chapter 4 States of Matter

section 1 Matter

What You'll Learn

- that matter is made of particles that are always moving
- how the particles are arranged in the three states of matter

Before You Read

Think about your classroom. On the lines below, describe some of the things in your classroom that take up space.

_____

_____

Read to Learn

Mark the Text

Identify States of Matter As you read the section, draw a circle around the name of each state of matter. Then underline the definition of each state.

What is matter?

Look around you. Maybe you see a glass of water. Maybe you see books on a shelf. These are examples of matter. **Matter** is anything that takes up space and has mass. You cannot always see matter. For example, air is matter.

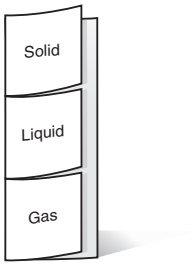
What determines a material's state of matter?

All matter is made up of tiny particles such as atoms, molecules, or ions. Each particle attracts other particles. These particles are always moving. A material's state of matter is determined by the movement of the particles and the strength of attraction between them.

There are four different states, or forms, of matter. They are solid, liquid, gas, and plasma. Plasma only happens at very high temperatures. It is found in stars, lightning, and neon lights and is not common on Earth. This chapter will focus on the three main states of matter—solid, liquid, and gas.

FOLDABLES™

A Find Main Ideas Make the following Foldable to record the main ideas about solids, liquids, and gases. Be sure to include examples.



Solids

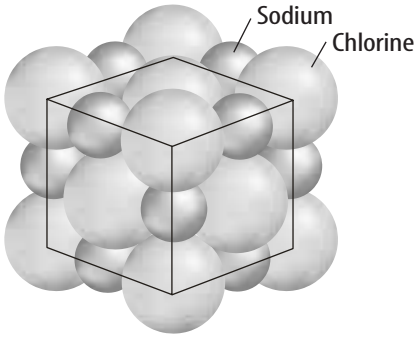
A **solid** is matter with a definite shape and volume. What happens to a rock when you put it in a bucket? It does not change shape or size. A solid does not change to take the shape of the container it is in. This is because the particles of a solid are packed close together.

Do the particles in a solid move?

The particles in all types of matter are always moving. A solid's particles are vibrating in place, however, they do not have enough energy to move out of their fixed positions.

What are crystalline solids?

Some solids have particles arranged in a three-dimensional pattern. This repeating pattern is called a crystal. Solids with this pattern are crystalline solids. Sodium chloride, or table salt, is an example. You can see the arrangement of the particles in sodium chloride in the figure. They are in the shape of a cube. Sugar, sand, and snow are crystalline solids.



What are amorphous solids?

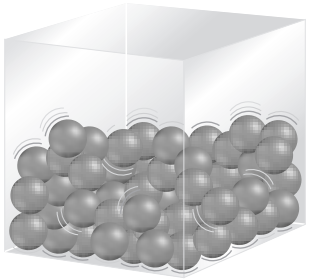
Some solids come together without forming crystals. They are called amorphous (uh MOR fuhs) solids. Their large particles are arranged randomly (in no certain order). Rubber, plastic, and glass are amorphous solids.

Liquids

You use liquids every day. Water is a liquid and so is orange juice. A **liquid** is matter that has a definite volume but no definite shape. A liquid takes the shape of its container but keeps the same volume. What happens if you pour 50 ml of orange juice from a bottle into a glass? You still have the same volume of orange juice, 50 ml, but the shape of the juice changes.

How are particles arranged in a liquid?

The particles in a liquid move more freely than those in a solid. So a liquid can have different shapes. The particles in a liquid have enough energy to move past one another. But they do not have enough energy to move far apart. The figure shows the arrangement of the particles in a liquid.



Liquid

Picture This

1. **Identify** Write the name of an item in the classroom that is close to the same shape as this crystal of sodium chloride.

_____

Reading Check

2. **Describe** Circle the sentence(s) that are true about a liquid.

It can change shape.
It has a definite shape.
Its volume stays the same.

Picture This

3. **Contrast** How are particles in a liquid different from particles in a solid?

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_____

_____

Do all liquids flow like water?

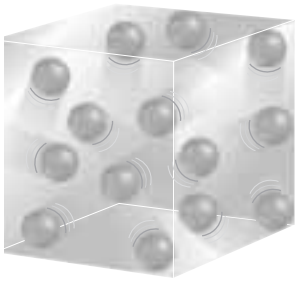
You know that honey flows slower than water. Other liquids do too. Some liquids flow more easily than others. **Viscosity** is how much a liquid resists flowing. The slower a liquid flows, the higher its viscosity. Honey has a high viscosity. It does not flow easily. Water has a low viscosity. It flows very easily. Viscosity describes the attraction between the particles of a liquid. For many liquids, viscosity increases as the liquid becomes colder.

