Chapter: 1. States of matter

Book/PDF: Chapter-01.pdf
Pages: 1–9
Exam level: Cambridge IGCSE (0610)

1) Big-picture overview

[cite_start]This chapter introduces the fundamental concept that all substances, or **matter**, exist in one of three states: **solid, liquid, or gas** (p. 1)[cite: 14, 15]. [cite_start]It explains the distinct properties of each state, such as shape, volume, and compressibility (p. 2)[cite: 22, 24, 26, 29]. [cite_start]The core of the chapter is the **kinetic particle theory**, a model used to explain these properties based on how particles are arranged and how they move (p. 2)[cite: 47]. [cite_start]This theory helps us understand everyday phenomena, like why solids expand when heated and why smells spread through a room (diffusion) (p. 2, 7)[cite: 23, 238]. [cite_start]You'll also learn about **changes of state**, like melting and boiling, and how to interpret heating and cooling curves, which show that temperature remains constant during these changes (p. 4)[cite: 85, 105]. This chapter is foundational for understanding chemical reactions and the physical world.

2) Syllabus mapping

Outcome code	Outcome description	Where covered (page)
C3.1 (a)	Describe the states of matter and explain their interconversion in terms of the kinetic particle theory.	[cite_start]1, 4 [cite: 7, 85]
C3.1 (b)	Describe and explain the properties of solids, liquids, and gases in terms of particle arrangement and motion.	[cite_start]2, 3 [cite: 36]
C3.1 (c)	Describe the effect of temperature and pressure on the volume of a gas.	[cite_start]6 [cite: 207]
C3.1 (d)	Describe and explain diffusion in terms of the kinetic particle theory.	[cite_start]7 [cite: 229]

Outcome code	Outcome description	Where covered (page)
C3.1 (e)	Describe the effect of relative molecular mass on the rate of diffusion of gases.	[cite_start]7 [cite: 251, 252]
C2.2 (d)	Interpret and use heating and cooling curves.	[cite_start]4, 5 [cite: 107, 141]
C2.2 (e)	Describe how the purity of a substance can be determined from melting and boiling point information.	[cite_start]5 [cite: 184, 188]

3) Key terms and definitions

Term	One-sentence definition	First appears (page)	Example/application
Matter	All the substances and materials from which the physical universe is composed.	[cite_start]1 [cite: 13]	Water, aluminium, and oxygen are all examples of matter.
States of matter	The three distinct physical forms that matter can exist in: solid, liquid, and gas.	[cite_start]1 [cite: 15]	[cite_start]Ice (solid), water (liquid), and steam (gas) are the three states of water (p. 1)[cite: 17].
Expansion	The slight increase in the size of solids when they are heated.	[cite_start]2 [cite: 23]	[cite_start]Railway tracks have gaps to allow for expansion on a hot day, preventing them from buckling (p. 2)[cite: 44].
Contraction	The decrease in the size of a substance when it is cooled.	[cite_start]2 [cite: 23]	[cite_start]A balloon filled with air will shrink if placed in a cold environment (p. 6)[cite: 210].
Kinetic particle	A scientific model explaining that all matter is made of tiny,	[cite_start]2 [cite: 36, 47]	[cite_start]This theory explains why gases fill their container—the

Term	One-sentence definition	First appears (page)	Example/application
theory	constantly moving particles.		particles move randomly to fill all available space (p. 3)[cite: 76].
Melting point	The specific temperature at which a solid turns into a liquid.	[cite_start]4 [cite: 90]	[cite_start]The melting point of pure water (ice) is 0°C (p. 4)[cite: 111].
Boiling point	The specific temperature at which a liquid turns into a gas, forming bubbles within the liquid.	[cite_start]4 [cite: 99]	[cite_start]The boiling point of pure water is 100°C (p. 4)[cite: 111].
Physical change	A change, such as a change of state, where no new substance is formed and the temperature remains constant during the change.	[cite_start]4 [cite: 105, 106]	Ice melting into water is a physical change.
Diffusion	The spreading out of gas or liquid particles in a random way to fill the available space.	[cite_start]7 [cite: 238]	The smell of perfume spreading across a room.

