

# Explaining change processes using a simple particle model of matter

Science teaching unit



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# Explaining change processes using a simple particle model of matter

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# Explaining change processes using a simple particle model of matter

## Background

This teaching sequence is designed for Key Stage 3. Some teachers may choose to split it into two parts, teaching lessons 1–4 (modelling physical change) at the beginning of Key Stage 3, leaving lessons 6–7 (modelling chemical change) until later. It links to the Secondary National Strategy Framework for science yearly learning objectives and provides coverage of parts of the QCA Programme of Study for science. The overall aim of the sequence is for pupils to develop a meaningful understanding of a scientific model to describe and explain the properties of matter during physical and chemical change processes, and to be able to use that model to explain change processes. In particular, they should be able to use the model to explain counter-intuitive aspects of the behaviour of matter during change processes (e.g. conservation of mass in processes involving changes in and out of the gaseous phase).

The overall aim is addressed through interactive teaching approaches where links between subject matter are explored and established through appropriate talk between teacher and pupils, and amongst pupils. Pupils' understanding will be built upon later, when the simple particle model is developed to include electron structure.

## Teaching design principles

The design of this sequence is based upon a number of key principles. These are listed below:

### Working on knowledge

The sequence involves:

- explicitly working from pupils' ideas about particle models of matter;
- developing, and learning how to use, a particle model of matter which is good enough to explain various physical and chemical change processes.



### Teaching approach

The sequence involves:

- introducing a model of the structure of matter based upon particles, to explain simple physical properties of matter in solids, liquids and gases;
- explicitly challenging common errors made by pupils in accounting for the properties and behaviour of matter in terms of a particle model;
- using the model to define chemical change and to distinguish it from physical change;
- using this model to define substance as distinct from mixture, and element as distinct from compound.

### Modes of interaction

The sequence involves:

- using different modes of interaction between teacher and pupils according to different teaching aims;
- providing opportunities for pupil-pupil talk, mainly in pairs.

### How science works

This sequence involves:

- developing the general idea of a scientific model as a device for explaining or accounting for various properties of matter, including physical and chemical change processes.

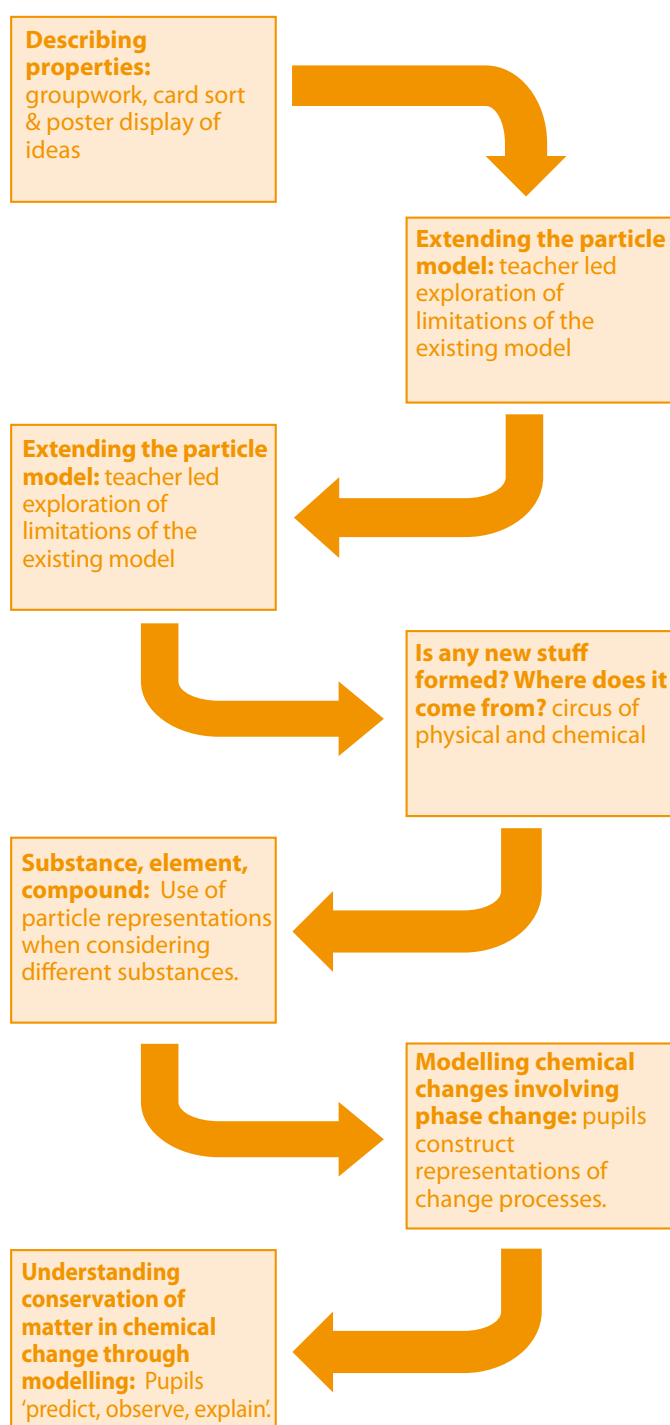
Overall, the teaching approach involves moving between the world of models, including the (simple) particle model of matter, and the observable properties and behaviour of matter. In subsequent teaching, it will be possible to differentiate this simple particle model from more sophisticated models, and to discuss the purpose of modelling in science.

### Pupils' curriculum starting points

By the time pupils arrive at their science lessons in Key Stage 3, they will have experienced some teaching about the properties of matter. Pupils ought to have experience of classifying matter as solid, liquid or gas, and have seen examples of both physical and chemical change.

What most pupils will NOT have is a coherent model to explain the properties and behaviour of matter, though many may have heard of atoms and molecules. The overall aim for this sequence of lessons is therefore to introduce a scientific model that is good enough to explain key properties of matter, and key aspects of physical and chemical change.

# Explaining change processes using a simple particle model of matter: Overview



# Lesson 1: Describing properties

In this lesson some key physical properties of solids, liquids and gases are reviewed and a 'pattern' in these properties identified. This pattern of properties is then used as a basis upon which to develop pupils' thinking about the internal structure of solids, liquids and gases.

## Activity 1.1: A review of the properties of solids, liquids and gases.

This activity starts with pupils' ideas about the characteristic properties of solids, liquids and gases.

### Teaching objectives

- To encourage the pupils to talk through their ideas about the properties of solids, liquids and gases, thereby motivating them to start thinking about this topic.
- To collect Assessment for Learning (AfL) baseline information about the pupils' existing ideas on this subject.
- To develop a shared view of the characteristic properties of solids, liquids and gases.

### Learning outcomes

By the end of the activity, pupils will be able to:

- identify their own ideas about the properties of solids, liquids and gases;
- begin to recognise characteristic properties of solids, liquids and gases.

### What to prepare

- Sheet 1.1: 'Solids, liquids and gases: properties'.
- Table 1.1 made into a card sort.

### Mode of interaction

**The teacher works with the pupils using an INTERACTIVE/ AUTHORITATIVE approach to identify the characteristic properties of solids, liquids and gases.**



### What happens during this activity

The purpose of this activity is for pupils to construct a model of solids, liquids and gases, through observing some of their features. Pupils carry out the activities on Sheet 1.1. They then assign the cards from Table 1.1 to match their observations with possible explanations about how the particles might be different at each state, and finally begin to visualise what these particles might look like, through poster work and role-play.

Evidence suggests that many Key Stage 3 pupils think that gases are 'nothing'; some examples are therefore included to encourage pupils to think about gases as being 'something' (substantial), and as having distinctive properties. This activity can be carried out as an interactive demonstration by the teacher or as a circus of activities which the pupils work round in pairs.


The examples and the intended focus for each are as follows:

Examples	Focus
<b>Plungers:</b> the plungers of sealed syringes of solids, liquids and gases are pushed down by the pupils.	There is little difference between the compressibility of solids and liquids, but gases are easily compressed.
<b>Beakers:</b> Ice and water are placed in beakers. Alternatively, a square of chocolate and a molten square of chocolate could be used.	Liquids take the shape of the containing vessel; solids have their own shape.
<b>Inverted glass:</b> An inverted glass is pushed down into a trough of water.	When the glass is under the water it remains 'empty' as the trapped air keeps the water out, showing that air is a real substance.
<b>Fluidity:</b> Can you push your hand through?	A hand can pass through the gas and liquid, but not the solid.
<b>Spacing:</b> Adding 10 cm <sup>3</sup> sugar to 25 cm <sup>3</sup> of hot water.	The final volume should be 35cm <sup>3</sup> , but is in fact less than this. This activity will help pupils to recognise that there are some gaps between the particles of the liquid.

