

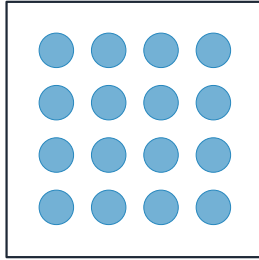
Exercise walk-through

1.1

Solids, liquids and gases

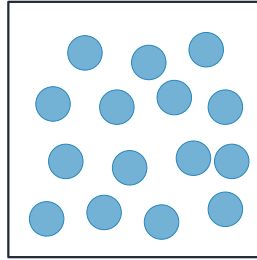
IGCSE Chemistry

The particle picture



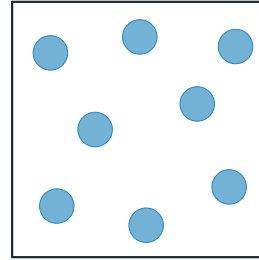
solid

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	atoms, molecules or ions – and they are always in motion
arrangement	solid: regular and touching. Liquid: close but disordered. Gas: far apart and random
density	how much mass 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

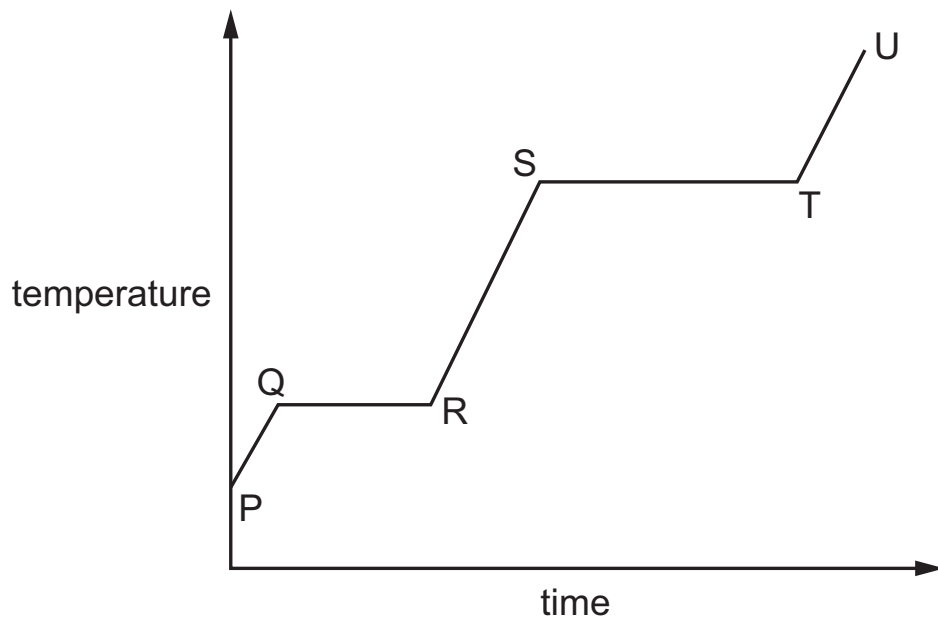
Before → after	Name	What changes
Solid → liquid	Melting	State; same substance
Gas → liquid	Condensation	State; same substance
Soluble solid → aqueous	Dissolving	Solute spreads through water

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** 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

