FREE SAMPLE | Buy the complete pack at notesbazar.in | page 1 of 13

S1.1 Introduction to the particulate nature of matter

How can we model the particulate nature of matter?

Standard Level and Higher Level (2 hours; there is no additional HL content in S1.1)

What you must be able to do

Statement	You must be able to...	Level
1.1.1 Elements, compounds, mixtures	Distinguish their properties; homogeneous versus heterogeneous mixtures; choose a method (solvation, filtration, recrystallization, evaporation, distillation, chromatography) to separate a mixture	SL HL
1.1.2 Kinetic molecular theory	Distinguish solids, liquids and gases; name the changes of state; use state symbols (s), (l), (g), (aq) in equations	SL HL
1.1.3 Temperature and kinetic energy	Temperature in kelvin measures average kinetic energy; interpret heating and cooling curves; convert between °C and K	SL HL

What is inside

1. Concept notes with 8 worked examples
2. Separation methods with apparatus diagrams
3. Common mistakes; investigation (IA) ideas
4. 15 Paper 1A-style MCQs, explained
5. 3 Paper 2-style questions (one data-based, Paper 1B style) with mark schemes
6. Quick-reference sheet and "I can" checklist

How to read these notes

SL = Standard Level content

HL = needed at Higher Level only

red = key term green = definition

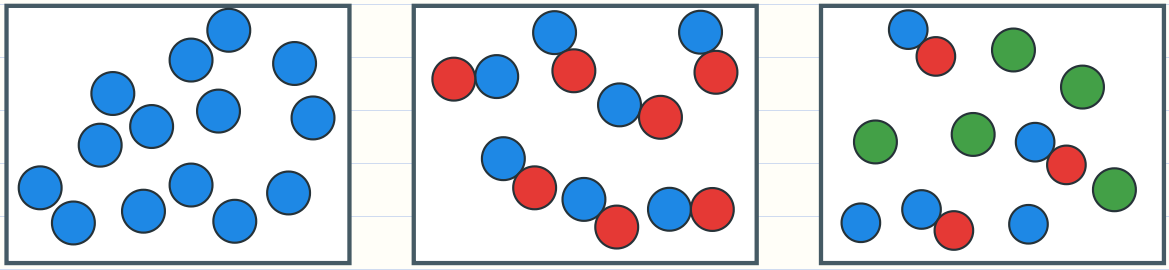
1 = one mark in the mark scheme

★ **Exam tip:** The Chemistry data booklet is allowed in Papers 1 and 2. In S1.1 you only need it for the periodic table and the Kelvin conversion; everything else here you must learn.

Independent Notes Bazar study notes for students taking IB Diploma Chemistry. Not endorsed by or affiliated with the International Baccalaureate Organization (IBO). All questions are original exam-style questions, not past-paper questions; all figures are drawn by us.

Elements, compounds and mixtures SL HL

Everything we study in chemistry is built from **atoms**. How the atoms are arranged and bonded decides what kind of matter we have. Matter is either a **pure substance** (an element or a compound) or a **mixture**.



element
one kind of atom

compound
different atoms bonded, fixed ratio

mixture
not bonded, any ratio

Particle models: an element, a compound and a mixture (each colour is a different element).

	Element	Compound	Mixture
Made of	one kind of atom only; cannot be broken into simpler substances by chemical means	atoms of two or more elements **chemically bonded** in a fixed ratio	two or more elements and/or compounds, **not** chemically bonded, in **no fixed ratio**
Properties	fixed properties (melting point, density…)	fixed properties, *different* from those of the elements it contains	vary with composition; each component keeps its own properties
Separation	–	only by a chemical reaction (e.g. electrolysis, heating with a reagent)	by **physical** methods (no new substances are made)
Examples	Na, O_2, Fe, S_8	NaCl, H_2O, CO_2	air, sea water, brass, crude oil

Definition **Element:** a substance that cannot be broken down into simpler substances by chemical means. **Compound:** a substance of two or more elements chemically bonded together in a fixed ratio. **Mixture:** two or more substances, not chemically bonded, in any proportion, separable by physical methods.

Homogeneous and heterogeneous mixtures

- A **homogeneous** mixture has the same composition and properties throughout (one phase): salt dissolved in water, air, brass and other alloys.
- A **heterogeneous** mixture has regions of different composition that can often be seen (more than one phase): sand in water, oil and water, granite.