The teacher reviews pupils' observations and moves towards an agreed pattern of properties of solids, liquids and gases. This may be along the lines of:

Property	Solids	Liquids	Gases
<b>1. Compressibility</b>	cannot be compressed	cannot be compressed	can be compressed
<b>2. Shape</b>	have a fixed shape	take shape of container	spread into space
<b>3. Fluidity</b>	cannot move hand through	can move hand through	can easily move hand through
<b>4. Density</b>	heavy/light	heavy/light	light

### Activity 1.2: Particle model development.

In this activity the pupils move towards explaining the pattern of properties of solids, liquids and gases in terms of what is 'inside' (the internal structure of) each substance. Refer to *Strengthening the teaching and learning of particles in Key Stage 3 science* – Handouts 1.7 and 1.8 when developing models with pupils. 

#### Teaching objective

- To encourage pupils to develop a model to represent the properties of solids, liquids and gases.

#### Learning outcomes

By the end of the activity, most pupils will be able to:

- begin to construct a particle model that accounts for the properties that they have observed.

#### What to prepare

- Each group needs a copy of the agreed pattern of properties.
- Poster paper and pens.

#### Mode of interaction

**Pupils work in small groups following an INTERACTIVE/ DIALOGIC approach as they put forward their ideas about what is inside solids, liquids and gases that gives rise to the distinctive pattern of properties.**




**DIALOGIC  
HOTSPOT**

### What happens during this activity

The question is posed:

*'What might the solids, liquids and gases be like inside in such a way that they give rise to this pattern of properties?'*

Show pupils Handout 2.5 from *Strengthening the teaching and learning of particles in Key Stage 3 science*. 


This is an image from a particular type of microscope. Ask pupils what it suggests about the arrangement of particles in this solid.

Pupils use the cards from the previous activity and their findings from Sheet 1.1.

They work in groups of four to develop models of what must be 'inside' the solid, liquid and gas to give rise to the pattern of properties. The models are presented on large posters.

In developing their models the pupils should be reminded that the aim is to account for the pattern of properties. Relative compressibility is commonly used by pupils to argue that the particles must be close together in solids and liquids but not in gases. This fits in with the relatively low densities of gases.

The pupils' model posters are displayed in the classroom. Through question and answer work, the teacher identifies key features of the models, and negotiates an 'agreed class model' that will form the basis of further modelling in this unit and will be referred back to during subsequent teaching.

Pupils work in groups of about eight. Using their posters, they develop a role-play to explain how solids, liquids and gases are different from each other. Refer to *Strengthening the teaching and learning of particles in Key Stage 3 science*.  Pupils relate the role-play to each of the features they have investigated, explaining how their model accounts for the observations they have previously made. Key questions to pose in moving towards a scientifically acceptable model for the three phases are:

- How do we explain compressibility?
- How do we explain fluidity?
- What is in between the particles?

These questions are returned to in the plenary for this activity.

## Plenary session

In the plenary, the teacher firstly reviews the posters produced by the pupils and then builds upon these by using the key questions to introduce a scientific particle model for the three states of matter.

### Q1: How do we explain compressibility?

Important points to be drawn out here: gases can be compressed and so there must be large spaces between the particles; liquids and solids cannot be compressed so the particles must be closely packed; compression in gases is caused by the particles being pushed closer together rather than the particles themselves being compressed.

### Q2: How do we explain fluidity?

In fluids (liquids and gases) the particles can move freely across one another whereas in solids they cannot. Pupils often suggest that this is because the particles in solids are tightly packed together. The scientific explanation goes one step further in recognising that there are bonds between solid particles that hold them together. Thus it is impossible to push your hand through the desk. The bonds hold the particles together too strongly with some kind of attractive force. Hold up a piece of wire and pull hard on either end:

*'See, I'm pulling on the wire but I'm not strong enough to snap it! I'm trying to pull apart the bonds between the particles but they're too strong!'*

Of course there are also bonds between the liquid particles but these are much weaker.

*'Can anybody think of any evidence that water particles are attracted to each other?'*

Pupils may suggest that water forms droplets, showing that water particles hold together in a group, rather than breaking away from each other as in the case of gases.

Some pupils might ask about the nature of the bonds. What exactly are they? At this point it is sufficient to refer to the bonds as 'a kind of attractive force' holding the particles together. A simple model for bonding is presented in the unit *Modelling Matter*.  
Pupils can simply represent these bonds by linking arms for a solid to show the bonds are strong and lightly touching each other when they represent a liquid. *See Strengthening the teaching and learning of particles in Key Stage 3 science.*

### Q3: What is in between the particles?

This is a key question. Many pupils will say 'air', as they expect air to 'fill' everything. Asking them how they would represent air with the model can challenge this incorrect idea. You will need to establish with them some of the components of air, e.g. oxygen and carbon dioxide. Furthermore how can air be compressed (in the syringe) if there is 'something' between the particles? The fact of the matter is that there is NOTHING between the particles.

The agreed particle model should, at this point in the lesson sequence, have the following features:

- particles are touching in the solid and liquid (not compressible) but are more widely spread out in the gas;
- particles are tightly packed in a regular arrangement in solids: the particles in solids cannot move freely over each other (as they can in liquids);
- the particles are strongly bonded in solids;
- there is nothing between the particles in solids liquids and gases.

**Note:** At this stage the model contains no reference to particle motion. This comes at a later stage.

### What to prepare

- Sheet 1.2 'Particle model of the states of matter'.

### Mode of interaction

**Pupils work in small groups, following an INTERACTIVE/AUTHORITATIVE approach, to review and annotate their posters and then to use their ideas about particles to account for phenomena seen earlier. The focus is on the correct science view.**



### What happens in this activity

The pupils are asked to annotate their posters in light of the agreed class model. The pupils finally use the newly-agreed model to explain some other observations and questions.

Provide pupils in their groups of 8 with some key questions to answer. They need to use role play and/or annotate their posters to answer these questions. This enables them to apply what they have learnt and to test the model they have some up with. Pupils can identify any improvements they may make to their models.

1. Compare the flow of treacle and water along a wooden plank. How are the particles different in each substance to account for their properties of flow?
2. Compare a block of aluminium with the same volume block of lead. Why are they different?
3. Is slime a solid or a liquid? Explain your answer.
4. Why does a balloon full of carbon dioxide sink whereas one full of helium rises?



## 1.1: Solids, liquids and gases: properties

**Compressibility:** Press the plunger down in the syringes. How far did the plunger move?

The syringe containing a solid (plasticine) .....

The syringe containing a liquid (water) .....

The syringe containing a gas (air) .....

What can you say about the *compressibility* of solids, liquids and gases? .....  
.....

**Beakers:** Fill one of the beakers with ice or a square of chocolate and one with water or a molten square of chocolate.

What shape does the water/molten chocolate take in the beaker? .....

What shape does the ice/ chocolate take in the beaker? .....

What can you say about the shape taken by solids (like ice) and liquids (like water)?  
.....  
.....

**Upside down glass:** Turn the glass upside-down and place it straight down into the tank of water.

Describe what you can see inside the glass .....

Why is there no water inside the glass? .....

**Fluidity:** Push your hand through the air in front of you. Push your hand through the water in the tank. Push your hand 'through' the desk (not too hard!).

How easy was it to move your hand through the different substances?

- gas (air) .....
- liquid (water) .....
- solid (desk) .....

What can you say about the *fluidity* of solids, liquids and gases? .....  
.....  
.....

**Adding sugar to hot water:** Add 10 cm<sup>3</sup> of sugar to 25 cm<sup>3</sup> of hot water in a 50cm<sup>3</sup> measuring cylinder. Record the final volume.

What did you expect the final volume to be? .....

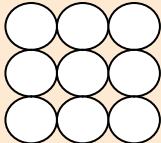
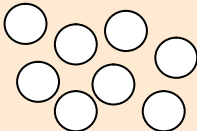
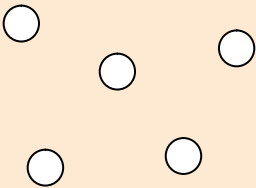
What explanations could there be for the actual result?.....

