3.2 Changes of state and internal energy

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS internal energy • physical changes • sublimates • Fusion • Vaporisation

Objective

State that mass is conserved in changes of state, that they are physical changes, and define and use internal energy to explain what heating does. Original questions for spec statements 4.3.1.2–4.3.2.1.

1 Key knowledge and worked examples

The six changes of state:

Change	Direction	Example
melting	solid → liquid	ice in a drink
freezing	liquid → solid	water in a freezer
boiling	liquid → gas, throughout	a rolling kettle
evaporating	liquid → gas, at the surface	a puddle drying
condensing	gas → liquid	mist on a mirror
sublimating	solid → gas directly	a block of dry ice becoming carbon dioxide gas

Two principles to apply to changes of state:

1. **Mass is conserved** – the particles are the same particles; only their arrangement changes.
2. Changes of state are **physical changes**: reverse the change and the material recovers its original properties. No new substance forms.

Internal energy = the **total kinetic energy and potential energy of all the particles** in the system.

Heating increases the particles' energy, and that energy takes one of two routes:

Route	What grows	What you see
temperature rises	particles' kinetic energy	thermometer climbs
state changes	particles' potential energy (bonds loosen)	temperature constant

The reverse happens on cooling: a liquid releasing energy may cool down, or freeze at constant temperature while potential energy falls.

Worked example (explanation). Explain why the temperature of melting ice stays at 0 °C even though the ice is being heated.

- Known route: a change of state is happening, so this is the potential-energy route.
- The energy supplied increases the particles' potential energy as the solid's structure breaks down.
- The particles' average kinetic energy does not change, and temperature is related to that average kinetic energy.
- Only when all the ice has melted does further energy raise the temperature again.

2 Practice

2.1 Name the change of state: (a) dew forming on grass at dawn; (b) wet clothes drying on a line; (c) a puddle becoming ice overnight. [3]

2.2 Water boils in a closed container from which no material escapes. State what happens to the total mass and to the arrangement of particles. [2]

2.3 Define internal energy. [2]

3 Exam-style questions

3.1 A sealed can of ice is warmed until it becomes water, then steam. Nothing enters or leaves the can.

(a) State what happens to the total mass of the contents, with a reason. [2]

(b) Explain what happens to the internal energy of the contents while the ice melts. [2]

(c) A student says "melting is a chemical change because the ice changes." Correct the student. [2]

3.2 Ethanol evaporates from an open dish. After a week the dish is empty.

(a) Explain, using the particle model, where the ethanol went. [3]

(b) State whether the ethanol's mass has been destroyed, and justify your answer. [2]

3.3 The table shows a substance's temperature as it cools.

Time in minutes	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Temperature in °C	88	76	60	60	60	48	35

(a) State what is happening between 2 and 4 minutes. [2]

(b) Explain why the temperature is constant there even though energy is leaving. [2]

(c) State the substance's freezing point. [1]

(d) At which stage is the particles' average kinetic energy falling fastest? Justify your choice. [2]

Solutions

2.1 (a) condensing. (b) evaporating. (c) freezing.

2.2 The mass stays the same – no particles are lost, boiling only changes their arrangement from close together to far apart; the particles spread out to fill the container as a gas.

2.3 Internal energy is the total kinetic energy and potential energy of all the particles (atoms and molecules) that make up the system.

3.1 (a) The total mass is unchanged: the sealed can keeps all particles in – a change of state conserves mass. (b) The internal energy increases: the supplied energy raises the particles' potential energy as the solid structure breaks down, while their average kinetic energy – and so the temperature – stays constant. (c) Melting is a physical change: if the water is refrozen it recovers the original properties of ice; no new substance is formed.

3.2 (a) The surface particles with the greatest energy escape the liquid's attraction; they become gas particles moving randomly with large gaps between them; the gas spreads through the air in the room, so the dish empties. (b) It has not been destroyed: the particles still exist as a gas mixed with the air – mass is conserved, only the state changed.

3.3 (a) The substance is freezing / changing from liquid to solid at constant temperature. (b) Energy is being transferred away, but it comes from the particles' potential energy as bonds form; the average kinetic energy – and hence the temperature – is unchanged until all the liquid has solidified. (c) 60 °C. (d) Between 1 and 2 minutes: the temperature falls fastest there (16 °C per minute, the steepest drop in the table), and temperature is related to the particles' average kinetic energy.