### Particle model of solids, liquids and gases

#### Where this unit fits in

**This unit builds on:**
- unit 4D Separating solids and liquids
- unit 5C Gases
- unit 5D Changing state
- unit 6C Dissolving

**The concepts in this unit are:**
- particles. Pupils are introduced to the concept of matter being made up of particles.

**This unit leads onto:**
- the particle model is applied in unit 7H Solutions
- unit 8I Heating and cooling
- unit 8A Food and digestion
- unit 8H The rock cycle
- unit 9L Pressure and moments

#### Prior learning

To make good progress, pupils starting this unit need to:
- recognise that matter exists as solids, liquids and gases
- know that solids melt to give liquids, that liquids boil to give gases, that gases condense to give liquids and that solids solidify/freeze to give solids
- know that some solids dissolve in water and can be recovered by evaporation

#### Framework yearly teaching objectives – Particles

Describe a simple particle model for matter, recognising:
- the size, arrangement, proximity, attractions and motion of particles in solids, liquids and gases
- the relationship between heating and movement of the particles.

Use the simple particle model to explain:
- why solids and liquids are much less compressible than gases
- why heating causes expansion in solids, liquids and gases
- why diffusion occurs in liquids and gases
- why air exerts a pressure
- why changes of state occur.

#### Expectations from the QCA Scheme of Work

At the end of this unit …

- **most pupils will** …
- **some pupils will not have made** …
- **some pupils will have progressed** …

**in terms of scientific enquiry** NC Programme of Study Sc1 1a, b, c

- describe and explain observations using the particle model.
- describe observations and try to offer explanations for them.
- compare explanations of a phenomenon and evaluate whether evidence supports or refutes them.

**in terms of materials and their properties** NC Programme of Study Sc3 1b

- classify materials as solid, liquid or gas
- explain their classification of some ‘difficult’ materials
- describe materials as being made of particles and describe the movement and arrangement of these
- begin to use the particle model to explain phenomena, e.g., the mixing of liquids, the expansion of a metal bar.
- classify materials as solid, liquid or gas and recognise that materials are made of particles.
- also use the particle model to explain a range of phenomena.

#### Suggested lesson allocation (see individual lesson planning guides)

<table>
<thead>
<tr>
<th>Direct route</th>
<th>G1 Developing theories</th>
<th>G2 Particle power</th>
<th>G3 Looking at evidence</th>
<th>G4 Spreading out</th>
<th>G5 Scientific models: Think about using models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra lessons (not included in pupil books)</td>
<td>G1 Developing theories</td>
<td>Extra lesson. Pupils need time to present their ideas.</td>
<td>G2 Particle power Extra lesson. Pupils need time to present their ideas.</td>
<td>G4 Spreading out</td>
<td>G5 Scientific models: Think about using models</td>
</tr>
</tbody>
</table>

#### Misconceptions

Pupils often think that the spaces that exist between particles in a solid, liquid or gas must be filled with air. Even though pupils can accept solids as being an ordered arrangement of particles they cannot suggest why it holds together. They also find it difficult to accept that the particles can actually vibrate within the solid. Pupils think liquids are just half way between solids and gases and so mentally and physically depict the liquid particles with spaces too big and give too much speed to the liquid particles, which is why they also commonly assume liquids can be compressed.

It is very important to work with the pupils’ prior ideas. They need to develop their prior ideas about matter until they know and understand the formal model of particles. Only then will they be able to use this model to predict and explain. Pupils should be given challenges to make them think and opportunities to express their thoughts in a safe environment where an evolving idea will be praised and all criticism is constructive.

#### Health and safety

(see activity notes to inform risk assessment)

Pupils handle a variety of substances in the course of this unit. Teachers need to inform their risk assessments using appropriate sources of information, e.g., Hazcards. Pupils should wear eye protection where necessary, wipe up all spills and wash their hands after handling chemicals.
Developing theories

Learning objectives

i. Scientists use evidence to develop theories.
ii. Scientists think about the evidence, then develop their ideas into a theory that can be tested.
iii. The particle model has been developed over time.

Scientific enquiry

iv. Pupils collect evidence and use it to develop a way of working. (Framework YTO Sc1 7a part)

Suggested alternative starter activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Learning objectives see above</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G1</td>
<td>i, ii, iii and iv</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
<td>R/G G R S</td>
</tr>
<tr>
<td>Activity G1a Practical</td>
<td>iv</td>
<td>How do different materials behave? Circus of four elicitation activities.</td>
<td>10 min per station</td>
<td>✓ (✓)</td>
</tr>
</tbody>
</table>

Suggested alternative main activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G1</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
<td>R/G G R S</td>
</tr>
<tr>
<td>Activity G1a Practical</td>
<td>How do different materials behave? Circus of four elicitation activities.</td>
<td>10 min per station</td>
<td>✓ (✓)</td>
</tr>
</tbody>
</table>

Suggested alternative plenary activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review learning</td>
<td>Pupils write a sentence to summarise a key idea from the lesson.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharing responses</td>
<td>Whole-class discussion of circus activities in Activity G1a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group feedback</td>
<td>In groups, pupils brainstorm what they have learnt about solids, liquids and gases.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word game</td>
<td>Question challenge.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking ahead</td>
<td>Pupils suggest what makes a piece of cloth count as a solid rather than a liquid.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Learning outcomes

Most pupils will ... | Some pupils, making less progress will ... | Some pupils, making more progress will ...

- know that scientists form theories by thinking about evidence and understand that a theory is only an idea, while the evidence is factual.
- know about the behaviour of solids, liquids and gases.

- know that scientists’ ideas are based on evidence
- know examples of solids, liquids and gases.

- also know that theories change as more evidence is collected
- be able to suggest explanations for the behaviour of solids, liquids and gases.

Key words

materials, molecules, particle, atom, theory

Out-of-lesson learning

Homework G1
Textbook G1 end-of-spread questions
Learning objectives
i The formal model of the structure of matter is about particles.
ii Description of the model.
iii Using the model to explain the properties of solids, liquids and gases.

Scientific enquiry
iv Experimental evidence and creative thinking combine to provide scientific explanations. (Framework YTO Sc1 7a)

### Suggested alternative starter activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Learning objectives</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G2</td>
<td>i and ii</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
<td>R/G</td>
</tr>
<tr>
<td>Activity G2a Discussion</td>
<td>i and ii</td>
<td>Particles in solids, liquids and gases Teacher describes the formal model and discusses the pupils’ own ideas, as appropriate. He/she should make specific points while referring to the OHT. Pupils then answer questions on the activity sheet.</td>
<td>15 min</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Activity G2b Practical</td>
<td>i, ii, iii and iv</td>
<td>Using the particle model Circus of activities. Pupils visit all, or a selection of, small activities and try to relate what they see to the particle model.</td>
<td>30 min</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Activity G2c Catalyst Interactive Presentations 1</td>
<td></td>
<td>Support animation for pupils who cannot identify common materials (e.g. water, wood, air) as solid, liquid or gas.</td>
<td>10 min</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Suggested alternative main activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G2 (i and ii)</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
<td>R/G</td>
</tr>
<tr>
<td>Activity G2a Discussion</td>
<td>Particles in solids, liquids and gases Teacher describes the formal model and discusses the pupils’ own ideas, as appropriate. He/she should make specific points while referring to the OHT. Pupils then answer questions on the activity sheet.</td>
<td>15 min</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Activity G2b Practical</td>
<td>Using the particle model Circus of activities. Pupils visit all, or a selection of, small activities and try to relate what they see to the particle model.</td>
<td>30 min</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Activity G2c Catalyst Interactive Presentations 1</td>
<td>Support animation for pupils who cannot identify common materials (e.g. water, wood, air) as solid, liquid or gas.</td>
<td>10 min</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Suggested alternative plenary activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>True and false statements summarising learning.</th>
<th>Group feedback</th>
<th>Word game</th>
<th>Looking ahead</th>
</tr>
</thead>
<tbody>
<tr>
<td>True and false statements summarising learning.</td>
<td>Whole-class discussion of responses and feedback on Activity G2a.</td>
<td>Groups of pupils discuss their results from circus Activity G2b.</td>
<td>Sort statements about key features of particle arrangements and behaviour in solids, liquids and gases.</td>
<td>Pupils suggest what happens to the particles in a solid when you heat it and the solid expands.</td>
</tr>
</tbody>
</table>

### Learning outcomes

<table>
<thead>
<tr>
<th>Most pupils will …</th>
<th>Some pupils, making less progress will …</th>
<th>Some pupils, making more progress will …</th>
</tr>
</thead>
<tbody>
<tr>
<td>be able to describe solids, liquids and gases using the formal model.</td>
<td>know that solids, liquids and gases are made up of particles.</td>
<td>also be able to use the model to explain their observations.</td>
</tr>
</tbody>
</table>

### Key words

- particle model
- dense
- density

### Out-of-lesson learning

- Homework G2
- Textbook G2 end-of-spread questions
Lesson planning guide

Looking at evidence

Learning objectives

i Explain observations in terms of particles.
ii Apply the particle model to expansion.

iii Explain observation using an accepted theory. (Framework YTO Sc1 7g)

Suggested alternative starter activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Learning objectives see above</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G3</td>
<td>i and ii</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
<td>R/G</td>
</tr>
<tr>
<td>Activity G3a Practical</td>
<td>i, ii and iii</td>
<td>Expansion in solids, liquids and gases A series of demonstrations. Pupils discuss what happens and explain using the particle model.</td>
<td>30 min</td>
<td>✓</td>
</tr>
<tr>
<td>Activity G3b Discussion</td>
<td>i and ii</td>
<td>Particles role play Pupils model particles in solids, liquids and gases.</td>
<td>20 min</td>
<td>✓</td>
</tr>
</tbody>
</table>

Suggested alternative main activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Learning objectives</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G3 i and ii</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
<td>R/G</td>
<td></td>
</tr>
<tr>
<td>Activity G3a Practical i, ii and iii</td>
<td>Expansion in solids, liquids and gases A series of demonstrations. Pupils discuss what happens and explain using the particle model.</td>
<td>30 min</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Activity G3b Discussion i and ii</td>
<td>Particles role play Pupils model particles in solids, liquids and gases.</td>
<td>20 min</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Suggested alternative plenary activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeze-frame role-play of particles.</td>
<td>Whole-class discussion of responses and feedback on Activity G3a.</td>
<td>20 min</td>
<td>R/G</td>
</tr>
<tr>
<td>Group feedback</td>
<td>Groups of pupils discuss the role play Activity G3b.</td>
<td>20 min</td>
<td>✓</td>
</tr>
<tr>
<td>Word game</td>
<td>Pupils match statement with particle explanation.</td>
<td>20 min</td>
<td>✓</td>
</tr>
<tr>
<td>Looking ahead</td>
<td>Pupils identify the advantages and disadvantages of expansion.</td>
<td>20 min</td>
<td>✓</td>
</tr>
</tbody>
</table>

Learning outcomes

Most pupils will …

• describe what happens when a material expands or changes state
• know that expanding, melting and evaporating require energy to be put into the material
• use the particle model in some of their explanations.

Some pupils, making less progress will …

• describe what happens when a material expands or changes state
• begin to use particles when explaining.

Some pupils, making more progress will …

• also relate the energy input to the movement of the particles
• be able to criticise their own and other explanations.

Key words:

- expands

Out-of-lesson learning

Homework G3
Textbook G3 end-of-spread questions

© Harcourt Education Ltd 2003 Catalyst 1
This worksheet may have been altered from the original on the CD-ROM.
### Learning objectives

- **i** Explain observations using the particle theory.
- **ii** Gas particles are moving at all times and pushing against surfaces.
- **iii** Diffusion occurs in liquids and gases.

### Scientific enquiry

- **iv** Use the particle theory to make predictions. (Framework YTO Sc1 7b)
- **v** Relate observations to scientific knowledge and understanding. (Framework YTO Sc1 7g)

### Suggested alternative starter activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Learning objective see above</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G4</td>
<td>i, ii and iii</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
<td>R/G, G, R, S</td>
</tr>
<tr>
<td>Activity G4a Practical</td>
<td>i, ii and iii</td>
<td><strong>Diffusion in gases</strong> Demo of bromine and air mixing. Introduction of word diffusion.</td>
<td>15 min</td>
<td>✓</td>
</tr>
<tr>
<td>Activity G4b Practical</td>
<td>iii</td>
<td><strong>Fresh air!</strong> Pupils carry out an experiment to see how quickly and how far gas particles from air freshener travel.</td>
<td>15 min</td>
<td>✓ (✓)</td>
</tr>
<tr>
<td>Activity G4c Practical</td>
<td>iii</td>
<td><strong>Diffusion in liquids</strong> Demo of copper sulphate solution diffusing through water in a gas jar.</td>
<td>5 min</td>
<td>✓</td>
</tr>
<tr>
<td>Activity G4d Practical</td>
<td>i, ii, iii, iv and v</td>
<td><strong>Diffusion: faster or slower</strong> Pupils use the particle model to make a prediction based on the mixing of potassium manganate(VII) and water.</td>
<td>20 min</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Activity G4e Practical</td>
<td>i, ii, iii, iv and v</td>
<td><strong>Empty bottle</strong> Demo of collapsing bottle/can experiment. Pupils make prediction of what will happen using the concept of particles. Pupils share ideas before demo is carried out.</td>
<td>15 min</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Suggested alternative main activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G4</td>
<td>i, ii and iii</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>20 min</td>
</tr>
<tr>
<td>Activity G4a Practical</td>
<td><strong>Diffusion in gases</strong> Demo of bromine and air mixing. Introduction of word diffusion.</td>
<td>15 min</td>
<td>✓</td>
</tr>
<tr>
<td>Activity G4b Practical</td>
<td><strong>Fresh air!</strong> Pupils carry out an experiment to see how quickly and how far gas particles from air freshener travel.</td>
<td>15 min</td>
<td>✓ (✓)</td>
</tr>
<tr>
<td>Activity G4c Practical</td>
<td><strong>Diffusion in liquids</strong> Demo of copper sulphate solution diffusing through water in a gas jar.</td>
<td>5 min</td>
<td>✓</td>
</tr>
<tr>
<td>Activity G4d Practical</td>
<td><strong>Diffusion: faster or slower</strong> Pupils use the particle model to make a prediction based on the mixing of potassium manganate(VII) and water.</td>
<td>20 min</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Activity G4e Practical</td>
<td><strong>Empty bottle</strong> Demo of collapsing bottle/can experiment. Pupils make prediction of what will happen using the concept of particles. Pupils share ideas before demo is carried out.</td>
<td>15 min</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Suggested alternative plenary activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils role-play diffusion.</td>
<td>Whole-class discussion of responses and feedback on Activity G4a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group feedback</td>
<td>Groups of pupils discuss their results from Activity G4e.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braintreeing</td>
<td>Check progress by playing 'guess what I am'.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking back</td>
<td>Pupils revise and consolidate knowledge from the unit.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Learning outcomes

- **Most pupils will**
  - know that diffusion is the mixing of gases and/or liquids without stirring and be able to describe what is happening using the concept of particles
  - be able to explain the collapse of a can when the air is pumped out, using the concept of particles.

- **Some pupils, making less progress will**
  - know that liquids and gases mix without being stirred
  - know that the particles in a liquid and a gas are always moving
  - know that the particles in a gas hit surfaces.

- **Some pupils, making more progress will**
  - also be able to describe and explain the relative speeds of diffusion in solids, liquids and gases using the particle model.

### Key words
- diffusion, gas pressure

### Out-of-lesson learning
- **Homework G4**
- **Textbook G4 end-of-spread questions**
- **Activity G4b**
Lesson planning
guide

Scientific models – Think about using models

Learning objectives
i Explain observations in unfamiliar contexts using the particle model.

The structure of this lesson is based around the CASE approach. The starter activities give concrete preparation. The main activities move away from the concrete towards a challenging situation, where pupils need to think. The extended plenary gives pupils time to discuss what they have learnt, to negotiate a method to commit to paper and express their ideas verbally to the rest of the class.

Scientific enquiry
ii Relate observations to scientific knowledge and understanding. (Framework YTO Sc1 7g)

Suggested alternative starter activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Learning objectives see above</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G5</td>
<td>i and ii</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>30 min</td>
<td>C/R/G</td>
</tr>
<tr>
<td>Activity G5a Discussion</td>
<td>i and ii</td>
<td>Using scientific models Pupils are given cards with everyday experiences on them. They prepare either OHTs or posters to explain what is happening in each scenario.</td>
<td>20 min</td>
<td>✓/✓/✓</td>
</tr>
</tbody>
</table>

Suggested main activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Learning objectives</th>
<th>Description</th>
<th>Approx. timing</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook G5</td>
<td>i and ii</td>
<td>Teacher-led explanation and questioning OR pupils work individually, in pairs or in small groups through the in-text questions and then onto the end-of-spread questions if time allows.</td>
<td>30 min</td>
<td>C/R/G</td>
</tr>
<tr>
<td>Activity G5a Discussion</td>
<td>i and ii</td>
<td>Pupils are given cards with everyday experiences on them. They prepare either OHTs or posters to explain what is happening in each scenario.</td>
<td>20 min</td>
<td>✓/✓/✓</td>
</tr>
</tbody>
</table>

Suggested alternative plenary activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Group feedback</th>
<th>Bridging to other topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils discuss their answers to the challenge cards in Activity G5a.</td>
<td>The particle model will be used again in a number of topics in the future.</td>
</tr>
</tbody>
</table>

Learning outcomes

<table>
<thead>
<tr>
<th>Most pupils will …</th>
<th>Some pupils, making less progress will …</th>
<th>Some pupils, making more progress will …</th>
</tr>
</thead>
<tbody>
<tr>
<td>• understand that scientists create models to explain their observations and other evidence.</td>
<td>• know that scientists use models</td>
<td>• also understand that a useful model can be used in unfamiliar contexts to explain new observations</td>
</tr>
<tr>
<td>• explain observations using the particle model in challenging and/or unfamiliar contexts.</td>
<td>• recognise familiar events (e.g. changes in state, expansion) in unfamiliar contexts and use their understanding of the particle theory in explanations.</td>
<td>• also be able to make predictions using the particle model in challenging/unfamiliar contexts.</td>
</tr>
</tbody>
</table>

Key words
model, red only: sublimation

Out-of-lesson learning
Textbook G5 end-of-spread questions

© Harcourt Education Ltd 2003 Catalyst 1
This worksheet may have been altered from the original on the CD-ROM.
Developing theories

Introduce the unit

- **Either** draw the outline of the unit map on the board then ask pupils to give you words to add, saying where to add them. Suggest some yourself when necessary to keep pupils on the right track.

