Kinetic Theory and States of Matter

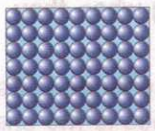
According to kinetic theory, everything's made of tiny little balls. The table, this book, your Gran...

Kinetic Theory is a Way of Explaining Matter

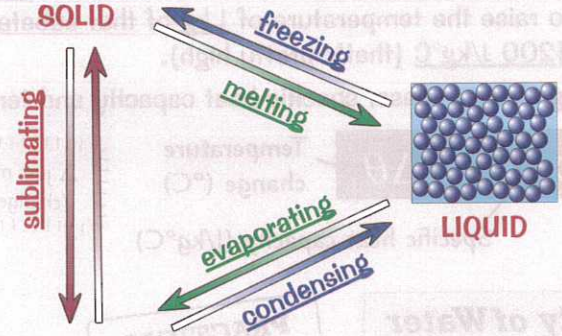
1) In kinetic theory, you can think of the particles that make up matter as tiny balls. You can explain the ways that matter behaves in terms of how these tiny balls move, and the forces between them.

2) Three states of matter are solid (e.g. ice), liquid (e.g. water) and gas (e.g. water vapour). The particles of a substance in each state are the same — only the arrangement and energy of the particles are different. If you reverse a change of state, the particles go back to how they were before.

3) So changes of state are physical changes (only the form of a substance changes). These are different from chemical reactions, where new substances are created by the reaction.



Strong forces of attraction hold the particles close together in a fixed, regular arrangement. The particles don't have much energy in their kinetic energy stores so they can only vibrate about their fixed positions.



The forces of attraction between the particles are weaker. The particles are close together, but can move past each other and form irregular arrangements. They have more energy in their kinetic energy stores than the particles in a solid — they move in random directions at low speeds.

There are almost no forces of attraction between the particles. Particles have more energy in their kinetic energy stores than those in liquids and are free to move — they travel in random directions at high speeds.

When a change of state occurs, the spacing between particles changes, so the internal energy (see next page) of the substance also changes. As the particles get closer together, their internal energy decreases.

4) The energy in a substance's thermal energy store is held by its particles in their kinetic energy stores — this is what the thermal energy store actually is.

5) When you heat a liquid, the extra energy is transferred into the particles' kinetic energy stores, making them move faster. Eventually, when enough of the particles have enough energy to overcome their attraction to each other, big bubbles of gas form in the liquid — this is boiling.

6) It's similar when you heat a solid. The extra energy makes the particles vibrate faster until eventually the forces between them are partly overcome and the particles start to move around — this is melting.

Density of a Substance Varies with State but Mass Doesn't

1) Provided you're working with a closed system (i.e. no particles can escape, and no new particles can get in) the mass of a substance isn't affected when it changes state. This makes sense — the mass of a substance is the mass of its particles, and the particles aren't changing, they're just being rearranged.

2) However, when a substance changes state its volume does change. The particles in most substances are closer together when they're a solid than a liquid (ice and water are an exception), and are closer together when they're a liquid than a gas (see the diagrams above).

3) Since density = mass ÷ volume (p.200), then density must change too. Generally, substances are most dense when they're solids and least dense when they're gases.

Physics — it's really about state of mind...

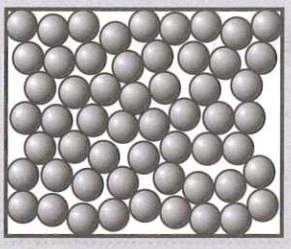
Remember, the mass of a substance just comes from the particles, not the spaces between them. So as something expands or contracts, its volume changes but its mass stays the same.

Q1 Explain how the density of a typical substance changes as it changes from solid to liquid to gas. [3 marks]

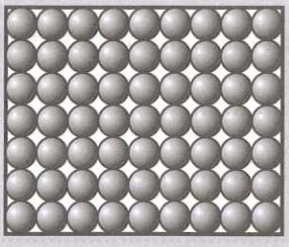
Kinetic Theory and States of Matter

Warm-Up

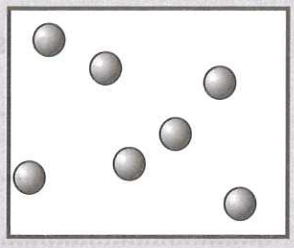
The images below show the particles in a substance when it is in three different states of matter. Label each image to show whether the substance is a solid, a liquid or a gas.



.....



.....



.....

1 Draw a line to match the change of state on the left to its description on the right.

Grade 4-6

condensation	gas to liquid
sublimation	liquid to gas
evaporation	solid to gas

[Total 1 mark]

2 The density of different states of matter varies.

Grade 4-6

a) Which of the following statements is true about the different states of matter?

- ☐ **A** A liquid is usually less dense than a gas.
- ☐ **B** A liquid is usually more dense than a solid.
- ☐ **C** A solid is usually more dense than a gas.
- ☐ **D** A solid is usually less dense than a gas.

[1]

b) A student notices that ice cubes float when he puts them into a glass of water. This is because ice is less dense than liquid water. Explain what this suggests about the arrangement of the water molecules in each state.

.....

.....

.....

.....

[2]

[Total 3 marks]

3 A student leaves a sealed glass flask with 200 ml of purified water in it on a windowsill on a hot day. He checks the flask every hour and observes that the volume of liquid water decreases throughout the day.

Grade 4–6

a) Suggest why the volume of liquid water has decreased during the day.

.....

[1]

b) Explain what happens to the total mass of the bottle and its contents during the day.

.....

.....

.....

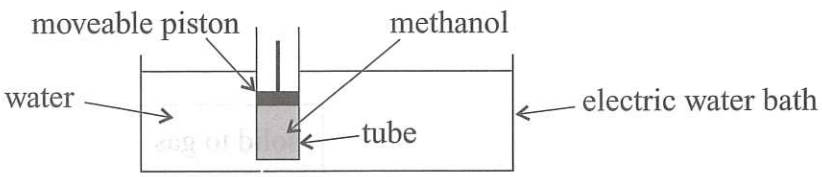
[2]

[Total 3 marks]

4 A student does an experiment to investigate methanol as it changes state. **Figure 1** shows their equipment. When the water bath is turned on, the water inside it begins to heat up.

Grade 6–7

Figure 1



As the water is heated, the piston begins to move upwards. After a short time, the tube containing the methanol begins to fill with gas. Explain this behaviour in terms of the energy transfers and the particles that make up the methanol.

.....

.....

.....

.....

.....

.....

.....

.....

[Total 5 marks]

Exam Practice Tip

Remember that all changes of state are physical changes, not chemical changes. Chemical changes result in a new substance being created. During a change of state, the particles in a substance move and either get closer together or further apart. The particles themselves don't change, so a change of state has to be a physical change.