C1a The particulate nature of matter

Introduction

This topic may go back over ideas that students have already met, so it does not need to take up much teaching time. Nevertheless, it is important for your students to understand the kinetic particle theory and the concept of diffusion. The kinetic particle theory links to work on a simple collision theory in Topic 2c *Rate of reaction* and to an explanation of fractional distillation in Topic 4a *Fuels*.

Links to other topics

Sections	Essential background knowledge	Useful links
1 Principles of chemistry		1c Atomic structure and the Periodic Table
2 Physical chemistry		2c Rate of reaction
4 Organic chemistry		4a Fuels

Topic overview

C1a.1	**Orientation** The purpose of this activity is to recap students' current knowledge and understanding of the three states of matter and the names of the processes involved when substances change states.
C1a.2	**The kinetic particle theory** This activity introduces the particulate models of solids, liquids and gases. The focus is on the different arrangements and movements of the particles in the three states. The names of the processes that bring about a change in state are emphasised and it relates these changes to the energy involved. Extended An explanation of the changes of state using the kinetic theory is then considered.
C1a.3	**Diffusion** This activity involves a series of simple diffusion experiments that involve dissolving crystals and mixing gases. Some of the experiments can be demonstrated and some are undertaken by the students themselves. Evidence for the kinetic model of matter is provided through reference to Brownian motion. Extended A more detailed study of Brownian motion is undertaken through observations in an illuminated smoke cell. Extended The Developing Investigative Skills feature in the Student Book (the diffusion of ammonia and hydrogen chloride in a sealed tube) is used to describe the dependency of rate of diffusion on molecular mass.
C1a.4	**Consolidation and summary** This activity allows for a quick recap of the key ideas of the topic and provides a link to subsequent work on atoms, elements and compounds.

Activity C1a.1 Orientation

Learning objectives

- To classify substances as solid, liquid or gas.
- To be familiar with the properties of typical solids, liquids and gases.
- To know that all substances are made up of particles.

Learning outcomes

- Be able to use the symbols (s), (l) and (g) to describe the three states of matter.
- Be able to state the distinguishing properties of solids, liquids and gases.

Resources

Student Book pages 10–11

Files on CD-ROM: C1a.1a_tech_notes

Resources for demonstration (see Technician's notes, below)

Approach

Students should be familiar with classifying solids, liquids and gases. They may also know the names of the processes that cause changes of state. So this activity can be relatively short.

Ask students to list four solids, four liquids and four gases they are familiar with. Emphasise that substances with the same classification can have quite different properties. For example: a candle and a metal rod (hardness), water and liquid honey (viscosity), air and bromine gas (colour). Use page 11 of the Student Book to summarise the different properties of solids, liquids and gases. Explain that these distinguishing properties are generally true, but that students need to be careful. For example, sand is obviously a solid, but it takes the shape of any container it is put in.

Finally, ask students to name some of the processes involved in changing states, such as melting, boiling (evaporation) and freezing.

SAFETY INFORMATION
Wear eye protection.
Wear chemical resistant gloves.
Keep bromine in fume cupboard.

Technician's notes

Be sure to check the latest safety notes on these resources before proceeding.

The following resources are needed for the demonstration on solids, liquids and gases:

a candle, a metal rod (similar diameter to a candle), a jar of liquid honey
a gas jar of bromine gas (in fume cupboard), eye protection, chemical resistant gloves

Answers

Page 11

1. (l).

2. Only the solid state has a fixed shape.

3. Fine sand will pour or flow like a liquid; it takes the shape of the container it is poured into (although under a microscope you would see gaps at the sides of the container).

Activity C1a.2 The kinetic particle theory

Learning objective

- To introduce the kinetic particle theory.

Learning outcomes

- Be able to describe the structure of solids, liquids and gases in terms of particle separation, arrangement and types of motion.
- Be able to describe the changes of state in terms of melting, boiling, evaporation, freezing, condensation and sublimation.
- Be able to describe qualitatively the pressure and temperature of a gas in terms of the motion of its particles.
- **Extended** Be able to explain changes of state in terms of the kinetic theory.

Common misconceptions

The particles in a liquid are not touching, that is, some students think that the arrangement of particles in a liquid is closer to that of a gas than to that of a solid.

Resources

Student Book pages 11–14

Worksheet C1a.2a The particulate nature of matter

Files on CD-ROM: C1a.2a_worksheet

Approach

Refer to the particle arrangements in solids, liquids and gases. Emphasise the arrangements and movements of the particles in each model.

Ask students to speculate on the strength of the forces between the particles in the three models. Then ask them to use their ideas to explain why gases expand on heating more than solids and liquids. Refer to the changes in the arrangement of particles as a solid changes into a liquid and then into a gas.