What is surface tension?

Did you know that a needle will float on the surface of water? It floats because the particles on the surface of a liquid pull themselves together and resist being pushed apart. This happens because of the attractive forces between the particles. Particles below the surface of a liquid are pulled in all directions. But particles at the surface of a liquid are pulled toward the center of the liquid and sideways along the surface. There are no particles above to pull on them. **Surface tension** is the uneven forces acting on the particles on the surface of a liquid. Surface tension makes it seem like there is a thin film stretched across the surface of a liquid.

Gases

Gas is matter that does not have a definite shape or volume. The particles in gas are far apart, as shown in the figure. Gas particles move quickly in all directions. They spread out evenly as far apart as possible. A gas will fill the container it is in. A gas can expand or be compressed.



Gas

Think of a balloon filled with air. What happens if you squeeze the air into a smaller part of the balloon? The gas particles get closer together. This happens because you decreased the volume of the container the gas was in. Most gases are invisible. The air you breathe is a mixture of gases.

What is vapor?

Water is a liquid at room temperature. But water can also be a gas. The gas state of water is called water vapor. Vapor is matter that is in the gas state but is usually found as a liquid or solid at room temperature.

Think it Over

4. **Compare** Which has the higher viscosity, mayonnaise or honey?

_____

Reading Check

5. **Determine** Is the following sentence true or false? Particles below the surface of a liquid are pulled in all directions.

_____

Picture This

6. **Describe** the arrangement and movement of the particles in a gas.

_____

_____

_____

After You Read

Mini Glossary

gas: matter that does not have a definite shape or volume

liquid: matter that has a definite volume but no definite shape that can flow

matter: anything that takes up space and has mass

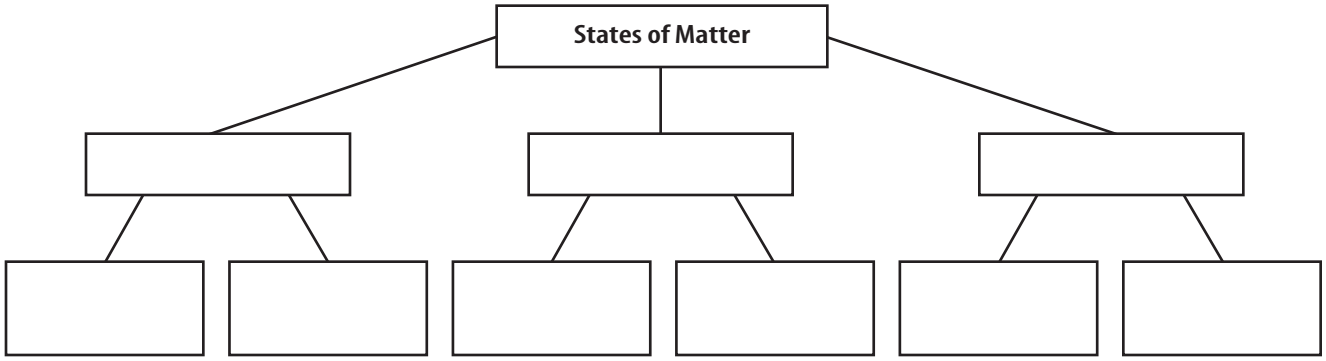
solid: matter with a definite shape and volume

surface tension: the uneven forces acting on the particles on the surface of a liquid

viscosity: how much a liquid resists flowing

1. Read the key terms and definitions in the Mini Glossary above. On the lines below, tell how a solid and a liquid are similar.

2. Complete the chart below. Identify the three main states of matter and give two examples of each.



3. Think of a way of organizing the traits of solids, liquids, and gases to help you remember their characteristics.

End of Section

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chapter 4 States of Matter

section 2 Changes of State

What You'll Learn

- about thermal energy and temperature
- changes in thermal energy and changes of state
- to show changes on a graph

Before You Read

How could you turn an ice cube into water? How could you turn water into an ice cube?

_____

_____

Read to Learn

Thermal Energy and Heat

Imagine a swan ice sculpture. As time passes, drops of water begin to fall from the sculpture. Drip by drip, the swan becomes a puddle of liquid water. What makes matter change from one state to another? To answer this question, you need to think about the particles that make up matter.

How does energy affect particles?

