Chapter 9.
The kinetic particle model of matter

G2 | Ji Yutong | 09/2023

New Words

State of matter：
Solid：
Liquid：
Gas：
Fluid：
Evaporation：
Boiling：
Melting：
jiggle:
Solidifying/freezing：
squash:
Condensation：
glacier：

vibration：
pollen：
grain:
rigid：
suspend：
bombardment：
diffuse：
dissolve：
magma：
diaphragm：

New Words

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	

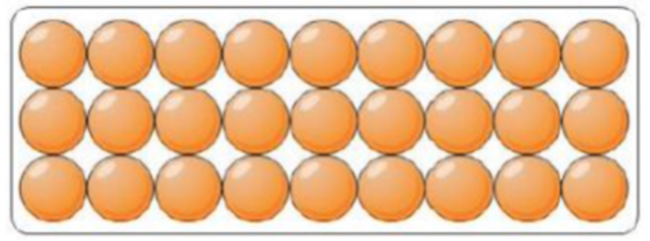
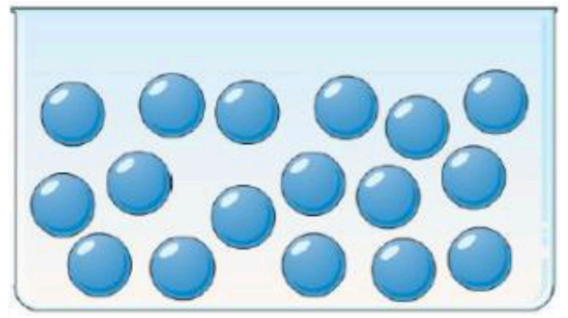
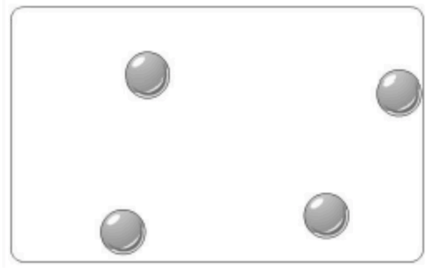
States of Matters

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

States	Volume	Shape	
Solid			
Liquid			
Gas			

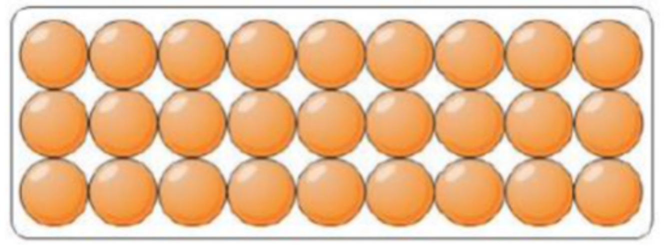
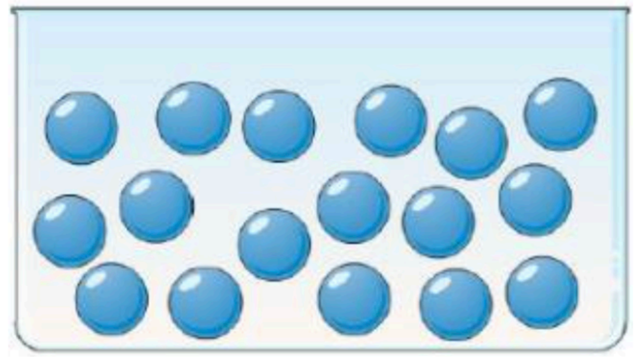
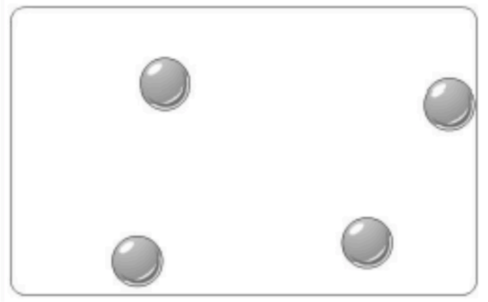
States of Matters

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

States	Volume	Shape	
Solid	*fixed volume;*		
Liquid	*fixed volume;*		
Gas	*Unfixed volume;*		

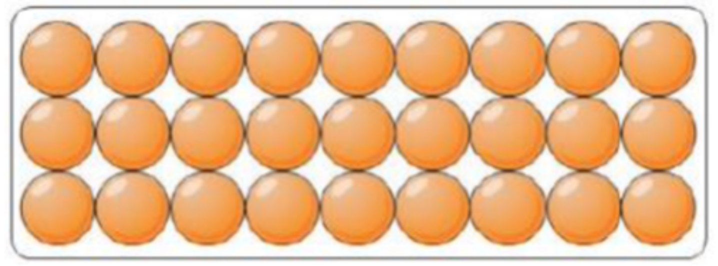
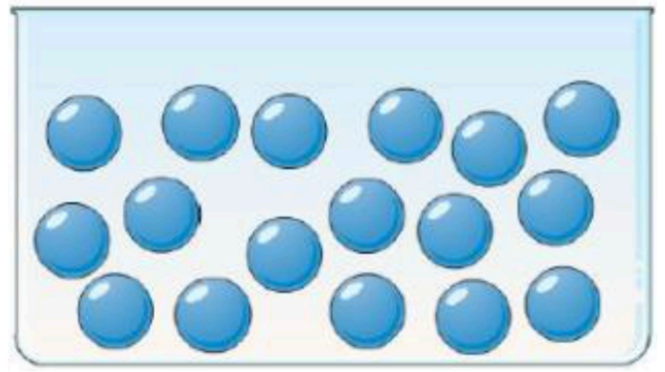
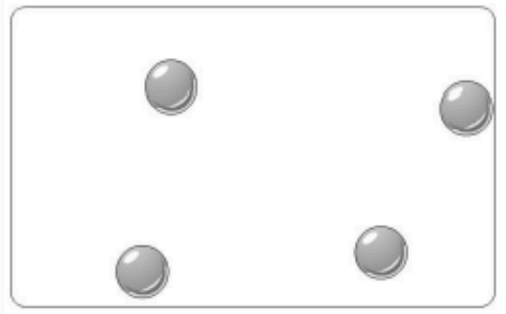
States of Matters

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

States	Volume	Shape	
Solid	*fixed volume;* ***Cannot be squashed***		
Liquid	*fixed volume;* *Cannot be squashed*		
Gas	*Unfixed volume; can be squashed*		

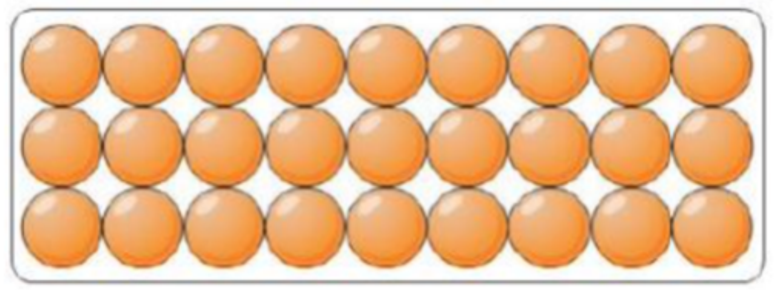
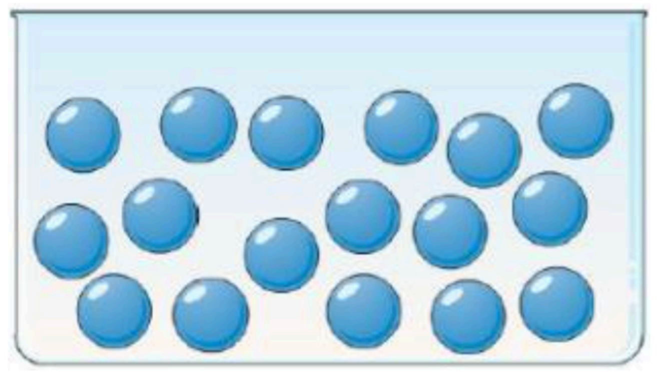
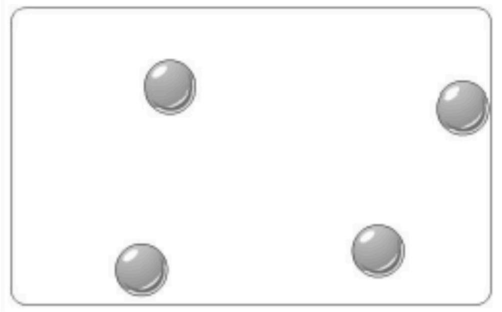
States of Matters

