CHAPTER 8
LESSON 2

States of Matter

Changes in State

Key Concepts

- How is temperature related to particle motion?
- How are temperature and thermal energy different?
- What happens to thermal energy when matter changes from one state to another?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	3. Particles of matter have both potential energy and kinetic energy.	
	4. When a solid melts, thermal energy is removed from the solid.	

Study Coach

Building Vocabulary Skim this lesson and circle any words you do not know. If you still do not understand a word after reading the lesson, look it up in the dictionary. Keep a list of these words and definitions to refer to when you study other chapters.

Read to Learn

Kinetic and Potential Energy

When snow melts after a snowstorm, all three states of water are present. The snow is a solid, the melted snow is a liquid, and the air above the snow and ice contains water vapor, a gas. What causes particles to change state?

Kinetic Energy

Recall that the particles that make up matter are always moving. These particles have **kinetic energy,** *the energy an object has due to its motion.* The faster particles move, the more kinetic energy they have. Within a given substance, such as water, particles in the solid state have the least amount of kinetic energy. This is because they only vibrate in place. Particles in the liquid state move faster than particles in the solid state. Therefore, they have more kinetic energy. Particles in the gaseous state move quickly. They have the most kinetic energy of particles of a given substance.

Temperature *is a measure of the average kinetic energy of all the particles in an object.* Within a given substance, a rise in temperature means that the particles, on average, are moving at greater speeds. Therefore, the particles have more kinetic energy. For example, water molecules at 25°C are moving faster and have more kinetic energy than water molecules at 10°C.

Key Concept Check

1. Relate How is temperature related to particle motion?

Potential Energy

In addition to kinetic energy, particles have potential energy. Recall that potential energy is stored energy due to the interactions between particles or objects. Think about holding a basketball and then letting it go. The gravitational force between the ball and Earth causes the ball to fall toward Earth. Before you let the ball go, it has potential, or stored, energy.

Potential energy typically increases when objects get farther apart. It decreases when objects get closer together. When you hold up a basketball, it is farther off the ground than when it is falling from your hands. It has a higher potential energy than when it is falling. When the basketball is touching the ground, it has no more potential energy. The farther an object is from Earth's surface, the greater its gravitational potential energy is. As the ball gets closer to the ground, its potential energy decreases.

You can think of the potential energy of particles in a similar way. The chemical potential energy of particles is due to their position relative to other particles. The chemical potential energy of particles increases and decreases as the distances between particles increase or decrease. Thus, particles that are farther apart have greater chemical potential energy than particles that are closer together.

Thermal Energy

Changes in state are caused by changes in thermal energy. **Thermal energy** *is the total potential and kinetic energies of an object.* You can change an object's state of matter by adding or removing thermal energy. When you add thermal energy to an object, these things can happen:

- Particles move faster (increased kinetic energy).
- Particles get farther apart (increased potential energy).
- Particles get faster and move farther apart (increased kinetic and potential energy).

The opposite is true when you remove thermal energy:

- Particles move slower (less kinetic energy).
- Particles get closer together (less potential energy).
- Particles move slower and closer together (less kinetic and potential energy).

If enough thermal energy is added or removed, a change of state can occur.

Reading Check

2. Apply Which has more potential energy: a baseball held 1 m above the ground or a baseball held 2 m above the ground?

Think it Over

3. Model Imagine two balls connected by a spring. In which arrangement do the balls have more potential energy: when they are pulled apart or when they are closer together?

Key Concept Check

4. Contrast How do thermal energy and temperature differ?

Solid to Liquid or Liquid to Solid

After you drink a beverage from an aluminum can, do you recycle the can? Aluminum recycling is one example of a process that involves matter changing from one state to another by adding or removing thermal energy.

Melting

The first part of the recycling process involves melting aluminum cans. To change matter from a solid to a liquid, thermal energy must be added. The graph below shows the relationship between increasing temperature and increasing thermal energy (potential energy + kinetic energy).

At first, the thermal energy and the temperature increase. The temperature stops rising when it reaches the melting point of the matter. The melting point is the temperature at which the solid changes to a liquid. As aluminum changes from solid to liquid, the temperature does not change. However, energy changes still occur.

