because they respond to electric fields.

section 1 review

Summary

States of Matter

- The kinetic theory is an explanation of how particles in matter move.
- Thermal energy is the total energy of a material's particles, including kinetic and potential energy.
- Temperature is the average kinetic energy of a substance.
- In most substances, as temperature increases the kinetic energy and disorder of the particles increase.

Thermal Expansion

- Some materials undergo thermal expansion when heated.
- Water expands when it changes from a liquid to a solid.

Solid or a Liquid?

- Amorphous solids have no definite melting point. They liquefy over a temperature range.
- Liquid crystals maintain some geometric order in the liquid state.

Self Check

1. **List** the three basic assumptions of the kinetic theory.
2. **Describe** the movement of the particles in solids, liquids, and gases.
3. **Describe** the movement of the particles at the melting point of a substance.
4. **Describe** the movement of the particles at the boiling point of a substance.
5. **Think Critically** Would the boiling point of water be higher or lower on the top of a mountain peak? How would the boiling point be affected in a pressurized boiler system? Explain.

Applying Math

6. **Interpret Data** Using the graph in **Figure 7,** describe the energy changes that are occurring when water goes from —15°C to 100°C.
7. **Make and Use Graphs** The melting point of acetic acid is 16.6°C and the boiling point is 117.9°C. Draw a graph similar to the graph in **Figure 7** showing the phase changes for acetic acid. Clearly mark the three phases, the boiling point, and the melting point on the graph.

Amanita Pictures

LAB

Thermal Energy Changes in Matter

Thermal energy changes in matter are important in your home, but you may not realize it. Your refrigerator removes thermal energy from warm food and releases it into the room. This process keeps food from spoiling by decreasing the temperature of the food.

Real-World Question

Can a study of thermal energy changes lead to better understanding of matter and energy?

Goals

- **Explain** the thermal energy changes that occur as matter goes from the solid to gas state.

Materials

beakers (2)	wire mesh	hot plate
ring clamp	ice	
ring stand	thermometer	

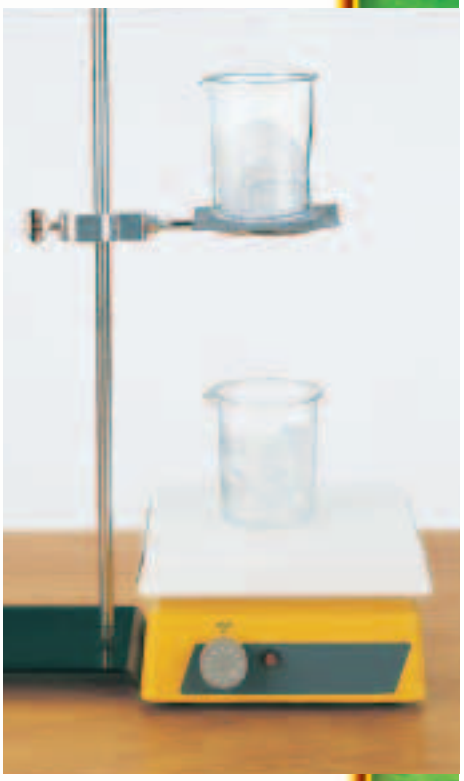
Safety Precautions

Procedure

1. Set up the equipment as pictured. Prepare a data table in your Science Journal.
2. Gently heat the ice in the lower beaker. Every 3 min record your observations and the temperature of the water in the bottom container. Do not touch the thermometer to the bottom or sides of the container.
3. After the ice in the beaker melts and the water begins to boil, observe the system for several more minutes and record your observations.
4. Turn off the heat and let your system completely cool before you clean up.

Conclude and Apply

1. **Draw** a picture of the system used in this lab in your Science Journal. Label the state the water started at in the lower beaker, the state it changed into in the lower beaker, the state above the lower beaker, and the state on the outside of the upper beaker.
2. **Find** the location on the diagram that has the greatest thermal energy and which has the least amount of thermal energy.
3. **Draw** a time-temperature graph using your data from your Science Journal.



Communicating Your Data

Compare your results with other groups in the lab. **For more help, refer to the Science Skill Handbook.**

Matt Meadows

CONTENTS

section 2

Properties of Fluids

Reading Guide

What You'll Learn

- **Explain** Archimedes' principle.
- **Explain** Pascal's principle.
- **Explain** Bernoulli's principle and explain how we use it.

Why It's Important

Properties of fluids determine the design of ships, airplanes, and hydraulic machines.

Review Vocabulary

density: mass per unit volume of a material

New Vocabulary

- buoyancy
- pressure
- viscosity

How do ships float?

Some ships are so huge that they are like floating cities. For example, aircraft carriers are large enough to allow airplanes to take off and land on their decks. Despite their weight, these ships are able to float. This is because a greater force pushing up on the ship opposes the weight—or force—of the ship pushing down. What is this force? This supporting force is called the buoyant force. **Buoyancy** is the ability of a fluid—a liquid or a gas—to exert an upward force on an object immersed in it. If the buoyant force is equal to the object's weight, the object will float. If the buoyant force is less than the object's weight, the object will sink.

Archimedes' Principle In the third century B.C., a Greek mathematician named Archimedes made a discovery about buoyancy. Archimedes found that the buoyant force on an object is equal to the weight of the fluid displaced by the object. For example, if you place a block of wood in water, it will push water out of the way as it begins to sink—but only until the weight of the water displaced equals the block's weight. When the weight of water displaced—the buoyant force—becomes equal to the weight of the block, it floats. If the weight of the water displaced is less than the weight of the block, the object sinks. **Figure 13** shows the forces that affect an object in a fluid.

Reading Check *Why do rocks sink and rubber balls float in a swimming pool?*

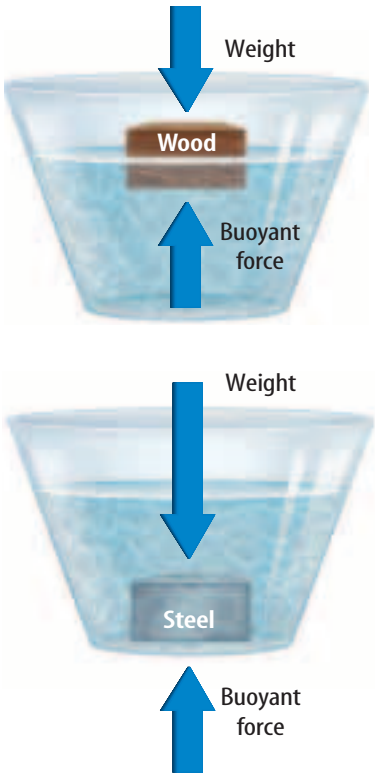


Figure 13 If the buoyant force of the fluid is equal to the weight of the object, the object floats. If the buoyant force of the fluid is less than the weight of the object, the object sinks.