Energy is the ability to do work or cause change. The energy of motion is called kinetic energy. Particles in matter are always moving. How much they move depends on how much kinetic energy they have. Particles with more kinetic energy move faster and farther apart. Particles with less kinetic energy move slower and stay closer together.

What is thermal energy?

Thermal energy is the total kinetic energy of all the particles in a sample of matter. Thermal energy depends on the number of particles in a substance and the amount of energy each particle has. The thermal energy of a substance changes if the number of particles changes. It also changes if the amount of energy each particle has changes. Suppose you have one cup of warm water and one cup of hot water. The hot water has more thermal energy. When you have the same size sample, the warmer substance has more thermal energy.

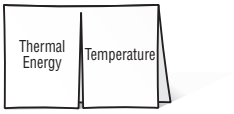
Mark the Text

Highlight Main Ideas As you read, highlight each way that matter can change from one state to another. For example, drops of water falling from an ice sculpture demonstrate a change from a solid to a liquid.

FOLDABLES™

B Compare and Contrast

Make the following Foldable to compare and contrast thermal energy and temperature.



Applying Math

1. **Calculate** What is the average of the following five numbers: 6, 5, 3, 5, 6? Show your work.

What is temperature?

Not all of the particles in a sample have the same amount of energy. Some have more energy than others. **Temperature** is the average kinetic energy of all the particles of a substance. You find an average by adding a group of numbers and dividing the total by the number of items in the group. For example, the average of the numbers 2, 4, 8, and 10 is $(2 + 4 + 8 + 10) \div 4 = 6$. Temperature is different from thermal energy, because thermal energy is a total and temperature is an average.

The iced tea in the figure is colder than the hot tea. In other words, the temperature of the iced tea is lower than the temperature of the hot tea. So the average kinetic energy of the particles in the iced tea is less than the average kinetic energy of the particles in the hot tea.

Particles in Motion

Picture This

2. **Infer** Which tea has more thermal energy?

What is heat?

What happens when you stand close to a fire? You get warm. When a warm object is close to a cooler object, thermal energy moves from the warm object to the cooler one. **Heat** is the movement of thermal energy from a substance at a higher temperature to a substance at a lower temperature. When a substance is heated, it gains thermal energy. This means its particles move faster. The temperature of the substance rises. A substance loses thermal energy when it is cooled. Its particles move more slowly and the temperature of the substance drops.

Think it Over

3. **Predict** On a bright, sunshiny day at the beach, which will heat up more quickly, the water or the sand?

Specific Heat

The specific heat of a substance is the amount of heat needed to raise the temperature of 1 g of the substance 1°C. Substances that have a low specific heat cool down and heat up quickly. They need only small amounts of heat to make their temperatures rise. A substance with a high specific heat cools down and heats up slowly. A larger amount of heat is needed to make its temperature rise or fall. Water has a high specific heat. Most metals and sand have a low specific heat.

Changes Between the Solid and Liquid States

Matter can change from one state to another when thermal energy is absorbed or released. This change is known as change of state.

What is melting?

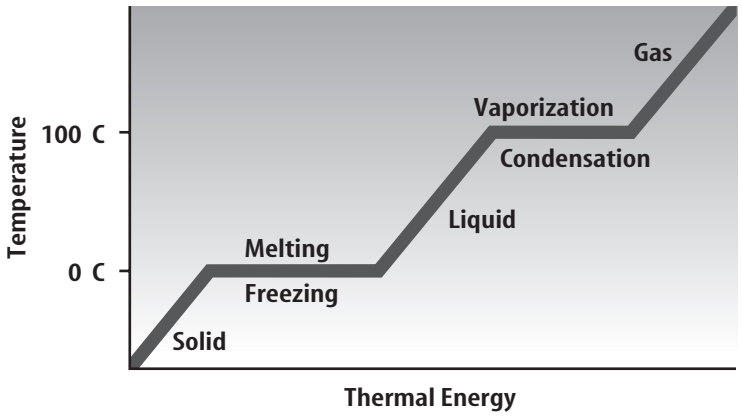
As ice is heated, it absorbs thermal energy. The temperature of the ice rises. At some point, the temperature stops rising. The ice begins to change into liquid water. **Melting** is the change from the solid state to the liquid state. The temperature at which a substance changes from a solid to a liquid is called the melting point. The melting point of water is 0°C.

Amorphous solids melt differently than crystalline solids. Amorphous solids do not have crystal structures to break down. They do not melt into liquids. They simply get softer and softer. For example, glassblowers can shape glass into beautiful vases while it is hot because glass is an amorphous solid.

