Lesson 13 Data analysis and interpretation

Objectives

Analyse data and look for patterns

Draw conclusions and explain them using scientific knowledge and understanding

Vocabulary

axis, line graph, pie chart, line of best fit, conclusion, evaluation, justify, explain

Resources

OHTs of S13.1

Handouts of S13.2 (on card, cut up beforehand; one set per pupil), S13.3 (one each), S13.4 and S13.5 (one per pair)

Demo apparatus of beaker with 200 ml of water on a tripod with a Bunsen under; a thermometer in the water or, if preferred, thermometer probe attached to a datalogger

By the end of the lesson pupils should be able to:

- recognise important features of graphs and use these to analyse and interpret information
- more confidently use prior knowledge to draw and justify conclusions

Possible follow-up activities or homework

Ask pupils to apply the handy hints collated in the plenary to one or two further data analysis questions, perhaps drawn from recent test papers.

Starter 5–8 minutes

Introduce the lesson objectives.

Give out a set of answer cards (**handout S13.2**) to each pupil and explain that you are going to show them a series of graphs (**OHT S13.1**) and ask some quick questions about each one (see notes below). Tell pupils to answer by holding up the correct card from their set. Allow about 5 minutes for this starter and encourage full participation.

Main activity 40–42 minutes

Activity 1 (10 minutes). The aim of the activity is for pupils to learn how to interpret data. Give out copies of **handout S13.3** and explain in detail how you would interpret the graph. Ensure you include the title, axis, scale of the axis, and type of graph that has been drawn, and whether it is a line of best fit and whether there are any anomalous results. Also explain the thinking process you would use in answering the questions. You may find it helpful to make an OHT of the graph on S13.3.

Activity 2 (15 minutes). Give out copies of **handout S13.4** to pairs of pupils and show them the demonstration set of apparatus. Tell them to work together to answer the questions. Say that you will not just be looking for correct answers but that they should be prepared to explain their thinking. Allow 8–10 minutes and then take feedback from the class. Focus on their thinking that enabled them to answer the questions, specifically answers to questions that could not be achieved by direct interpretation of the graph.

Activity 3 (15–17 minutes). Give out copies of **handout S13.5**. Explain that the two drawings give information about the human menstrual cycle. Tell pupils to work in pairs, to look at the data in the pictures and to write two or three questions that could be asked about it. Explain that, as in activity 1, some questions should relate directly to the data and some should not (give examples from activity 1). Allow pupils access to textbooks if required. After 8–10 minutes tell the pairs to swap questions with another pair and try to answer the questions they receive. Throughout, circulate to check pupils' thinking. Tell the pairs to swap back and to decide as a four which were good questions and why. Take feedback from the class on the outcomes of this last discussion.

Plenary 10 minutes

Ask pupils to think about what they have been taught during this lesson and, in pairs, devise criteria or rules for representing data in the form of a graph (e.g. the picture should help understand the numbers). Ask them also to devise some tactics for interpreting graphs (e.g. always read the labels on the axes). Give them 5 minutes' thinking time and then take feedback. Record their ideas on the board or flipchart. Try to produce a short list of 'handy hints'.

Questions for data analysis starter

Graph A

1 What is the name of the axis labelled ‘M’? (*y*-axis or vertical axis)

2 What is the name of the axis labelled ‘N’? (*x*-axis or horizontal axis)

3 What is each division worth on the *x*-axis? (50 units)

4 If I moved two divisions along the *x*-axis, how much would the value increase? (100 units)

Graph B

5 What is the value of P? (90 units)

Graph C

6 What type of graph is this? (pie chart)

7 If segment R is 60%, what is the approximate value of segment X? (25%)

Graph D

8 Approximately how much gas was given off after 2 minutes? (30 cm^3)

9 Approximately how much gas was given off between 2 and 3 minutes? (60 cm^3)

Graph E

10 What type of graph is this? (Line graph)

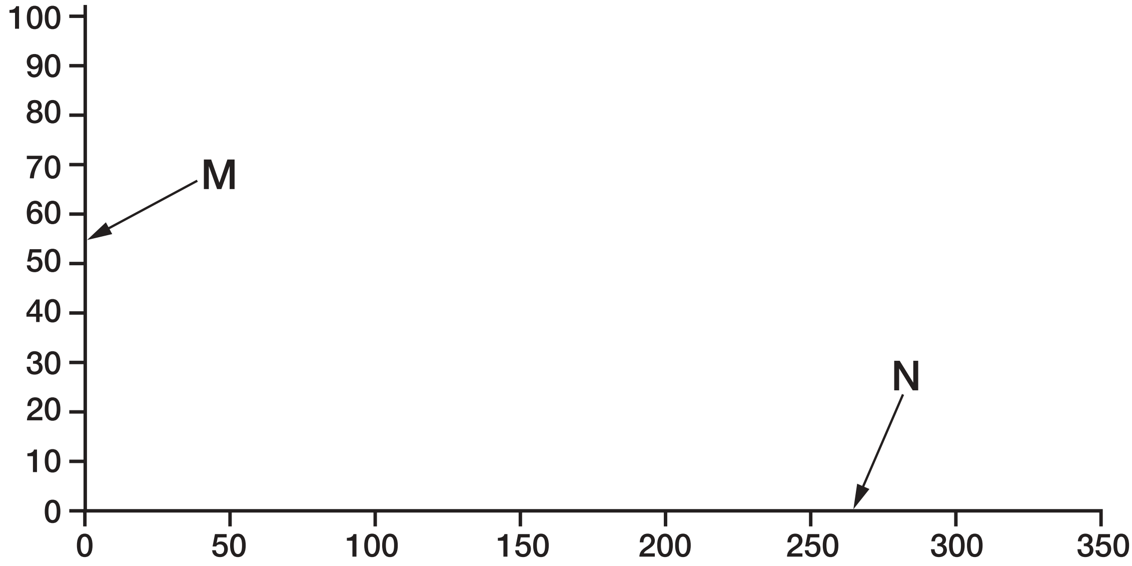
11 What is the missing value in the table? (35 cm)

12 (Extension question) What happened to the spring when the mass of 1000 g (1 kg) was hung on it? (The spring was over-stretched and broke. The length of spring that remained attached was permanently extended.)

