Chapter 13: States of Matter

13.1 The Nature of Gases

13.1 Kinetic Theory and a Model for Gases

- The word *kinetic* refers to motion.
  - –The energy an object has because of its motion is called **kinetic energy.**
  - –According to the **kinetic theory,** all matter consists of tiny particles that are in constant motion.

Kinetic Theory and a Model for Gases

- According to kinetic theory:
  - **The particles in a gas are considered to be small, hard spheres with an insignificant volume.**
  - **The motion of the particles in a gas is rapid, constant, and random.**
  - **All collisions between particles in a gas are perfectly elastic.**

Gas Pressure

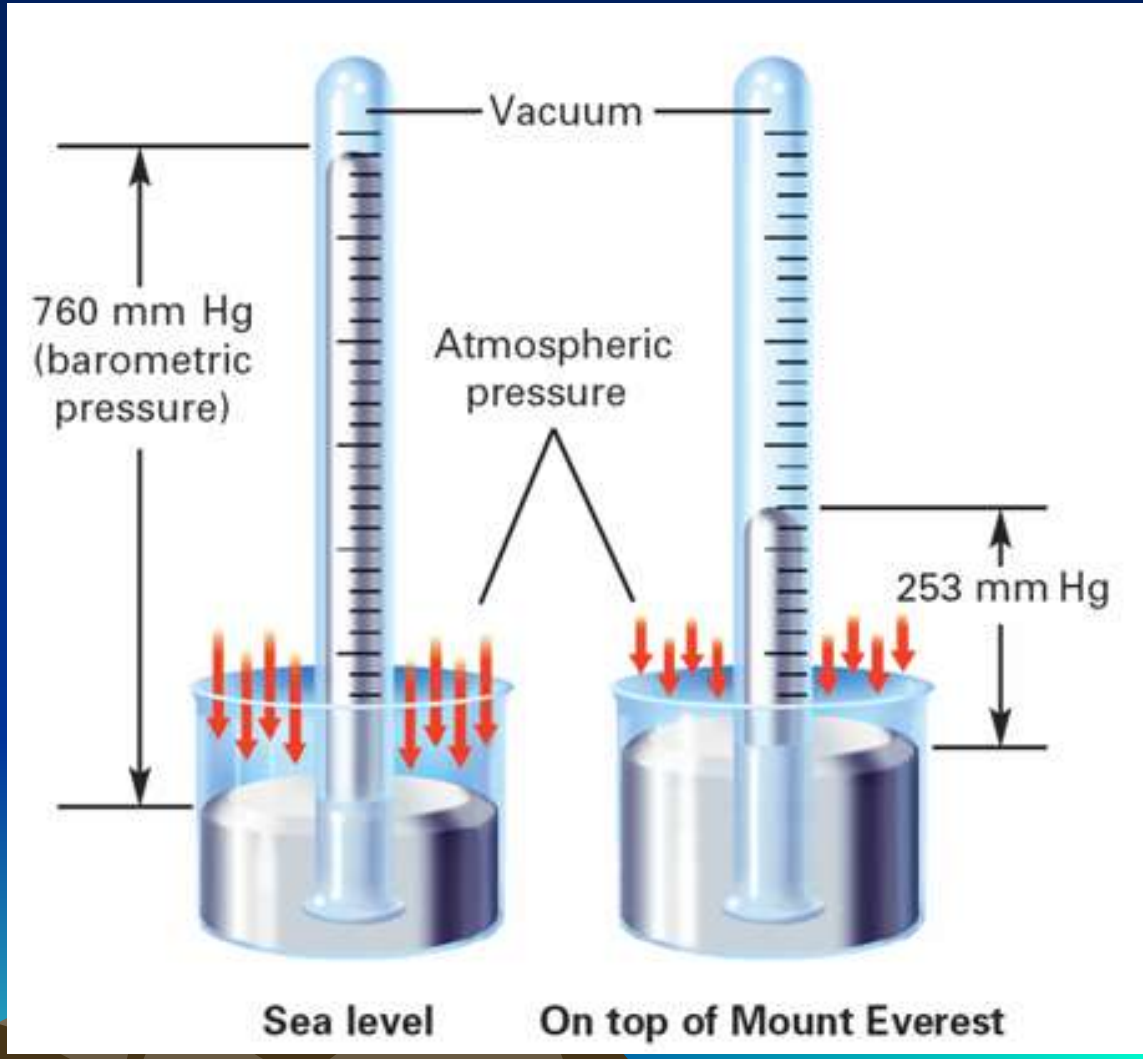
- **Gas pressure** results from the force exerted by a gas per unit surface area of an object.
  - An empty space with no particles and no pressure is called a **vacuum**.
  - **Atmospheric pressure** results from the collisions of atoms and molecules in air with objects.