**Table 1.1**

The particles are very close together without any gaps	The particles are very far apart	The particles are close together, but may have some gaps
The particles are held together by very strong forces	The particles are held together by quite strong forces	The particles are held together by weak forces

## 1.2: Particle models of solids, liquids and gases

### Solid

<p><b>Solid</b></p> 	<ul style="list-style-type: none"><li>● The particles are touching.</li><li>● The particles are joined together strongly – so you cannot put your hand through a big piece of solid.</li><li>● The particles are vibrating on the spot – we will find out more about this later.</li></ul>
<p><b>Liquid</b></p> 	<ul style="list-style-type: none"><li>● The particles are touching.</li><li>● The particles are not joined together strongly – so you can put your hand through some liquid.</li><li>● The particles are very weakly joined together – so the liquid does not jump out of the container.</li><li>● The particles are moving – they roll about over each other.</li></ul>
<p><b>Gas</b></p> 	<ul style="list-style-type: none"><li>● The particles are very spread out.</li><li>● The particles are not joined together.</li><li>● The particles are moving quickly – colliding with each other and spreading out to fill the available space.</li></ul>

## Lesson 2: Extending the particle model

In this lesson further physical properties (expansion and diffusion) are considered and this leads to the idea that the particles in solids, liquids and gases must be in a state of continuous motion.

### Activity 2.1: Review of the particle model

#### Teaching objective

- To develop the particle model further in order to explain the motion of the particles in each state.

#### Learning outcome

By the end of this activity, most pupils will be able to:

- apply the particle model to different situations, in particular using ideas about the movement of the particles.

#### Mode of interaction

**The teacher reviews key features of the model through question and answer work: INTERACTIVE/ AUTHORITATIVE approach.**




#### What happens during this activity

The teacher leads a review of the particle model that was agreed by the class in the last lesson. Key features of the model are:

- particles are touching in the solid and liquid (not compressible) but are more widely spread out in the gas;
- particles are tightly packed in a regular arrangement in solids: the particles in solids cannot move freely over each other (as they can in liquids);
- there is nothing between the particles in solids, liquids and gases.

### Activity 2.2 Brownian motion

Show pupils a simulation of Brownian motion using a slide from *Strengthening the teaching and learning of particles in Key Stage 3 science*. 

This image may be elaborated by using smoke cells, or observing fine talc or lycopodium powder on a drop of water through a microscope, or observing pollen grains on drops of water, as Robert Brown did, through a digital microscope.

The purpose of these images is to introduce the idea that particles are generally in a state of motion.

### Activity 2.3: Observing expansion and diffusion effects

In this activity the pupils observe various phenomena involving expansion and diffusion. This will help pupils to recognise that the particles are moving and that the rate of movement is dependent on temperature.

#### Teaching objectives

- To familiarise pupils with a range of examples of diffusion and expansion involving solids, liquids and gases.
- To build up an agreed account of what happens for each example of diffusion and expansion.

#### Learning outcome

By the end of this activity, pupils will be able to:

- recognise examples of diffusion and expansion in solids, liquids and gases.

#### Mode of interaction

**Pairs of pupils talk through the examples in the circus.  
The teacher reviews their observations with an INTERACTIVE/AUTHORITATIVE approach to establish an agreed account.**



#### What to prepare

Sheet 2.1: 'Expansion and diffusion: what happens?'

#### What happens in this activity

Pupils move around a circus of examples of expansion and diffusion and address questions on a prompt-sheet focusing on what happens in each case.

The examples in the circus, and the rationale for choosing each, are as follows:

Examples	Rationale
<b>1. Metal expansion:</b> A long needle (knitting needle) is held in a tall clamp stand so that it is horizontal with its tip balanced on a block. The stand (but not the needle) is heated. The expansion of the metal stand causes the clamped end of the needle to rise so that the needle is no longer horizontal.	This shows the expansion of a solid when heated. Pupils will often be surprised that a solid, which they imagine to be 'unchangeable', can expand. For this to happen the particles must have moved in some way, as no new metal has been created to make the stand longer.
<b>2. Gas expansion:</b> Flask of air under water, warmed by the pupils, hands. Alternatively use the two activities from <i>Strengthening the teaching and learning of particles in Key Stage 3 science</i> – Handouts 2.12 A and B. These are more complex demonstrations involving the expansion of gases.	This reinforces the idea that gas is matter and behaves like the metal by expanding.
<b>3. Potassium manganate (VII) in water:</b> A crystal of potassium manganate (VII) is placed into a beaker of warm water at the start of the circus.	The pupils can observe the movement of the purple colour around the beaker, when 'nothing is being done' to the beaker/ water.
<b>4. 'Before and after' potassium manganate (VII) in agar:</b> the potassium manganate (VII) will diffuse slowly through the agar, so a sample would need to be set up before the lesson.	The pupils can observe the movement of the purple colour through the agar, when 'nothing is being done' to the agar. This shows diffusion in a gel.
<b>5. Blackcurrant cordial and orange juice:</b> If left during the lesson the two layers of drink will diffuse.	This demonstrates an everyday example of diffusion, which shows the pupils that the phenomena they are observing can be applied to everyday settings.
<b>6. Air freshener:</b> A strongly smelling air fresher is placed at the front of the room at the start of the activity. Pupils are asked to raise their hands as soon as they can detect the smell.	This shows an everyday example of diffusion.

**7. Red and blue water:** Two containers contain the same volume of water (about 1 litre). One has hot water, the other cold. Five drops of red food colouring are added to the one with hot water: the time it takes for the colour to disperse through the water is noted. Five drops of blue colouring are added to the other container with cold water and the time it takes to disperse is noted.

This shows the difference in the speed of diffusion when the temperature of a substance is increased.

### Activity 2.4: Model development: movement of particles

In this activity the pupils consider how the current particle model must be developed to account for their observations of expansion and diffusion phenomena.

#### Teaching objectives

- To provide opportunities for pupils to show that they can use the particle model to generate explanations of two new physical properties of matter – diffusion and expansion.
- To generate an agreed class explanation of diffusion and expansion in terms of particles.

#### Learning outcomes

By the end of the activity, pupils will be able to:

- model diffusion and expansion in terms of a simple particle model.

#### What to prepare

- Pupils will need their complete sheet 2.1 "Expansion and diffusion: what happens".

#### Mode of interaction

The teacher works with the pupils using an **INTERACTIVE/DIALOGIC** approach, encouraging them to suggest their explanations for the expansion and diffusion examples.



**DIALOGIC  
HOTSPOT**

**In the plenary the teacher takes an INTERACTIVE/AUTHORITATIVE approach, building on the pupils' ideas to develop the scientific account of expansion and diffusion.**



### What happens during this activity

Pupils work in groups of about eight and use their ideas of the particle model to role play what is happening in each experiment. Assign different experiments to different groups. This will help to develop a particle-based explanation for each example of expansion and diffusion. The instruction from the teacher is:

*'Think carefully about each of these examples. How might we explain each one in terms of our particle model?'*

*'For example, with the air freshener. How can we explain the spreading of the smell? Nothing is making the air freshener move around the room. It just happens! Like the smell of perfume. How can we picture what is going on here in terms of particles? What does this event tell us about the particles in the air and the air freshener?'*

The teacher can role-play the idea of gas particles spreading from a source with pupils to model the explanation.

### Plenary sessions

The groups report back on their ideas, showing their role-plays, and the teacher draws upon features of pupils' models to generate an agreed class model to explain diffusion and expansion. This will be along the following lines:

Examples	Particle explanation
<b>1. Metal expansion</b>	When the stand is heated, the particles in the stand move around more and take up more space (no new metal has been created to make the stand longer). There is no expansion of individual particles.
<b>2. Gas expansion</b>	When the gas is warmed, the particles move around more quickly and take up more space. Some of the particles escape into the water, hence the bubbles. This reinforces the idea that gas is matter and behaves just like the metal solid in 'metal expansion'.



<b>3. Potassium manganate (VII) in water</b>	The crystal dissolves in the water and then the crystal particles intermingle continuously with the water particles. It seems that the two sets of particles must be moving around 'of their own accord' as 'nothing is being done' to the beaker/water. This takes place in a matter of hours.
<b>4. 'Before and after' potassium manganate (VII) in agar</b>	The potassium manganate (VII) particles intermingle slowly with the gel particles when 'nothing is being done' to the agar. This can be seen in the course of 1 lesson, and gets more pronounced with time.
<b>5. Blackcurrant cordial and orange juice</b>	The blackcurrant cordial and orange particles intermingle at the interface between the liquids.
<b>6. Air freshener</b>	The air freshener particles intermingle with the air particles and gradually spread throughout the space.
<b>7. Red and blue water</b>	The particles in the red, hot water are moving faster, and are therefore able to spread more quickly.

The picture to build up is:

- In solids, the particles are in a constant state of vibration about a fixed point.
- When solids are heated the particles vibrate more to cause expansion. Diffusion through solids is very slow since the particles are closely packed and have limited motion (see example 4 above).
- In liquids, the particles are continuously moving over one another.
- When liquids are heated the particles move around more and take up more space. Diffusion through liquids is a slow process since the particles are close together (see examples 3, 5 and 7 above).
- In gases, the particles are moving freely past one another (at very high speeds of the order of 300m/s).