- **Or** give out the unit map and ask pupils to work in groups deciding how to add the listed words to the diagram. Then go through it on the board as each group gives suggestions.

Share learning objectives

- Ask pupils to write a list of FAQs they would put on a website telling people about properties of solids, liquids and gases, and previous ideas about what matter is made up of. Collect suggestions as a whole-class activity, steering pupils towards those related to the objectives. Conclude by highlighting the questions you want them to be able to answer at the end of the lesson.

Problem solving

- Divide the class into groups of three or four. Give each group a pupil sheet. After a few minutes ask groups to report who they think was the murderer, and why.

- Emphasise ideas of evidence pointing to several conclusions, and which evidence is the most important.

Brainstorming

- Divide the class into three sets of small groups. Give each set of groups a question from the list opposite. Each group in turn reports back to the class. Write correct answers on the board.

Capture interest

- Show the class an inflated balloon. Ask ‘What’s inside it?’ Pop it with a pin and ask ‘Where did the air go?’

- Ask ‘What if the balloon were full of water instead?’ (If feeling brave, throw a water bomb out of the window!)

- Fill another balloon (in advance) with polyurethane foam. Show pupils some polyurethane foam and explain that this is what is in the balloon. Ask them to suggest what will happen when the balloon is popped, then pop it.

---

**Suggested alternative starter activities (5–10 minutes)**

<table>
<thead>
<tr>
<th>Introduce the unit</th>
<th>Share learning objectives</th>
<th>Problem solving</th>
<th>Brainstorming</th>
<th>Capture interest</th>
</tr>
</thead>
</table>
| Unit map for Particle model of solids, liquids and gases. | • Find out how the idea of atoms developed.  
• Find out how different materials behave. (Sc1) | Murder mystery to highlight the importance of looking at evidence. | Questions about solids, liquids and gases. | Popping balloons demonstration. |

---

**Questions**

- What are the properties of solids?
- What are the properties of liquids?
- What are the properties of gases?

**Equipment**

- balloons, mounted needle, balloon filled with polyurethane foam (from a DIY shop)
Particle model of solids, liquids and gases

Copy the unit map and use these words to help you complete it. You may add words of your own too.

- atoms
- contract
- dense
- density
- diffusion
- elements R
- expand
- far apart
- further apart
- gas
- gas pressure
- liquid
- matter R
- molecules
- movement
- particles
- pour
- shape
- solid
- sublimation R
- theory
- touching
- vibrate
- volume
Developing theories

Problem solving

Read the information about the Murder Mystery and decide who you think is the murderer. Make sure you know which piece of evidence backs up your conclusion.

Murder Mystery

William Brown is found stabbed to death in the Geography classroom. Police gather the following pieces of evidence.

1. Mars bar wrapper found near the body.
2. Red woollen fibres found on the body.
3. James White has bloodstains on his right sleeve.
4. Earlier in the day William had a heated argument with John Green. He accused John of stealing his pen.
5. Michael Black seen eating a Mars bar shortly before the body was found.
6. James White is wearing a red woollen jumper.
7. Sheath knife discovered in John Green’s bag.
8. Michael Black was seen going into the Geography room about half an hour before the body was discovered.

Look carefully at each piece of evidence. Decide which you think are important and which are not. Use the evidence to decide who is most likely to have killed William Brown.
Recap last lesson

- Show the pupil sheet on an OHT. Review briefly the properties of solids, liquids and gases then ask pupils to think of an explanation for these properties.

Share learning objectives

- Ask pupils to write a list of FAQs they would put on a website introducing the particle model. Collect suggestions as a whole-class activity, steering pupils towards those related to the objectives. Conclude by highlighting the questions you want them to be able to answer at the end of the lesson.

Problem solving

- Explain that models are simplified ‘pictures’ that help us understand why things work as they do. A model is not intended to be perfect in every way, but it can be useful. Sometimes we use different models of the same thing for different purposes. For example, the London Underground or ‘tube’ map is a model of London. It is strangely distorted and no good for finding the nearest station to your house, but it is very helpful when planning your journey by tube from A to B.

- Hand out the pupil sheet showing part of a street map and a tube map of central London. Allow a few minutes then discuss pupils’ answers, going over why they chose a particular map for a task.

Capture interest (1)

- Present to the class an inflated balloon and one which has been left to deflate. Ask ‘Where did the air inside go?’ and ‘How did it get out?’

Capture interest (2)

- Show pupils the space taken up by 10 g of water (i.e. 10 cm³) using a small measuring cylinder or small beaker.

- Ask pupils to suggest the space taken up by 10 g of water vapour or ‘water gas’ (this can be called steam – but you need to be careful to avoid confusion with the visible clouds).

- Show pupils five inflated balloons – their total combined volume is equal to that of the 10 g of water vapour. Explain that the water particles are much more spread out in the gas than in the liquid.
Recap last lesson

**Particle power**

**solids**
- have a fixed volume
- have a fixed shape
- do not compress

**liquids**
- have a fixed volume
- do not have a fixed shape
- do not compress

**gases**
- do not have a fixed volume
- do not have a fixed shape
- are easy to compress
Problem solving

Here is a street map of central London and a tube map of the same area.

● The street map shows the ‘real’ location of the streets and stations.
● The tube map shows the location of the underground train or ‘tube’ stations in relation to each other.

Here are some tasks to do. For each task, decide which model is best – the street map or the tube map.

Tasks
1. Which station is closest to the Tower of London?
2. How would you travel from Notting Hill Gate to Leicester Square?
3. How far is it along the river from the London Eye to the Tower of London?
4. Is Paddington further north than Blackfriars?
Looking at evidence

**Recap last lesson**
- Review how the particle model explains the properties of solids, liquids and gases in terms of the particle arrangement. You could use the pupil sheet for this. Collect ideas on the board.

**Share learning objectives**
- Ask pupils to write a list of FAQs they would put on a website telling people about evidence for the particle model. Collect suggestions as a whole-class activity, steering pupils towards those related to the objectives. Conclude by highlighting the questions you want them to be able to answer at the end of the lesson.

**Problem solving**
- Make a set of nine statement cards from the pupil sheet for each pair of pupils. Ask pairs to divide the cards into two groups: theories and evidence.
- Ask pupils, in turn, to say into which group they placed a card and why. Lead on to a class discussion on what is a theory and what is evidence.

**Capture interest (1)**
- Fill a small box with beads. Show pupils that the beads are regularly arranged. Explain that in a solid, the particles are fixed in position and can only vibrate.
- Shake the box. Explain that the beads are no longer fixed in position and are now moving randomly.
- Shake the box more vigorously so that some beads jump out of the box. Explain that in a gas, the particles are moving randomly. These particles are much further apart than in a liquid.

**Capture interest (2)**
- Show an animation of particles in solids, liquids and gases. Explain how the particles move more as they are given more energy. Reinforce ideas of the arrangement of particles in solids, gases and liquids.
- Explain that liquids can be poured because their particles can roll over each other.
- Explain that particles in solids and liquids are close so cannot be squashed. In gases, the particles are far apart and therefore can be squashed closer.

---

**Suggested alternative starter activities (5–10 minutes)**

<table>
<thead>
<tr>
<th>Recap last lesson</th>
<th>Share learning objectives</th>
<th>Problem solving</th>
<th>Capture interest (1)</th>
<th>Capture interest (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class discussion of the particle model of solids, liquids and gases.</td>
<td>● Be able to explain observations in terms of particles.</td>
<td>Pupils sort cards of statements into evidence or theories.</td>
<td>Use beads or beans in a box to model particles in solid, liquid, gas.</td>
<td>Animation to show movement of particles in solids, liquids and gases. Catalyst Interactive Presentations 1</td>
</tr>
</tbody>
</table>

**Capture interest (1)**
- Pupil sheet

**Capture interest (2)**
- Catalyst Interactive Presentations 1

---

© Harcourt Education Ltd 2003 Catalyst 1
This worksheet may have been altered from the original on the CD-ROM.
Recap last lesson

The particle model tells us that the different states of matter are caused by the balance between forces of attraction holding the particles together and movement energy trying to tear them apart. Think of it in terms of a competition:

- **Solids** – particles can only vibrate about fixed positions; the forces of attraction are winning.

- **Gases** – the particles fly about at high speed having broken free from each other; the movement energy is winning.

- **Liquids** – some freedom/some attraction – a score draw!

Use the ideas above to explain the following facts.

1. A solid has a fixed shape.
2. A liquid takes the shape of the container it is in.
3. A gas will escape from an open container.

Looking at evidence

Recap last lesson

The particle model tells us that the different states of matter are caused by the balance between forces of attraction holding the particles together and movement energy trying to tear them apart. Think of it in terms of a competition:

- **Solids** – particles can only vibrate about fixed positions; the forces of attraction are winning.

- **Gases** – the particles fly about at high speed having broken free from each other; the movement energy is winning.

- **Liquids** – some freedom/some attraction – a score draw!

Use the ideas above to explain the following facts.

1. A solid has a fixed shape.
2. A liquid takes the shape of the container it is in.
3. A gas will escape from an open container.
<table>
<thead>
<tr>
<th>Problem solving</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manchester United football team has won many trophies.</strong></td>
</tr>
<tr>
<td><strong>Manchester United football team is successful because it has the best players.</strong></td>
</tr>
<tr>
<td><strong>Manchester United football team has very expensive players.</strong></td>
</tr>
<tr>
<td><strong>Elvis Presley had many number 1 hit records.</strong></td>
</tr>
<tr>
<td><strong>Elvis Presley sang rock’n’roll songs.</strong></td>
</tr>
<tr>
<td><strong>Elvis Presley would not have been so successful in today’s music scene.</strong></td>
</tr>
<tr>
<td><strong>Cabbage is green.</strong></td>
</tr>
<tr>
<td><strong>Most pupils do not like cabbage because of its colour.</strong></td>
</tr>
<tr>
<td><strong>Few pupils are seen eating cabbage.</strong></td>
</tr>
</tbody>
</table>
Recap last lesson

- Hand out the pupil sheet. Allow a few minutes, then go over the answers.

Share learning objectives

- Ask pupils to write a list of FAQs they would put on a website telling people about the movement of particles (diffusion and air pressure). Collect suggestions as a whole-class activity, steering pupils towards those related to the objectives. Conclude by highlighting the questions you want them to be able to answer at the end of the lesson.

Capture interest (1)

- About one-fifth fill a large measuring cylinder with peas. Fill it up with beans (leave space for shaking). This models a smelly substance (the peas) and the air in the room (the beans).

- Shake the cylinder vigorously, telling the pupils that this is how the particles are moving all the time. Stop at intervals to show how the peas are mixing with the beans. Explain that this is the process by which gases mix and is called diffusion.

Capture interest (2)

- At the front of the room pour a little perfume onto a watchglass. Pupils time how long it takes for them to smell the perfume.

- Use a tape measure to see how far each pupil with a stopclock is from the perfume to the nearest metre. Sketch on the board a graph of time of arrival against distance. Ask them to describe the relationship between distance and time for the perfume to arrive.

- Discuss how the ‘smell particles’ reached the pupils and why they reached some pupils before others.

Capture interest (3)

- Show photos/video clips of mid-19th century cyclists. Explain that the tyres were made of solid rubber. Every bump was felt!

- Show photos/video clips of modern bicycles.

- Ask for an explanation involving the particle model why modern pneumatic tyres are more comfortable.
Recap last lesson

Here are some statements about particles in solids, liquids and gases.

A  Solid particles are close together.
B  Solid particles are in a rigid arrangement.
C  Solid particles are regularly arranged.
D  Liquid particles are close together.
E  Liquid particles are free to move around in the liquid.
F  Liquid particles are randomly arranged.
G  Gas particles are far apart.
H  Gas particles are free to move around.
I  Gas particles are randomly arranged.

Choose which of the statements gives the best explanation for each of these observations.

1  Liquids do not have a fixed shape.
2  Gases are easy to compress.
3  Solids have a fixed volume.
4  Liquids do not compress.
5  Gases do not have a fixed volume.
6  Solids have a fixed shape.
Scientific models – Think about

Bridging to the unit

- Show pupils a closed cardboard box (containing several balls) and ask them to describe what is inside the box.

- When they say they can’t, ask them why not. They will say that they cannot see what is in the box. Explain how this is similar to describing what particles are like. Introduce the idea of using models to describe what we cannot see.

- Shake the box, then tilt it from side to side. The balls will make a noise as they move.

- Ask pupils what is in the box. They should suggest several objects and maybe that they are round.

Setting the context

- Explain that models must be based on evidence. Ask pupils to work in groups to list the evidence they think will support each of these statements.

- Collect ideas from each group and write them on the board. Discuss what evidence suggests the statements are true.

Concrete preparation (1)

- Introduce pupils to two theories:
  1. Behaviour and personality are inherited.
  2. Behaviour and personality are a result of upbringing and childhood experience.

- Give each group of two or three pupils a set of cards from the pupil sheet. Ask pupils to divide the cards into two sets of evidence, one set to support each theory.

- Ask groups to report back their ideas to the class, then direct a class discussion on the value of evidence in supporting theories (not on the merits of these particular theories!)

Concrete preparation (2)

- Tell pupils that today we believe living organisms to be made up of cells, but this idea was developed over many years.

- Present the class with an OHT of the timescale for the development of this model. Some parts may need to be explained to the class.

- Discuss how some evidence conflicts with earlier ideas, and how each piece of evidence leads to a refinement of the model.

Suggested alternative starter activities (5–10 minutes)

<table>
<thead>
<tr>
<th>Bridging to the unit</th>
<th>Setting the context</th>
<th>Concrete preparation (1)</th>
<th>Concrete preparation (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illustrate (by using a sealed box of balls) how models are useful for describing things we can’t touch and see.</td>
<td>Think about evidence needed to back up statements (models) about everyday life.</td>
<td>Pupils sort cards of evidence into two groups, to back up two given theories.</td>
<td>Use an OHT timeline to show the development of the cellular model for living things.</td>
</tr>
</tbody>
</table>

**Equipment**
cardboard box, several balls or large beads

**Statements**
Men are stronger than women.
Our winter weather is becoming warmer and wetter.
People are using cars to travel more each year.

➔ *Pupil sheet*
Scientific models

Concrete preparation (1)

Identical twins raised in different families still have similar likes and dislikes.

Brothers or sisters brought up in the same household can have very different personalities.

Most musicians come from families where one or both parents are musicians.

Parents who did not go to university may have a son or daughter who does.

A brilliant mathematician had a daughter who went to Oxford University to study mathematics at the age of 12.

A science teacher has a son who becomes an artist.
Concrete preparation (2)

Development of the cellular model for living things

up to 17th century

People had no idea that living things had any structure. Most believed that living things developed from non-living material.

1595

Zacharias Jansen made the first microscope. It was able to magnify up to about $\times 9$.

1665

A British scientist Robert Hooke used a microscope to look at thin slices of cork. He saw many box shapes that he called cells.

1673

Antoni van Leeuwenhoek, a Dutch amateur scientist, used a microscope he made himself to confirm Hooke’s idea that living things are made of cells.

1838

Matthias Schleiden, a German, used a microscope of improved design to look at many different specimens of plant material. He concluded that all plants are made of cells.

1839

Theodor Schwann concluded that all animal tissue is made of cells.

1933

The electron microscope was invented. This enabled scientists to look at structures inside cells, for example chloroplasts.
How do different materials behave?

Running the activity

It is suggested that the activity is run as a ‘circus’ of four experiments:
(1) Squashing, (2) Changing shape, (3) How far do smells travel? and
(4) What do they weigh? The last two have additional Extension questions.

Have enough sets of each ‘station’ to generate small working groups. The pupil sheets can be laminated and one copy left at each station. Some of the stations take longer to complete than others, so extra sets of apparatus for the longer stations will speed up completion of the whole activity. Longer stations include:
(2) Changing shape and (3) How far do smells travel?

Before they start, clarify certain points with the pupils. For example:

- Orange juice is used in one of the activities instead of water, so that the pupils identify with the material, and also because the colour will be easier to see changing shape. Warn pupils about the safety implications – they must not taste anything in the lab!
- Asking pupils not to pull the plungers out of the syringes – they don’t go back in when the syringe is sealed.

Some activities have questions to follow the practical – if time is an issue, pupils can work quickly to gather their results and then answer the questions afterwards, or for homework. In this case copies of the pupil sheets will need to be handed to each pupil. Alternatively, pupils could be asked to visit two stations only, giving them longer to answer the questions.

Expected outcomes

The pupils should be able to compare solids, liquids and gases in terms of:

- ‘squashability’
- changing shape
- smells travelling
- ideas about density, although this term is not used explicitly in the activity.

