5B The Gas Laws and Prerequisite Concepts

King

考点一：Particle theory of matter

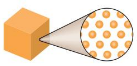
5.16 describe the relationship between the mass, volume, and density of solids, liquids, and gases using the particle model of matter

5.17 explain the effects of changes in temperature on the density of solids, liquids,and gases and relate the results to the particle model of matter

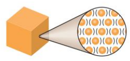
1. The Particle Model of Matter

Particle model of matter is a model that explains the arrangement of particles (atoms, molecules or ions) in a certain phase of matter.

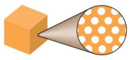
1) All matter is made up of tiny particles.



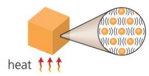
2) The particles of matter are always moving.



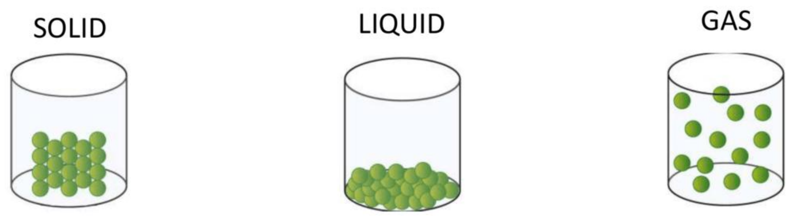
3) The particles have spaces between them.



4) Adding heat to matter makes the particles move faster

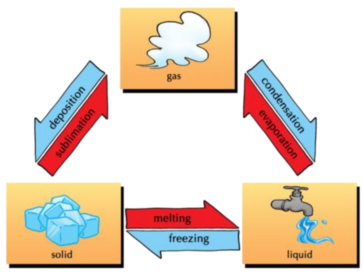


2. Three states of matter



Particle Distribution	Particles in solids are very close together	Particles in liquids are farther apart than in a solid, but closer than in a gas.	Particles in a gas are quite spread out.
Strength of particle bonds	The bonds between particles in solids are very strong	The bonds between particles in liquids are stronger than gases, but weaker than solids	The bonds between particles in gases are quite weak
Particle motion	Particles in solids have very little motion; they only vibrate.	Particles in liquids move around very little	Gas particles have a lot of motion; they move around fast and bounce into one another
Density	Solids usually have a greater density than liquids and gases	The density of liquids is usually in between that of solids and gases	Gases usually have a lower density than solids and liquids.
Mass	Solids usually have a greater mass than liquids and gases.	The mass of liquids is usually in between that of solids and gases.	Gases usually have a lower mass than solids and liquids.
Volume	Solids keep their own shape when put into a container; they take up the smallest amount of volume.	Liquids take on the shape of a container, but they do not fill out the whole container	Gases take on the shape of a container and they take up/fill out the entire space of the container that they are placed in.
Changes in Density due to Temperature	When you add heat to a solid, its density **decreases** When you remove heat, its density... **increases**	When you add heat to a solid, its density **decreases** When you remove heat, its density... **increases**	When you add heat to a solid, its density... **decreases** When you remove heat, its density... **increases**

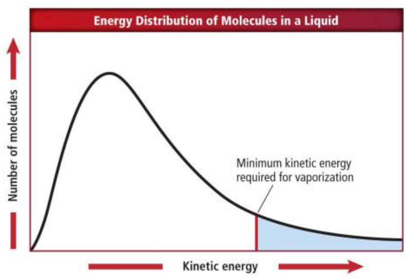
3. Different changes of state



Melting occurs when heat flows into a solid object.

• *Heat is the transfer of energy from an object at a higher temperature to an object at a lower temperature*

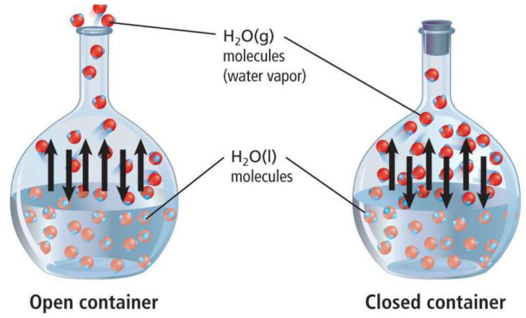
The **melting point** of a crystalline solid is the temperature at which the forces holding the crystal lattice together are broken and it becomes a liquid.



