The Particulate Nature of Matter

IB / A Level Chemistry Exam Preparation Notes

Topic focus
Matter classification • elements, compounds and mixtures • separation techniques • kinetic molecular theory • states and changes of state • heating curves • Kelvin temperature

Designed for fast revision, exam-question planning, and last-minute checking of common mistakes.

How to Use These Notes

This resource converts the core content into exam-ready revision notes. It is written for IB Chemistry and A Level Chemistry students, with emphasis on definitions, command words, particle-level explanations and common mark-scheme points.

Use this page for...	What to focus on
First revision	Read the boxed definitions and summary tables. Draw the diagrams from memory.
Exam practice	Use the “How to answer” boxes and the common traps checklist.
Last-minute review	Memorise the definition wording, state symbols, state-change names, and heating-curve explanations.

Syllabus map

Core idea	You should be able to...
Particulate model	Explain matter using atoms, molecules and ions; recognise that scientific models are useful but limited.
Elements, compounds, mixtures	Distinguish pure substances from mixtures; compare elements, compounds, homogeneous mixtures and heterogeneous mixtures.
Separation methods	Choose a physical separation method based on a property difference such as solubility, boiling point, magnetism or adsorption.
Kinetic molecular theory	Relate physical properties of solids, liquids and gases to particle arrangement, motion and attractions.
Changes of state	Name and explain melting, freezing, vaporisation, condensation, sublimation and deposition.
Temperature and energy	Interpret heating curves and convert between Celsius and Kelvin.

1. The Particulate Model of Matter

Chemistry explains the behaviour of substances by modelling them as particles. These particles may be atoms, molecules or ions. The model is powerful because many physical properties can be explained by considering how particles are arranged, how they move, and how strongly they attract each other.

> Core definition
> Matter is anything that has mass and occupies space. The particulate model describes matter as being made from tiny particles separated by spaces and in constant motion.

Why models matter

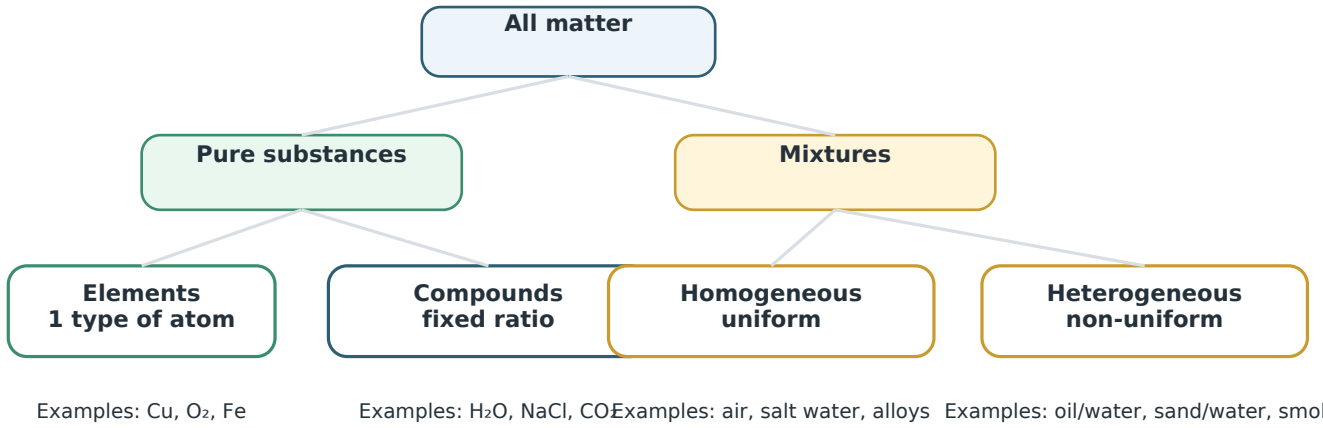
- Particles are too small to be observed directly with the naked eye, so models help us explain and predict behaviour.
- Models simplify reality. They are useful for patterns and predictions, but every model has limits.
- A good exam answer connects the macroscopic observation (what you see) to the particle-level explanation (what particles do).