4) Core concepts explained

1.1 Solids, liquids and gases (p. 1-2)

- [cite_start]Matter exists in three states: solid, liquid, and gas[cite: 14].
- **Solids** have a definite shape and volume. [cite_start]Their size can change slightly with temperature (expansion/contraction) but they cannot be compressed[cite: 22, 23, 10].
- **Liquids** have a fixed volume but take the shape of their container. [cite_start]Their volume also changes slightly with temperature[cite: 24, 25].

- [cite_start]**Gases** have no definite shape or volume; they expand to fill any container they are in. Their volume is greatly affected by temperature and pressure[cite: 26, 27, 28].
- [cite_start]Both liquids and gases are **compressible** (their volume can be reduced by pressure), but gases are much more compressible than liquids[cite: 29, 30].

Feature	Solid	Liquid	Gas
Arrangement of particles	[cite_start]Tightly packed in a regular, fixed pattern (p. 3)[cite: 71].	[cite_start]Close together but randomly arranged (p. 3)[cite: 61].	[cite_start]Far apart and randomly arranged (p. 3)[cite: 64].
Movement of particles	[cite_start]Vibrate about fixed positions (p. 3)[cite: 71].	[cite_start]Move around and slide past each other (p. 3)[cite: 73].	[cite_start]Move quickly and randomly in all directions (p. 3)[cite: 76].
Forces between particles	[cite_start]Very strong attractive forces (p. 2)[cite: 38].	[cite_start]Weaker attractive forces than in solids (p. 3)[cite: 62].	[cite_start]Almost no attractive forces (p. 3)[cite: 67].
Shape	[cite_start]Definite shape (p. 2)[cite: 22].	[cite_start]Takes shape of container (p. 2)[cite: 24].	[cite_start]No definite shape; fills container (p. 2)[cite: 27].
Volume	[cite_start]Definite volume (p. 2)[cite: 22].	[cite_start]Definite volume (p. 2)[cite: 24].	[cite_start]No definite volume (p. 2)[cite: 26].
Compressibility	[cite_start]Cannot be compressed (p. 1)[cite: 10].	[cite_start]Not easily compressed (p. 2)[cite: 30].	[cite_start]Easily compressed (p. 2)[cite: 29].

1.2 The kinetic particle theory of matter (p. 2-3)

- [cite_start]All matter is made of tiny, invisible, moving particles (atoms, molecules, or ions) (p. 2)[cite: 32, 33].
- [cite_start]The particles are always moving; the higher the temperature, the faster they move on average (p. 2)[cite: 34].

- [cite_start]At the same temperature, heavier particles move more slowly than lighter particles (p. 2)[cite: 35].
- [cite_start]In solids, strong forces hold particles in a regular, vibrating structure, which is why many solids form crystals (p. 2)[cite: 38, 40].
- [cite_start]In liquids, particles have more energy, and forces are weaker, allowing them to move randomly past one another (p. 3)[cite: 61, 62].
- [cite_start]In gases, particles are far apart, move very rapidly and randomly, and have almost no forces of attraction between them (p. 3)[cite: 64, 65, 67].

1.3 Changes of state (p. 4-5)

- [cite_start]When a substance changes state, it's a **physical change** where no new substances are formed and the temperature stays constant during the transition (p. 4)[cite: 105, 106].
- **Heating a solid**: Particles gain energy and vibrate faster, causing expansion. [cite_start]At the melting point, particles gain enough energy to overcome the strong forces, the regular structure breaks down, and the solid **melts** into a liquid (p. 4)[cite: 86, 87, 88, 89, 90].
- **Heating a liquid**: Particles gain more energy and move faster. Some at the surface escape to form a gas (evaporation). [cite_start]At the boiling point, particles have enough energy to form bubbles of gas inside the liquid, and the liquid **boils** (p. 4)[cite: 123, 97, 98, 99].
- **Cooling a gas**: Particles lose energy, move slower and closer together. [cite_start]Attractive forces become significant, and the gas **condenses** into a liquid (p. 4)[cite: 102, 103].
- **Cooling a liquid**: Particles lose more energy, slow down, and lock into a fixed, regular pattern. [cite_start]The liquid **freezes** into a solid (p. 4)[cite: 104].
- A pure substance has a sharp, fixed melting and boiling point. [cite_start]Impurities lower the melting point and cause melting to occur over a range of temperatures (p. 5)[cite: 184, 185, 188].

