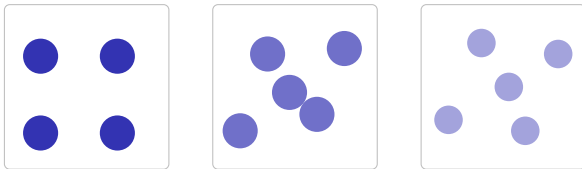


States of Matter

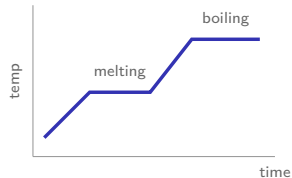
IGCSE Chemistry ■ Topic 1

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

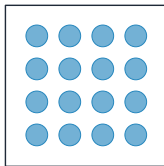


heating and cooling curves

1

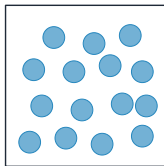
Particles

The particle picture



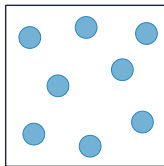
solid

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

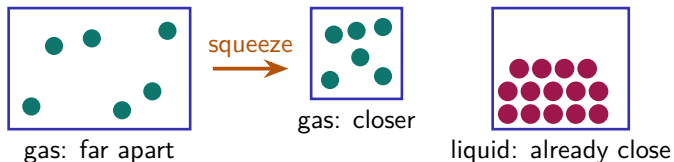
Explain the syringe observations

Your turn

A sealed syringe of gas compresses easily. A syringe of water hardly compresses. Explain the difference in terms of particles. [2]

- A. Compare the spaces between particles.
- B. Explain what compression changes.

Compression reduces the spaces



- 1 Gas (1)** Gas particles are far apart; they can be pushed closer together.
- 2 Liquid (1)** Liquid particles are already close together, leaving very little space to remove.
- 3 Check** The particles themselves do not shrink. A liquid can flow because its particles move past one another.

Separate arrangement, separation and motion

State	Separation	Arrangement	Motion
Solid	Touching	Regular	Vibrate in fixed places
Liquid	Touching / close	Random	Move past each other
Gas	Far apart	Random	Move in all directions

Complete the particle model

Your turn

For a solid, give arrangement and motion. For a liquid, give separation, arrangement and motion. For a gas, give separation.

- A. Keep separation different from arrangement.
- B. Use the particle diagram to justify each answer.

Use the feature the question asks for

- 1 **Separation** Solid and liquid: touching / close. Gas: far apart.
- 2 **Arrangement** Solid: regular. Liquid and gas: random.
- 3 **Motion** Solid: vibrates in fixed positions. Liquid and gas: random movement; liquid particles move past each other.
- 4 **Source** This completes the six blanks in 0620/42 N25 Q1(a) [3]. Six blanks are not automatically six marks.

Link observable properties to particles

Observation	Particle explanation
Solid keeps its shape	Particles vibrate about fixed positions
Liquid flows, keeps volume	Close particles move past one another
Gas fills its container	Widely separated particles move randomly
Gas compresses easily	Large spaces can be reduced

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

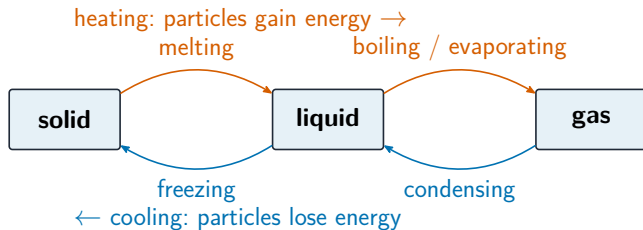
Every row follows from how far apart the particles are and how strongly they attract. Say that once and the whole table is derivable.

Name the physical change precisely

Before → after	Name	What changes
Solid → liquid	Melting	State; same substance
Gas → liquid	Condensation	State; same substance
Soluble solid → aqueous	Dissolving	Solute spreads through water

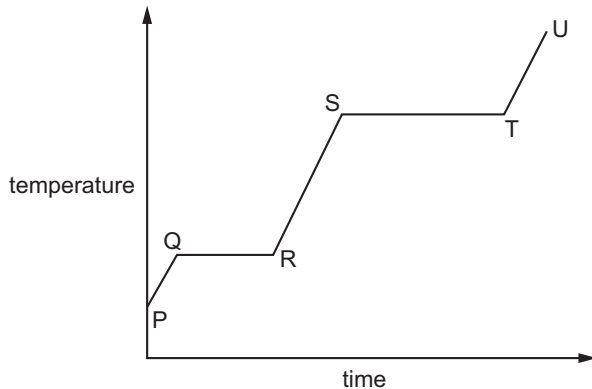
Changes of state

During melting and boiling of a pure substance at fixed pressure, energy overcomes attractions at **constant** temperature. Freezing and condensing give that energy back.