Exam language to practise

Command word	What the examiner wants
Describe	State what is seen or what changes. Example: particles are closely packed in a regular arrangement.
Explain	Give a reason using particle motion, energy, attractions or structure.
Distinguish	State clear differences between two ideas, not just one description.
Compare	Give similarities and differences, ideally using the same features for both.

2. Classification of Matter

Matter is first classified as either a pure substance or a mixture. Pure substances have a fixed composition. Mixtures can vary in composition and can usually be separated by physical methods.



Definitions you must know

Term	Exam-ready definition	Example
Element	A pure substance made from atoms with the same number of protons; it cannot be chemically broken down into simpler substances.	Copper, oxygen, iron
Atom	The smallest particle of an element that shows the characteristic properties of that element.	A carbon atom
Compound	A substance formed when atoms of different elements are chemically bonded together in a fixed ratio.	H_2O, NaCl, CO_2
Mixture	A combination of two or more substances that are not chemically bonded and are not in a fixed ratio.	Air, seawater, bronze
Homogeneous mixture	A mixture with uniform composition and properties throughout.	Salt water, air, steel
Heterogeneous mixture	A mixture with non-uniform composition and properties; different parts can often be seen.	Oil and water, sand and water

Common exam trap
A homogeneous mixture is not the same as a pure substance. Salt water looks uniform, but it still contains water molecules and dissolved ions.

Elements, Compounds and Mixtures: High-Yield Comparisons

Feature	Element	Compound	Mixture
Composition	One type of atom only.	Different elements chemically combined in a fixed ratio.	Two or more substances physically combined in variable proportions.
Formula	Shown by a symbol or molecular formula, e.g. Fe, O_2.	Shown by a chemical formula, e.g. H_2O, $Mg(OH)_2$.	No single chemical formula for the whole mixture.
Properties	Has its own characteristic physical and chemical properties.	Properties differ from those of its component elements.	Components usually retain their individual properties.
Separation	Cannot be chemically broken down into simpler substances.	Can only be separated into elements by chemical reactions.	Components can be separated by physical methods.
Examples	C, Cu, Cl_2, S_8.	NaCl, NH_3, CH_4, glucose.	Air, seawater, bronze, smoke.

Formula and symbol accuracy

Chemistry is case-sensitive. Co is cobalt, an element. CO is carbon monoxide, a compound. A small change in symbols can completely change the meaning.

Useful examples to remember

Substance	Classification	Why
Gold	Element	Made from one type of atom.
Water	Compound	Hydrogen and oxygen atoms chemically bonded in a 2:1 ratio.
Air	Homogeneous mixture	Mainly nitrogen and oxygen gases uniformly mixed, not chemically bonded.
Bronze	Homogeneous mixture / alloy	Copper and tin atoms mixed in variable proportions; no fixed chemical formula.
Oil and water	Heterogeneous mixture	Non-uniform; two layers form because the particle interactions differ.

3. Mixtures and Separation Techniques

A mixture can be separated if its components have different physical properties. In exam answers, always identify the property difference before naming the technique.

Mixture / situation	Property difference used	Best method	Key exam note
Sand and salt	Salt dissolves in water; sand does not.	Solvation + filtration + evaporation / crystallisation	Dissolve salt first, filter off sand, then recover salt.
Salt water	Water has a much lower boiling point than dissolved salt.	Simple distillation	Water evaporates and condenses as the distillate.
Ethanol and water	Different but relatively close boiling points.	Fractional distillation	A fractionating column improves separation.
Iron and sulfur	Iron is magnetic; sulfur is not.	Magnetic separation	Works only if no chemical reaction has formed iron sulfide.
Food colouring pigments	Different attractions to paper and solvent.	Paper chromatography	Components travel different distances.
Impure solid product	Impurities and product have different solubilities at different temperatures.	Recrystallisation	Hot solvent dissolves product; crystals form on cooling.