1.4 The effects of temperature and pressure on gases (p. 6)

- [cite_start]**Temperature**: Increasing the temperature of a gas increases the kinetic energy of its particles, making them move faster (p. 6)[cite: 200]. [cite_start]These faster particles collide with the walls of the container more frequently and with more force, increasing the **pressure** (p. 6)[cite: 199, 200]. [cite_start]If the container is flexible (like a balloon), the volume will increase (p. 6)[cite: 212].
- [cite_start]**Pressure**: Increasing the pressure on a gas (e.g., in a bicycle pump) forces the particles closer together (p. 6)[cite: 218]. [cite_start]This increases the frequency of collisions,

and frictional forces cause the temperature to rise (p. 6)[cite: 218].

1.5 Diffusion (p. 7)

- [cite_start]Diffusion is the net movement of particles from a region of higher concentration to a region of lower concentration, caused by their random motion (p. 7)[cite: 238].
- [cite_start]It happens in liquids and gases because their particles are free to move randomly (p. 7)[cite: 229].
- [cite_start]Diffusion is much faster in gases than in liquids because gas particles move much more rapidly and have more space between them to move into (p. 8)[cite: 257, 258].
- [cite_start]At a given temperature, gases with a lower relative molecular mass (lighter particles) diffuse faster than gases with a higher relative molecular mass (heavier particles) (p. 7)[cite: 251, 252].

5) Diagrams and micrographs (figures)

- [cite_start]**Figure 1.6 The arrangement of particles in solids, liquids and gases (p. 3)** [cite: 77]
  - **What it shows**: Three boxes illustrating the particle arrangement and motion for each state of matter.
  - [cite_start]**Solid**: Particles are shown in a regular, tightly packed grid, with small marks to indicate they are vibrating in fixed positions[cite: 71].
  - [cite_start]**Liquid**: Particles are shown close together but randomly scattered, with arrows indicating they can move around each other[cite: 73].
  - [cite_start]**Gas**: Particles are shown very far apart, with long arrows indicating they are moving freely and randomly in all directions[cite: 76].
- [cite_start]**Figure 1.7 Graph of temperature against time (Heating Curve) (p. 4)** [cite: 132]
  - **What it shows**: A graph plotting temperature (°C) on the y-axis against time (minutes) on the x-axis for water being heated from ice at -15°C to steam above 100°C.
  - [cite_start]**Labels**: The curve has five distinct sections: solid (ice) heating up, a flat plateau at 0°C (melting), liquid (water) heating up, a second flat plateau at 100°C (boiling), and gas (steam) heating up[cite: 127, 116, 117, 118, 121].
  - **Revision sketch**: Draw axes (Temp vs. Time). Start below zero, draw a rising line. Then a flat horizontal line at 0°C. Then another rising line (steeper than the first). Then a longer flat horizontal line at 100°C. Finally, a third rising line. Label each section.
- [cite_start]**Figure 1.12 Diffusion of ammonia and hydrogen chloride (p. 7)** [cite: 248]

- **What it shows**: A glass tube with cotton wool at each end, demonstrating the different rates of diffusion of two gases.
- [cite_start]**Labels**: Glass tube, mineral wool soaked in concentrated hydrochloric acid (left), mineral wool soaked in concentrated ammonia solution (right), white ring of ammonium chloride forming closer to the HCl end[cite: 243, 246, 232].
- [cite_start]**Principle**: Ammonia particles are lighter than hydrogen chloride particles, so they diffuse faster and travel further down the tube in the same amount of time[cite: 251, 252].

6) Processes and cycles

Changes of State

- **Melting (Solid → Liquid)**
  i. [cite_start]A solid is heated, providing energy to its particles[cite: 86].
  ii. [cite_start]Particles vibrate more and more vigorously, pushing each other apart (expansion) [cite: 86, 87].
  iii. [cite_start]At the melting point, particles gain enough energy to overcome the strong forces holding them in a fixed lattice[cite: 90, 180].
  iv. The regular structure breaks down, and particles begin to slide past one another. [cite_start]The substance is now a liquid[cite: 89].
  - **Input**: Heat energy. **Output**: Liquid. **Condition**: Must reach melting point temperature.
- **Boiling (Liquid → Gas)**
  i. [cite_start]A liquid is heated, increasing the average kinetic energy of its particles[cite: 123].
  ii. Particles move faster and collide more often. [cite_start]Some particles at the surface gain enough energy to escape into the gas phase (evaporation)[cite: 123, 124, 125].
  iii. [cite_start]At the boiling point, particles throughout the liquid have enough energy to overcome attractive forces and form bubbles of gas[cite: 98, 99].
  iv. These bubbles rise to the surface and escape. [cite_start]The substance is now a gas[cite: 96].
  - **Input**: Heat energy. **Output**: Gas (vapour). **Condition**: Must reach boiling point temperature.