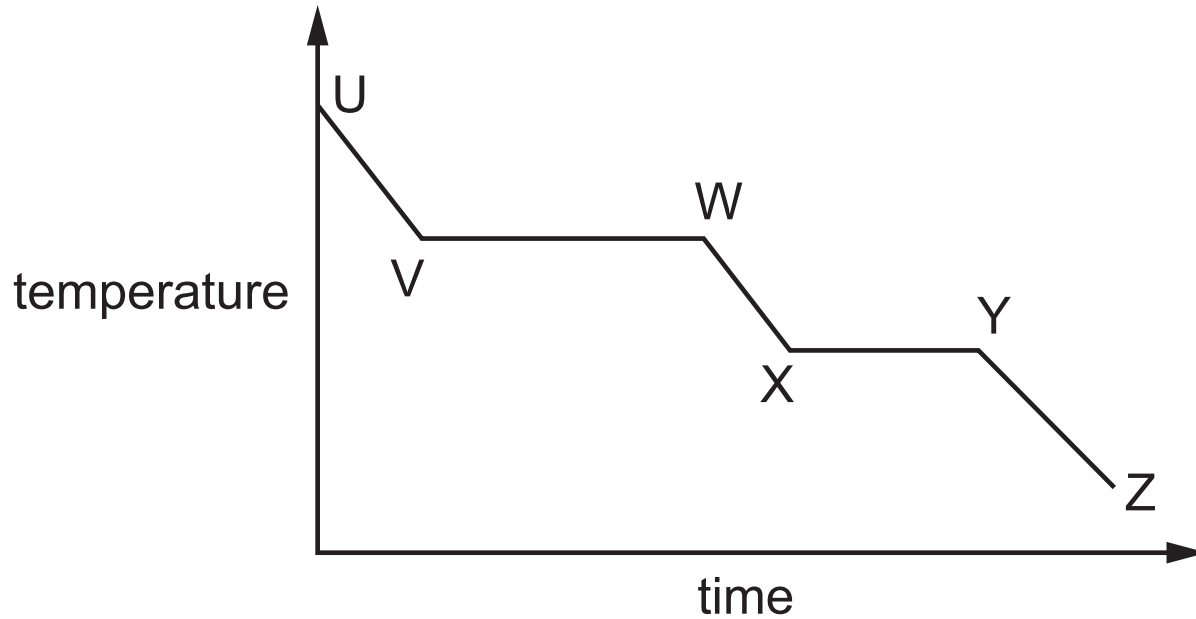
A pure solid is heated steadily while it melts. Explain why the temperature stays constant. [2]

- 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.

