States of Matter

- Can you identify the states of matter present in the photo shown?

Kinetic Theory

- The **kinetic theory** is an explanation of how particles in matter behave.

Kinetic Theory

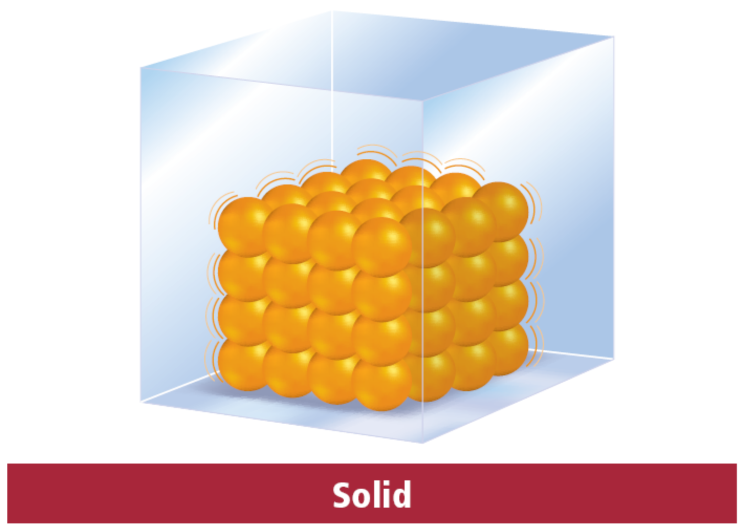
- The three assumptions of the kinetic theory are as follows:
    - All matter is composed of small particles (atoms, molecules, and ions).
    - These particles are in constant, random motion.
    - These particles are colliding with each other and the walls of their container.

Kinetic Theory

- 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.

Thermal Energy

- 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

- 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.

Average Kinetic Energy

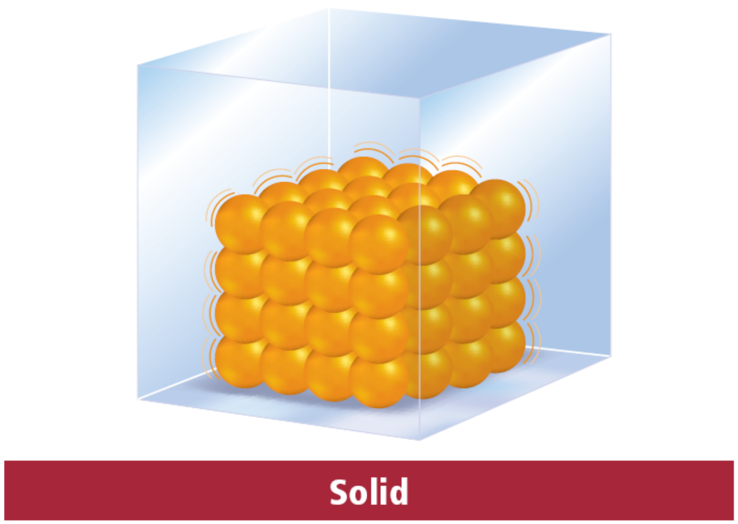
- In science, temperature means the average kinetic energy of particles in the substance, or how fast the particles are moving.
- On average, molecules of frozen water at 0°C will move slower than molecules of water at 100°C.

Average Kinetic Energy

- Water molecules at 0°C have lower average kinetic energy than the molecules at 100°C.
- Molecules have kinetic energy at all temperatures, including absolute zero.

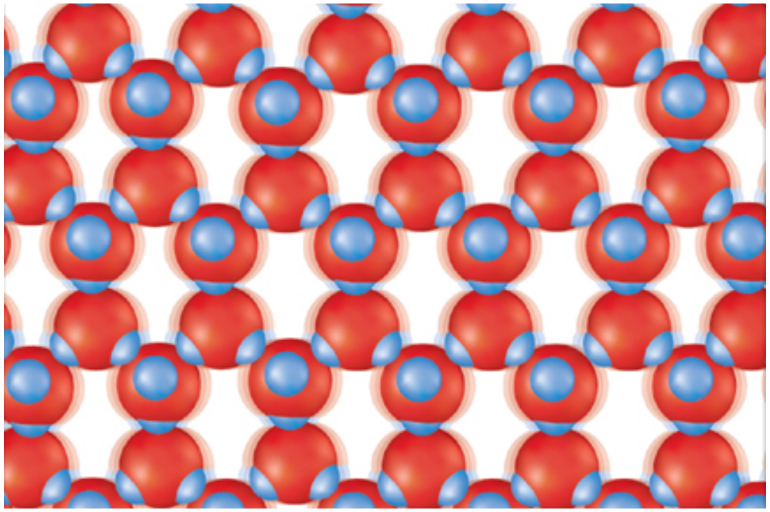
Solid State

- The particles of a solid are closely packed together.
- Most solid materials have a specific type of geometric arrangement in which they form when cooled.



Solid State

- 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.



Liquid State

- What happens to a solid when thermal energy or heat is added to it?
- The particles on the surface of the solid vibrate faster.
- These particles collide with and transfer energy to other particles.
- Soon the particles have enough kinetic energy to overcome the attractive forces.