What is freezing?

A liquid can be changed back into a solid by cooling it. **Freezing** is the change from the liquid state to the solid state. As the liquid cools, it loses thermal energy. Its particles slow down and come closer together. Attractive forces begin to trap particles and crystals form. Freezing and melting are opposite processes.

As you can see in the graph, the temperature at which a substance changes from the liquid state to the solid state is called the freezing point. The freezing point of the liquid state of a substance is the same temperature as the melting point of the solid state. For example, solid water melts at 0°C and liquid water freezes at 0°C.



Think it Over

4. Infer Is an ice cube that is melting gaining or losing thermal energy?

Picture This

5. Reading a Graph Look at the graph. What two processes, besides melting and freezing, happen at the same temperature?

When does the temperature change again?

The temperature of a substance stays the same while it is freezing. Energy is released during freezing because particles in a liquid have more energy than particles in a solid. This energy is released into the surroundings. The temperature of the substance begins to decrease again after all of the liquid has become solid.

Changes Between the Liquid and Gas States

It rained overnight. You and your friends have fun jumping in puddles the next morning. But by afternoon, the puddles are gone. The liquid water in the puddles changed into a gas. Matter changes between the liquid and gas states through vaporization and condensation.

How does a liquid change to a gas?

When liquid water is heated, its temperature rises until it is 100°C. At this point, liquid water changes into water vapor. **Vaporization** is the change from a liquid to a gas. The temperature of a substance does not change during vaporization. But, the substance absorbs thermal energy. This energy makes the particles move faster until they have enough energy to escape the liquid as gas particles.

Vaporization

There are two forms of vaporization. Vaporization below the surface of a liquid is called boiling. When a liquid boils, bubbles within the liquid rise to the surface, as shown in the figure. The temperature at which a liquid boils is called the boiling point.

What is evaporation?

Vaporization at the surface of a liquid is called evaporation. Evaporation happens at temperatures below the boiling point. Evaporation explains how puddles dry up. Imagine that you could see individual water molecules in a puddle. You would see that they move at different speeds. Remember temperature is a measure of the average kinetic energy of the molecules. Some of the molecules that are moving fastest pull away from the attractive forces of the other molecules and escape from the surface of the water.

Picture This

6. **Label** Draw arrows to show the direction of the movement of bubbles in the boiling water.

Reading Check

7. **Name** the two forms of vaporization.

_____

_____

During evaporation, the fastest molecules also must be close to the surface of the liquid. They also have to be moving in the right direction and they have to keep from hitting other molecules as they leave. The particles that are still in the liquid are the slower, cooler ones. Evaporation cools the liquid and anything near the liquid. Evaporation cools you when you sweat. Perspiration evaporates from your skin.

What is condensation?

What happens to a glass of cold lemonade on a hot day? The outside of the glass becomes covered with drops of water. What happened? As a gas cools, its particles slow down. The particles slow down enough for their attractions to bring them together. When the particles come together, they form droplets of liquid. This process is called condensation. **Condensation** is the change from a gas to a liquid. It is the opposite of vaporization.

Reading Check

8. Explain What is the opposite of vaporization?

_____

As a gas condenses to a liquid, it releases the thermal energy that it absorbed when it became a gas. The temperature of the substance does not change during condensation. The decrease in energy changes the arrangement of the particles. After the change of state is complete, the temperature continues to drop.

Condensation formed the water droplets on your glass of lemonade. Condensation also is how rain forms. Water vapor in the atmosphere condenses to make water droplets in clouds. When the droplets are large enough, they fall to the ground as rain.

Changes Between the Solid and Gas States

Some substances can change from the solid state to the gas state without ever becoming a liquid. This process is called sublimation. During sublimation, the particles on the surface of the solid gain enough energy to become a gas.

Reading Check

9. Determine Why are some substances able to go directly from a solid state to a gas state?

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One example of a substance that goes through sublimation is dry ice. Dry ice is the solid form of carbon dioxide. At room temperature and pressure, carbon dioxide is not a liquid. It is a gas. Therefore, as dry ice absorbs thermal energy from the objects around it, it changes directly into a gas. When dry ice becomes a gas, it absorbs thermal energy from water vapor in the air. The loss of thermal energy causes the water vapor to cool and condense into liquid water droplets. This causes fog to form.