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

Read the original heating curve



Original 0620/22 N25 Q2: temperature against time.

When do fixed particles become mobile?

Your turn

On the original P–U heating curve, select the interval where particles change from fixed positions to moving past one another.

- A. Choose P–Q, Q–R, S–T or T–U.
- B. Name the change and the states present.

Identify the first plateau

- 1 **Answer** Q–R: the solid melts. This is option B in 0620/22 N25 Q2 [1].
- 2 **Before** On P–Q, the solid warms; its particles vibrate more vigorously about fixed positions.
- 3 **During** On Q–R, solid and liquid coexist while particles leave their fixed positions. S–T is boiling, not melting.

Why does temperature stay constant?

Your turn

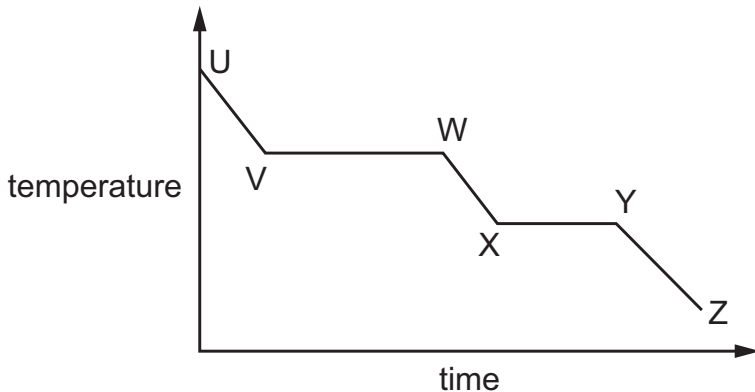
A pure solid is heated steadily while it melts. Explain why the temperature stays constant. [2]

- A. Explain what the transferred energy changes.
- B. Distinguish attractions between particles from bonds within a molecule.

Explain a plateau without breaking molecules

- 1 **Energy (1)** Energy supplied overcomes forces of attraction between particles.
- 2 **Temperature (1)** It does not increase the particles' average kinetic energy during the change, so temperature stays constant.
- 3 **Identity** The substance remains the same. Melting ice does not break O–H bonds to form hydrogen and oxygen.

Read the original cooling curve



Original 0620/22 M25 Q2: U–Z retains the original scale.

Which cooling-curve statement is correct?

Your turn

On the original U–Z curve, identify the liquid-only interval and describe its particles.

- A. Distinguish a falling segment from a change-of-state plateau.
- B. State the direction of energy transfer during cooling.

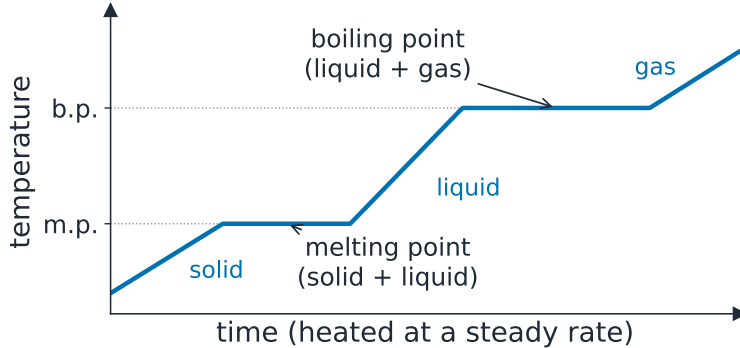
Read cooling in the correct direction

Interval	State / change	Energy
U–V	Gas cools	Energy transferred out
V–W	Gas condenses; gas + liquid	Energy transferred out
W–X	Liquid cools; close, random particles	Energy transferred out
X–Y	Liquid freezes; liquid + solid	Energy transferred out
Y–Z	Solid cools	Energy transferred out

Check the original cooling-curve choices

- 1 Correct** W–X is liquid: its particles are close together and randomly arranged. This is option C in 0620/22 M25 Q2 [1].
- 2 Reject** U–V cools gas; it is not condensing. V–W releases energy; it does not absorb it.
- 3 Reject** Y–Z cools solid. Freezing has already happened on X–Y.