Liquid State

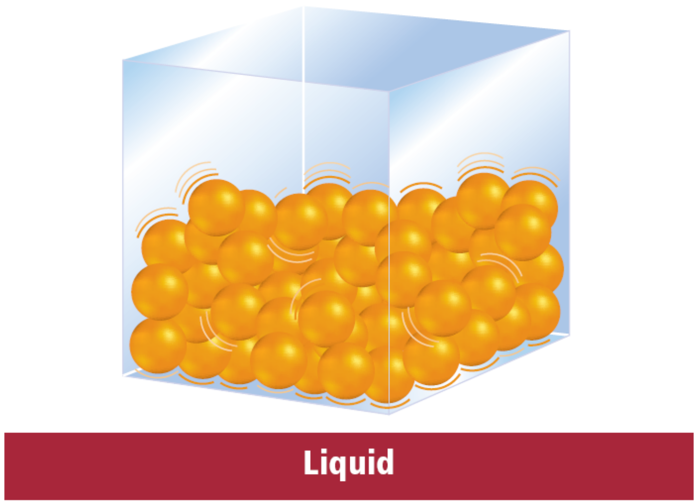
- The particles gain enough kinetic energy to slip out of their ordered arrangement and the solid melts.
- This is known as the **melting point**, or the temperature at which a solid begins to liquefy.
- Energy is required for the particles to slip out of the ordered arrangement.

Liquid State

- 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**.
- Particles in a liquid have more kinetic energy than particles in a solid.

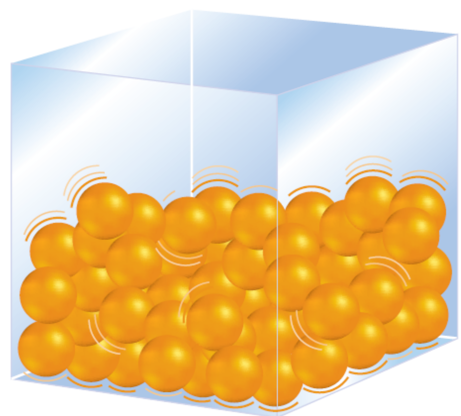
Liquid Flow

- This extra kinetic energy allows particles to partially overcome the attractions to other particles.
- The particles can slide past each other, allowing liquids to flow and take the shape of their container.



Liquid Flow

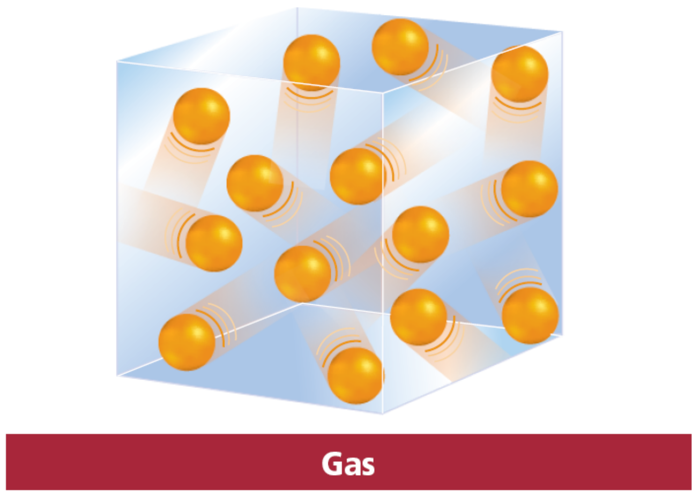
- However, the particles in a liquid have not completely overcome the attractive forces between them
- This causes the particles to cling together, giving liquids a definite volume.



Liquid

Gas State

- 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.



Gas State

- How does a liquid become a gas?
- The particles in a liquid are constantly moving.

Gas State

- 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.

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.

Gas State

- 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 State

- Unlike evaporation, boiling occurs throughout a liquid at a specific temperature depending on the pressure on the surface of the liquid.
- 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.

Click image to view movie

Gas State

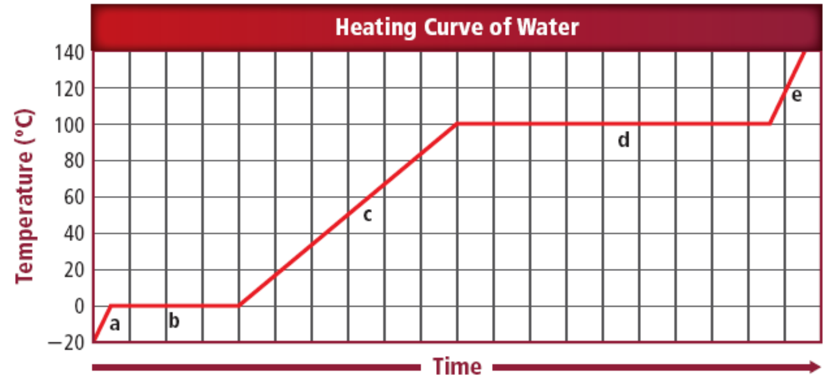
- **Heat of vaporization** is the amount of energy required for the liquid at its boiling point to become a gas.

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.
- **Diffusion** is the spreading of particles throughout a given volume until they are uniformly distributed.

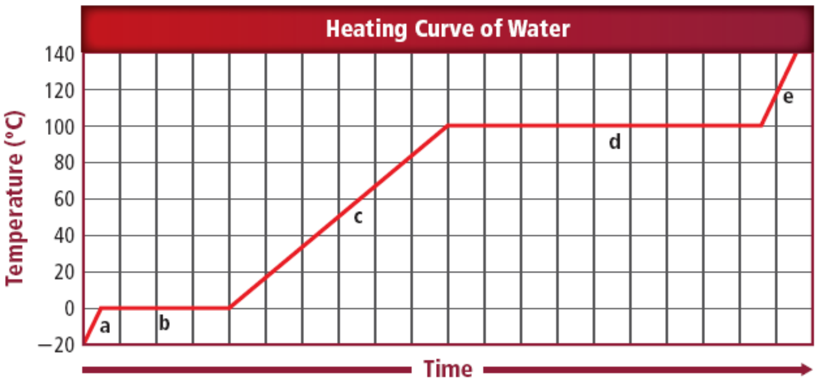
Heating Curve of a Liquid

- 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.