Pitfalls

Pulled out plungers! It would be wise to have spare syringes available.

Safety notes

Pupils must not taste the orange juice or popcorn.
They should avoid all skin contact with the perfumed oils.

Answers

(1) Squashing

1. Gas can be squashed the most. (Liquids and solids cannot be squashed.)

(2) Changing shape

1. It is more important here that pupils ‘have a go’ without cheating by doing the experiment first. It is not important if their predictions are ‘wrong’.
2 Air can change shape.
3 Wood cannot change shape.

1 Possible ideas: woodcarvers need to use a lot of force to carve the wood, pieces are broken off, and the carving cannot be made back into the piece of wood again – changing the shape of a balloon is easy and it just bounces back.

4 This activity can generate some lively discussion because peas are solid, yet they pour! This will lead into discussion about the behaviour of particles next lesson.

2 Both can be poured. The separate peas are the same shape because they are solid, but the whole group of peas can be poured.
3 Possible ideas: solids cannot change shape but liquids and gases can. Small pieces of solids together can behave like liquids.

(3) How far do smells travel?

Core:
1 It is more important that the pupils ‘have a go’ than get the right answer here, but their answers will provide information about alternative frameworks for discussion next lesson. Pupils should realise that something is travelling from the oil to your nose.
2 Gases, liquids, solids
3 Some people have a stronger sense of smell, or may be more sensitive to ‘notes’ in a perfume, so may not smell the perfumes in the same order.

Extension:
4 This question asks about Sc1 ideas. Possible suggestions: testing a broader range of people, using people with very strong sense of smell, testing more people to take averages, etc.

(4) What do they weigh?

Core:
1 It is more important that pupils ‘have a go’ than that they give the ‘right’ answer here.
2 Sand, water, air
3 Solids are usually heaviest, gases usually lightest.
4 Ideas may focus on there being ‘less popcorn’ in the cooked beaker or ‘lots of air/space between the popcorn’.

Extension:
4 Used the same beakers, so the beakers have the same mass. Used the same volumes of material in each beaker.
How do different materials behave?

It is suggested that this activity is run as a ‘circus’ of four experiments.

### Equipment

There will need to be enough stations to occupy all the working groups – probably at least three sets of each station.

#### (1) Squashing

For each station:

- three syringes (100 ml work well) prepared as follows:
  1. Fill one with sand, one with water, and leave one containing air.
  2. Depress the plunger to half way down each syringe (no air gaps for sand or water).
  3. Seal the syringes using a suitable contact adhesive or by melting the end on a hot-plate.
- a sign to remind pupils not to pull out the plungers on the syringes
- spare syringes in case pupils do pull plungers out

#### (2) Changing shape

(This station takes longer – have an extra station set up if necessary.)

For each station:

- a balloon, partly blown up (not too hard) so that pupils can squash it (a long, thin one is ideal, but a round one will do)
- a wooden block
- a beaker of orange juice
- a beaker of dried peas (similar volume to orange juice)
- two measuring cylinders big enough to pour orange juice or peas into
- other shapes of containers

#### (3) How far do smells travel?

(This station takes longer – have an extra station set up if necessary.)

For each station:

- three or more different perfumed oils (pot pourri refresher oils work well)
- cotton wool
- Petri dishes (or ready-prepared cotton wool balls soaked in oil in lidded Petri dishes)
- a metre ruler

#### (4) What do they weigh?

For each station:

- a balance
- five beakers (all the same size) filled to the same level and labelled with:
  1. water
  2. air (empty beaker)
  3. sand
  4. uncooked popcorn
  5. cooked popcorn (the plain, white, unsweetened variety)
How do different materials behave? (continued)

For your information

Running the activity

Have enough sets of each ‘station’ to generate small working groups. The pupil sheets can be laminated and one copy left at each station. Some of the stations take longer to complete than others, so extra sets of apparatus for the longer stations will speed up completion of the whole activity. Longer stations include:

(2) Changing shape and (3) How far do smells travel?

Before they start, clarify certain points with the pupils. For example:

- Orange juice is used in one of the activities instead of water, so that the pupils identify with the material, and also because the colour will be easier to see changing shape. Warn pupils about the safety implications – they must not taste anything in the lab!
- Asking pupils not to pull the plungers out of the syringes – they don’t go back in when the syringe is sealed.

Some activities have questions to follow the practical – if time is an issue, pupils can work quickly to gather their results and then answer the questions afterwards, or for homework. In this case copies of the pupil sheets will need to be handed to each pupil. Alternatively, pupils could be asked to visit two stations only, giving them longer to answer the questions.

Expected outcomes

The pupils should be able to compare solids, liquids and gases in terms of:

- ‘squashability’
- changing shape
- smells travelling
- ideas about density, although this term is not used explicitly in the activity.

Pitfalls

Pulled out plungers! It would be wise to have spare syringes available.

Safety notes

Pupils must not taste the orange juice or popcorn. They should avoid all skin contact with the perfumed oils.
(1) Squashing

You are going to try to squash some materials. You will test sand, water and air.

1. Which do you think can be squashed the most – air, water or sand? Write down your prediction.
2. Why do you think this? Write down the reasons for your choice.
3. Press down the plunger of each syringe. Do not try to pull the plunger out!
4. Make a table for your results. Write in it how far down the plunger went for sand, air and water.
5. Did the results match your prediction?

Which could you squash the most – the solid, the liquid or the gas?
How do different materials behave? (continued)

(2) Changing shape

You are going to find out if some materials can change shape. You will test a balloon full of air, a wooden block, orange juice and dried peas.

Write down your results for each material.

1. Look at the four materials before you start. Which do you think will be able to change shape? Talk about your ideas with your partner.

2. Try to change the air in the balloon into different shapes. Can air change shape?

3. Try to change the shape of the wooden block. Can wood change shape?

Woodcarvers can make wood into many shapes. How is changing the shape of wood different to changing the shape of a balloon? Write down your ideas.

4. Try to pour the orange juice and peas into different containers. Do they change shape? Does each pea change shape?

How is pouring peas different to pouring orange juice? Write down your ideas.

5. Make a table and write in it how the different materials changed shape.

What have you found out about solids, liquids and gases? Write down your ideas.

Do not taste the orange juice!
How far do smells travel?

You are going to find out how far smells travel through the air.

1. Work in pairs. You need to decide who is going to do the testing and who is going to do the smelling.
2. The ‘smeller’ needs to stand a couple of metres away.
3. The ‘tester’ puts some perfume on a piece of cotton wool on a Petri dish. Hold the dish out and stand still.
4. The ‘smeller’ moves slowly towards the cotton wool and sniffs carefully.
5. When the ‘smeller’ can smell the perfume, you need to measure the distance.
6. Try the experiment for the different perfumes.
7. Swap places to find out if you both smell the perfume from the same distances.
8. Design a table to show the distances for each perfume, for each ‘smeller’.

How do you think the smell of the perfume reached your nose? Talk about this with your partner and write down your ideas.

Which smells do you think travel fastest:
- Smells from a gas (like chlorine from a swimming pool)?
- Smells from a liquid (like a cup of coffee)?
- Smells from a solid (like strong cheese)?

Put solid, liquid and gas in order, starting with the smells that travels fastest.

Were the results the same for different people? How were they different? Write down what you found.

Suppose you were testing how strong the perfumes were for a perfume company. How could you extend this experiment to get more reliable results? Write down your ideas.
(4) What do they weigh?

In this activity you are going to find out how much different materials weigh. You will test the same volumes of water, sand, air, cooked popcorn and uncooked popcorn.

1. Look at the materials. Write down which you think are heavy and which you think are light.

2. Weigh the materials and write your results in a table.

① Look at the results for air, sand and water. Write these down in order, starting with the heaviest.

② Think about solids, liquids and gases. Which of these do you think is usually the heaviest? Which is usually lightest?

③ Look at the results for the two types of popcorn. Why do you think they are different? Write down your ideas.

4. In this experiment, how did you make sure that the materials were compared in a fair way?
Running the activity

Hold a class discussion about particles (using the G2a Resource sheet OHT) before giving pupils Activity sheet G2a to complete. Encourage pupils to discuss their own ideas. The discussion should include the following points.

- All materials are made from particles (sometimes called atoms/molecules/bits).
- The way these particles are arranged is different in solids, liquids and gases.
- Nothing exists between the particles.
- Particles move differently in solids, liquids and gases.
- The particles and the gaps between them are very small.
- Something holds the particles together tightly in solids, less tightly in liquids, and not at all in gases.
- Particle theory is useful because we can explain the behaviour of matter or stuff around us.

It is important to link the properties of the states of matter to the circus of experiments in the previous lesson (Activity G1a).

(Useful information: There are 50 000 000 000 000 000 000 particles in a thimbleful of air!)

ICT opportunities

Most KS3 CD-ROMs have animations of particle theory which could be used here. They would be best run using a light projector attached to a PC.

Answers

<table>
<thead>
<tr>
<th>Type</th>
<th>Purpose</th>
<th>Differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion</td>
<td>Pupils discuss the particle model then answer questions to test their understanding of particles in solids, liquids and gases.</td>
<td>Core, Help</td>
</tr>
</tbody>
</table>

**Help:**

1. See Core above.

**Missing words are as follows:**
- a solid (or liquid);
- b particles, liquid;
- c far, light;
- d tightly

Solids cannot change shape because the particles are held firmly in place. They cannot be squashed. In a liquid the particles are moving and sliding over each other.

A gas can be squashed because the particles are very far apart.

A liquid is nearly as heavy as a solid because the particles are still close together.
**Particles in solids, liquids and gases**

You are going to use what you have learnt in the discussion to show how the particle model can explain the behaviour of solids, liquids and gases.

1. Copy and complete the table by answering the questions.

<table>
<thead>
<tr>
<th></th>
<th>Solid</th>
<th>Liquid</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>arranged in a pattern?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How do the particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>move?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How strongly are the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>particles held together?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Use the information in your table to explain why solids cannot change shape but liquids can.
2. Why can a gas be squashed easily?
3. Why is a liquid nearly as heavy as a solid?
You are going to use what you have learnt in the discussion to show how the particle model can explain the behaviour of solids, liquids and gases.

1. Complete the table below.

<table>
<thead>
<tr>
<th>Are the particles arranged in a pattern?</th>
<th>Solid</th>
<th>Liquid</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the particles move?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How strongly are the particles held together?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Complete these sentences by choosing from the words below.

- A .................. cannot be squashed but a gas can.
- The ...................................... in a ...................................... are not arranged in a pattern but are close together.
- The particles in a gas are ...................... apart. This is why a gas is ...................... .
- The particles in a solid are held together ...................... .
Particles in solids, liquids and gases

- **Solid**
- **Liquid**
- **Gas**

Steam

Water

Bath tap
Using the particle model

Running the activity

It is suggested that the lesson is run as a ‘circus’ of four activities: (1) Smoke cell, (2) Solid or not? (3) Squeeze and (4) Blocks. Activity (3) has an additional Extension question.

Have enough sets of each ‘station’ to generate small working groups. The pupil sheets can be laminated and one copy left at each station. (2) Solid or not? is the longest activity – either ask pupils to think about just a few examples from the range offered, or set up an extra station for this activity.

Some activities have questions to follow the practical – if time is an issue, pupils can work quickly to gather their results and then answer the questions afterwards, or for homework. In this case copies of the pupil sheets will need to be handed to each pupil. Alternatively, pupils could be asked to visit two stations only, giving them longer to answer the questions.

Ask each group to prepare feedback on one activity for a plenary.

ICT opportunities

If possible, the microscopic examination of the smoke cell could be shown on a monitor by linking to a PC.

Expected outcomes

Pupils are able to link properties of solids, liquids and gases to the particle model.

Pitfalls

(1) Smoke cell – the smoke cell may need refilling periodically.

(2) Solid or not? is quite challenging. Consider directing less able pupils away from this activity.

Answers

(1) Smoke cell
1 Smoke particles are moving constantly.
2 The sketch should show random movement.
3 Ideas include: particles are moving in the air (main idea) and bumping into the solid smoke particles (extension idea) causing them to move.

(2) Solid or not?
1 Ideas include: Can it change shape? Is it hard? Can it be poured? Is it heavy? etc.
2–4 All materials are difficult to classify. Pupils should discuss the contradictions under the criteria they have chosen for their experiment, and use diagrams to support their explanations.

(3) Squeeze
Core:
2 The air- and water-filled balloons change shape, the polystyrene ball does not.

The important point for marking the pupils’ diagrams is that the arrangement of particles should be the same, i.e. follow the model for solid, liquid and gas.
Extension:

- No space between particles in a liquid – water cannot be compressed.
- Diagrams should show two balloons, same number of particles in each, second balloon has particles closer together.

(4) Blocks

1. The blocks are the same size and shape, but different colours/sponge can be squashed/some are metal, etc.
2. Outcome not important – it is more important at this stage that pupils are willing to attempt predictions.

So that the same volume/amount of material was being compared – to make a fair comparison.

The main idea is that there is ‘air’ in the sponge. More able pupils may mention density.

Higher level understanding may be shown by pupils who suggest that particles in denser materials may be closer together, or even that the individual particles themselves may be heavier.
It is suggested that the lesson is run as a ‘circus’ of four activities: (1) Smoke cell, (2) Solid or not? (3) Squash and (4) Blocks.

**Equipment**

There will need to be enough stations to occupy all the working groups – probably about three sets of each station. Extra water-filled balloons could be kept as spares. An extra station for (2) Solid or not? might be needed.

For each station:

1. **Smoke cell**
   - a smoke cell
   - a microscope
   - a low voltage supply and leads

   Apparatus needs to be set up, working. The smoke cell may need refilling occasionally. Fill the smoke cell using smoke from a smouldering piece of string, using a dropping pipette to collect the smoke.

2. **Solid or not?**
   - a range of ‘difficult to classify’ labelled solids, e.g. cotton wool, ‘slime’, beaker of dried peas, beaker of sand, sponge, sheet of paper, plastic bag, rubber glove, plasticine, piece of soft fabric

   Pupils are going to decide how to approach this activity themselves, but suggested available apparatus includes:
   - shaped containers (e.g. beakers, measuring cylinders)
   - a balance

3. **Squash**
   - a solid ball (not an air-filled one) e.g. metal, rubber or polystyrene (these are sold in craft shops and haberdashery shops) – as big as possible, a bit bigger than a tennis ball is fine. Labelled ‘solid ball’.
   - a balloon labelled ‘air’ (permanent marker) filled so it is roughly the same size as the ball.
   - a balloon labelled ‘water’ (permanent marker) filled so it is roughly the same size as the ball.

4. **Blocks**
   - four ‘materials’ blocks of different densities but the same size: one needs to be sponge (so that pupils can see the air spaces); the others could be wood, polystyrene and/or metals of differing densities
   - balance set to weigh in grams

**For your information**

**Running the activity**

Have enough sets of each ‘station’ to generate small working groups. The pupil sheets can be laminated and one copy left at each station. (2) Solid or not? is the longest activity – either ask pupils to think about just a few examples from the range offered, or set up an extra station for this activity.

---

**Using the particle model**

<table>
<thead>
<tr>
<th>Type</th>
<th>Purpose</th>
<th>Differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical</td>
<td>Pupils carry out activities that show some examples of the behaviour of solids, liquids and gases, then apply their understanding of the particle model to explain what they see.</td>
<td>Core (Extension)</td>
</tr>
</tbody>
</table>

---

**Technician activity notes**

Using the particle model

Practical Pupils carry out activities that show some examples of the behaviour of solids, liquids and gases, then apply their understanding of the particle model to explain what they see.
Some activities have questions to follow the practical – if time is an issue, pupils can work quickly to gather their results and then answer the questions afterwards, or for homework. In this case copies of the pupil sheets will need to be handed to each pupil. Alternatively, pupils could be asked to visit two stations only, giving them longer to answer the questions.

Ask each group to prepare feedback on one activity for a plenary.

Expected outcomes
Pupils are able to link properties of solids, liquids and gases to the particle model.

Pitfalls
(1) **Smoke cell** – the smoke cell may need refilling periodically.
(2) **Solid or not?** is quite challenging. Consider directing less able pupils away from this activity.
(1) Smoke cell

You are going to look at some smoke through a microscope and use ideas about particles to explain what you see.

Look down the microscope at the smoke.

1. Describe what you can see.
2. Draw a sketch to show how one smoke particle moves.
3. Use ideas about particles to explain what you see. Write down your ideas.
(2) Solid or not?

You are going to look at some materials and decide whether they are solid or not.

1. What will you look for to decide if a material is solid or not? Discuss this with your partner and write down a short list.

2. Look at each material. Decide in what ways it behaves like a solid, and in what ways it does not.

3. Copy this table and complete it for each material. Write down your decision in the last column.

<table>
<thead>
<tr>
<th>Name of material</th>
<th>Like a solid because...</th>
<th>Not like a solid because...</th>
<th>Solid or not?</th>
</tr>
</thead>
</table>

4. Choose one material. Draw diagrams to show what happened in your tests. Write captions for each diagram to show how the material behaves like a solid, and how it does not.

© Harcourt Education Ltd 2003 Catalyst 1
This worksheet may have been altered from the original on the CD-ROM.
(3) Squeeze

You are going to investigate whether solids, liquids and gases can change shape. You will test balloons filled with air and water and a solid ball. You will then use ideas about particles to explain what you have found.

1. Handle the balloons and the ball. Find out which change shape when you squeeze them.

2. Write down what you find out.

These diagrams show how the particles are arranged before squeezing.

- **When a balloon of water is squeezed, it bulges out because the total volume of water does not change.**
  - Use ideas about particles to explain why the volume does not change.
  - Draw diagrams to show why it is possible to squash an air filled balloon to make it smaller.