Worked example 1: classify the sample

Classify each sample as an element, a compound, a homogeneous mixture or a heterogeneous mixture: (a) sodium chloride, (b) oxygen gas, (c) brass, (d) muddy water.

(a) **Compound**: sodium and chlorine bonded in a 1:1 ratio. (b) **Element**: only oxygen atoms (bonded in O_2 molecules, but all the same element). (c) **Homogeneous mixture**: an alloy of copper and zinc, uniform throughout, no fixed ratio. (d) **Heterogeneous mixture**: insoluble soil particles are visible in water.

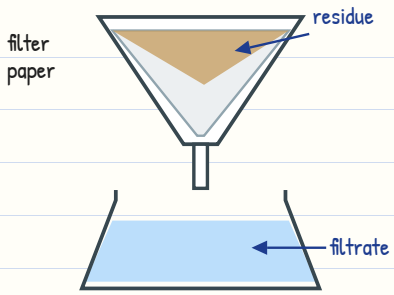
A molecule of one element (O_2, S_8) is still an element, not a compound.

✗ Don't do this: Saying that a compound is "a mixture of elements". The elements in a compound are bonded in a fixed ratio and have lost their own properties; a mixture of the same elements would keep them.

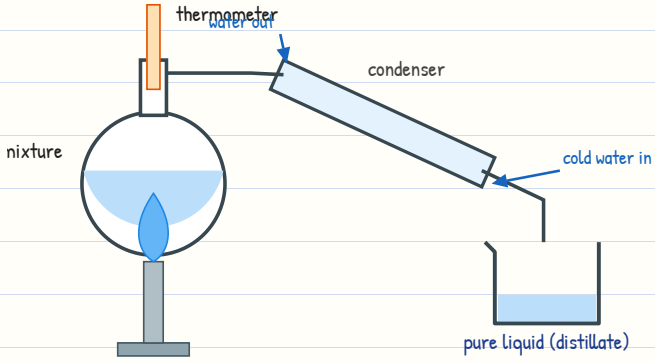
Separating mixtures SL HL

Separation uses a **difference in a physical property** between the components. The right choice depends on the state of the components, their solubility and their boiling points.

Method	Separates	Principle and key points
Solvation (dissolving)	a soluble from an insoluble solid	The solute particles are surrounded by solvent particles and spread through the liquid. Add a solvent that dissolves one component only (e.g. water for salt and sand).
Filtration	an insoluble solid from a liquid	Particles of the solid are too big for the pores of the filter paper: they stay as the **residue**; the liquid passes through as the **filtrate**.
Evaporation / crystallization	a dissolved solid from its solution	Heat to drive off the solvent; stop heating when crystals begin to form and leave to crystallise (or the solid may decompose or spatter).
Recrystallization	purifies an impure solid	Dissolve in the *minimum* of hot solvent, filter hot (removes insoluble impurities), cool slowly so pure crystals form (soluble impurities stay in solution), filter, wash with a little cold solvent, dry.
Simple distillation	a liquid from a solution or from a liquid with a much higher boiling point	Boil, condense the vapour in a condenser (water enters at the **bottom**, leaves at the top) and collect the distillate.
Fractional distillation	miscible liquids with different boiling points	A fractionating column gives repeated evaporation and condensation; the component with the lower boiling point reaches the top first.
Chromatography	small amounts of dissolved substances (dyes, amino acids)	Components are shared differently between a **stationary phase** (paper) and a **mobile phase** (solvent); the one more soluble in the solvent travels further.



Filtration



Simple distillation

Choosing a method

- Is one component an **insoluble solid**? Filtration. Is the wanted solid **dissolved**? Evaporate/crystallise. Is the **solvent** wanted? Simple distillation.
- Liquids that mix completely and have different boiling points: **fractional** distillation. Tiny samples of coloured substances: chromatography.
- Impure solid with a solubility that rises strongly with temperature: recrystallization.

★ ***Exam tip:*** Marks in "describe how to separate" questions are for the **order** of steps and the **reason** for each ("because only the salt dissolves in water"). Always name the property that differs.

