

# 13 States of Matter



## KINETIC THEORY

### 13.1 The Nature of Gases

**Essential Understanding** Temperature and pressure affect gases much more than they affect any other state of matter.

#### Kinetic Theory and a Model for Gases

1. The energy an object has because of its motion is called \_\_\_\_\_.
2. Summarize the 3 assumptions of the Kinetic Theory:
  - 1.
  - 2.
  - 3.

Circle the letter of each sentence that is true about the assumptions of the kinetic theory concerning gases.

- a. A gas is composed of particles with insignificant volume that are relatively far apart.
  - b. Strong attractive forces exist between particles of a gas.
  - c. Gases tend to collect near the bottom of a container.
  - d. The paths of uninterrupted travel of particles in a gas are relatively short because the particles are constantly colliding with each other or with other objects.
3. Is the following statement true or false? According to the kinetic theory, collisions between particles in a gas are perfectly elastic because kinetic energy is transferred without loss from one particle to another, and the total kinetic energy remains constant.
- \_\_\_\_\_

#### Gas Pressure

4. Gas pressure results from the force exerted by a gas per \_\_\_\_\_.
5. Simultaneous collisions of billions of particles in a gas with an object result in \_\_\_\_\_.
6. What force holds the particles of air in Earth's atmosphere? \_\_\_\_\_
7. What kind of pressure is measured with a barometer? \_\_\_\_\_

8. Look at Figure 13.2. What accounts for the difference in height of the two columns of mercury shown in the figure?

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9. Circle the letter next to every name of a unit of pressure.

- |             |           |
|-------------|-----------|
| a. mm Hg    | d. kPa    |
| b. standard | e. atm    |
| c. pascal   | f. degree |

10. Standard temperature and pressure (STP) are defined as

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## Kinetic Energy and Temperature

11. What happens to the temperature of a substance when the average kinetic energy of its particles increases?

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12. The temperature 0 K, or  $-273.15^{\circ}\text{C}$ , is called \_\_\_\_\_ zero.  
Theoretically, particles of matter at this temperature would have no

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## Practice Problems:

1. What pressure, in kilopascals (kPa) AND in atmospheres (atm), does a gas exert at 385 mmHg? Show work using dimensional analysis.

*Answers: 51.3 kPa and 0.507 atm*

2. What pressure, in kilopascals (kPa) AND in mmHg, does a gas exert at 1.561 atm? Show work using dimensional analysis.

*Answers: 1186 mmHg and 158.1 kPa*

3. The pressure at the top of mount Everest is 33.7 kPa. Is that pressure greater or less than 0.25 atm? Explain and show work.

4. As the temperature of a gas increases, the average speed of its molecules \_\_\_\_\_.

A) decreases

B) increases

C) remains constant

D) decreases, then increases

E) increases, then decreases

5. As the temperature of a substance decreases, the average kinetic energy of its particles \_\_\_\_\_.

A) decreases

B) increases

C) remains constant

D) decreases, then increases

E) increases, then decreases

# CH13 TEMPERATURE CONVERSIONS

The Formula to go from Celsius to Kelvin:	The Formula to go from Celsius to Fahrenheit:
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- The recommended temperature of coffee is  $82^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The melting point of Aluminum is  $660^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The coldest temperature recorded on Earth is  $-89^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The hottest temperature recorded on Earth is  $58^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The average surface temperature of Saturn is  $-130^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The temperature of camp fire is  $897^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The average surface temperature of Venus is  $500^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The average surface temperature of Jupiter is  $-121^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The melting point of lead is  $328^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_
- The average surface temperature of the Sun is  $5507^{\circ}\text{C}$ .  
Kelvin = \_\_\_\_\_  
Fahrenheit = \_\_\_\_\_

## 13.2 The Nature of Liquids

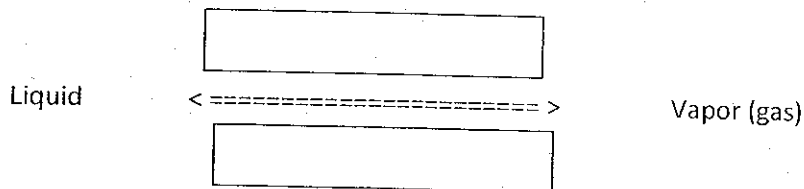
**Essential Understanding** The properties and physical changes of liquids are the result of the particle motion and the attraction between particles in a liquid.

### A Model for Liquids

13. Is the following sentence true or false? The kinetic theory states that there are no attractions between the particles of a liquid. \_\_\_\_\_
14. Circle the letter next to each sentence that is true about the particles of a liquid.
- a. Most of the particles in a liquid have enough kinetic energy to escape into a gaseous state.
  - b. Liquids are much denser than gases because intermolecular forces reduce the amount of space between the particles in a liquid.
  - c. Increasing pressure on a liquid has almost no effect on its volume.
  - d. Liquid particles are free to slide past one another.