Diffusion

- **Equation for the reaction of ammonia and hydrogen chloride:**

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

(Ammonia gas + Hydrogen chloride gas → Ammonium chloride solid) [cite_start](p. 7) [cite: 247]

7) Formulae and calculations

Not covered in this chapter.

8) Required practicals / experiments

[cite_start]Experiment 1: Obtaining a Cooling Curve for Stearic Acid (p. 5) [cite: 141]

- **Aim**: To plot a cooling curve for stearic acid and determine its freezing point.
- [cite_start]**Apparatus**: Boiling tube, stearic acid, thermometer, beaker, warm water (above 80°C), clamp stand (p. 5)[cite: 144, 145, 146, 147, 148, 149].
- **Method**:
    i. [cite_start]Melt solid stearic acid in a boiling tube by placing it in a beaker of hot water (heated to ~80°C)[cite: 142].
    ii. [cite_start]Remove the boiling tube from the hot water[cite: 150].
    iii. [cite_start]Place a thermometer into the molten stearic acid and record the initial temperature (at time = 0)[cite: 143].
    iv. [cite_start]Record the temperature every minute for 12 minutes, stirring gently with the thermometer while the acid is still liquid[cite: 143, 151].
    v. Plot a graph of Temperature (°C) against Time (minutes).
- **Variables**:
    - **Independent Variable (IV)**: Time (minutes).
    - **Dependent Variable (DV)**: Temperature of stearic acid (°C).
    - **Control Variables**: Amount of stearic acid, room temperature, stirring method.
- **Safety**: Wear eye protection. [cite_start]Be careful when handling hot water[cite: 139, 140].
- **Expected Results**: The graph will show the temperature decreasing steadily, then a flat plateau where the temperature remains constant for several minutes, and finally the temperature decreasing again. [cite_start]The temperature of the flat plateau is the freezing point (and also the melting point) of stearic acid, which is 69°C according to the data provided (p. 5)[cite: 164, 165, 166, 167, 168, 169].

Experiment 2: Diffusion of Gases (p. 7)

- **Aim**: To demonstrate that gases diffuse, and that their rate of diffusion depends on their molecular mass.
- [cite_start]**Apparatus**: Long glass tube with stoppers, two pieces of cotton or mineral wool, concentrated ammonia solution, concentrated hydrochloric acid (p. 7)[cite: 243, 246]. (This is a teacher demonstration performed in a fume cupboard) [cite_start][cite: 253].
- **Method**:
    i. Place the dry glass tube horizontally.
    ii. Simultaneously, place one piece of cotton wool soaked in concentrated ammonia solution at one end and another piece soaked in concentrated hydrochloric acid at the other end.
    iii. Stopper both ends of the tube.
    iv. [cite_start]Observe where a white ring of solid ammonium chloride forms in the tube[cite: 249, 250].
- **Variables**:
    - **IV**: Type of gas (ammonia vs. hydrogen chloride).
    - **DV**: Distance travelled by the gas before reacting (position of the white ring).
    - **Control Variables**: Temperature, pressure (atmospheric), length of the tube.
- **Expected Results**: A white ring of ammonium chloride forms inside the tube. [cite_start]This ring forms closer to the end with hydrochloric acid because the ammonia particles are lighter (lower molecular mass) and diffuse faster than the heavier hydrogen chloride particles[cite: 251, 252].

9) Data handling and graphing

- [cite_start]**Heating and Cooling Curves**: These graphs plot **temperature (y-axis)** against **time (x-axis)** as a substance is heated or cooled at a constant rate (p. 4)[cite: 108, 132].
- **Trends to look for**:
    - **Sloping sections**: The temperature of the substance is changing, but it remains in a single state (solid, liquid, or gas).
    - **Horizontal plateaus**: The temperature remains constant even though heat is being added or removed. [cite_start]This indicates a **change of state** is occurring (melting/freezing or boiling/condensing) (p. 4)[cite: 110]. [cite_start]The energy is being used to overcome (or form) forces between particles, not to increase their kinetic energy[cite: 181].
- **Anomalies**: In a school lab setting, the plateaus may not be perfectly flat due to uneven heating/cooling or heat loss to the surroundings.