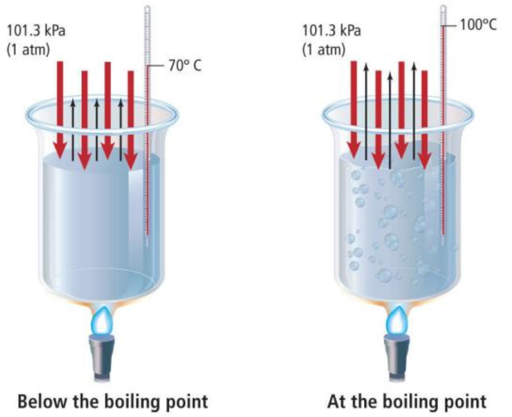
• **Vaporization** is the process by which a liquid changes to a gas or vapor.

• **Evaporation** is vaporization only at the surface of a liquid.

In a closed container, the pressure exerted by a vapor over a liquid is called **vapor pressure**.



The **boiling point** is the temperature at which the vapor pressure of a liquid equals the atmospheric pressure.



• **Sublimation** is the process by which a solid changes into a gas without becoming a liquid.

• As heat flows from water to the surroundings, the particles lose energy.

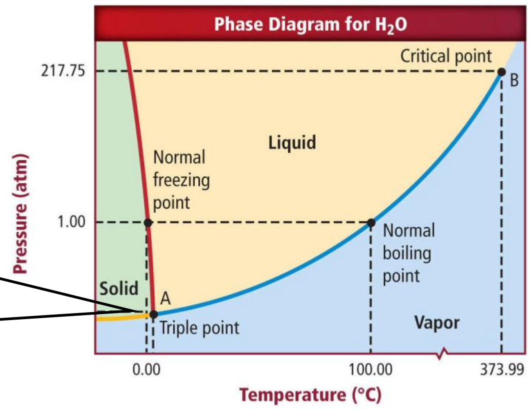
• The **freezing point** is the temperature at which a liquid is converted into a crystalline solid.

• As energy flows from water vapor, the velocity decreases.

• The process by which a gas or vapor becomes a liquid is called **condensation**.

• **Deposition** is the process by which a gas or vapor changes directly to a solid, and is the reverse of **sublimation**.

The **triple point** is the point on a phase diagram that represents the temperature and pressure at which all three phases of a substance can



考点二：Gas

5.18 analyse quantitatively the density of various substances

5.19 describe qualitatively the relationship between mass and weight

5.20 describe quantitatively the relationship between force, area, and pressure

5.21 explain qualitatively the relationship between pressure, volume, and temperature when liquid and gaseous fluids are compressed or heated

5.22 Perform calculations using the ideal gas equations: $PV = nRT$, $P_1V_1/T_1 = P_2V_2/T_2$, and Dalton's law of partial pressures.

1. Kinetic energy

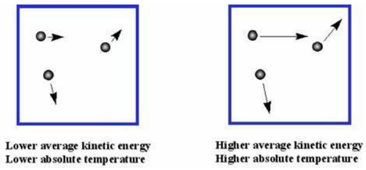
kinetic energy: energy due to motion

Kinetic energy of a particle depends on mass and velocity

$$KE = \frac{1}{2}mv^2$$

2. Temperature

Temperature is a measure of the average kinetic energy of the particles in a sample of matter.

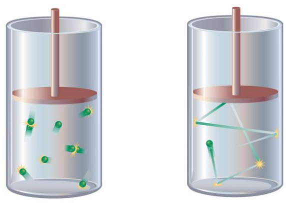


3. Kinetic molecular theory

Kinetic molecular theory is a theory that describes the physical properties of gases at their molecular level. The concepts of the kinetic molecular theory are as follows.

1) *Gases contain particles that are in constant, random motion.*

2) *These particles collide with each other constantly. The collisions are completely elastic.*



3) *The volume of a gas molecule is negligible compared to the volume of the container in which the gas is present. But these particles have a considerable mass.*

4) *There are no intermolecular forces between gas molecules.*

5) *The average kinetic energy of the gas is proportional to the absolute temperature of the gas.*

4. Gas pressure

a) Definition

Pressure is defined as force per unit area.

• Gas particles exert pressure when they collide with the walls of their container.

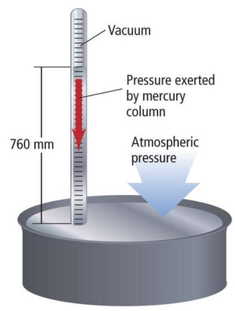
*The particles in the earth's atmosphere exert pressure in all directions called **air pressure**.*

• There is less air pressure at high altitudes because there are fewer particles present, since the force of gravity is less

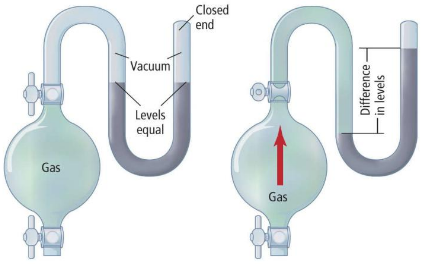
b) Unit

• **Torricelli** invented the barometer.