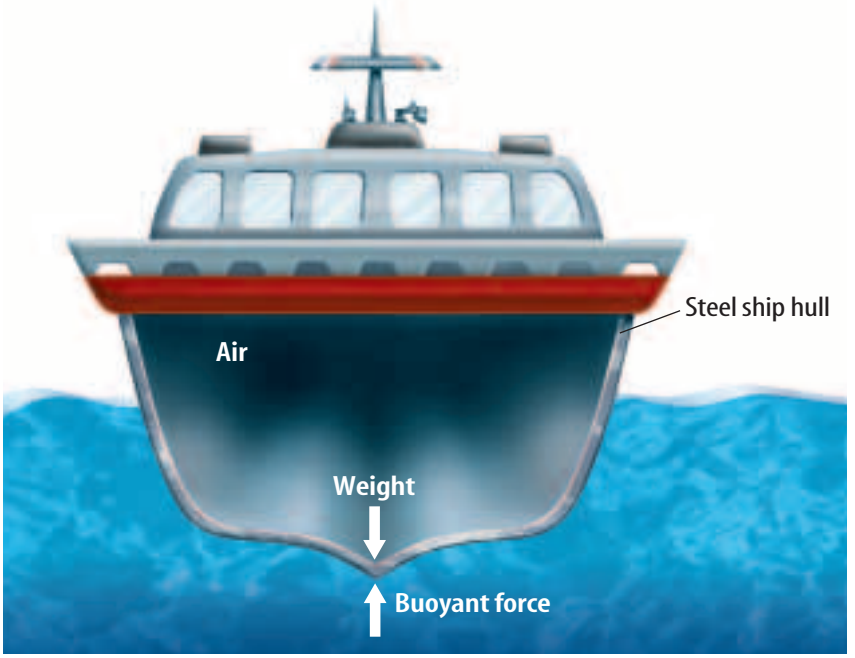


Figure 14 An empty hull of a ship contains mostly air. Its density is much lower than the density of a solid-steel hull. The lower density of the steel and air combination is what allows the ship to float in water. **Explain** *why a boat that takes in water will sink.*

Density Would a steel block the same size as a wood block float in water? They both displace the same volume and weight of water when submerged. Therefore, the buoyant force on the blocks is equal. Yet the steel block sinks and the wood block floats. What is different? The volume of the blocks and the volume of the water displaced each have different masses. If the three equal volumes have different masses, they must have different densities. Remember that density is mass per unit volume. The density of the steel block is greater than the density of water. The density of the wood block is less than the density of water. An object will float if its density is less than the density of the fluid it is placed in.

Suppose you formed the steel block into the shape of a hull filled with air, as in **Figure 14.** Now the same mass takes up a larger volume. The overall density of the steel boat and air is less than the density of water. The boat will now float.

Pascal's Principle

If you are underwater, you can feel the pressure of the water all around you. **Pressure** is force exerted per unit area, or $P=F/A$. Do you realize that Earth's atmosphere is a fluid? Earth's atmosphere exerts pressure all around you.

Blaise Pascal (1623–1662), a French scientist, discovered a useful property of fluids. According to Pascal's principle, pressure applied to a fluid is transmitted throughout the fluid. For example, when you squeeze one end of a balloon, the balloon expands out on the other end. When you squeeze one end of a toothpaste tube, toothpaste emerges from the other end. The pressure has been transmitted through the fluid toothpaste.

Mini LAB

Observing Density and Buoyancy of Substances

Procedure

1. Pour 10 mL of **corn syrup** into a 100-mL beaker. In another **beaker,** add 3 to 4 drops of **food coloring** to 10 mL of **water.** Pour the dyed water into the 100-mL beaker containing corn syrup. Add 10 mL of **vegetable oil** to the beaker.
2. Drop a 0.5-cm square piece of **aluminum foil,** a **steel nut,** and a **whole peppercorn** into the 100-mL beaker.

Analysis

1. Using the concept of density, explain why the contents of the beaker separated into layers.
2. Using the concept of buoyancy, explain why the foil, steel nut, and peppercorn settled in their places.

Applying the Principle Hydraulic machines are machines that move heavy loads in accordance with Pascal's principle. Maybe you've seen a car raised using a hydraulic lift in an auto repair shop. A pipe that is filled with fluid connects small and large cylinders as shown in **Figure 15.** Pressure applied to the small cylinder is transferred through the fluid to the large cylinder. Because pressure remains constant throughout the fluid, according to Pascal's principle, more force is available to lift a heavy load by increasing the surface area. With a hydraulic machine, you could use your weight to lift something much heavier than you are. Do the following activity to see how force, pressure, and area are related.

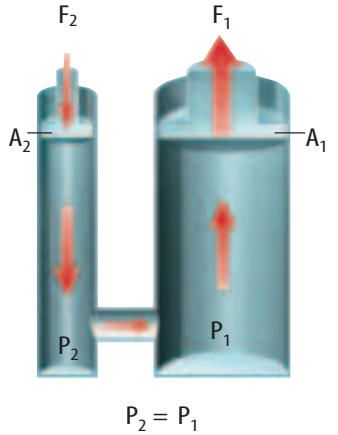


Figure 15 The pressure remains the same throughout the fluid in a hydraulic lift.

Applying Math — Solve a One-Step Equation

CALCULATING FORCES USING PASCAL'S PRINCIPLE A hydraulic lift is used to lift a heavy machine that is pushing down on a 2.8 m^2 piston (A_1) with a force (F_1) of 3,700 N. What force (F_2) needs to be exerted on a 0.072 m^2 piston (A_2) to lift the machine?

IDENTIFY known values and the unknown value

Identify the known values:

The force on piston one is 3,700 N → means → $F_1 = 3{,}700$ N

The area of piston one is 2.8 m^2 → means → $A_1 = 2.8\ m^2$

The area of piston two is 0.072 m^2 → means → $A_2 = 0.072\ m^2$

Identify the unknown value:

What force needs to be exerted? → means → $F_2 = ?$

SOLVE the problem

Substitute the known values $F_1 = 3{,}700$ N, $A_1 = 2.8\ m^2$, and $A_2 = 0.072\ m^2$:

$$P_1 = P_2 = \frac{F_1}{A_1} = \frac{F_2}{A_2}, \text{ then } F_2 = \frac{F_1 A_2}{A_1} = \frac{3{,}700\text{N} \times 0.072\text{m}^2}{2.8\text{m}^2} = 95\ \text{N}$$

In this equation, m^2 is divided by m^2: $\frac{N\,\cancel{m^2}}{\cancel{m^2}} = N$ the result is N, which is the unit for force.

CHECK your answer

Does your answer seem reasonable? Substitute the values for F_1, A_1, F_2, and A_2 back into the original equation. If both sides are equal, the answer is correct.