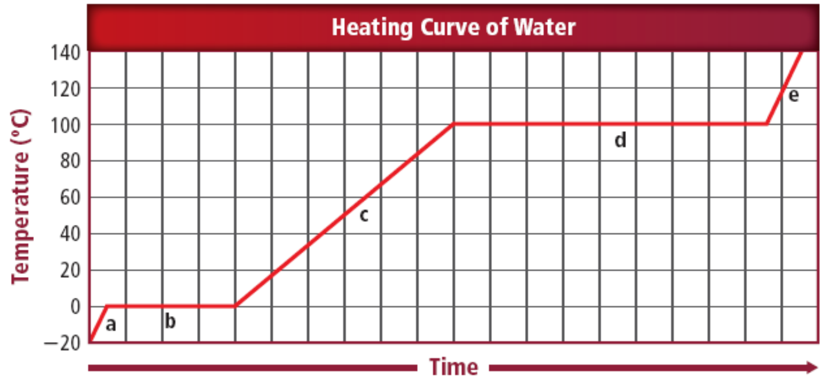
Heating Curve of a Liquid

- The temperature remains constant during melting.
- After the attractive forces are overcome, particles move more freely and their average kinetic energy, or temperature, increases.



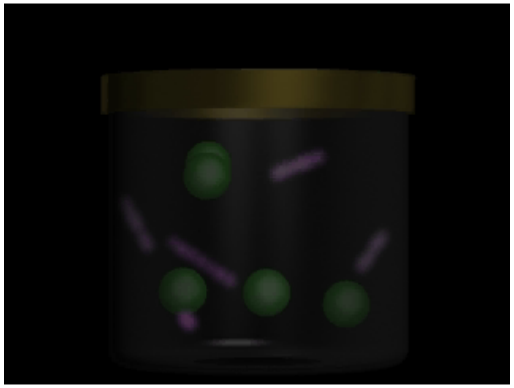
Heating Curve of a Liquid

- At 100°C, water is boiling or vaporizing and the temperature remains constant again.



Plasma State

- 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.



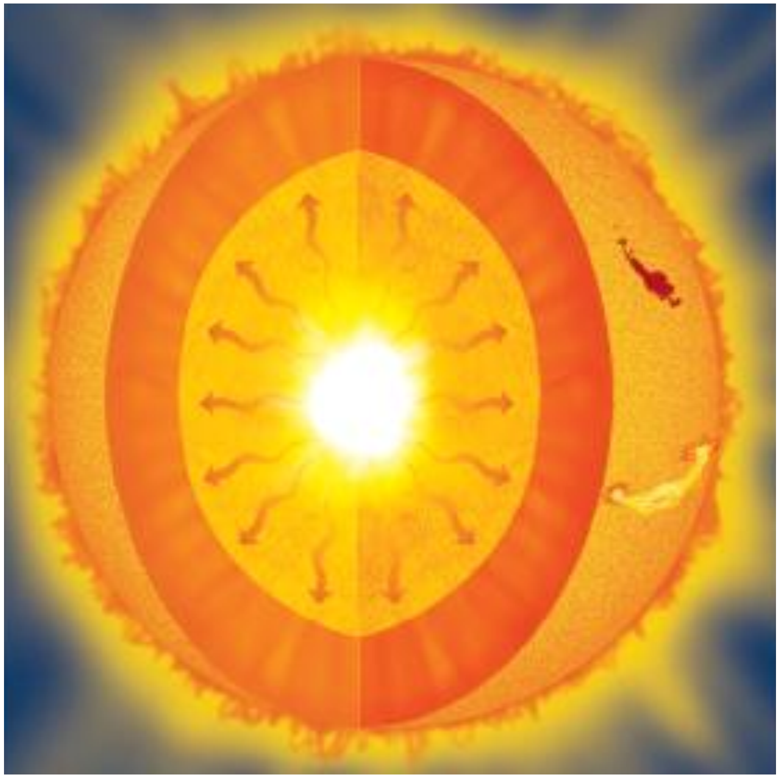
Click image to view movie

Plasma State

- 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.

Plasma State

- All of the observed stars including the Sun consist of plasma. Plasma also is found in lightning bolts, neon and fluorescent tubes, and auroras.