How to choose a method
Ask: Which physical property is different? Solubility suggests filtration or crystallisation; boiling point suggests distillation; adsorption/solubility in a moving solvent suggests chromatography.

Key separation vocabulary

Term	Meaning
Residue	The insoluble solid left on the filter paper after filtration.
Filtrate	The liquid or solution that passes through the filter paper.
Solute	The substance dissolved in a solvent.
Solvent	The liquid that dissolves the solute.
Aqueous	Dissolved in water; shown by the state symbol (aq).

Separation Method Details

Filtration

Filtration separates an insoluble solid from a liquid or solution. The solid remains as the residue; the liquid that passes through is the filtrate. Example: sand can be separated from salt water by filtration.

Evaporation and crystallisation

Evaporation removes a solvent to leave a dissolved solid behind. Crystallisation is used when you want good crystals of a product; the solution is concentrated and then allowed to cool so crystals form.

Distillation

Distillation separates a liquid from a solution or separates liquids with different boiling points. The component with the lower boiling point vaporises first, then condenses in the condenser.

Paper chromatography

Paper chromatography separates substances because they have different relative attractions for the stationary phase and the mobile phase. A component that is more soluble in the solvent travels further up the paper.

> Exam phrase for chromatography
> Different components have different affinities for the stationary phase and different solubilities in the mobile phase, so they move at different rates and separate.

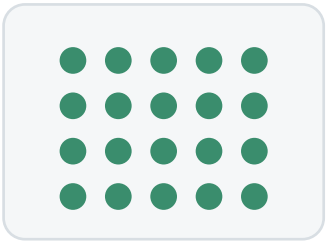
Purification after reactions

- A reaction mixture may contain desired product, excess reactants, solvent and side-products.
- Purification improves purity but may reduce yield because some product can be lost with impurities.
- The best method depends on the physical properties of the product and impurities.

4. Kinetic Molecular Theory

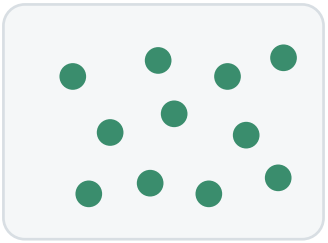
Kinetic molecular theory explains the physical properties of solids, liquids and gases using particle motion, particle arrangement and inter-particle forces.

Solid



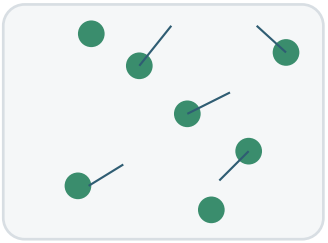
fixed positions; vibration

Liquid



particles slide past each other

Gas



far apart; random rapid motion

Feature	Solid	Liquid	Gas
Particle arrangement	Closely packed, usually ordered.	Close together but less ordered.	Far apart and randomly arranged.
Motion	Vibrate about fixed positions.	Move/slide past each other.	Move rapidly and randomly in all directions.
Inter-particle forces	Strong enough to hold particles in fixed positions.	Weaker than in solids; particles remain close.	Negligible except during collisions.
Shape	Fixed shape.	No fixed shape; takes container shape.	No fixed shape.
Volume	Fixed volume.	Fixed volume.	No fixed volume; fills container.
Flow?	Does not flow.	Flows.	Flows.

Key fact
Temperature is a measure of the average kinetic energy of the particles in a substance.

Fluids

Liquids and gases are called fluids because their particles can move past each other, allowing the substance to flow.

Diffusion and Particle Speed

Diffusion is the spreading out of particles from a region where they are more concentrated to a region where they are less concentrated. It is caused by random particle motion.

$$E_k = \frac{1}{2}mv^2$$

At the same temperature, different gases have the same average kinetic energy. Therefore, particles with lower mass must have a higher average speed than heavier particles.