- **Typical Exam Prompts**: "From the graph, determine the melting point of the substance." (Answer: The temperature of the first plateau). "Explain what is happening to the particles in section B of the graph." (Answer: The solid is melting; particles are gaining energy to overcome forces and break out of the fixed lattice).

10) Common misconceptions and exam tips

- **Misconception**: Particles themselves expand or melt when heated.
  - **Correct understanding**: The particles themselves do not change. When heated, they gain kinetic energy and vibrate more (in solids) or move faster (in liquids/gases). [cite_start]The expansion is due to the average distance *between* the particles increasing (p. 4)[cite: 87].
  - **Quick tip**: Think of people in a crowd. If they start jumping around more, the whole crowd takes up more space, but the individual people don't get bigger.
- **Misconception**: Boiling and evaporation are the same process.
  - [cite_start]**Correct understanding**: **Evaporation** can happen at any temperature and only occurs at the surface of the liquid (p. 4)[cite: 97, 124]. [cite_start]**Boiling** happens at a specific temperature (the boiling point) and occurs throughout the entire liquid, forming bubbles (p. 4)[cite: 98, 99].
  - **Quick tip**: A puddle evaporates on a cool day. A kettle boils at 100°C.
- **Misconception**: When a substance melts or boils, the temperature keeps rising.
  - [cite_start]**Correct understanding**: During a change of state for a pure substance, the temperature remains constant until the change is complete (p. 4)[cite: 91, 105]. This is shown by the flat plateaus on heating/cooling curves.
  - **Quick tip**: Remember: "Flat line means changing state."
- **Exam Tip**: Remember that lighter gas particles diffuse faster. An exam question might give you the relative molecular masses (Mr) of two gases and ask which diffuses quicker. [cite_start]Pick the one with the smaller Mr value (p. 7)[cite: 251].

11) Exam-style practice

Multiple-choice questions (MCQs)

1. Which statement correctly describes the particles in a gas?
   A. They are packed tightly in a regular pattern.
   B. They vibrate about fixed positions.

C. They move randomly and are far apart.

D. They slide past one another.

[cite_start]**Answer**: C. Gas particles are far apart and move randomly (p. 3)[cite: 64, 65].

2. What is the process called when a solid turns directly into a liquid?

   A. Boiling

   B. Condensing

   C. Melting

   D. Freezing

   [cite_start]**Answer**: C. Melting is the change from solid to liquid (p. 4)[cite: 90].

3. The kinetic particle theory states that as temperature increases, particles...

   A. get smaller.

   B. move more slowly.

   C. move faster on average.

   D. stick together.

   [cite_start]**Answer**: C. Higher temperature means higher average kinetic energy, so particles move faster (p. 2)[cite: 34].

4. A heating curve for a pure substance shows a horizontal plateau. What is happening during this time?

   A. The substance is cooling down.

   B. The substance is changing state.

   C. The temperature is rising rapidly.

   D. No energy is being supplied.

   [cite_start]**Answer**: B. Temperature remains constant during a change of state (p. 4)[cite: 105].

5. Which gas will diffuse the fastest at the same temperature?

   A. Methane (Mr = 16)

   B. Oxygen (Mr = 32)

   C. Carbon dioxide (Mr = 44)

   D. Sulfur dioxide (Mr = 64)

   [cite_start]**Answer**: A. The gas with the lowest relative molecular mass diffuses fastest (p. 2, 7)[cite: 35, 251].

6. The term for the slight increase in volume of a solid when heated is...

   A. Diffusion

   B. Contraction

   C. Condensation

   D. Expansion

   [cite_start]**Answer**: D. Solids usually increase slightly in size when heated, which is called expansion (p. 2)[cite: 23].