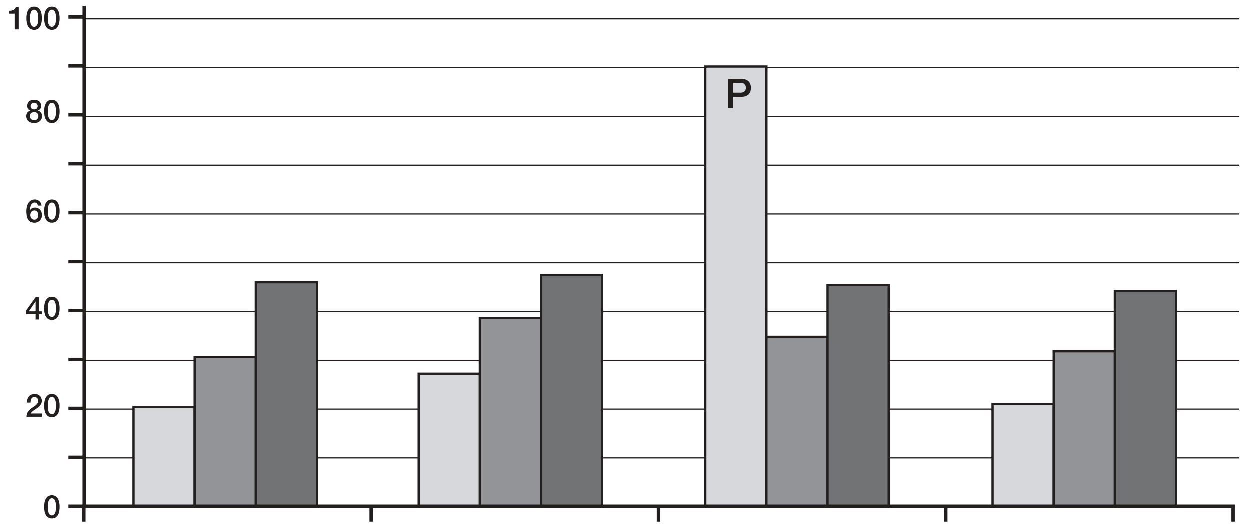
Data analysis starter

S13.1

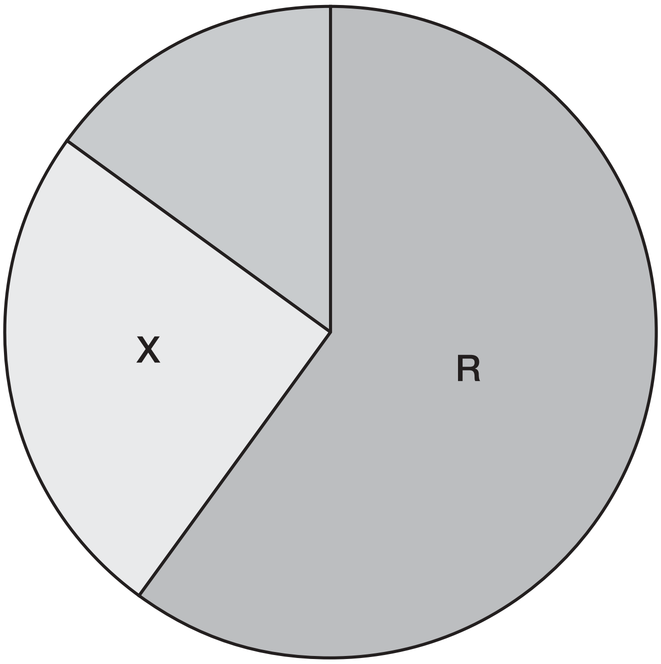
Graph A



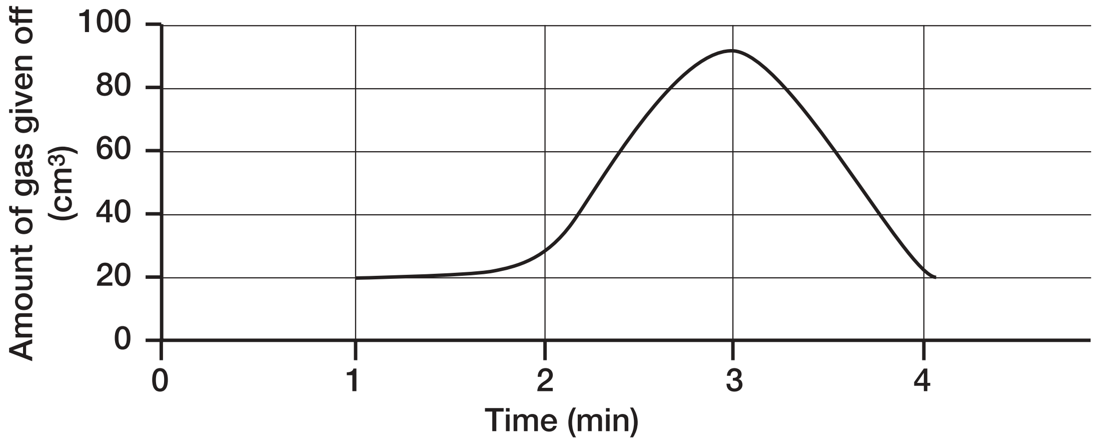
Graph B



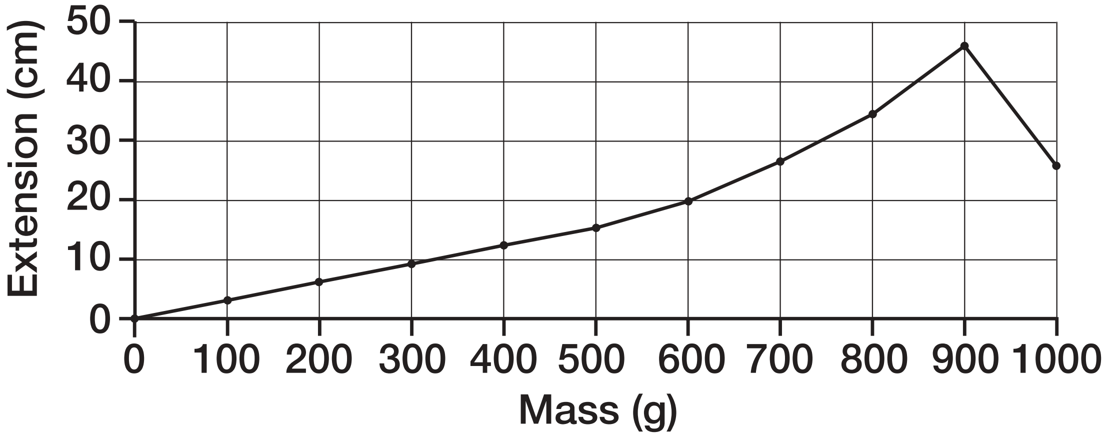
Graph C



Graph D



Graph E



Mass (g)	Spring extension (cm)
0	0
100	3
200	6
300	9
400	12
500	15
600	20
700	27
800	
900	45
1000	25

Answer cards for starter **S13.2**

y-axis or vertical axis	90 units
x-axis or horizontal axis	line graph
50 units	pie chart
100 units	60 cm^3
30 cm^3	25%
35 cm	

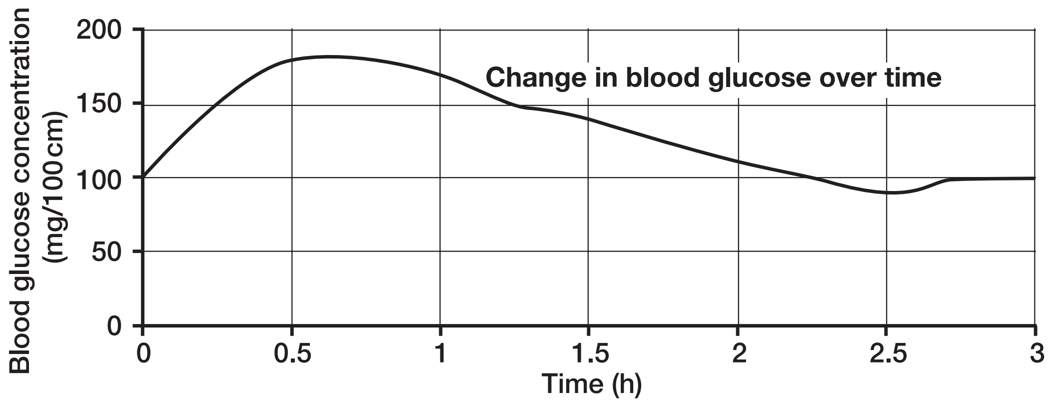
Maintaining a supply of energy S13.3

Sarah ate a large bowl of pasta for tea, which contains high concentrations of carbohydrates.

When carbohydrates are digested they are broken down into sugars. Glucose is the most common of these.

Glucose is an important energy source for the body.

The graph below shows the concentration of glucose in Sarah's body over a given period.



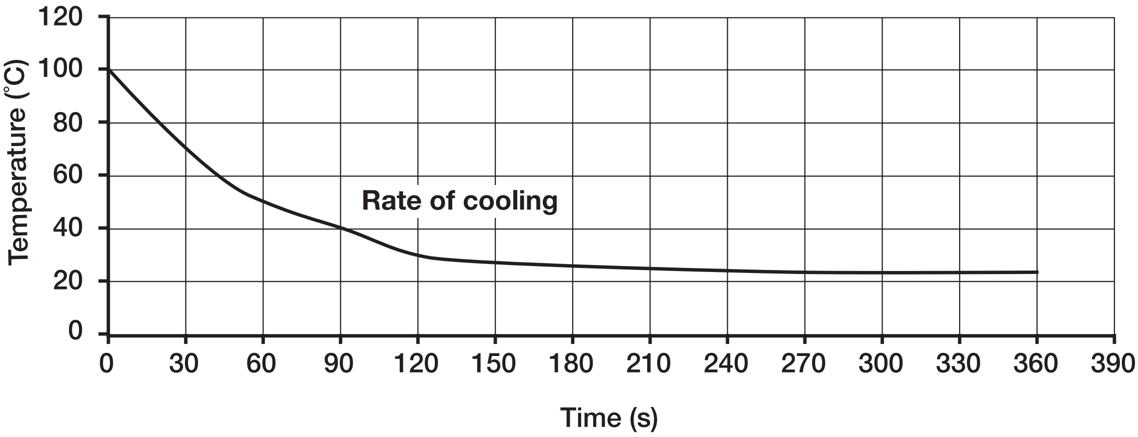
1 Use the graph to explain why it is important to Sarah that she eats lots of pasta before she runs a marathon.

2 An hour before the race Sarah eats a bowl of pasta to provide energy for the forthcoming marathon. Sarah knows it takes her around 2½ hours to complete a marathon. When should her coach advise her to take the glucose tablets she carries with her?

3 Sarah's coach has advised her that she must have a balanced diet during training. What are the nutrients that go together to form a balanced diet?