The value you calculate for F_2 can be used to recalculate one of the known values, F_1, A_1, or A_2. If F_2 is correct, the value you calculate for the known value will be the same as the value given in the problem.

Practice Problems

1. A heavy crate applied a force of 1,500 N on a 25-m^2 piston. What force needs to be exerted on the 0.80-m^2 piston to lift the crate?

For more practice problems, go to page 834, and visit gpscience.com/extra_problems.

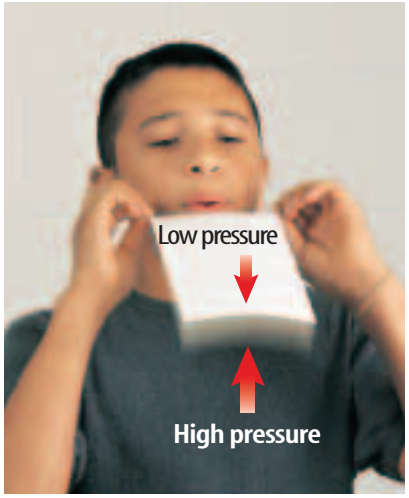


Figure 16 The air above the sheet of paper is moving faster than the air under the paper, creating a low-pressure area above the paper, so the paper rises.

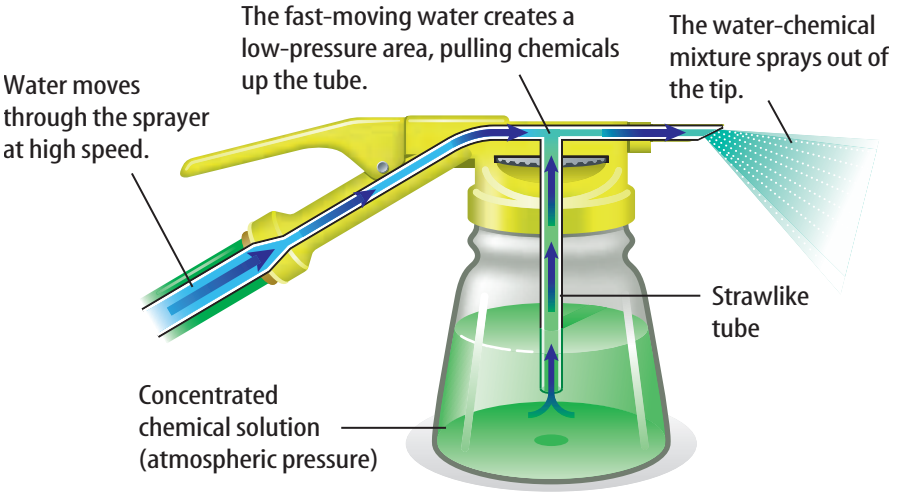
Bernoulli's Principle

Daniel Bernoulli (1700–1782) was a Swiss scientist who studied the properties of moving fluids such as water and air. He published his discovery in 1738. According to Bernoulli's principle, as the velocity of a fluid increases, the pressure exerted by the fluid decreases. One way to demonstrate Bernoulli's principle is to blow across the top surface of a sheet of paper, as in **Figure 16.** The paper will rise. The velocity of the air you blew over the top surface of the paper is greater than that of the quiet air below it. As a result, the air pressure pushing down on the top of the paper is lower than the air pressure pushing up on the paper. The net force below the paper pushes the paper upward. This principle is used today when designing aircraft wings and fluid-transporting piping systems.

Another application of Bernoulli's principle is the hose-end sprayer. This sprayer is used to apply fertilizers, herbicides, and insecticides to yards and gardens. To use this sprayer, a concentrated solution of the chemical that is to be applied is placed in the sprayer. The sprayer is attached to a garden hose, as shown in **Figure 17.** A strawlike tube is attached to the lid of the unit. The end of the tube is submerged into the concentrated chemical. The water to the garden hose is turned to a high flow rate. When you are ready to apply the chemicals to the lawn or plant area, you must push a trigger on the sprayer attachment. This allows the water in the hose to flow at a high rate of speed, creating a low pressure area above the strawlike tube. The concentrated chemical solution is sucked up through the straw and into the stream of water. The concentrated solution is mixed with water, reducing the concentration to the appropriate level and creating a spray that is easy to apply.

Reading Check ***How does pressure change as the velocity of a fluid increases?***

Figure 17 Bernoulli's principle was used in designing the hose-end sprayer.
Define *Bernoulli's principle.*



Fluid Flow

Another property exhibited by fluid is its tendency to flow. The resistance to flow by a fluid is called **viscosity.** Fluids vary in their tendency to flow. For example, when you take syrup out of the refrigerator and pour it, the flow of syrup is slow. But if this syrup were heated, it would flow much faster. Water has a low viscosity because it flows easily. Cold syrup has a high viscosity because it flows slowly.

When a container of liquid is tilted to allow flow to begin, the flowing particles will transfer energy to the particles that are stationary. In effect, the flowing particles are pulling the other particles, causing them to flow, too. If the flowing particles do not effectively pull the other particles into motion, then the liquid has a high viscosity, or a high resistance to flow. If the flowing particles pull the other particles into motion easily, then the liquid has low viscosity, or a low resistance to flow.

Reading Check *How does temperature affect viscosity?*

INTEGRATE Earth Science

Magma and Viscosity
Magma, or liquefied rock from a volcano, is an example of a liquid with varying viscosity. The viscosity of magma depends upon its composition. The viscosity of the magma flow determines the shape of the volcanic cone. In your Science Journal, infer the type of volcano cone that is created with high- and low-viscosity lava flows.

section 2 review

Summary

How do ships float?

- Buoyancy is the ability of a liquid or gas to exert an upward force on an object immersed in it.
- If the buoyant force is equal to the object's weight, the object will float. If the buoyant force is less than the object's weight, the object will sink.

Pascal's Principle

- Pascal's principle says that pressure applied to a fluid is transmitted throughout the fluid.

Bernoulli's Principle

- Bernoulli's principle says that as the velocity of a fluid increases, the pressure exerted by the fluid decreases.

Fluid Flow

- The resistance to flow by a fluid is called viscosity.
- Increasing the temperature increases the rate of energy transfer between the particles. This decreases the resistance to flow, or the viscosity.

Self Check

1. **Describe** the two opposing forces that are acting on an object floating in water.
2. **Explain** how a heavy boat floats on water.
3. **Explain** Use Pascal's principle to explain why squeezing a plastic mustard bottle forces mustard out the top.
4. **Describe,** using Bernoulli's principle, how roofs are lifted off buildings in tornados.
5. **Think Critically** If you fill a balloon with air, tie it off, and release it, it will fall to the floor. Why does it fall instead of float? What would happen if the balloon contained helium?

