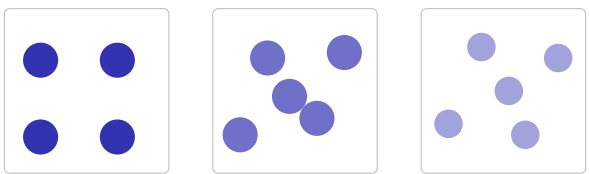
States of Matter

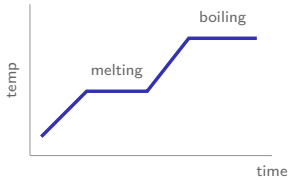
IGCSE Chemistry ▪ Topic 1

IGCSE Chemistry



What we will cover

1. The three states & their particles
2. Changes of state
3. Heating & cooling curves
4. Gas pressure
5. Diffusion



heating and cooling curves

1 Particles

The three states of matter

- **solid** 固体 – regular; vibrate in place; fixed shape and volume
- **liquid** 液体 – close; can slide; fixed volume, takes the container
- **gas** 气体 – far apart, fast; fills the container; easy to compress

Kinetic particle theory 粒子动理论: heating raises the particles' kinetic energy.

Properties you can observe

You do not need a microscope to tell the three states apart.

- A solid has a fixed shape and a fixed **volume** 体积. It does not flow and you cannot **compress** 压缩 it (squeeze it smaller).
- A liquid has a fixed volume but no fixed shape. It flows and takes the shape of its container. It is almost impossible to compress.
- A gas has no fixed shape and no fixed volume. It flows and spreads out to fill the whole container. A gas is easy to compress.

The three states, compared

the particles 粒子	**atoms** 原子, **molecules** 分子 or **ions** 离子 – and they are always in **motion** 运动
arrangement 排列	solid: regular and touching. Liquid: close but disordered. Gas: far apart and random
density 密度	how much **mass** 质量 is packed into a volume – high for solids and liquids, very low for gases
can it be compressed?	solid no; liquid almost none; gas yes, easily
does it flow?	solid no; liquid and gas yes
fixed shape?	only the solid; a liquid keeps its volume, a gas fills its container

Every row follows from how far apart the particles are and how strongly they attract. Say that once and the whole table is derivable.

Changes of state

Melting and boiling take energy (to break attractions) at constant temperature.
Freezing and condensing give that energy back.

> Some solids **sublime** 升华 straight to gas (iodine, dry ice).

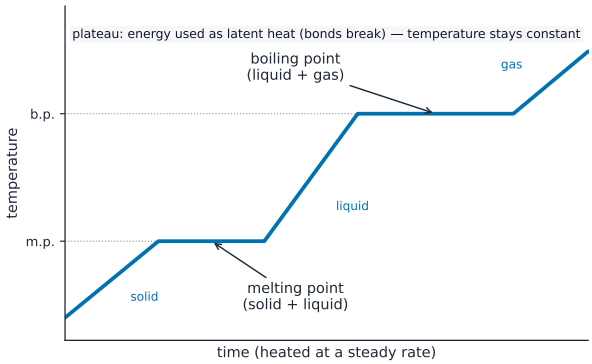
Heating and cooling curves

Two flat parts on a heating curve:

- at the **melting point** 熔点 (solid + liquid)
- at the **boiling point** 沸点 (liquid + gas)

The heat breaks **forces of attraction** 引力, so the temperature holds steady.

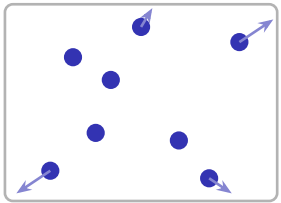
Heating and cooling curves, in detail



Temperature stays constant at the melting and boiling points while forces of attraction are broken

2 Gases

Gas pressure



particles hitting the walls cause the pressure

heat → faster, harder, more often → more pressure

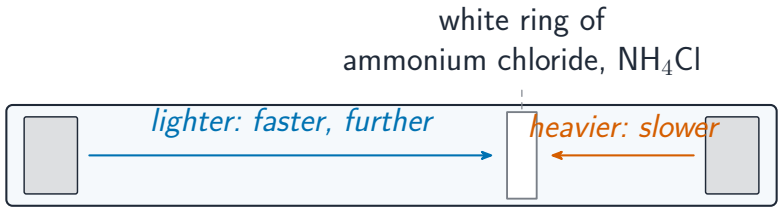
Squeeze a gas (smaller volume) and the particles hit the walls more often, so the **pressure** 压强 rises.

Diffusion

Diffusion 扩散: particles spread from high to low **concentration** 浓度.

> A lighter gas diffuses faster. Light NH_3 ($M_r = 17$) beats heavy HCl ($M_r = 36.5$), so the white ring forms nearer the HCl end.

Diffusion, in detail



The lighter gas diffuses faster: NH_3 ($M_r = 17$) beats HCl ($M_r = 36.5$), so the white ring forms nearer the HCl end.

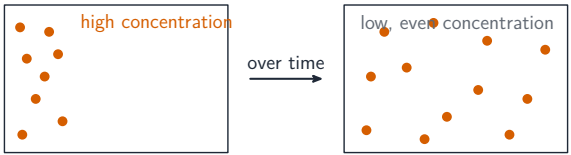
Worked example – which gas travels further?

Bromine ($M_r = 160$) and ammonia ($M_r = 17$) start at opposite ends of a long tube. Where do they meet?