Expansion of Matter

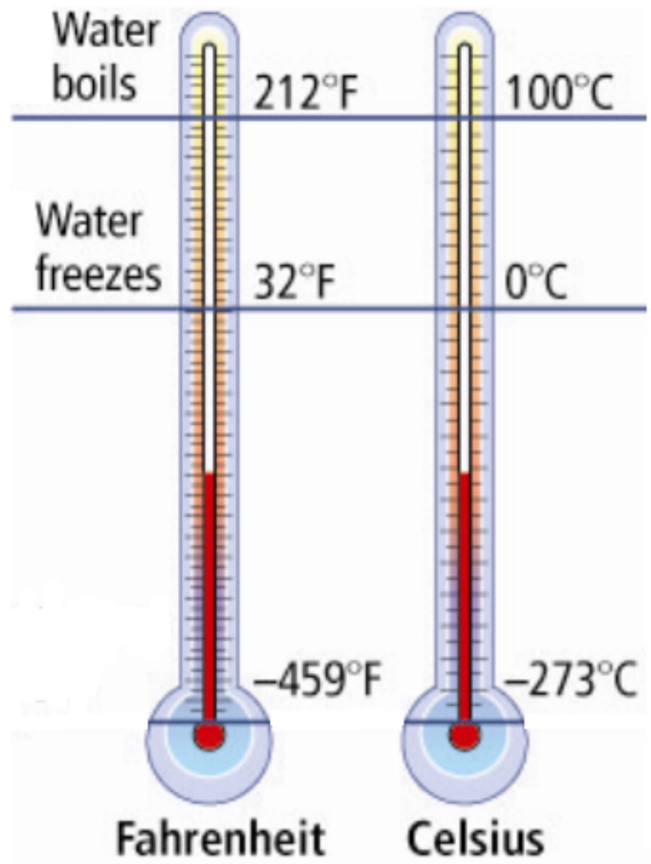
- Particles move faster and separate as the temperature rises. This separation of particles results in an expansion of the entire object, known as thermal expansion.
- **Thermal expansion** is an increase in the size of a substance when the temperature is increased.

Expansion of Matter

- 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.

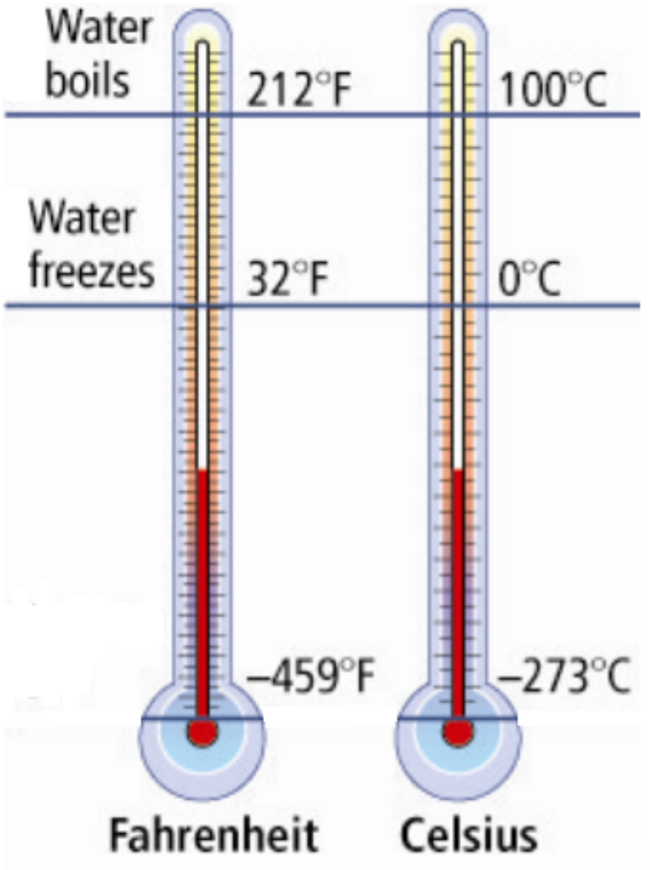
Expansion in Liquids

- A common example of expansion in liquids occurs in thermometers.
- The addition of energy causes the particles of the liquid in the thermometer to move faster.



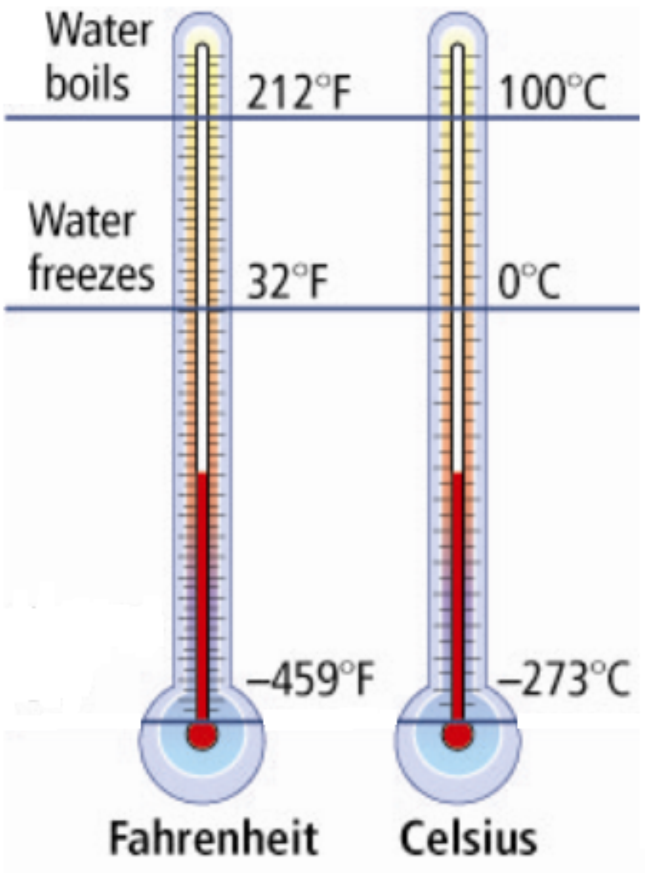
Expansion in Liquids

- The particles in the liquid in the narrow thermometer tube start to move farther apart as their motion increases.



Expansion in Liquids

- The liquid has to expand only slightly to show a large change on the temperature scale.