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

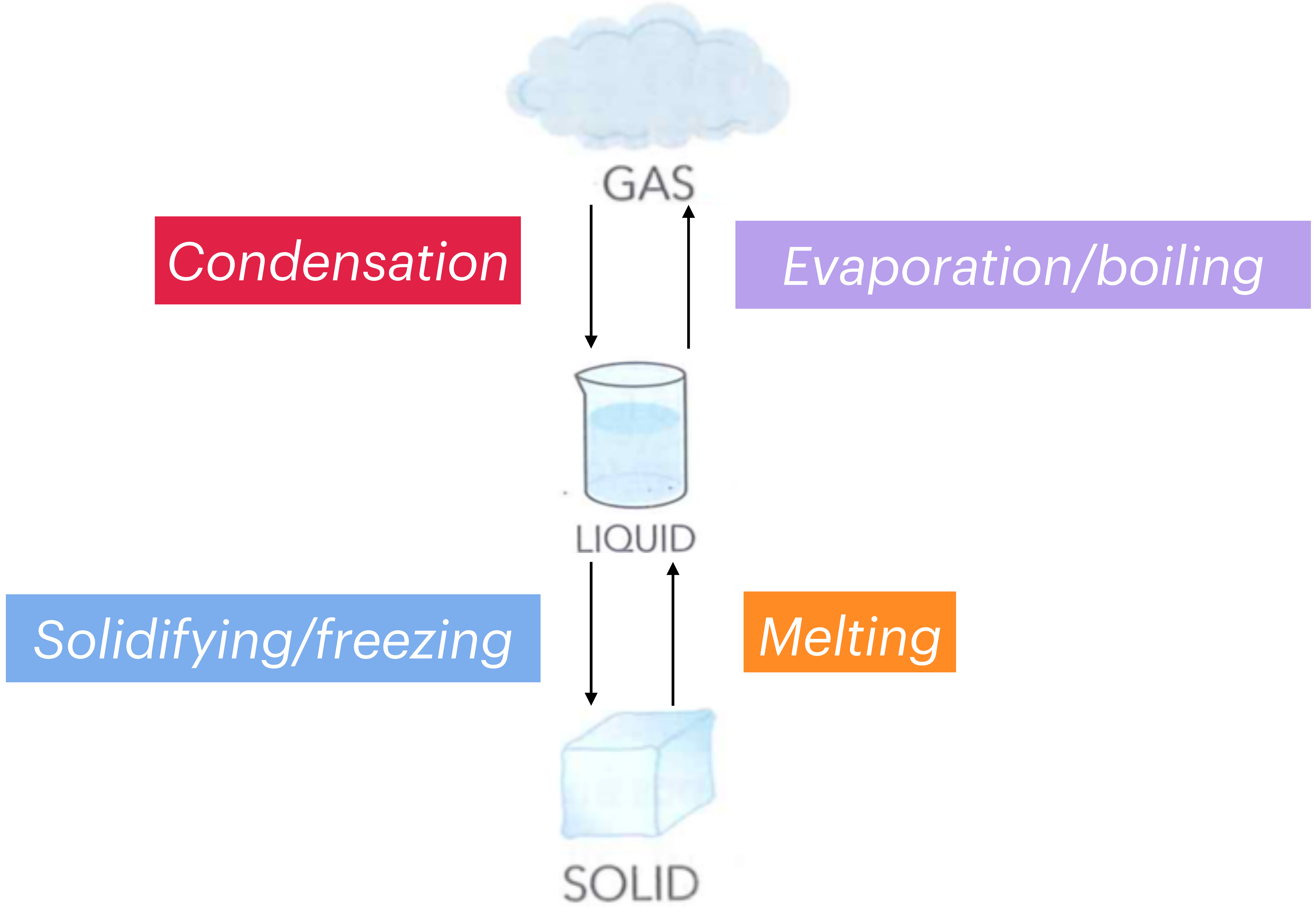
States	Volume	Shape	
Solid	*fixed volume;* ***Cannot be squashed*** *(Why?=>No space btw molecules; will have repulsion when being compressed)*		
Liquid	*fixed volume;* *Cannot be squashed*		
Gas	*Unfixed volume; can be squashed*		

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	*fixed volume;* ***Cannot be squashed*** *(Why?=>No space btw molecules; will have repulsion when being compressed)*	*fixed*	
Liquid	*fixed volume;* *Cannot be squashed*	*Take the shape of its container*	
Gas	*Unfixed volume; can be squashed*	*Expand to fill its container*	

Change of States:



Boiling point/condensing point:
Liquid <=> gas

Melting point/**freezing** point:
Solid <=> liquid

Change of States:

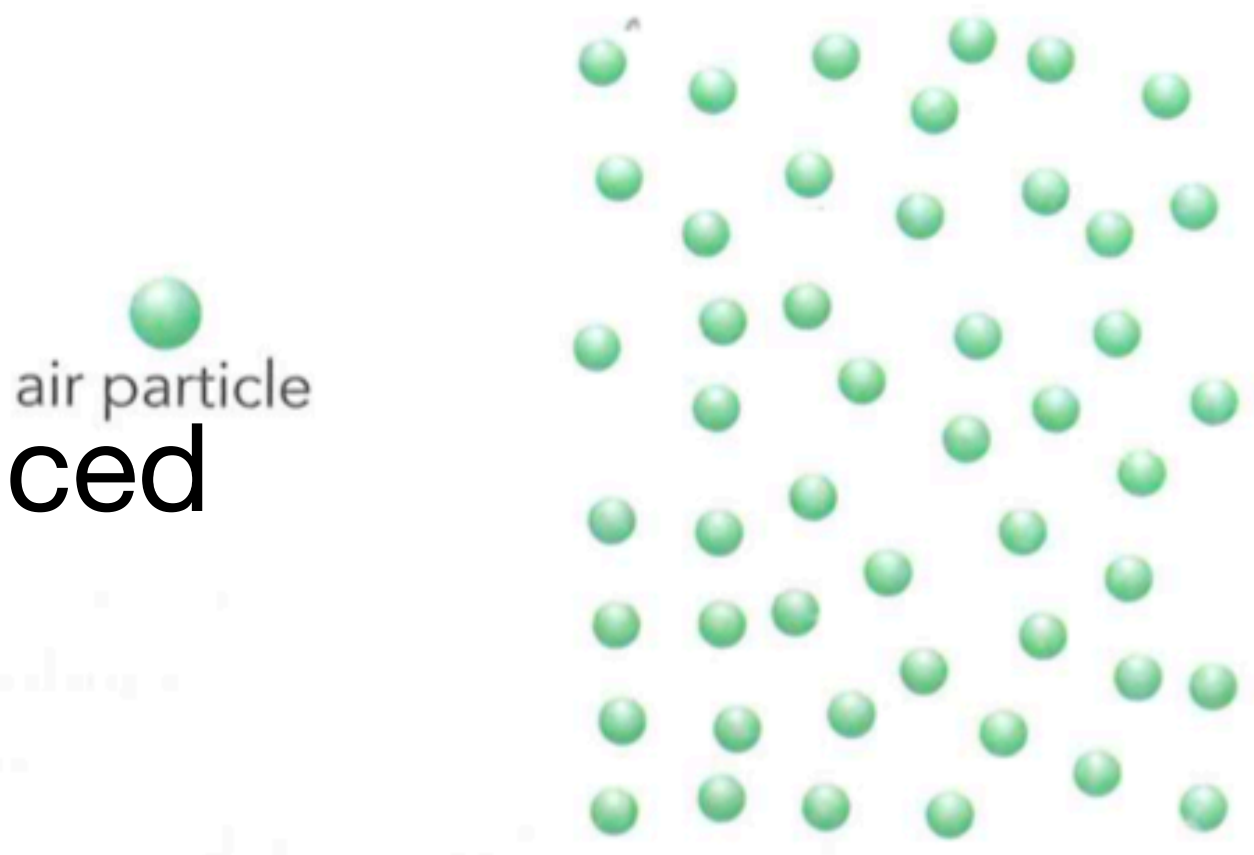
There are two ways for liquid to change state from liquid to gas: **evaporation and boiling**. What's the difference between these two ways?

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

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:

<u>Matter is made up of identical, spherical, ***moving*** molecules</u>

★**<u>Particle movement and temperature:</u>**

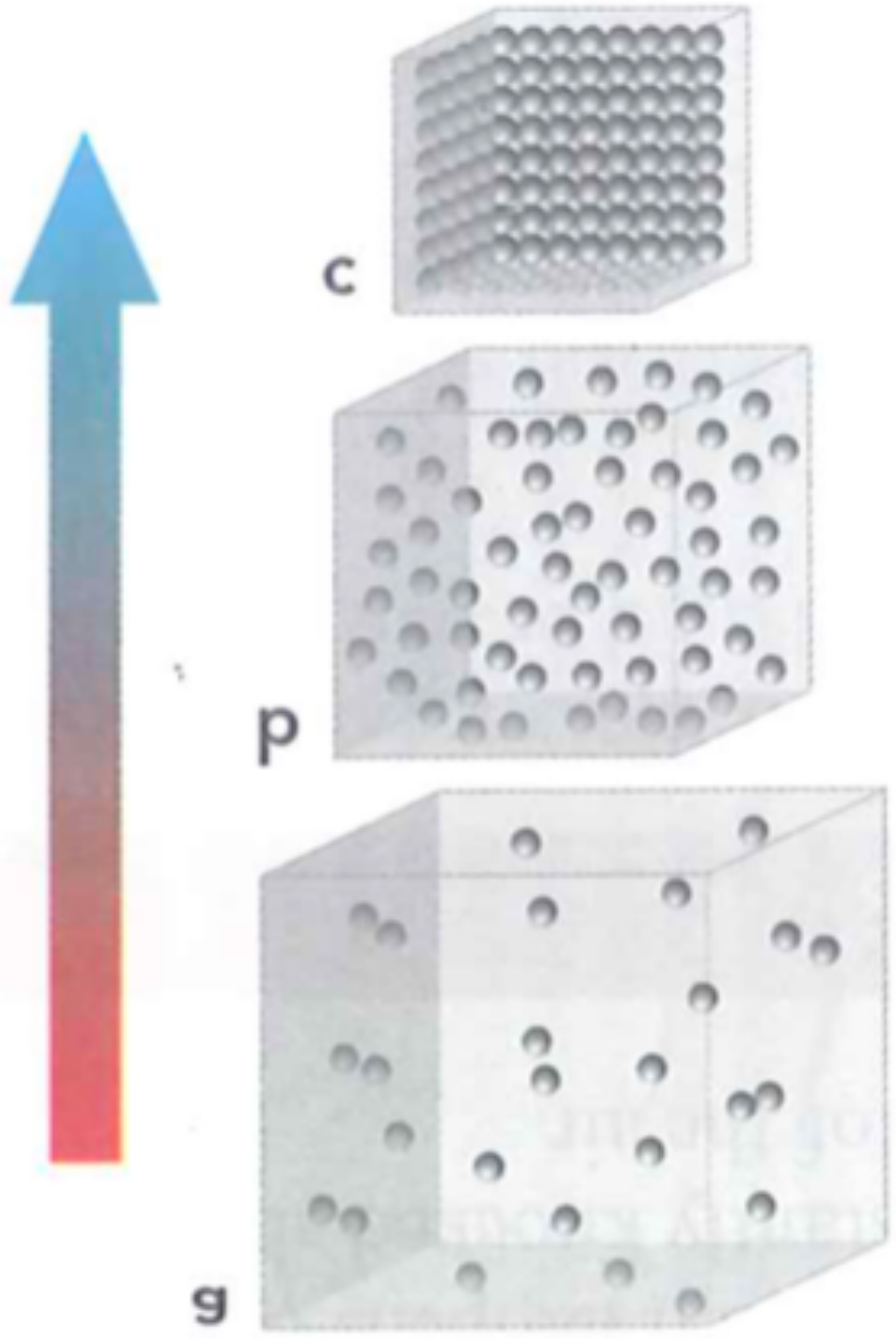
Temperature is ***<u>average kinetic energy</u>*** of particles in a matter

<u>Absolute zero:</u>

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

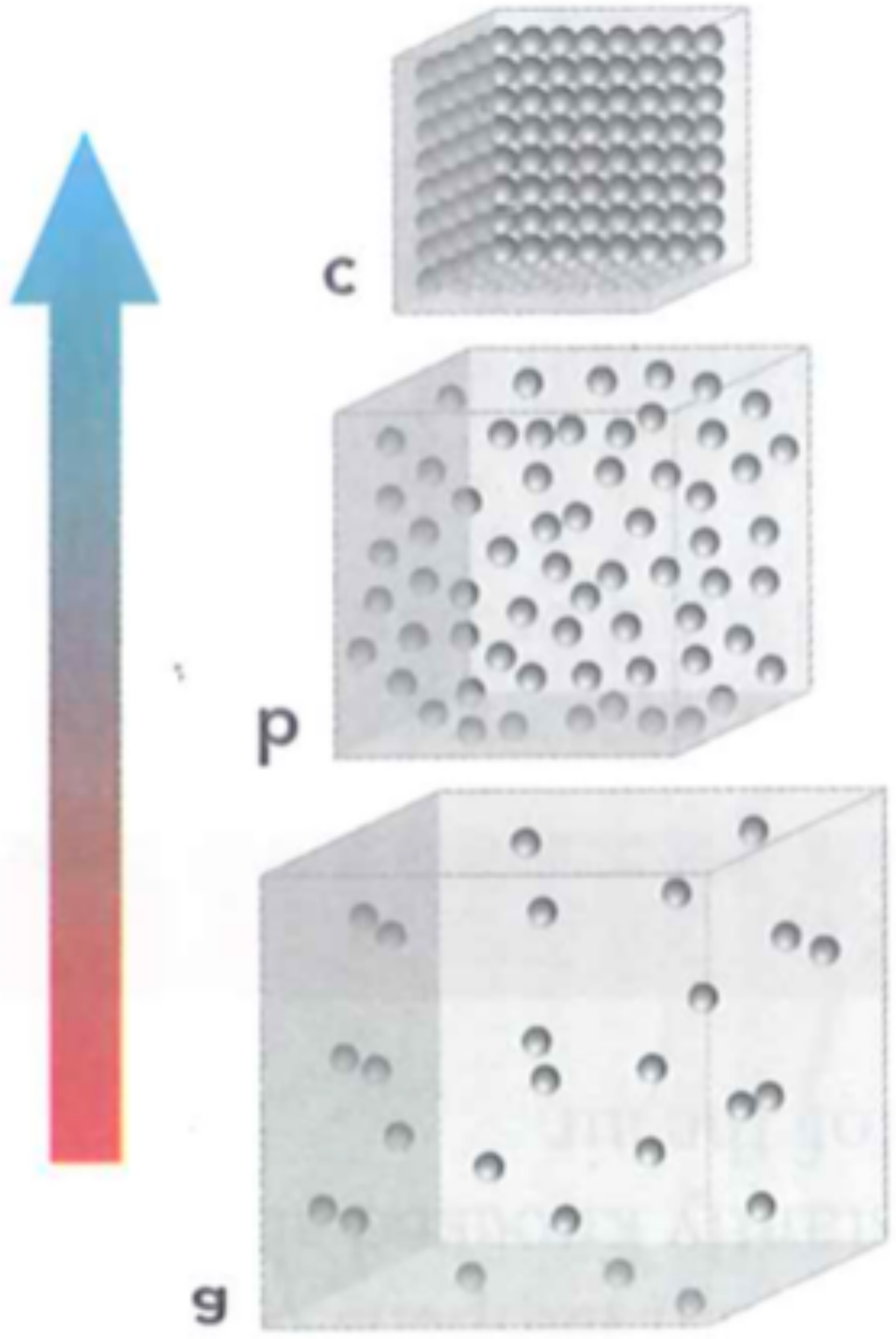
The kinetic particle model of matter

States	Arrangement to explain shape	Seperation to explain volume	Motion to explain arrangement
Solid			
Liquid			
Gas			



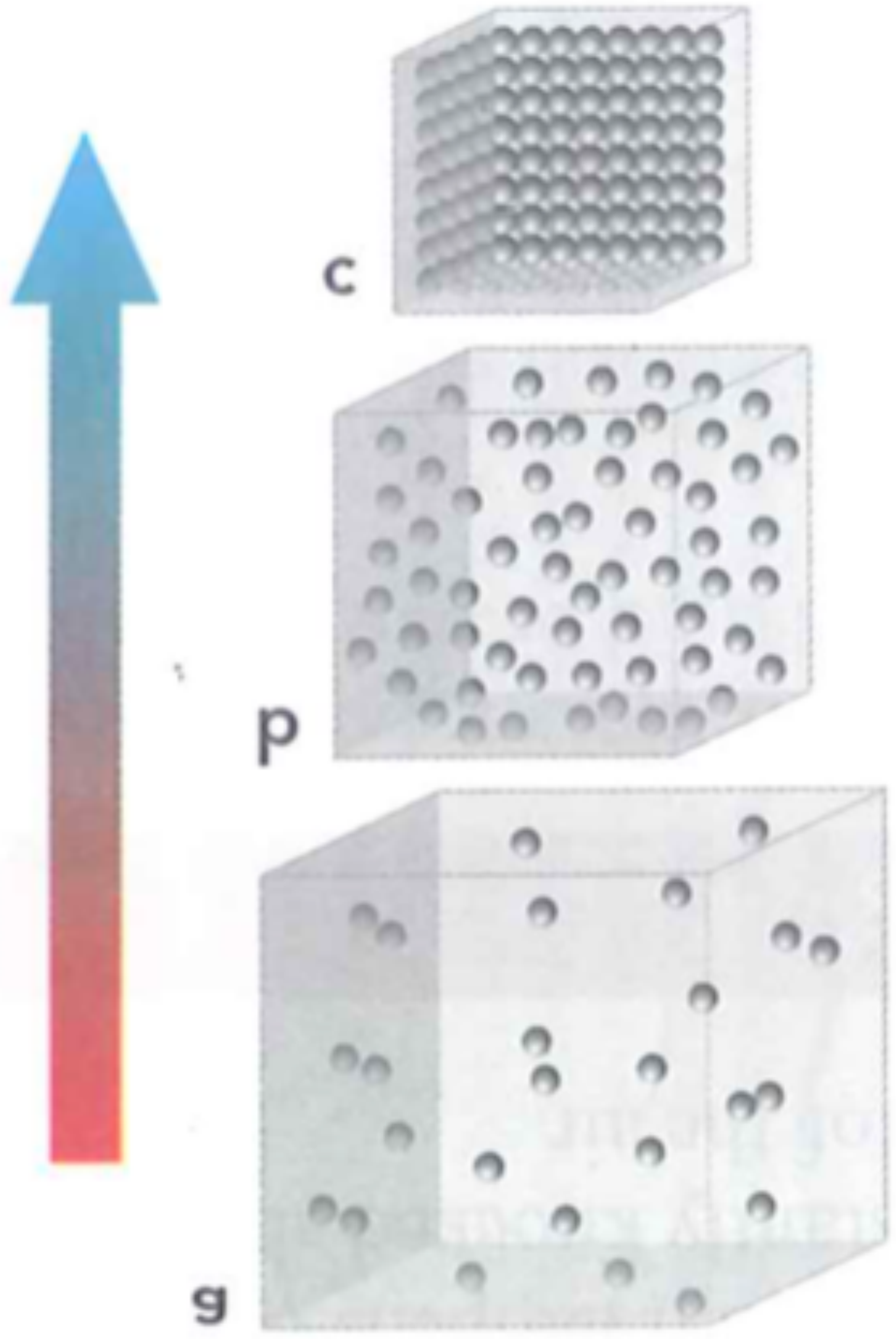
The kinetic particle model of matter

States	Arrangement to explain shape	Seperation to explain volume	Motion to explain arrangement
Solid	*Regular*		
Liquid	*Irregular*		
Gas	*Irregular*		