When gases are heated the particles move around more quickly and take up more space. Diffusion of gases is a relatively quick process since the particles are free to move past each other (see example 6 above).

## 2.1: Expansion and diffusion: what happens?

1. **Metal expansion:** Heat the metal rod part of the clamp stand.

What happens to the needle?

What is making the needle move?

**KEY QUESTION:** Why does the heated metal expand? Relate your answer to what is happening to the particles.

2. **Warming air:** Turn the flask upside-down and place the neck under the water; put your hands around the flask bottom. (Amend if the alternative activities are used)

What do you see?

Where have the bubbles come from?

**KEY QUESTION:** Why does the warmed air come out of the flask?

3. **Purple crystals in water:** Gently put a purple crystal into a beaker of water. Do not stir it!

What can you see happening?

**KEY QUESTION:** How come the colour from the purple solid spreads out?

4. **Purple crystals in jelly:** Dish A was set up just before the lesson and dish B was set up last night.

What differences can you see?

**KEY QUESTION:** How does the purple colour spread from the solid crystal through the solid jelly?

- 5. Blackcurrant cordial and orange juice:** Glass A was set up just before the lesson and glass B was set up last night.

What differences can you see?

**KEY QUESTION:** How come the colours from the different juices seem to be mixing?

- 6. Air freshener:** Open the air freshener.

How far away from the air freshener do you need to get so that you can't smell it?

**KEY QUESTION:** How does the smell from the air freshener get to your nose?

- 7. Red and blue water:** Fill two containers to the same volume, about 1 litre. One has hot water, the other cold. Add five drops of red food colouring to the one with hot water and time how quickly it takes for the colour to disperse through the water. Add five drops of blue colouring to the other container with cold water and record the time it takes to spread.

What are the main differences between the time it takes for the food colouring to spread in hot and cold water?

**KEY QUESTION:** Explain why this result is seen, using ideas about what is happening to the particles.

## Lesson 3: Changing state

In this lesson the pupils consider how the particle model can be used to explain change of state.

### Activity 3.1 The changing state of water

#### Teaching objectives

- To introduce the properties associated with change of state.
- To model phase change in terms of the simple particle model

#### Learning outcome

By the end of this activity, pupils will be able to:

- model changes of state in terms of the simple particle model of matter.

#### Mode of interaction

The teacher works with the pupils through an **INTERACTIVE/DIALOGIC** approach encouraging them to suggest their explanations for the changes in state.



**DIALOGIC  
HOTSPOT**

In the plenary session the teacher takes an **INTERACTIVE/AUTHORITATIVE** approach in developing the scientific account of changes in state, building on the pupils' ideas.



### What happens during this activity

Although pupils will be very familiar with the change of state of water from ice to water to steam, teachers may wish to demonstrate the process using a thermometer to follow the temperature at which phase changes occur. During the demonstration the teacher might pose the following questions:

*Where is the water going? Where are the particles of water going? Do the particles just disappear? Can you see any evidence that the evaporated water is still in the room?*

*'Why does the temperature of the ice not go above 0°C? Why does the temperature of the water not go above 100°C?'*

After the demonstration, use a range of other models to simulate what is happening to the particles. This will enable pupils to connect what they have observed to what is happening at the particle level. Such models could include using polystyrene or other balls on a tray and applying a form of vibration to the tray, either through a signal generator or loud speaker cone. Pupils need to see a clear connection between the amount of energy put into a system and the vibrational energy that is transferred to the particles. Demonstrate the making of popcorn to pupils. Ask them to explain how this model can be used to represent the changes in state that they have observed. Ask pupils to identify any clear weaknesses of the model and make suggestions for improvement where appropriate.

*'What you need to do now is to draw upon your particle ideas to explain, in as much detail as you can, what is happening as the ice melts to form water and the water boils to form steam'.*

Ask pupils to model the changes of state using role-play in groups of about eight. Pupils should pay particular attention to account for the lack of temperature change at the melting and boiling points, although the amount of energy going into the system is not altered.

### Plenary

The teacher draws together key features of pupils' models to develop an explanation of phase change that is agreed by the class:

1. When the ice is heated, the particles vibrate more until the bonds between them break and the ice melts, turning into water. As the ice is being heated its temperature does not rise: the heating is doing the work of breaking the bonds between ice particles.
2. When the water is heated, the water particles move around more quickly and the temperature of the water rises.
3. At about 100 °C, the bonds between the water particles break down and the liquid water changes into gaseous steam. Although the water is being continuously heated at 100 °C, the temperature does not rise further. The heating at this point is doing the work of breaking the bonds between water particles.

Pupils should be provided with opportunities to transfer their understanding to new contexts. Provide groups of pupils with different scenarios to explain, using the particle model. Here are some suggestions:-

1. Ice-cream melts at a higher temperature than ice. How does the movement of the particles in these substances compare at zero degrees centigrade?
2. At room temperature, carbon dioxide and iodine turn straight from a solid to a gas.

This is called sublimation. Using the particle model, explain why their liquid states may not exist. Note: The liquid states can exist, but not at room temperature and pressure.

3. Metals have much higher boiling points than other solids. What can you deduce about the forces and energy of particles in a metal?

## Lesson 4: Is any new stuff formed? Where does it come from?

### Teaching 'story'

In this lesson, pupils differentiate between mixtures and compounds in terms of properties, and respond to a key question: In some change processes, we mix things. In others, completely new things are formed. How can we model these different processes in terms of the particle model? It is possible for this lesson to roll over into the next one, if pupils need more time for consolidation.

### Activity 4.1: Is any new stuff formed?

Pupils review examples of change processes in order to reach the conclusion that deciding by direct observation whether new stuff has been formed is not straightforward.

### Teaching objectives

- To address a key problem: if we can't tell by direct observation whether new stuff is formed, is there any way we can use our particle model to help?
- To generate information about pupils' explanations of change and notions of matter.

### Learning outcomes

By the end of this activity, pupils will be able to:

- recognise that a change in some properties might indicate that new stuff is formed (e.g. taste, colour), but that changes in other properties may not indicate that new stuff is formed (e.g. shape);
- appreciate that it is very difficult to tell by direct observation whether new stuff has formed.

### What to prepare

- Sheet 4.1: 'New stuff?'
- Complete a risk assessment.

## Mode of interaction

Pairs of pupils take an **INTERACTIVE/DIALOGIC** approach in putting forward their ideas about whether or not new stuff has been produced.



**DIALOGIC  
HOTSPOT**

## What happens in this activity

Pupils go round a circus of examples of change processes and address questions on prompt sheets. The examples include physical and chemical changes, as well as mixing processes which do not include physical or chemical change. The prompts direct pupils towards changes in properties which indicate that a new substance is formed (and properties which can change when no new substance is formed). A key conclusion of the activity is that it isn't straightforward to tell by observation if new stuff is formed.

It is worth noting that we have not used the school science notion that physical change is reversible but chemical change is not, because of the problems that it leads to: how can you 'reverse' the change when wood is filed to produce sawdust, or a block of chocolate melts to a sticky mess in a warm bag?

The examples in the circus, and the rationale for choosing each one, are as follows:

Example	Rationale
<b>1. Melting chocolate</b>	Physical change: resulting in change of shape. Properties that remain the same include colour, consistency, and melting point. The taste and texture may change depending upon the method of heating. See the RSC publication <i>Inspirational Chemistry</i> .
<b>2. Burning magnesium</b>	Chemical change: resulting in change of properties like colour, consistency.
<b>3. Making silver bromide</b>	Chemical change: resulting in change of properties like colour, but also state.
<b>4. Dissolving salt</b>	Physical change: involving change in properties like colour, state, consistency, but not taste.
<b>5. Making orange squash</b>	Mixing: involving change in state, but not colour, taste.
<b>6. Reacting dilute acid with marble chips</b>	Chemical change: involving change in state, colour.



### Plenary session

The teacher collates pupils' responses, identifying properties that appear to give a 'good' indication that 'new stuff' has formed, or ones that are 'not so safe' for indicating that 'new stuff' has formed. This leads to the idea that it is very difficult to identify by observation alone when new stuff has formed.

### Activity 4.2: Exploration: properties of iron, sulfur, iron sulfide

The teacher demonstrates the formation of iron sulfide or other compounds made by direct combination. Details of these can be found in *Strengthening the teaching and learning of particles in Key Stage 3 science*, handout 3.12, to illustrate how changes in key properties can indicate that new stuff has formed.

### Teaching objectives

- To demonstrate how changes in key properties (e.g. magnetic attraction) can indicate that new stuff has formed.
- To allow pupils to model a chemical change for the first time using a simple particle model.