### Evaporation

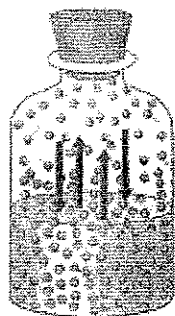
15. The conversion of a liquid to a gas or vapor is called \_\_\_\_\_.
16. When vaporization occurs at the surface of a liquid that is not boiling, the process is called \_\_\_\_\_.



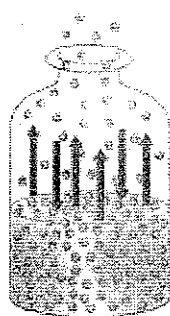
17. As a liquid evaporates, why do only some of the particles break away from the surface of the liquid? Why does the liquid evaporate faster if the temperature is increased?
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

18. Is the following sentence true or false? Evaporation is a cooling process because the particles in a liquid with the highest kinetic energy tend to escape first, leaving the remaining particles with a lower average kinetic energy and, thus, a lower temperature.
- \_\_\_\_\_

Questions 7–10 refer to either container A or container B below. Think of each container as a system involving both liquid water and water vapor.



(a)



(b)

19. From which of the containers are water molecules able to escape? \_\_\_\_\_
20. In which container can a dynamic equilibrium be established between water molecules in the liquid state and water molecules in the vapor state? \_\_\_\_\_
21. In which container will the water level remain constant? \_\_\_\_\_
22. From which container is it possible for all of the liquid water to disappear through evaporation? \_\_\_\_\_
23. What causes the chill you may feel after stepping out of a swimming pool on a warm, windy day?

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## Vapor Pressure

24. Circle the letter next to each sentence that is true about vapor pressure.
- a. Vapor pressure exists when particles of a liquid in a closed, partly filled container vaporize and collide with the walls of the container.
  - b. After a time in a closed, partly filled container, a liquid will evaporate and its vapor will condense at equal rates.
  - c. Look at Figure 13.6b. Condensation on the inside of the terrarium indicates that there is no liquid-vapor equilibrium in the sealed terrarium.
  - d. When the temperature of a contained liquid increases, its vapor pressure increases.

## Boiling Point

25. The boiling point of a liquid is the temperature at which the vapor pressure of the liquid is just equal to the \_\_\_\_\_.
26. Look at Figure 13.8. Why does the boiling point decrease as altitude increases?

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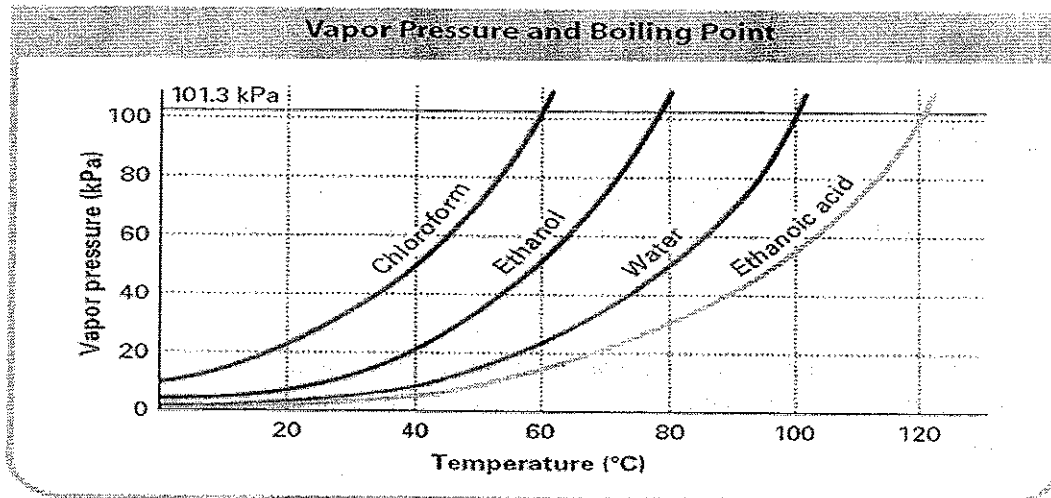
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27. Use Figure 13.9. At approximately what temperature would ethanol boil atop Mount Everest, where the atmospheric pressure is 34 kPa? Circle the letter next to the best estimate.

a. 50°C                      b. 100°C                      c. 0°C                      d. 85°C

28. Is the following sentence true or false? After a liquid reaches its boiling point, its temperature continues to rise until all the liquid vaporizes. \_\_\_\_\_

## Practice Problems:



1. What is the boiling point of chloroform at standard pressure (101.3 kPa)?
2. What is the vapor pressure of ethanol at 40°C?
3. What would the atmospheric pressure need to be for ethanoic acid to boil at 80°C?
4. What must the atmospheric pressure be in order get water to boil at 298K?
5. Draw a diagram to show the relative amounts of atmospheric pressures at (1) below sea level, (2) at sea level, (3) above sea level. Then explain explain why pasta would take longer to cook on the top of Mount Everest than they would at sea level.  
*Hint: use figure 13.8 in your text to help you*

## 13.3 The Nature of Solids

### Essential Understanding

The properties of solids are related to their structure.