Reading Check

5. Infer What must be added to matter to change it from a solid to a liquid?

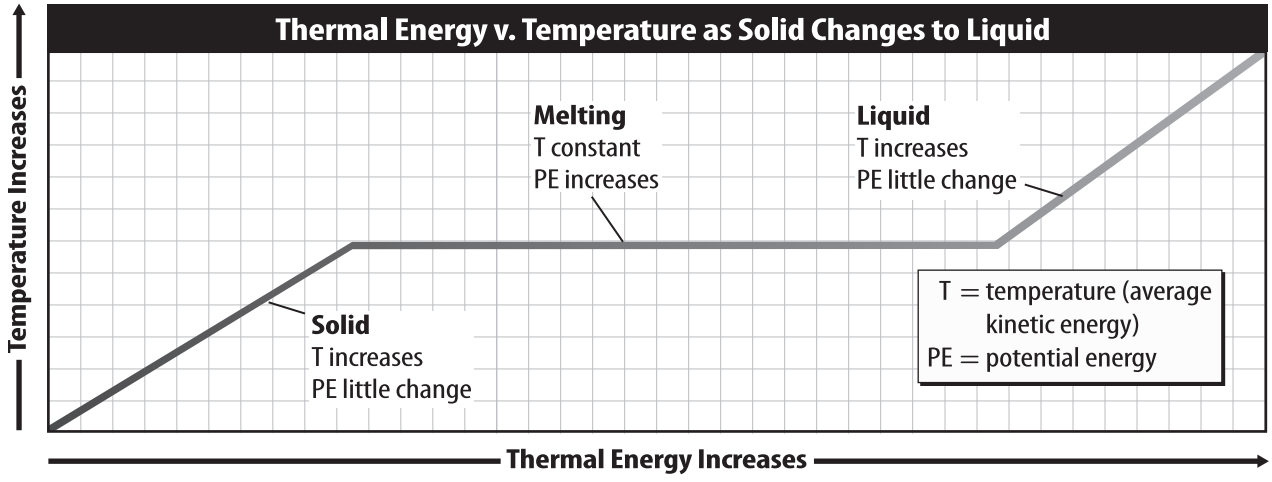
Energy Changes

What happens when a solid reaches its melting point? Notice that the line on the graph below is horizontal. This means that the temperature, or average kinetic energy, stops increasing. However, the amount of thermal energy continues to increase. How is this possible?

Once a solid reaches the melting point, additional thermal energy causes the particles to overcome their attractive forces. The particles move farther apart and potential energy increases. Once a solid completely melts, the addition of thermal energy will cause the kinetic energy of the particles to increase again, as shown by a temperature increase.

Visual Check

6. Analyze During melting, which factor remains constant?



Freezing

After the aluminum melts, it is poured into molds to cool. As the aluminum cools, thermal energy leaves it. If enough energy is removed, the aluminum will freeze. Freezing is a process that is the opposite of melting—liquid changes to solid. The temperature at which matter changes from the liquid state to the solid state is its freezing point. You can look at the graph of melting on the previous page to follow the process of freezing as thermal energy is removed. To observe the temperature and thermal energy changes that take place as liquid aluminum forms solid blocks, move from right to left on the graph on the previous page.

Liquid to Gas or Gas to Liquid

When you heat water, do you ever notice how bubbles begin to form at the bottom and rise to the surface? The bubbles contain water vapor, a gas. As the water heats, it changes from the liquid state to the gaseous state. *The change in state of a liquid into a gas is* **vaporization.** The figure below shows two types of vaporization—evaporation and boiling. The two types of vaporization differ in where they take place in the liquid.

Boiling

Vaporization that occurs within a liquid is called boiling. During boiling, vaporization takes place throughout the liquid. The temperature at which boiling occurs in a liquid is called its boiling point.