Cooling hot water S13.4

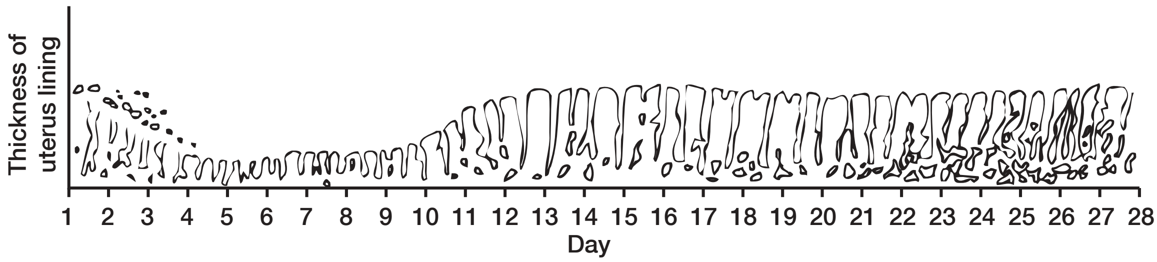
A group of Year 7 pupils investigated how long it takes a 200 ml beaker of water to cool from 100 °C to room temperature. They recorded their results in the graph below.

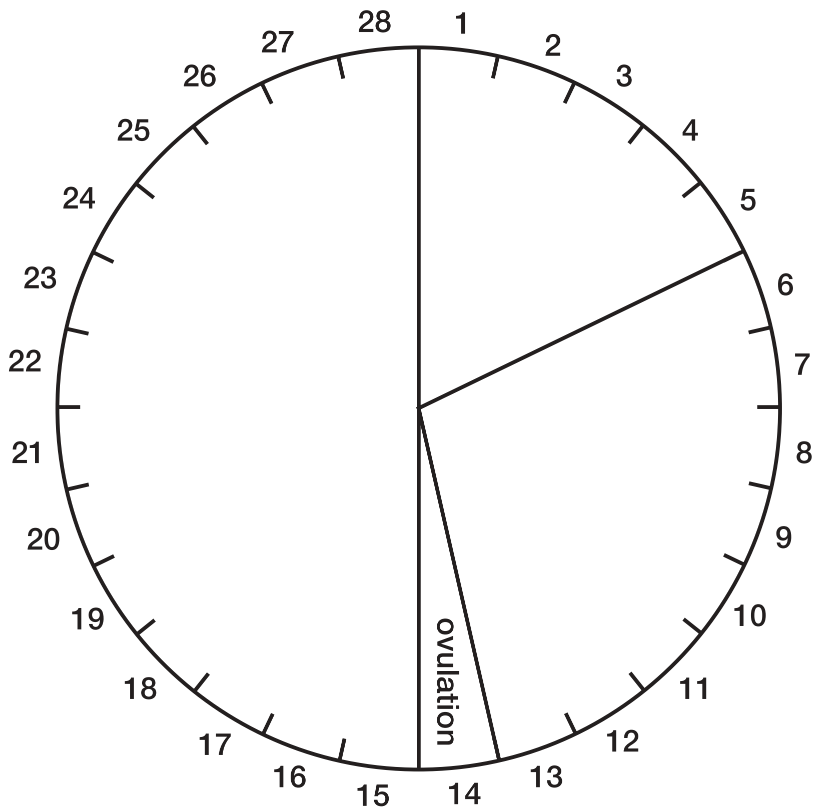


1. What was the rate of cooling between 30 and 120 seconds?
2. Why do you think the rate of cooling slowed after 120 seconds?
3. Use the information in the graph and from what you know of this investigation to explain how energy was transferred from the Bunsen to the liquid.
4. One of the group noticed that as the liquid cooled the amount of steam given off by the water decreased. Why do you think that was?

Menstrual cycle diagrams

The two diagrams below provide information on the human menstrual cycle. The cycle itself varies between different individuals and so these drawings are only approximate generalisations. Write some questions involving data analysis and interpretation based on the two diagrams.





Lesson 14 Working with variables

Objectives

Recognise relevant variables in contexts which may be unfamiliar

Recognise and correctly use the terms *independent* and *dependent variable*

Make predictions based on chosen variables

Vocabulary

variable, independent variable, dependent variable, control variables, controlled investigation, prediction

Resources

OHT of S14.2

Handouts of S14.1, S14.3, S14.4 and S14.5 (one per pair)

Handout of S14.6 (one each)

By the end of the lesson pupils should be able to:

- identify with confidence possible variables in an investigation
- correctly use the terms *independent* and *dependent variable*
- recognise and describe variables which need to be controlled
- make appropriate predictions with confidence

Possible follow-up activities or homework

Review any investigation recently undertaken and add improvements through the correct use of ideas and language from this lesson.

Starter 10 minutes

Introduce the objectives.

Tell the pupils to work in pairs. Give each pair a copy of **handout S14.1**, explaining that the task is to identify possible variables. Allocate to each pair one of the investigation questions. Tell them that they have 5 minutes to produce the answers. Take feedback for each of the questions by asking the pairs in turn to call out their variables. List as many as you can on the board or OHT as they speak. Pause briefly after each group to invite suggestions from the rest of the class. At this stage do not make judgements on the suggestions.

Main activity 40 minutes

Activity 1. Tell the class that there are two questions to answer and they need to pay close attention. Show **OHT S14.2** and, while pupils look at this, read out loud from **handout S14.3** the explanation of how Sally and James conducted their investigation. Then read out the two questions. Allow 5 minutes for pupils in pairs to decide their answers. Take feedback through questions and answers and record the main points on the board.

Now ask the pupils to think further about Sally and James' investigation. Give each pair a copy of S14.3 as a reminder, and **handout S14.4**. Tell them to review all the variables in the investigations and decide (a) which Sally and James changed, (b) which they measured and (c) which they should have controlled (kept the same). Tell them to record their answers in the Venn diagram on S14.4. Allow 5 minutes; circulate during this time to check pupils' thinking and provide support as necessary. At this point remind or tell pupils that the variable changed is called the *independent* variable and the variable measured is called the *dependent* variable.

Activity 2. Give each pair a copy of **handout S14.5** which outlines a scenario for investigation. Tell pupils to read the handout and answer the questions at the bottom. Allow 10 minutes for this; circulate while the pupils are working to check their ideas and offer support as required. Take feedback from the whole class.

Activity 3. This extends the idea of identifying variables to making predictions. Give out **handout S14.6** and remind the class about the enzyme investigation described. Allow 10 minutes for individuals or pairs to complete the questions.

Plenary 10 minutes

Return to the lists of variables produced during the lesson starter. Ask each pair of pupils to look back at the list they produced and make any additions or deletions they wish. Then ask each pair to narrow down the investigation by identifying an independent and a dependent variable, and to make a prediction. Either take feedback through whole-class questions or tell pairs to form fours and explain their chosen investigation to each other. Ensure all pupils make full and correct use of the scientific terms.

Identifying variables S14.1

What are the possible variables in each of the following investigations?
Which would you select to investigate?

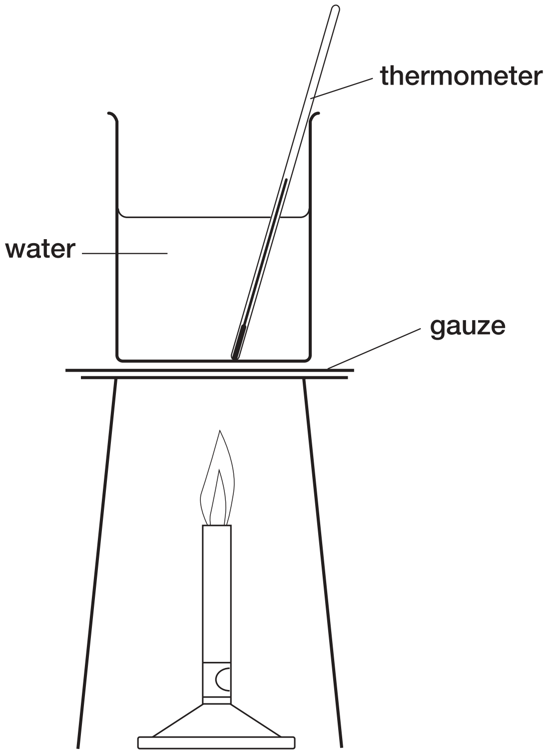
1 How quickly do plants photosynthesise?

2 How many insects are attracted to different plants?

3 Which plant grows the quickest?

4 How quickly can a plant grow?

Sally and James' investigation: results S14.2



Time (s)	Expt 1 Temperature (°C)	Expt 2 Temperature (°C)	Expt 3 Temperature (°C)	Average temperature (°C)
0	23	19	19	20
30	30	25	28	28
60	35	31	43	36
90	40	38	50	43
120	48	45	61	51
150	54	51	68	58
180	60	57	80	66
210	67	66	93	75
240	78	75	102	85
270	84	83	102	90
300	95	89	102	95

Sally and James' investigation: method S14.3

Sally and James' teacher asked them to design and carry out an experiment to investigate the effect that adding salt has on the boiling temperature of pure water. They decided to use the apparatus in the diagram and the procedure they followed was as follows.

Experiment 1

In the first experiment they placed 3 heaped spatulas of salt into a beaker which Sally had filled about two thirds full from a cold-water tap in the lab. They then stirred the water until the salt had dissolved. Next Sally collected the apparatus so that James could assemble their equipment. Sally then lit the Bunsen and they timed the temperature increase every 30 seconds.