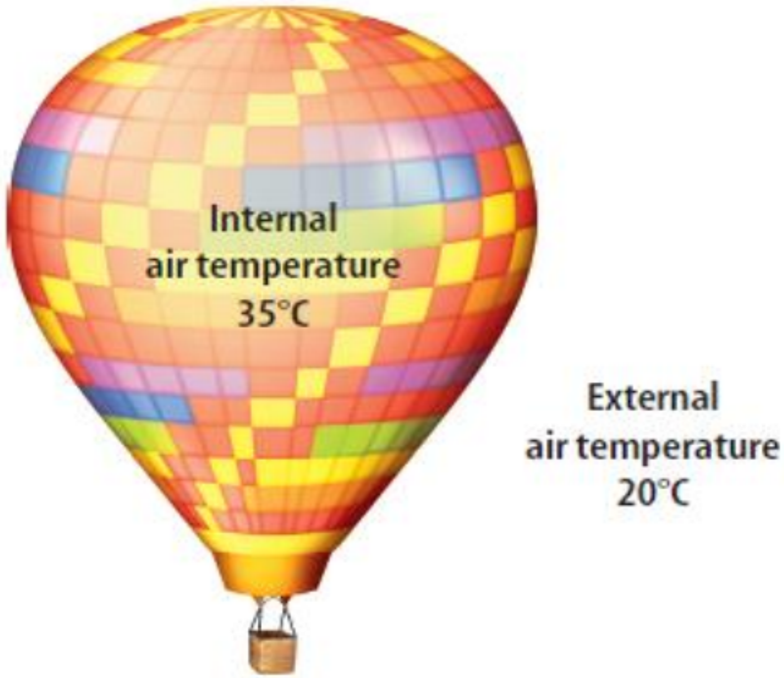


Expansion in Gases

- 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.

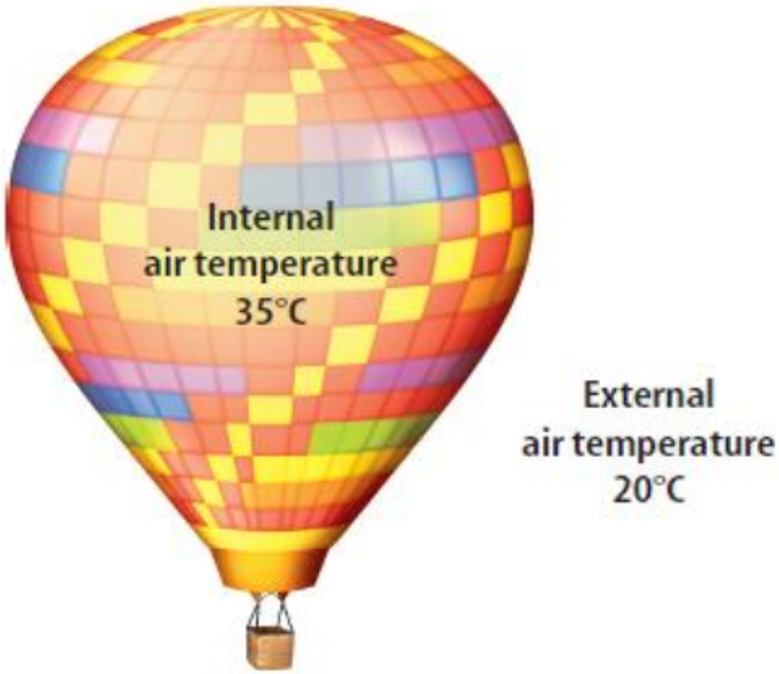
Expansion in Gases

- As the hot-air balloon expands, the number of particles per cubic centimeter decreases.



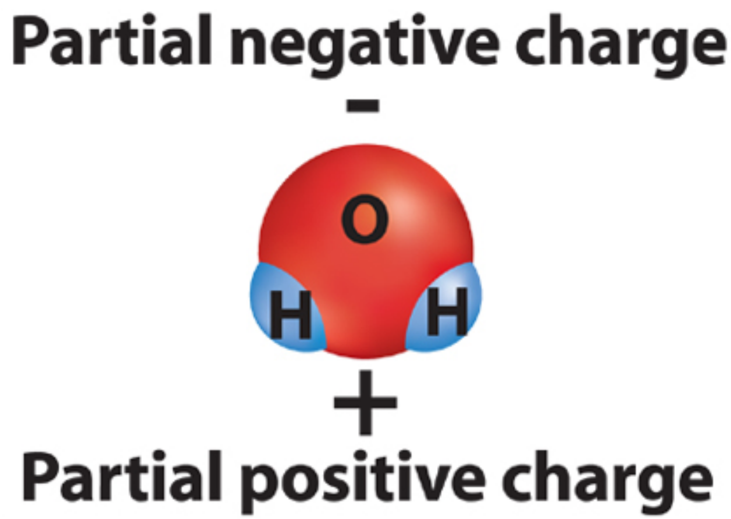
Expansion in Gases

- This expansion results in a decreased density of the hot air. The density of the air in the hot-air balloon is lower than the density of the cooler air outside, which allows the balloon will rise.



The Strange Behavior of Water

- Water molecules are unusual in that they have highly positive and highly negative areas.
- These charged regions affect the behavior of water.
- As the temperature of water drops, the particles move closer together.



The Strange Behavior of Water

- 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 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

- 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.
- These solids lack the highly ordered structure found in crystals
- They are known as amorphous solids from the Greek word for “without form.”

Amorphous Solids

- The particles that make up amorphous solids are typically long, chainlike structures that can be jumbled and twisted instead of being neatly stacked into geometric arrangements.
- 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.

Amorphous Solids

- One example of this is obsidian—a volcanic glass. Obsidian forms when lava cools quickly, such as when it spills into water.