---

**Extension**

- Be careful not to burst the water balloon!
Using the particle model (continued)

(4) Blocks
You are going to compare the weights of some different materials and use the idea of particles to explain your results.

1 Look at the blocks. In what ways are the blocks the same? In what ways are they different? Write down your observations.

2 What do you think you will find out when you weigh the blocks? Write down your predictions.

3 Weigh the blocks using the balance.

4 Copy and complete this table.

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight in g</th>
</tr>
</thead>
</table>

Why do you think the blocks in this experiment are all the same size?

Talk to your partner about why you think the blocks weigh different amounts. Use ideas about particles in your discussion. Write down your ideas.
Expansion in solids, liquids and gases

Running the activity

This is a series of three (or more) linked teacher demonstrations. It is not intended that they should be ‘written up’, but that they be used as a stimulus for class discussion about the particulate model of changes on heating.

The demonstrations feed into the subsequent pupil role plays.

There are four suggested demonstrations given for solids, so teachers can choose which to do depending on the equipment available.

(1) Expansion in solids

a Ball and ring:
- Show that the metal ball fits through the ring.
- Heat the ball.
- Show that it does not now fit.
- Let the ball cool (while you are doing other demos).
- Show that ball fits through the ring again.

b Bar and gauge:
- Show that metal bar fits into the gauge (some gauges are adjustable, in which case the gauge should be tightened to fit the bar).
- Heat the bar.
- Show that it does not now fit.
- Let the bar cool (while you are doing other demos).
- Show that bar fits into the gauge again.

c Bar breaker:
- Set up the equipment as shown in the diagram.
- Heat the long metal bar and, as it expands, tighten the screw (a pupil can do this with a spanner, but not by hand, as it may get hot).
- Leave to cool.
- As the long metal bar cools, it contracts, breaking the cast iron bar.
d Rod and flag:
- Set up the equipment as shown. The pin needs to rest on the mat so it ‘rolls’.
- Heat the metal rod – the flag will turn as the bar expands.

Suggested topics for discussion
- Discuss what is happening in terms of particles moving about more/pushing against each other more when they get warmer.
- Discuss the ideas of energy change – the heat from the flame is giving particles in the metal more energy and causing them to heat up/vibrate more/push against each other to cause expansion.
- Discuss why expansion in solids causes problems in hot engines and why they need to be oiled.

(2) Expansion in liquids
- Keep the flask in an ice bath until needed (in a plastic container to stop it rolling off the bench).
- Pass the flask between pupils – if they warm the flask with their hands, the water will rise up the tubing. Warn pupils to be careful not to poke eyes with the tubing!
- If the water nears the top of the tubing, it can be cooled again in the ice bath.
- If the pupils’ hands do not make a very great change, try plunging the flask in a water bath of hot water.

Suggested topics for discussion:
- Discuss what is happening in terms of particles moving about more/pushing against each other more when they get warmer.
- Discuss the ideas of energy change – our hands feel cold because the particles in the water are taking energy from our hands and using the energy to get warmer/move more.
- Explain that this idea is the basis for making a thermometer – discuss the need to make a scale on the tube so that we can measure temperature.

(3) Expansion in gases
- The flask can be made to change temperature by passing between hands and plunging in ice or hot water baths. Warn pupils to be careful not to poke eyes with the tubing!
- Note that if the temperature changes are too great, the slug of water may be pushed out of the tube altogether. (It is wise to have a spare set up.)
- The change in the level of the water slug should be much greater than with the previous water flask thermometer.

Suggested topics for discussion
- Air changes volume more quickly and to a greater extent than water – gases expand more easily on heating.
- Discuss what is happening in terms of particles moving about more/pushing against each other more when they get warmer.
- Discuss the ideas of energy change – the heat is giving particles more energy and causing them to heat up/move about more/push against each other to cause expansion.
- Discuss why you need to squeeze air out of hot-water bottles before you screw the top on, and why tinned or bottled food is allowed to cool before the lids are put on.
ICT opportunities

Many CD-ROMs for KS3 science show animated particulate model illustrations which could be used to support this activity.

Expected outcomes

Pupils should know about expansion and contraction on heating and cooling and more able pupils should be able to explain this using the formal model of kinetic theory.

Safety notes

Warn pupils to be careful not to poke eyes with the long glass tubes.

All the hot metal items take a considerable time to cool down. Warn pupils not to touch them even if they look cool!
Expansion in solids, liquids and gases

Equipment

(1) Expansion in solids

For all demonstrations:
- a Bunsen burner, heat-proof mat, matches

For demonstrations a–d:
- an ‘expansion’ ball and ring
- a ‘bar breaker’ – holder, long metal bar, cast iron bar and screw. A new cast iron bar will be needed for each demonstration.
- a metal bar and gauge
- a metal rod at least 50 cm long, e.g. from a retort stand
- a stand and clamp
- a heat-proof mat
- a long pin with attached paper flag

(2) Expansion in liquids

- an ice bath
- a hot water bath (both baths big enough to take flask)
- a round-bottomed flask full of coloured water (use food dye) with bung and thin glass tube (at least 30 cm)
- a plastic container to put flask in (to stop it rolling off the bench)
(3) Expansion in gases

- an ice bath and hot water bath (the ones used in ‘liquids’ can be used for both demonstrations)
- a round-bottomed flask with bung and thin glass tubing (at least 50 cm long) with a slug of coloured (food dye) water – set up by sucking a small slug of water into the tube before attaching it to the flask (the slug should be just above the bung at room temperature)
- a spare set-up of the above, in case the temperature changes are great enough to push the slug out of the tube altogether!

For your information

Running the activity

This is a series of three (or more) linked teacher demonstrations. It is not intended that they should be ‘written up’, but that they be used as a stimulus for class discussion about the particulate model of changes on heating.

The demonstrations feed into the subsequent pupil role plays.

There are four suggested demonstrations given for solids, so teachers can choose which to do depending on the equipment available.

(1) Expansion in solids

a Ball and ring:
- Show that the metal ball fits through the ring.
- Heat the ball.
- Show that it does not now fit.
- Let the ball cool (while you are doing other demos).
- Show that ball fits through the ring again.

b Bar and gauge:
- Show that metal bar fits into the gauge (some gauges are adjustable, in which case the gauge should be tightened to fit the bar).
- Heat the bar.
- Show that it does not now fit.
- Let the bar cool (while you are doing other demos).
- Show that bar fits into the gauge again.

c Bar breaker:
- Set up the equipment as shown in the diagram.
- Heat the long metal bar and, as it expands, tighten the screw (a pupil can do this with a spanner, but not by hand, as it may get hot).
- Leave to cool.
- As the long metal bar cools, it contracts, breaking the cast iron bar.

d Rod and flag:
- Set up the equipment as shown. The pin needs to rest on the mat so it ‘rolls’.
- Heat the metal rod – the flag will turn as the bar expands.

Suggested topics for discussion

- Discuss what is happening in terms of particles moving about more/pushing against each other more when they get warmer.
- Discuss the ideas of energy change – the heat from the flame is giving particles in the metal more energy and causing them to heat up/vibrate more/push against each other to cause expansion.
- Discuss why expansion in solids causes problems in hot engines and why they need to be oiled.
(2) Expansion in liquids

- Keep the flask in an ice bath until needed (in a plastic container to stop it rolling off the bench).
- Pass the flask between pupils – if they warm the flask with their hands, the water will rise up the tubing. *Warn pupils to be careful not to poke eyes with the tubing!*
- If the water nears the top of the tubing, it can be cooled again in the ice bath.
- If the pupils’ hands do not make a very great change, try plunging the flask in a water bath of hot water.

**Suggested topics for discussion:**

- Discuss what is happening in terms of particles moving about more/pushing against each other more when they get warmer.
- Discuss the ideas of energy change – our hands feel cold because the particles in the water are taking energy from our hands and using the energy to get warmer/move more.
- Explain that this idea is the basis for making a thermometer – discuss the need to make a scale on the tube so that we can measure temperature.

(3) Expansion in gases

- The flask can be made to change temperature by passing between hands and plunging in ice or hot water baths. *Warn pupils to be careful not to poke eyes with the tubing!*
- Note that if the temperature changes are too great, the slug of water may be pushed out of the tube altogether. (It is wise to have a spare set up.)
- The change in the level of the water slug should be much greater than with the previous water flask thermometer.

**Suggested topics for discussion**

- Air changes volume more quickly and to a greater extent than water – gases expand more easily on heating.
- Discuss what is happening in terms of particles moving about more/pushing against each other more when they get warmer.
- Discuss the ideas of energy change – the heat is giving particles more energy and causing them to heat up/move about more/push against each other to cause expansion.
- Discuss why you need to squeeze air out of hot-water bottles before you screw the top on, and why tinned or bottled food is allowed to cool before the lids are put on.

**Expected outcomes**

Pupils should know about expansion and contraction on heating and cooling and more able pupils should be able to explain this using the formal model of kinetic theory.

**Safety notes**

Warn pupils to be careful not to poke eyes with the long glass tubes.

All the hot metal items take a considerable time to cool down. Warn pupils not to touch them even if they look cool!
Running the activity

If possible, most of this can take place outside – a tennis court is ideal. Run the first part using the bench indoors.

(1) **Solids**: This needs running carefully to make sure nobody gets hurt! The longer the bench, the better this works – you can put two or more tables together if necessary. The last two pupils at each end will probably fall off. Make sure there are no bags or stools at each end of the bench. You can ‘pick’ the pupils to go at each end that you judge to be fast footed!

If you are concerned, you can run this as a ‘sharks in the sea’ activity with two chalk lines on the floor – pupils sit tightly between lines. As they jiggle, more and more people get pushed over the lines to be ‘eaten by sharks’.

(2) **Liquids** and (3) **Gases**: These can be run in groups of no less than 10 pupils. One pupil needs to take the place of the ‘caller’, shouting instructions from the sheet at everyone else.

**ICT opportunities**

If you are using ‘callers’ for the groups, you could record some of the behaviour of the ‘particles’ to show on-screen in the classroom. ‘Good’ examples of pupils behaving as solids, liquids and gases can be used as a basis for discussion.

**Safety notes**

See the suggestions above.

If pupils can go outside there is less likelihood of pupils running around as ‘gas particles’ getting hurt.

**Answers**

1. As particles vibrate more, the solid will expand because the particles are pushing each other apart.
2. Particles can move past each other into different shapes.
3. The particles need much more space to move around.
Particles role play

You and your friends are going to be particles in a solid, liquid and gas. You will act out what happens when you are heated up.

(1) Solid

1. Sit with some friends so that you are squashed up on a long bench.
2. Start jiggling about more and more.
3. Watch what happens to your friends at each end of the bench.

Particles ‘jiggle about’ more when they get warmer.

① How does this help explain why solids expand when we heat them?

(2) Liquid

4. Stand in a group, holding on to a friend with one hand.
5. Walk around the group. Stay very close to each other and touch other pupils as you pass them.
6. As you walk around like this, try to make a long line, then try to make a group.

② How does this explain why liquids can change shape?

(3) Gas

7. Now let go of your hands and move away from your friends.
8. Move around quickly and in all directions.

③ Why does this explain why liquids expand when they turn into gases?
**Running the activity**

Place the two gas jars on top of each other with bromine in the top jar; carefully remove the cover slips to allow the gases to mix. Repeat with bromine in the bottom jar.

Use the G4a Resource sheet as an OHT to show what is happening.

**Suggested topics for discussion**

- Bromine mixes downwards more quickly because it is heavier than air.
- The bromine particles are spreading out and mixing with the air particles.
- Link this activity to G1a (3) How far do smells travel? This demonstration gives the opportunity to introduce the word ‘diffusion’.
- Applications of diffusion include the use of bread-smell machines installed in some supermarkets to encourage bread sales, and smoke alarms used in homes.
- Chlorine, like bromine, is heavier than air and settled in the trenches to kill soldiers during the First World War.

**ICT opportunities**

A digital camera could be used to take a series of ‘time lapse’ photographs.

**Expected outcomes**

Pupils know the meaning of the word ‘diffusion’.

**Safety notes**

Bromine is very toxic and corrosive. The gas jar should be prepared and left for use in a working fume cupboard. The teacher should wear eye protection and rubber gloves whilst removing the cover slips. The gas jars should be left in the fume cupboard until the end of the lesson.

When preparing gas jars of bromine there should always be a solution of sodium thiosulphate available to flood any skin area contaminated with bromine.
Diffusion in gases

Equipment
For the demonstration:
- two gas jars of bromine gas (with lids)
- two gas jars of air
- sheets of white paper
- a digital camera (optional)

Running the activity
Place the two gas jars on top of each other with bromine in the top jar; carefully remove the cover slips to allow the gases to mix. Repeat with bromine in the bottom jar.

Use the G4a Resource sheet as an OHT to show what is happening.

Suggested topics for discussion
- Bromine mixes downwards more quickly because it is heavier than air.
- The bromine particles are spreading out and mixing with the air particles.
- Link this activity to G1a (3) How far do smells travel? This demonstration gives the opportunity to introduce the word ‘diffusion’.
- Applications of diffusion include the use of bread-smell machines installed in some supermarkets to encourage bread sales, and smoke alarms used in homes.
- Chlorine, like bromine, is heavier than air and settled in the trenches to kill soldiers during the First World War.

Expected outcomes
Pupils know the meaning of the word ‘diffusion’.

Safety notes
Bromine is very toxic and corrosive. The gas jar should be prepared and left for use in a working fume cupboard. The teacher should wear eye protection and rubber gloves whilst removing the cover slips. The gas jars should be left in the fume cupboard until the end of the lesson.

When preparing gas jars of bromine there should always be a solution of sodium thiosulphate available to flood any skin area contaminated with bromine.
Diffusion in gases

before mixing

after mixing

key

- particle of bromine
- particle of air
Running the activity

Pupils work in threes, taking it in turns (if time allows) to hold the watchglass.

The air freshener quickly fills up the lab! Trustworthy pupils could perhaps be allowed to carry out their experiment outside the classroom (but indoors).

If you haven’t already used the Starter activity G4 ‘Capture interest (2)’, then you could repeat this activity but have a pupil standing with the watchglass of air freshener at the front of the class. Gather other pupils around the front bench, ask them to raise their hands when the air freshener smell reaches them – the effect of the spreading air freshener should be seen by the pattern of raised hands.

Expected outcomes

Pupils know how far and fast gas particles can travel. This is diffusion.

Safety notes

Take care when spraying the air freshener, to avoid eyes and skin.
Take care not to drop the watchglasses.

Answers

Core:
1. The puddle of liquid disappeared. (More able pupils should be encouraged to use term ‘evaporated’.)
2. See results
3. Pupil’s account of diffusion

Extension:
4. a. Evaporation
   b. Hand is losing heat
   c. Air freshener is using the heat to evaporate
Equipment

For each group:

- a watchglass
- an aerosol air freshener
- a stopclock

For your information

Running the activity

Pupils work in threes, taking it in turns (if time allows) to hold the watchglass. The air freshener quickly fills up the lab! Trustworthy pupils could perhaps be allowed to carry out their experiment outside the classroom (but indoors).

If you haven’t already used the Starter activity G4 ‘Capture interest (2)’, then you could repeat this activity but have a pupil standing with the watchglass of air freshener at the front of the class. Gather other pupils around the front bench, ask them to raise their hands when the air freshener smell reaches them – the effect of the spreading air freshener should be seen by the pattern of raised hands.

Expected outcomes

Pupils know how far and fast gas particles can travel. This is diffusion.

Safety notes

Take care when spraying the air freshener, to avoid eyes and skin.
Take care not to drop the watchglasses.
Fresh air!

You are going to find out how air freshener fills a room with smell.

Obtaining evidence

Work in groups of three. One of you will hold a watchglass, one will spray the air freshener and one will work the stopclock.

If there is already a strong smell of air freshener in the room, ask your teacher if you can do this experiment outside the classroom.

1 The pupil with the stopclock stands about 2 m away.
2 One pupil places a watchglass on the back of the hand.
3 The other pupil sprays some air freshener directly onto the watchglass. Hold it close to make a small puddle of liquid.
4 Start the stopclock immediately.
5 The pupil with the watchglass tells the others how their hand feels.
6 When the pupil standing 2 m away smells the air freshener, stop the clock.

If there is time, repeat the experiment and take it in turns with the watchglass.

Considering evidence and evaluating

1. What did you see happen to the air freshener?
2. How long did it take the person with the stopclock to smell the air freshener?
3. Imagine you are a particle of air freshener in a can. Explain what happens to you and the particles around you as you travel from the can to your partner’s nose. Use these words to help you.

Most people feel their hands going cold under the watchglass.

a. What is happening to the air freshener when your hand feels cold?

b. If your hand feels cooler, is it losing heat or gaining heat?

c. Why do you think the air freshener causes this to happen?
Running the activity

Fill the gas jar about $\frac{1}{3}$ full with water. Use the rubber tubing and the funnel to pour the saturated copper sulphate solution carefully into the bottom of the jar to make a layer below the water. If possible, do this in a place where the jar can be left, unmoved, for a couple of weeks.

A lid on the jar keeps dust out and helps stop water evaporation. Use a board marker to mark the position of the top of the layer and note the time and date.

Pupils can look at the jar every lesson to see the progress of the blue layer up the jar.

(Useful information: Diffusion is much slower in water than in air, but sharks can detect wounded fish and animals by being able to detect blood diffusing in sea water in concentrations of parts per million!)

ICT opportunities

If a digital camera is available, ‘time lapse’ photos can be taken daily to show the progress of the blue colour up the jar.