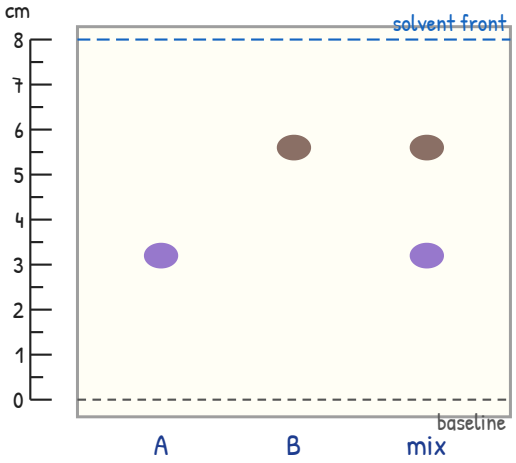
Chromatography and choosing a method SL HL

In paper chromatography a spot of the mixture is placed on a pencil **baseline** (ink would dissolve). The paper stands with its lower edge in solvent below the baseline. The solvent rises, carrying components upwards at different rates. Remove the paper before the solvent reaches the top and mark the **solvent front** at once.

Definition ✎ $R_f = \dfrac{\text{distance moved by the spot (from the baseline to the centre of the spot)}}{\text{distance moved by the solvent front (from the baseline)}}$. R_f has no unit and lies between 0 and 1. It is constant for a substance in a given solvent and paper, so spots can be identified by comparing R_f values or by running known samples alongside.

Worked example 2: identify using R_f

The chromatogram shows two known dyes A and B and a mixture. The solvent front moved 8.0 cm. Calculate R_f for each spot in the mixture and say what the mixture contains.



Spot nearer the baseline: $R_f = 3.2/8.0 = 0.40$; upper spot: $R_f = 5.6/8.0 = 0.70$. These match A (3.2 cm) and B (5.6 cm), so the mixture contains **both A and B** and nothing else.

Worked example 3: planning a separation

A mixture contains iron filings, sand and sodium chloride. Outline how to obtain each substance.

(1) Pass a **magnet** over the dry mixture to remove the iron (a physical property: only iron is attracted). (2) Add water and stir: sodium chloride **dissolves** (solvation), sand does not. (3) **Filter**: sand is the residue; wash and dry it. (4) **Evaporate** the filtrate until crystals begin to form, cool, filter and dry to obtain sodium chloride crystals.

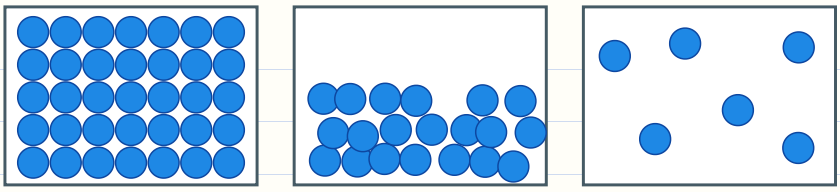
Practical: running a paper chromatogram

1. Draw a pencil baseline about 1.5 cm from the bottom of the paper and put small, concentrated spots of each sample on it, well apart.
2. Stand the paper in a covered container with the solvent **below** the baseline (otherwise the spots dissolve into the solvent pool). The lid keeps the air saturated with solvent vapour.
3. Remove the paper when the solvent front is near the top, mark the front immediately in pencil and dry the paper.
4. Measure from the baseline to the centre of each spot and to the front (uncertainty about ±0.1 cm with a ruler) and calculate each $. Compare with known substances run on the same paper in the same solvent.

Colourless spots need a locating agent or UV light first. Small $ values mean the substance is held strongly by the paper (stationary phase); values near 1 mean it is carried along by the solvent (mobile phase).

Kinetic molecular theory and the states of matter SL HL

The **kinetic molecular theory** is a model that explains physical properties by assuming matter is made of particles (atoms, molecules or ions) that are always in motion. The state depends on how strongly the particles attract each other compared with how much energy they have.



solid liquid gas

	Solid (s)	Liquid (l)	Gas (g)
Arrangement	close together, regular pattern	close together, irregular	far apart, random
Movement	vibrate about fixed positions	move past one another (slide)	rapid, random, in straight lines between collisions
Forces between particles	strongest	strong	negligible (very weak)
Shape / volume	fixed shape, fixed volume	no fixed shape, fixed volume	no fixed shape or volume
Compressible?	no	hardly	yes (large gaps)
Density	high	high	low