Liquid Crystals

- Liquid crystals are another group of materials that do not change states in the usual manner.
- 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

- 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.

How do ships float?

- Despite their weight, 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.

How do ships float?

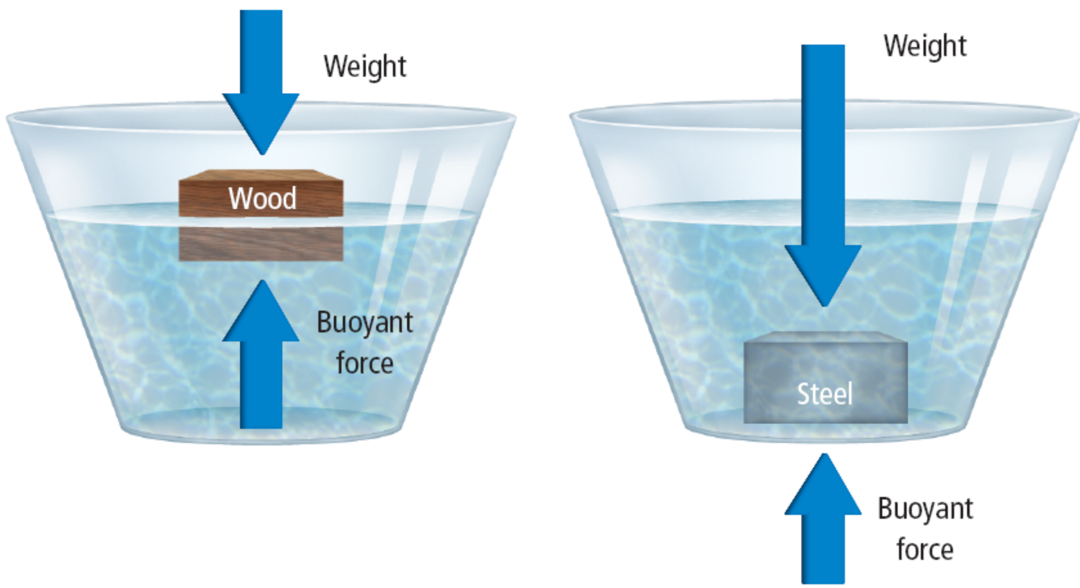
- This supporting force is called the buoyant force.
- **Buoyancy** is the ability of a fluid—a liquid or a gas—to exert an upward force on an object immersed in it.
- If the buoyant force is less than the object’s weight, the object will sink.

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.

Density

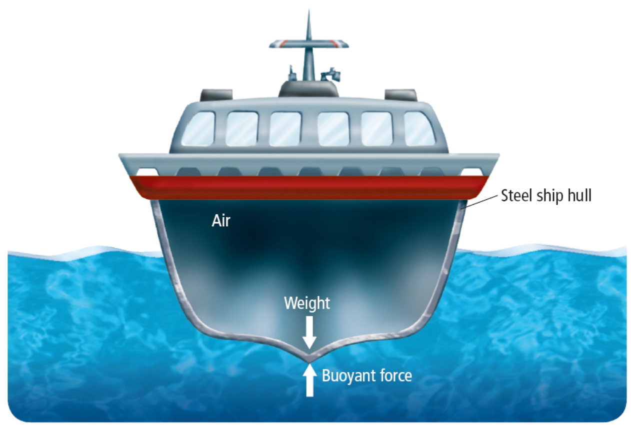
- An object will float if its density is less than the density of the fluid it is placed in.



Properties of Fluids

Density

- Suppose you form a steel block into the shape of a hull filled with air. The steel has the same mass but 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

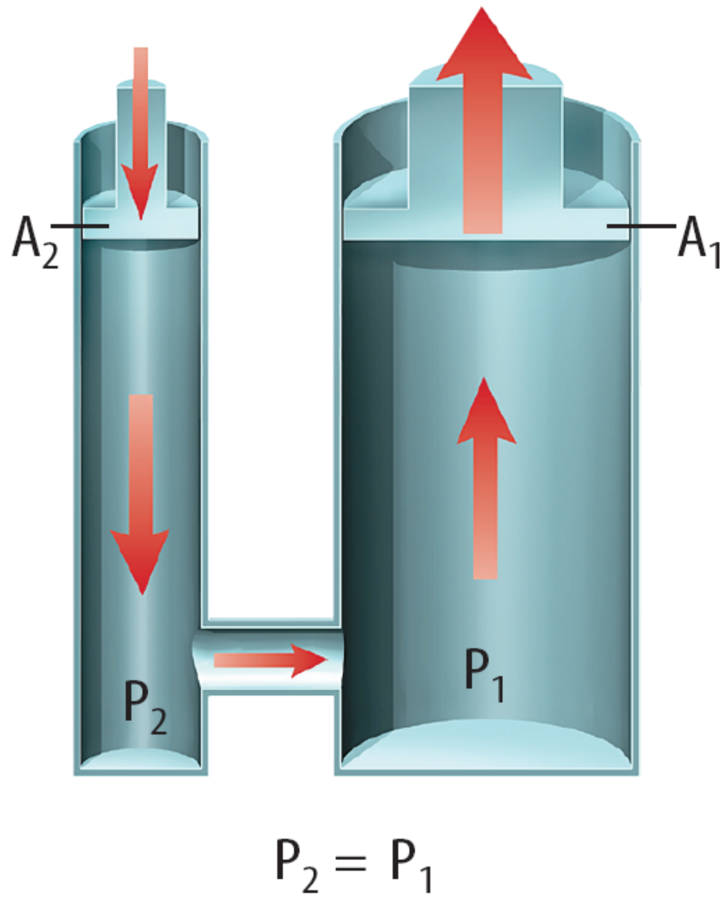
- **Pressure** is force exerted per unit area.
- Blaise Pascal (1692-1662), a French scientist, discovered a useful property of fluids.
- According to Pascal's principle, pressure applied to a fluid is transmitted throughout the fluid.