Emphasise the names of the key processes: melting/freezing, evaporating/boiling/condensation. Ensure that students understand the different types of movement of the particles. They should also understand the average energy of the particles in each of the three states of matter – solid (vibration – relatively low energy), liquid (moving around – translation – more energy than in a solid hence the possibility of evaporation) and gas (rapid movement – translation – relatively high energy). Ask the students to use the kinetic model to predict the relationship between pressure and volume, and temperature and pressure, of a gas.

Extended Use the flowchart on page 12 of the Student Book to emphasise the nature of the changes in particles as one state changes into another.

Finally, use Worksheet C1a.2a to check that students understand the key differences between the three states. (Note: this worksheet can also be used in Topic 2c *Rate of reaction* as part of the orientation activity.)

Answers

Page 15

1. The particles in a solid state vibrate.
2. Water particles are held together more strongly in solid water.
3. Evaporation is the process in which faster-moving particles escape from the surface of the liquid.
4. A solid changes to a liquid at its melting point.

Worksheet C1a.2a

1. False; 2. True; 3. True; 4. True; 5. True; 6. True; 7. True;

8. False; 9. True; 10. True; 11. False; 12. False.

Note: 11 – at the melting point, generally, the volume of solid and volume of liquid will be the same.

C1a.2a The particulate nature of matter

Cut out the cards and then sort them into piles of ‘True’, ‘False’ or ‘Not sure’.

1 In a solid the particles are not moving.	2 The particles in a gas are very far apart.	3 In a liquid the particles will be constantly bumping into each other.
4 The particles in a gas are moving at high speed.	5 The particles in a solid are held together by various types of forces.	6 Solid A has a higher melting point than solid B so the forces holding the particles together in A are stronger than those in B.
7 As a liquid is heated the particles move faster.	8 As a solid is heated the particles stay still.	9 The forces between gas particles are very small.
10 When a liquid evaporates particles escape from the surface of the liquid.	11 When a solid melts and forms a liquid the particles usually move further apart.	12 When gas particles mix together, this is known as dispersion.

Activity C1a.3 Diffusion

Learning objectives

- To observe, perform and discuss a range of diffusion experiments.

Learning outcomes

- Be able to show an understanding of the random motion of particles in a suspension (sometimes known as Brownian motion) as evidence for the kinetic particle (atoms, molecules or ions) model of matter.
- Be able to describe and explain diffusion.
- **Extended** Be able to describe and explain Brownian motion in terms of random molecular bombardment.
- **Extended** Be able to state evidence for Brownian motion.
- **Extended** Be able to describe the dependence of rate of diffusion on molecular mass.

Common misconceptions

Gas particles move relatively slowly because the diffusion of gases is relatively slow.

Resources

Student Book pages 15–18

Files on CD-ROM: C1a.3a_tech_notes

Resources for demonstration and class practical (see Technician's notes, below)

Approach

Arrange a mixture of student practical activities and demonstrations. For example:

Student practical activities – diffusion

1. Add a crystal of potassium manganate(VII) to still water in a Petri dish. Leave the Petri dish unmoved for at least 20 minutes. Compare observations with those on page 15 of the Student Book.

2. Mix carbon dioxide and air in test tubes and test with limewater (a safer alternative to the hydrogen and air equivalent – see Student Book page 16). You may have to introduce the test for carbon dioxide if students have not seen it before.

A simple carbon dioxide generator (marble chips and dilute hydrochloric acid) can be used to provide a source of the gas. One test tube is filled with carbon dioxide and then connected vertically to a test tube containing air. The tubes are held together for a few minutes and then each tube is tested with limewater to identify carbon dioxide.

The experiment can be performed twice: once with the carbon dioxide test tube on the bottom; once with the carbon dioxide test tube on the top. You should be able to observe diffusion in both cases, even though carbon dioxide is heavier than air.

SAFETY INFORMATION
Wear eye protection.

Introduce Brownian motion by reference to the movement of pollen grains in a suspension with water.

Extended Ideally let the students observe Brownian motion in a smoke cell. Ask the students to describe what they see and to suggest an explanation.

Extended **Demonstration: diffusion of hydrogen chloride and ammonia**

Hydrogen chloride and ammonia – see Student Book page 17. Pay attention to safety – this demonstration needs to be set up very carefully. The concentrated hydrochloric acid and concentrated ammonia solution must be in separate small beakers and kept a good distance apart (or kept in stoppered reagent bottles), in a fume cupboard. Soak one cotton wool ball in each solution and squeeze to remove excess liquid. Use tongs or tweezers to carefully place the cotton wool in the ends of the long tube. Replace the rubber bungs. While you are waiting you can demonstrate what happens when the two gases come into contact with each other. There is a microscale version of this demonstration available in the CLEAPSS guide L195.