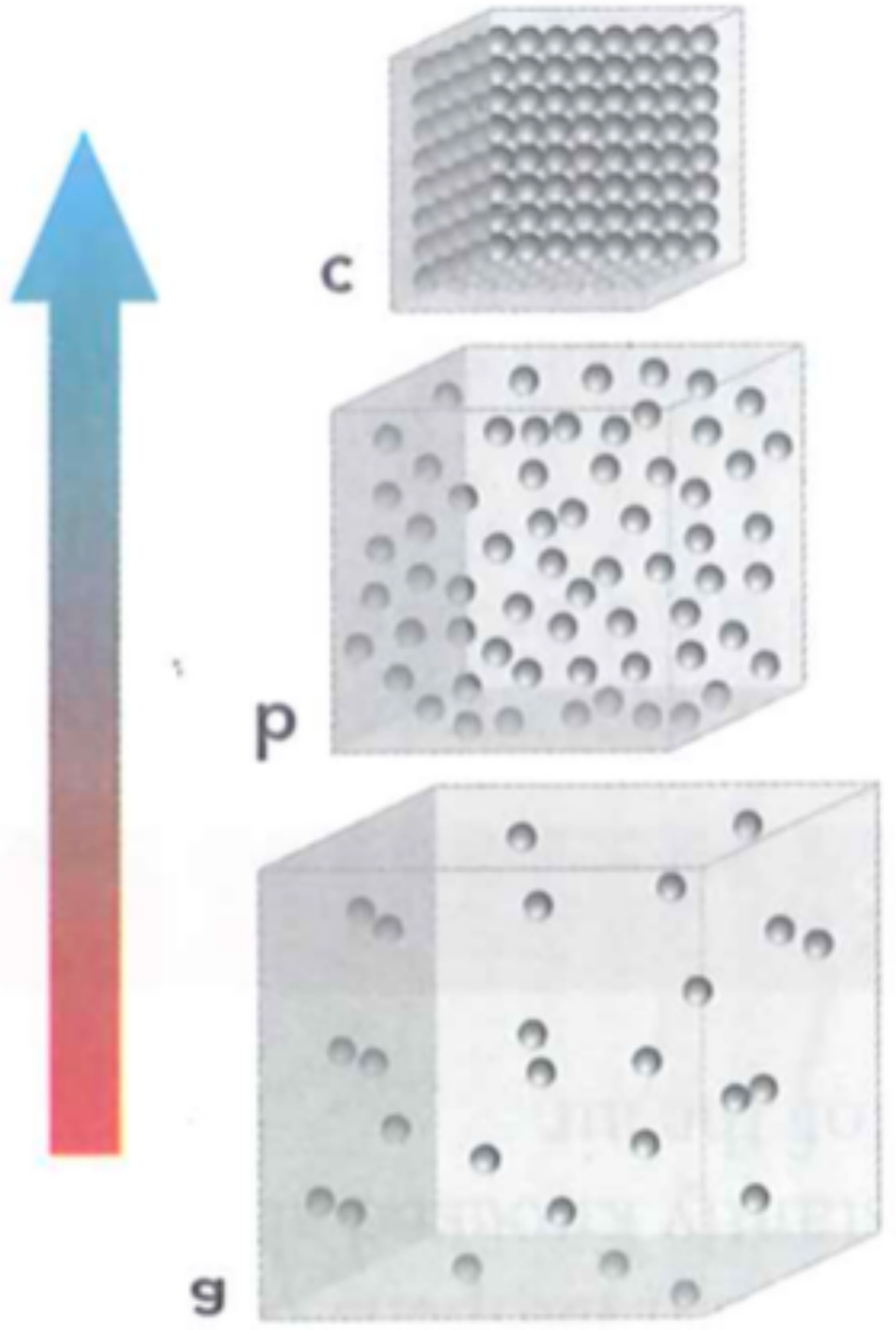
The kinetic particle model of matter

States	Arrangement to explain shape	Seperation to explain volume	Motion to explain arrangement
Solid	*Regular*	Very close	
Liquid	*Irregular*	Slightly less close than in a solid	
Gas	*Irregular*	Far apart, separate from each other	



The kinetic particle model of matter

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

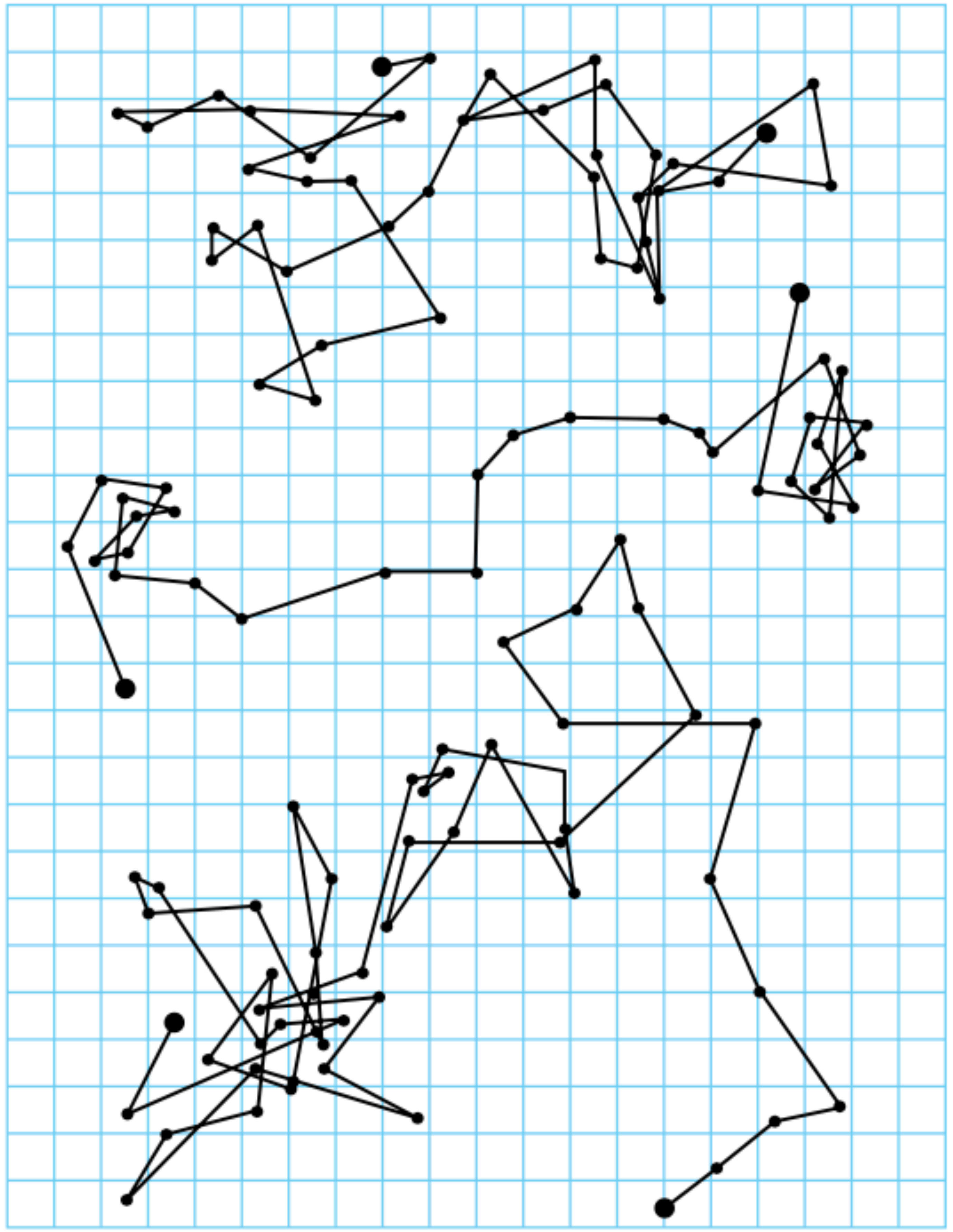


Evidence for the kinetic model: Brownian motion

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 uneven molecular **bombardment**