Experiment 2

For the second experiment Sally and James carried out the investigation in much the same way because James had reminded Sally that this would make sure their experiment was a fair test.

Experiment 3

Unfortunately, as Sally and James began to carry out the final experiment, they realised that they were running out of time. They decided to increase the gas flow as they were sure this would heat the water up much quicker, enabling them to get their third set of results – they believed that you must have exactly three sets of results before an average can be calculated.

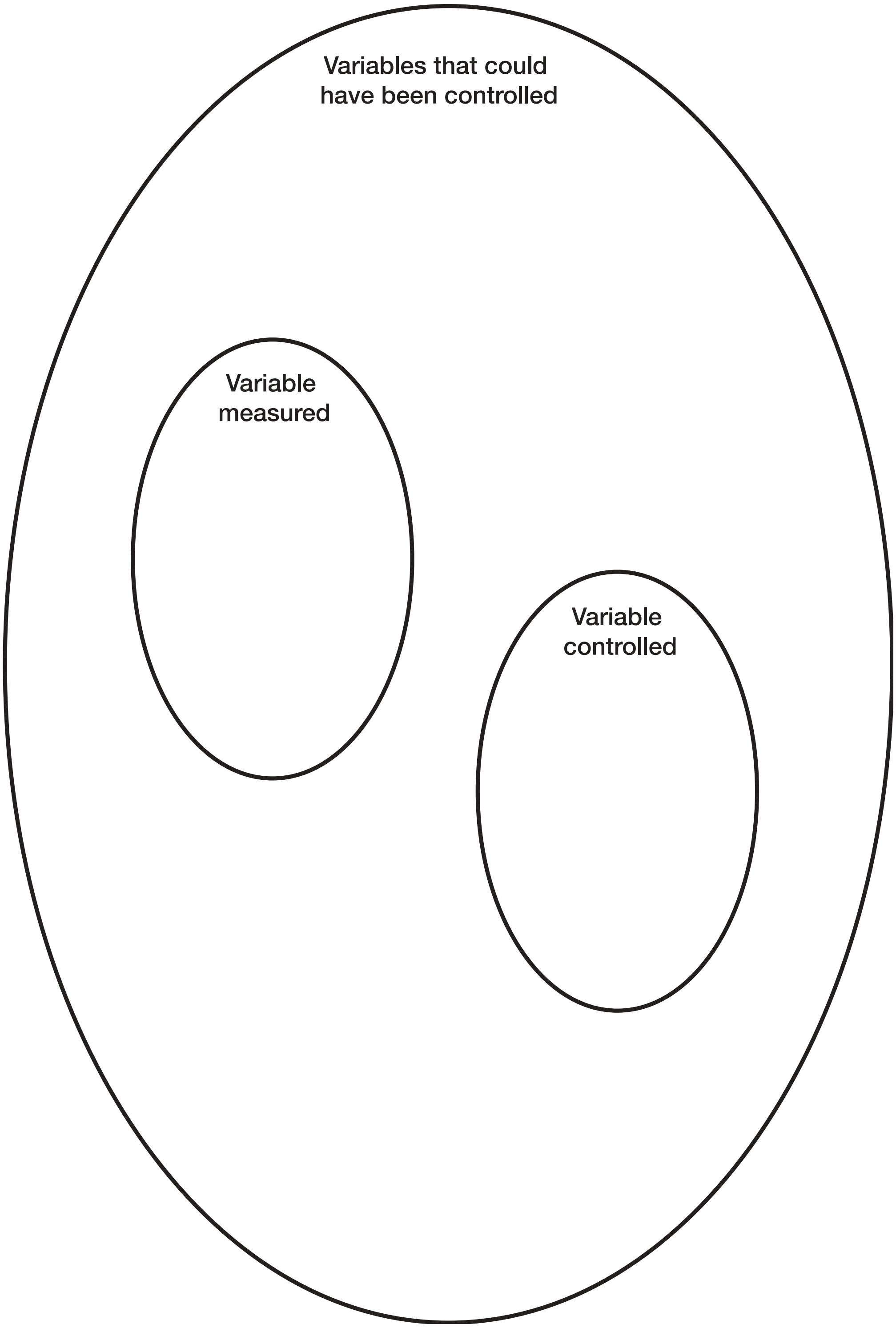
Questions

1 Did Sally and James control all the necessary variables?

2 Would Sally and James be able to draw a valid conclusion based on their results?

Justify your answers.

Sorting variables



Investigating mouldy fruit

S14.5

Yesterday I bought six peaches from the supermarket. Like last week they felt a bit hard to eat so I put them out in the kitchen to ripen. I had to do this with last week's peaches and after three days they were soft and ripe and good to eat.

I was disappointed to find this morning that three of the six peaches left out in the kitchen were beginning to go mouldy.

Last week the peaches were fine and ripened well after three days. This week some of the peaches went mouldy after 24 hours.

1 In your groups suggest reasons why there was a difference in ripening between this week's fruit and last week's fruit. Make a list of these reasons.

For each reason write a sentence to explain how this might have encouraged the mould to grow.

2 If you wanted to investigate this further, what would you do? Write a sentence to describe the investigation. Then write down the independent and dependent variables and those which would need to be controlled.

What we would investigate

Independent variable

Dependent variable

Variables to be controlled

Making predictions S14.6

Prediction 1

Testing under what conditions enzymes work most quickly is a common investigation. One enzyme used is pepsin, which is found in the stomach. It digests proteins such as those found in egg white. Egg white in water is a cloudy mixture but as the egg white is digested by pepsin the mixture becomes clear.

Think about this investigation and what you can remember about enzymes and, **on your own**, complete the prediction below.

I predict that the hotter the temperature of the pepsin and egg white mix, the …

This is because …

Now compare your ideas with those of your partner.

If you were going to try this investigation, what would be the independent and dependent variables? What variables would you need to control?

Independent variable

Dependent variable

Variables to be controlled

Prediction 2

In an investigation into shadows at different times of the day the independent variable is the time of day and the dependent variable is the size of the shadow. From what you know about shadows, what would you predict will happen to the size of shadow from 9 o'clock in the morning until 3 o'clock in the afternoon?

I predict that…

Lesson 15 Evaluating evidence

Objectives

Develop confidence to judge quality of evidence and justify judgements in terms of scientific knowledge and understanding

Know and use the terms reliability, accuracy and sufficiency with respect to evidence

Vocabulary

evidence, conclusion, reliable, reliability, accurate, accuracy, sufficient, relevant, repeat measurements, sample, sampling

Resources

A magnet and supply of paper clips per pair

Three water samples in lemonade bottles: one with clean water; one with sand added; the last with muddy tap water and small suspended bits of rubbish

A supply of coloured pens or pencils

Handout of S15.1 (one each)

Handout of S15.2 (one per pair)

By the end of the lesson pupils should be able to**:**

- identify and justify whether results are reliable
- identify and justify when results are accurate enough
- identify and justify when enough results have been collected

Possible follow-up activities or homework

Tell the class to watch a television programme such as *Tomorrow's World* and note each time reliable, accurate, scientific evidence is given. Ask pupils to be ready to explain what they found in the next lesson.

Starter — 10 minutes

Introduce the lesson objectives and stress that this lesson is not about learning new science but about judging how good evidence is, or needs to be, for sensible conclusions to be made.

Tell pupils to work in pairs and make sure each pair has a magnet and a supply of paper clips. Tell the pairs to find out very quickly how many paper clips the magnet can pick up. They can write down the number. Tell them to do the activity again – do they get the same number? Do this again – how many now? Ask for feedback on how many times pupils would want to repeat this activity to be certain of reliable results. Take feedback on how in any investigation pupils would want to ensure their results were reliable. Record significant points on the board under the heading 'reliability'.

Main activity — 35 minutes

Show the three samples of water. Tell pupils in pairs to quickly consider what evidence they would look for to know that the water was clean and safe enough for swimming. The class could be asked which they would prefer to swim in and why, with the emphasis on explaining their reasoning. Take feedback and list the evidence that would indicate that water is unsuitable for swimming.

Explain that the Environment Agency regularly takes samples of water near beaches to check water quality and whether the water is fit for swimming. Give out **handout S15.1** which contains information about how and when the samples are taken. To decide whether the water quality is good enough the Environment Agency needs to have enough results that are reliable, accurate and relevant. Tell pupils to read individually through the text on the worksheet. Then, working on their own or with a partner, they should underline in different colours any words or sentences that describe how the Environment Agency tries to collect enough (sufficient) evidence that is reliable and accurate. Definitions are given on the worksheet. Allow 20 minutes for this, all the time circulating to provide support or ask questions as necessary. Take feedback on whether the pupils believe the evidence is reliable, accurate and sufficient and, in particular, elicit their reasons.