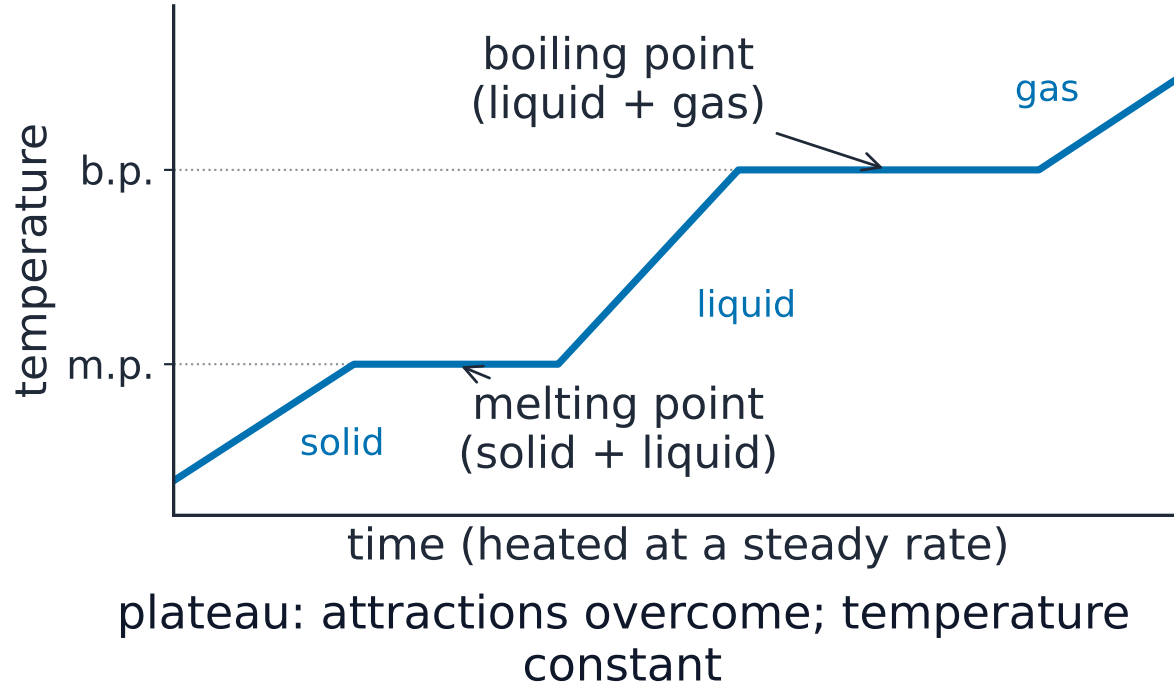
Read cooling in the correct direction

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

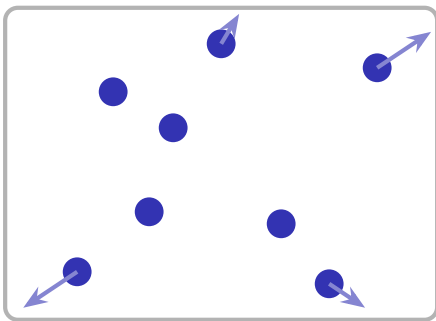


Temperature stays constant at the melting and boiling points while forces of attraction are overcome

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

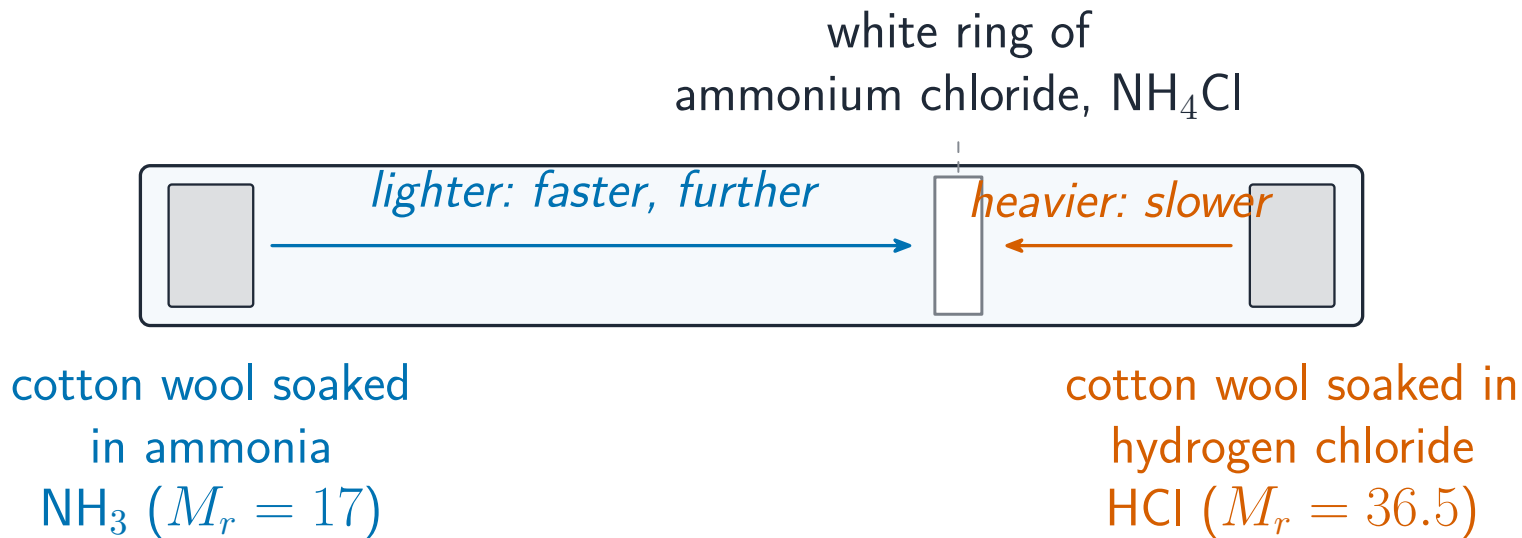
Squeeze a gas (smaller volume) and the particles hit the walls more often, so the
pressure rises.

Diffusion

Diffusion : net spreading from higher to lower **concentration** , 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.

Diffusion, in detail



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

Is the white ring a change of state?