State symbols

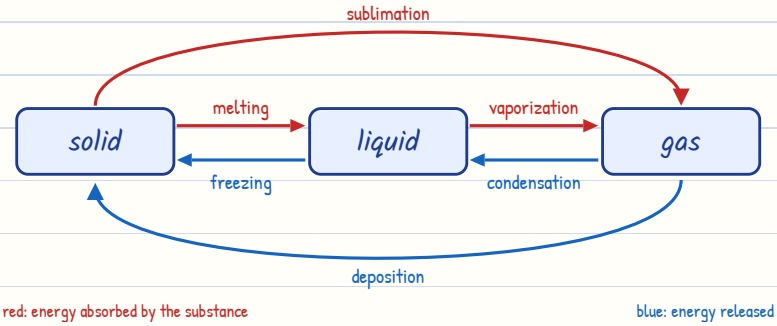
Use (s) solid, (l) liquid, (g) gas and (aq) aqueous (dissolved in water). A precipitate is an insoluble solid formed in a solution, so it is (s).

Worked example 4: adding state symbols

Write balanced equations with state symbols for (a) magnesium ribbon reacting with dilute hydrochloric acid to give a solution of magnesium chloride and hydrogen gas; (b) silver nitrate solution mixed with sodium chloride solution to form a white precipitate of silver chloride (ionic equation); (c) steam condensing.

(a) $\mathrm{Mg(s) + 2\,HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)}$ (b) $\mathrm{Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)}$ (c) $\mathrm{H_2O(g) \longrightarrow H_2O(l)}$. Check: (a) 1 Mg, 2 H, 2 Cl on each side; (b) one silver, one chlorine, net charge zero on each side.

Names of the changes of state



- **Evaporation** happens at the surface at any temperature (the fastest particles escape); **boiling** happens throughout the liquid at the boiling point, when vapour bubbles form. Both are **vaporization**.
- Sublimation: iodine or solid CO_2 ("dry ice") changing straight to gas. Deposition: frost forming from water vapour.

Temperature, kinetic energy and heating curves SL HL

Definition ✎ **Temperature** T (in kelvin, K) is a measure of the **average kinetic energy** E_k of the particles: $E_k \propto T$. At the same temperature all substances have the same average E_k, but the particles are not all moving at the same speed.

The kelvin is the SI unit. A change of 1 K equals a change of 1 °C, but the zero is different: 0 K (absolute zero) is the lowest possible temperature, where particle motion is at its minimum. Convert with $T/\mathrm{K} = \theta/^\circ\mathrm{C} + 273$ (273.15 is also acceptable; follow the precision of the data). A **temperature difference** is the same number in °C and K.

Worked example 5: converting temperatures

Convert (a) 25 °C to K, (b) −196 °C (the boiling point of nitrogen) to K, (c) 310 K to °C. (d) Water is heated from 20 °C to 80 °C; state the temperature rise in K.

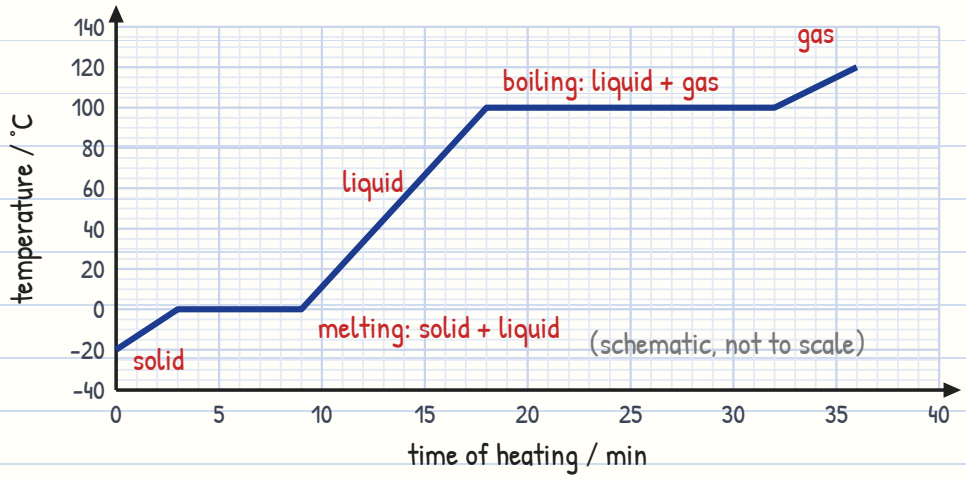
(a) $25 + 273 = 298$ K. (b) $-196 + 273 = 77$ K. (c) $310 - 273 = 37$ °C. (d) rise $= 60$ °C $= 60$ K.