Expected outcomes

Observation of diffusion. Pupils can be prompted to discuss how slowly diffusion in liquids occurs compared to gases (e.g. air freshener).

Pitfalls

Pouring the copper sulphate into the jar is not easy! Try a practice run first.

Safety notes

Copper sulphate is harmful and has been known to irritate and sensitise the skin. Avoid skin contact.
**Diffusion in liquids**

**Equipment**
For the demonstration:
- a gas jar and lid
- saturated copper sulphate solution in a beaker
- rubber tubing long enough to reach into the bottom of the gas jar (about 40 cm long)
- a funnel to fit tubing
- a digital camera (optional)

**For your information**

**Running the activity**
Fill the gas jar about \( \frac{3}{4} \) full with water. Use the rubber tubing and the funnel to pour the saturated copper sulphate solution carefully into the bottom of the jar to make a layer below the water. If possible, do this in a place where the jar can be left, unmoved, for a couple of weeks.

A lid on the jar keeps dust out and helps stop water evaporation. Use a board marker to mark the position of the top of the layer and note the time and date.

Pupils can look at the jar every lesson to see the progress of the blue layer up the jar.

(Useful information: Diffusion is much slower in water than in air, but sharks can detect wounded fish and animals by being able to detect blood diffusing in sea water in concentrations of parts per million!)

**Expected outcomes**
Observation of diffusion. Pupils can be prompted to discuss how slowly diffusion in liquids occurs compared to gases (e.g. air freshener).

**Pitfalls**
Pouring the copper sulphate into the jar is not easy! Try a practice run first.

**Safety notes**
Copper sulphate is harmful and has been known to irritate and sensitise the skin. Avoid skin contact.

---

**Type** | **Purpose** | **Differentiation**
--- | --- | ---
Practical | A demonstration to show diffusion of copper sulphate solution in a gas jar. | Core, Help, Extension
No pupil sheets
Running the activity

It is strongly recommended that teachers ‘dispense’ the potassium manganate(VII) to pupils by going to the group when they are ready to use a crystal.

Keep a kettle of water ‘on the boil’ throughout the lesson.

Core: Pupils carry out the first experiment as shown, then plan and carry out their own. There is an Extension question for more able pupils to evaluate their experiment and suggest improvements.

Help: Pupils record their results and answers on the sheet.

Expected outcomes

Pupils understand how the rate of diffusion varies with temperature.

Safety notes

Potassium manganate(VII) is harmful.

Answers

Core and Help:

1. Hot water (but a ‘right’ answer here is not important)
2. The particles move faster in hot water.
3. The higher the temperature of the water, the faster diffusion happens.
4. Diagrams should show that the solid particles in the crystal have spread through the liquid particles in the water.

Extension:

5. a. It is hard to tell when the colour is evenly mixed.
b. Putting white paper behind beakers; taking several readings and an average; using a colorimeter to measure light absorption.
Diffusion: faster or slower

Equipment

For each group:
- potassium manganate(VII) (potassium permanganate) crystals – very small (size of a large grain of rice)
- forceps
- a glass tube
- 150 ml beaker
- a stopclock
- a kettle of water needs to be kept ‘on the boil’ all lesson
- some pupils may ask for ice

For your information

Running the activity

Teachers should ‘dispense’ the potassium manganate(VII) to pupils by going to the group when they are ready to use a crystal.

Keep a kettle of water ‘on the boil’ throughout the lesson.

Core: Pupils carry out the first experiment as shown, then plan and carry out their own. There is an Extension question for more able pupils to evaluate their experiment and suggest improvements.

Help: Pupils record their results and answers on the sheet.

Expected outcomes

Pupils understand how the rate of diffusion varies with temperature.

Safety notes

Potassium manganate(VII) is harmful.
Diffusion is caused by the movement of particles through a liquid or a gas. You are going to carry out an experiment to see if you can change how fast diffusion happens.

Obtaining evidence
1 Fill a beaker with 50 cm³ hot water.
2 Stand it on a piece of white paper. Leave it to settle.
3 Measure the temperature of the water. Write it down.
4 Gently place a glass tube in the water.
5 Use forceps to put a small crystal of potassium manganate(VII) into the tube – it will sink to the bottom of the water.
6 Start your stopclock.
7 Stop the clock when all the water looks the same colour.
8 Write down your results.

Planning and predicting
9 Think about how you could adapt your experiment to test how fast diffusion happens at two different temperatures. Write down your ideas.

10 Check your ideas with your teacher and then do the two experiments.

Presenting the results
11 Design a table to show your results.

Considering the evidence
3 Was your prediction right? Write down a sentence to show how diffusion depends on temperature.
4 Draw diagrams to show what happens to the particles of potassium manganate(VII) and water during the experiment.

5 Different pupils can get different results for this experiment.
   a Explain why it is difficult to measure the time precisely.
   b Suggest a way the experiment could be improved to make the results more reliable.
Diffusion is caused by the movement of particles through a liquid or a gas. You are going to carry out an experiment to see if you can change how fast diffusion happens.

Obtaining evidence

1. Fill a beaker with 50 cm³ hot water.
2. Stand it on a piece of white paper and leave it to settle.
3. Measure the temperature of the water. Write the temperature here. .................. °C
4. Gently place a glass tube in the water.
5. Use forceps to put a small crystal of potassium manganate(VII) into the tube – it will sink to the bottom of the water.
6. Start your stopclock.
7. Stop the clock when all the water looks the same colour.
8. Write the time here. ...................................... seconds

Planning and predicting

9. Think about how you could adapt your experiment to test how fast diffusion happens at two different temperatures. Write your ideas here.

...............................................................................................................................................................................................................
...............................................................................................................................................................................................................
...............................................................................................................................................................................................................
...............................................................................................................................................................................................................
...............................................................................................................................................................................................................
...............................................................................................................................................................................................................
...............................................................................................................................................................................................................

10. Check your ideas with your teacher and then do the two experiments.

Do you think diffusion will be faster in hot water or cold water? ...............................................

Do you think particles will move faster in hot water or cold water? ...............................................

Potassium manganate(VII) is harmful – use a very small crystal and be careful not to let it touch your skin.
**Diffusion: faster or slower** (continued)

### Presenting the results

1. Fill in the table.

<table>
<thead>
<tr>
<th>Temperature of water in °C</th>
<th>Time taken in seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Considering the evidence

3. Was your prediction right? Fill in the gaps in this sentence.

   The .................................. the temperature of the water,

   the .................................. diffusion happens.

4. This diagram shows the particles at the start of the experiment. Fill in the second beaker to show what the particles look like at the end of the experiment.
Running the activity

Try not to call this activity ‘the collapsing bottle experiment’ as it tells the pupils what will happen!

Tell pupils that empty bottles are really full of air. So what happens when we take all the air out? Show the pupils the bottle and pump. Discuss the ideas on the G4e Resource sheet (can be made into an OHT).

Ask pupils to discuss in pairs what they predict will happen and, for more able pupils, put forward reasons in terms of particle theory.

The OHT can be photocopied for pupils to complete with their ideas and explanations.

Allow pupils to share their ideas about what will happen before the demonstration. After the demonstration refer back to the OHT to discuss the ‘accepted’ explanation for what happens.

Pitfalls

You need to use pressure hosing otherwise the hose collapses instead of the bottle!

Safety notes

All those present for the demonstration to wear eye protection.
Empty bottle

**Equipment**

- A plastic bottle or metal can to collapse: e.g. an ‘oil can’ type is best, but difficult to find; plastic fizzy drink bottles or large containers (such as sold containing white spirit) are a good alternative
- A vacuum pump with pressure tube connector (available from school science suppliers)

**For your information**

**Running the activity**

Try not to call this activity ‘the collapsing bottle experiment’ as it tells the pupils what will happen!

Tell pupils that empty bottles are really full of air. So what happens when we take all the air out? Show the pupils the bottle and pump. Discuss the ideas on the G4e Resource sheet (can be made into an OHT).

Ask pupils to discuss in pairs what they predict will happen and, for more able pupils, put forward reasons in terms of particle theory.

The OHT can be photocopied for pupils to complete with their ideas and explanations.

Run a plenary for pupils to share their ideas before the demonstration. After the demonstration refer back to the OHT to discuss the ‘accepted’ explanation for what happens.

**Pitfalls**

You need to use thick-walled pressure tubing otherwise the tube collapses instead of the bottle!

**Safety notes**

All those present for the demonstration to wear eye protection.
Empty bottle

Before

Air particles hitting the insides – pushing OUT.

After

Air particles hitting the outside – pushing IN.

What happens next? Why?
Running the activity

Cut up the pupil sheets into cards to provide examples of everyday effects of particulate theory – at Core, Help and Extension levels. Organise pupils into small ability groups and give each group a card. Pupils think about what happens in their example and then try to explain this using particulate theory. Remind pupils that they can copy diagrams of the particle model from worksheets already in their books.

The activity can be run in two ways:

- Pupils produce posters explaining their ideas. The lesson then concludes with groups coming together (about four groups together works well) to explain to each other what they think, using their posters to support their explanation. (See plenary activities for lesson G5.)
- Pupils use blank OHTs and pens to present their ideas. Show pupils how to use lined paper underneath to keep their writing straight, and tell them that they can ‘trace’ diagrams through the sheet. Each group gives a short talk to the whole class about their ideas.

In either case, listening pupils should be encouraged to ask questions or add to the ideas – but not criticise! The second option can be time consuming if the class is very large.

ICT opportunities

Some pupils could use PowerPoint to make a slide show of their ideas.

Pitfalls

The first time pupils do a presentation activity they may be shy. Choose the first speakers carefully – not too brilliant to put people off, not too shy to speak!
Using scientific models

Activity

Core

Rail tracks

David’s dad is laying new steel tracks along a railway line. He leaves gaps between each length of track. He says that these are to stop the track buckling in hot weather.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

Bike tyres

Liz has a mountain bike. She fills her tyres with air. The tyres give a smooth ride because they change shape around small bumps on the road. She tries a new, solid rubber tyre. She finds it very uncomfortable over bumpy ground.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

Perfume

Alice sells perfume in a shop. She tells her customers to wear the perfume on their wrists. This is where warm blood is very near the surface of the skin. She tells them that this makes the perfume give off its smell faster.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

Bath towel

Jay hangs his wet bath towel on the washing line every morning. He notices that it dries fastest if it is windy or sunny, but is often still wet in the evening on cold, still days.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

Bike tyres

Liz has a mountain bike. She fills her tyres with air. The tyres give a smooth ride because they change shape around small bumps on the road. She tries a new, solid rubber tyre. She finds it very uncomfortable over bumpy ground.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

Perfume

Alice sells perfume in a shop. She tells her customers to wear the perfume on their wrists. This is where warm blood is very near the surface of the skin. She tells them that this makes the perfume give off its smell faster.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

Bath towel

Jay hangs his wet bath towel on the washing line every morning. He notices that it dries fastest if it is windy or sunny, but is often still wet in the evening on cold, still days.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.
**Using scientific models**

**Swimming pool**
Joe and Eve run to the swimming pool. They then have races by running through the water. However hard they try, they run much slower through the water than through the air.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

**Chip shop**
Sue lives next to a chip shop. She gets fed up with smelling the fish and chips every night. Her friend Sam lives two streets further away and never smells anything.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

**Jam jar**
Kaz is trying to open a jar of jam. The lid is metal, and it is stuck. His mum suggests running it under the hot tap. She says the lid will get bigger and will screw off easily.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

**Water bed**
Jack has a water bed. The bed has a big plastic bag filled with water instead of a mattress. He says it is really comfortable because it fits around the shape of his body when he lies down.

What to do
Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.
**Diving disaster**

When divers go deep underwater, the water puts pressure on their bodies. They often get tiny bubbles of air in their blood. If they come back up to the surface too quickly then the bubbles expand, blocking blood vessels – the divers can die.

**What to do**

Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.

---

**Fridge**

In the cooling pipes of a fridge there is a liquid with a boiling point at nearly room temperature. A fan makes the liquid evaporate. As the liquid evaporates it makes the fridge get colder and colder.

**What to do**

Draw some diagrams to help you explain to other groups:

1. what is happening in your example
2. how ideas about particles can be used to explain what is happening.

At the end of the lesson you will present your ideas to the other groups.
Review learning

- Pupils work in pairs or alone to write a sentence to describe something they have observed or learnt for the first time in this lesson.

- Pupils could also identify one thing that they found difficult to do and say why.

Sharing responses

- Ask pupils to say if any of the results of the activities surprised them because they didn’t match their predictions.

- For each circus station, discuss the answers to the questions and check understanding.

- Summarise what has been learnt about the behaviour of solids, liquids and gases.

Group feedback

- In groups, pupils discuss what they have learnt about the behaviour of solids, liquids and gases.

- They write an agreed list of points to share with the rest of the class about either solids, liquids or gases.

- Ask one group to present their ideas for solids, liquids and gases and ask the rest of the class if they have anything more to add.

Word game

- Pupils work in pairs to devise five quick questions about today’s lesson. Each pair then challenges another pair to answer their questions. Each pair must be able to provide an acceptable answer for their own questions in the event that the other pair cannot.

- The questions could always be collected and used as a quick quiz next lesson to revisit this lesson.

Looking ahead

- Pupils can work alone or in pairs to think about what crucial piece of evidence they would use to justify a piece of cloth being classified as a solid rather than as a liquid.

- Alternatively, show the class a powder and ask them to suggest how they would classify it and why.
**Particle power**

**Suggested alternative plenary activities (5–10 minutes)**

<table>
<thead>
<tr>
<th>Review learning</th>
<th>Sharing responses</th>
<th>Group feedback</th>
<th>Word game</th>
<th>Looking ahead</th>
</tr>
</thead>
<tbody>
<tr>
<td>True and false statements summarising learning.</td>
<td>Whole-class discussion of responses and feedback on Activity G2a.</td>
<td>Groups of pupils discuss their results from circus Activity G2b.</td>
<td>Sort statements about key features of particle arrangements and behaviour in solids, liquids and gases.</td>
<td>Pupils suggest what happens to the particles in a solid when you heat it and the solid expands.</td>
</tr>
</tbody>
</table>

**Review learning**

- Give pupils two cards, one saying ‘agree’ and one saying ‘disagree’.
- Each pupil devises a statement about what they have learnt in this lesson. The statement can be true or false.
- The statement is read out and the class respond together by each showing a card.
- The pupil who devised the question states which of the two cards is appropriate and says why.
- The teacher notes the responses of the class and of individual pupils in order to identify possible misconceptions.

**Sharing responses**

- Ask pupils to link back to activities and ideas from the last lesson and match what they say against the formal model being presented. Ask which activities from the last lesson provide evidence for the statements.

**Group feedback**

- Allocate each pair one activity. They first describe the activity and what they observed happening. They then describe what they think the underlying particle behaviour was in the activity. They may find it useful to use drawings to support their response.

**Word game**

- Show the statements on the Pupil sheet on the OHP. Pupils group statements according to whether they describe solids, liquids or gases.

**Looking ahead**

- Pupils work alone or in pairs. The purpose is to elicit pupils’ ideas about whether they believe it is the particle itself that changes or that the particle is conserved in the change, but that something in its behaviour changes.
- The question can be set for individuals to consider and suggest answers to. They then share responses with other pupils. Make it clear they may not know the answer and need to suggest their ideas and predictions.
- Suggestions can be summarised and recorded in pupils’ books to reconsider after further lessons.

---

**Statements**

- a) Particles in solids are very closely packed together.
- b) Sometimes the particles in a substance are very far apart.
- c) Particles can move.
- d) Some particles are joined together and can’t move apart.
- e) Particles in liquids are joined loosely and can move around.

**Question**

What happens to the particles in a solid when you heat it and the solid expands?
Word game

Version 1: observable features

- No strength.
- Only mix very slowly if at all.
- Little strength.
- You can’t feel it.
- It’s heavy.
- Can feel hard.
- Often strong.
- Mix and spread out quickly.
- Hard to compress (cannot be squashed).
- Mix quite easily.
- Spread out to fill any container.
- It can be squashed.
- Easily compressed (it can be squashed).
- No fixed shape.
- Have a fixed shape.
- It’s runny so it can change its shape.
- It flows from one place to another.
- It stays in one place.
Word game

Version 2: describing particles

- The particles move quickly and in any direction from point A to point B.
- Particles are able to change position by sliding over each other.
- The particles are held strongly together.
- Particles are all touching.
- Particles vibrate faster when they are heated.
- Particles move extremely quickly when they are heated.
- The particles are not held together.
- The particles are not arranged in any particular pattern.
- The particles are held weakly together.
- The particles are organised in a regular pattern.
- The particles move more quickly when they are heated.
- The particles are not arranged in any pattern.
- Particles are close together.
- Particles are far apart.
- Particles are not able to move from point A to point B or change position.
Review learning

- Divide pupils into groups of between four and six pupils. Each group devises a role-play to show how they believe the particles are behaving in the material suggested to them.

- At various points, stop the role-play by telling the pupils to ‘freeze’ and ask individual pupils to describe themselves in terms of their size, energy, movement, direction.

Sharing responses

- Pupils make sketches to represent the particle arrangements in the examples demonstrated. They are asked to justify their choice of representation.

Group feedback

- In their groups from the role-play activity, pupils discuss their answers to the questions.

- Ask pupils to discuss how the role-play helped them to understand how particles in matter behave.

Word game

- Ask pupils to read the two sets of statements. One set describes an event or situation. The second set provides a possible appropriate explanation. Using the particle model pupils work in pairs to match the statements.

Looking ahead

- Pupils suggest one useful example of expansion and one disadvantage of expansion.

- Alternatively, present students with three scenarios involving expansion and ask them to describe what is happening and why.