Gas Pressure

- Gas pressure is the result of simultaneous collisions of billions of rapidly moving particles in a gas with an object.

Gas Pressure

- A **barometer** is a device that is used to measure atmospheric pressure.



Gas Pressure

- The SI unit of pressure is the **pascal (Pa).**
- One **standard atmosphere (atm)** is the pressure required to support 760 mm of mercury in a mercury barometer at 25°C.

$$1\ \text{atm} = 760\ \text{mm Hg} = 101.3\ \text{kPa}$$

Sample Problem 13.1

Converting Between Units of Pressure

A pressure gauge records a pressure of 450 kPa. What is this measurement expressed in atmospheres and millimeters of mercury?

for Sample Problem 13.1

1. What pressure, in kilopascals and in atmospheres, does a gas exert at 385 mm Hg?

Kinetic Energy and Temperature

- Average Kinetic Energy
  - The particles in any collection of atoms or molecules at a given temperature have a wide range of kinetic energies. Most of the particles have kinetic energies somewhere in the middle of this range.

Kinetic Energy and Temperature

- **Absolute zero** (0 K, or –273.15°C) is the temperature at which the motion of particles theoretically ceases.
  - –Particles would have no kinetic energy at absolute zero.
  - –Absolute zero has never been produced in the laboratory.

Kinetic Energy and Temperature

- Average Kinetic Energy and Kelvin Temperature
  - The Kelvin temperature of a substance is directly proportional to the average kinetic energy of the particles of the substance.

13.1 Section Quiz.

– 1. According to the kinetic theory, the particles in a gas

a) are attracted to each other.

b) are in constant random motion.

c) have the same kinetic energy

d) have a significant volume.

13.1 Section Quiz.

– 2. The pressure a gas exerts on another object is caused by

a) the physical size of the gas particles.

b) collisions between gas particles and the object.

c) collisions between gas particles.

d) the chemical composition of the gas.

13.1 Section Quiz.

–3. The average kinetic energy of the particles in a substance is directly proportional to the

a) Fahrenheit temperature.

b) Kelvin temperature.

c) molar mass of the substance.

d)Celsius temperature.

13.2 The Nature of Liquids

A Model for Liquids

- The interplay between the disruptive motions of particles in a liquid and the attractions among the particles determines the physical properties of liquids.

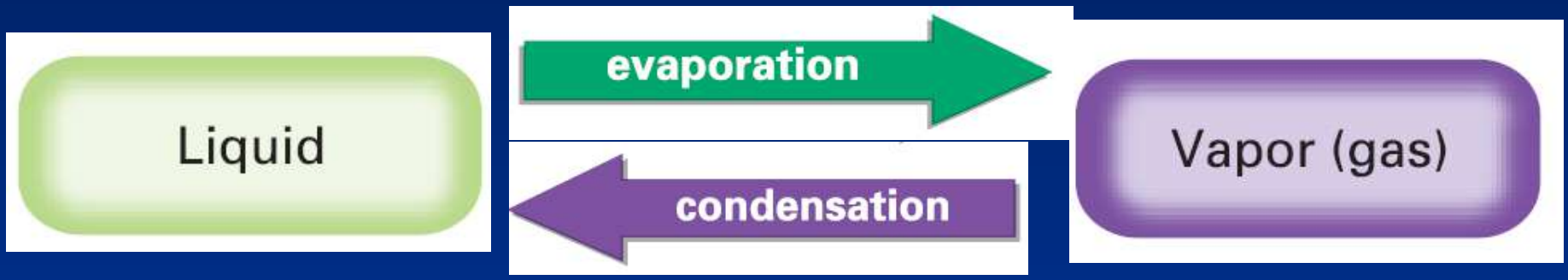
Evaporation

- The conversion of a liquid to a gas or vapor is called **vaporization.**
- When such a conversion occurs at the surface of a liquid that is not boiling, the process is called **evaporation.**

Evaporation

– During evaporation, only those molecules with a certain minimum kinetic energy can escape from the surface of the liquid.