After You Read

Mini Glossary

condensation: the change from a gas to a liquid

freezing: the change from the liquid state to the solid state

heat: movement of thermal energy from a substance at a higher temperature to a substance at a lower temperature

melting: the change from the solid state to the liquid state

temperature: the average kinetic energy of all the particles of a substance

thermal energy: the total kinetic energy of all the particles in a sample of matter

vaporization: the change from a liquid to a gas

1. Review the terms and their definitions in the Mini Glossary. How is freezing related to melting?

2. Above each arrow, write the name of the process needed to make the change in states of matter.

3. You were asked to highlight each way that matter can change states. How did highlighting help you to learn the ways?

End of Section

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chapter 4 States of Matter

section 3 Behavior of Fluids

What You'll Learn

- why some things float and others sink
- how pressure is moved through fluids

Before You Read

What happens to a balloon if you keep blowing air into it? On the lines below, describe what happens and why.

_____

_____

_____

Read to Learn

Mark the Text

Locating Information
Underline every heading in the reading that asks a question. Then, highlight the answers to those questions as you find them.

Pressure

Suppose you and your friends want to play volleyball, but the ball is flat. You pump air into the ball until it is firm. The ball is firm because of the movement of the air particles inside the ball. The air particles inside the ball bump into each other and against the walls of the ball. When the particles bump into the walls of the ball, they push with a force on the walls. The force pushes the surface of the ball outward. The forces of all the individual particles add together to make up the pressure of the air inside the ball.

What is pressure?

Pressure is equal to the force put on a surface divided by the total area over which the force is applied.

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

When force is measured in newtons (N) and area is measured in square meters (m^2), pressure is measured in newtons per square meter (N/m^2). This unit of pressure is called a pascal (Pa). A more useful unit when talking about atmospheric pressure is the kilopascal (kPa), which is 1,000 pascals.

Applying Math

1. **Compute** A person standing on one foot is applying a force of 500 N. If the foot covers 100 cm^2, what is the pressure? Show your work.

_____

_____

How are force and area related to pressure?

The formula for pressure tells you that pressure depends on the amount of force and the area over which the force is applied. This means that as the force increases over a given area, pressure increases. If the force decreases in that same area, pressure decreases.

The opposite is true if the force stays the same, but the area over which it is applied changes. If a force is applied to a smaller area, pressure increases. If the same amount of force is spread out over a larger area, pressure decreases.

The figures below show this. The force of the dancer's weight remains the same. However, the area where the force is applied changes. Her pointed toes have less area than her flat feet. So, the pressure of the dancer's weight on pointed toes is greater than the pressure on her flat feet.

Reading Check

2. Explain What happens to pressure when the area decreases but the force stays the same?

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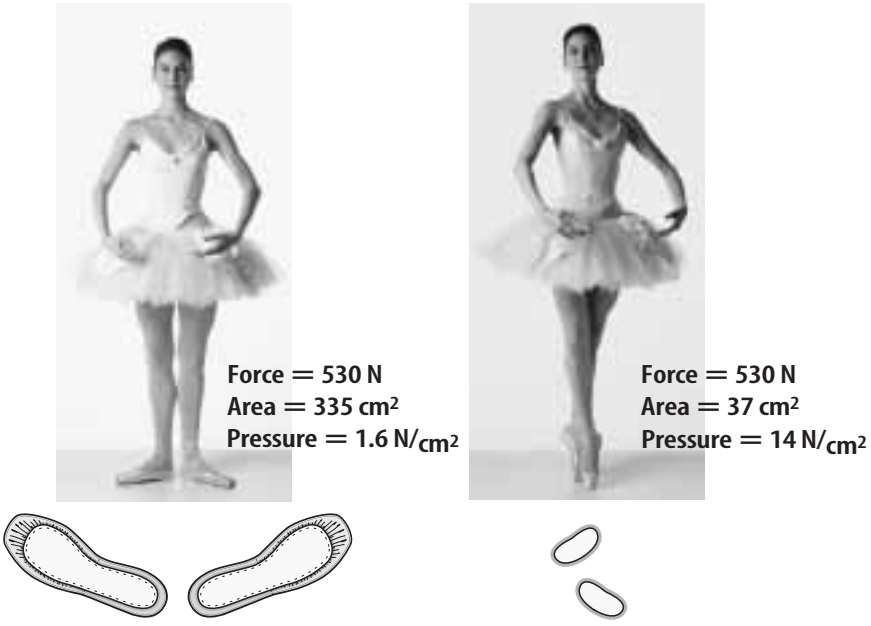
_____