Applying Math

6. **Find Force** The density of water is 1.0 g/cm^3. How many kilograms of water does a submerged 120-cm^3 block displace? One kilogram has a force of 9.8 N. What is the buoyant force on the block?
7. **Solve an Equation** To lift an object weighing 20,000 N, how much force is needed on a small piston with an area of 0.072 m^2 if the large piston has an area of 2.8 m^2?

section 3

Behavior of Gases

Reading Guide

What You'll Learn

- **Explain** how a gas exerts pressure on its container.
- **Explain** how a gas is affected when pressure, temperature, or volume is changed.

Why It's Important

Being able to explain and to predict the behavior of gases is useful because you live in a sea of air.

Review Vocabulary

temperature: a measure of the average kinetic energy of all the particles in an object

New Vocabulary

- pascal

Pressure

You learned from the kinetic theory that gas particles are constantly moving and colliding with anything in their path. The collisions of these particles in the air result in pressure. Pressure is the amount of force exerted per unit of area.

Often, gases are confined within containers. A balloon and a bicycle tire are considered to be containers. They remain inflated because of collisions the air particles have with the walls of their container, as shown in **Figure 18.** This collection of forces, caused by the collisions of the particles, pushes the walls of the container outward. If more air is pumped into the balloon, the number of air particles is increased. This causes more collisions with the walls of the container, which causes it to expand. Since the bicycle tire can't expand much, its pressure increases.

Pressure is measured in a unit called **pascal** (Pa), the SI unit of pressure. Because pressure is the amount of force divided by area, one pascal of pressure is one Newton per square meter or 1 N/m^2. This is a small pressure unit, so most pressures are given in kilopascals (kPa), or 1,000 pascals. At sea level, atmospheric pressure is 101.3 kPa. This means that at Earth's surface, the atmosphere exerts a force of about 101,300 N on every square meter—about the weight of a large truck. More information about the atmosphere is shown in **Figure 19.** Notice the temperature and pressure differences in the atmosphere as the distance from the surface of Earth increases.

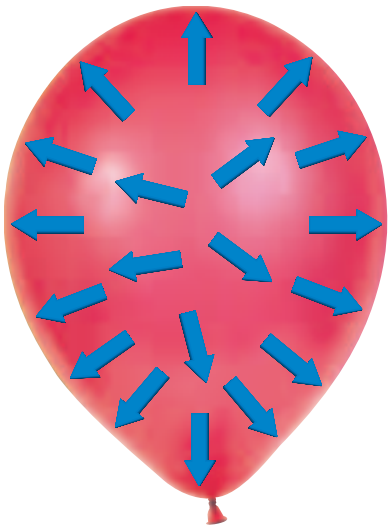


Figure 18 The force created by the many particles in air striking the balloon's walls pushes the wall outward, keeping the balloon inflated.
Explain *why the term pressure can be used to describe these forces.*

Reading Check *How are force, area, and pressure related?*

file photo

CONTENTS

NATIONAL GEOGRAPHIC

VISUALIZING ATMOSPHERIC LAYERS

Figure 19

Earth's atmosphere is divided into five layers. The air gets thinner as distance from Earth's surface increases. Temperature is variable, however, due to differences in the way the layers absorb incoming solar energy.

The Hubble Space Telescope

500 km

Exosphere (on average, 1,100°C; pressure negligible)

Gas molecules are sparse in the exosphere (beyond 500 km). The *Landsat 7* satellite and the *Hubble Space Telescope* orbit in this layer, at an altitude of about 700 km and 600 km respectively. Beyond the exosphere there is nothing but the vacuum of interplanetary space.

The space shuttle crosses all the atmosphere's layers.

Thermosphere (−80°C to 1,000°C; pressure negligible)

Compared to the exosphere, gas molecules are slightly more concentrated in the thermosphere (85–500 km). Air pressure is still very low, however, and temperatures range widely. Light displays called auroras form in this layer over polar regions.

Auroras

The temperature drops dramatically in the mesosphere (50–85 km), the coldest layer. The stratosphere (10–50 km) contains a belt of ozone, a gas that absorbs most of the Sun's harmful ultraviolet rays. Clouds and weather systems form in the troposphere (1–10 km), the only layer in which air-breathing organisms typically can survive.

Meteors

Jets and weather balloons fly in the atmosphere's lowest layers.

85 km

Mesosphere (−80°C to −25°C; 0.3 to 0.01 kPa)

50 km

Ozone Layer

Stratosphere (−55°C to −20°C; 27 to 0.3 kPa)

10 km

0 km

Troposphere (−55°C to 15°C; 100 to 27 kPa)

Figure 20
Balloons are used to measure the weather conditions at high altitudes. These balloons expand as they rise due to decreased pressure. **Describe** *what eventually happens to the balloon.*

Boyle's Law

You now know how gas creates pressure in a container. What happens to the gas pressure if you decrease the size of the container? You know that the pressure of a gas depends on how often its particles strike the walls of the container. If you squeeze gas into a smaller space, its particles will strike the walls more often—giving an increased pressure. The opposite is true, too. If you give the gas particles more space, they will hit the walls less often—gas pressure will be reduced. Robert Boyle (1627–1691), a British scientist, described this property of gases. According to Boyle's law, if you decrease the volume of a container of gas and hold the temperature constant, the pressure of the gas will increase. An increase in the volume of the container causes the pressure to drop, if the temperature remains constant.

The behavior of weather balloons, as shown in **Figure 20,** can be explained using Boyle's law. Rubber or neoprene weather balloons are used to carry sensing instruments to high altitudes to detect weather information. The balloons are inflated near Earth's surface with a low-density gas. As the balloon rises, the atmospheric pressure decreases. The balloon gradually expands to a volume of 30 to 200 times its original size. At some point the expanding balloon ruptures. Boyle's law states that as pressure is decreased the volume increases, as demonstrated by the weather balloon. The opposite also is true, as shown by the graph in **Figure 21.** As the pressure is increased, the volume will decrease.