Your turn

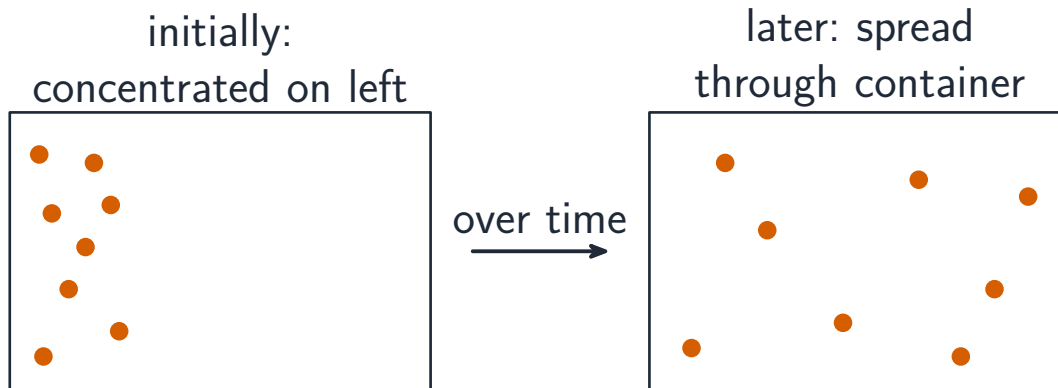
Ammonia gas and hydrogen chloride gas react to form solid ammonium chloride. Is this simply deposition? Explain.

- 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.

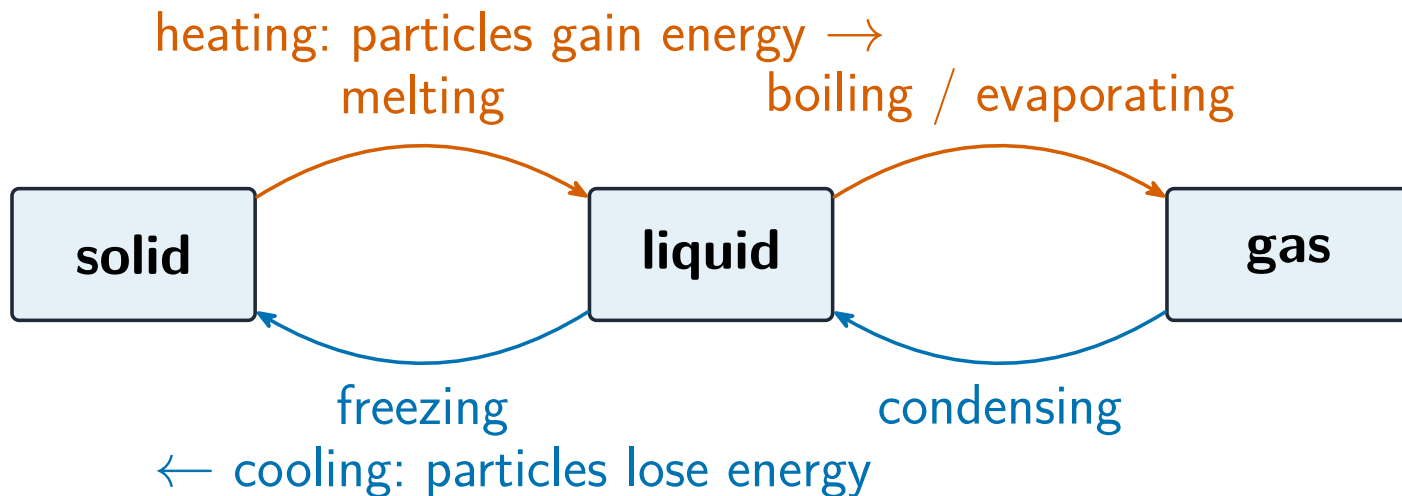
Particles diffuse from high to low concentration