Picture This

3. Identify In the figure, circle the greater area amount. Put a box around the greater pressure amount.



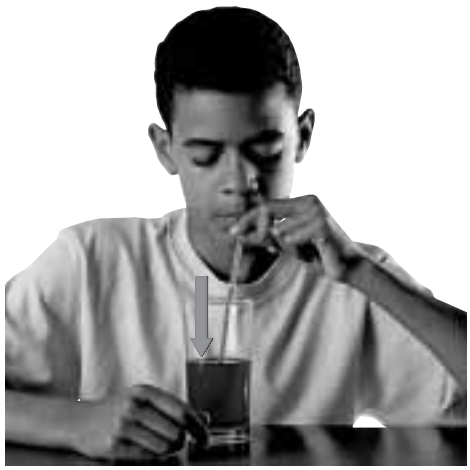
Joshua Ets-Hokin/PhotoDisc

What is atmospheric pressure?

You cannot see it and you usually cannot feel it, but the air around you presses on you with great force. Air pressure on objects is known as atmospheric pressure because air makes up the atmosphere around Earth. Atmospheric pressure is 101.3 kPa at sea level. So, air puts a force of about 101,000 N on every square meter it touches. This is about the weight of a large truck.

How does air pressure help you?

Air pressure helps you. Air pressure allows you to drink from a straw. Look at the figure. When you first suck on a straw, you remove the air from it. Air pressure pushes down on the liquid in your glass and forces it up into the straw. If you tried to drink through a straw in a sealed, airtight container, it would not work. The air would not be able to push down on the surface of the drink.



Richard Hutchings

Why don't you feel the force of air?

You don't feel the force of air because pressure from the fluids in your body balances it. The fluids in your body put an outward pressure on your body. This pressure balances the pressure from the air on the surface of your body.

How does atmospheric pressure change?

Atmospheric pressure changes with altitude. Altitude is the height above sea level. As altitude increases, atmospheric pressure decreases, because there are fewer air particles in a given volume. Since there are fewer particles, they bump into each other less often, and therefore there is less pressure.

A French physician named Blaise Pascal was the first one to test this idea. He partially filled a balloon with air. The balloon was carried to the top of a mountain. The figure shows what happened. The balloon expanded while being carried up the mountain. The amount of air inside the balloon stayed the same. But, the air pressure pushing in on it from the outside decreased. This allowed the particles of air inside the balloon to spread out further.

Picture This

4. Label By the arrow in the figure, write what is pushing down on the liquid in the glass.

Picture This

5. Infer What will happen as the hiker brings the balloon back down the mountain?

_____

_____

How does air pressure affect travelers?

Have you ever been in an airplane? Have you driven up a mountain? If so, you have probably felt a popping sensation in your ears. As the air pressure drops, the air pressure in your ears increases. Soon the air pressure in your ears is greater than the air pressure outside your body. When some air is released from your ears, you hear a pop. This release of air makes the pressure inside and outside your ears the same. The pressure in an airplane is controlled so the pressure does not change greatly during a flight.

Reading Check

6. **Explain** What causes your ears to pop when you are flying?

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Changes in Gas Pressure

The pressure of a gas in closed containers can change just like atmospheric pressure can change. The pressure of a gas in a closed container changes with volume and temperature.

What happens if the volume of a gas in a closed container decreases?

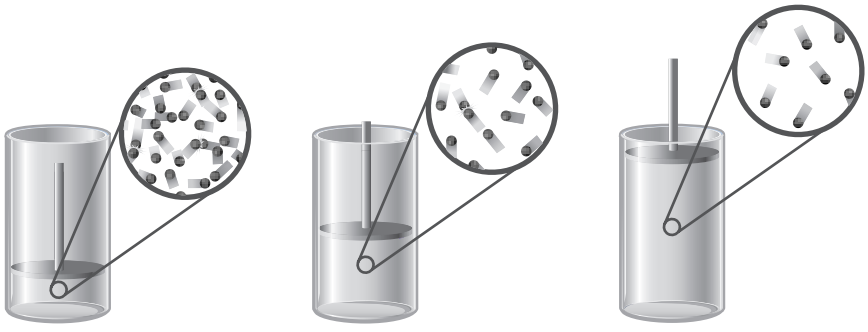
If you squeeze part of a filled balloon, the rest of the balloon gets firmer. When you squeeze a balloon, you decrease its volume. The same number of particles is now in a smaller space. The particles bump into each other and the walls of the container more often. This increases the pressure. Any time you decrease the volume of a space without changing its temperature, pressure increases.

What happens if the volume of a gas increases?

Look at the figures below. They show a piston moving and changing the pressure of the gas particles. If you make a container larger and do not change its temperature, the particles will bump into each other less often. Therefore, the pressure will be less. So, as volume increases, pressure decreases.