How to explain faster diffusion
A lighter gas diffuses faster because, at the same temperature, it has the same average kinetic energy but a lower mass. Since $E_k = \frac{1}{2}mv^2$, lower mass means a higher average speed.

Temperature and diffusion

- Increasing temperature increases the average kinetic energy of particles.
- Particles move faster and spread out more quickly.
- Diffusion is usually faster in gases than in liquids because gas particles are further apart and move more freely.

State symbols in equations

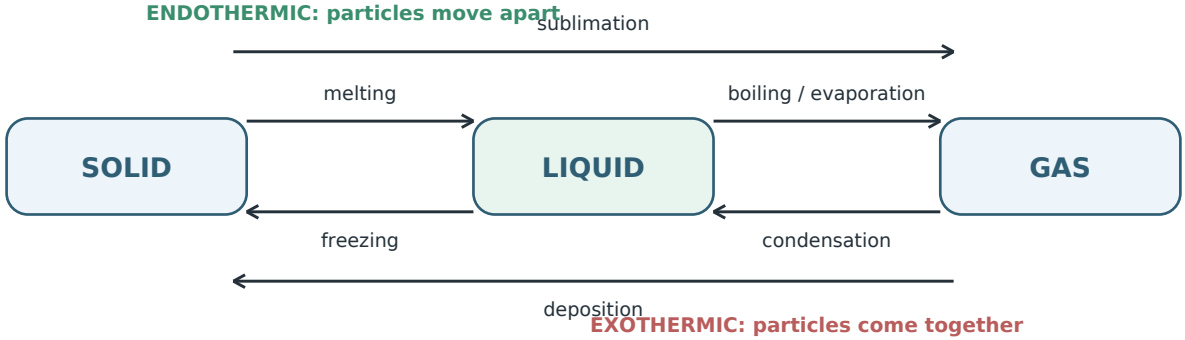
State	Symbol	Example
solid	(s)	Fe(s), NaCl(s)
liquid	(l)	$H_2O(l)$, $Br_2(l)$
gas	(g)	$O_2(g)$, $CO_2(g)$
aqueous solution	(aq)	HCl(aq), NaOH(aq)

Example with state symbols: $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

Exam habit
Include state symbols whenever possible. They show chemical understanding and are often required in ionic equations, precipitation reactions and gas-forming reactions.

5. Changes of State

Matter changes state when particles gain or lose enough energy for inter-particle attractions to be overcome or formed.



Change	Direction	Energy change	Particle explanation
Melting	solid → liquid	Endothermic	Energy weakens attractions so particles leave fixed positions and move past each other.
Freezing	liquid → solid	Exothermic	Particles lose energy and attractions hold them in fixed positions.
Vaporisation	liquid → gas	Endothermic	Particles gain enough energy to separate widely and move freely.
Condensation	gas → liquid	Exothermic	Particles lose energy and attractions bring them closer together.
Sublimation	solid → gas	Endothermic	Particles change directly from solid to gas without becoming liquid.
Deposition	gas → solid	Exothermic	Particles change directly from gas to solid.

Important equality
For a pure substance at the same pressure: melting point = freezing point and boiling point = condensation point.

Evaporation, Boiling and Pressure

Feature	Evaporation	Boiling
Where it happens	At the surface only.	Throughout the liquid.
Temperature	Can occur below the boiling point over a range of temperatures.	Occurs at a fixed boiling point for a given pressure.
Bubbles?	No bubbles throughout the liquid.	Bubbles of vapour form throughout the liquid.
Rate increases when...	Temperature rises, surface area increases, air flow increases, humidity decreases.	Temperature reaches the boiling point.

The boiling point is the temperature at which the vapour pressure of the liquid equals the external pressure. If external pressure is lower, boiling occurs at a lower temperature. If external pressure is higher, boiling occurs at a higher temperature.