Materials

- You are a solid piece of iron.
- You are a cup of water
- You are a piece of tungsten in a light filament that has just been switched on or switched off.
- You are a balloon filled with air.

Pupil sheet
## Word game

Match each observation to the correct explanation.

<table>
<thead>
<tr>
<th>Observation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromine and air mix and spread out quickly.</td>
<td>The particles are held together weakly and are able to change position by sliding over each other.</td>
</tr>
<tr>
<td>A wooden stool is not squashed flat when you sit on it.</td>
<td>The particles are far apart.</td>
</tr>
<tr>
<td>Water pours easily from one container to another.</td>
<td>The particles are all touching and are held strongly together.</td>
</tr>
<tr>
<td>A metal saucepan can be used over and over again.</td>
<td>The particles vibrate more strongly when heated.</td>
</tr>
<tr>
<td>Air trapped in a syringe can be squashed (compressed).</td>
<td>The particles are organised in a regular pattern and are held strongly together.</td>
</tr>
<tr>
<td>A metal rod increases in size (expands) when heated.</td>
<td>The particles are far apart and are able to move quickly and in any direction.</td>
</tr>
</tbody>
</table>
**Review learning**

- Divide pupils into groups of between eight and ten pupils.
- Ask pupils in each group to carry out a role-play of perfume/stink bomb being released.
- At various points stop the role-play by telling the pupils to ‘freeze’ and ask individual pupils to describe who they are, what type of particle their neighbours are and how they themselves are feeling in terms of their energy, movement and direction.

**Sharing responses**

- Ask pupils to first of all describe what they can actually see happening.
- Then use the particle model to explain why they see what they see.

**Group feedback**

- Pupils compare their predictions with the results of the demonstration of the collapsing can. Pupils say if their prediction was correct or not and explain what happened by referring to the particle model.

**Brainstorming**

- Give a pupil a word that is either a material or an event.
- Other pupils ask closed questions to determine in as few questions as possible what the word is. The pupil may only give yes or no responses.

**Looking back**

- Pupils revise and consolidate knowledge from the unit. They can use the Unit map, Pupil check list or the Test yourself questions.

---

**Questions**

- What evidence is there that the particles are moving?
- How fast the particles of bromine and air are moving?
- What evidence do they have for how fast they are moving?

**Words**

- Diffusion
- Expansion
- Melted chocolate
- Stone
- Helium balloon

---

**Suggested alternative plenary activities (5–10 minutes)**

<table>
<thead>
<tr>
<th>Review learning</th>
<th>Sharing responses</th>
<th>Group feedback</th>
<th>Brainstorming</th>
<th>Looking back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils role-play diffusion.</td>
<td>Whole-class discussion of responses and feedback on Activity G4a.</td>
<td>Groups of pupils discuss their results from Activity G4e.</td>
<td>Check progress by playing ‘guess what I am’.</td>
<td>Pupils revise and consolidate knowledge from the unit.</td>
</tr>
</tbody>
</table>
Scientific models – Think about

**Plenaries**

<table>
<thead>
<tr>
<th><strong>Group feedback</strong></th>
<th><strong>Bridging to other topics</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils discuss their answers to the challenge cards in Activity G5a.</td>
<td>The particle model will be used again in a number of topics in the future.</td>
</tr>
</tbody>
</table>

**Suggested alternative plenary activities (5–10 minutes)**

- Pupils present their ideas to the rest of the class.
- Pupils discuss the accuracy of their particle sketches.
- Discuss what additional information they could include if they could present their particle diagrams in 3D.

**Bridging to other topics**

- Describe to pupils other events or changes that they will explain using the particle model. See the examples.
- Make sure all pupils are secure with the basics of the particle model before moving on from this unit.

**Examples**

7E Neutralisation reaction (if met before this unit they could now apply their ideas of particles to how the reaction takes place)
7H Making solutions
8A How food is digested
8B How gases get into our bloodstream from our lungs
8E Atoms and elements
8F How compounds and mixtures are different
8G Explaining how rocks are weathered in the freeze thaw process
8I How energy is transferred when things heat up or cool down
9C Movement of gases in and out of plants
9L What causes gas pressure
Developing theories

1  a  Write under each picture if it is a solid, a liquid or a gas.

b  Colour each word a different colour.

c  These are the properties of solids, liquids and gases.

Colour the properties to match the words above.
2 Ideas about what everything is made from have changed over time.

Match the people to their theories.

- **Empedocles · 450BC**
  - “Everything is made up of four different substances: fire, air, water and earth.”

- **John Dalton · 1803AD**
  - “Atoms are a great idea. Different materials are made from different atoms. When you turn water into steam or ice the atoms behave differently.”

- **Democritus · 430BC**
  - He wrote an Atomic Theory. He said that his observations could only be explained using the idea of atoms.

- **Everything is made from earth, air, fire and water.**

- **Different things are made out of different atoms.**
Particle power

1. These drawings show the particles in a solid, a liquid and a gas. Match them to their descriptions.

- Solid: The particles are packed closely together in neat rows.
- Liquid: The particles are far apart, not in any pattern.
- Gas: The particles are touching. They are not in a regular pattern.

2. The particles in solids, liquids and gases are moving all the time.

Use these words to fill in the gaps.

- liquid
- can’t
- quickly
- vibrate

a. The particles in a solid wobble or .........................................
   They ........................ move around.

b. The particles in a ........................................ vibrate more than in a solid.
   They ........................ move around.
   They ........................ over each other.

c. The particles in a gas are moving ........................................ in all directions.
Looking at evidence

1 Here is a diagram of the particles in a solid.

Anita makes some observations about solids. Tick ✓ the facts about particles that explain Anita’s observations.

<table>
<thead>
<tr>
<th>Anita’s observations</th>
<th>Particles are close together</th>
<th>Particles are stuck together</th>
<th>Particles can’t move around</th>
</tr>
</thead>
<tbody>
<tr>
<td>You can’t stir a solid.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You can’t squash a solid.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You can’t pour a solid.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A solid keeps its shape.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A solid always takes up the same volume.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 Here is a diagram of the particles in a liquid.

Write true or false for each sentence.

a You can squash a liquid because the particles are not touching. ......................................

b You can pour a liquid because the particles can slide over each other. ......................................

c A liquid keeps its volume but not its shape. ......................................
3 Look carefully at the diagram of particles in a gas.

Use these words to fill in the gaps.

- The ...................................... and ...................................... of a gas can change because the particles are far apart.
- A gas can be ...................................... into a smaller volume because its particles can be ...................................... closer together.

4 In a solid, the particles vibrate on the spot. As they get hotter, they vibrate more and take up more space. The solid gets bigger.

When a hot solid cools, the particles vibrate less.

Look at these diagrams of particles in a solid as it cools down.

Write true or false for each sentence.

- A hot solid has a smaller volume than a cold solid. .................................
- The particles in a hot solid vibrate more. .................................
- The particles in hot and cold solids are touching. .................................
- As a solid cools it gets smaller because the particles take up less space. .................................
1 Jordan’s homework is about diffusion.
   a Mark Jordan’s answers with ✓ and ✗.
   b Write down the correct answers.

   ................................................................................................................................................................................................................
   ................................................................................................................................................................................................................
   ................................................................................................................................................................................................................

2 These diagrams show the particles in two gases as they mix together. They are mixed up!
Write numbers in the boxes to put them in order.

![Diagrams showing particles in two gases mixing]

a Gas particles move very slowly.
b Two different gases always mix themselves up.
c The mixing and spreading of particles in gases and liquids is called diffusion.
d Smells spread by diffusion of the smelly gas particles in the air.
e The particles in liquids move more slowly than the particles in gases.
f Diffusion is faster in liquids than in gases.
3 Look at these pictures of a sugar mouse dissolving in water.

What happens as the mouse dissolves?
Write a story to go with the pictures.
Use these words to help you.

**dissolves**
**spreads**
**mixed**
**moving**
**breaks up**
**particles**

When the sugar mouse is put in water, the water .................................................
particles loosen the sugar particles.
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
**Scientific models**

1. This picture shows some hot toffee.

   a. Is the toffee a solid, liquid or gas? ......................................

   b. Draw a diagram of the particles in hot toffee. Use this space.  

   c. The toffee is hot.  
   Colour the words that describe the particles.
   
   - far apart
   - vibrating
   - touching
   - stuck together
   - sliding over each other
   - move faster
   - move slower
   - move further apart
   - stick together

   d. The toffee cools down.  
   Colour the words that describe the particles.

   e. When the toffee has cooled enough it will turn into a:  
   solid ☐  liquid ☐  gas ☐

   f. The toffee is now cold.  
   Draw a diagram of the particles.
   Use this space.
Scientific models (continued)

2 This drawing shows a kettle boiling. Hot, gassy water called steam is coming out of the spout.

a Draw a diagram of the particles in hot steam. Use this space.

b Steam is a gas. Colour the words that describe how the particles move.

- far apart
- vibrating
- not stuck together
- moving quickly in all directions
- sliding quickly over each other
- stuck together

As the steam cools down it will change into:

- solid ice
- liquid water
- gassy steam

The steam cools down. Colour the words that describe the particles.

- slowing down
- speeding up
- moving closer together
- moving further apart
- stick together
- break apart
G1 Developing theories

1. a. Correct order under pictures is solid, liquid, gas.
   b. Solid properties – not easy to squash, not easy to pour, shape does not change, volume does not change.
   c. Liquid properties – not easy to squash, easy to pour, shape can change, volume does not change.
   d. Gas properties – easy to squash, not easy to pour, shape can change, volume can change.

2. Empedocles – Everything is made from earth, air, fire and water.
   Democritus – Different things are made out of different atoms.
   John Dalton – He wrote an Atomic Theory. He said that his observations could only be explained using the idea of atoms.

G2 Particle power

1. solid – The particles are packed closely together in neat rows.
   liquid – The particles are touching. They are not in a regular pattern.
   gas – The particles are far apart, not in any pattern.

2. a. vibrate, can’t
   b. liquid, can, slide
   c. quickly

G3 Looking at evidence

1. | Anita’s observations | Facts |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles are close together</td>
<td>Particles are stuck together</td>
</tr>
<tr>
<td>You can’t stir a solid</td>
<td>✔</td>
</tr>
<tr>
<td>You can’t squash a solid</td>
<td>✔</td>
</tr>
<tr>
<td>You can’t pour a solid</td>
<td>✔</td>
</tr>
<tr>
<td>A solid keeps its shape</td>
<td>✔</td>
</tr>
<tr>
<td>A solid always takes up the same volume</td>
<td>✔</td>
</tr>
</tbody>
</table>

2. a. false  b. true  c. true

3. a. shape, volume  b. squashed, pushed

4. a. false  b. true  c. true  d. true

G4 Spreading out

1. a. Correct homework answers are b, c, d, and e.
   b. Gas particles move very quickly.
   f. Diffusion is slower in liquids than in gases. or Diffusion is faster in gases than in liquids.

2. Correct order of numbers is 2, 3, 1.

3. A correct individual ‘story’ about dissolving.

G5 Scientific models

1. a. liquid
   b. Diagram showing molecules in a liquid.
   c. touching, sliding over each other
   d. move slower, stick together
   e. solid
   f. Diagram showing molecules in a solid.

2. a. Diagram showing molecules in a gas.
   b. far apart, moving quickly in all directions
   c. liquid water
   d. slowing down, moving closer together, stick together
Developing theories

HELP

1 Copy and complete the table below using the words **solid**, **liquid**
or **gas**.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Physical state</th>
</tr>
</thead>
<tbody>
<tr>
<td>water at 20 °C</td>
<td></td>
</tr>
<tr>
<td>ice at −5 °C</td>
<td></td>
</tr>
<tr>
<td>a plastic box</td>
<td></td>
</tr>
<tr>
<td>air</td>
<td></td>
</tr>
<tr>
<td>carbon dioxide from a fizzy drink</td>
<td></td>
</tr>
<tr>
<td>petrol in a car fuel tank</td>
<td></td>
</tr>
</tbody>
</table>

2 These words are missing from sentences **a** to **f** below. Write down the missing word for each sentence.

- **a** Solid materials are usually ......................... .
- **b** A material that expands to fill up the whole of its container is probably a ......................... .
- **c** If a material exists as a single lump then it must be a .......................... .
- **d** Liquids can be easily ......................... when you try to squeeze it.
- **e** A gas can be ......................... when you try to squeeze it.
- **f** If a substance that flows can also be boiled, it is probably a .......................... .
Developing theories (continued)

CORE

Here are some different ideas about the things that make up matter. The ideas are from three Ancient Greek scientists.

Write down the order in which you think the scientists had the ideas.

Idea A
Everything is made from earth, air, fire and water.
(Empedocles)

Idea B
Different materials are made from different types of atoms.
(Democritus)

Idea C
Everything is made from water.
(Thales)

Use the information below to help you answer questions 4 and 5.

Aristotle decided that Democritus was wrong and Empedocles was right: atoms did not exist, and everything was made up of the four ‘elements’ earth, fire, air and water. Aristotle’s theory survived for 2000 years, until scientists like John Dalton realised how wrong he was. Dalton published his work about atoms in 1803.

In 1827 another British scientist, called Robert Brown, was looking at pollen grains in water using one of the new microscopes. He noticed that the pollen grains were constantly moving all over the place. Their movement was completely random. Scientists began to call this effect ‘Brownian motion’ but they could not understand why it happened. It seemed to occur whenever you had very tiny solid particles in either still air or still water.

Eventually, scientists hit on the idea that they could link Dalton’s ideas about atoms with Brown’s observations. They suggested that invisible particles in the water were constantly moving around. They kept on colliding with the pollen grains, which moved as a result of the collisions.

We can now explain Brownian motion as ‘the random movement of visible particles resulting from collisions with very small, invisible atoms or molecules that are constantly in motion’.
Developing theories (continued)

4 a Suggest a reason why Aristotle rejected the Democritus theory about atoms.

b Look back at the information. Why was Robert Brown able to observe events caused by particles when scientists before him had not?

c Do you think that the Aristotle theory moved scientific understanding forward or held it back? Explain your views.

EXTENSION

5 a Was Dalton’s work, done before the Robert Brown experiments, a theory or a fact?

b Why was the work of Robert Brown so important?

c Scientists are still doing experiments and arguing about what particles are really like. Explain whether you think we will ever really know about particles, or whether we have now probably found out everything there is to know about them.

6 Imagine you are introducing an alien to the three states of matter. The alien does not know about solids, liquids or gases, but does understand English and how classification keys work.

Choose suitable properties that will divide up the three states of matter and use them to create a key that the alien can use to classify some samples of solids, liquids and gases.

There are several possible answers.
HELP

1 Draw and label three boxes like this in your book.

![Solid, Liquid, Gas boxes]

Inside each box, draw circles like this 📐 to show how the particles are arranged in each of the three physical states.

CORE

2 This question is about the forces between particles.
   
   a Write two sentences to describe how particles are arranged in a liquid.
   
   b How is the arrangement of particles in a solid different from the arrangement in a liquid?
   
   c Explain why gas particles are so far away from each other.

3 Why could the arrangement of particles in one solid material make it more dense than the arrangement in a different solid?
EXTENSION

4 Look at the data in the table.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density in g/cm³</th>
<th>Melting point in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>magnesium</td>
<td>1.7</td>
<td>650</td>
</tr>
<tr>
<td>X</td>
<td>3.5</td>
<td>3550</td>
</tr>
<tr>
<td>Y</td>
<td>7.0</td>
<td>420</td>
</tr>
<tr>
<td>Z</td>
<td>0.0008</td>
<td>−248</td>
</tr>
</tbody>
</table>

a What must be true about the forces between the particles in substance X and the particles in substance Z? How do you know?

b Magnesium and substance Y were both heated from 400 °C to 500 °C. In what way would the arrangement of their particles now be different? Why would they be different?

c A sample of water has a mass of 10 g. What would be the mass of a sample of substance Y that had exactly the same volume as the water? Explain your answer.

d Is substance Z most likely to be a solid, a liquid or a gas at room temperature? How do you know?

e How does the arrangement of the particles and the forces between them, in substance Z, explain its very low melting point?
Looking at evidence

HELP

1 Materials have all sorts of different properties. Here are some of the reasons for this.

- The particles in a liquid are not joined together as strongly as particles in a solid.
- Particles can slide over each other.
- Particles that are very close together cannot be pushed any closer.
- Particles that are far apart can be pushed closer together.
- Particles in a gas move quickly from one place to another.

Explain the observations below by choosing the correct reason A to E. You may not need all of the reasons.

a You cannot squash a piece of steel.

b A liquid will flow through a tube.

c When the wind blows you can feel the air on your face.

d A gas is easy to compress (squash).

e Iron is usually a solid and water is usually a liquid.
Looking at evidence (continued)

CORE

2 Look at the diagrams below.

![Diagram of a bar before and after heating]

- a What has happened to the length of the bar?
- b What has happened to the diameter of the bar?
- c What name is given to the change in shape that has happened to the bar?
- d When railway lines are laid, a small gap is left between the end of one rail and the start of the next one. Why is this necessary?
- e Laboratory thermometers are often filled with mercury, which melts at $-39 \degree C$ and boils at $357 \degree C$. Why is mercury used instead of water in thermometers that read from $-10 \degree C$ to $110 \degree C$?

EXTENSION

3 Look again at the diagram in question 2. One of your friends says that all this has happened because the particles in the bar have got bigger, so they take up more space. Explain in terms of particles whether your friend is correct or not. If not, give a better explanation.
Looking at evidence (continued)

4 Use your knowledge of the particle theory to explain why the following observations happen in the way they do.

- **a** It is easier to walk upright in the air than to walk upright, up to your neck in water, in a swimming pool.