### Learning outcomes

By the end of this activity, pupils will be able to:

- recognise a broader range of key properties and changes which indicate that new stuff may have formed;
- attempt to model chemical change with different kinds of particles.

### What to prepare

- Sheet 4.2: 'Iron and sulfur'.

### Mode of interaction

**The teacher takes an INTERACTIVE/ AUTHORITATIVE approach whilst carrying out the demonstration, drawing attention to the key properties of iron, sulfur and iron sulfide.**



Pairs of pupils take an **INTERACTIVE/DIALOGIC** approach whilst putting forward their ideas for modelling the formation of iron sulfide.



**DIALOGIC  
HOTSPOT**

### What happens in this activity

#### a. Teacher demonstration: making iron sulfide

The formation of iron sulfide has long been used to introduce the notion of chemical change. It has the advantage of involving reactants and products in one phase. Furthermore, the stoichiometry of the reaction enables simple diagrams of the interaction of the particles to be drawn.

The teacher provides samples of coarse iron filings and sulfur for pupils who note key properties, particularly that iron is attracted to a magnet but sulfur is not. The teacher then demonstrates the reaction by heating a spatula of iron filings mixed with a spatula of sulfur in a pyrex tube. The resulting 'stuff' is grey: it is not a metal and it is not sulfur. It is no longer attracted to a magnet. These changes give a 'good indication' that new stuff has been formed.

#### b. Modelling iron sulfide formation

The worksheet 'Iron and Sulfur' supports the modelling of the reaction of iron and sulfur. At this stage in the lesson, pupils are asked to make links between the particle model of matter developed in the lessons on physical change, and their observations of the properties of matter in chemical change. Introduce a wider range of models that pupils can use to explain what has happened to the iron and sulfur. Provide pupils with sweets, e.g. mints, toffees and mint toffees, paper clips of different colours, lego blocks, modelling clay etc. See *Strengthening the teaching and learning of particles in Key Stage 3 science*, handouts 3.5, 3.6 for details of how to use these models. Handout 3.15 addresses some of the strengths and weaknesses of these models.

Pairs of pupils work together to produce models and diagrams of likely arrangements of particles in pure iron, pure sulfur, a mixture of iron and sulfur, and the product after the reaction. 'Chemical jigsaws'—a modelling kit produced jointly by the RSC ([www.rsc.org](http://www.rsc.org)) and SEP ([www.sep.org.uk](http://www.sep.org.uk)) could be used to support these discussions.

Note the distinction which is made here between 'bits' and 'particles'. When iron filings and sulfur powder are mixed it is assumed that 'bits' of each substance are mixed. Each bit is made up from atom-sized particles. When iron and sulfur react chemically it is assumed that the atom-sized particles combine.

A common difficulty that pupils have when first introduced to particle representations of chemical change is that they assume that changes in *properties* are due to changes in *the particles themselves*, rather than the way in which they are combined (e.g. 'yellow sulfur particles *change into* grey iron sulfide particles'). This will need to be addressed explicitly when the particle model is introduced.

### Activity 4.3: Defining physical and chemical change, substance and mixture

#### Teaching objectives

- To introduce pupils to formal definitions of substance, element and compound.
- To allow pupils the opportunity to use this new terminology appropriately in terms of the models of change processes that they have met so far in this unit.

#### Learning outcomes

By the end of this activity, pupils will be able to:

- appreciate the meaning of the terms substance, element and compound;
- attempt to use the terms in the context of particle models that they have developed.

#### What to prepare

- Worksheet 4.3: 'Definitions'
- Worksheet 4.4a: 'You're the teacher!'
- Worksheet 4.4b: 'Modelling dissolving'

#### Mode of interaction

**The teacher takes an INTERACTIVE/ AUTHORITATIVE approach to introduce the new terminology: asking lots of questions, making links between the new terms, particle models and examples of each.**



#### What happens in this activity

The teacher introduces definitions for *substance*, *atom*, *element*, *molecule*, *compound*, *mixture*, drawing on the 'Definition' sheet. In conjunction with this, the teacher uses a range of different models to exemplify each types of particle, giving familiar examples. Sweets are particularly useful, and the strengths and weaknesses of the models can also be addressed.

The teacher should refer to investigations undertaken earlier by the pupils and apply the appropriate terminology to the substances involved.

#### Plenary

The worksheets 'You're the teacher!' and the extension sheet 'Modelling dissolving' are then used to provide opportunities for pupils to practise using the new terminology.

Experience suggests that pupils will find it particularly difficult to learn to use this new terminology and to describe change processes in terms of changes in bonding between atoms. During subsequent lessons this process of using visual and verbal representations of particles to describe change will need constant reinforcement.

Through the worksheets, pupils return to the examples of change processes met at the beginning of the lesson. They are presented with pieces of written work by fictitious pupils. Working together, they have to identify errors in the language used by the fictitious pupils, and suggest alternatives.

As an extension task, pupils are presented with an activity in which they generate visual and verbal models of the process of dissolving sugar. They should be shown concrete examples of dissolving first, before they attempt to visualise how the particles are arranged. Pupils will need to be reminded of the arrangement of particles in a liquid.

## 4.1: New stuff?

### 1. Melting chocolate

When cooks put chocolate on top of a cake, they start with solid chocolate like this:



iStockphoto.com/Gustavo Andrade

...and melt it slowly over hot water like this:



iStockphoto.com/Sandra O'claire

The chocolate sets on the top of the cake like this:



iStockphoto.com/Pavel Mirmanov

#### Questions to ask yourselves:

- What has changed about the appearance of the chocolate on the top of the cake compared to the block of chocolate at the start?
- What has stayed the same?
- Think how it would taste: the same or different?
- Could you melt the chocolate again, and make it into a different shape?

**So... do you think that any 'new stuff' has been formed? Yes/No**

Explain your answer!

## 2. Burning magnesium

Take a small piece of magnesium ribbon. Make sure everyone is wearing their safety goggles. Pick up the magnesium ribbon with special heating tongs and set it alight in the Bunsen burner flame. Be safe! Keep all hot apparatus over the heatproof mat, including the white ash that is left after the magnesium has burnt.

### Questions to ask yourselves:

- What has changed about the appearance of the magnesium ribbon since it was burnt, compared to what is left at the end? What has stayed the same?
- Hint: think about a range of properties of the magnesium (texture, hardness, colour).
- Could you burn again what is left at the end?

### So... do you think that any 'new stuff' has been formed? Yes/No

Explain your answer!

## 3. Making silver bromide

You will need *dropping bottles* of two chemicals: silver nitrate solution, and sodium bromide solution.

Take a look at the silver nitrate solution. Describe what you can see in the bottle:

Now, take a look at the sodium bromide solution. Describe what you can see in the bottle:

.....  
FOR THE NEXT BIT, IT IS IMPORTANT THAT YOU DON'T GET THE SQUIRTERS  
(Their proper name is 'pipettes') FROM THE BOTTLES MIXED UP!  
Work carefully, wearing safety goggles.

Put ONE SQUIRT of silver nitrate solution into a clean test-tube. Add ONE SQUIRT of sodium bromide solution.

Describe what you see: .....

Make sure you wait a minute or two: is something happening at the bottom of the tube?

### Questions to ask yourselves:

- What has changed about the appearance of what is in the test tube since you mixed the silver nitrate and sodium bromide solutions, compared with before mixing?
- Has anything stayed the same?
- Think about the name of this activity: Making silver bromide. Think about the names of the chemicals that you mixed. Is this telling you anything?

### So... do you think that any 'new stuff' has been formed? Yes/No

Explain your answer.

#### 4. Dissolving salt

Take a small beaker, and half fill it with water.

Add one spatula of salt. (DON'T add any more – it won't work if you do!)

Stir the water and salt together until the salt dissolves.

##### Questions to ask yourselves:

- What has changed about the appearance of what is in the beaker since the salt dissolved, compared to when you first added the salt?
- Do you think that the salty taste will be there still, even though you can't see the salt? (DON'T taste the water!)
- Do you think that you could get salt granules back again from the salt-and-water mixture?

**So... do you think that any 'new stuff' has been formed? Yes/No**

Explain your answer!

#### 5. Making orange squash

Imagine making a glass of orange squash:

##### Questions to ask yourselves:

- What has changed about what is in the glass since the drink was made? Hint: think about colour, taste...
- Could you separate the water or the concentrated squash from the drink?

**So... do you think that any 'new stuff' has been formed? Yes/No**

Explain your answer!

#### 6. Adding marble to acid

SAFETY: Wear eye protection. Don't get acid on your clothes or skin. Be careful of splashes!

Put 2cm of acid into the bottom of a large test tube, using a pipette. DON'T ADD ANY MORE THAN THIS!

