1.1 Solids, liquids and gases

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

KEY WORDS particles • pressure • solid • liquid • volume

Objective

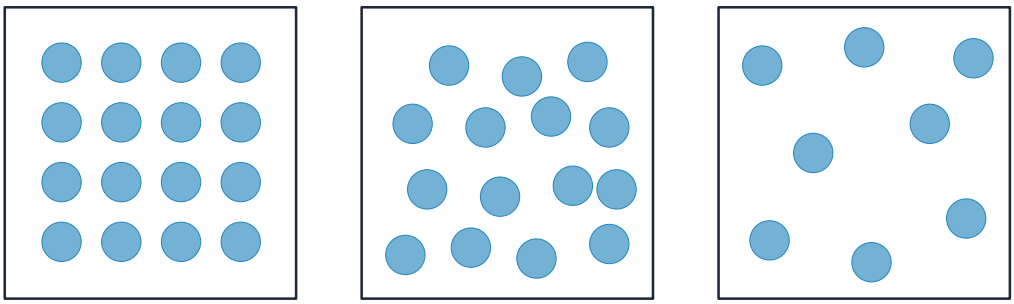
Build the skills to answer exam questions on **solids, liquids and gases** – their properties, the particle picture, **changes of state** , and gas behaviour.

You must be able to:

- describe the arrangement, separation and motion of particles in each state
- name the changes of state and explain them with the particle theory
- explain why temperature is constant during melting/boiling, and gas behaviour

1 Key knowledge and worked examples

■ Particles and changes of state



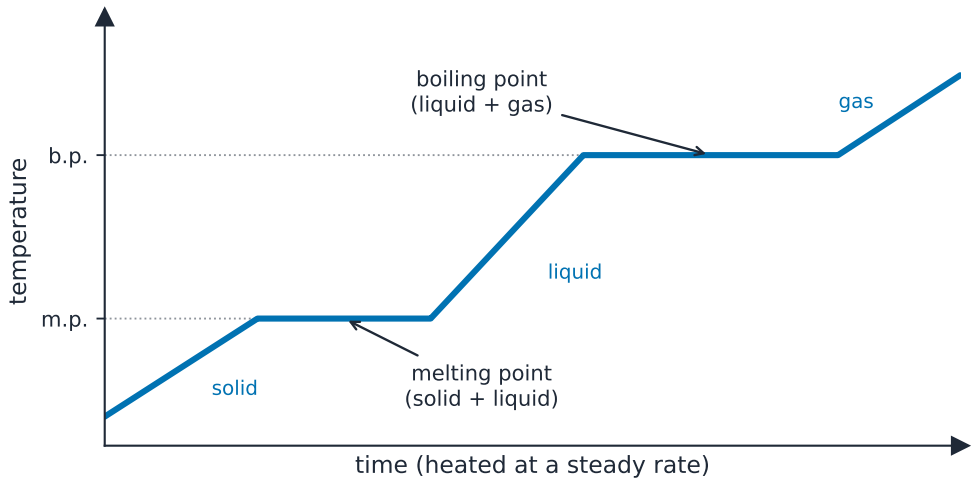
solid
regular, touching
vibrate in place

liquid
close, random
slide past each other

gas
far apart, random
move fast

Packed and regular in a solid, close and random in a liquid, far apart in a gas

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plateau: attractions overcome; temperature constant

For a pure substance at fixed pressure, temperature stays constant while attractions are overcome

- **changes:** melting, freezing, evaporation, boiling, condensation (and sublimation).
- heating a gas at fixed volume raises its pressure: particles move faster and collide with walls harder and more often;
- heating a fixed mass of gas at constant pressure increases its volume; decreasing pressure at constant temperature also increases its volume. The particles themselves do not grow.

The three states, and the two experiments that prove particles move

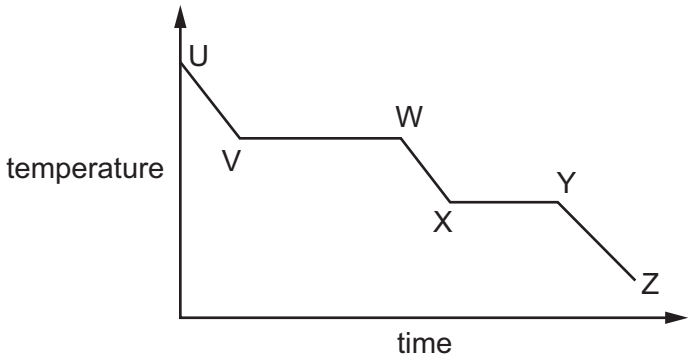
	arrangement	**movement**	**forces between particles**
solid	regular, closely packed, touching	vibrate about fixed positions	strong
liquid	close together, irregular	move around each other	weaker
gas	far apart, random	move quickly in all directions	very weak or none

That table answers most questions on its own: a gas is easily compressed because of the space between its particles; a solid keeps its shape because its particles cannot change places; a liquid takes the shape of its container but keeps a fixed volume.

The changes of state, with the direction of energy: **melting** solid→liquid and **boiling** liquid→gas both take energy IN to overcome attractions between particles, not to break molecules apart. **Condensing** gas→liquid and **freezing** liquid→solid both give energy OUT. **Sublimation** goes straight from solid

to gas.

Worked curve reading: 0620/22 N25 Q2 has a first plateau Q–R: solid melts and particles become mobile. The second plateau S–T is boiling. On 0620/22 M25 Q2, W–X is liquid cooling: particles are close and randomly arranged. V–W is condensation; X–Y is freezing. Cooling transfers energy to the surroundings, even while temperature stays constant.



Name the physical change (0620/42 N25 Q1b): solid → liquid is melting; gas → liquid is condensation; a soluble solid → aqueous solution is dissolving. Dissolving is not melting.

Diffusion is the net spreading of a substance from a region of higher concentration to a region of lower concentration, caused by the random movement of the particles. Two rules explain every diffusion question:

- diffusion is **faster at a higher temperature**, because the particles have more kinetic energy and move faster;
- diffusion is **faster for a lighter particle** – at the same temperature a molecule with a smaller relative molecular mass moves faster.

Worked example (the classic tube experiment). Cotton wool soaked in concentrated ammonia is put in one end of a long tube and cotton wool soaked in concentrated hydrochloric acid in the other. A white ring of ammonium chloride forms nearer the acid end. Explain.

1. Both liquids evaporate and their gas particles diffuse along the tube.
2. Ammonia, $M_r = 17$, is lighter than hydrogen chloride, $M_r = 36.5$.
3. The lighter ammonia molecules move faster, so they travel further before the gases meet.
4. The ring therefore forms nearer the hydrogen chloride end.

Physical or chemical? Ammonia and hydrogen chloride react to form a new substance, ammonium chloride. This is a chemical reaction, not simply deposition. Iodine vapour forming solid iodine is deposition: the substance remains iodine.

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2 Practice

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]

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]

3 Exam-style questions

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

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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]

(b) Explain why a gas can be compressed but a liquid cannot. [2]

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

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]

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

(c) Predict and explain the effect of warming the whole tube. [2]

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(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]

(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]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- gas → liquid
- **condensation**

2.2

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

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**

2.4

- solid → gas (skipping liquid): **sublimation**
- energy is **taken in**

2.5

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

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

3.2

(a)

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

(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**

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**

3.4

(a)

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

(b)

- $M_r(\mathrm{NH_3}) = 17$ and $M_r(\mathrm{HCl}) = 36.5$, so ammonia is **lighter**
- at the same temperature, lighter molecules **move faster**
- ammonia travels further, so the ring forms **nearer the acid end**

(c)

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

(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

(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

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