7. Impurities added to water will cause its freezing point to...
   A. increase.
   B. decrease and occur over a range.
   C. stay exactly at 0°C.
   D. become the boiling point.
   [cite_start]**Answer**: B. Impurities lower the melting/freezing point (p. 5)[cite: 185].
8. Which state(s) of matter can be easily compressed?
   A. Solids only
   B. Liquids only
   C. Gases only
   D. Liquids and gases
   [cite_start]**Answer**: C. Gases are much more compressible than liquids or solids (p. 2)[cite: 29, 30].
9. In the diffusion experiment with ammonia and HCl, a white ring of ammonium chloride forms. This shows that...
   A. Both substances are solids.
   B. Particles in gases are stationary.
   C. The two gases have reacted.
   D. Diffusion only happens in liquids.
   [cite_start]**Answer**: C. The white cloud is a product of the reaction between the two diffused gases (p. 7)[cite: 250].
10. What is a key feature of a physical change?
    A. A new substance is always formed.
    B. It is always irreversible.
    C. The change is easily reversed and no new substance is formed.
    D. It only happens to gases.
    [cite_start]**Answer**: C. During a physical change, like melting or boiling, no new substance is formed (p. 4)[cite: 106].

Short-answer questions

1. **Explain**, using the kinetic particle theory, why a solid expands when it is heated.
   - When a solid is heated, its particles gain kinetic energy [1]. This causes them to vibrate more vigorously about their fixed positions [1]. [cite_start]The increased vibration makes them push their neighbouring particles further away, causing the entire solid to expand in volume [1] (p. 4)[cite: 86, 87].
2. A jar of coffee is opened on one side of a room. **Explain** how people on the other side of the room can smell it.

    - [cite_start]This happens due to a process called diffusion [1] (p. 7)[cite: 238]. Gas particles from the coffee spread out from the jar, moving randomly and mixing with the air particles [1]. The particles eventually travel across the room and reach people's noses [1].
3. Why is diffusion much slower in liquids than in gases?
    - [cite_start]In a liquid, the particles are much closer together than in a gas [1] (p. 3)[cite: 61, 64]. [cite_start]This means there is less free space for particles to move into, and they collide more often, slowing down their overall movement [1] (p. 8)[cite: 258].
4. A student plots a cooling curve for a substance. The graph has a flat section at 80°C. What two conclusions can be drawn?
    - The freezing point (or melting point) of the substance is 80°C [1]. [cite_start]The substance is pure, because it freezes at a sharp, constant temperature [1] (p. 5)[cite: 184].
5. When a bicycle tyre is pumped up quickly, the pump gets hot. **Explain** why.
    - [cite_start]As the pump is used, the air inside is put under increased pressure [1] (p. 6)[cite: 217]. [cite_start]This forces the gas particles closer together, causing them to collide more frequently, which increases the temperature [1] (p. 6)[cite: 218].

Structured questions

1. The diagram shows apparatus used to investigate the rate of diffusion of ammonia gas and hydrogen chloride gas.
   a. **State** what is observed in the glass tube after a few minutes. (1 mark)
   b. **Explain** why the observation does not appear in the exact centre of the tube. (2 marks)
   c. **Explain** what would happen to the time taken for the observation to appear if the experiment was carried out at a lower temperature. (2 marks)
   Marking Points:
   a. [cite_start]A white ring / cloud / solid is formed in the tube [1] (p. 7)[cite: 249].
   b. The white ring forms closer to the hydrochloric acid end [1]. [cite_start]This is because ammonia particles are lighter / have a lower molecular mass than hydrogen chloride particles, so they diffuse faster [1] (p. 7)[cite: 251, 252].
   c. It would take more time for the ring to form [1]. [cite_start]At a lower temperature, all particles have less kinetic energy and move more slowly, so diffusion is slower [1] (p. 2)[cite: 34].
2. The graph shows the heating curve for water, starting from ice at -15°C.
   a. **Identify** the melting point and boiling point of water from the graph. (2 marks)
   b. **Describe** the arrangement and movement of particles in the section where the substance is all liquid. (2 marks)
   c. **Explain**, in terms of energy and forces, what is happening during the second plateau. (2 marks)

Marking Points:

a. Melting point = 0°C [1]. [cite_start]Boiling point = 100°C [1] (p. 4)[cite: 111, 203].
b. The particles are close together but randomly arranged [1]. [cite_start]They are able to move around and slide past one another [1] (p. 3)[cite: 61, 73].
c. The substance is boiling (liquid turning to gas) [1]. [cite_start]The heat energy being supplied is used to overcome the forces of attraction between the particles, rather than increasing their kinetic energy, so the temperature remains constant [1] (p. 4)[cite: 181].

