Chapter 9. The kinetic particle model of matter

Contents:

New word list:

State of matter：物态	vibration：振动	
Solid：固体	pollen：花粉	
Liquid：液体	grain: 颗粒	
Gas：气体	rigid：刚性的	
Fluid：流体 （气体+液体）	suspend：悬浮	
Evaporation：蒸发	bombardment：轰击	
Boiling：沸腾	diffuse：扩散，弥漫	
Melting： 熔化	dissolve：溶解	jiggle: 摆动
Solidifying/freezing：凝固	magma：岩浆	squash: 挤压
Condensation：冷凝/凝结	diaphragm：横膈膜	glacier：冰川

2 Thermal physics

2.1 Kinetic particle model of matter

2.1.1 States of matter

Core

1. Know the distinguishing properties of solids, liquids and gases
2. Know the terms for the changes in state between solids, liquids and gases (gas to solid and solid to gas transfers are **not** required)

Supplement

2.1 Kinetic particle model of matter continued

2.1.2 Particle model

Core

1 Describe the particle structure of solids, liquids and gases in terms of the arrangement, separation and motion of the particles, and represent these states using simple particle diagrams

2 Describe the relationship between the motion of particles and temperature, including the idea that there is a lowest possible temperature (–273 °C), known as absolute zero, where the particles have least kinetic energy

3 Describe the pressure and the changes in pressure of a gas in terms of the motion of its particles and their collisions with a surface

4 Know that the random motion of microscopic particles in a suspension is evidence for the kinetic particle model of matter

5 Describe and explain this motion (sometimes known as Brownian motion) in terms of random collisions between the microscopic particles in a suspension and the particles of the gas or liquid

Supplement

6 Know that the forces and distances between particles (atoms, molecules, ions and electrons) and the motion of the particles affects the properties of solids, liquids and gases

7 Describe the pressure and the changes in pressure of a gas in terms of the forces exerted by particles colliding with surfaces, creating a force per unit area

8 Know that microscopic particles may be moved by collisions with light fast-moving molecules and correctly use the terms atoms or molecules as distinct from microscopic particles

2.1.3 Gases and the absolute scale of temperature

Core

1 Describe qualitatively, in terms of particles, the effect on the pressure of a fixed mass of gas of:

(a) a change of temperature at constant volume

(b) a change of volume at constant temperature

2 Convert temperatures between kelvin and degrees Celsius; recall and use the equation

T (in K) = θ (in °C) + 273

Supplement

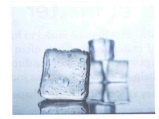
3 Recall and use the equation

pV = constant

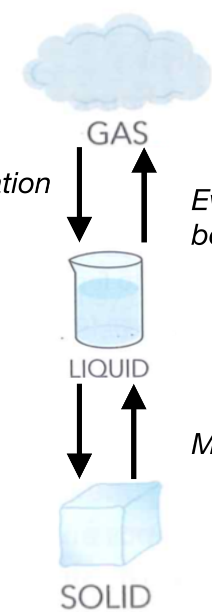
for a fixed mass of gas at constant temperature, including a graphical representation of this relationship

9.1 States of matters

Do you know the three states of matter? And what are the differences between them. Fill in the form below.

States	Volume	Shape	
Solid *(rigid)*	*fixed volume;* *Cannot be squashed*	*fixed*	
Liquid *(Not rigid)*	*fixed volume;* *Cannot be squashed*	*Take the shape of its container*	
Gas *(Not rigid)*	*Unfixed volume; can be squashed*	*Expand to fill its container*	

Change of states:



Condensation

Evaporation/ boiling

Solidifying/ freezing

Melting

Boiling point/condensing point:

Liquid <=> gas

Melting point/freezing point:

Solid <=> liquid

There are two ways for liquid to change state from liquid to gas: **evaporation and boiling.** What's the difference between these two ways?

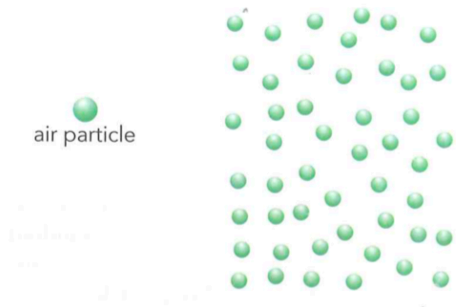
Evaporation happens at any temperature; boiling happens at boiling point.