Picture This

7. **Interpret** Circle the piston that has the least pressure.



As volume increases, pressure decreases.

How does temperature affect pressure?

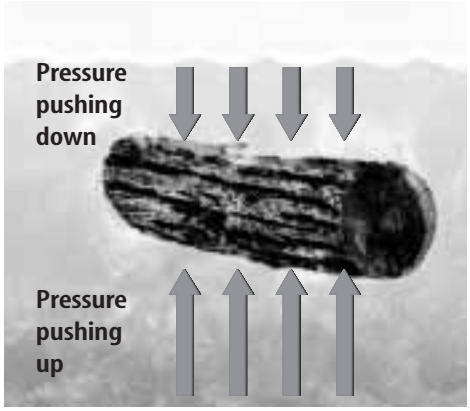
Recall that temperature rises as the kinetic energy of the particles in a substance increases. The greater the kinetic energy, the faster the particles move. The faster the particles move, the more they bump into each other. This makes the pressure greater, even though the volume of the gas stays the same. If the temperature of a gas in a closed container increases, the pressure of the gas also will increase.

Float or Sink

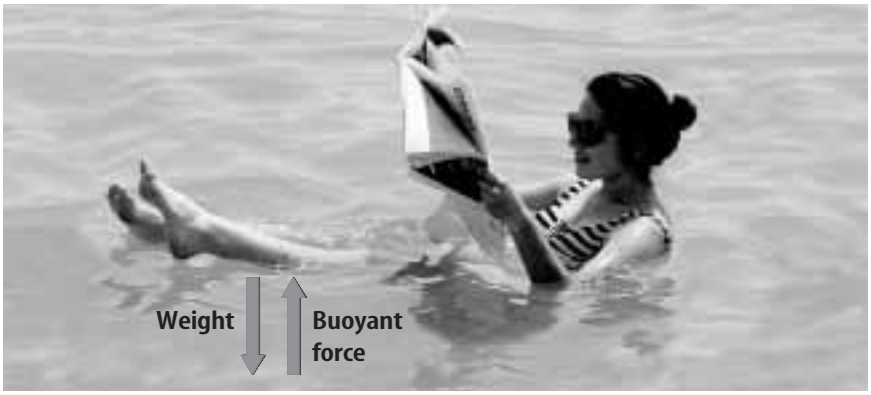
Water pressure pushes on you in all directions when you are under water. Water pressure increases as you go deeper in the water. The pressure pushing up on the bottom of an object becomes greater than the pressure pushing down on it. This is because the bottom of the object is deeper in the water.

What makes an object float in water?

Suppose you throw a small log in a lake. As shown in the figure, the water pressure under the log is greater than the water pressure above the log. This pushes the log up and makes it float. **Buoyant force** is the force that pushes up on an object in a fluid.



Buoyant force cannot make everything float. If the buoyant force is equal to the weight of an object, the object will float like the person shown below. But if the buoyant force is less than the weight of an object, the object will sink.



Picture This

8. Determine In the first figure, why are the arrows under the log longer than the arrows above the log?

_____

_____

_____

Picture This

9. Describe What would happen to the person in the second figure if the weight arrow were longer than the buoyant force arrow?

_____

_____

What is Archimedes' Principle?

What determines the buoyant force? **Archimedes'** (ar kuh MEE deez) **principle** states that the buoyant force of an object is equal to the weight of the fluid removed by the object. Think about a beaker that is filled to the top with water. If you put an object in the beaker, some water will spill out. If you weigh the spilled water, you will find the buoyant force on the object.

What is density?

Understanding density can help you decide if an object will float. **Density** is mass divided by volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

If an object is less dense than the fluid it is in, it will float. If an object is more dense than the fluid it is in, it will sink. What if an object has the same density as the fluid? It will not float or sink. It will stay at the same level in the fluid.

Applying Math

10. Calculate You are given a sample of a solid that has a mass of 12.0 g. Its volume is 4.0 cm^3. What is its density in g/cm^3? Will it float in water? (The density of water is 1.0 g/cm^3.) Show your work.

Pascal's Principle

What happens if you squeeze a plastic container filled with water? If the container is closed, the water has nowhere to go. The pressure in the water increases by the same amount everywhere in the container—not just where you squeeze. **Pascal's principle** states that when a force is applied to a fluid in a closed container, the increase in pressure is moved equally to all parts of the fluid.

How do hydraulic systems work?