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.

Applying the Principle

- A pipe that is filled with fluid connects small and large cylinders.



Applying the Principle

- 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.

Bernoulli's Principle

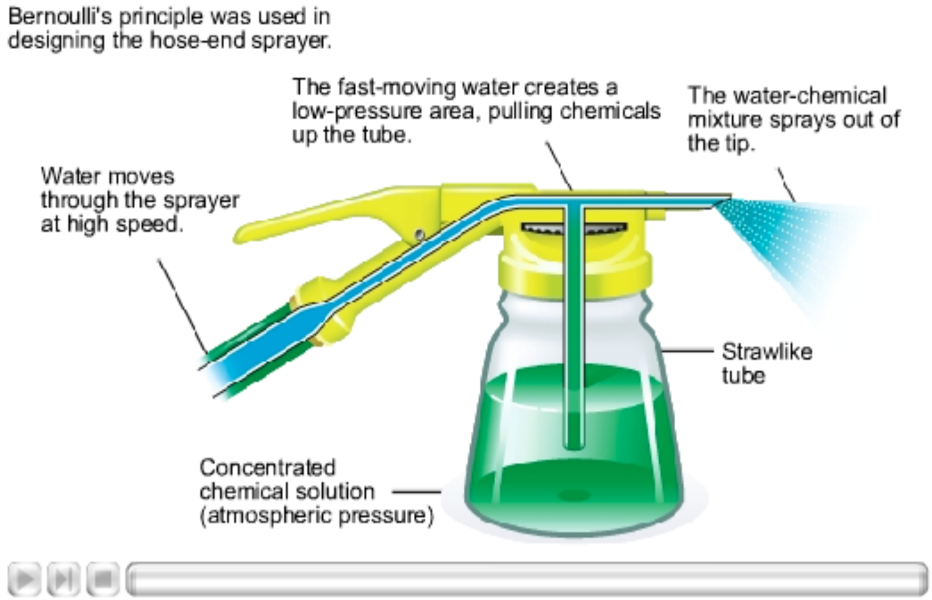
- According to Bernoulli's principle, as the velocity of a fluid increases, the pressure exerted by the fluid decreases.
- One way to demonstrate Bernoulli's principle is to blow across the top surface of a sheet of paper.
- The paper will rise.

Bernoulli's Principle

- 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.

Bernoulli's Principle

- Another application of Bernoulli's principle is the hose-end sprayer.



MAC OSX users click here to view.

Bernoulli's Principle

- 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.

Fluid Flow

- Another property exhibited by fluid is its tendency to flow. The resistance to flow by a fluid is called **viscosity**.
- When a container of liquid is tilted to allow flow to begin, the flowing particles will transfer energy to the particles that are stationary.

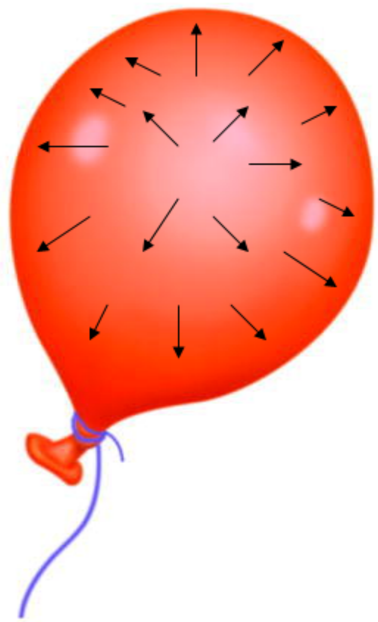
Properties of Fluids

Fluid Flow

- 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.

Pressure

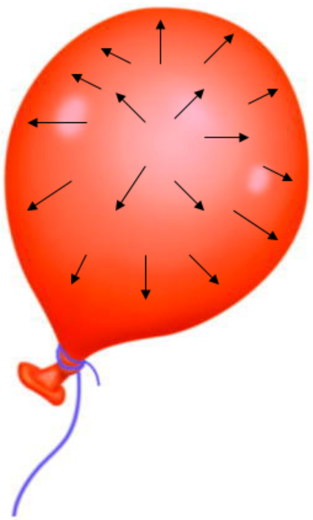
- **Pressure** is the amount of force exerted per unit of area, or *P* = *F*/*A*.
- A balloon and a bicycle tire are considered to be containers.
- They remain inflated because of collisions the air particles have with the walls of their container.



Behavior of Gases

Pressure

- 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.



Pressure

- 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.

Pressure

- At sea level, atmospheric pressure is 101.3 kPa.
- 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.