Plenary — 15 minutes

Give **handout S15.2** to each pair of pupils. Explain that this is another exercise to judge reliability of evidence. Give them 10 minutes to answer the questions and then ask individuals to give their answers and their explanations. Notes on the answers are given below.

Plenary answers

1

Temperature in °C	Time in seconds		
	1st try	2nd try	Mean
5	562	578	570
20	395	245	320
35	270	372	321
50	260	388	324

Temperature in °C	Time in seconds			
	1st try	2nd try	3rd try	Mean
5	562	578	522	554
20	395	245	530	390
35	270	372	210	284
50	260	388	801	483

Temperature in °C	Time in seconds				
	1st try	2nd try	3rd try	4th try	Mean
5	562	578	522	330	498
20	395	245	530	378	387
35	270	372	210	128	245
50	260	388	801	711	540

2 (a) after one reading 50 °C (260 s)

(b) after two readings 20 °C (320 s)

(c) after three readings 35 °C (284 s)

(d) after four readings 35 °C (245 s)

3 Only at the fourth set was there consistency of result (not measurement) with the previous result.

4 The second group achieved consistency in their results.

5 Repeat the experiment at other temperatures between 20 °C and 50 °C.
Ignore any results that are obviously anomalies (flukes).
Compare the patterns in the results for each group in the class.

Water sampling at beaches S15.1

Read the following extract from the Environment Agency's procedure for sampling water around Britain's coast. Use three different coloured pencils and make up a key (colour in the squares) for identifying words that describe when the techniques are:

- ❑ Reliable (the results would be consistent if repeated)
- ❑ Accurate (the results are precise and correct)
- ❑ Sufficient (there are enough results to give confidence in the conclusions)

Bathing water directive

Standards are set to ensure the protection of bathers. The standards assess the number of coliforms in the water. Coliforms are bacteria, which are used as an indicator for pollution. The coliforms themselves do not cause health problems but indicate whether nearby sewage outfalls are being controlled.

The standards are:

- 95% of the samples must not exceed 10 000 total coliforms per 100 ml; and
- 95% of the samples must not exceed 2000 faecal coliforms per 100 ml.

In order for bathing water to comply, 95% of the samples (i.e. at least 19 out of the 20 taken) must meet these standards, plus other criteria.

(Faecal coliforms are those bacteria that are present as a direct result of human faeces being dumped into the sea.)

Sampling and the collection of data

The bathing season (which is the period to which bathing water standards apply) in England and Wales has been set as starting on 15 May and continuing until 30 September. The Environment Agency is required to begin sampling two weeks before the bathing season and to sample regularly throughout the season. The minimum sampling frequency is once per fortnight but the Environment Agency has a policy of taking at least 20 samples during the bathing season. This is equivalent to one sample a week. Samples are taken at the same spot in the bathing water on each sampling occasion at a depth of 30 cm, to ensure consistency. The sample point has been set to reflect the area regularly used by the highest density of bathers.

Each sample is analysed for total coliforms, faecal coliforms and faecal streptococci (another kind of bacteria that is used as an indicator). A measure of the transparency (or turbidity) of the water is also made. On each sampling occasion the water is also checked for unusual colour, and for the presence of mineral oils, surface-active agents (manufactured substances that make the water foam) and phenols (an industrial chemical). Further chemical analysis is performed if it is believed that these substances may be present in the bathing water. Each bathing water location is sampled once each season for pH (a test for acidity). If any bathing water has not complied with the coliform standards in the previous season then two samples are taken for salmonellae (a bacterial indicator from both animal and human sources) and two for enterovirus analysis (which indicates human sewage pollution).

There is a risk that some bathing waters will pass in one year and fail in another, due to the relatively small number of samples taken, even though their quality of water has not significantly changed. Changes in quality can occur from year to year as a result of differences in the weather.

- 86% of coastal bathing waters complied each year from 1999 to 2001, compared with only 57% in 1988 to 1990.
- The percentage of bathing waters consistently failing has been reduced to 0.5% from 13% over the same period.

The sampling results are available to the public on the Environment Agency website at http://216.31.193.171/asp/1_introduction.asp. Go to the section called 'Your environment', click on 'What's in your backyard?' and look for bathing water data maps, etc.

At what temperature do enzymes work best? S15.2

Working in pairs, read through this handout and answer the questions at the end. You may find calculators helpful.

Groups of pupils were investigating at what temperature amylase digests starch quickest. One group tried their test four times because they weren't sure how good their results were. Their results are in the tables below. The first table is complete and shows their results after one go.

Temperature in °C	Time in seconds
	1st try
5	562
20	395
35	270
50	260

Temperature in °C	Time in seconds		
	1st try	2nd try	Mean
5	562	578	
20	395	245	
35	270	372	
50	260	388	

Temperature in °C	Time in seconds			
	1st try	2nd try	3rd try	Mean
5	562	578	522	
20	395	245	530	
35	270	372	210	
50	260	388	801	

Temperature in °C	Time in seconds				
	1st try	2nd try	3rd try	4th try	Mean
5	562	578	522	330	
20	395	245	530	378	
35	270	372	210	128	
50	260	388	801	711	

Questions

1 Work out the means for each temperature in the other three tables.

2 At which temperature does the enzyme work fastest:

(a) after one reading?

(b) after two readings?

(c) after three readings?

(d) after four readings?

Tick the set of results that you think gives the best evidence. Explain your choice.

3 Why did the group keep going until the fourth set of readings?

4 Another group got this set of results.

Temperature in °C	Time in seconds			
	1st try	2nd try	3rd try	Mean
5	402	425	439	422
20	346	369	383	366
35	194	217	231	214
50	620	643	657	640

Why did this second group think they didn't need a fourth set of readings?

5 Which of these ideas would give the class more reliable evidence? Tick the right ones.

- ❑ Use more accurate thermometers.
- ❑ Add all the class groups' results together to get better averages.
- ❑ Do ten tries at each temperature to get a more accurate average.
- ❑ Repeat the experiment at temperatures below 5 °C.
- ❑ Repeat the experiment at temperatures above 50 °C.
- ❑ Repeat the experiment at other temperatures between 20 °C and 50 °C.
- ❑ Ignore any results that are obviously anomalies (flukes).
- ❑ Compare the patterns in the results for each group in the class.

Explain your reasons.

Lesson 16 How scientists work

Objectives

Recall that scientists work by looking for evidence

Recognise that scientific theories change as new evidence is found

Vocabulary

scientific investigation/enquiry, question, survey, correlation, secondary source, variable, identify, classify, technique, model, element, evidence, theory

Resources

Handouts of S16.1 copied onto card and cut up (one set per group of three pupils)

Handout of 16.2 (optional)

Handout of 16.3 (one per group of three initially, but have sufficient for one each by the end of the lesson)

Diagram on final page of 16.3 either on OHT acetate or enlarged to A3

Handout of 16.4 (one each)

Sets of red, green and blue coloured pencils

By the end of the lesson pupils should be able to:

- identify questions that could be investigated scientifically
- explain, using one or two examples, some ways in which scientists work
- explain the importance of evidence and how scientists can change their ideas as new evidence becomes available

Possible follow-up activities or homework

Use handout 16.2 to sort the scientific enquiries from the starter.

Use one or both tasks on handout 16.5.

Starter 15 minutes

Arrange pupils in groups of three, each group having a set of cards made from **handout S16.1**. Each card has a question. Tell the pupils to sort the cards into three categories:

1 questions that can be scientifically investigated;

2 questions that cannot be scientifically investigated;

3 questions that they are unsure about.

Tell the pupils that they must decide as a group about each question and be able to explain their reasoning. Allow 10 minutes, during which time you should circulate and listen to the discussion. Then take feedback from the groups, exploring particularly questions where there is disagreement over the category.

Extension: pupils could further classify group 1 questions into different categories of scientific enquiry using **handout S16.2** which identifies six types. You will need to explain or remind pupils about these six types of scientific enquiry before they begin the task.

Main activity 30 minutes

Tell pupils to continue working in groups of three. Give out sets of coloured pencils and **handout S16.3** which includes the instructions for the task and the text. Go through the task before the pupils begin. Circulate among the groups listening to the discussion and asking questions as appropriate. This will allow you to identify areas of uncertainty or misunderstanding. Allow 20 minutes for the groups to complete the activity. Take feedback by asking groups in turn to mark a master copy of the text either on an OHT or on a paper version enlarged to A3. Ensure that each group explains their reasoning and allow time for other pupils to ask questions. Avoid the pursuit of correct answers but emphasise the need for sound reasoning. At all times encourage pupils to pronounce the names of the scientists and any scientific terms correctly.

Plenary 15 minutes

Give every pupil a copy of handout **S16.4** which has the names of some of the scientists mentioned earlier in the lesson. Ask each pupil to recall the text in the main activity and to write some brief words or notes to explain how one or two scientists worked. To cover the whole list you may wish to allocate scientists to pupils or you may let pupils choose. Allow 5 minutes. Then ask pupils individually to explain a little of how 'their' scientist worked. Allow other pupils to ask questions as appropriate. Ensure that as far as possible all pupils have the chance to participate.