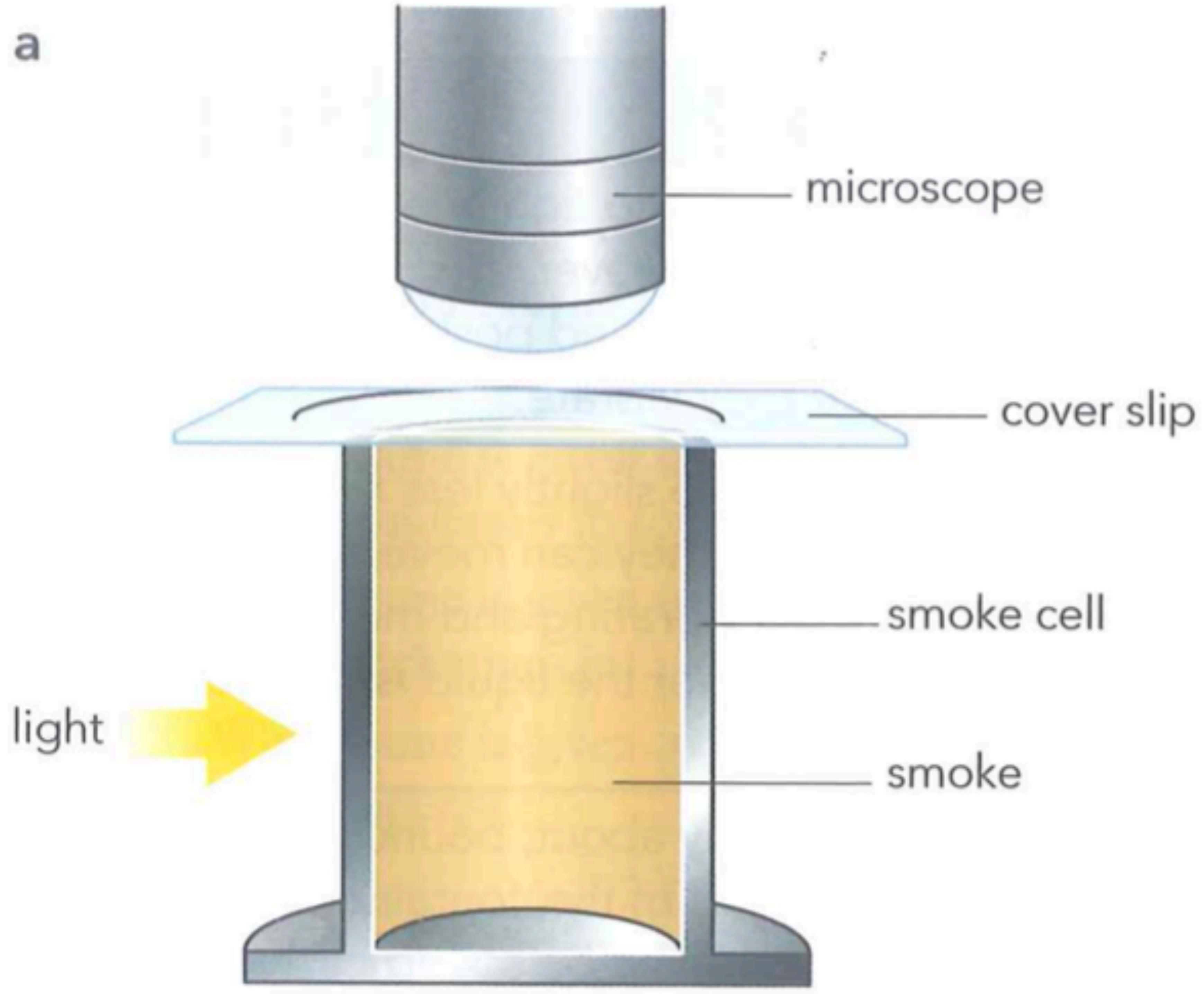


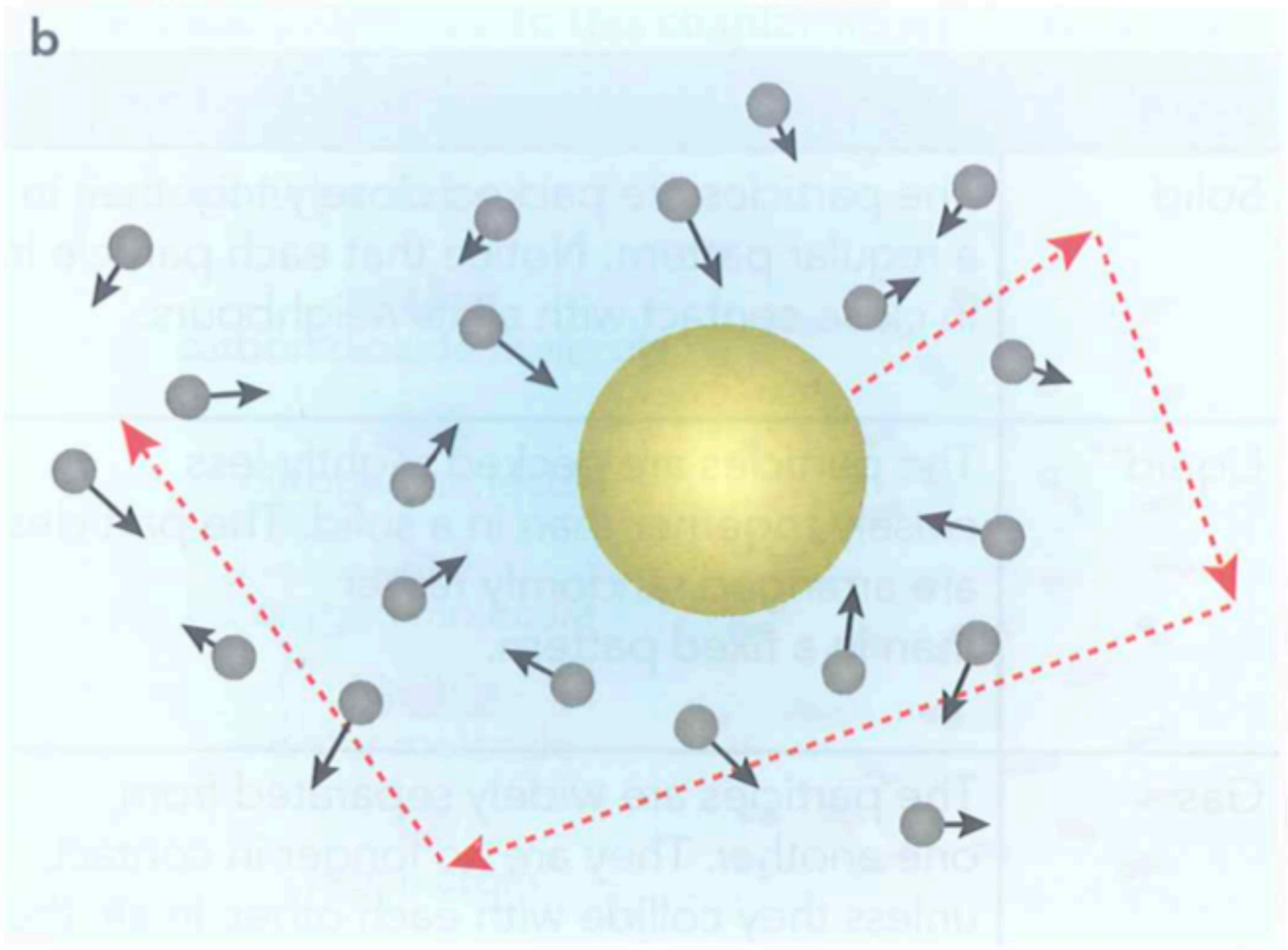
★**Explanation:**

Smaller, lighter water molecules around pollen particles move very **fast**, they ***collide repeatedly*** with pollen particles. Collisions exert uneven forces on pollen particles and change the motion of them.

Evidence for the kinetic model: Brownian motion

Brownian motion of smoke particles:





Evidence for the kinetic model: 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).

So air molecules move ***fast*** about, collide with smoke particles repeatedly. The bombardment of air molecules are ***random*** and ***uneven***, so the movement of smoke particles are random too.

Exercise

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.