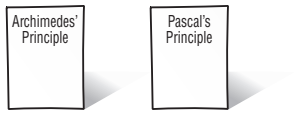
Have you ever wondered how a car is raised and lowered at the mechanic's shop? A device called a hydraulic (hy DRAW lihk) system is used. It uses Pascal's principle to increase force. Look at the figure of the hydraulic lift on the next page. There is a downward force on the piston on the left. This increases the pressure in the fluid in the tube. The increased pressure is moved to the piston on the right. Why is the piston on the right able to lift the car? Recall that pressure is equal to force divided by area.

$$\text{pressure} = \frac{\text{force}}{\text{area}} \text{ or } \text{force} = \text{pressure} \times \text{area}$$

FOLDABLES™

Organize Information

Write down information about Archimedes' and Pascal's principles on two quarter sheets of paper.

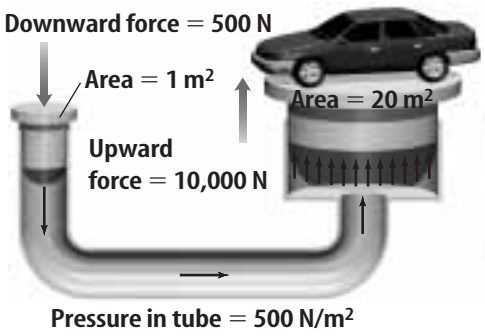


Reading Check

11. Identify What does a hydraulic system increase using Pascal's principle?

Greater Area If the two pistons on the tube have the same area, the force on both pistons will be the same. But the piston on the right has a greater surface area. If you multiply the same pressure by a larger area, the force is greater. So the force on the right will be greater.

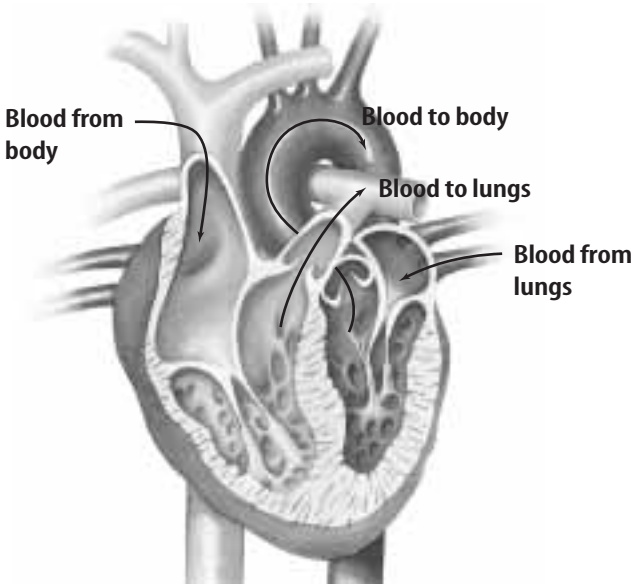
Hydraulic Lift



What are force pumps?

If you punch a hole in the top of a closed milk carton, the milk is pushed out the hole when you squeeze the carton. This is known as a force pump. A force pump makes it possible to squeeze toothpaste out of a tube.

A heart has two force pumps. One force pump pushes the blood from the heart to the lungs. The blood picks up oxygen in the lungs and returns to the heart. Another force pump pushes the blood with oxygen in it to the rest of the body. The two force pumps in a heart are shown below.



Picture This

12. Calculate How many times greater is the upward force on the car than the downward force on the piston? (Hint: Divide the upward force by the downward force.)

a. 5
b. 10
c. 20
d. 25

Picture This

13. Interpreting Diagrams Use a highlighter to trace the path of the blood as it enters and leaves the heart. Start where the blood comes in from the body.

After You Read

Mini Glossary

Archimedes' principle: the buoyant force of an object is equal to the weight of the fluid removed by the object

buoyant force: the force that pushes up on an object that is in a fluid

density: mass divided by volume

Pascal's principle: when a force is applied to a fluid in a closed container, the increase in pressure is moved equally to all parts of the fluid

pressure: the force put on a surface divided by the total area over which the force is applied

1. Review the terms and their definitions in the Mini Glossary. Rewrite Archimedes' principle in your own words.

2. Complete the table by circling whether pressure increases or decreases as a result of the event.

Event	Pressure
Force increases	increases / decreases
Force decreases	increases / decreases
Area over which force is applied increases	increases / decreases
Volume decreases	increases / decreases
Temperature increases	increases / decreases

3. You were asked to highlight the answers to the headings that were questions as you read. How did this help you make sure you understood the main ideas of the heading?

End of Section

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