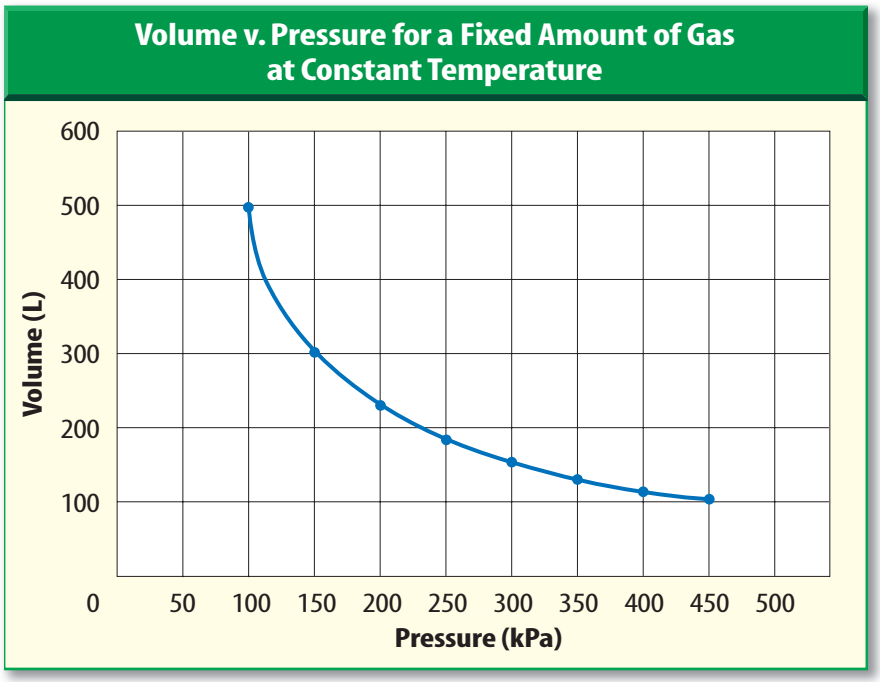


Figure 21 The graph shows that, as pressure increases, volume decreases; as pressure decreases, volume increases.
Use Graphs *What is the volume of the gas at 100 kPa?*

Mark Burnett/Photo Researchers

Boyle's Law in Action When Boyle's law is applied to a real life situation, we find that the pressure multiplied by the volume is always equal to a constant if the temperature is constant. As the pressure and volume change indirectly, the constant will remain the same. You can use the equations P_1V_1 = constant = P_2V_2 to express this mathematically. This shows us that the product of the initial pressure and volume—designated with the subscript 1—is equal to the product of the final pressure and volume—designated with the subscript 2. Using this equation, you can find one unknown value, as shown in the example problem below.

Reading Check *What is $P_1V_1 = P_2V_2$ known as?*

Science Online

Topic: Compressed Gases
Visit gpscience.com for Web links to information about compressed gases.

Activity Make a brochure about the information that you learn. Share the brochure with your class.

Applying Math — Solve a One-Step Equation

USING BOYLE'S LAW A balloon has a volume of 10.0 L at a pressure of 101 kPa. What will be the new volume when the pressure drops to 43.0 kPa?

IDENTIFY known values and the unknown value

Identify the known values:

The initial pressure is 101 kPa. means $P_1 = 101$ kPa

The initial volume is 10.0 L. means $V_1 = 10.0$ L

The final pressure is 43.0 kPa. means $P_2 = 430$ kPa

Identify the unknown value:

What is the new volume? means $V_2 = ?$

SOLVE the problem

Substitute the known values $P_1 = 101$ kPa, $V_1 = 10.0$ L, and $P_2 = 43.0$ kPa into the equation:

$$P_1V_1 = P_2V_2, \text{ then } V_2 = \frac{P_1V_1}{P_2} = \frac{(101\text{ kPa})(10.0\text{ L})}{43.0\text{ kPa}} = 23.5\text{ L}$$

In this equation, kPa is divided by kPa: $\frac{\cancel{\text{kPa}}\text{ L}}{\cancel{\text{kPa}}} = \text{L}$ the result is L, which is the unit for volume.

CHECK your answer

Does your answer seem reasonable? Multiplying the values for P_1 and V_1 gives a pressure of 1010 kPa. Multiplying the values for P_2 and V_2 gives a pressure of 1010.5 kPa. These values are reasonably close and differ because of round-off error. So the calculated volume is correct.

The value you calculate for V_2 can be used to recalculate one of the known values, P_1, V_1, or P_2. If V_2 is correct, the value you calculate for the known value will be the same as the value given in the problem.

Practice Problems

1. A volume of helium occupies 11.0 L at 98.0 kPa. What is the new volume if the pressure drops to 86.2 kPa?

For more practice problems, go to page 834, and visit gpscience.com/extra_problems.

Mini LAB

Observing Pressure

Safety Precautions

Procedure

1. Blow up a **balloon** to about half its maximum size.
2. Place the balloon on a **beaker** filled with **ice water.**

Analysis

1. Explain what happened to the balloon when you placed it on the beaker.
2. If the volume of the half-filled balloon was 0.5 L at a temperature of 298 K, what would the volume of the balloon be if the temperature increased to 358 K?

Try at Home

The Pressure-Temperature Relationship

Have you ever read the words "keep away from heat" on a pressurized spray canister? What happens if you heat an enclosed gas? The particles of gas will strike the walls of the canister more often. Because this canister is rigid, its volume cannot increase. Instead, its pressure increases. If the pressure becomes greater than the canister can hold, it will explode. At a constant volume, an increase in temperature results in an increase in pressure.

Charles's Law

If you've watched a hot-air balloon being inflated, you know that gases expand when they are heated. Because particles in the hot air are farther apart than particles in the cool air, the hot air is less dense than the cool air. This difference in density allows the hot air balloon to rise. Jacques Charles (1746–1823) was a French scientist who studied gases. According to Charles's law, the volume of a gas increases with increasing temperature, as long as pressure does not change. As with Boyle's law, the reverse is true, also. The volume of a gas shrinks with decreasing temperature, as shown in **Figure 22.**

Charles's law can be explained using the kinetic theory of matter. As a gas is heated, its particles move faster and faster and its temperature increases. Because the gas particles move faster, they begin to strike the walls of their container more often and with more force. In the hot-air balloon, the walls have room to expand so instead of increased pressure, the volume increases.

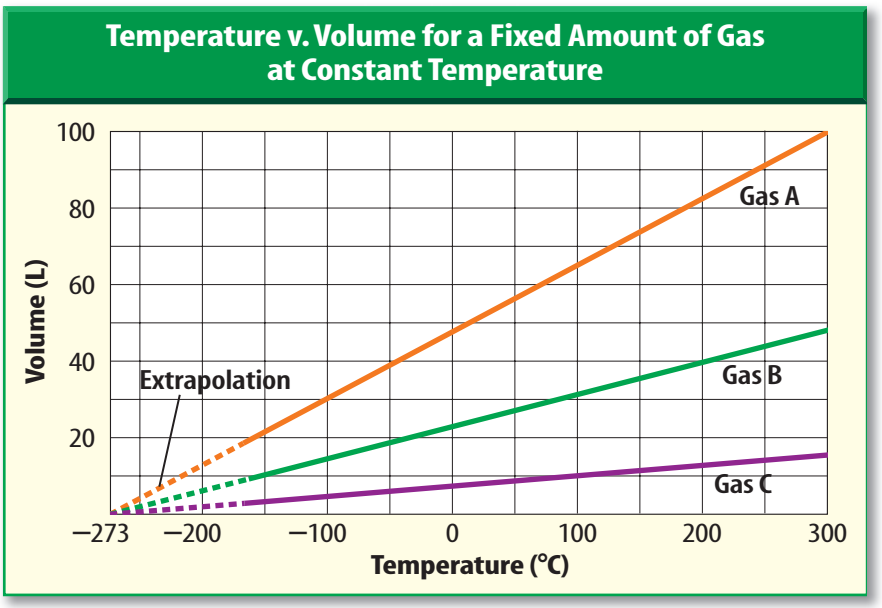


Figure 22 The volume of a gas increases when the temperature increases at constant pressure. **Explain** *how you can determine which gas had the greatest volume change.*