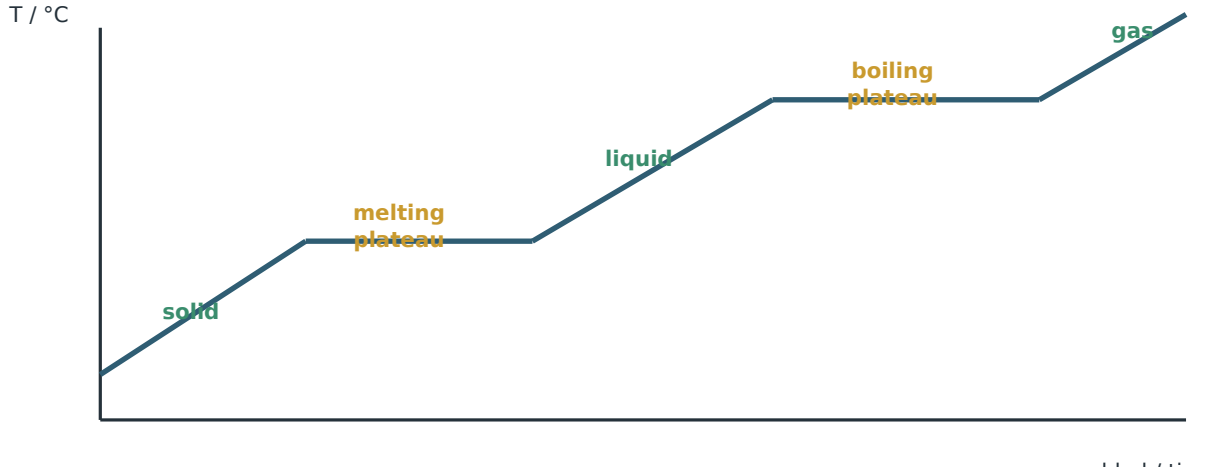
Application examples
Pressure cooker: higher pressure raises the boiling point, so food cooks faster.
High mountains: lower pressure lowers the boiling point, so cooking can take longer.
Gas canisters: butane or propane can be stored as liquids under pressure.

Sublimation examples

- Solid carbon dioxide changes directly to carbon dioxide gas at room temperature.
- Iodine can sublime when warmed, producing a purple vapour.
- Snow can gradually disappear in very cold weather by sublimation, even when it has not melted.

6. Heating Curves and Temperature Plateaus

A heating curve shows how temperature changes as energy is added to a substance at constant pressure. Sloping regions and flat regions mean different things.



Sloping sections: temperature rises because average kinetic energy increases.
Flat sections: energy breaks intermolecular forces, so temperature stays constant.

Region	What happens	What energy does
Solid warms	Particles vibrate more strongly in fixed positions.	Increases average kinetic energy, so temperature rises.
Melting plateau	Solid and liquid are both present.	Breaks some inter-particle attractions; temperature stays constant.
Liquid warms	Particles move faster while still close together.	Increases average kinetic energy, so temperature rises.
Boiling plateau	Liquid and gas are both present.	Breaks remaining inter-particle attractions; temperature stays constant.
Gas warms	Gas particles move faster.	Increases average kinetic energy, so temperature rises.

Mark-scheme phrase
During a change of state, added energy is used to overcome inter-particle forces, not to increase average kinetic energy. Therefore, the temperature remains constant.

Common error
Do not write that particles “stop moving” during a plateau. They still move; the average kinetic energy is constant while potential energy increases.

7. Kelvin Temperature and Energy

The kelvin (K) is the SI unit of temperature. It is called absolute temperature because 0 K is absolute zero, the lowest possible temperature.

$$T(K) = T(°C) + 273.15$$

For many exam calculations, 273 may be used instead of 273.15 unless a question requires more precision.

