

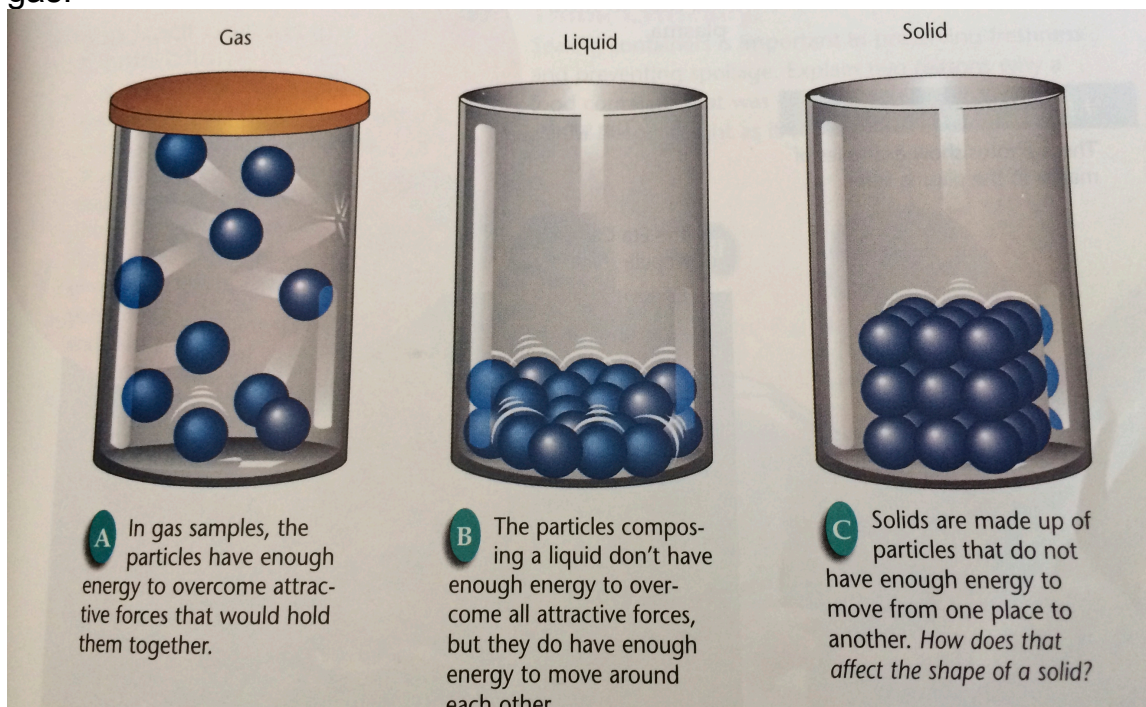
Chapter 17 States of Matter

Section 17.1 Solids, Liquids, and Gases

Terms:

- States of matter
- Kinetic Theory of Matter
- Crystal
- Plasma
- Thermal Expansion

After swimming on a hot day, Eli was having a refreshing glass of ice water. As he rested by the pool, the water on his arm evaporated and the ice cubes melted in his glass. In this example, ice, liquid water, and water vapor represent the three most familiar states of matter—solid, liquid, and gas.



All matter takes up space and has mass, yet matter can exist in different states. There are four **states of matter**—solid, liquid, gas, and plasma. The state of a sample of matter depends on its temperature. For example, water ordinarily exists as ice at low temperatures and as liquid water at moderate temperatures. At higher temperatures, water changes to the gas state as water vapor. At still higher temperatures, the matter in water becomes plasma. Each state has characteristics that are used to identify it.

The reason that each state of matter has these characteristics is due to the tiny particles in constant motion that make up all matter. This idea is called the **kinetic molecular theory of matter**. The particles in solid matter are held close together by forces between them. This is why a solid can't be squeezed into a smaller space. The particles can vibrate so close to their neighbors, but they lack enough energy to move out of position. Thus, they lack enough energy to move over or around each other.