Using Charles's Law The formula that relates the variables of temperature to volume shows a direct relationship, $V_1/T_1 = V_2/T_2$, when temperature is given in kelvin. When using Charles's law, the pressure must be kept constant. What would be the resulting volume of a 2.0-L balloon at 25.0°C that was placed in a container of ice water at 3.0°C, as shown in **Figure 23?**

$$V_1 = 2.0\ \text{L} \qquad T_1 = 25.0°\text{C} + 273 = 298\ \text{K}$$

$$V_2 = ? \qquad T_2 = 3.0°\text{C} + 273 = 276\ \text{K}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \frac{2.0\ \text{L}}{298\ \text{K}} = \frac{V_2}{276\ \text{K}}$$

$$V_2 = \frac{(2.0\ \text{L})(276\ \text{K})}{298\ \text{K}} = 1.9\ \text{L}$$

As Charles's law predicts, the volume decreased as the temperature of the trapped gas decreased. This assumed no changes in pressure.

Reading Check ***According to Charles's law, what happens to the volume of a gas if the temperature increases?***

Figure 23 Charles's law states that as the temperature of a gas is lowered, the volume decreases.
Calculate *If the balloon in the text was placed in a freezer at 5°C, what would be the new volume?*

section 3 review

Summary

Pressure

- Pressure is the amount of force exerted per unit area.
- Pressure is measured in pascals.

Boyle's Law

- Boyle's law states that if the temperature is constant, as the volume of a gas decreases the pressure increases. It states also that at constant temperature, as the volume of a gas increases the pressure decreases.

The Pressure-Temperature Relationship

- This relationship describes how, at a constant volume, the pressure increases with increasing temperature.

Charles's Law

- Charles's law states that at constant pressure, the volume of a gas increases with increasing temperature.

Self Check

1. **Explain** why a gas has pressure.
2. **Describe** Earth's atmosphere at sea level. How does the pressure change as the distance from Earth increases?
3. **Explain,** using Boyle's law, the volume change of an inflated balloon that a diver takes to a pressure of 2 atm.
4. **Explain,** using Charles's law, the purpose of a gas burner on a hot-air balloon.
5. **Think Critically** Labels on cylinders of compressed gases state the highest temperature to which the cylinder may be exposed. Give a reason for this warning.

Applying Math

6. **Find Volume** A helium balloon has a volume of 2.00 L at 101 kPa. As the balloon rises the pressure drops to 97.0 kPa. What is the new volume?
7. **Solve One-Step Equations** If a 5-L balloon at 25°C was gently heated to 30°C, what new volume would the balloon have?

Matt Meadows

LAB

Testing the Viscosity of Common Liquids

Goals

- Observe and compare the viscosity of common liquids.

Materials

room temperature household liquids such as:
- dish detergent
- corn syrup
- pancake syrup
- shampoo
- vegetable oil
- vinegar
- molasses
- water

spheres such as glass marbles or steel balls
100-mL graduated cylinders
150-mL beaker
ruler
stopwatch

Safety Precautions

Dispose of wastes as directed by your teacher.

Real-World Question

The resistance to flow of a liquid is called viscosity, and it can be measured and compared. One example of the importance of a liquid's viscosity is motor oil in car engines. The viscosity of motor oil in your family car is important because it keeps the engine lubricated. It must cling to the moving parts and not run off, leaving the parts dry and unlubricated. If the engine is not properly lubricated, it will be damaged eventually. The motor oil must maintain its viscosity in all types of weather, from extreme heat in the summer to freezing cold in the winter. Can the study of viscosity lead to a better understanding of the properties of matter?

Procedure

1. Measure equal amounts of the liquids to be tested into the graduated cylinders.
2. Measure the depth of the liquid.
3. Copy the data chart into your Science Journal.
4. Place the sphere on the surface of the liquid. Using a stopwatch, measure and record how long it takes for it to travel to the bottom of the liquid.
5. Remove the sphere and repeat step 4 two more times for the same liquid.
6. Rinse and dry the sphere.
7. Repeat steps 4, 5, and 6 for two more liquids.

John Evans

Viscosity of Common Liquids

Substance	Trial	Depth of Liquid (cm)	Time (s)	Speed (cm/s)

Analyze Your Data

1. **Graph** the average speed of the sphere for each liquid on a bar graph.
2. **Interpret Data** In which liquid did the sphere move the fastest? Would that liquid have a high or low viscosity? Explain.

Conclude and Apply

1. **Infer** Would it matter if you dropped or threw the sphere into the liquid instead of placing it there? Explain your answer.
2. **Analyze Results** What effect does temperature play in the viscosity of a liquid? What would happen to the viscosity of your slowest liquid if you made it colder? Explain.
3. **Infer** If the temperature of the liquids is dropped to 10°C, would all of the liquids have an equivalent change in viscosity? Explain your answer.
4. **Explain** Would corn syrup, molasses, or pancake syrup make a good lubricant in a car engine? Explain your answer.

Communicating Your Data

Compare your results with other groups and discuss differences noted. Why might these differences have occurred? **For more help, refer to the Science Skill Handbook.**

SCIENCE Stats

Hot and Cold

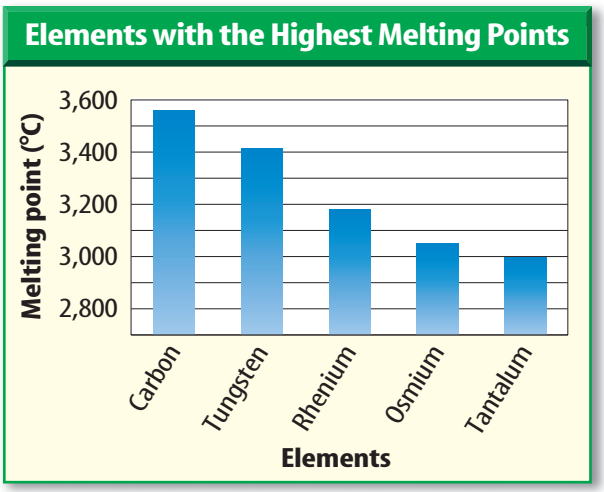
Did you know...

... The world's coldest substance, liquid helium, is about −269°C. It's used in cryogenics research, which is the study of extremely low temperatures. Cryogenics has enabled physicians to freeze and preserve body parts, such as corneas from human eyes. The freezing keeps cells alive until they are needed.