• **Barometers(气压计)** are instruments used to measure atmospheric air pressure



Manometers(压力计) measure gas pressure in a closed container



• The SI unit of force is the **newton (N)**.

• One **pascal(Pa)** is equal to a force of one **Newton per square meter** or **N/m²**.

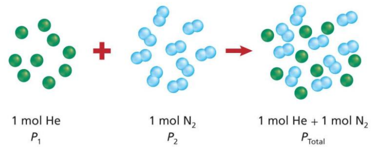
• One atmosphere is equal to **760 mm Hg** or 101.3 **kilopascals**.

1 atm=1Bar=760 mmHg=760 Torr=101kPa

c) Partial pressures

Dalton's law of **partial pressures** states that the total pressure of a mixture of gases is equal to the sum of the pressures of all the gases of the mixture

$$P_{total} = P1 + P2 + P3 + ...Pn$$



5. Gas law

a) Boyle's law

Boyle's law or Mariotte'ss law states that **pressure** of an ideal gas is inversely proportional to **volume** under conditions of **constant mass** and **temperature**.

*When the gas volume **increases**, pressure **decreases**. When the volume **decreases**, pressure **increases**.*

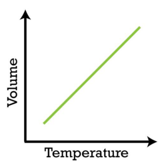
$$P_1V_1 = P_2V_2$$

$$P \propto 1/V$$

b) **Charles's law** states that the **volume** of a given amount of gas is directly proportional to its **kelvin temperature** at constant pressure.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

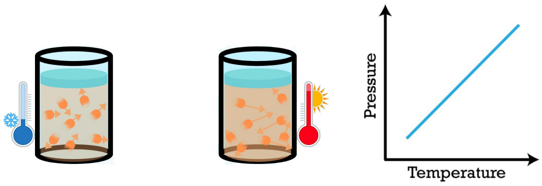
$$V \propto T$$



c) **Gay-Lussac's law** states that the **pressure** of a fixed amount of gas varies directly with the **kelvin temperature** when the volume remains constant.

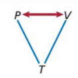
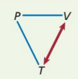
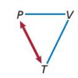
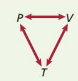
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P \propto T$$



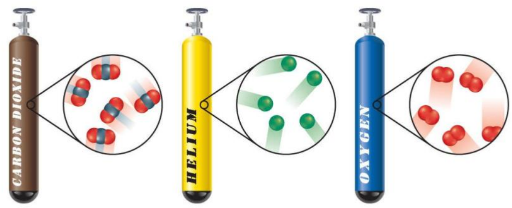
The **combined gas law** states the relationship among pressure, temperature, and volume of a fixed amount of gas.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Law	Boyle's	Charles's	Gay-Lussac's	Combined
Formula	$P_1V_1 = P_2V_2$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
What is constant?	amount of gas, temperature	amount of gas, pressure	amount of gas, volume	amount of gas
Graphic organizer				

6. The Ideal Gas Law

Avogadro's principle states that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.



- *The **molar volume** of a gas is the volume 1 mol occupies at 0.00°C and 1.00 atm of pressure.*
- *0.00°C and 1.00 atm are called **standard temperature** and **pressure (STP)**.*
- *At **STP**, 1 mol of gas occupies **22.4 L***

Ideal gas particles occupy a negligible volume and are far enough apart to exert minimal attractive or repulsive forces on each other

The **ideal gas law** describes the physical behavior of an **ideal gas** in terms of pressure, volume, temperature, and amount.

$$PV = nRT$$

The **ideal gas law** can be used to find **molar mass** if the **mass** of the gas is known, or the **density** of the gas if its **molar mass** is known

$$PV = nRT \rightarrow \text{substitute } n = \frac{m}{M} \rightarrow PV = \frac{mRT}{M}$$

$$M = \frac{mRT}{PV} \rightarrow \text{substitute } \frac{m}{V} = D \rightarrow M = \frac{DRT}{P} \quad M = \frac{mRT}{PV} \quad D = \frac{MP}{RT}$$

*At very **high pressures** and very **low temperatures, real gases** behave differently than **ideal gases**.*