Solids

The kinetic molecular theory of matter explains why a solid holds its shape. A metal spoon, a cube of sugar, and a piece of cement are classified as solids. Every solid has a definite shape and a definite volume. For example, a metal spoon stays spoon-shaped whether it's in your hand or in a glass of water. And, because no ordinary amount of force can squeeze the spoon into a smaller space, it has a definite volume.

Crystalline Solids

In most solids, the particles are arranged in repeating geometric patterns. These arrangements are **crystals**. Different kinds of solids have crystals of different shapes. In the magnified view in the figure to the right, you can see that crystals of table salt are tiny cubes. A snowflake is a crystal of water that has the shape of a hexagon.

Noncrystalline Solids

Some materials, such as glass, many plastics, and some kinds of wax, appear to be solids but are not made of crystals. They are often called amorphous solids. The word *amorphous* means "having no form." Many scientists think some of these noncrystalline materials should be classified as thick liquids.

Liquids

If you don't eat it quickly enough, a solid scoop of ice cream will turn into a liquid, taking the same shape as your bowl or cup. A liquid flows and takes the shape of its container. However, like solids, liquids can't normally be squeezed into a smaller volume.

Just as the kinetic theory explains the properties of solids, it also explains the properties of liquids. Because a liquid can't be squeezed, its particles also must be closer together, like those of a solid. However, they have enough kinetic energy to move over and around each other. This movement of particles lets a liquid flow and take the shape of its container. Because its particles are held close together, almost as close as those of a solid, liquid matter does have a definite volume.

Gases

You may have pumped air into a basketball, tire, or balloon and noticed that the air takes the shape of the object. Gases are “sloppy”—they expand or contract to fill the space available to them and can be squeezed into a smaller space. A gas has neither a definite shape or a definite volume.

According to the kinetic theory of matter, the particles of a gas have enough energy to separate completely from one another. Therefore, the particles are free to move in all directions until they have spread evenly throughout their container.

The figure below explains the relationship between particles and energy in a solid, in a liquid, and in a gas.

Plasma

So far, you’ve learned about the three familiar states of matter. But none of these is the most common state of matter in the universe. For example, 99 percent of the mass of our solar system is contained in the sun. The most common form of matter in the universe is the type found in stars like the sun and in nebulae. Such matter is plasma.

Plasma is a gaslike mixture of positively and negatively charged particles. You know that particles of matter move faster as the matter is heated to higher temperatures. The faster they move, the greater the force with which they bump into other particles, or collide. As matter is heated to very high temperatures, the particles begin to collide violently. As a result, the particles break up into the smaller particles they are made of. These particles are electrically charged.

Besides light from the sun, you can observe the effects of plasma in your home or school. When fluorescent light is switched on, electricity causes particles of mercury gas inside the tube to form plasma.

Thermal Expansion

You have learned how the kinetic theory accounts for characteristics of different states of matter you see and touch every day. The kinetic theory also explains other things you may have observed. For example, have you ever noticed the strips of metal that run across the floors and up the walls in long hallways of concrete and steel buildings? Maybe you’ve seen those strips in your school. These strips usually cover gaps in the building structure called expansion joints. Expansion joints allow the building to expand in hot weather and shrink in

cold weather without cracking the concrete. As you drive onto or off a bridge, you will usually pass over a large steel expansion joint.

The Heat and Motion Connection Almost all matter expands as it gets hotter and contracts when it cools. This characteristic of matter is called **thermal expansion**. You can compare thermal expansion to a crowd of people. When the people are quiet and still, they are able to move close together. As the people become restless, they jostle one another and the crowd spreads out.

How does kinetic theory of matter explain thermal expansion? In a solid, forces between the particles hold them together. As the solid is heated, these particles move faster and faster and vibrate against each other with more force. As a result, the particles spread apart slightly in all directions, and the solid expand. This explains why expansion joints are needed in buildings and on bridges. The same effect also occurs in liquids and gases. A common example of this is shown in thermometers. As the liquid in a bulb is heated, the energy causes more movement of the particles. This energy is transferred to other parts of the liquid. The liquid in the narrow part has to expand only slightly to show a large change in the temperature scale.