Worked example 6: temperature and kinetic energy

A gas is heated from 27 °C to 127 °C. By what factor does the average kinetic energy of its particles increase?

$T_1 = 27 + 273 = 300$ K and $T_2 = 127 + 273 = 400$ K. Since $E_k \propto T$, the factor is $400/300 = 1.33$. (The wrong ratio $127/27 = 4.7$ comes from using °C.) The gas is not at "twice" the energy until it reaches 600 K = 327 °C.

Heating curve of a pure substance



- **Sloping sections**: energy supplied raises the average kinetic energy, so the temperature rises (the particles move faster; in a solid they vibrate more).
- **Flat sections** (melting point, boiling point): energy supplied is used to **overcome the attractions** between particles (increasing their potential energy), not to raise the temperature. Two states coexist.
- The boiling plateau is longer than the melting plateau because much more energy is needed to separate particles completely than to let them slide.
- A pure substance melts and boils at fixed temperatures. An impure sample melts over a range and at a lower temperature, and a mixture has no sharp plateau. This is how melting point shows purity.

- Cooling curves mirror heating curves: the plateau at the freezing point is where the liquid becomes solid, as energy is released to the surroundings.

Worked example 7: reading a curve

A pure solid is heated steadily. The temperature is 20 °C at 0 min, reaches 78 °C at 6 min and stays at 78 °C until 11 min, then rises again. State the melting point in K and what is happening between 6 and 11 min.

Melting point $= 78 + 273 = 351$ K. Between 6 and 11 min the substance is melting, so solid and liquid coexist; the energy supplied overcomes the forces between particles, so the average kinetic energy and the temperature stay constant.

Worked example 8: which change of state?

Name the change of state in each case: (a) mothballs slowly disappear in a cupboard; (b) wet washing dries on a line at 15 °C; (c) a kettle's water becomes steam at 100 °C; (d) butter becomes a liquid in a warm pan; (e) steam on a cold mirror leaves droplets.

(a) **sublimation** (solid to gas); (b) **evaporation** (a liquid to a gas below the boiling point); (c) **boiling**; (d) **melting**; (e) **condensation**.

Common mistakes

Mistake	Correct idea
"Air is a compound because it contains oxygen and nitrogen."	Air is a homogeneous mixture: the gases are not bonded and are in no fixed ratio.
"Water is a mixture of hydrogen and oxygen."	Water is a compound with a fixed 2:1 ratio of H:O atoms; its properties differ from both gases.
Measuring the spot's distance to its edge, or from the paper's edge	Both distances in R_f are measured from the baseline, to the centre of the spot and to the solvent front.
Drawing the baseline in ink	Use pencil: ink would run in the solvent.
Using °C in a ratio of kinetic energies	Convert to kelvin first; $E_k \propto T$ only on the Kelvin scale.
"Particles in a solid do not move."	They vibrate about fixed positions. Only at 0 K would motion be at its minimum.
"Particles expand when heated."	The particles themselves do not change size; the average separation grows because they move faster.
"Boiling is the same as evaporation."	Both are vaporization. Evaporation happens at the surface at any temperature; boiling is throughout the liquid at the boiling point.
"The temperature rises during melting."	It stays constant: the energy goes into overcoming the attractions between particles.

Investigation ideas (IA)

- How does the solvent composition (e.g. propanone : water ratio) affect the R_f values of the dyes in black felt-tip pens? Independent variable: the solvent ratio; dependent variable: R_f; control paper, spot size, time.

FREE SAMPLE | Buy the complete pack at notesbazar.in | page 9 of 13

- How does the percentage of an impurity (e.g. salt) affect the freezing point of water or of a solid such as stearic acid? Plot cooling curves and read the plateau; discuss uncertainty in the thermometer (±0.5 °C) and timing.
- How does the temperature of water affect the rate at which sugar dissolves? Relate the answer to the average kinetic energy of the particles.

Link: Structure 2.2 (intermolecular forces explain the order of boiling points and why substances mix) and Reactivity 2.2 (the distribution of kinetic energies and reaction rate).

15 multiple-choice questions

One mark each; no marks lost for a wrong answer. Use the periodic table in the data booklet where needed. Answers and explanations are on the next page.