Celsius / °C	Kelvin / K	Notes
−273.15	0	Absolute zero.
0	273.15	Melting point of ice at 1 atm.
25	298.15	Approximate room temperature.
100	373.15	Boiling point of water at 1 atm.

Average kinetic energy vs total energy

Idea	Meaning	Exam example
Average kinetic energy	Energy per particle on average; depends on temperature.	Two samples at the same temperature have the same average kinetic energy per particle.
Total kinetic energy	Energy of all particles together; depends on temperature and amount of substance.	A larger mass at the same temperature has more total kinetic energy because it contains more particles.

Why “average” matters
Not every particle in a sample has the same kinetic energy. Particles collide and exchange energy, so a sample contains a distribution of kinetic energies.

8. High-Yield Exam Traps and Corrected Answers

Trap	Wrong idea	Correct exam answer
Homogeneous mixture vs pure substance	If it looks uniform, it must be pure.	Uniform mixtures still contain more than one substance and have variable composition.
Compounds vs mixtures	Compounds are mixtures of elements.	In compounds, atoms are chemically bonded in a fixed ratio; in mixtures, substances are not chemically bonded.
State-change plateaus	Temperature stays constant because heating stops.	Energy is still supplied; it is used to overcome inter-particle attractions.
Melting/boiling and kinetic energy	Kinetic energy increases during melting or boiling.	Average kinetic energy stays constant during the state change; potential energy increases.
Evaporation and boiling	Evaporation is the same as boiling.	Evaporation occurs at the surface over a range of temperatures; boiling occurs throughout at a fixed temperature for a given pressure.
Diffusion	Particles move from high concentration because they “want” to spread out.	Particles move randomly; net movement is from higher to lower concentration.
Steam burns	Steam and boiling water at the same temperature cause the same burn.	Steam releases extra energy when it condenses on skin, so it can cause more severe burns.

Checklist before you finish an answer

- Have you used particle language: arrangement, motion, distance and attractions?
- Have you named the correct physical property for a separation method?
- Have you used the correct state symbol: (s), (l), (g), or (aq)?
- Have you avoided saying that kinetic energy increases during a state-change plateau?
- Have you explained observations at both the visible level and particle level?

9. Model Answers for Common Question Types

Q1. Distinguish between an element and a compound.

Model answer: An element is a pure substance made from one type of atom and cannot be chemically broken down into simpler substances. A compound contains atoms of different elements chemically bonded together in a fixed ratio and can be decomposed by chemical reactions.

Q2. Explain why salt water is a homogeneous mixture rather than a compound.

Model answer: Salt water contains water and dissolved ions that are not chemically bonded together in a fixed ratio. The composition can vary, but the mixture is uniform throughout. The components can be separated by physical methods such as evaporation or distillation.

Q3. Use kinetic molecular theory to explain why a gas fills its container.

Model answer: Gas particles are far apart and the attractive forces between them are negligible. They move rapidly and randomly in all directions, so they spread out until they occupy all available volume.

Q4. Explain why the temperature remains constant while a pure liquid boils.

Model answer: At the boiling point, energy is used to overcome the inter-particle attractions between liquid particles so that gas forms. The average kinetic energy of the particles does not increase during this process, so the temperature stays constant.

Q5. Explain why steam can cause a more serious burn than boiling water at the same temperature.

Model answer: Steam contains energy needed for vaporisation. When steam touches cooler skin, it condenses to liquid water and releases this energy to the skin, in addition to cooling from 100 °C. Therefore, more energy is transferred than from the same mass of boiling water.

10. Exam Practice Questions

Answer these before checking the mark scheme. They are written in an IB/A level style and focus on the same skills as the notes.