Exercise

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

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

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

Gases, the kinetic model and the gas laws

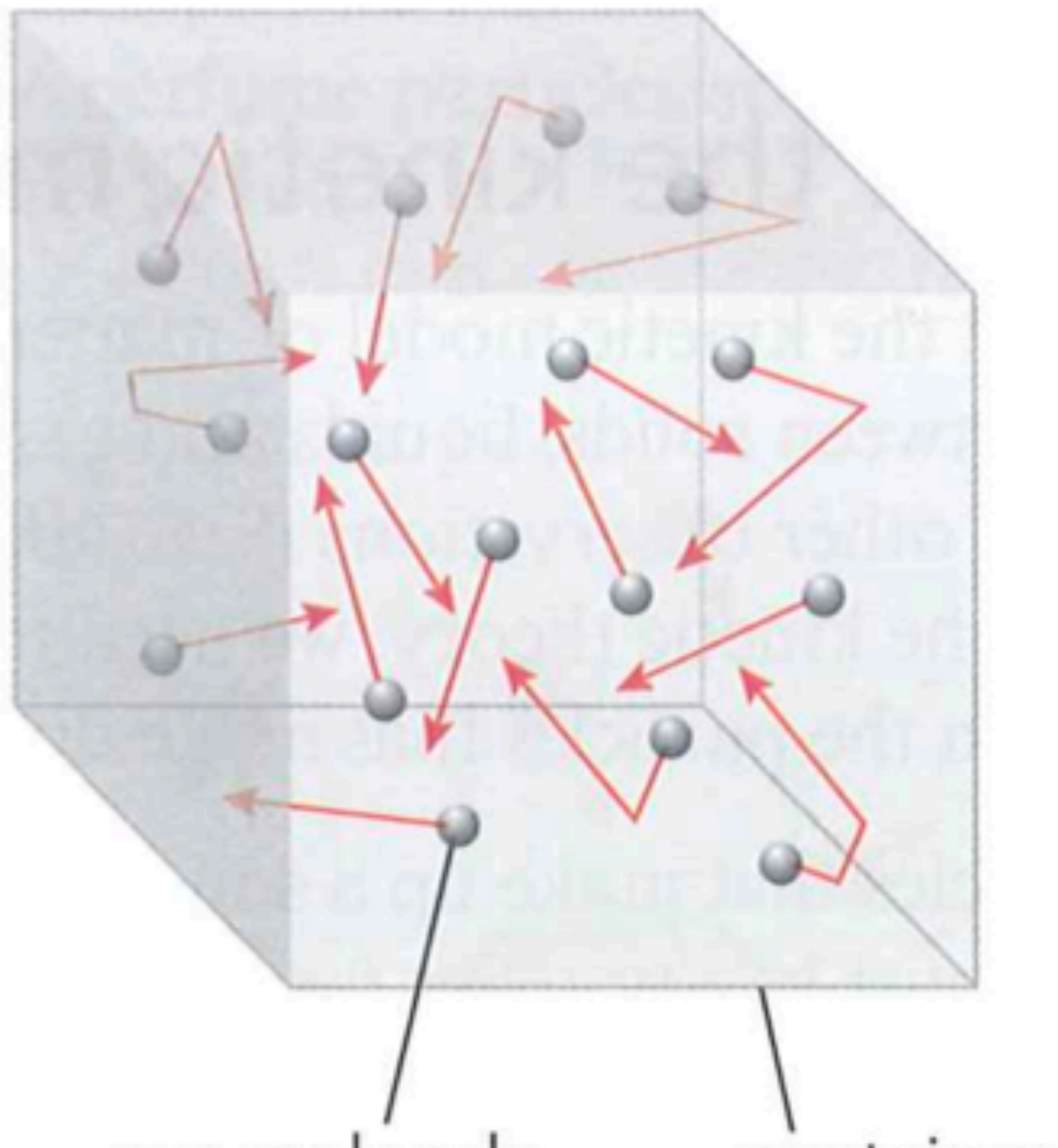
Why do gases cause pressure on the wall of its container?

★ 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?

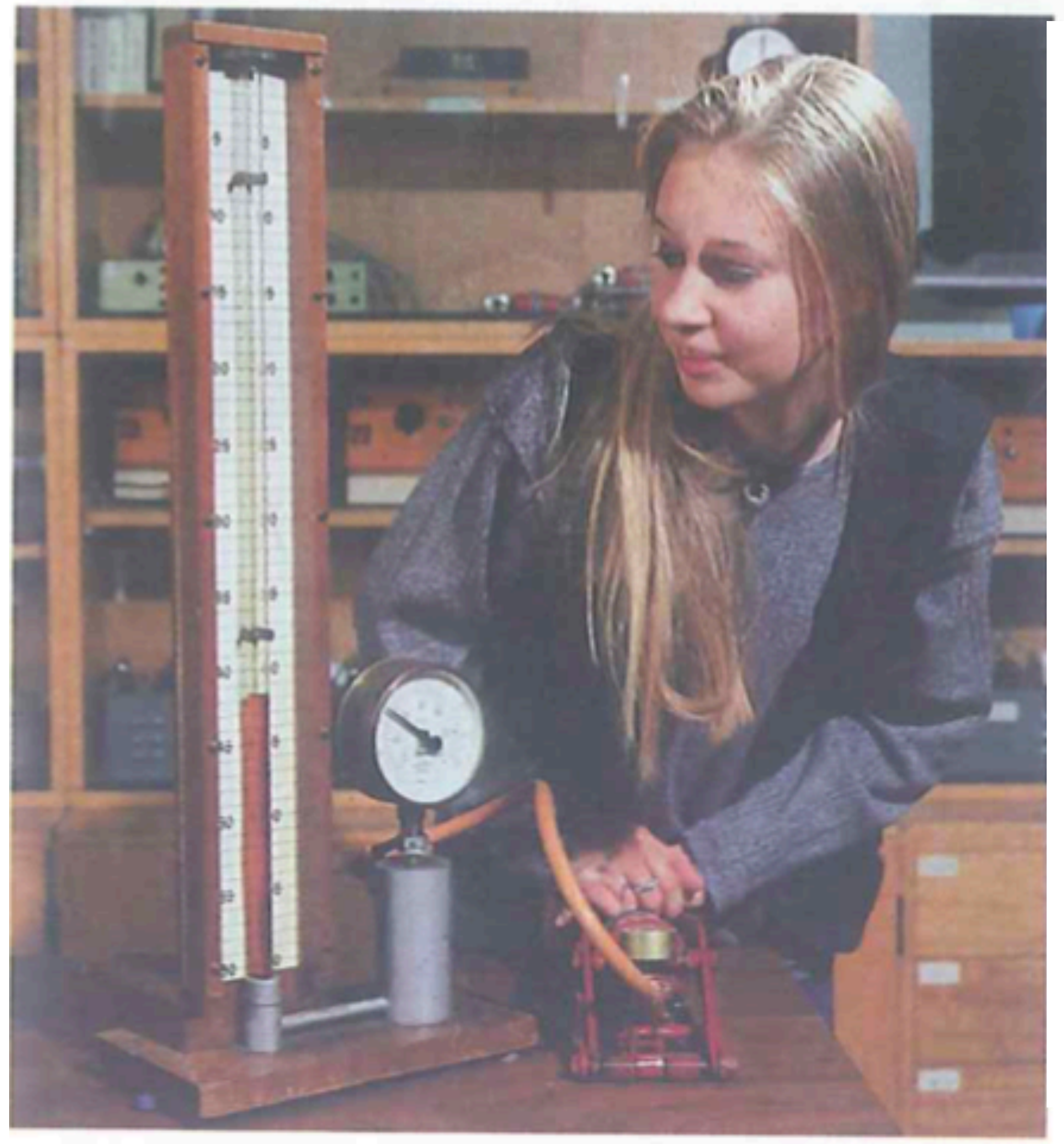
Molecules hit the wall with ***larger forces and more frequently***. So pressure increases.

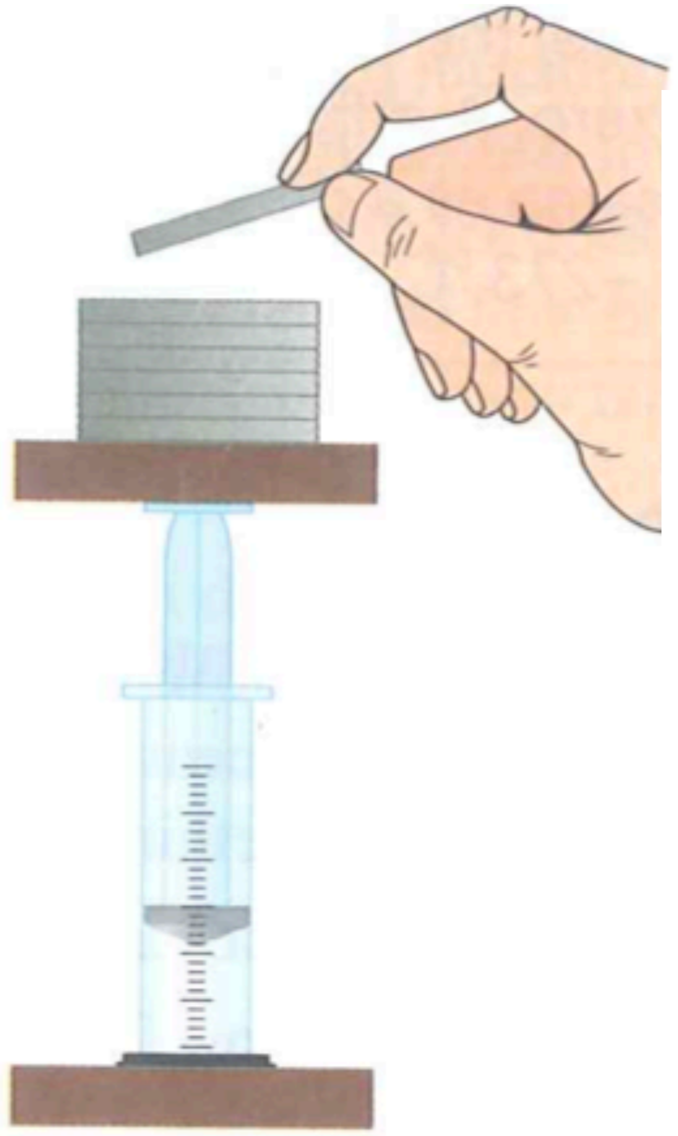
Compress the gas?