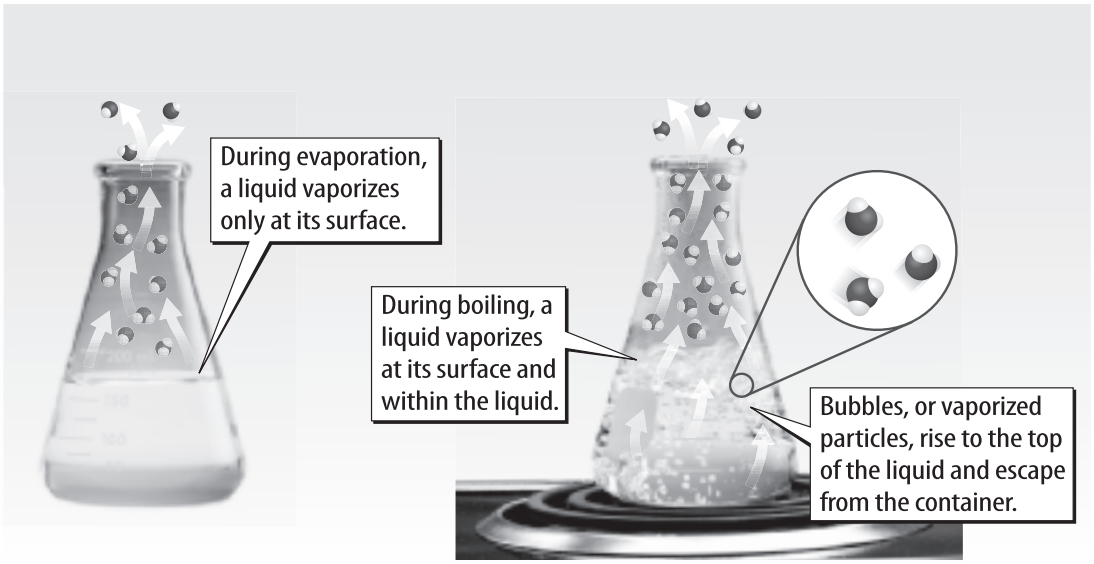
Reading Check

7. Define *freezing.*

Visual Check

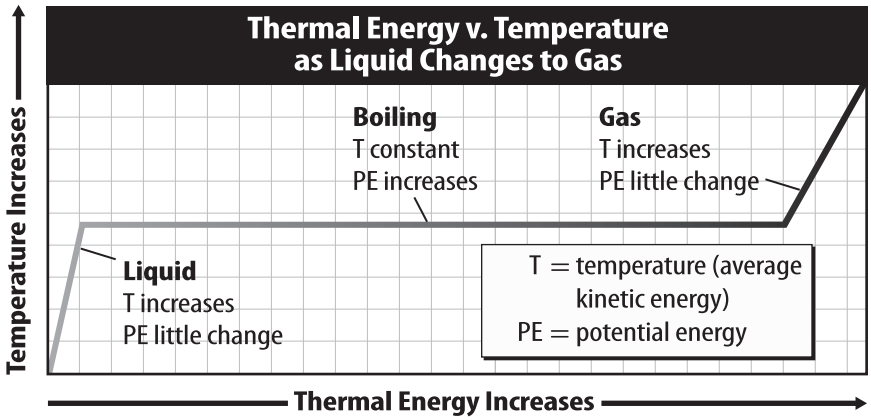
8. Explain Why doesn't the evaporation flask have bubbles below the surface?

Boiling and Evaporation



Visual Check

9. Explain Why does the liquid change to a gas?



In the graph above, notice the energy changes that occur as thermal energy is added. The kinetic energy of particles increases until the liquid reaches its boiling point. At the boiling point, the potential energy of particles begins increasing. The particles move farther apart until the attractive forces no longer hold them together. At the boiling point, the liquid changes to a gas. When boiling ends, if thermal energy continues to be added, the kinetic energy of the gas particles begins to increase again. Therefore, the temperature begins to increase again as shown on the graph above.

Evaporation

Unlike boiling, **evaporation** *is vaporization that occurs only at the surface of a liquid.* A small amount of liquid in an open container will disappear after several days due to evaporation.

Condensation

Boiling and evaporation are processes that change a liquid to a gas. The opposite process also occurs. When a gas loses enough thermal energy, the gas changes to a liquid, or condenses. *The change of state from a gas to a liquid is called* **condensation.** Overnight, water vapor often condenses on blades of grass and forms dew.

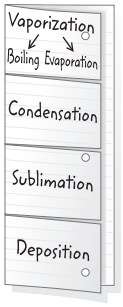
Solid to Gas or Gas to Solid

A solid can become a gas without turning into a liquid. Also, a gas can become a solid without turning into a liquid.

Solid to Gas Dry ice is solid carbon dioxide. It turns immediately into a gas when thermal energy is added to it. The process is called sublimation. **Sublimation** *is the change of state from a solid to a gas without going through the liquid state.* As dry ice sublimes, it cools and condenses the water vapor in the surrounding air, creating a thick fog.

FOLDABLES®

Make a four-tab Foldable and record what you learn about each term under the tabs.