1. Which substance is a compound?

   A brass **B** argon **C** sodium chloride **D** sea water

2. Which statement describes a homogeneous mixture?

   A It has the same composition throughout and its components are not chemically bonded.

   B It has elements chemically bonded in a fixed ratio.

   C It has visibly separate phases.

   D It contains only one kind of atom.

3. A student has an impure sample of a solid that is much more soluble in hot water than in cold water. Which method is best for purifying it?

   A fractional distillation **B** recrystallization **C** paper chromatography **D** filtration of the cold mixture only

4. Ethanol (boiling point 78 °C) and water (boiling point 100 °C) mix completely. Which method separates them?

   A filtration **B** recrystallization **C** evaporation to dryness **D** fractional distillation

5. In a paper chromatography experiment the solvent front moves 12.0 cm from the baseline and the centre of a spot moves 3.0 cm. What is the R_f value of the spot?

   A 4.0 **B** 0.75 **C** 0.25 **D** 0.33

6. Which statement about the particles in a liquid is correct?

   A They are close together, arranged irregularly and able to move past one another.

   B They are in fixed positions in a regular pattern.

   C They are far apart and move randomly.

   D They are close together but cannot move.

7. Frost forms on a cold window as water vapour in the air changes directly into ice. What is the name of this change of state?

   A sublimation **B** condensation **C** freezing **D** deposition

8. Which equation, with state symbols, represents the formation of a precipitate of lead(II) iodide?

   A $\mathrm{Pb^{2+}(aq) + 2\,I^-(aq) \longrightarrow PbI_2(aq)}$

   B $\mathrm{Pb^{2+}(aq) + 2\,I^-(aq) \longrightarrow PbI_2(s)}$

   C $\mathrm{Pb^{2+}(s) + 2\,I^-(s) \longrightarrow PbI_2(aq)}$

   D $\mathrm{Pb^{2+}(aq) + 2\,I^-(aq) \longrightarrow PbI_2(l)}$

9. What is the temperature 37 °C in kelvin?

   A 310 K **B** 236 K **C** 37 K **D** 273 K

10. A fixed mass of gas is heated from 27 °C to 327 °C. By what factor does the average kinetic energy of its particles change?

    A it increases twelve-fold **B** it increases fourfold **C** it doubles **D** it stays the same

11. A pure solid is heated steadily and starts to melt. Why does the temperature stay constant during melting?

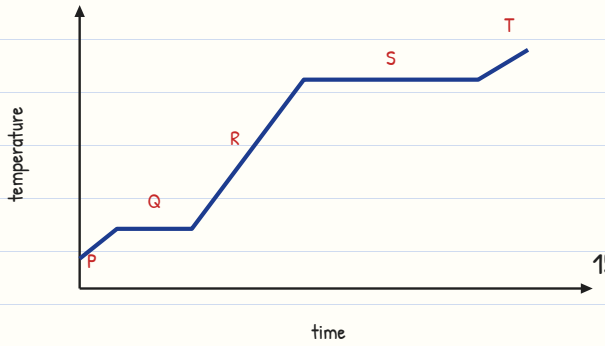
    A The particles stop moving.

    B The energy supplied increases the average kinetic energy of the particles.

    C The substance loses energy to the surroundings as fast as it gains it.

    D The energy supplied overcomes forces between particles instead of raising their average kinetic energy.

12. The diagram shows the heating curve of a pure substance (not to scale). In which section are both liquid and gas particles present?



A Q
B S
C R
D T

13. Which statement distinguishes a mixture from a compound?

A The components of a mixture keep their own properties and can be separated by physical methods.
B A mixture always has a fixed melting point.
C A mixture has its components in a fixed ratio.
D A mixture can only be separated by chemical reactions.

14. According to the kinetic molecular theory, why can a gas be compressed much more easily than a liquid?

A The particles of a gas repel each other strongly.
B There are large gaps between the particles of a gas.
C The particles of a gas are smaller than those of a liquid.
D The particles of a gas have no mass.

15. Which statement applies to boiling but not to evaporation?

A Some particles escape from the liquid surface.
B Energy is absorbed by the liquid.
C Bubbles of vapour form throughout the liquid at a fixed temperature for a given external pressure.
D A gas forms from a liquid.