Extended Students can then tackle the Developing Investigative Skills section on page 17 of the Student Book.

SAFETY INFORMATION
Wear eye protection.
Keep hydrogen chloride and ammonia solutions in separate beakers and a suitable distance apart, or in stoppered reagent bottles, in a fume cupboard. Avoid inhaling vapour and wear chemical resistant gloves. Use tongs or tweezers to handle cotton wool soaked with hydrogen chloride and ammonia solutions.

Technician's notes

Be sure to check the latest safety notes on these resources before proceeding.

The following resources are needed for the demonstration and class practical on diffusion, per group:

potassium manganate(VII) crystals and Petri dishes
carbon dioxide generator (marble chips and dilute hydrochloric acid), test tubes
limewater and droppers

The following resources are needed for the demonstration of Brownian motion in a smoke cell:

microscope and lamp, smoke cell, wax taper or candle and teat pipette

The following resources are needed for the demonstration of diffusion of hydrogen chloride and ammonia:

long glass tube, cotton wool balls, rubber bungs, stands and clamps (Student book page 17)
concentrated ammonia solution, beaker and tongs
concentrated hydrochloric acid solution, beaker and tongs

Answers

Developing Investigative Skills, page 17

1. Using tongs and with the students wearing eye protection and rubber gloves.
2. Avoiding breathing the fumes or use a fume cupboard.
3. The ammonia.
4. It travelled approximately twice as far as the hydrogen chloride.
5. The hydrogen chloride has approximately double the mass of the ammonia.

Page 18

1. Diffusion is the mixing and moving of particles in liquids and gases.

2. The particles in the potassium manganate(VII) dissolve in the water and diffuse throughout the solution.

3. The particles of perfume vapour/gas diffuse in the air and spread throughout the whole room.

4. All elements contain atoms.

5. a) A microscope was used to observe Brownian motion from the random motion of pollen grains on the surface of some water.

   b) The air particles are constantly colliding with the smoke particles.

Activity C1a.4 Consolidation and summary

Learning objectives

- To review the key learning points of the topic.
- To test understanding through answering questions.

Learning outcomes

- Be familiar with the knowledge and understanding summarised in the End of Topic Checklist.
- Be able to apply this knowledge and understanding by answering the End of Topic Questions.

Resources

Student Book pages 19–20

Approach

Refer students to the section on page 18 in the Student Book on *Elements, Atoms and Molecules*. Explain that for the rest of the course the term ‘particle’ will not be precise enough. Students will need to use terms like ‘atoms’ and ‘molecules’ (and ‘ions’) correctly to identify the type of particle. Emphasise that students will be learning more about these types of particles in the topics that follow.

This consolidation exercise can be done individually or in small groups. Give priority to listening to students’ ideas and explanations. Finally, use the Science in Context feature on *The States of Matter* (Student Book page 14) to discuss plasma as a potential fourth state of matter.

Answers

End of Topic Questions mark scheme

Question	Correct answer	Marks
1	Gas.	1 mark
2	The particles in a liquid are close together, often touching. The particles can move around and are not in a fixed position.	1 mark 1 mark
3	Solid.	1 mark
4	The forces between the particles (atoms) in aluminium are greater than those between the particles (atoms) in sodium.	1 mark
5 a)	Melting.	1 mark
5 b)	Evaporation or boiling.	1 mark
5 c)	Condensation.	1 mark
5 d)	Freezing or solidification.	1 mark
6	The boiling point.	1 mark
7	The particles in a liquid are constantly moving even at low temperatures in the polar regions. Water particles can break away from the surface (evaporate) and form water vapour.	1 mark 1 mark
8	The student's statement is correct. In both solids and liquids the particles are quite close together – in a gas the particles are much further apart. The speeds at which the the particles in solids and liquids are moving are more similar – in a gas the particles are moving at very high speeds.	1 mark 1 mark
9	Diffusion.	1 mark
10	There is no physical barrier between the particles of bromine and air. The particles in these gases are moving at high speed and colliding with each other. Over time the mixing will be complete and so there will be air and bromine particles in both gas jars.	1 mark 1 mark
11 a)	Specks of light in random motion.	1 mark
11 b)	Collisions between smoke particles and air particles.	1 mark
12	Nitrogen will diffuse at the greatest rate. Nitrogen has the lowest (relative) molecular mass.	1 mark 1 mark
	Total:	21 marks