Add one small piece of marble.

Watch what happens.

##### Questions to ask yourselves:

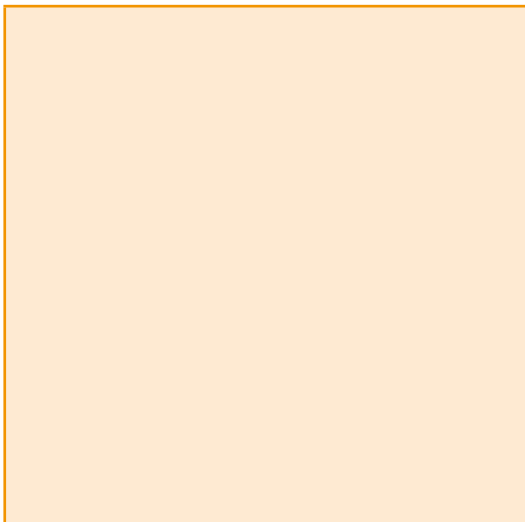
- What changes about the appearance of what is in the tube, compared to the acid and marble on their own?
- Hint: look at the size of the marble. What might be in the bubbles?

**So... do you think that any 'new stuff' has been formed? Yes/No**

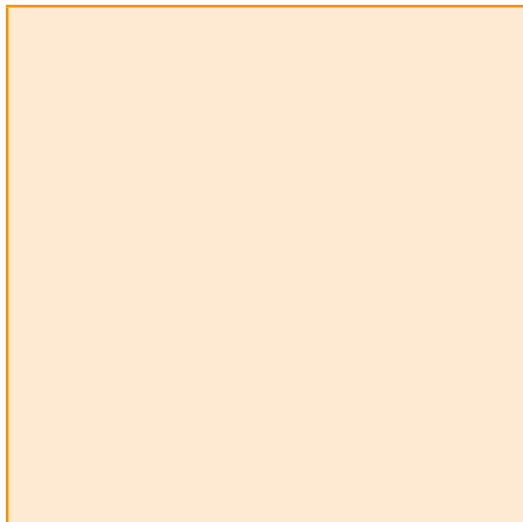
Explain your answer!

## 4.2: Iron and sulfur

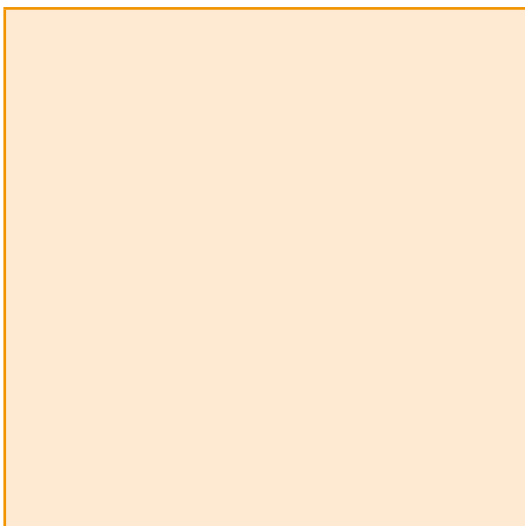
**The particles in iron**



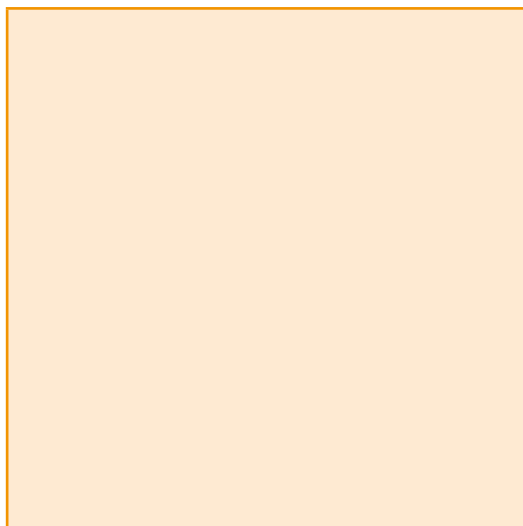
**The particles in sulfur**



**The particles when the iron and sulfur are mixed together but not heated**



**The particles of the new material after heating (iron sulfide)**



The model and diagrams should have the following features:

- particles are *touching and bonded* in solid iron and solid sulfur;
- bits of iron and sulfur are *touching but not bonded* in a mixture of solid iron and solid sulfur;
- a new substance has formed after the reaction; this is modelled as a *recombination* of the iron and sulfur particles, so that iron and sulfur particles are *touching and bonded to each other*.



## 4.3: Definitions

### Substances

- *Substances* are made up of 'one kind of stuff'.
- They do not contain 'bits' of different stuff that you can separate out.
- The atoms in substances are in a *regular pattern*.
- Iron is a substance that contains a regular pattern of iron atoms.
- Sulfur is a substance which contains a regular pattern of sulfur atoms.
- Iron sulfide is a substance containing iron and sulfur atoms which are *bonded* in a regular pattern.

### Mixtures

- *Mixtures* contain 'more than one kind of stuff'.
- You can sometimes see 'different bits' in mixtures, but sometimes the different bits are too small to see.
- The atoms in the different bits of mixtures are in completely different patterns.
- A mixture of yellow sulfur and grey iron filings has different bits, and the atoms in each bit are different.

### Elements

- *Elements* are substances: they are 'one kind of stuff'.
- Elements contain *just one kind of atom*.
- Iron is an element: it is made of iron atoms.
- Sulfur is an element: it is made of sulfur atoms. There are just over 100 different kinds of elements.

### Molecules

- These are small groups of atoms that are chemically bonded.
- They can range from just two chemically bonded atoms; for example hydrogen, to several thousand bonded atoms, for example as in starch.
- They may be elements because they contain the same type of atoms, for example oxygen, where two oxygen atoms are chemically bonded to each other.
- They may be compounds, where the types of atoms are different; for example water, where one oxygen and two hydrogen atoms are chemically bonded.

## Compounds

- *Compounds* are substances: they are 'one kind of stuff'.
- Compounds contain *more than one kind of atom*.
- The atoms in compounds are in a regular pattern.
- Iron sulfide is a compound made of iron and sulfur atoms, bonded in a regular pattern.
- There are millions of compounds, made up of atoms in different arrangements.

## Physical change

- In *physical change*, no new substance is formed.
- Melting, boiling, freezing, and condensing are all physical changes.

## Chemical change

- In *chemical changes*, new substances are formed.
- In chemical changes, the pattern of arrangement of atoms changes.
- Burning ('combustion') is the chemical change that we have seen most often in this topic.

## 4.4a: You're the teacher!

You have just taught your pupils about substances, mixtures, compounds, and physical and chemical change. But DISASTER! When you get their work in to mark, it is clear that they are having problems.

Here are three pieces of work. For each one:

- underline all the mistakes that the pupils have made;
- working with your partner, write a better piece of work using the terms more accurately.

### Katie's description of diluting orange squash

We took two substances, water and orange squash. Working carefully, we reacted the substance and made a new compound called orange juice. The atoms in the orange juice are all bonded together in a regular pattern, which is why the orange juice is so runny.

### John's description of burning magnesium ribbon in air

We took a piece of magnesium, which is a well-known compound used in science lessons. We burnt it in air, which is a mixture of many elements like oxygen, nitrogen and carbon dioxide. The element that we made is called magnesium oxide. I don't really know why it is an element, though.

### Phil's description of melting chocolate

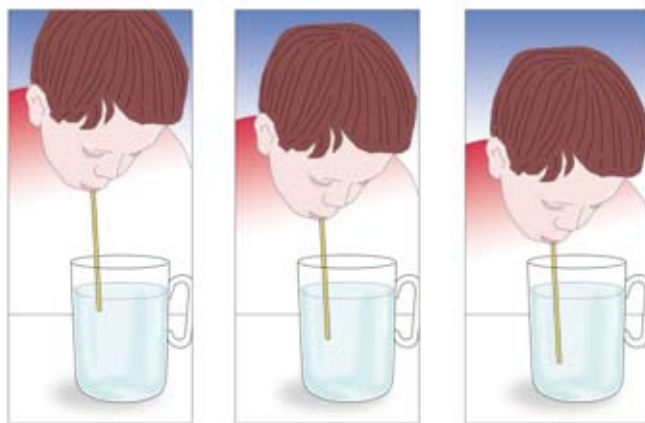
We took a big block of chocolate and put it in a bowl. We heated the bowl over some boiling water and stirred it until the chocolate dissolved into a liquid. We formed a new substance because the runny chocolate had changed its shape and just wasn't the same as the block of chocolate. We didn't eat any of it (well, not much).