Cryogenics laboratory

Oxyacetylene torch

... The hottest known flame is made by burning a mixture of oxygen and acetylene. The flame of an oxyacetylene torch can become as hot as 3,300°C. That's more than two times hotter than the melting point of steel.



Applying Math

1. In 1983, the temperature dropped to −89°C in Vostok, Antarctica. How many more degrees Celsius would the temperature need to drop for the air to become a liquid?
2. Look at the graph above. List the elements that could be melted by an oxyacetylene torch.

CONTENTS

Reviewing Main Ideas

Section 1 Kinetic Theory

1. Four states of matter exist: solid, liquid, gas, and plasma.
2. According to the kinetic theory, all matter is made of constantly moving particles that collide without losing energy.
3. Most matter expands when heated and contracts when cooled. This expansion joint allows the concrete to expand and contract without damage.

4. Changes of state can be interpreted in terms of the kinetic theory of matter.

Section 2 Properties of Fluids

1. Archimedes' principle states that the buoyant force of an object in a fluid is equal to the weight of the fluid displaced. The buoyant force on this penny was less than its weight, so the penny sank.

2. Pascal's principle states that pressure applied to a fluid is transmitted unchanged throughout the fluid.
3. Bernoulli's principle states that the pressure exerted by a fluid decreases as its velocity increases.

Section 3 Behavior of Gases

1. Gas pressure results from moving particles colliding with the inside walls of the container.
2. The SI unit of pressure is the pascal (Pa). Because this is a small pressure unit, pressures often are given in kilopascals.
3. Boyle's law states that the volume of a gas decreases when the pressure increases at constant temperature.
4. Charles's law states that the volume of a gas increases when the temperature increases at constant pressure.
5. At constant volume, as the temperature of a gas increases, so does the pressure of a gas. The pressure in this cylinder will increase as the sun increases the temperature.

FOLDABLES™ Use the Foldable that you made at the beginning of this chapter to help you review solids, liquids, and gases.

Using Vocabulary

boiling point p. 479	melting point p. 478
buoyancy p. 485	pascal p. 490
diffusion p. 479	plasma p. 480
heat of fusion p. 478	pressure p. 486
heat of vaporization p. 479	thermal expansion p. 481
kinetic theory p. 476	viscosity p. 489

Answer the following questions using complete sentences.

1. What is the property of a fluid that represents its resistance to flow?
2. What is the SI unit of pressure?
3. What term is used to describe the amount of force exerted per unit of area?
4. What is the temperature when a solid begins to liquefy?
5. What theory is used to explain the behavior of particles in matter?
6. What is the ability of a fluid to exert an upward force on an object?

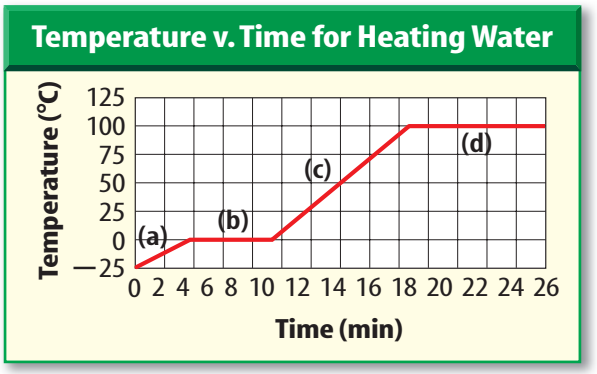
Checking Concepts

Choose the word or phrase that best answers the question.

7. What is the temperature at which all particle motion of matter ceases?
   A) absolute zero **C)** boiling point
   B) melting point **D)** heat of fusion
8. What is the most common state of matter in the universe?
   A) solid **C)** gas
   B) liquid **D)** plasma
9. Which of the following would be used to measure pressure?
   A) gram **C)** kilopascals
   B) newtons **D)** kilograms
10. Which of the following uses Pascal's principle?
    A) aerodynamics **C)** buoyancy
    B) hydraulics **D)** changes of state
11. Which of the following uses Bernoulli's principle?
    A) airplane **C)** skateboard
    B) piston **D)** snowboard
12. The particles in which of the following are farthest apart from each other?
    A) gas **C)** liquid
    B) solid **D)** plasma
13. What is the upward force in a liquid?
    A) pressure **C)** buoyancy
    B) kinetic theory **D)** diffusion
14. What is the amount of energy needed to change a solid to a liquid at its melting point called?
    A) heat of fusion
    B) heat of vaporization
    C) temperature
    D) absolute zero

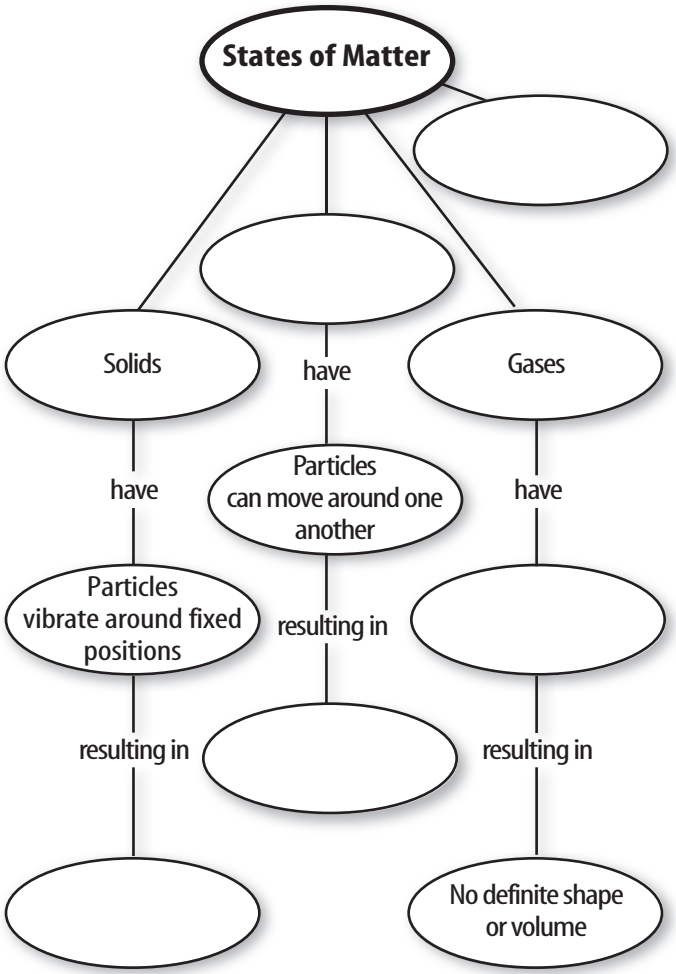
Interpreting Graphics

Use the graph below to answer question 15.



15. A group of students heated ice until it turned to steam. They measured the temperature each minute. Their graph is provided above. Explain what is happening at each letter (a, b, c, d) in the graph.