Question cards S16.1

How does temperature affect the rate of enzyme activity?	Do children's feet grow more in the summer than in the winter?
Does eating jelly make your nails grow stronger?	Do faster cars have spoilers?
Do plants that live in shaded areas contain more chlorophyll than plants that live in lighter conditions?	Why are some people frightened of spiders?
How do greenfly reproduce?	How do moths find their mates?
How are sedimentary rocks classified?	Which is the quickest way to reduce pulse rate? (a) Meditation; (b) breathing into a paper bag; (c) using aromatherapy oils; (d) lying on your left-hand side.
Do all copper compounds make flames glow blue/green?	What patterns can you see when you add different elements to acid?
Why are chlorides added to drinking water?	How does adding carbon to iron in steel making affect its strength?

Do Supertums tablets stop indigestion faster than Acigon tablets?	Which method increases bubble production of photosynthesising pond weed the most? (a) Changing the light intensity; (b) increasing dissolved CO_2 in H_2O.
How can elements be sorted into groups?	Is it cruel to use animals for laboratory experiments?
Which is the best way to speed up a chemical reaction? (a) Increasing concentration of solution; (b) increasing temperature.	What would happen if the world ran out of oil?
Are solar panels a good idea?	Do teenagers use more energy than adults?
How could reducing the population of a primary consumer in a food web affect the other organisms?	Why is there gravity on the Moon?
How fast do snails move?	Do heavy objects fall faster than light objects?
Why do dolphins make high pitch noises and whales make low pitch noises?	What types of forces are there?

Is increasing the coils of an electromagnet a more effective way of increasing its strength than increasing the current supplied?	When you make a catapult, does the elastic band length affect the distance the missile travels more than the width of the elastic band?
How does electricity flow through a circuit?	How can particle arrangement in solids, liquids and gases be used to explain conduction, convection and radiation?
Who was the more important scientist, Newton or Galileo?	Are cacti ugly?
How do particles in a solid, a liquid and a gas move?	Why does the mass of magnesium increase when it is burnt?
How are respiration and combustion similar?	Is open-cast coal mining bad?

Types of scientific enquiry S16.2

Decide which type of enquiry would be most suitable for each question (only those that could be answered scientifically) and place the question card in the appropriate space. Any which are difficult to match should be put in the space labelled 'Other'. Be prepared to justify your choices.

A Surveys and correlations	B Using secondary sources
C Controlling variables (fair test)	D Identification and classification
E Using and evaluating a technique	F Other

How some of the elements were discovered S16.3

Task

Scientists work in lots of different ways. Throughout history they have developed ideas or models using the evidence available to them.

- Work in groups of three.
- Read the following text.
- Use a blue pencil to underline the names of any scientists.
  Use a red pencil to underline the model or idea that they used.
  Use a green pencil to underline any evidence that they had to support their idea or observation.
- The final page gives a selection of ways in which scientists can work. If you have time, write the names of some of the scientists you read about against any box which describes how they worked.

Text

Over 2000 years ago an Ancient Greek scientist called Empedocles came up with the idea that everything is made of just four elements: fire, water, air and earth. He had been watching wood burn and reached the conclusion that the smoke was air from the wood rising up to its natural home (the air), the sap bubbling out of the burning wood was water trying to get back to the seas, the flames were trying to reach back up to the Sun, and the ash left behind was a natural part of the Earth.

People at this time also knew that you could get metals like lead, copper, tin and iron from rocks by burning them with charcoal (carbon). Other elements like gold, silver and sulfur could be found in the rocks.

Early scientists, or alchemists, tried all sorts of fantastic recipes to try to turn substances like egg yolks, sand and urine into gold. They predicted that a substance that contained air, water, fire and earth would turn into gold. There was more than a little wizardry or magic thrown in, with spells and the search for something called the ‘philosopher’s stone’ that they believed would turn anything into gold. Their work was not particularly systematic and often the results could not be repeated. They were far more interested in becoming rich than in science.

In 1669 a German alchemist called Hennig Brand was trying to turn 50 bucketfuls of urine into gold. He believed he had a good chance of success, as the urine was the right sort of colour. He evaporated off all the liquid then mixed the residue with water and let it ferment until it turned black. After that he mixed in some gold-coloured sand and heated up the mixture inside a big flask called a retort. The whole thing started to give off fumes and glow and flicker. It did not go out for a long time. He called his discovery ‘cold fire’. When he followed his recipe again he got the same results. He did not know it at the time but he had discovered the element called phosphorus. He was probably the first person to extract an element by a chemical reaction other than smelting.

In 1667 an Irish chemist called Robert Boyle did a series of experiments that led him to believe that there were a lot more than four elements. He collected enough data to be able to say that his elements could be combined to make new substances but could not be separated to make simpler substances. His systematic work led to many other scientists carrying out careful controlled experiments.

Around 1720 a German scientist called Georg Stahl re-investigated burning. He thought that when things burnt they gave off a substance called phlogiston and left behind something called a calx (ash). Different substances had the same phlogiston but different sorts of calx.

In 1774 an Englishman called Joseph Priestley was experimenting with mercury. When he heated it in air it turned into red mercury calx as the phlogiston escaped. He then heated the red mercury calx in a closed flask; it turned back into silver-coloured mercury. He thought the calx had joined with phlogiston inside the air in the flask. The flask now contained ‘de-phlogisticated’ air, which we now know as oxygen. At the time people did not know that air is a mixture of gases so they had to try to think of other explanations or theories about what was happening in chemical reactions.

In 1779, in France, Antoine Lavoisier was carrying out similar experiments but he was carefully measuring the masses of everything during the experiments and keeping an accurate record of any temperature changes. He also found out that mice could not survive in the air left behind when mercury turns red but could survive in the gas produced after the mercury calx turned back into silver metal. He realised that air must be a mixture of gases and named the gas made in this reaction ‘oxygene’. Soon after a Scotsman called Daniel Rutherford separated nitrogen from air. We now call mercury calx mercury oxide.

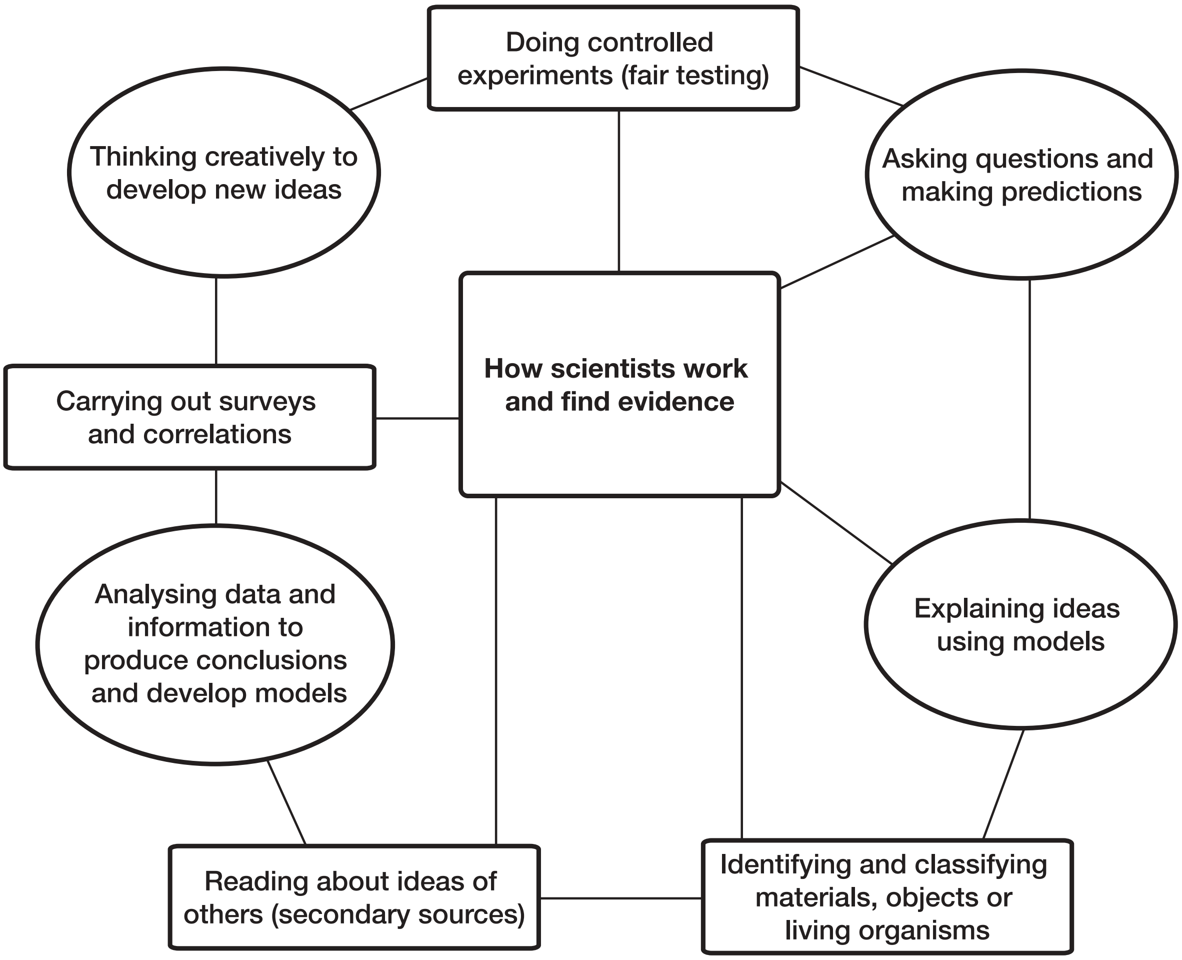
In the early 1800s, in England, Humphry Davy discovered sodium, potassium, barium, boron, calcium, magnesium and many other elements using the newly discovered techniques to make very strong electric currents. Many other new elements were being discovered, and 19th-century chemists were doing lots of careful measuring and systematic, repeated experiments to collect data about how these elements reacted with each other, their melting points and boiling points and their electrical properties.