## 4.4b: Modelling dissolving

Imagine taking a cup of hot water, adding a teaspoon of sugar, and stirring until the sugar is fully dissolved (so that it can no longer be seen):



Then, imagine taking a straw and sipping the liquid from different parts of the cup:



You can taste the sweet, sugary taste equally, no matter where you sip from.

Using all the ideas that you have learnt over the last few lessons, draw three diagrams to represent how the particles in the hot water, the sugar crystals on the teaspoon, and the sugar solution are arranged:

<b>The hot water</b>	<b>The sugar crystals on the teaspoon</b>
<b>The sugar solution</b>	

## Lesson 5: Substance, element, compound

The lesson begins with a review of the terms introduced in the previous lesson; the pupils then practise using these terms.

### Activity 5.1: Substance, element, compound

#### Teaching objectives

- To establish a common understanding of the terms substance, element and compound, and an agreed way of representing the particles in elements, substances and compounds.
- To familiarise pupils with some well-known elements and compounds, highlighting key properties and features of nomenclature that indicate whether they are elements or compounds.

#### Learning outcomes

By the end of this activity, most pupils will be able to:

- use the terms substance, element and compound, and their associated particle representations, with increasing confidence.

#### What to prepare

- Sheet 5.1: Looking at properties

#### Mode of interaction

**The teacher takes an INTERACTIVE/ AUTHORITATIVE approach in posing questions to help consolidate new definitions and particle representations.**



### What happens in this activity

The lesson begins with a plenary review of the particle, and verbal descriptions of substance/mixture, molecule, element/compound, physical/chemical change introduced previously. Pupils then practise using these particle and visual representations in subsequent parts of the lesson when presented with information about elements, and in differentiating between elements, mixtures and compounds.

The worksheet 'Looking at properties' is used first. This is a circus activity in which pupils examine samples of elements, photographs of elements, and writing about elements. The aim is to enable pupils to become accustomed to using the new term element in relation to familiar and unfamiliar substances. One compound is also included to remind pupils that both elements and compounds are examples of substances. Pupils use a range of different models to demonstrate their ideas about what these substances look like (see *Strengthening the teaching and learning of particles in Key Stage 3 science* Handouts 3.5 and 3.6). Pupils are provided with a prompt sheet to focus their attention as they review the examples. The examples, and the rationale for their selection, are as follows:

Example	Rationale
<b>Calcium chloride</b>	This is a compound; the name suggests that it consists of more than one kind of particle
<b>Gold</b>	Familiar material; element; metal
<b>Uranium</b>	Material possibly familiar as a 'scientific material'; element
<b>Oxygen gas</b>	Familiar name; non-metal, gaseous element
<b>Nitrogen gas</b>	As above
<b>Chlorine gas</b>	As above
<b>Calcium</b>	Familiar material; element; metal; can be contrasted with calcium chloride
<b>Iron</b>	Familiar material; element; metal
<b>Sulfur</b>	Familiar non-metallic element.

The prompt questions used by pupils, and their purpose, are as follows:

Prompt	Purpose
Does it have a name including two 'scientific' words?	Introducing pupils to the idea that chemical nomenclature is related to the chemical structure of substances, and that the name may indicate that the substance is made of more than one kind of particle.
Is it a metal? Is it a gas? Is it neither a metal nor a gas?	This is drawn upon later, when discussing the fact that most elements familiar to pupils are metals or gases.
Is it found in the home? Have we used it in science lessons?	This is to introduce the fact that the scientific language being used by pupils is applicable to all materials, not just those familiar from school science lessons.
Is it poisonous? Is it radioactive? Is it expensive? Is it cheap?	These questions are included to prompt discussion about the range of materials that are elements.
Can you see anything to suggest that this material is a mixture (such as different colours...)?	This question is to focus pupils on the fact that we are dealing with substances, not mixtures.

When pupils have had the chance to review the examples, the teacher undertakes a short plenary session to emphasise the following points:

- the chemical name of a substance often indicates if more than one kind of atom is in the substance's structure;
- elements are often metals or gases;
- the models of matter that we are dealing with are used to explain all matter, not just the chemicals found in laboratories;
- it is often possible to see more than one substance in a mixture just by looking at it. However, even if only one substance can be seen, it is not possible to conclude that only one substance is actually there.

### Plenary session: 'Tell me why'

In this activity, pupils have the opportunity to use the new terminology and 'rules of thumb' to identify and distinguish between some substances (particularly compounds) and mixtures. The teacher presents examples of elements, mixtures and compounds. Pupils have to say whether each one is an element, mixture or compound, and explain why using appropriate language. The examples suggested, and the rationale for choosing these, are as follows:



Example	Rationale
<b>Soil</b>	Many pupils will know that soil is a <b>mixture</b> of sand, water, organic matter...
<b>Sand</b>	<b>Mixture:</b> pupils may refer to the different colour of grains, the fact that sand is made as different coloured stones erode...
<b>Orange juice</b>	<b>Mixture:</b> Pupils may refer to the contents labelling on boxes of orange juice. This example allows the teacher to distinguish between the meanings of 'pure' used in everyday language and chemistry.
<b>Milk</b>	<b>Mixture:</b> Pupils may refer to the fact that milk contains protein and calcium, or refer to the separation of milk and cream at the top of the bottle.
<b>Scrambled egg</b>	<b>Mixture:</b> Pupils may know that milk and butter are often added, or refer to the fact that egg white and egg yolk are mixed in cooking.
<b>Copper sulfate</b>	<b>Compound:</b> The name of the substance contains two words, indicating the presence of more than one kind of particle.
<b>Salt</b>	<b>Compound:</b> Pupils may know that the chemical name is sodium chloride, which indicates the presence of two kinds of particle.
<b>Water</b>	<b>Compound:</b> Pupils may know that 'water is H <sub>2</sub> O', indicating two types of particle.
<b>Potassium manganate (VII)</b>	<b>Compound:</b> The name of the substance indicates the presence of more than one kind of particle.
<b>Iodine</b>	This is an unfamiliar <b>element</b> . It allows the teacher to work systematically through questions that might be asked: Can we see anything to indicate a mixture? Two words in the name? This reinforces the point that visual features do not always easily enable us to know the structure in terms of particles.

This plenary session could be organised in a variety of ways (whole-class quiz, teams, etc.). Good prompting questions include:

*'Think about its appearance/how it is made: is there any evidence for more than one substance?'*

*'Do you know this substance's chemical name/think about the chemical name: is there any evidence for more than one kind of particle in its structure?'*

## 5.1: Looking at properties

Example	Prompt questions for each example
calcium chloride	Does it have a name including two 'scientific' words? Is it a metal? Is it a gas? Is it neither a metal nor a gas? Is it found in the home? Have we used it in science lessons? Is it poisonous? Is it radioactive? Is it expensive? Is it cheap? Can you see anything to suggest that this material is a <i>mixture</i> (such as different colours...)?
gold	
uranium	
oxygen gas	
nitrogen gas	
chlorine gas	
calcium	
iron	
sulfur	

## Lesson 6: Modelling chemical changes involving phase change

This lesson focuses on modelling chemical changes that involve phase changes.

### Teaching 'story'

Pupils are taught how to model chemical change processes, which involve phase change, in terms of particles and the newly-introduced terminology. There is a good deal of evidence to suggest that pupils find it more difficult to think of gases as matter, compared to solids and liquids. Examples are chosen to bring possible difficulties to the surface, and to make it plausible that gases can be involved in physical and chemical change.

### Activity 6.1: Modelling chemical change

#### Teaching objectives

- To revise and consolidate the use of terminology and representations introduced so far in this unit.

#### Learning outcomes

By the end of this activity, pupils will be able to:

- use the terms *substance*, *element*, *molecule*, *mixture*, *compound*, *physical change* and *chemical change*, and their associated representations, to explain simple physical and chemical change processes.

#### Mode of interaction

Pairs of pupils work on these changes with an **INTERACTIVE/AUTHORITATIVE** approach focusing on the correct scientific view.



### What happens in this activity

In this activity, pupils are asked to construct particle and verbal representations of the structure of matter during change processes and to describe these in terms of substance/element/mixture/compound/physical and chemical change in order to revise the use of the new terminology and representations. Pupils are then presented with a new chemical change process to model, which involves a phase change.

Examples of these could be:

- burning magnesium ribbon or any other metal in air;
- burning a splint – emphasising that it is made from carbon and hydrogen;
- displacing copper from copper sulfate solution with iron or zinc;
- displacing hydrogen from an acid using a metal.