16. Copy and complete this concept map.



Thinking Critically

17. Explain Use the temperature-pressure relationship to explain why you should check your tire pressure when the temperature changes.

18. Describe the changes that occur inside a helium balloon as it rises from sea level.

19. Explain why aerosol cans have a "do not incinerate" warning.

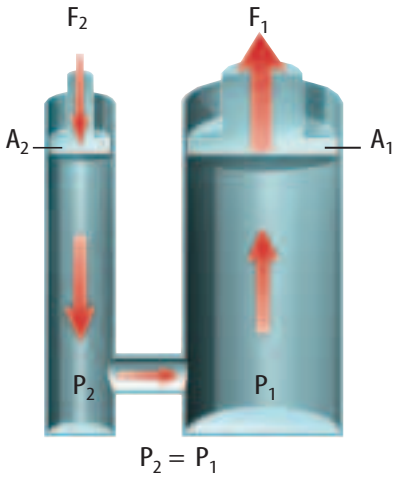
20. Explain The Dead Sea is a solution that is so dense you float on it easily. Explain why you are able to float easily, using the terms *density* and *buoyant force.*

Applying Math

21. Use Numbers As elevation increases, boiling point decreases. List each of the following locations as *at sea level, above sea level,* or *below sea level.* (Boiling point of water is given in parenthesis.)

Death Valley (100.3°C), Denver (94°C), Madison (99°C), Mt. Everest (76.5°C), Mt. McKinley (79°C), New York City (100°C), Salt Lake City (95.6°C)

Use the illustration below to answer question 22.



22. Solve One-Step Equations A hydraulic lift is used to lift a heavy box that is pushing down on a 3.0 m^2 piston (A_1) with a force (F_1) of 1,500 N. What force needs to be exerted on a 0.08 m^2 piston (A_2) to lift the machine?

23. Calculate What would be the resulting volume of a 1.5 L balloon at 25.0°C that was placed in a container of hot water at 90.0°C?

24. Use Numbers A balloon has a volume of 25.0 L at a pressure of 98.7 kPa. What will be the new volume when the pressure is 51.2 kPa?

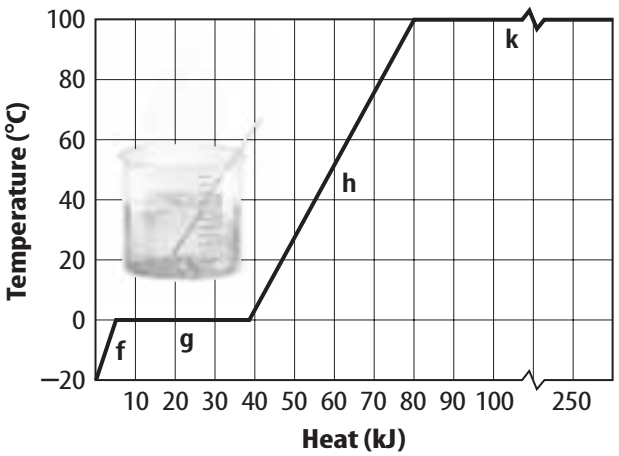
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which state of matter would you expect to find water, at −25°C and 1 atm on Earth?
A. solid **C.** gas
B. liquid **D.** plasma

Use the graph below to answer questions 2 and 3.

State Changes of Water



2. Which points on the graph is water increasing in kinetic energy?
A. F and G **C.** F and H
B. G and K **D.** H and K

3. On which points on the graph is the added energy used to overcome the bonds between particles?
A. F and G **C.** F and H
B. G and K **D.** H and K

4. Which of the following is unlikely to contain plasma?
A. stars **C.** lightning
B. neon lights **D.** water

Test-Taking Tip

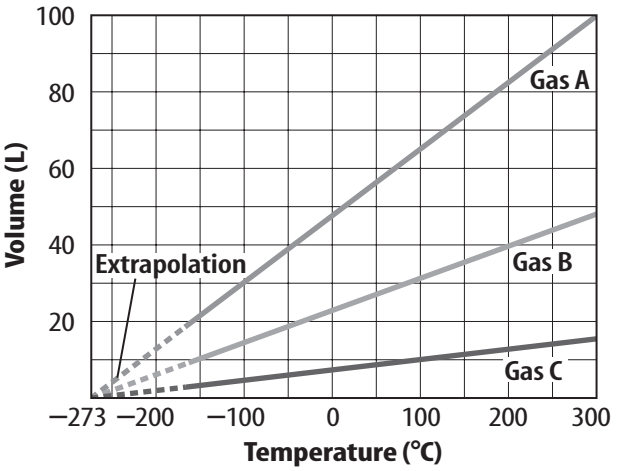
Read Carefully Read all choices before answering the questions.

5. Which term is the amount of energy required for a liquid at its boiling point to become a gas?
A. heat of vaporization
B. diffusion
C. heat of fusion
D. thermal energy

6. In which state of matter do particles stay close together, yet are able to slide past each other?
A. solid **C.** gas
B. liquid **D.** plasma

Use the graph below to answer questions 7 and 8

Gas Characteristics



7. Which of the following statements is true?
A. Gas A had the greatest increase in volume.
B. Gas B had the greatest increase in volume.
C. Gas C had the greatest increase in volume.
D. The gases had the same increase in volume.

8. Approximately what temperature is the volume of Gas B about 40 L^3?
A. 100°C **C.** 200°C
B. 150°C **D.** 300°C

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

9. If you place two wood blocks in water and one sinks while the other floats, what do you know about the densities of the blocks?

Use the illustration below to answer question 10.

10. A weather balloon is inflated near Earth's surface with a low-density gas. Explain why the balloon rises when it is released.

11. Motor oil with a lower viscosity grade flows more easily than oil with a higher viscosity grade. Which grade of oil would be better for cold-weather driving? Explain.

12. The air in a scuba tank is under more than 200 times normal air pressure. Why should a filled scuba tank never be left in a hot car for an extended period of time?

13. A large crate applies a force of 2,500 N to a piston with an area of 25 m^2. What force must be applied to a piston with an area of 5.0 m^2 in order to lift the crate?

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the illustration below to answer questions 14 and 15.

14. Explain why the hot-air balloon can still float in the air when it is carrying a basket filled with people.

15. Explain what will happen when the burner on the hot-air balloon is turned off when the balloon is in the air.

16. Scuba divers often add or remove air from their buoyancy vests to maintain neutral buoyancy. This means they will neither sink to the bottom, nor float to the surface. If the diver takes a deep breath, the diver will rise slightly. When the diver exhales, the diver will sink slightly. Explain why this happens.

17. A penny will sink in a beaker of water, but it will float in a beaker of mercury. Explain how this is possible.

18. Explain the difference between evaporation and boiling.

19. Use the kinetic theory to explain how the temperature and the pressure of a given amount of gas are related.