Think it Over

10. Apply Clouds can form when water vapor in the air condenses. Clouds are what state of matter?

Gas to Solid The opposite of sublimation is deposition. **Deposition** *is the change of state of a gas to a solid without going through the liquid state.* For deposition to happen, thermal energy must be removed from the gas. Frost on grass on a fall morning is often the result of deposition. As water vapor loses thermal energy, it changes into solid frost.

States of Water

Water is the only substance that exists naturally as a solid, a liquid, and a gas within Earth's temperature range. To better understand the energy changes during a change in state, look at the heating curve of water shown in the graph below.

Adding Thermal Energy

Suppose you place a beaker of ice on a hot plate. The hot plate moves thermal energy to the beaker and the ice. The temperature of the ice increases. Recall that this means the average kinetic energy of the water molecules increases.

At 0°C, the melting point of water, the water molecules vibrate so rapidly that they begin to move out of their places. At this point, any added thermal energy causes the particles to overcome their attractive forces, and melting occurs. Once melting is complete, the kinetic energy of the particles begins to increase again as more thermal energy is added. Then the temperature begins to increase, too.

When water reaches 100°C, its boiling point, liquid water begins to change to water vapor. Again, kinetic energy stays the same as vaporization occurs. When the change of state is complete, the kinetic energy of molecules increases again, and so does the temperature.

Reading Check

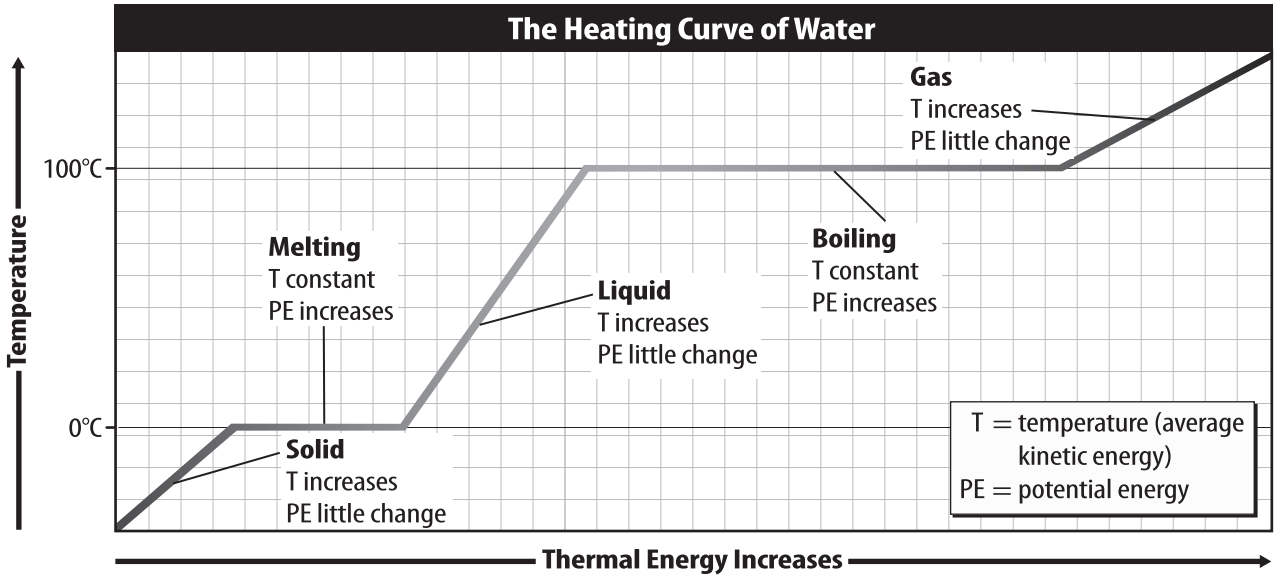
11. Evaluate Why are sublimation and deposition unusual changes of state?

Key Concept Check

12. Describe the changes in thermal energy as water goes from a solid to a liquid.

Visual Check

13. Locate Circle the location on the graph where water reaches its boiling point.



Removing Thermal Energy

The removal of thermal energy is the reverse of the process shown in the heating curve of water. You can follow what happens to water vapor as you remove thermal energy by following the graph on the previous page from right to left. Cooling water vapor changes the gas to a liquid. Cooling the water further changes it to ice.