Vapor Pressure



- **Vapor pressure** is a measure of the force exerted by a gas above a liquid.

Vapor Pressure

– In a system at constant vapor pressure, a dynamic equilibrium exists between the vapor and the liquid. The system is in equilibrium because the rate of evaporation of liquid equals the rate of condensation of vapor.

Vapor Pressure

- Vapor Pressure and Temperature Change
  - An increase in the temperature of a contained liquid increases the vapor pressure.
  - The particles in the warmed liquid have increased kinetic energy. As a result, more of the particles will have the minimum kinetic energy necessary to escape the surface of the liquid.

Vapor Pressure

– Vapor Pressure Measurements

- The vapor pressure of a liquid can be determined with a device called a **manometer**.

Boiling Point

- When a liquid is heated to a temperature at which particles throughout the liquid have enough kinetic energy to vaporize, the liquid begins to boil.

Boiling Point

- The temperature at which the vapor pressure of the liquid is just equal to the external pressure on the liquid is the **boiling point (bp).**

Boiling Point and Pressure Changes

- Because a liquid boils when its vapor pressure is equal to the external pressure, liquids don't always boil at the same temperature.
  - –At a lower external pressure, the boiling point decreases.
  - –At a higher external pressure, the boiling point increases.

Boiling Point

- Normal Boiling Point
  - Because a liquid can have various boiling points depending on pressure, the **normal boiling point** is defined as the boiling point of a liquid at a pressure of 101.3 kPa.

13.2 Section Quiz

- 1.In liquids, the attractive forces are

  a) very weak compared with the kinetic energies of the particles.

  b) strong enough to keep the particles confined to fixed locations in the liquid.

  c) strong enough to keep the particles from evaporating.

  d) strong enough to keep particles relatively close together.

13.2 Section Quiz

–2. Which one of the following is a process that absorbs energy?

a) freezing

b) condensation

c) evaporation

d) solidifying

13.2 Section Quiz

- 3.In a sealed gas-liquid system at constant temperature eventually

  a) there will be no more evaporation.

  b) the rate of condensation decreases to zero.

  c) the rate of condensation exceeds the rate of evaporation.

  d) the rate of evaporation equals the rate of condensation.

13.2 Section Quiz

– 4. Where must particles have enough kinetic energy to vaporize for boiling to occur?

a) at the surface of the liquid

b) at the bottom of the container

c) along the sides of the container

d) throughout the liquid

13.2 Section Quiz

–5.The boiling point of a liquid

a) increases at higher altitudes.

b) decreases at higher altitudes.

c) is the same at all altitudes.

d) decreases as the pressure increases.

13.3 The Nature of Solids

A Model for Solids

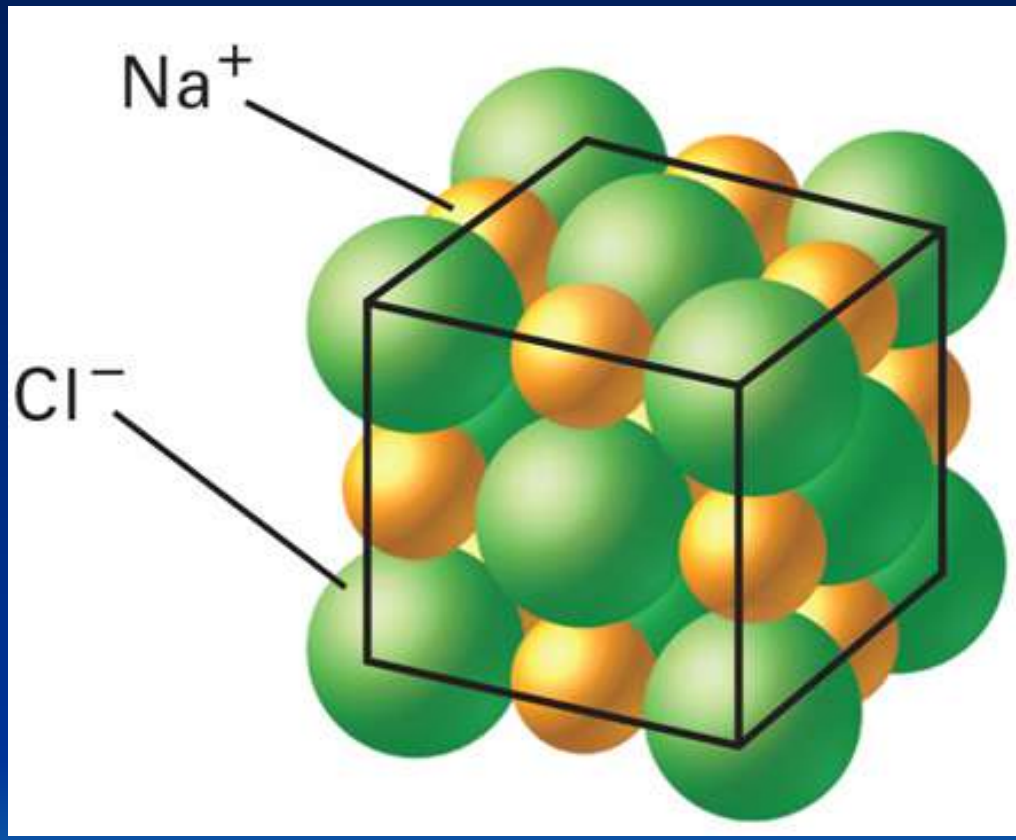
- The general properties of solids reflect the orderly arrangement of their particles and the fixed locations of their particles.