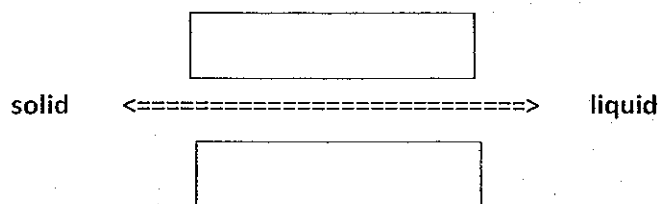
### A Model for Solids

29. Is the following sentence true or false? Although particles in solids have kinetic energy, the motion of particles in solids is restricted to vibrations about fixed points.

\_\_\_\_\_

30. A solid melts when \_\_\_\_\_.

31. Is the following sentence true or false? The temperature at which the liquid and solid states of a substance are in equilibrium is the same as the melting point *and* the freezing point of the substance. \_\_\_\_\_





# 13.3

## THE NATURE OF SOLIDS

### Section Review

#### Objectives

- Evaluate how the way particles are organized explains the properties of solids
- Identify the factors that determine the shape of a crystal
- Explain how allotropes of an element are different

#### Vocabulary

- melting point
- crystal
- unit cell
- allotropes
- amorphous solid
- glass

#### Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

Solids tend to be dense and difficult to 1. They do not  
 flow or take the shape of their containers, like liquids do, because  
 the particles in solids vibrate around 2 points. When a solid  
 is heated until its particles vibrate so rapidly that they are no longer  
 held in fixed positions, the solid 3. The 4 is the  
 temperature at which a solid changes to a liquid. The melting and  
5 of a substance are at the same temperature. In general,  
 ionic solids tend to have relatively 6 melting points, while  
 molecular solids tend to have relatively low melting points. Most  
 solids are 7. The particles are arranged in a pattern known  
 as a crystal 8. The smallest subunit of a crystal lattice  
 is the 9. Some solids lack an ordered internal structure  
 and are called 10 solids.

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_
10. \_\_\_\_\_

### Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

- \_\_\_\_\_ 11. Glasses do not melt at a definite temperature, but soften gradually.
- \_\_\_\_\_ 12. Solid substances can exist in more than one form.
- \_\_\_\_\_ 13. Allotropes are two or more different elements that exist in the same state with the same crystal system.
- \_\_\_\_\_ 14. When the atoms in a solid have a random arrangement, the solid is a glass.
- \_\_\_\_\_ 15. The type of bonding that exists between the atoms in a crystal tends to determine the melting point of the solid.

### Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ 16. crystal	a. describes a solid in which the particles are randomly arranged
_____ 17. unit cell	b. transparent fusion products of inorganic substances that have cooled to a rigid state without crystallizing
_____ 18. rhombohedral	c. the smallest group of particles within a crystal that retains the geometric shape of the crystal
_____ 19. amorphous	d. the temperature at which a solid changes to a liquid
_____ 20. glasses	e. has a regular three-dimensional arrangement of particles
_____ 21. solid	f. one of the seven crystal systems.
_____ 22. melting point	g. dense state of matter that has a fixed shape and is not easily compressed

### Part D Questions and Problems

Answer the following in the space provided.

- 24. Explain what happens at the particle level when a solid melts.

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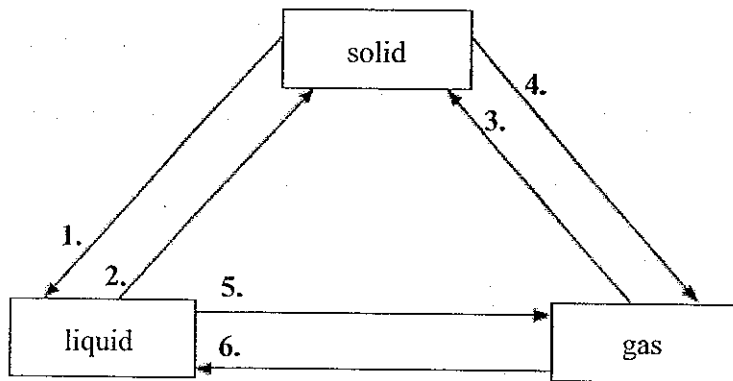
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# 13.4 Changes of State

**Essential Understanding** Changes of state depend on changes in energy of the particles involved.

On each arrow, fill in the appropriate change of state.