- **b** A syringe full of air can be compressed but a syringe full of water cannot.

- **c** You can use a nail made of solid iron but not one made of liquid iron.

- **d** You can pour liquid drink from a container but, if it is frozen, it falls out in one piece.

- **e** If you drop a brick on your big toe it hurts a lot more than if you spill lots of water onto it.
‘Hundreds and thousands’ are tiny coloured strands often used to decorate trifles. If you do not eat the trifle quickly, the dye from the coloured strands spreads into the surrounding custard topping. This topping contains a lot of liquid and the dye can dissolve into it.

a. What do you call the spreading out of particles?

b. If you put hundreds and thousands into water, how fast would the colour spread out compared with on top of a trifle – slower, faster or at the same speed?

c. If you drop a crystal of purple potassium permanganate into water, what happens to the colour of the water?

d. If you burn your toast, what happens to the smoke particles?

2. Copy this balloon. Make it quite large.

Draw ten particles, inside the balloon. You must show:

- how they are packed together
- why the balloon stays blown up.
**CORE**

3 These diagrams show the numbers of air particles inside and outside a flexible metal can. The particles push against the can from the inside and from the outside.

**Key**  is an air particle.

The arrow shows the direction of movement.

a In which diagram is the pressure inside the can equal to the pressure outside the can?

b Which diagram shows a slightly lower pressure inside the can than outside the can?

c For the remaining can, explain how the pressure inside the can compares with the pressure outside the can. Give reasons for your answer.

4 Sarah brought her Nan a bowl of hyacinths for Christmas. When she visited her Nan she could smell the scent of the hyacinths as soon as she entered the house, even though the bowl was at the other end of the lounge.

Write a couple of sentences explaining how the scent could have got from the lounge to the front door.
EXTENSION

5 This diagram shows the apparatus used in an experiment. Hydrogen chloride fumes diffuse along the glass tube and react with ammonia fumes, forming a white solid where the two gases meet.

The two cotton wool balls were put into the glass tube at the same time and a stopclock started. The clock was stopped when the ring of white solid first appeared. The time taken for this to happen was 100 seconds.

a If the hydrogen chloride gas travelled 10 centimetres in 100 seconds, how far would it travel in one second? This is the speed of the hydrogen chloride particle.

b If the ammonia gas travelled 20 centimetres in 100 seconds, how far would it travel in one second? This is the speed of the ammonia particle.

c A hydrogen chloride particle is about twice as heavy as an ammonia particle. What is the relationship between the mass of a particle and the speed at which it travels?

d In fact, gas particles can travel at speeds of several hundred metres per second. Using your ideas about diffusion, explain why it took so long for the ammonia and hydrogen chloride particles to reach each other.
## Developing theories

### HELP

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Underscores show answers, other text in table copied by pupils.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>water at 20 °C – <strong>liquid</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>ice at −5 °C – <strong>solid</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>a plastic box – <strong>solid</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>air – <strong>gas</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>carbon dioxide from a fizzy drink – <strong>gas</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>petrol in a car fuel tank – <strong>liquid</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>$\text{Total for Help} = 12$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 a</td>
<td>hard</td>
<td>1</td>
</tr>
<tr>
<td>2 b</td>
<td>gas</td>
<td>1</td>
</tr>
<tr>
<td>2 c</td>
<td>solid</td>
<td>1</td>
</tr>
<tr>
<td>2 d</td>
<td>poured</td>
<td>1</td>
</tr>
<tr>
<td>2 e</td>
<td>squashed</td>
<td>1</td>
</tr>
<tr>
<td>2 f</td>
<td>liquid</td>
<td>1</td>
</tr>
</tbody>
</table>

## CORE

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 a</td>
<td>C, A, B</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><em>C before A, one mark; A before B, one mark</em></td>
<td></td>
</tr>
<tr>
<td>4 a</td>
<td>There was no evidence for them. <strong>Accept equivalent answers.</strong></td>
<td>1</td>
</tr>
<tr>
<td>4 b</td>
<td>The microscope had been invented so he could see individual pollen grains. <strong>Accept equivalent answers.</strong></td>
<td>1</td>
</tr>
<tr>
<td>4 c</td>
<td>He held it back because the wrong view was held for 2000 years. <strong>Accept equivalent answers.</strong></td>
<td>1</td>
</tr>
</tbody>
</table>

$\text{Total for Core} = 7$
Developing theories (continued)

EXTENSION

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>5a</td>
<td>Theory</td>
<td>1</td>
</tr>
<tr>
<td>5b</td>
<td>The first observation of tiny objects that could only be explained using the particle model. Accept equivalent answers.</td>
<td>1</td>
</tr>
<tr>
<td>5c</td>
<td>Either: Pupils present an argument that we probably know everything now, with a very convincing reason why we should; or: suggest that we might change our ideas again in the future because new evidence might not fit in with current thinking. Maximum two marks.</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>There are several possible answers. For example:</td>
<td>5</td>
</tr>
</tbody>
</table>

Award one mark for each 'yes' and 'no' response in the key (up to four marks) and one mark for quality of presentation, regardless of content.

Total for Extension 10
**HELP**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In the solid diagram, the particles must be regular and touching.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>In the liquid, the particles must be randomly placed with at least 50% touching at least one other particle.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>In the gas, pupils must show just a few particles a long way apart.</td>
<td>1</td>
</tr>
</tbody>
</table>

Total for Help 3

**CORE**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>The particles are mostly touching at least one other particle.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>The particles are able to move/slide over each other.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Accept equivalent answers.</em></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>The particles in a solid are in a regular pattern, but in a liquid they are arranged irregularly.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Accept equivalent answers.</em></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>There are no attractive forces or very weak attractive forces between gas particles.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Accept equivalent answers.</em></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Its particles are packed into a smaller volume than the same number of particles in a less dense material.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Accept equivalent answers.</em></td>
<td></td>
</tr>
</tbody>
</table>

Total for Core 5

**EXTENSION**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>4a</td>
<td>The forces between particles in X are much stronger than in Z because X is very hard to melt but Z is very easy to melt.</td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>The particles in magnesium would stay much the same, but the particles in Y have begun to move around <em>(or reference to random and regular arrangements)</em> because Y will have melted but magnesium will not.</td>
<td>1</td>
</tr>
<tr>
<td>c</td>
<td>70 g because its density is seven times greater than water.</td>
<td>1</td>
</tr>
<tr>
<td>d</td>
<td>Gas because it has a very low density and so its particles must be very spread out.</td>
<td>1</td>
</tr>
<tr>
<td>e</td>
<td>The particles are far apart so there are no attractive forces or very weak attractive forces between them. Weak attractive forces mean that it does not need much energy to separate the particles.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Accept equivalent answers.</em></td>
<td></td>
</tr>
</tbody>
</table>

Total for Extension 10
### HELP

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>1b</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>1c</td>
<td>E</td>
<td>1</td>
</tr>
<tr>
<td>1d</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>1e</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total for Help</strong></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

### CORE

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>It has increased / got longer.</td>
<td>1</td>
</tr>
<tr>
<td>2b</td>
<td>It has increased / got wider.</td>
<td>1</td>
</tr>
<tr>
<td>2c</td>
<td>Expansion</td>
<td>1</td>
</tr>
<tr>
<td>2d</td>
<td>So rails can expand on hot days (without buckling)</td>
<td>1</td>
</tr>
<tr>
<td>2e</td>
<td>Water would boil / Mercury will remain a liquid in this range of temperatures.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>Total for Core</strong></td>
<td>5</td>
</tr>
</tbody>
</table>

### EXTENSION

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
</table>
| 3        | Not correct.  
The individual particles do not actually get bigger, they just vibrate harder.  
They need more space in which to move, so the particles are forced further apart. | 1    |
| 4a       | Particles in air are far apart so offer little resistance.  
Particles in water are close together so offer lots of resistance. | 1    |
| 4b       | Particles in air are not close so can be pushed closer together.  
Particles in water are already close so cannot be packed much closer. | 1    |
| 4c       | Solid iron has particles in fixed positions so is rigid.  
Liquid iron particles can flow so it won’t keep its shape. | 1    |
| 4d       | Liquid drink has particles that can flow.  
Frozen drink has particles in a fixed position so won’t flow. | 1    |
| 4e       | Brick particles are in a fixed position and close together so weight is concentrated.  
Water particles flow round your toe so weight is not concentrated. | 1    |
|          | **Total for Extension**                                 | 13   |
Spreading out

HELP

1a Diffusion 1
b Faster 1
c It slowly turns purple. 1
d They spread around the room. 1

2 The particles in the balloon must have space between them and some must be hitting the inside surface of the balloon. 1

Total for Help 6

CORE

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>3b</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>3c</td>
<td>The pressure inside is larger than the pressure outside because there are more particles hitting the inside than the outside.</td>
<td>1</td>
</tr>
</tbody>
</table>

4 The scent particles from the hyacinth diffuse / spread into the air. Eventually they spread through all the house. 
Accept equivalent answers. 1

Total for Core 6

EXTENSION

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>5a</td>
<td>0.1 cm</td>
<td>1</td>
</tr>
<tr>
<td>5b</td>
<td>0.2 cm</td>
<td>1</td>
</tr>
</tbody>
</table>
| 5c       | The heavier the particle, the slower it moves. 
Accept equivalent answers. | 1 |
| 5d       | The particles are moving fast really but they collide with air particles in the tube which stops the gas particles from moving straight towards each other. | 1 |

Total for Extension 6
Particle model of solids, liquids and gases

1 For each substance below, show whether it is a solid, a liquid or a gas by joining it to the correct box.

- ice
- oxygen
- petrol

- liquid
- solid
- gas

- carbon dioxide
- copper sulphate solution
- salt

2 Complete these sentences by writing **shape** or **size** in each space.
   a. Solids keep the same ....................... and ......................
   b. Liquids keep the same ....................... but not the same ......................
   c. Gases do not keep the same ....................... or ......................

3 Which of these sentences explains why a can collapses when the air is removed from it? Circle the correct letter.
   A. There are more air particles outside the can than inside.
   B. There are more air particles inside the can than outside.
   C. The air particles inside the can aren’t pushing as hard as they were.
   D. All the air has been sucked out.

4 Beth says that jelly is a liquid, but Adam says that jelly is a solid.
   a. Write down one observation that supports Beth’s argument.
   ..............................................................
   b. Write down one observation that supports Adam’s argument.
   ..............................................................
   c. Is jelly a solid, a liquid, a gas or a mixture? ......................

5 Geri did some experiments where she tried to squash solids, liquids and gases in syringes. She wrote down these statements. Underline the true statement(s).
   A. Gases can be squashed.
   B. Liquids can be squashed.
   C. Solids cannot be squashed.
6 **a** Which diagram shows the arrangement of particles in a solid? ..........  

**b** Which diagram shows the arrangement of particles in a liquid? ..........  

**c** Which diagram shows the arrangement of particles in a gas? ..........  

7 Simon investigated particles by heating a bar and seeing how it fitted in a gauge. Before he heated the bar, it fitted perfectly in the gauge, but when he heated the bar it changed.

Underline the statements that are true.

A The bar expanded.  
B The bar contracted.  
C The bar got longer.  
D The bar got shorter.  
E The bar got thinner.  
F The bar got thicker.  
G The particles in the bar expanded.  
H The particles in the bar contracted.  
I The particles in the bar moved further apart.  
J The particles in the bar moved closer together.  

8 Which of these sentences best explains why diffusion happens when gases mix? Circle the correct letter.

A Both gases are made of particles.  
B Particles move around all the time.  
C Particles are very small.  
D Gas particles are attracted towards each other.
Particle model of solids, liquids and gases (continued)

9 Which of these sentences best explains why gases have a pressure? Circle the correct letter.

A Gases are made of particles which push against each other.
B Particles are very small and move around.
C Particles move and hit the walls of their container.
D Gas particles are attracted towards each other.

10 Complete the crossword.

Across
1 There are no pulling forces between the particles in a .......... .
3 A .......... is an idea that explains something.
5 When the particles of a gas hit the sides of the container they give a little push. We call this force gas .......... .
8 The particles in a .......... are close together, but they can move around.

Down
2 Everything is made up of tiny particles called .......... .
4 There are many fewer particles in 1 litre of gas than 1 litre of liquid. Gas is less .......... than liquid.
6 The particles are closely packed in neat rows in a .......... .
7 In diffusion, the different particles move around and .......... together.
Particle model of solids, liquids and gases

1 For each substance below, show whether it is a solid, a liquid or a gas by joining it to the correct box.

- ice ● liquid
- oxygen ● solid
- petrol ● gas
- carbon dioxide
- copper sulphate solution
- salt

2 Complete these sentences by writing **shape** or **size** in each space.

- a Solids keep the same **shape** and **size**.
- b Liquids keep the same **size** but not the same **shape**.
- c Gases do not keep the same **shape** or **size**.

3 Which of these sentences explains why a can collapses when the air is removed from it? Circle the correct letter.

A There are more air particles outside the can than inside.
B There are more air particles inside the can than outside.
C The air particles inside the can aren’t pushing as hard as they were.
D All the air has been sucked out.

4 Beth says that jelly is a liquid, but Adam says that jelly is a solid.

- a Write down one observation that supports Beth’s argument.
  ...............................................................................................................................................................

- b Write down one observation that supports Adam’s argument.
  ...............................................................................................................................................................

- c Is jelly a solid, a liquid, a gas or a mixture? **mixture**

5 Geri did some experiments where she tried to squash solids, liquids and gases in syringes. She wrote down these statements. Underline the true statement(s).

- A **Gases can be squashed.**
- B **Liquids can be squashed.**
- C **Solids cannot be squashed.**
Particle model of solids, liquids and gases (continued)

6 a Which diagram shows the arrangement of particles in a solid? ..............
   b Which diagram shows the arrangement of particles in a liquid? ..............
   c Which diagram shows the arrangement of particles in a gas? ..............

7 Simon investigated particles by heating a bar and seeing how it fitted in a gauge. Before he heated the bar, it fitted perfectly in the gauge, but when he heated the bar it changed.

Underline the statements that are true.

A The bar expanded.
B The bar contracted.
C The bar got longer.
D The bar got shorter.
E The bar got thinner.
F The bar got thicker.
G The particles in the bar expanded.
H The particles in the bar contracted.
I The particles in the bar moved further apart.
J The particles in the bar moved closer together.

8 Which of these sentences best explains why diffusion happens when gases mix? Circle the correct letter.

A Both gases are made of particles.
B Particles move around all the time.
C Particles are very small.
D Gas particles are attracted towards each other.
Particle model of solids, liquids and gases
(continued)

9 Which of these sentences best explains why gases have a pressure? Circle the correct letter.

A Gases are made of particles which push against each other.
B Particles are very small and move around.
C Particles move and hit the walls of their container.
D Gas particles are attracted towards each other.

10 Complete the crossword.

Across
1 There are no pulling forces between the particles in a .......... .
3 A .......... is an idea that explains something.
5 When the particles of a gas hit the sides of the container they give a little push. We call this force gas .......... .
8 The particles in a .......... are close together, but they can move around.

Down
2 Everything is made up of tiny particles called .......... .
4 There are many fewer particles in 1 litre of gas than 1 litre of liquid.
Gas is less .......... than liquid.
6 The particles are closely packed in neat rows in a .......... .
7 In diffusion, the different particles move around and .......... together.
1 For each of these substances, write down if it is a solid, a liquid or a gas.
   a water  b air  c rock  

2 What is the missing word in each sentence?
   a Water is a .......... because it keeps the same volume but not the same size.
   b Ice is a .......... because it keeps the same volume and the same size.
   c Steam is a .......... because it does not keep the same volume or the same size.

3 James says that tomato ketchup is a liquid, but Madge says that tomato ketchup is a solid. They made some observations:
   ● Tomato ketchup always has the same volume.
   ● Tomato ketchup can slowly change shape.
   ● Tomato ketchup is red.
   ● Tomato ketchup has a soft surface.

   a Write down one observation that supports James’s argument.
   b Write down one observation that supports Madge’s argument.
   c How should James and Madge classify tomato ketchup?
   d Explain your answer to c.

4 Look at the particle diagrams below. Say which one shows the arrangement of particles in a:
   a gas  b liquid  c solid

   d In which one – solid, liquid or gas – do the particles move the fastest?
5 Andrew did some experiments with solids, liquids and gases. He filled a closed syringe with one substance at a time and pressed the plunger.

Answer the questions below by choosing the letter (A to D) of the best answer.

A The plunger did not move.
B The plunger moved a little way then stopped.
C The plunger moved in and sprang back out when released.
D The plunger moved in right to the end of the syringe.

a Which sentence describes what happened when Andrew put a gas in the syringe? 1 mark

b Which sentence describes what happened when Andrew put a liquid in the syringe? 1 mark

c Which sentence describes what happened when Andrew put a solid in the syringe? 1 mark

6 Yasmin investigated particles by heating a bar and seeing how it fitted in a gauge. Before heating the bar, it fitted perfectly in the gauge.

a Choose the correct word to complete the sentences.
   i When the bar was heated, it got longer/shorter. 1 mark
   ii When the bar was heated, it got thinner/thicker. 1 mark

b i Explain what happened during heating to the way the particles in the bar were arranged. 1 mark
   ii Why did this lead to the changes which Yasmin observed? 1 mark
David had a small dish containing a special jelly called agar. He placed a pink crystal on it, like this:

After a few days he checked the dish and it looked like this:

**a** What has happened to the pink colour of the crystal?  

1 mark

**b** How could David measure the change in the size of the spot?

1 mark

**c** What is the scientific word for what has happened?

1 mark

David repeats the experiment. He has replaced the jelly with water.