9.2 The kinetic particle model of matter

Kinetic: *relating to movement*

Particle: *atoms, molecules, ions*

Model: a way of representing of a system can not be experienced directly, usually simplified



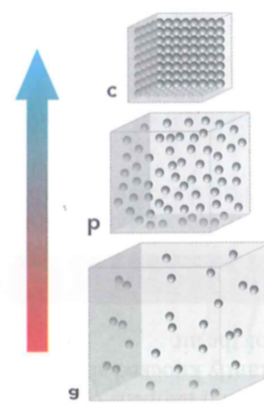
The kinetic particle model:

Matter is made up of identical, spherical, ***moving*** *molecules*

<u>Particle movement and temperature: Temperature is average kinetic energy of particles in a matter</u>

Absolute zero: the temperature at which the particles have **the minimum/least kinetic energy**

<u>Evidence for the kinetic model: Brownian motion</u>

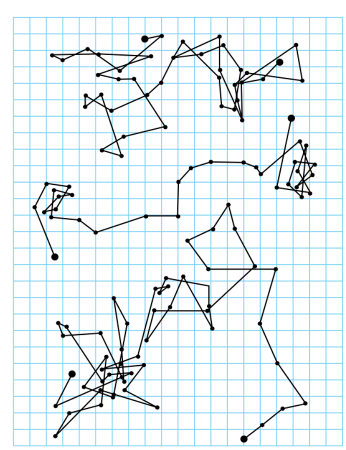


In 1827, Scientist **Robert Brown** observed pollen grains jiggling about using a microscope.

Brownian motion:

The motion of particles suspended in a liquid or gas, caused by

States	Arrangement to explain shape	Seperation to explain volume	Motion to explain arrangement
Solid	*Regular*	Very close	Vibrate about a fixed point
Liquid	*Irregular*	Slightly less close than in a solid	Vibrate and move from place to place within the liquid
Gas	*Irregular*	Far apart, separate from each other	Move freely in all direction at high speed

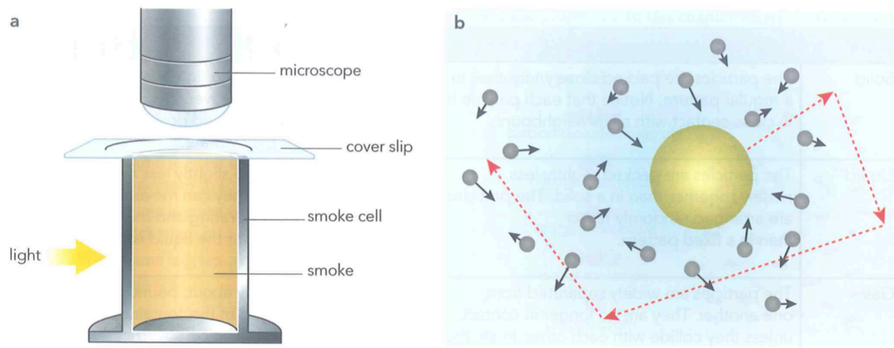


uneven molecular bombardment

Explanation:

Smaller, lighter molecules around pollen particles move very fast, they *collide repeated with pollen。 particles. Collision exerts forces on pollen particles and changes the motion of them.*

Brownian motion of smoke particles:



More about brownian motion:

Air molecules usually have an average diameter of 4×10^{-10} m, a smoke particle with a lot of molecules in it, has a diameter around 10^{-7} m, so smoke particles are much larger than air molecules (250 times). Smoke particles are also much heavier. Since temperature is proportional to the average kinetic energy of particles, at the same temperature, the speed of air molecules are much faster. So air molecules move fast about, collide with smoke particles repeatedly. The bombardment of air molecules are random, so the movement of smoke particles are random too.

Using the kinetic model to explain following phenomena:

1. Solids keep their shape, liquids take up shape of their container; gas fill their container

Particles in solids only can vibrate about a fixed point, and they are packed closely together, so solids keep their shape; Particles in liquid can move from place to place within the liquid, so liquids take the shape of its container; Particles in gas can move about in complete freedom, so gas expand to fill its container.

2. You can smell perfume across the room. Sugar crystal in a hotter drink dissolve more quickly.

Perfume molecules spread out because they are free to move. Sugar molecules dissolve in the drink and spread throughout the liquid carried by the mobile particles.

3. Most solids expand when they melt. Liquid expands a lot when they boil.

Molecules in liquids are slightly less close than in solids. Molecules in far are further apart from each other.

Forces and the kinetic model

States	Attractive forces between molecules
Solid	*Very strong*
Liquid	*Strong, less stronger than that in solid*
Gas	*Negligible*

Why do particles stick together to make solids/liquids?

The attractive forces between molecules make them stick together to form solids/liquids; the closer the molecules, the stronger the force

9.3 Gases, the kinetic model and the gas laws

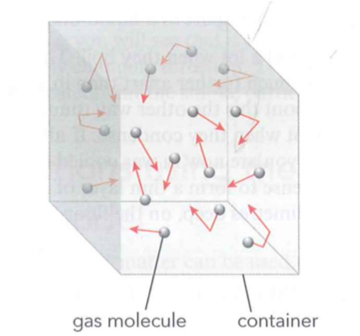
Why do gases cause pressure on the wall of its container?

Gas molecules collide with/hit the wall;

momentum of gas molecules change;

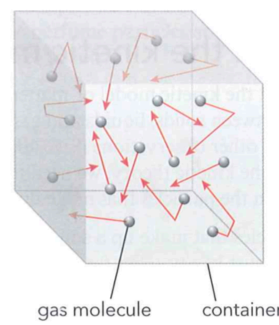
cause a force on the wall ($F = \frac{\Delta p}{\Delta t}$)*;*

pressure is the force exerted on the unit area ($p = \frac{F}{A}$)



Heat the gas?