Working in pairs, pupils are asked to generate sentences to describe the change processes, involving the terms *substance*, *element*, *molecule*, *mixture*, *compound*, *physical change* and *chemical change*. For example in the case of burning magnesium ribbon in air, pupils might report:

- two *substances* were heated together, magnesium and oxygen;
- magnesium and oxygen are *elements*;
- oxygen is found in the air, which is a *mixture* of gases;
- after the oxygen and magnesium had reacted, a *new substance* formed, magnesium oxide;
- magnesium oxide is a *compound*, because it is made of atoms from two different elements;
- this is a *chemical* reaction, because a new *substance* has formed.

The teacher then briefly demonstrates a familiar chemical change: the precipitation of silver chloride when solutions of silver nitrate and sodium chloride are mixed.

*Strengthening the teaching and learning of particles in Key Stage 3 science* – Handout 4.12 may be used in conjunction with the handouts here.

After watching the demonstration, pupils work in pairs to produce a visual representation of the arrangement of the particles, with prompting. Worksheet 6.1 'Solids appear!' can be used to support this activity. Pairs of pupils then come together to compare, contrast and review each others' representations.

No attempt is made to model the structure of the nitrate ion at this stage. Furthermore, given their complexity, no attempt is made to represent the structure of aqueous solutions. Teachers may, however, choose to do this with certain groups as an extension activity.

The teacher reviews models produced by pupils, drawing out salient features. An agreed, shared model is generated for each example.

<b>Silver nitrate solution</b>	<p><b>Salient features to draw out:</b></p> <ul style="list-style-type: none"> <li>● It is a solution</li> <li>● It contains water, silver and nitrate particles</li> <li>● Because it is a liquid, the particles are touching, but not bonded.</li> <li>● It will be necessary to discuss issues of size and scale with pupils.</li> </ul>
<b>Sodium chloride solution</b>	<p><b>Salient features to draw out:</b></p> <ul style="list-style-type: none"> <li>● It is a solution</li> <li>● It contains water, silver and nitrate particles</li> <li>● Because it is a liquid, the particles are touching, but not bonded.</li> <li>● It will be necessary to discuss issues of size and scale with pupils.</li> </ul>
<b>Silver chloride solid powder</b>	<p><b>Salient features to draw out:</b></p> <ul style="list-style-type: none"> <li>● It is a solid substance</li> <li>● It is a compound</li> <li>● The particles are touching and bonded</li> </ul>

## 6.1: Solids appear!

<b>Our representation of silver nitrate solution</b>	<b>Hints:</b> <ul style="list-style-type: none"><li>● It is a liquid</li><li>● It contains water, silver and nitrate particles</li></ul>
<b>Our representation of sodium chloride solution</b>	<b>Hints:</b> <ul style="list-style-type: none"><li>● It is a liquid</li><li>● It contains water, sodium and chloride particles</li></ul>
<b>Our representation of the silver chloride solid powder (precipitate)</b>	<b>Hints:</b> <ul style="list-style-type: none"><li>● It is a solid substance</li><li>● It is a compound</li></ul>

# Lesson 7: Understanding conservation of matter in chemical change through modelling

In this final lesson of the sequence pupils are taught how to use particle models to explain the conservation of substance and mass in chemical change processes.

## Activity 7.1: Weighing air

Pupils are presented with a demonstration which raises a question: How come air makes things heavier? They then use the particle model to explain why an inflated balloon is heavier than a 'flat' balloon. Finally, pupils are presented with various physical and chemical change processes involving gases. They have to model each process in terms of particles, explaining changes in mass.

### Teaching objectives

- To make the conservation of substance and conservation of mass plausible to pupils, particularly in change processes involving changes into, and out of, the gas phase.

### Learning outcomes

By the end of this activity, pupils will be able to:

- explain the conservation of mass in terms of changes in particles;
- appreciate how mass is conserved in changes into, and out of, the gas phase.

### What to prepare

- The Sheets 'Weighing air' and 'What happens to the weight?' can be used to support this activity.

### Mode of interaction

Pairs of pupils work on these changes with an **INTERACTIVE/AUTHORITATIVE** approach focusing on the correct scientific view, with the support of the teacher






### What happens in this activity

There is considerable evidence that pupils find it difficult to appreciate that matter and mass are conserved in change processes, particularly those involving gases. Many pupils do not focus on matter in the gas phase during change processes. Even when gases are focused upon, they are often thought to have zero mass or negative mass ('bubbles make things lighter'). This is true for both physical and chemical changes. This lesson therefore begins with a 'predict-observe-explain' activity: pupils initially predict what will happen to the mass of a balloon when it is inflated. The process is not a physical or chemical change, enabling attention to focus on the mass of gases. Once the mass of air in a balloon has been dealt with, conservation of mass in physical and chemical change processes involving gases is addressed.

The procedure of inflating and weighing a balloon is then carried out. Pupils now generate models, involving particles, to address the question: why does the mass of the balloon increase? For many pupils, the fact that 'air makes things heavier' is highly counter-intuitive: surely inflated balloons get lighter and float upwards? This problem often relates to pupils not appreciating the distinction between mass and density. During this activity, teachers can make explicit this problem with pupils by asking questions. Some ways of opening up problems, and dealing with them, are suggested below:

Problem	Suggested opening with pupils	Possible ways of making the scientific view plausible
Pupils expect that adding a gas to a balloon makes it lighter (or not to change its mass).	How come the inflated balloon is heavier than the empty one?	'Think about all the air particles that you're adding: the particles must weigh something'.
Pupils think that the air particles in the balloon 'just float there', so don't add mass.	Remember the sealed syringe filled with air, and how we could push the air particles closer together? Would that make the syringe heavier? What if we could cool the air to make liquid air? What would it weigh then? Supposing you evaporate water to steam: will it lose its mass? Where will the mass come from when steam condenses on a cold window?	The purpose of these questions is to get pupils to think through the logically the implication that phase change between the liquid and gas phases involves mass change.
Pupils think that air is 'just nothing'.	Show pupils how water does not enter an inverted glass beaker when it is pushed into water. Ask: How come the water doesn't fill the beaker?	This activity aims to make plausible to pupils the fact that air and gases in general are 'something' rather than 'nothing'.

Pupils now practise modelling change processes involving gas in terms of particles, and explain how mass is conserved. The teacher initially demonstrates four examples, three of which should be familiar from previous lessons. The worksheet 'What happens to the weight?' can be used to support this activity.

The examples, and the rationale for choosing them, are as follows. *Strengthening the teaching and learning of particles in Key Stage 3 science* has further examples – Handout 4.3 and 4.4: 

Example	Rationale
1. The reaction of marble chips and dilute acid	This is a chemical change involving the evolution of a gas, which can be seen in the form of bubbles. If the reaction is carried out in a conical flask with a balloon stretched across its neck, the balloon will inflate as the gas is evolved. Mass is conserved provided there is an air-tight seal between the balloon and the neck of the flask, and providing that diffusion through the balloon is not too rapid.
2. The oxidation of magnesium	This is a chemical change in which a gaseous reactant (oxygen) reacts with a solid to form a solid product. This allows pupils to model the change in terms of particle recombination, and appreciate how gases can contribute mass in chemical change processes.
3. The precipitation of silver chloride from aqueous silver nitrate and aqueous sodium chloride	This is a chemical change involving reactants and products in the liquid and solid phases. It is perhaps the least counter-intuitive for pupils. It can be used to explain in terms of a particle model that solids do not have greater mass than liquids.
4. Dissolving sodium chloride	This physical change can be used to illustrate how changes between the solid and aqueous phases do not involve changes in mass.

Working in discussion pairs, pupils generate predictions, based on explanations in terms of particles, about what will happen to mass during these change processes.

The teacher demonstrates the changes and works with pupils to generate agreed explanations of the conservation of mass in terms of particle representations.

## 7.1: Weighing air



I predict that the inflated balloon will be:



- ☐ HEAVIER than when it was flat;
- ☐ LIGHTER than when it was flat;
- ☐ THE SAME WEIGHT as when it was flat.

MY REASONS:

WHAT ACTUALLY HAPPENED:

MY EXPLANATION:

## 7.2: What happens to the weight?

<p><b>Reaction/Example</b></p> 	<p><b>Prediction</b></p> <p>We predict that as the gas fills the balloon, the reading on the balance will show:</p> <p>Getting heavier</p> <p>Getting lighter</p> <p>Staying the same</p> <p>Our explanation:</p>
	<p>We predict that after the magnesium oxide has formed, the reading on the balance will show:</p> <p>Heavier</p> <p>Lighter</p> <p>Staying the same</p> <p>Our explanation:</p>



We predict that after the solid powder has formed, the reading on the balance will show that it is:

Heavier

Lighter

Same as before

Our explanation:



We predict that after the salt has dissolved, the reading on the balance will show that it is:

Heavier

Lighter

Same as before

Our explanation:

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