Answers and explanations

1 C	2 A	3 B	4 D	5 C	6 A	7 D	8 B
9 A	10 C	11 D	12 B	13 A	14 B	15 C	

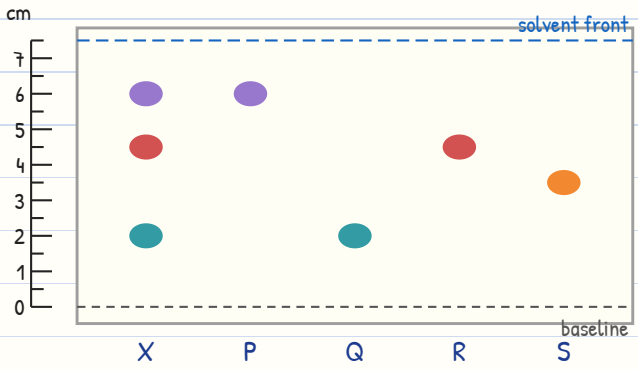
1. **C.** Sodium chloride contains two elements chemically bonded in a fixed ratio. Brass is an alloy (a mixture of copper and zinc), argon is an element and sea water is a mixture.
2. **A.** A homogeneous mixture (for example air or a salt solution) is uniform throughout but its components keep their own identity. Fixed-ratio bonding describes a compound; visible phases describe a heterogeneous mixture.
3. **B.** Dissolve in the minimum of hot solvent, filter hot, cool to crystallise the pure solid and filter again. Distillation is for liquids and filtration alone cannot remove dissolved impurities.
4. **D.** Miscible liquids with different boiling points are separated by fractional distillation. Filtration needs an insoluble solid; evaporating to dryness would lose the ethanol.
5. **C.** $R_f = 3.0/12.0 = 0.25$. 4.0 is the inverted ratio, 0.75 uses $9.0/12.0$ and 0.33 uses $3.0/9.0$. R_f has no unit and is always less than 1.
6. **A.** In a liquid the particles touch but are not in fixed positions, so a liquid flows and has no fixed shape but does have a fixed volume.
7. **D.** Gas to solid without passing through the liquid state is deposition. Sublimation is the reverse (solid to gas).
8. **B.** Ions in solution are (aq); a precipitate is an insoluble solid, (s). The equation is balanced in atoms and in charge (2+ and 2 × 1− give zero).
9. **A.** $T = 37 + 273 = 310$ K (310.15 K if 273.15 is used). 236 K results from subtracting instead of adding.
10. **C.** Average kinetic energy is proportional to the temperature in kelvin: 300 K to 600 K is a factor of 2. Using the Celsius values (a factor of about 12) is the usual mistake.

11. **D.** Temperature measures the average kinetic energy. During a change of state the energy input goes into the potential energy of the particles (overcoming attractions), so the temperature is constant.
12. **B.** Section S is the plateau at the boiling point where liquid and gas coexist. Q is the plateau at the melting point (solid and liquid); R is the liquid warming; T is the gas warming.
13. **A.** In a mixture the substances are not chemically bonded, so they keep their properties and physical separation is possible. A compound has a fixed composition and needs a chemical reaction to be broken down.
14. **B.** Most of the volume of a gas is empty space. The particles themselves are the same size in either state and have mass.
15. **C.** Evaporation happens at the surface at any temperature; boiling happens throughout the liquid at the boiling point, when bubbles of vapour can form. Both absorb energy and both make a gas from a liquid.

Structured questions

Question 1 (8 marks)

A student runs chromatography on a black ink X using a mixture of solvents. Reference dyes P, Q, R and S are run on the same paper. The chromatogram is shown after the solvent front reached the top mark. All spots are shown at the position of their centre.



(a) State why the baseline is drawn in pencil, not ink. [1]

(b) Determine the R_f value of the spot of X that has travelled furthest. [2]

(c) Deduce which of the reference dyes are present in X. [2]

(d) Explain why the three spots of X travel different distances. [2]

(e) Suggest why X cannot be a single pure compound. [1]

Mark scheme

- (a) ink would dissolve/run in the solvent (and contaminate the chromatogram); pencil is insoluble **1**
- (b) distance 6.0 cm and solvent front 7.5 cm **1**; $R_f = 6.0/7.5 = 0.80$ **1**
- (c) P, Q and R **1** (spots at 6.0, 2.0 and 4.5 cm line up with those of X); S (3.5 cm) is not present **1**
- (d) the components have different solubilities in the mobile phase/different attraction to the stationary phase **1**; the one more soluble in the solvent (less strongly held by the paper) travels further **1**
- (e) a pure compound would give one spot; X gives three, so it is a mixture **1**

Question 2 (6 marks)

Naphthalene is a white solid with a melting point of 80 °C. It is also used as a moth repellent because it slowly changes straight from solid to vapour at room temperature.