Summary:

- **There are four states of matter: solid, liquid, gas, and plasma.**
- **According to the kinetic theory, all matter is made of constantly moving particles.**
- **Most matter expands when heated and contract when cooled.**

Section 17.2 Changing States of Matter

Terms:

- **Evaporation**
- **Condensation**
- **Heat of fusion**
- **Heat of vaporization**

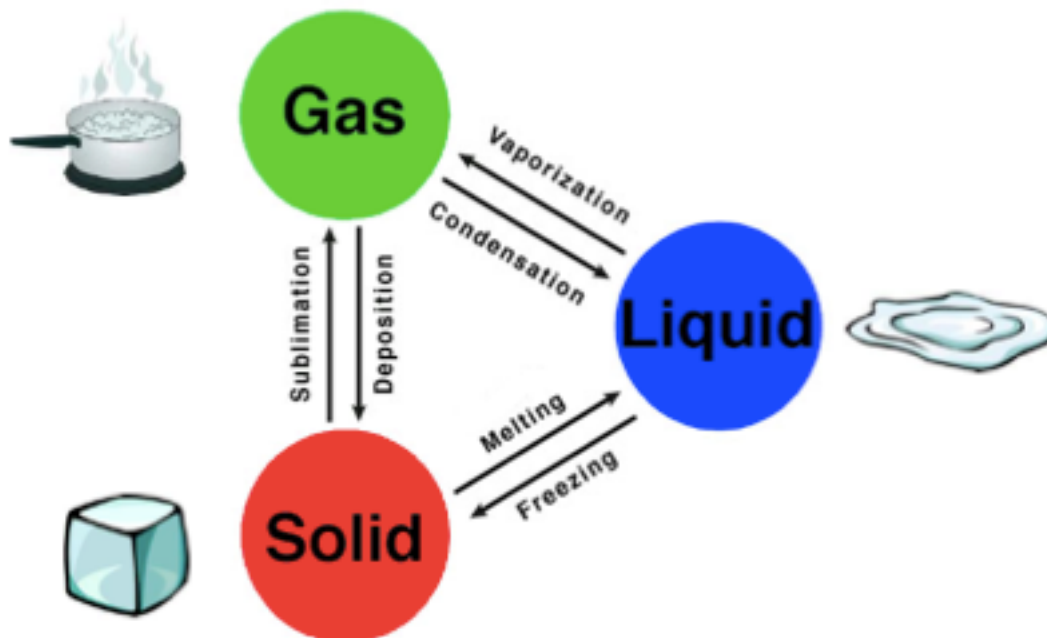
Identifying Changes in State

If you've ever seen ice cream melt before you could eat it, you have seen matter change state. Solid ice crystals in the ice cream melt when they change from the solid state to the liquid state. When melting, a solid changes into a liquid. You put water in the freeze to make ice cubes. When freezing, matter change from the liquid state to the solid state.

When you boil water, you observe another change of state, called vaporization. When boiling, you add heat to a liquid until it reaches a temperature at which it changes to bubbles of gas below its surface. Many liquids don't need to boil to change to a gas. During **evaporation**, a liquid changes to a gas gradually at temperatures below the boiling point. When you come out of a pool into warm air, water on your skin soon evaporates. You'll see later how this drying helps cool you. Evaporation also helps dry, or solidify, concrete.

Have you noticed that ice cubes seem to shrink when they've been in the freezer for a long time? This shrinkage happens because of another change of state called sublimation. In sublimation, a solid changes directly to a gas without going through the liquid state.

You see another change of state when your glass of ice-cold soda "sweats." The drops of water on your glass appear when gaseous water condenses on the cold surface. **Condensation** takes place when a gas changes to a liquid. Generally, as a gas will condense when cooled to or below its boiling point. Two examples of this are condensation on a bathroom mirror post-shower, and condensation on a car window in the morning.