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

Boyle's Laws:

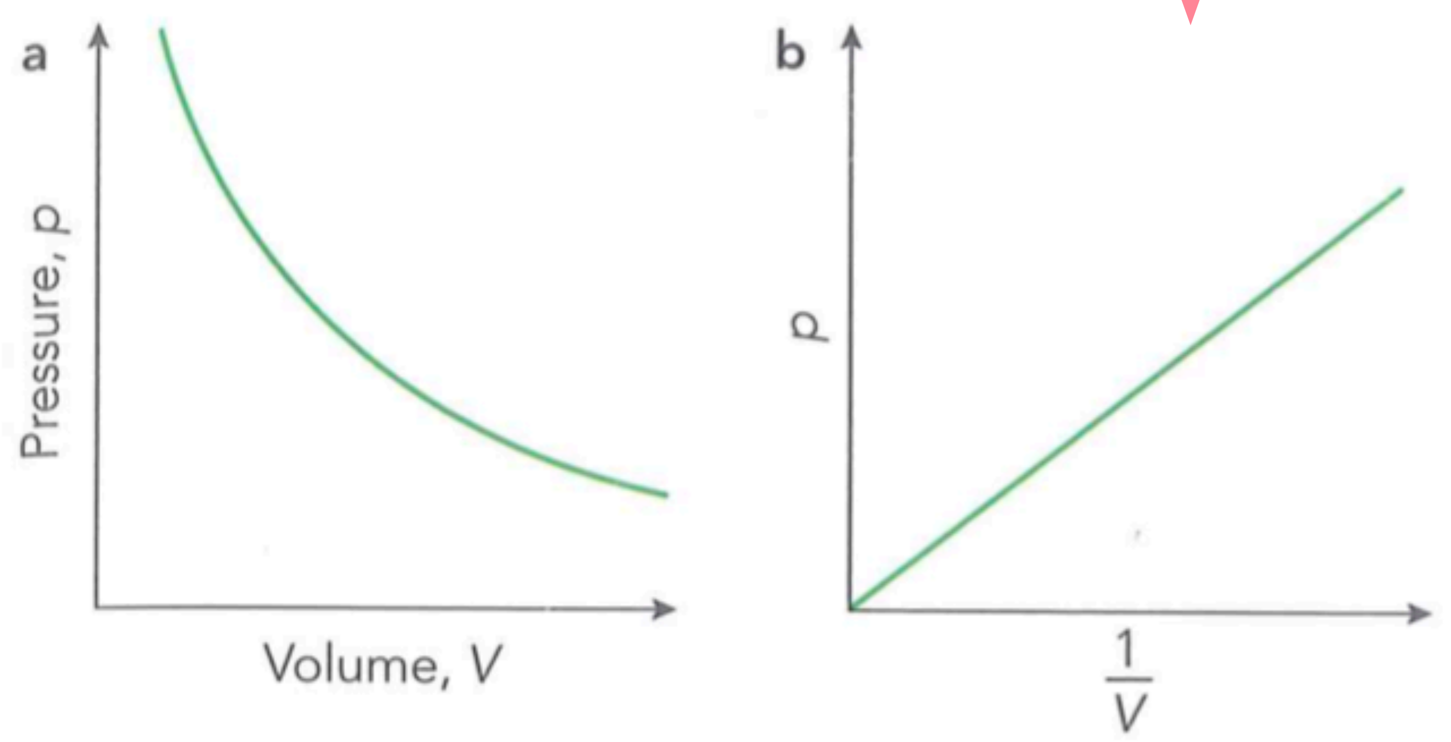
For a **<u>fixed mass</u>** of gas, the temperature, volume and pressure of the gas all affects each other.





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

p is inversely proportional to V



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

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

Units:
Use the same unit for both p values.
Use the same unit for both V values.

Exercise

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 pressure is 1 atmosphere? Assume that the temperature does not change.

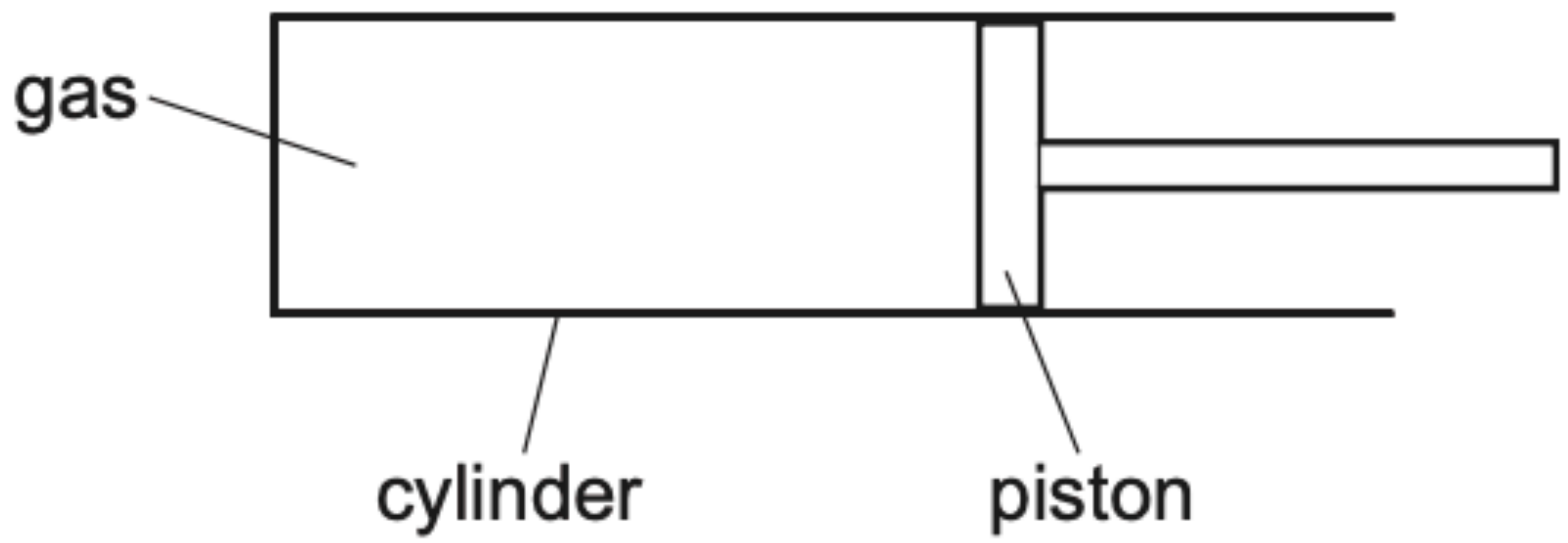
The gas law

Heated: Charles's law

At constant pressure, constant ==> thermal expansion (热胀冷缩)

$$\frac{V}{T} = const$$

A gas is contained in a cylinder by a movable piston.



The gas is heated so that it expands at **constant pressure**.

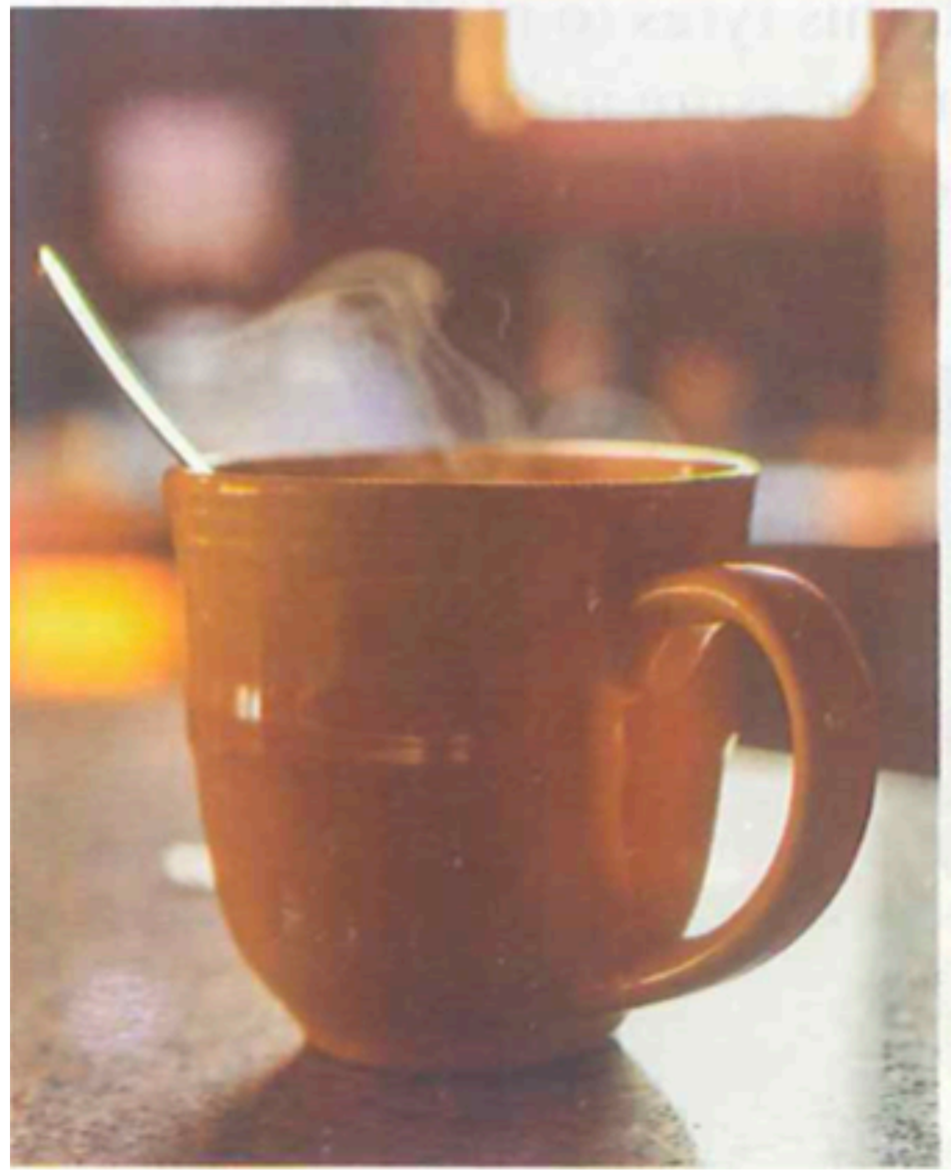
How is the force of each collision of a gas particle with the piston affected and how does the frequency of collisions between the gas particles and the piston change?