- lighter particles move faster at the same temperature
- ammonia's **relative molecular mass** 相对分子质量 is far smaller, so it diffuses faster
- they meet nearer the bromine end, where the white ring of **ammonium chloride** 氯化铵 forms

Rate of diffusion falls as M_r rises. The exam gives you two masses and expects you to say which travels further, and why.

Particles diffuse from high to low concentration

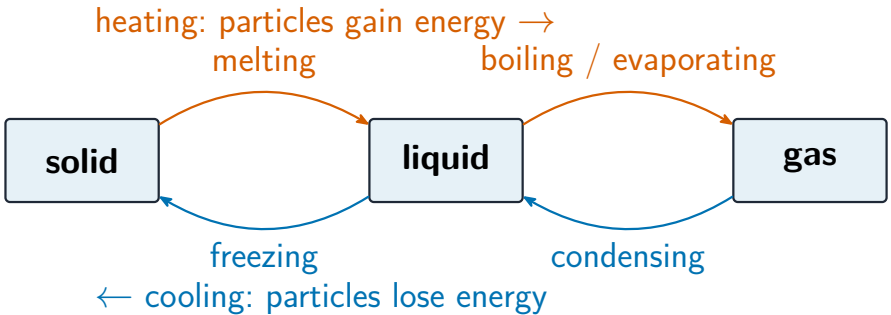


start: **crowded** on one side end: spread out **evenly**

particles move randomly from **high** to **low** concentration - this is why you can smell food across a room

Particles diffuse from high to low concentration until they are spread out evenly

Changes of state, continued

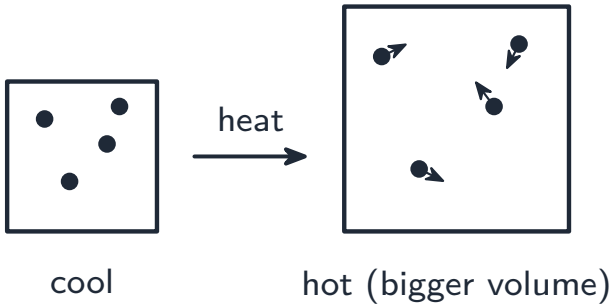


Heating: solid → liquid → gas; cooling reverses each change

Changes of state, continued (2)

Ice melting to water: a change of state as the solid warms.

Effect of temperature

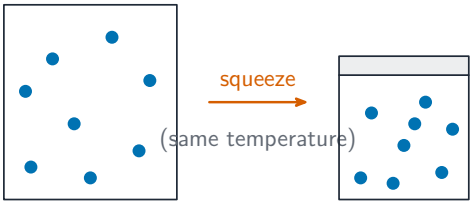


A heated gas: faster particles spread out and take up more space

Changes of state, continued (3)

Warmed solid iodine turns straight into a purple gas (sublimation)

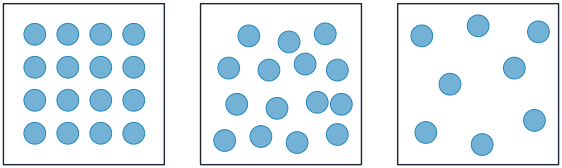
Effect of pressure



smaller space $\rightarrow$
particles hit the walls
more often $\rightarrow$
higher pressure

Squeezing a gas into a smaller volume makes the particles hit the walls more often, so the pressure rises

The particle picture



solid
regular, touching
vibrate in place

liquid
close, random
slide past
each other

gas
far apart,
random
move fast

Particles are packed and regular in a solid, close and random in a liquid, and far apart in a gas

Exam tips

- During **melting** and **boiling** the temperature stays constant (the flat parts of a heating curve), because the energy breaks the forces between particles instead of making them move faster.
- **Evaporation** happens only at the surface and at any temperature; **boiling** happens throughout the liquid at one fixed temperature.
- Explain gas behaviour with the particle theory: heating a gas at fixed volume raises the pressure because the particles hit the walls harder and more often – the particles themselves do not get bigger.
- **Diffusion** is faster for lighter particles (smaller M_r) and cannot happen in solids. In the ammonia/hydrogen chloride tube the lighter ammonia travels further, so the white ring forms nearer the HCl end.

3 Recap

Worked example – comparing diffusion

Ammonia ($M_r = 17$) and hydrogen chloride ($M_r = 36.5$) diffuse from opposite ends of a tube. Where does the white ring form?

- Diffusion is the random movement of particles from high to low concentration.
- At the same temperature all gas particles have the same average kinetic energy.
- NH_3 is lighter, so it moves faster than HCl.
- It travels further before they meet $\Rightarrow$ the ring forms nearer the HCl end.

Lighter particles diffuse faster at the same temperature. Say "lower M_r $\Rightarrow$ faster" – do not just say "it is a gas".

Topic 1 – key takeaways

1 States

solid packed, liquid close, gas far apart

2 Changes

melt, freeze, boil, condense, sublime

3 Curves

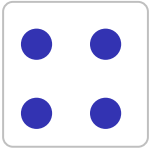
flat at the melting & boiling points

4 Diffusion

lighter particles diffuse faster

Check yourself

1. In which state do particles vibrate in fixed places?
2. What is the name for solid turning straight to gas?
3. Why is a heating curve flat at the melting point?
4. Which diffuses faster: a light or a heavy gas?



Answers **1.** a solid **2.** sublimation **3.** heat breaks the forces, not raising the temperature **4.** the lighter gas