A Model for Solids

- **The melting point** (mp) is the temperature at which a solid changes into a liquid.

Crystal Structure and Unit Cells

- In a **crystal,** the particles are arranged in an orderly, repeating, three-dimensional pattern called a crystal lattice.



Crystal Structure and Unit Cells

- The smallest group of particles within a crystal that retains the geometric shape of the crystal is known as a **unit cell.**
  - A crystal lattice is a repeating array of any one of fourteen kinds of unit cells.
  - There are from one to four types of unit cells that can be associated with each crystal system.

Allotropes

- **Allotropes** are two or more different molecular forms of the same element in the same physical state.
  - Allotropes have different properties because their structures are different.
  - Only a few elements have allotropes.

Non-Crystalline Solids

- An **amorphous solid** lacks an ordered internal structure.
  - Rubber, plastic, asphalt, and glass are amorphous solids.
  - A **glass** is a transparent fusion product of inorganic substances that have cooled to a rigid state without crystallizing.

13.3 Section Quiz

– 1. A solid will melt when

a) all the particles have the same kinetic energy.

b) bonds form between the particles.

c) disruptive vibrations overcome attractive forces.

d) attractions overcome disruptive vibrations.

13.3 Section Quiz

- 2.Which of the following affect the shape of crystals?
  - (1) angles between the faces
  - (2) number of edges of equal length per face
  - (3) size of the crystal

    a) (1) only

    b) (2) only

    c) (3) only

    d) (1) and (2)

13.3 Section Quiz

– 3.Allotropes have different properties because

a) their atoms are arranged in different patterns.

b) they are composed of different elements.

c) they are in different states.

d) they consist of different isotopes of the same element.

13.4 Changes of State

Sublimation

- The change of a substance from a solid to a vapor without passing through the liquid state is called **sublimation.**
  - –Sublimation occurs in solids with vapor pressures that exceed atmospheric pressure at or near room temperature.