Molecules hit the wall with larger forces and more frequently. So pressure increases.



Compress the gas?

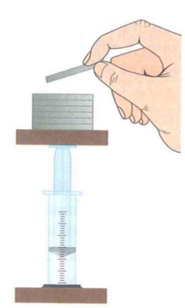
Molecules don't move far before collide with the wall, so collision is more frequent, so pressure increases.

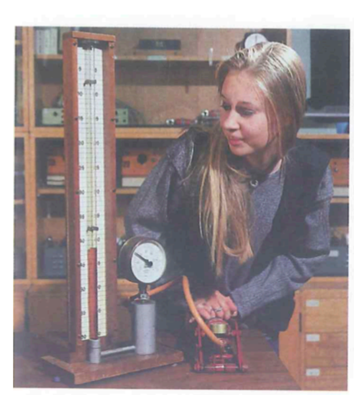
The gas laws:

For a **<u>fixed mass</u>** of gas, the temperature, volume and pressure of the gas all affects each other.

1. Compressed: **<u>Boyle's law</u>**

At constant temperature, pressure × volume = constant, ***<u>pV = constant</u>*** ($p_1V_1 = p_2V_2$)





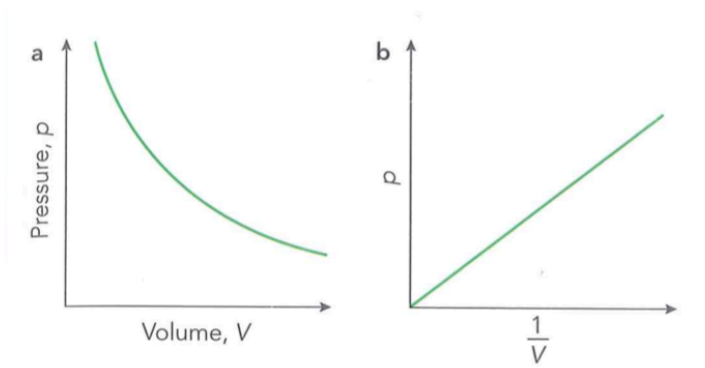
Units:

Pressure, p/Pa	Volume, V/cm^3	Pressure × volume, pV/Pa cm^3
100	60	6000
125	48	6000
150	40	6000
200	30	6000
250	24	6000
300	20	6000

Use the same unit for both V values.

Use the same unit for both p values.

p is inversely proportional to V



Exercise 9.1:

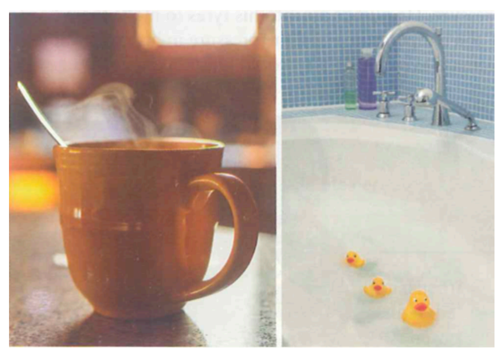
A cube diver releases a bubble of air. The bubble has a volume of 2 cm3. He watches it rise to the surface, expanding as it rises. The diver is at a depth where the pressure is 5 atmospheres. What will the volume of the bubble be when it reaches the surface, where the volume is 1 atmosphere? Assume that the temperature does not change.

- Boyle's law (Equation 1)
  $PV = C_1 \quad \text{or} \quad P_1V_1 = P_2V_2$
- Charles's law (Equation 2)
  $\frac{V}{T} = C_2 \quad \text{or} \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$
- Avogadro's law (Equation 3)
  $\frac{V}{N} = C_3 \quad \text{or} \quad \frac{V_1}{N_1} = \frac{V_2}{N_2}$
- Gay-Lussac's law (Equation 4)
  $\frac{P}{T} = C_4 \quad \text{or} \quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$

2. Heated: Charles's law

At constant pressure, $\frac{V}{T} = constant$ *==> thermal expansion (热胀冷缩)*

9.4 Temperature and the Celsius scale



Temperature:

Macroscopic: measure of how hot or cool something is

Microscopic: average k.e. of particles in the object

Temperature vs internal energy:

average k.e. of individual particles in the object

Total energy (k.e. + p.e.) of all particles in the object

Measuring temperature:

Thermometer

(Mercury/alcohol thermometer: thermal expansion: expands when gets hotter)

The Celsius scale (°C):

Fixed points: 0 °C: the melting point of pure ice at atmospheric pressure

100 °C: the boiling point of pure water at atmospheric pressure

Divide the space between 0 °C and 100 °C into 100 equal parts.

The Kelvin temperature scale: absolute temperature

Start from absolute zero (0K = -273 °C);

A change of temperature in one degree is the same for both scales;

Conversion between Kelvin temperature and degree Celsius:

$$T(K) = \theta(^\circ C) + 273$$