## Sublimation

- 32. The process of sublimation requires \_\_\_\_\_ energy than evaporation.
- 33. Is the following sentence true or false? Solids have vapor pressure because some particles near the surface of a solid substance have enough kinetic energy to escape directly into the vapor phase. \_\_\_\_\_

## Phase Diagrams

34. What does a phase diagram show?

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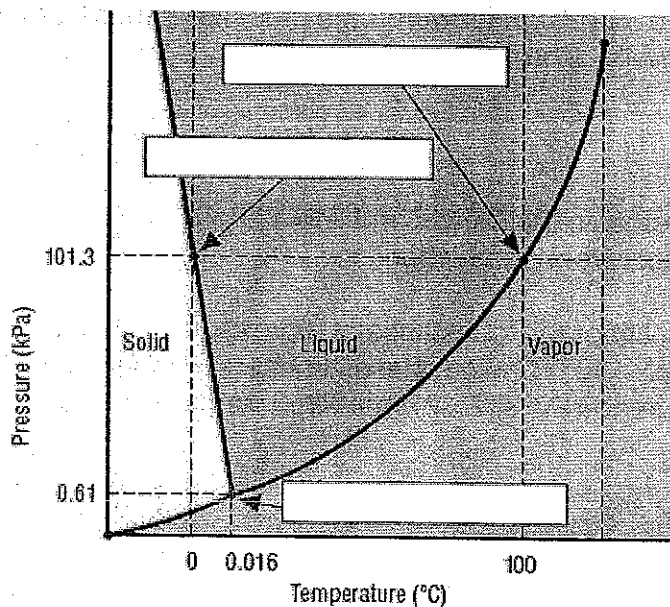
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35. What is the triple point of a substance?

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36. In the phase diagram for water shown below, label the melting point and boiling point at normal atmospheric pressure, and the triple point.



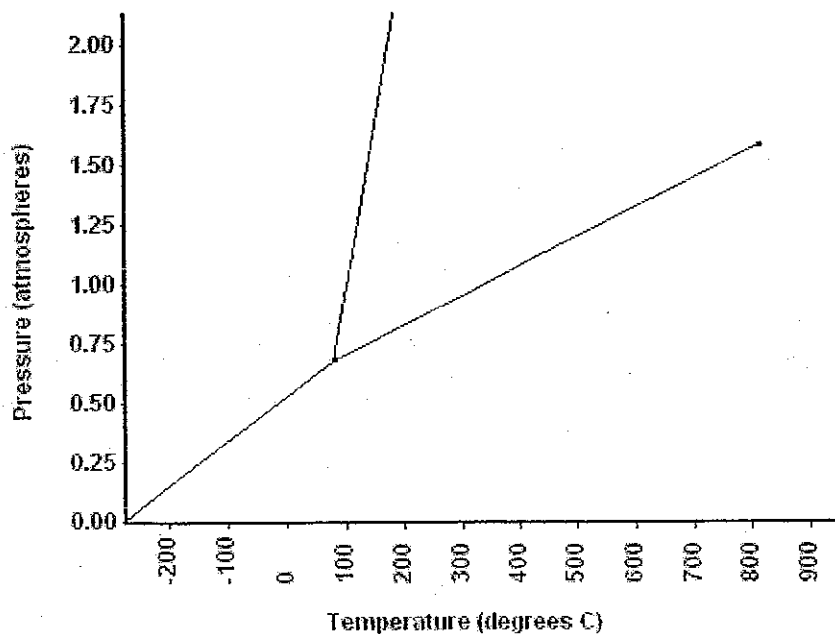
37. Use the phase diagram above to answer the following question. Why is a laboratory required to produce the conditions necessary for observing water at the triple point?

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Refer to the phase diagram below when answering the questions on this worksheet:



- 1) What is the normal freezing point of this substance? \_\_\_\_\_
- 2) What is the normal boiling point of this substance? \_\_\_\_\_
- 3) What is the normal melting point of this substance? \_\_\_\_\_
- 4) If I had a quantity of this substance at a pressure of 1.25 atm and a temperature of 300<sup>o</sup> C and lowered the pressure to 0.25 atm, what phase transition(s) would occur?
- 5) At what temperature do the gas and liquid phases become indistinguishable from each other? \_\_\_\_\_
- 6) If I had a quantity of this substance at a pressure of 0.75 atm and a temperature of -100<sup>o</sup> C, what phase change(s) would occur if I increased the temperature to 600<sup>o</sup> C? At what temperature(s) would they occur?