Scientists were beginning to look for patterns and make predictions about reactions. They knew that lithium, sodium and potassium reacted in very similar ways; that calcium, magnesium, barium and strontium had very similar properties; and that chlorine, bromine and iodine reacted similarly.

By 1860 the first international chemistry conference took place in Germany. Scientists shared information and developed the theory that elements were made of small invisible atoms. Some 50 to 60 elements were known and scientists had started to work out how much they weighed when compared with each other; this was one of the keys to developing the periodic table.

In 1869 a Russian called Dmitri Mendeleev found out all he could about every one of the 63 known elements. He wrote a card for each one and arranged them in order of their atomic masses. He then rearranged them so that elements with similar properties were in groups under each other. This left him with a number of gaps in his table. The next step he took was to predict that these gaps would be filled by new, undiscovered elements. He even predicted their colours, masses and properties. A lot of other scientists thought he was crazy until six years later, in 1875, when a Frenchman, de Boisbaudran, discovered the element gallium that had all the properties Mendeleev had predicted and fitted into the gap he had left in his table under aluminium. In 1886 another of the predicted elements, germanium, was found by Winkler, a German. It fitted in the space left between silicon and tin. Soon after, another then another of Mendeleev's predicted elements was found and scientists began to take his work seriously.

Mendeleev did not know why the elements showed this pattern. It was not until the nature of the invisible atoms was revealed in the 20th century by the careful, systematic, controlled work of Marie Curie, Ernest Rutherford, Niels Bohr and many other research scientists that we began to understand how the periodic table works. We now know about more than a hundred different elements and work is still going on trying to find some of the heaviest, unstable ones.


Doing controlled experiments (fair testing)
Thinking creatively to develop new ideas
Asking questions and making predictions
How scientists work and find evidence
Carrying out surveys and correlations
Analysing data and information to produce conclusions and develop models
Explaining ideas using models
Reading about ideas of others (secondary sources)
Identifying and classifying materials, objects or living organisms

How scientists worked

S16.4

Scientist	How they were working
Empedocles	
Hennig Brand	
Robert Boyle	
Georg Stahl	
Joseph Priestley	
Antoine Lavoisier	
Humphry Davy	
Dmitri Mendeleev	
Marie Curie	

Elemental history

The table below gives you information about when different elements were discovered and who discovered them.

There are two tasks.

- Sort the elements into date order. Start with those known in ancient times up to those discovered in the 20th century. Are there any patterns in the data that link to the periodic table?
- Choose different colours to represent different countries. Make a key on a periodic table and then shade in the elements according to the nationality of the discoverer.

To find out more visit www.webelements.com/webelements/scholar

Symbol	Discovered in	Discovered by	Nationality
H	1783	Lavoisier	French
He	1868	Lockyer	English
Li	1817	Arfvedson	Swedish
Be	1797	Vauquelin	French
B	1808	Davy/Gay-Lussac/ Thenard	English/French/ French
C	Known since ancient times		
	1779	Scheele (graphite)	German
	1814	Davy (diamond)	English
N	1772	Rutherford	Scottish
O	1774	Priestley/Scheele	English/German
F	1886	Moissan	French
Ne	1898	Ramsay/Travers	Scottish/English
Na	1807	Davy	English
Mg	1808	Davy	English
Al	1825	Oersted	Danish
Si	1824	Berzelius	Swedish
P	1669	Brand	German

Symbol	Discovered in	Discovered by	Nationality
S	Known since ancient times		
Cl	1810	Davy	English
Ar	1894	Rayleigh/Ramsay	English/Scottish
K	1807	Davy	English
Ca	1808	Davy	English
Sc	1879	Nilson	Swedish
Ti	1791	Gregor	English
V	1801	Del Rio	Spanish
Cr	1797	Vauquelin	French
Mn	1774	Gahn	Swedish
Fe	1300–1200BC	The Hittites	
Co	1739	Brandt	Swedish
Ni	1751	Cronstedt	Swedish
Cu	Known since ancient times		
Zn	1500	Marggraf	German
Ga	1875	de Boisbaudran	French
Ge	1886	Winkler	German
As	Known since ancient times		
Se	1817	Berzelius	Swedish
Br	1826	Balard	French
Kr	1896	Ramsay/Travers	Scottish/English
Rb	1861	Bunsen/Kirchhoff	German
Sr	1790	Crawford	Scottish
Zr	1789	Klaproth	German
Nb	1801	Hatchett	English
Mo	1778	Scheele	German
Pb	Known since ancient times		
Ru	1844	Klaus	Russian

Symbol	Discovered in	Discovered by	Nationality
Rh	1803	Wollaston	English
Ag	Known since ancient times		
Cd	1817	Strohmeyer	German
Sn	Known since ancient times		
Sb	Known since ancient times		
Te	1798	Klaproth	German
I	1811	Courtois	French
Cs	1860	Bunsen, Kirchhoff	German
Ba	1808	Davy	English
Hf	1923	Coster, Hevesy	Danish
Ta	1802	Ekeberg	Swedish
W	1783	de Elhuyar	Spanish
Os	1803	Tennant	English
Pt	1735	de Ulloa	Spanish
Au	Known since ancient times		
Hg	Known since ancient times		
Fr	1939	Perey	French
Ra	1898	P. and M. Curie	French/Polish
Po	1898	M. Curie	Polish
Ce	1805	Vauquelin	French
Pr	1885	von Welsbach	Austrian
U	1789	Klaproth	German
Bk	1949	Ghiorso, Thompson, Seaborg	American
Am	1944	Seaborg, Ghiorso, James, Morgan	American
Y	1794	Gadolin	Finnish
Eu	1901	Demarçay	French
Bh	1981	Armbruster, Munzenberg	German

Lesson 17 Drawing information together

Objectives

Be able to draw on a range of scientific ideas including from everyday life

Explain scientific ideas using appropriate vocabulary

Vocabulary

scientific explanation, evidence, everyday experience, scientific idea, general knowledge

Resources

Green and red cards (see lesson 8)

Handout of S17.1 cut up into cards (one card per pair)

Handout of S17.2 (one per pair and some spares)

Enlarged version of S17.2

Practical equipment and materials as appropriate

A selection of science texts

Stout metal tube 50–100 cm long and 3–5 cm diameter

By the end of the lesson pupils should be able to:

- explore their own knowledge to identify scientific and general information relevant to a problem
- draw such information together to provide a valid scientific explanation

Possible follow-up activities or homework

Provide another common scenario for pupils to explain, e.g. fat is an essential part of our diet but too much is bad for us.

Starter 10–15 minutes

Introduce the lesson objectives.

Give each pupil a green and a red card as used in booster lesson 8. Read out the true/false statements (see below) and go through the quiz at a good pace. Point out that the questions are both scientific and of everyday importance. Pupils should draw on knowledge from their lessons and from what they might have seen on television, for example. Ensure all pupils participate by showing their selected card: green for true and red for false. Take a little time at the end to discuss any statements that gave particular difficulty.

Main activity 30–35 minutes

Tell the pupils to work in pairs. Allocate to each pair one statement from **handout S17.1**. If you think it appropriate you could also provide the physical examples or equipment. Distribute to each pair a copy of **handout S17.2** and tell them to complete the sheet by writing down those things they know, those things they think, and the evidence or reasons for these. Pupils may want to refer to science textbooks, so have a selection available. Once the three boxes are as complete as possible the pair writes down a scientific explanation in the remaining box.