Heating and cooling curves, in detail



plateau: attractions overcome; temperature constant

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

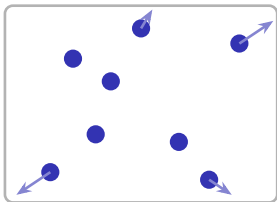
2

Gases

State what is held constant

Experiment	What changes	Particle explanation
Heat at fixed volume	Pressure rises	Faster, harder, more frequent wall collisions
Heat at constant pressure	Volume increases	Expansion maintains pressure
Raise pressure at fixed temperature	Volume decreases	Particles closer; more wall collisions

Gas pressure



particles hitting the walls
cause the pressure

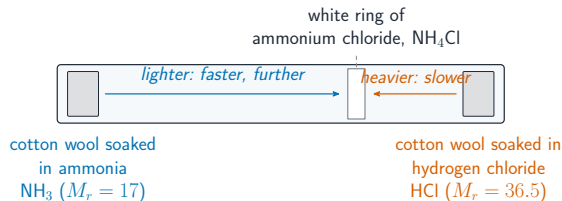
heat at fixed volume →
faster, harder, more often
→ more pressure

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

Diffusion

Diffusion 扩散: net spreading from higher to lower **concentration** 浓度, caused by random particle motion.

At the same temperature, a gas with smaller M_r diffuses faster. Light NH_3 ($M_r = 17$) beats heavy HCl ($M_r = 36.5$), so the white ring forms nearer the HCl end.



Is the white ring a change of state?

Your turn

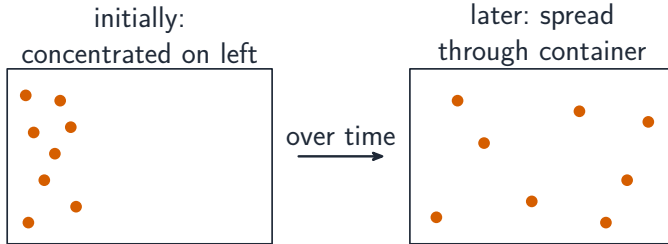
Ammonia gas and hydrogen chloride gas react to form solid ammonium chloride. Is this simply deposition? Explain.

- A. Compare the substances before and after.
- B. Contrast this with iodine vapour forming solid iodine.

A new substance means a chemical reaction

- 1 **Reaction** $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$
- 2 **Distinction** The gases react to make a different substance. This is a chemical reaction, not just a change of state.
- 3 **Physical example** Iodine vapour forming solid iodine is gas $\rightarrow$ solid: deposition. It remains iodine.

Particles diffuse from high to low concentration



Particles move randomly in all directions.
Net spreading: higher to lower concentration.

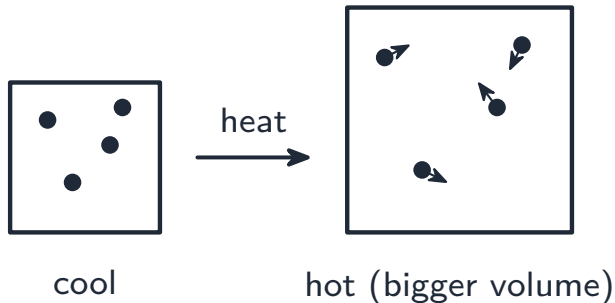
Net spreading is from higher to lower concentration; random motion continues after mixing

Changes of state, continued (2)



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

Effect of temperature



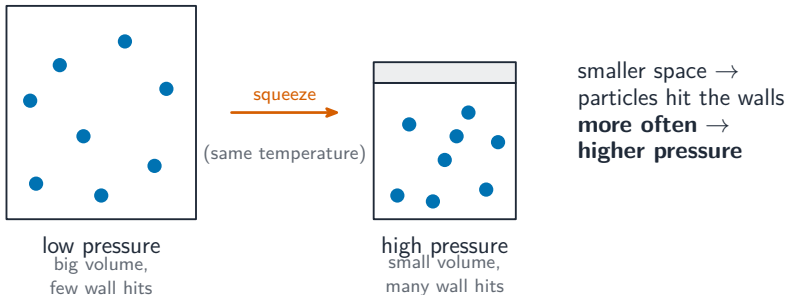
At constant pressure, heating a fixed mass increases gas volume; particles do not grow

Changes of state, continued (3)



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

Effect of pressure



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

Exam tips

- During **melting** and **boiling** the temperature stays constant (the flat parts of a heating curve), because energy overcomes 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 net spreading from higher to lower concentration, caused by random particle motion.
- At the same temperature the gases 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

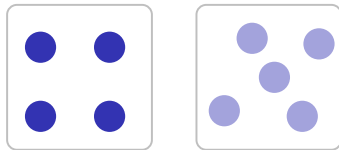
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Diffusion

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