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



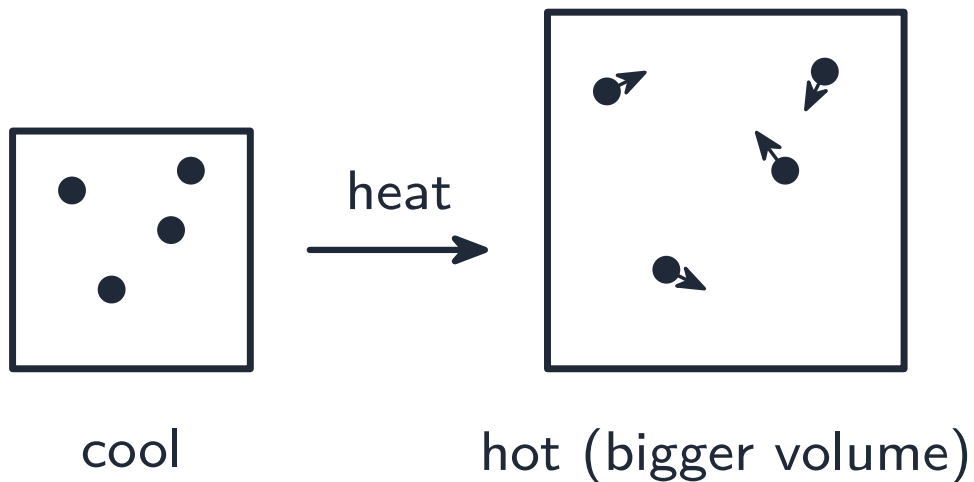
Heating: solid → liquid → gas; cooling reverses each change

Changes of state, continued (2)



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

Effect of temperature



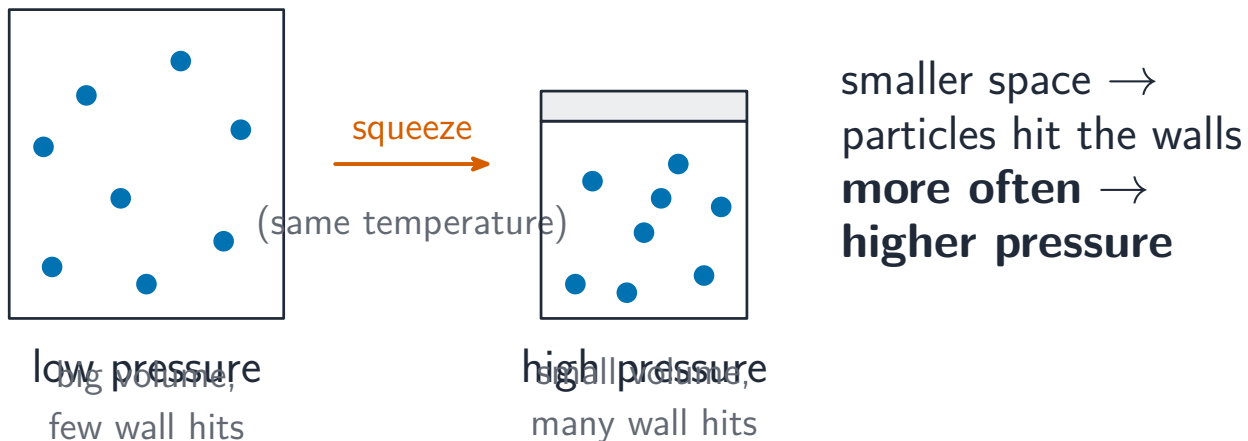
At constant pressure, heating a fixed mass increases gas volume; particles do not grow

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

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”.

Exercises 2.1-2.3

2.1 Name the change of state from gas to liquid.

[1]

2.2 Describe the arrangement and motion of particles in a liquid.

[2]

2.3 Explain, in terms of particles, why a gas can be compressed but a liquid cannot. [2]

Exercises 2.1-2.3

2.1 Name the change of state from gas to liquid.

[1]

2.1

- gas → liquid
- **condensation**

2.2 Describe the arrangement and motion of particles in a liquid.

[2]

2.2

- arrangement: close together, **random**
- motion: they **move and slide past each other**

2.3 Explain, in terms of particles, why a gas can be compressed but a liquid cannot. [2]

2.3

- a gas: particles far apart with large spaces, so they can be pushed closer
- a liquid: particles already touching, so **almost no space to remove**

Exercises 2.4·2.5

2.4 Name the change of state from solid directly to gas, and state whether energy is taken in or given out. [2]

2.5 Explain why a smell spreads through a room faster on a hot day. [2]

Exercises 2.4·2.5

2.4 Name the change of state from solid directly to gas, and state whether energy is taken in or given out. [2]

2.4

- solid $\rightarrow$ gas (skipping liquid): **sublimation**
 - energy is **taken in**
-