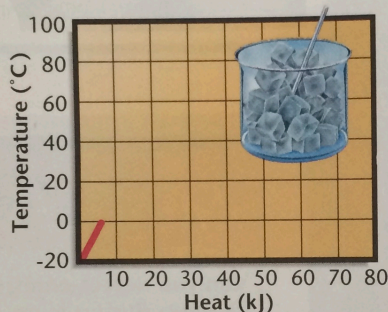
Heat and State Changes

The kinetic theory of matter explains changes of state. The amount of energy needed to change a material from the solid state to the liquid state is the **heat of fusion**. For water, the heat of fusion is 334kJ/kg. the amount of energy needs to change a material from a liquid to a gas is the **heat of vaporization**. For water, this value is 2260 kJ/kg. The figure below details the energy changes involved in state changes.

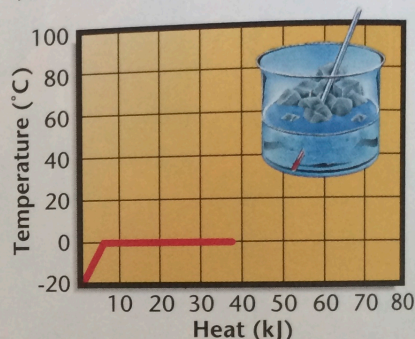
You can also use the kinetic theory to explain how water evaporates from your skin and how it cools you. When a liquid evaporates from your skin, the particles do not all have the same kinetic energy. Many fast moving particles break away from the liquid and become a gas. As these fast-moving water particles leave, the average kinetic energy of the remaining particles becomes less. As a result, the temperature of the remaining water goes down. Because the water is now cooler than your skin, it takes heat from your skin and cools you!

In this example, watch how temperature, energy supplied, and the motion of particles are related.

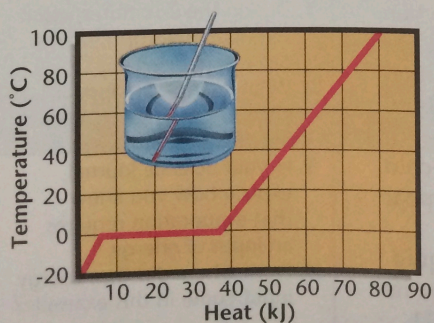
A As a sample of ice is warmed and the temperature is measured every 30 seconds, the particles of solid water absorb the applied heat energy. What effect does this energy have on the motion of the particles?



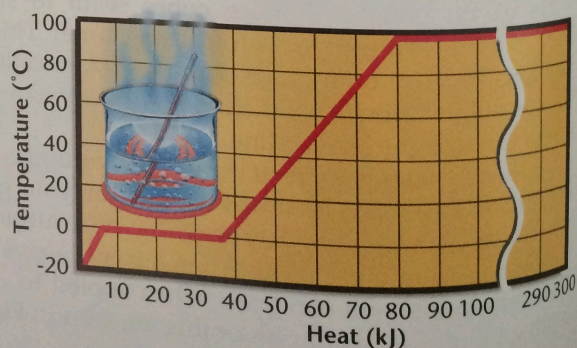
B As heat energy continues to be supplied, you may notice that the solid water now begins to appear as a liquid, but the temperature is not rising. To change a solid to a liquid, many forces must be overcome. For each kilogram of ice you want to melt, 334 kJ must be supplied.



C Once the work of melting is accomplished, the applied heat energy causes the water particles making up the liquid to move faster. As you can see on the graph, the temperature begins to rise.



D Once the boiling point has been reached, the liquid becomes a gas, and the temperature again remains constant. At the heat of vaporization, the forces of attraction between particles are totally overcome. This requires 2260 kJ of energy. Why do you think this value is so much higher than the heat of fusion?



Summary:

- Changes of state can be interpreted in terms of the kinetic theory of matter.
- The energy of the heat of fusion and vaporization overcomes attractive forces between particles of matter.