(a) State the name of the change of state in which a solid changes directly to a gas. [1]

(b) Describe the arrangement and the movement of the particles in solid and in liquid naphthalene. [2]

(c) Convert the melting point to kelvin. [1]

(d) Naphthalene is heated steadily from 25 °C. Explain why the temperature stays at 80 °C for a time even though energy is still supplied. [2]

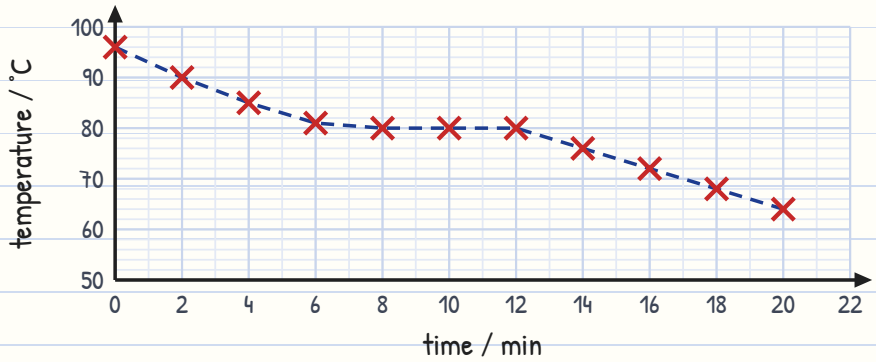
Mark scheme

- (a) sublimation 1
- (b) solid: regular arrangement, particles vibrate about fixed positions 1; liquid: irregular, close together, particles can slide past one another 1
- (c) $80 + 273 = 353$ K 1 (353.15 K accepted)
- (d) the solid is melting (solid and liquid present) 1; the energy is used to overcome the forces between the particles, not to increase their average kinetic energy 1

Question 3 (7 marks): data-based (Paper 1B style)

A student heated a sample of a pure organic solid until it melted, then allowed the liquid to cool in a test tube in air while recording its temperature every two minutes. The data are plotted; each cross is a measurement and the dashed line joins them.

time / min	0	2	4	6	8	10	12	14	16	18	20
temperature / °C	96	90	85	81	80	80	80	76	72	68	64



(a) State the freezing point of the substance in °C and in K. [2]

(b) State the physical state(s) of the sample at 10 min. [1]

(c) Calculate the average rate of cooling between 0 and 6 min, in °C min^{-1}. [2]

(d) Explain, in terms of particles and energy, why the temperature is constant between 8 and 12 min. [2]

Mark scheme

- (a) 80 °C 1; $80 + 273 = 353$ K 1
- (b) liquid and solid (both) 1
- (c) $(96 - 81)/6$ 1; $= 2.5$ °C min^{-1} 1

- (d) the liquid is freezing; particles form attractions and settle into fixed positions 1; energy is released to the surroundings at the same rate as it is lost, so the average kinetic energy of the particles (and the temperature) stays constant 1

Quick reference

Classification

element: one kind of atom

compound: bonded atoms, fixed ratio

mixture: not bonded, any ratio (homogeneous or heterogeneous)

Separations

filtration (insoluble solid), evaporation/crystallization, recrystallization, simple and fractional distillation, chromatography (R_f = spot distance ÷ solvent distance)

States and symbols

(s) (l) (g) (aq)

melting, freezing, vaporization (evaporation, boiling), condensation, sublimation, deposition

Temperature

$T/\mathrm{K} = \theta/^\circ\mathrm{C} + 273$; $E_k \propto T$ (in K)

flat part of a curve: change of state, potential energy rises

"I can" checklist

☐ I can distinguish elements, compounds and homogeneous and heterogeneous mixtures.

☐ I can choose and describe a separation method and calculate R_f.

☐ I can describe the three states with the kinetic molecular theory and name every change of state.

☐ I can use state symbols in equations.

☐ I can interpret heating and cooling curves and convert between °C and K.