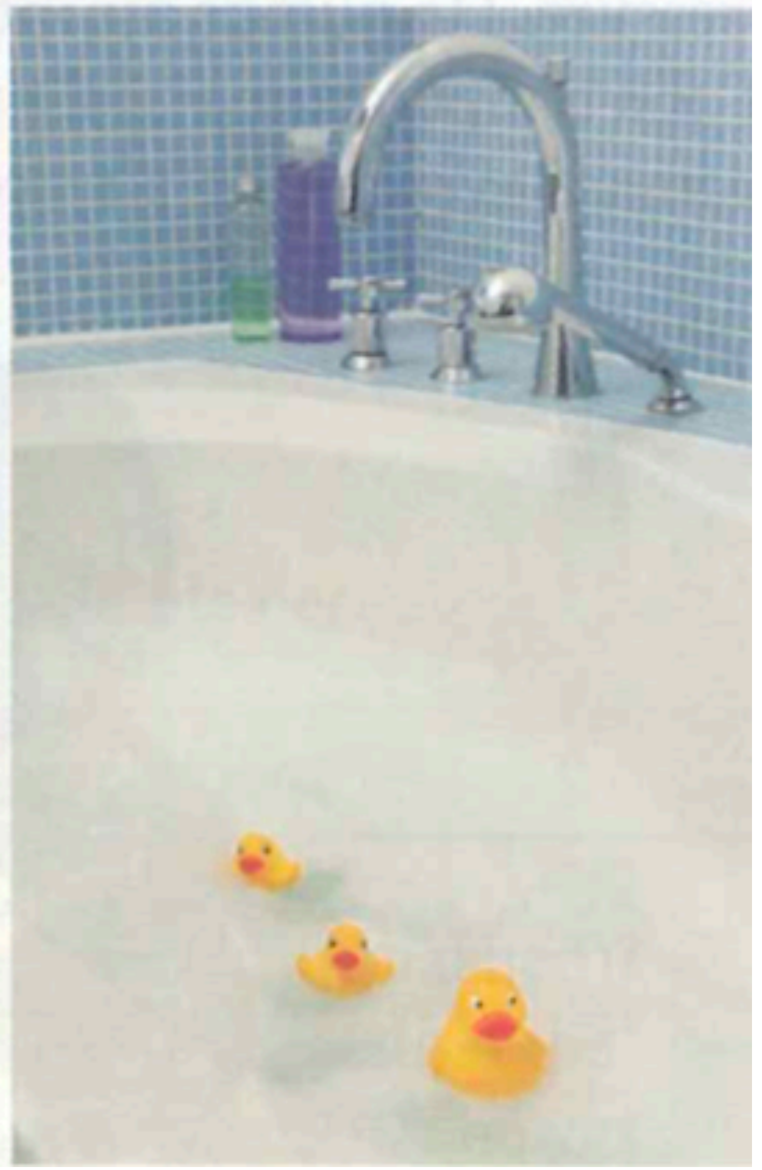
	force	frequency
A	increases	decreases
B	increases	increases
C	stays the same	decreases
D	stays the same	increases

Temperature

Temperature

Macroscopic: measure of how hot or cool something is
Microscopic: ***average k.e. of particles in the object***



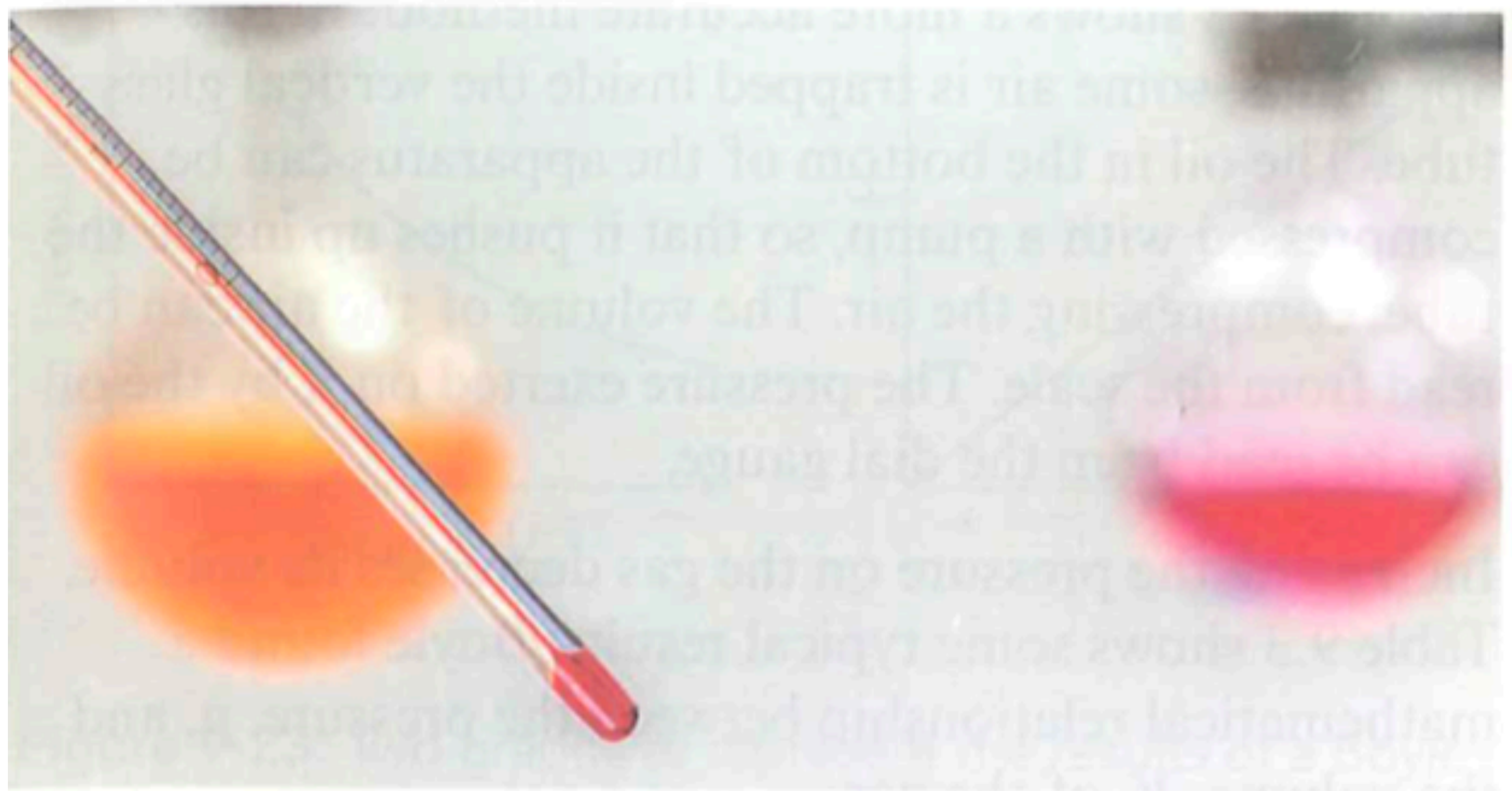


Temperature vs internal energy:

Temperature: average k.e. of **individual** particles in the object
Internal energy: **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 vs Kelvin scale

The Celsius scale ($^\circ C$):

Fixed points: $0^\circ C$: the melting point of pure ice at atmospheric pressure

$100^\circ C$: the boiling point of pure water at atmospheric pressure

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

The Kelvin temperature scale (K): absolute temperature

Start from absolute zero (0K = -273$^\circ C$);

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

Conversion between Kelvin temperature and degree Celsius:

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