**d** How will this affect what happens to the pink colour?

1 mark
James says that tomato ketchup is a liquid, but Madge says that tomato ketchup is a solid. They made some observations:

- Tomato ketchup always has the same volume.
- Tomato ketchup can slowly change shape.
- Tomato ketchup is red.
- Tomato ketchup has a soft surface.

a Write down one observation that supports James’s argument.  

b Write down one observation that supports Madge’s argument.  

c How should James and Madge classify tomato ketchup?  

d Explain your answer to c.  

Andrew did some experiments with solids, liquids and gases. He filled a closed syringe with one substance at a time and pressed the plunger.

Answer the questions below by choosing the letter (A to D) of the best answer.

A The plunger did not move.  
B The plunger moved a little way then stopped.  
C The plunger moved in and sprang back out when released.  
D The plunger moved in right to the end of the syringe.

a Which sentence describes what happened when Andrew put a gas in the syringe?  

b Which sentence describes what happened when Andrew put a liquid in the syringe?  

c Which sentence describes what happened when Andrew put a solid in the syringe?
3 Look at the particle diagrams below. Say which one shows the arrangement of particles in:

- **a** gas  
- **b** liquid  
- **c** solid

3 marks

**d** In which one – solid, liquid or gas – do the particles move the fastest?  
1 mark

4 Yasmin investigated particles by heating a bar and seeing how it fitted in a gauge. Before heating the bar, it fitted perfectly in the gauge.

- **a** Choose the correct words to complete the sentences.
  - i When the bar was heated, it got **longer**/shorter.  
  - ii When the bar was heated, it got **thinner**/thicker.  

  1 mark, 1 mark

- **b** i Explain what happened during heating to the way the particles in the bar were arranged.  

  1 mark

  - ii Why did this lead to the changes which Yasmin observed?  

  1 mark

5 Wayne used a pump to suck all of the air out of a large metal can. After the air was removed, the can collapsed.

- **a** What do air particles do that causes air pressure?  

  1 mark

- **b** As the can started to collapse, was the air pressure greater inside or outside the can?  

  1 mark

- **c** What does this tell us about the quantity of air particles in the can compared to the quantity of air particles outside the can?  

  1 mark

- **d** Using ideas about particles, write one sentence to explain why the can collapsed.  

  1 mark
Particle model of solids, liquids and gases (continued)

6 Ruth leaves a bottle of perfume open in her bedroom, and then lies on her bed on the other side of the room to read a magazine. The smell of the perfume spreads out through the room.

a Using ideas about particles, explain why Ruth could smell the perfume after a few minutes.

b Using ideas about particles, explain why it took a few minutes before Ruth could smell the perfume.

7 David had a small dish containing a special jelly called agar. He placed a small pink crystal on it. After a few days the dish looked like this:

David repeated the experiment. He used water instead of jelly.

a How would this affect what happened to the pink colour?

b Explain how the particles in the jelly and the water caused this effect.

c Why would the pink colour be paler?
# Particle model of solids, liquids and gases

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 a</strong></td>
<td>Liquid</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>Gas</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>Solid</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>2 a</strong></td>
<td>Liquid</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>Solid</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>Gas</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>3 a</strong></td>
<td>Tomato ketchup can slowly change shape.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>Tomato ketchup always has the same volume.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td><em>Either</em> as a liquid or a mixture</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>d</strong></td>
<td>Has the properties of a liquid/can change shape like a liquid/has the properties of both solids and liquids. <em>Accept equivalent answers.</em></td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td><strong>4 a</strong></td>
<td>A</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>C</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>B</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>d</strong></td>
<td>gas</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>5 a</strong></td>
<td>C The plunger moved in and sprang back out when released.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>B The plunger moved a little way then stopped.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>A The plunger did not move</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>6 a i</strong></td>
<td>Longer</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>ii</strong></td>
<td>Thicker</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>b i</strong></td>
<td>The particles moved further apart. <em>Accept equivalent answers.</em></td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td><strong>ii</strong></td>
<td>As the particles have moved further apart, they take up more space (or volume) so the dimensions of the bar increase in all directions. <em>Accept equivalent answers. Award 1 mark for particle.</em></td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td><strong>7 a</strong></td>
<td>Spread out</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>With a ruler</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>Diffusion</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>d</strong></td>
<td>It will spread out faster.</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Scores in the range of:  

<table>
<thead>
<tr>
<th>Scores in the range of</th>
<th>NC Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>4–7</td>
<td>2</td>
</tr>
<tr>
<td>8–13</td>
<td>3</td>
</tr>
<tr>
<td>14–17</td>
<td>4</td>
</tr>
<tr>
<td>18–25</td>
<td>5</td>
</tr>
</tbody>
</table>
## Particle model of solids, liquids and gases

### End of unit test mark scheme

#### Red (NC Tier 3–6)

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Mark</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 a</strong></td>
<td>Tomato ketchup can slowly change shape.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>1 b</strong></td>
<td>Tomato ketchup always has the same volume.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>1 c</strong></td>
<td>Either as a mixture or a liquid</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
| **1 d** | Has the properties of both solids and liquid/has the properties of a liquid/can change shape like a liquid  
*Accept equivalent answers.* | 1 | 5 |
| **2 a** | C The plunger moved in and sprang back out when released. | 1 | 4 |
| **2 b** | B The plunger moved a little way then stopped. | 1 | 4 |
| **2 c** | A The plunger did not move. | 1 | 4 |
| **3 a** | A | 1 | 4 |
| **3 b** | C | 1 | 4 |
| **3 c** | B | 1 | 4 |
| **3 d** | gas | 1 | 4 |
| **4 a i** | Longer | 1 | 3 |
| **4 a ii** | Thicker | 1 | 3 |
| **4 b i** | The particles moved further apart.  
*Accept equivalent answers.* | 1 | 5 |
| **4 b ii** | As the particles have moved further apart, they take up more space (or volume) so the dimensions of the bar increase in all directions.  
*Accept equivalent answers.* | 1 | 5 |
| **5 a** | Collide with the walls (of their container) | 1 | 5 |
| **5 b** | Outside the can | 1 | 5 |
| **5 c** | Fewer particles inside the can  
*Obviously there must always be more particles outside the can, but the question is written to allow access rather than ask about the number of air particles per unit volume.* | 1 | 5 |
| **5 d** | The can collapsed because the particles outside the can pushed inwards harder than the particles inside the can pushed outwards.  
*Accept equivalent answers.* | 1 | 5 |
| **6 a** | Because particles spread out. *Accept equivalent answers. Do not accept particles move without more explanation.* | 1 | 6 |
| **6 b** | It takes time for the perfume particles to travel/perfume particles travel slowly because they keep colliding with air particles.  
*Accept equivalent answers.* | 1 | 6 |
| **7 a** | The colour would spread out faster. | 1 | 4 |
| **7 b** | Water particles move/slide over each other faster; jelly particles move slower/are more tightly packed | 2 | 5 |
| **7 c** | More spread out | 1 | 5 |

### Scores in the range of:

<table>
<thead>
<tr>
<th>Range</th>
<th>NC Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>4–8</td>
<td>3</td>
</tr>
<tr>
<td>9–14</td>
<td>4</td>
</tr>
<tr>
<td>15–18</td>
<td>5</td>
</tr>
<tr>
<td>19–25</td>
<td>6</td>
</tr>
</tbody>
</table>
# Particle model of solids, liquids and gases

<table>
<thead>
<tr>
<th>Learning outcomes</th>
<th>I can do this very well</th>
<th>I can do this quite well</th>
<th>I need to do more work on this</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can describe how scientists think about evidence and use it to develop new ideas that can be tested.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can describe evidence to support the idea of particles.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can recognise and draw arrangements of particles in solids, liquids and gases.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can use the particle model to explain how solids, liquids and gases vary in their physical properties.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can explain how a metal expands using my ideas of particles.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can explain how diffusion takes place using the particle model.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can use the particle model to explain gas pressure.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can use my ideas of particles to explain patterns in the properties of solids, liquids and gases.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can use my ideas of particles to help predict the behaviour of solids, liquids and gases.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Particle model of solids, liquids and gases

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>atom</td>
<td>Anything that is made up of particles. A material may be a solid, a liquid or a gas.</td>
</tr>
<tr>
<td>dense</td>
<td>A state of matter that is dense and has a fixed shape and volume.</td>
</tr>
<tr>
<td>density</td>
<td>A state of matter that flows. The shape of a liquid can change, but its volume is fixed.</td>
</tr>
<tr>
<td>diffusion</td>
<td>A state of matter that is not very dense. A gas is easily squashed. Its shape and volume can change.</td>
</tr>
<tr>
<td>element</td>
<td>The smallest part of an element.</td>
</tr>
<tr>
<td>expand</td>
<td>A set of ideas to explain something.</td>
</tr>
<tr>
<td>gas</td>
<td>Tiny parts that make up every type of matter.</td>
</tr>
<tr>
<td>gas pressure</td>
<td>A group of two or more atoms joined together.</td>
</tr>
<tr>
<td>liquid</td>
<td>Anything that has mass is made up of matter. Matter contains particles. R</td>
</tr>
<tr>
<td>matter</td>
<td>A substance that contains only one type of atom. R</td>
</tr>
<tr>
<td>model</td>
<td>The idea that everything is made up of particles.</td>
</tr>
<tr>
<td>molecule</td>
<td>A dense material has a lot of particles in a small volume.</td>
</tr>
<tr>
<td>particle model</td>
<td>How heavy a material is for its size.</td>
</tr>
<tr>
<td>particles</td>
<td>To get bigger. A solid expands when you heat it because the particles move faster and take up more space.</td>
</tr>
<tr>
<td>solid</td>
<td>Gas or liquid particles spreading out as their particles move and mix.</td>
</tr>
<tr>
<td>sublimation</td>
<td>A force caused by gas particles hitting the sides of their container.</td>
</tr>
<tr>
<td>theory</td>
<td>An idea or picture made up by a scientist to show a situation that cannot be seen. A model helps scientists think through explanations.</td>
</tr>
<tr>
<td></td>
<td>Changing straight from a solid to a gas without becoming a liquid. R</td>
</tr>
</tbody>
</table>
Particle model of solids, liquids and gases

atom, dense, density, diffusion, element, expand, gas, gas pressure, liquid, material, matter, model, molecule, particle, particle model, solid, sublimation, theory.
**G1 Developing theories**

**Green**
- a. Empedocles
- b. Leucippus

1. | 580 BC | 520 BC | 480 BC | 450 BC | 430 BC |
   | Thales (all made of water) | Anaximander (all made of fire) | Heraclitus (air) | Empedocles (earth, air, fire, water) | Democritus (atoms with more detail) |
   | 580 BC | 520 BC | 480 BC | 450 BC | 430 BC |
   | Thales (all made of water) | Anaximander (all made of fire) | Heraclitus (air) | Empedocles (earth, air, fire, water) | Democritus (atoms with more detail) |

2. Individual answers.

**Red**
- a. In a solid.
- b. Less dense.

1. | Properties | Solid | Liquid | Gas |
   | forces between particles | high | medium | none |
   | regular pattern of particles | high | none | none |
   | space between particles | none | low | high |
   | compressibility ('squashability') | none | none | high |
   | density | high | high | low |
   | speed of particles | none | low | high |
   | vibration of particles | low | medium | high |

2. The particles in the liquid are very close together. In the steam there are great distances between the particles.

**G2 Particle power**

**Green**
- a. Particles are packed closely together, arranged in neat rows, are joined together strongly and do not move much.
- b. The particles are close together but are joined together less strongly than in a solid. The particles can slide over each other and are not in a regular pattern.
- c. The particles in a solid are held together with stronger forces than the particles in a liquid.
- d. The particles are moving quickly.
- e. In a gas, there are no forces holding the particles together.
- f. B

1. The particles in a solid are held together most strongly. In liquids the particles are in neat, ordered rows. In gases the particles are moving most quickly.

2. A liquid.

3. a. They both have the same mass, 1 kg, so neither is heavier than the other.
   - b. The steam.
   - c. The water.

**Red**
- a. In a solid.
- b. Less dense.

1. The ideas of Empedocles and Aristotle that everything is composed of earth, air, fire and water.
- c. The ideas of Democritus and Dalton that matter is composed of atoms.

2. Individual answers.

**G3 Looking at evidence**

**Green**
- a. The particles are joined together by strong forces.
- b. The particles are already touching each other. You can’t push them any closer together.
c Because the particles aren’t joined together as strongly as in a solid. The particles can move over each other.

d The particles are already touching. You can’t push them closer together.

e There are large spaces between the particles. So you can push them closer together.

f The particles aren’t held together. They just move aside when we walk through them.

1 There are no spaces between the particles in a liquid. They touch each other so you can’t push them together any closer.

2 The wind has fast moving air particles. When they hit the sails, the particles push against the sails which then moves the ship.

Red

a The particles in a solid are touching each other. There is no space between them so you cannot push them together any closer.

b The particles in a liquid are touching each other. There is no space between them so you cannot push them together any closer.

c The particles in a gas are very far apart from each other. Most of the space in a gas is empty. Therefore the particles can be squashed together quite easily. The particles of a gas cannot be felt except when they move very quickly, as in the wind and blowing your breath.

d The particles of aluminium will vibrate less rapidly as it cools. These smaller vibrations mean that the particles take up less space, so the overall size of the aluminium decreases.

1 The man will hurt himself when he hits the water because there are no spaces between the particles in the water. They touch each other so you can’t push them together any closer. They can’t be compressed. If he fell on the floor of a bouncy castle full of air, there is lots of spaces between the particles of air in the castle. The particles of air will be compressed, pushed together more closely, so he will have a soft landing.

2 The wind has fast moving air particles. When they hit the sails, the particles push against the sails which then moves the ship.

G4 Spreading out

Green

a It takes time for the particles of gas from the stink bomb to spread through the air particles to reach people further away.

b There is more space between the particles of gas. The particles of the diffusing substance don’t bump into the gas particles as often as they would in the liquid whose particles are closer together.

c More of the purple substance had diffused to the top.

d Gas particles move quickly in all directions.

e Gas pressure is caused by the gas particles hitting the walls of the container they are in.

1 Gas particles can move and spread out in all directions. Eventually, they spread out evenly in the air. This mixing is called diffusion. Gas pressure is caused by the particles of a gas hitting the sides of the container. Each hit gives the container a little push.

2 There is no space in between the particles of a solid for particles of another substance to diffuse in.

3 As you put more air particles into the balloon, there are more hits of air particles on the walls inside the balloon. This causes more pressure inside the balloon so it gets bigger.

Red

a It takes time for the particles of gas from the stink bomb to spread through the air particles to reach people further away.

b On a hot day. The particles of the stink bomb and air move more quickly at higher temperatures.

1 Diffusion is faster in a gas than in a liquid. There are lots of spaces between particles of a gas, so the diffusing substance can travel easily through the space. The particles of a liquid touch each other, so there is no space for the diffusing particles to slip in except by replacing the liquid particles as these move about.

2 Appropriate diagram showing that some diffusion has occurred.

3 The particles of a gas move faster when they are heated. The faster they move, the more collisions they make with the inner walls of the tyre. More collisions cause the pressure in the tyre to be higher, making the tyre harder.

4 On a hot day the air particles inside the balloons move faster than on a cooler day. The faster moving air particles hit the walls inside the balloons more frequently causing higher pressure. The higher pressures make the balloons expand until some of them burst.

G5 Scientific models

Green

a Individual answers.

b Smell them, shake them, etc.

c i Similar rectangular shape.

ii Different size and weight.

d As the air in the balloon became colder, the gas particles moved slower and got much closer together.

e The particles will move faster as they heat up and therefore get further apart and take up more space, making the balloon get bigger.
f The hot glass is like a liquid. The particles of the glass can slide about over each other.

g The liquid glass particles move about each other when they are hot. After they cool down they stop moving and are fixed in one place so the shape remains fixed.

1 a The liquid will become a gas.
   b The liquid mercury will become a solid if it is cooled to a very low temperature.
   c Nitrogen will become a liquid if it is cooled to a very low temperature.

2 a The hot food sends some particles into gas. The food particles diffuse in the air and spread throughout the house.
   b The metal lid contracts to a smaller size than the glass, so it becomes very tight on the glass jar.

Red

a She could shake them, compare their shapes and sizes, smell them.

b They are similar in that they are both rectangular in shape. They differ in size and weight.

c As the particles of air are cooled, they move less quickly so they take up less space. They also make fewer collisions on the wall of the balloon, so the balloon becomes smaller.

d As the air particles warm up they move more quickly and take up more space. They make more collisions with the walls of the balloon so the balloon gets bigger.

e The glass particles move and slide about each other when they are hot.

f In the cold glass bottle the particles are in fixed positions and do not move around. In the hot ball of glass the particles move around and slide over each other.

g i When the iodine is heated, the particles of the solid move very quickly and become gas particles.
   ii When the hot iodine gas particles are cooled, they become stationary and turn into a solid.

h The pulling forces between the particles in the solid metal are very strong. When the testing machine pulls hard enough, these strong pulling forces are overcome and the metal breaks apart.

1 When the solid carbon dioxide warmed up it would turn into a gas. There is no liquid stage in-between the solid and gas, like iodine, so there would be no flooding on Mars.

2 Models are made to experiment with ideas which cannot actually be made into real objects or would cost too much to make if they could. They experiment with the models to try to understand how similar objects or situations would work.

3 Glass has some liquid properties that cause a very very slow flow downwards due to gravity. This only occurs after a great deal of time has passed.

4 It may be dangerous to add very hot water to very cold glass because the glass could shatter. This is caused by the sudden expansion of the surface of the glass where the hot water first touches it, while the glass beneath the surface is still cold.