Reading Check

14. Describe what happens to water vapor when thermal energy is removed from it.

Conservation of Mass and Energy

The diagram below shows the energy changes that take place as thermal energy is added or removed from matter. Notice that there are three sets of opposite processes:

- melting and freezing
- vaporization and condensation
- sublimation and deposition

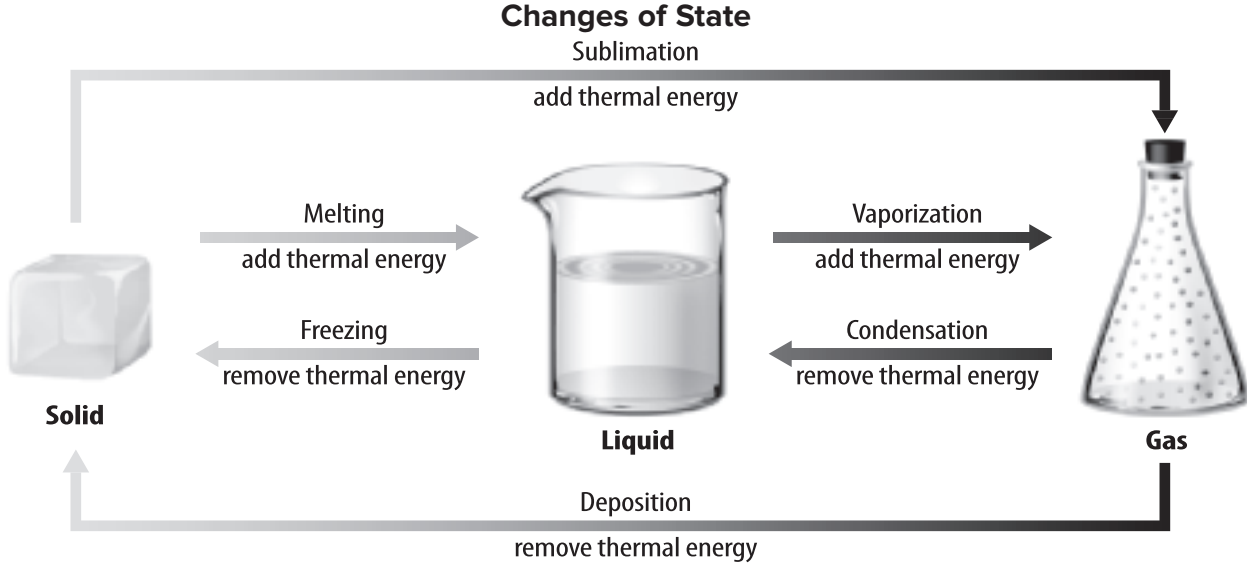
During all of these changes of state, matter and energy are always conserved.

Sometimes, such as when water vaporizes, it seems to have disappeared. However, it has just formed an invisible gas. If the gas were captured and its mass added to the remaining mass of the liquid, you would see that matter is conserved.

The same is true for energy. Surrounding matter often absorbs thermal energy. If you measured thermal energy in the matter and the surrounding matter, you would find that energy is also conserved.

Visual Check

15. Draw Circle the state of matter that results when thermal energy is added to a liquid.



Mini Glossary

condensation: the change of state from a gas to a liquid

deposition: the change of state of a gas to a solid without going through the liquid state

evaporation: vaporization that occurs only at the surface of a liquid

kinetic energy: the energy an object has due to its motion

sublimation: the change of state from a solid to a gas without going through the liquid state

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

thermal energy: the total potential and kinetic energies of an object

vaporization: the change in state of a liquid into a gas

1. **Review the terms and their definitions in the Mini Glossary. Write a sentence that includes an example of one change of state and its opposite process.**

2. **Write the correct term next to its opposite term in each row of the table below.**

Happens When Thermal Energy Is Added	Happens When Thermal Energy Is Removed
melting	
	condensation
sublimation	

3. **Name two types of vaporization. How are they different?**

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

ConnectED

Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

END OF LESSON

Lesson 2 Changes in State

Predict *three facts that will be discussed in Lesson 2 after reading the headings. Write your facts in your Science Journal.*

Main Idea

Kinetic and Potential Energy

I found this on page _____.

I found this on page _____.

Thermal Energy

I found this on page _____.

I found this on page _____.

Details

Relate kinetic energy *and* temperature *to particle motion. Draw arrows to show correlating increase or decrease.*

Particle Motion	Kinetic Energy of Particles	Temperature
↑		

Contrast *the potential energy of particles.*

Particles farther apart	Particles closer together

Detail *changes in* thermal energy.