2.5 Explain why a smell spreads through a room faster on a hot day. [2]

2.5

- particles have more kinetic energy on a hot day, so they **move faster**
- they **diffuse** through the room more quickly

Exercise 3.1

3.1 Which property is true for a gas but not a liquid?

[1]

☐

A it flows

B it has a fixed volume

C it is easily compressed

D it has a fixed shape

Exercise 3.1

3.1 Which property is true for a gas but not a liquid?

[1]

☐

A it flows

B it has a fixed volume

C it is easily compressed

D it has a fixed shape

3.1 C

- a gas is **easily compressed**; a liquid is not
- A is true for both; B is a liquid; D is a solid

Exercise 3.2 (a)

3.2 A solid is heated until it melts and then boils.

(a) Explain, using the particle theory, why the temperature stays constant while the solid melts. [2]

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(a) Explain, using the particle theory, why the temperature stays constant while the solid melts. [2]

(a)

- supplied energy goes into **overcoming attractions** between particles, not into increasing their average kinetic energy
- so the **temperature stays constant** while melting

Exercise 3.2 (b)

3.2 A solid is heated until it melts and then boils.

(b) Explain why a gas can be compressed but a liquid cannot.

[2]

Exercise 3.2 (b)

3.2 A solid is heated until it melts and then boils.

(b) Explain why a gas can be compressed but a liquid cannot.

[2]

(b)

- a gas has particles far apart with space, so it can be squeezed
- a liquid's particles are already close, with **almost no space**

Exercise 3.3

3.3 A fixed mass of gas in a sealed rigid container is heated. Explain why its pressure rises. [3]

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3.3

- heating gives the particles more kinetic energy, so they **move faster**
- they hit the walls **harder and more often**
- in a **fixed volume** the **pressure rises**

Exercise 3.4 (a)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(a) Name the process by which the gases travel along the tube, and define it. [2]

Exercise 3.4 (a)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(a) Name the process by which the gases travel along the tube, and define it. [2]

(a)

- **diffusion**
- spreading from higher to lower concentration because of **random movement**

Exercise 3.4 (b)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(b) The white ring forms nearer the hydrochloric acid end. Explain why. [3]

Exercise 3.4 (b)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(b) The white ring forms nearer the hydrochloric acid end. Explain why. [3]

(b)

- $M_r(\text{NH}_3) = 17$ and $M_r(\text{HCl}) = 36.5$, so ammonia is **lighter**
- at the same temperature, lighter molecules **move faster**
- ammonia travels further, so the ring forms **nearer the acid end**

Exercise 3.4 (c)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(c) Predict and explain the effect of warming the whole tube.

[2]

Exercise 3.4 (c)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(c) Predict and explain the effect of warming the whole tube.

[2]

(c)

- the ring would form **sooner**
- particles gain kinetic energy and **diffuse faster**

Exercise 3.4 (d)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(d) Describe the arrangement and movement of the particles in the ammonia gas, and contrast them with the particles in the solid white ring. [4]

Exercise 3.4 (d)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(d) Describe the arrangement and movement of the particles in the ammonia gas, and contrast them with the particles in the solid white ring. [4]

(d)

- ammonia gas: particles **far apart** and randomly arranged, moving quickly in all directions
- solid ring: particles **close together** in a regular arrangement, only **vibrating** about fixed positions

Exercise 3.4 (e)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(e) The white solid is ammonium chloride. Explain why its formation from ammonia and hydrogen chloride is a chemical reaction rather than only a change of state. [2]

Exercise 3.4 (e)

3.4 A long glass tube has cotton wool soaked in concentrated ammonia solution at one end and cotton wool soaked in concentrated hydrochloric acid at the other. After a few minutes a white ring forms inside the tube.

(e) The white solid is ammonium chloride. Explain why its formation from ammonia and hydrogen chloride is a chemical reaction rather than only a change of state. [2]

(e)

- the reaction produces a **new substance**, ammonium chloride, from ammonia and hydrogen chloride
- a physical change of state changes particle arrangement/separation while the substance remains the same