1 Multiple choice. Which is a homogeneous mixture? A water and oil B sand and water C salt water D copper metal

2 Multiple choice. Which statement is correct? A compounds have variable composition B mixtures are chemically bonded C elements cannot be chemically broken down D mixtures have fixed formulae

3 Multiple choice. Which method is best for separating a liquid from dissolved salt? A filtration B distillation C magnetic separation D chromatography

4 Short answer. Define the term compound. (2)

5 Short answer. Explain why bronze is usually classified as a mixture even though it contains metal atoms. (2)

6 Short answer. Describe two differences between particles in a liquid and particles in a gas. (2)

7 Short answer. A gas with a strong smell spreads across a room faster at 35 °C than at 15 °C. Explain why. (2)

8 Short answer. Solid carbon dioxide changes directly into carbon dioxide gas at room temperature. Name the process and describe the particle change. (2)

9 Structured. A student heats a pure solid. The temperature rises, then remains constant for several minutes, then rises again. Explain what happens during the constant-temperature section. (3)

10 Calculation. Convert 45 °C to kelvin and convert 310 K to °C. (2)

11 Application. Explain why distillation may not be practical for producing very large quantities of drinking water from seawater. (2)

12 Application. During very cold weather, snow slowly disappears without liquid water being seen. Explain how this is possible. (2)

Mark Scheme / Answer Guide

1 C - salt water is uniform throughout and contains dissolved ions and water.

2 C - elements cannot be chemically broken down into simpler substances.

3 B - distillation separates using boiling point; water vaporises and condenses.

4 A compound is made from atoms of different elements; chemically bonded together; in a fixed ratio. Any two for 2 marks.

5 Bronze contains copper and tin atoms mixed physically; composition can vary; atoms are not present in a fixed chemical formula. Any two for 2 marks.

6 Liquid particles are close together; gas particles are far apart. Liquid particles slide past each other; gas particles move rapidly and randomly in all directions. Gas forces are negligible compared with liquids. Any two clear differences.

7 At higher temperature, particles have greater average kinetic energy; they move faster; random motion spreads particles more quickly.

8 Sublimation. Particles change from closely packed solid arrangement directly to widely spaced gas particles; attractions are overcome.

9 The solid is melting. Energy supplied is used to overcome inter-particle forces / loosen particles from fixed positions. Average kinetic energy does not increase, so temperature remains constant. Solid and liquid are both present.

10 45 °C = 318 K (or 318.15 K). 310 K = 37 °C (or 36.85 °C).

11 Distillation requires a large energy input to boil water; it is expensive / slow for large volumes; equipment costs can be high.

12 Snow can sublime: solid water changes directly to water vapour without melting; this can happen below 0 °C when particles at the surface gain enough energy to escape.

Final revision prompt
Try writing one paragraph that links: particles - kinetic energy - inter-particle forces - state changes - temperature plateaus. This single paragraph tests most of the topic.

One-Page Summary: What to Memorise

Area	Must-know points
Matter model	Matter is made of particles: atoms, molecules or ions. Models explain behaviour but have limitations.
Element	Pure substance made from atoms with the same number of protons; cannot be chemically broken down.
Compound	Different elements chemically bonded in a fixed ratio; properties differ from component elements.
Mixture	Substances physically combined, not chemically bonded, variable composition, separated by physical methods.
Homogeneous vs heterogeneous	Homogeneous = uniform; heterogeneous = non-uniform.
Separation	Choose based on physical property difference: solubility, boiling point, magnetism or chromatography behaviour.
Kinetic molecular theory	State depends on particle arrangement, motion and strength of attractions relative to kinetic energy.
Temperature	Temperature measures average kinetic energy. Kelvin = Celsius + 273.15.
Changes of state	Melting, boiling/vaporisation and sublimation are endothermic. Freezing, condensation and deposition are exothermic.
Heating curves	Slopes = temperature increases. Plateaus = state change; energy overcomes attractions; temperature constant.
Boiling vs evaporation	Boiling occurs throughout at a fixed temperature for a given pressure. Evaporation occurs at the surface over a range of temperatures.
Diffusion	Random particle motion causes spreading. Higher temperature and lower particle mass usually increase diffusion rate.

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