12) Quick revision checklist

- [ ] I can state the three states of matter and describe the particle arrangement in each.
- [ ] I can explain the properties of solids, liquids, and gases using the kinetic particle theory.
- [ ] I know the names for all changes of state (melting, freezing, boiling, condensing, evaporation).
- [ ] I can draw and label a heating curve for a pure substance.
- [ ] I can explain why temperature stays constant during a change of state.
- [ ] I understand that a pure substance has a sharp melting point, but an impure one melts over a range.
- [ ] I can describe the effect of changing temperature and pressure on the volume of a gas.
- [ ] I can define diffusion and explain it using the kinetic particle theory.
- [ ] I can explain why lighter gases diffuse faster than heavier gases.

13) Flashcards (ready-to-use)

Question	Answer
Q1: What are the three states of matter?	[cite_start]**A1:** Solid, liquid, and gas (p. 1)[cite: 14].
Q2: How are particles arranged in a solid?	[cite_start]**A2:** In a regular, tightly packed lattice (p. 3)[cite: 71].
Q3: How do particles move in a liquid?	[cite_start]**A3:** They slide past one another randomly (p. 3)[cite: 73].
Q4: What are the key properties of a gas?	[cite_start]**A4:** No fixed shape or volume; easily compressed (p. 2)[cite: 26, 29].

Question	Answer
Q5: What is the kinetic particle theory?	[cite_start]**A5:** The idea that all matter is made of tiny, constantly moving particles (p. 2)[cite: 48].
Q6: What happens to particle motion as temperature increases?	[cite_start]**A6:** Particles move faster on average (p. 2)[cite: 34].
Q7: What is melting?	[cite_start]**A7:** The change of state from solid to liquid at the melting point (p. 4)[cite: 90].
Q8: What is boiling?	[cite_start]**A8:** The change of state from liquid to gas at the boiling point, occurring throughout the liquid (p. 4)[cite: 99].
Q9: What happens to temperature during a change of state?	[cite_start]**A9:** It remains constant (p. 4)[cite: 105].
Q10: What does a horizontal plateau on a heating curve represent?	[cite_start]**A10:** A change of state (e.g., melting or boiling) (p. 4)[cite: 110].
Q11: How do impurities affect a substance's melting point?	[cite_start]**A11:** They lower the melting point and cause it to melt over a range of temperatures (p. 5)[cite: 185, 188].
Q12: What is diffusion?	[cite_start]**A12:** The random spreading out of particles to fill an available space (p. 7)[cite: 238].
Q13: Why is diffusion faster in gases than in liquids?	[cite_start]**A13:** Gas particles move faster and are further apart (p. 8)[cite: 257, 258].
Q14: Which diffuses faster: ammonia (NH_3) or hydrogen chloride (HCl)? Why?	[cite_start]**A14:** Ammonia, because its particles are lighter (have a smaller relative molecular mass) (p. 7)[cite: 251, 252].
Q15: Why does heating a balloon make it expand?	[cite_start]**A15:** The air particles inside gain energy, move faster, and hit the balloon walls more often and harder, increasing the pressure and volume (p. 6)[cite: 200, 212].

14) 60-second recap

This chapter covers the three states of matter: solids have a fixed shape and volume with particles vibrating in a lattice; liquids have a fixed volume but take the container's shape, with particles sliding past each other; and gases have no fixed shape or volume, with particles moving randomly and far apart. The kinetic particle theory explains these properties, stating that all matter consists of moving particles whose speed increases with temperature. Changes of state, like melting and boiling, occur at constant temperatures, which can be seen as plateaus on heating curves. Pure substances have sharp melting points. Finally, diffusion is the random spreading of particles, which is faster in gases than liquids, and faster for lighter gas particles.

15) References to pages

- **States of matter (introduction)** → pages 1, 2
- **Properties of solids, liquids, gases** → pages 2, 3
- **Kinetic particle theory** → pages 2, 3
- **Crystals** → pages 2, 3
- **Changes of state** → page 4
- **Melting and boiling points** → page 4
- **Heating and cooling curves** → pages 4, 5
- **Purity and melting points** → page 5
- **Effect of temperature/pressure on gases** → page 6
- **Diffusion** → pages 7, 8
- **Diffusion of ammonia and HCl** → page 7

16) Excluded "Going further" sections (not summarized)

Not covered in this chapter. Total excluded: 0.