Phase Diagrams

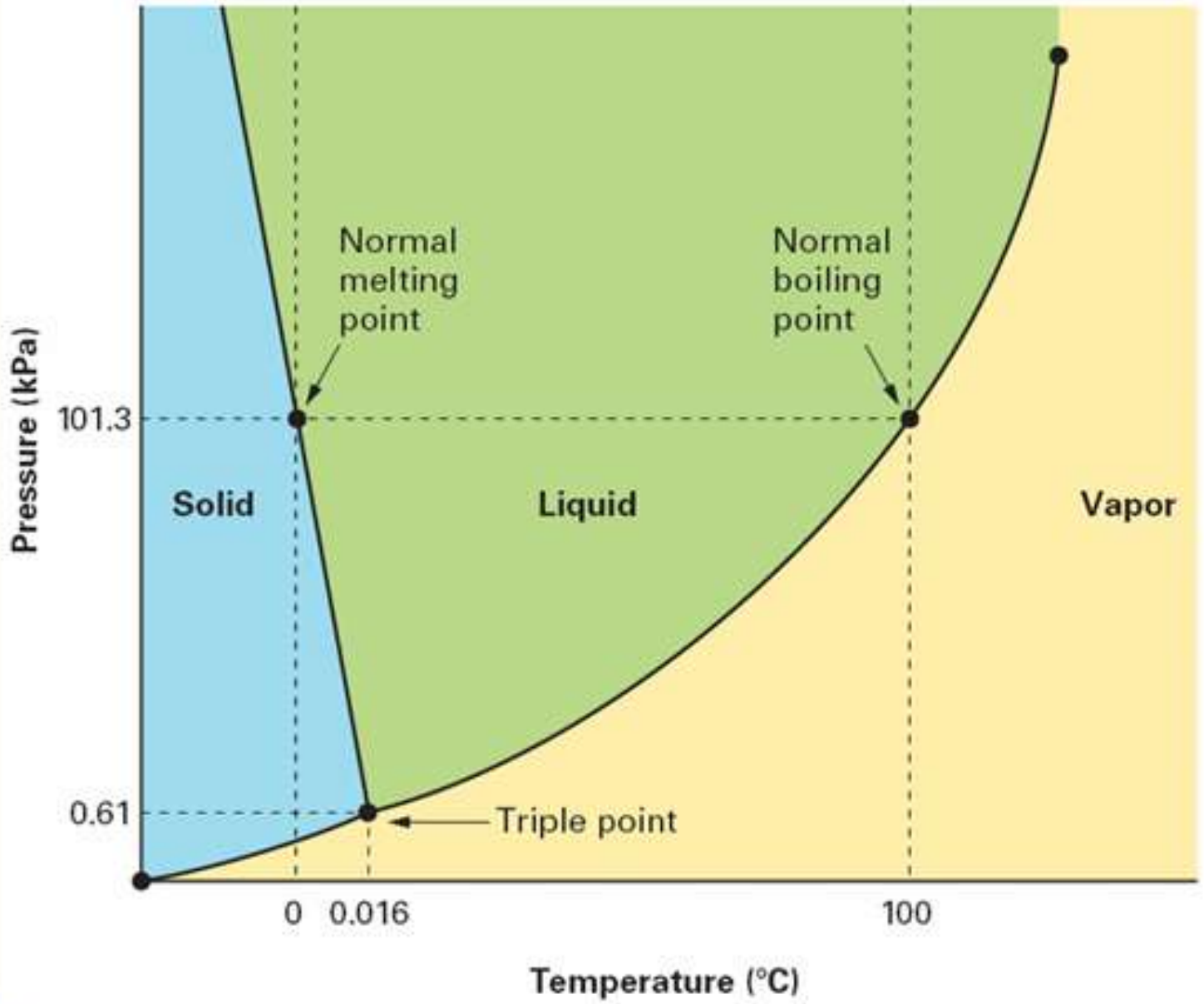
- A **phase diagram** is a graph that gives the conditions of temperature and pressure at which a substance exists as solid, liquid, and gas (vapor).

Phase Diagrams

– The conditions of pressure and temperature at which two phases exist in equilibrium are indicated on a phase diagram by a line separating the phases.

13.4

Phase Diagram of Water



13.4 Phase Diagrams

- The **triple point** describes the only set of conditions at which all three phases can exist in equilibrium with one another.

13.4 Section Quiz.

– 1. Identify the change of state that occurs when solid CO_2 changes to CO_2 gas as it is heated.

a) condensation

b) freezing

c) vaporization

d) sublimation

13.4 Section Quiz.

- 2.Sublimation occurs in solids if the vapor pressure at or near room temperature

  a) exceeds atmospheric pressure.

  b) equals atmospheric pressure.

  c) is less than atmospheric pressure.

  d) is less than half the atmospheric pressure.

13.4 Section Quiz.

–3. What is the significance of a line in a phase diagram?

a) Only one phase is present.

b) Two phases are in equilibrium.

c) Three phases are in equilibrium.

d) The distinction between two phases disappears.

13.4 Section Quiz.

–4. What is the significance of the triple point in a phase diagram?

a) Temperature and pressure are equal.

b) Two phases are in equilibrium.

c) Three phases are in equilibrium.

d) The distinction among three phases disappears.