Boyle's Law

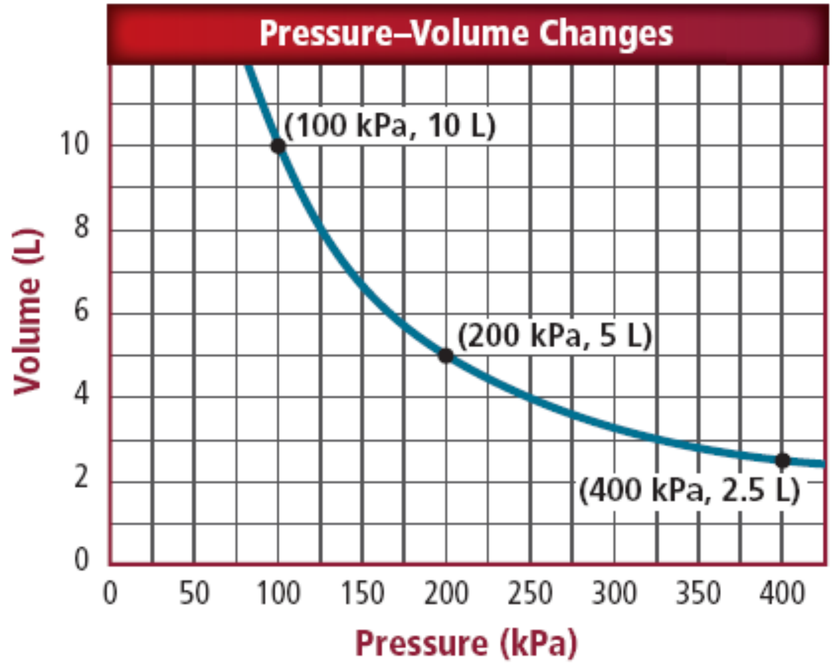
- What happens to the gas pressure if you decrease the size of the container?
- If you squeeze gas into a smaller space, its particles will strike the walls more often —giving an increased pressure. The opposite is true, too.

Boyle's Law

- 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.

Boyle's Law

- Boyle's law states that as pressure is decreased the volume increases.
- The opposite also is true, as shown by the graph.
- As the pressure is increased, the volume will decrease.



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.

Boyle's Law in Action

- 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.

The Pressure-Temperature Relationship

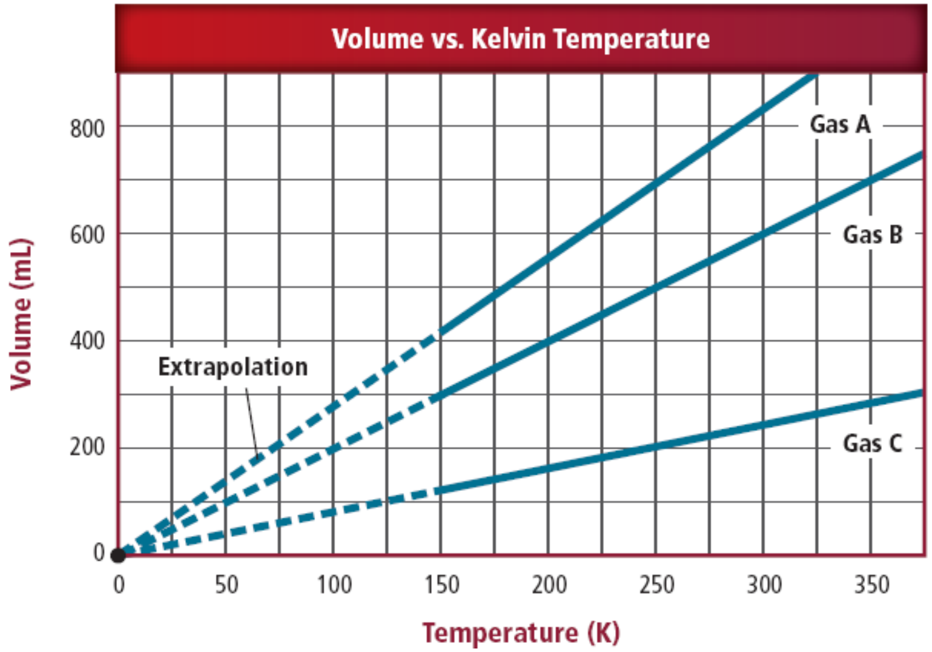
- What happens if you heat an enclosed gas? The particles of gas will strike the walls of the canister more often.
- If the pressure becomes greater than the canister can hold, it will explode.
- At a constant volume, an increase in temperature results in an increase in pressure.

Charles's Law

- 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

Charles's Law

- As with Boyle's law, the reverse is true, also.



Charles's Law

- 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.

Using Charles's Law

- The formula that relates the variables of temperature to volume shows a direct relationship when temperature is given in Kelvin.

Charles's Law Equation

$$\frac{\text{initial voulume}}{\text{initial temperature (K)}} = \frac{\text{final volume}}{\text{final temperature (K)}}$$

$$\frac{V_i}{T_i} = \frac{V_f}{T_f}$$

- When using Charles's law, the pressure must be kept constant.

Using Charles's Law

- What would be the resulting volume of a 2.0-L balloon at 20.0°C that was placed in a container of ice water at 3.0°C?

Using Charles's Law

- As Charles's law predicts, the volume decreased as the temperature of the trapped gas decreased.

Identify the Unknown: final volume: V_f

List the Knowns:
initial volume: $V_i = 2.0\ \text{L}$
initial temperature: $T_i = 20°\text{C} = 20.0°\text{C} + 273 = 293\ \text{K}$
final temperature: $T_f = 3.0°\text{C} = 3.0°\text{C} + 273 = 276\ \text{K}$

Set Up the Problem:

$$\frac{V_i}{T_i} = \frac{V_f}{T_f}$$

$$V_f = T_f\left(\frac{V_i}{T_i}\right)$$

Solve the Problem:

$$V_f = 276\ \text{K}\left(\frac{2.0\ \text{L}}{239\ \text{K}}\right)$$
$$= 2.3\ \text{L}$$