Add thermal energy	particles move	increased
	particles get	increased
Remove thermal energy	particles move	kinetic energy
	particles get	potential energy

Compare thermal energy *with* temperature.

Main Idea

Solid to Liquid or Liquid to Solid

I found this on page _____ .

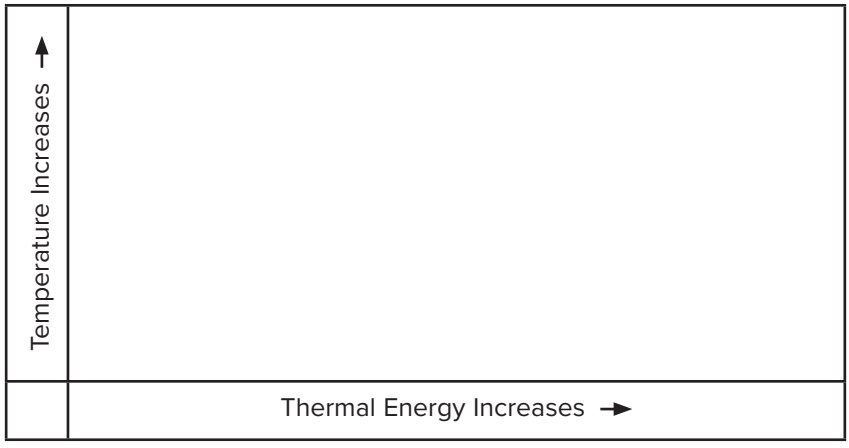
I found this on page _____ .

Liquid to Gas or Gas to Liquid

I found this on page _____ .

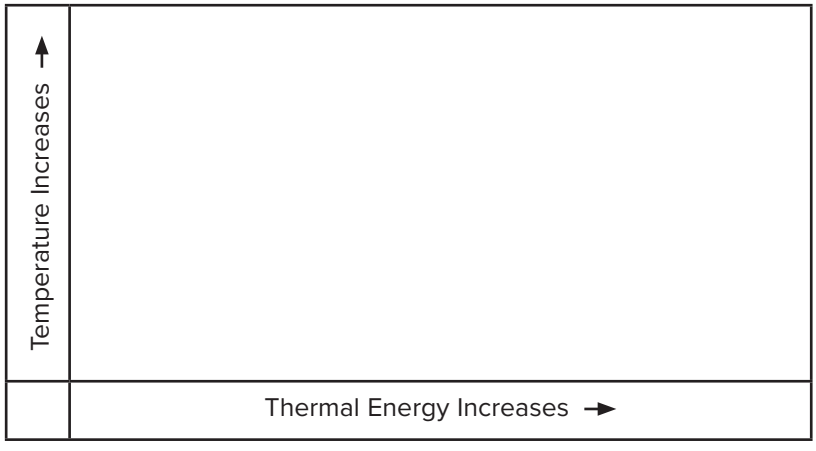
Details

Model *the process of melting. Draw a line to indicate the* **thermal energy** *versus* **temperature** *changes as a solid changes to a liquid. Label the line to indicate the changes in* **temperature** *(T) and potential energy (PE).*



Contrast *freezing with melting.*

Represent *the process of boiling. Draw a line to indicate the* **thermal energy** *versus* **temperature** *changes as a liquid changes to a gas. Label the line to indicate the changes in* **temperature** *(T) and potential energy (PE).*



Main Idea

I found this on page _____.

Details

Differentiate *terms associated with changes of state.*

Term	Description
Vaporization	
Evaporation	
Boiling	
Condensation	

Solid to Gas or Gas to Solid

I found this on page _____.

Compare sublimation *with* deposition.

_____

_____

States of Water

I found this on page _____.

Characterize *water.*

Melting point: _____ Boiling point: _____

Unique because: _____

_____

Conservation of Mass and Energy

I found this on page _____.

Restate *concepts of conservation of mass and energy.*

Mass: Matter changes _____, but the total amount of the matter _____.

Energy: Thermal energy is sometimes _____ by surrounding matter, but the total energy is _____.

Connect It Suppose that you want to compare the mass of a block of ice to its mass as liquid water. You mass the ice, and then you mass a pan. You put the ice in the pan and place it over high heat. What will you find if you measure the mass of the water after it has been boiling for several minutes?

_____

_____

_____