While pupils are working in pairs, go around and listen to the conversations. As appropriate, ask questions or provide other information to enable the pairs to complete the task successfully.

Draw the activity to a close by completing a large version of S17.2; a flipchart or OHT is useful for this. Invite pupils to contribute ideas from their own completed handouts, all the time making the point that coming to scientific explanations means reviewing what we know and think and then trying to set this into context. Acknowledge that in doing this we may generate ideas which may be inaccurate or even wrong but the process will often allow these to be corrected.

Plenary 10–15 minutes

Remind pupils of the objectives for the lesson. Then show the class the stout metal tube, saying that such tubes are sometimes carried in the boot of a car. Ask pupils in pairs to speculate why. If needed, you can offer one or both of the following hints: ‘It’s a tool’ and ‘In case of a puncture’. Work towards the scientific explanation that the tube is used to extend the leverage of the wheel brace. Finally remind the class that this is another example of a scientific explanation of an everyday action.

Starter: drawing information together

Tell pupils that you will read out a series of statements. Ask them to show the green card if they think the statement is true and the red card if they think it is false.

1	pH 2 is acidic.	T
2	All soils are pH 7.	F
3	Acid rain is the only factor which can make soils acidic.	F
4	All plants grow healthily in soil of any pH.	F
5	Plants always give out carbon dioxide and take in oxygen.	F
6	Air contains carbon dioxide naturally. It is vital for food production.	T
7	Carbon monoxide is poisonous.	T
8	Humans can live in pure oxygen.	F
9	Fossil fuels produce nitrogen when they are burned.	F
10	Carbon dioxide produced when fossil fuels are burned dissolves in rainwater to make acid rain.	T
11	Burning fossil fuels produces oxides of nitrogen and sulfur which dissolve in rainwater to make it acidic.	T
12	Sulfur dioxide and carbon dioxide are produced naturally when a volcano erupts. This makes rainwater acidic.	T
13	The chemical symbol for sulfur is Su.	F
14	Acid rain does not affect sandstone.	F
15	Global warming has something to do with carbon dioxide.	T
16	Iron is not affected by acid rain.	F
17	The ozone layer absorbs harmful ultraviolet light.	T
18	We breathe in oxygen and breathe out carbon dioxide.	F
19	Acid rain kills animals.	T
20	We cannot reduce the amount of acid fumes that enter the air.	F
21	Lichens can be used to monitor air pollution.	T
22	Pesticides can accumulate in food chains.	T
23	We must burn fossil fuels to generate electricity.	F
24	We use up energy and so have always to produce more.	F

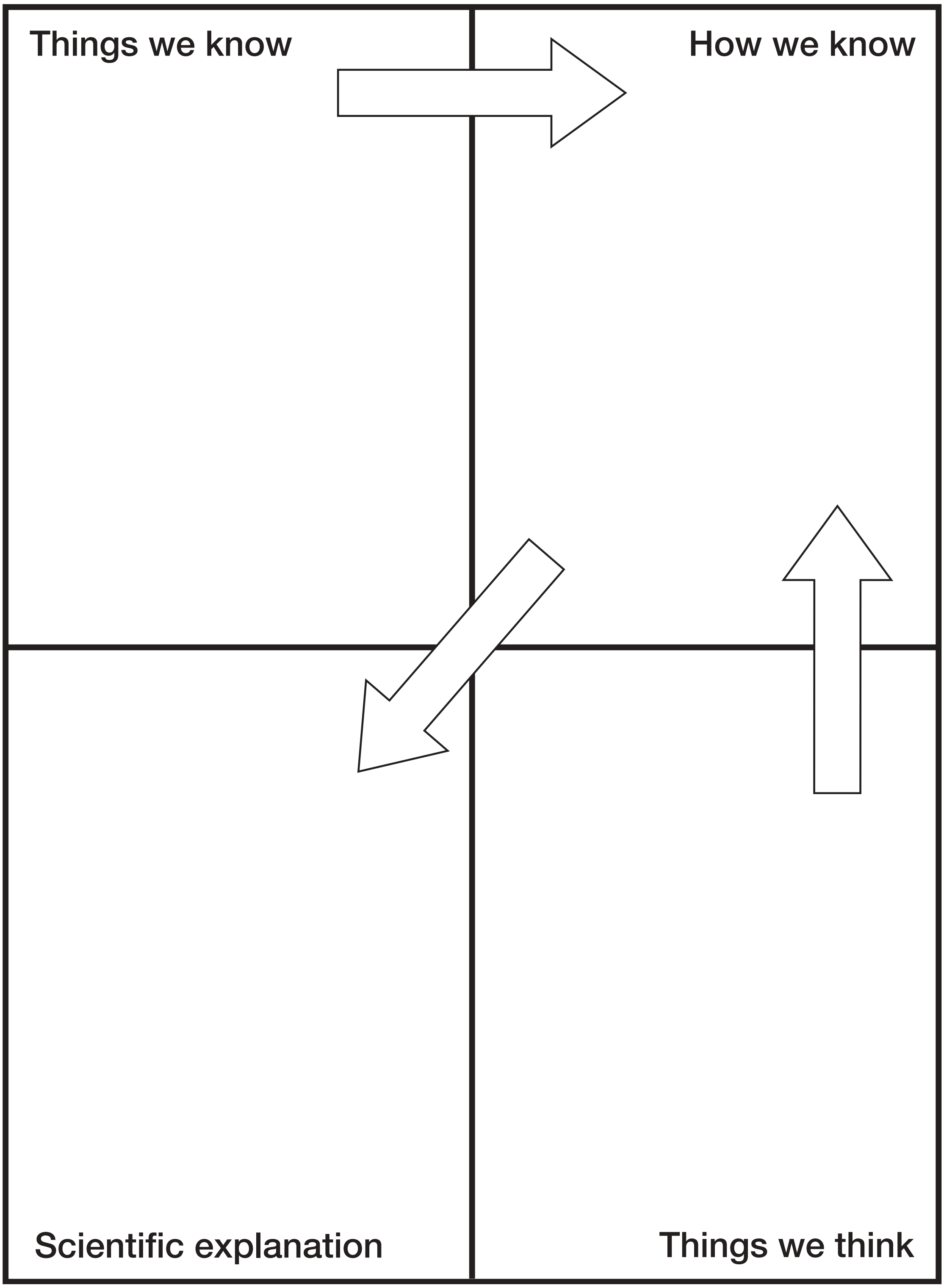
This starter quiz could give rise to another booster lesson based around discussions of the answers to the above statements. You could use the quiz again in the plenary for that lesson to assess how pupils have moved on.

Science statements S17.1

A sharper knife can cut cheese more easily.
Milk goes off more quickly if left in an open container at room temperature.
Stirring brown sugar into water causes the sugar crystals to vanish but the water to turn brown.
Taking stomach powder or tablets stops stomach ache.
Blood flows around the body as a liquid, but as soon as you cut yourself it forms a solid scab.
Tin cans aren't made of tin any more. You can tell this because a magnet will pick up a tin can but not a piece of tin foil.

Scientific explanation writing frame

S17.2



Lesson 18 Modelling solids, liquids and gases

Objectives

Clarify knowledge and understanding of the particle model and its representation in diagrams

Develop confidence in using this understanding in a range of situations

Vocabulary

particles, atoms, molecules, states of matter, evaporation, melting, freezing, boiling, condensing, compression, expansion, conduction, temperature, pressure

Resources

Handout S18.1 (one set copied onto card and cut up)

Handouts of S18.2 to S18.4 (one each per pupil)

Mini-whiteboards or a supply of paper

By the end of the lesson pupils should be able to:

- recognise the limitations of particle models
- use particle models to represent relative separation and arrangements of particles in solids, liquids and gases
- use models to represent changes in particle arrangements when there are changes in temperature and pressure

Starter 10 minutes

Introduce the objectives.

Remind the class how to play a loop card game. Give out the cards prepared from **S18.1**. Ensure that all 30 cards are distributed. Ask one pupil to begin and encourage pupils to answer quickly and read out the next question. Time how long it takes to complete the game. You could run the game a second time to try to increase the speed of completion or you could move on to the main activity and run the loop game again at the end of the lesson.

Main activity 40 minutes

Activity 1 (2 minutes). Mini-whiteboards, if available, would be ideal here, otherwise pupils need several sheets of paper to draw on. Tell pupils to quickly draw a five-particle arrangement to represent a solid and hold their pictures for you to see. Repeat the instruction for a five-particle arrangement for a gas and then a liquid. You will be able to judge from these pictures the extent of pupils' misconceptions, and where you should best target your support.

Activity 2 (10 minutes). Prepare for this activity by writing the key words and phrases (see notes below) on the board or OHT. Distribute **handout S18.2**. Tell pupils to draw the particle arrangements in a solid, a liquid and a gas in the 'first draft' boxes. Pupils should then compare drawings with a partner and check whether they have drawn them carefully enough to show (a) the size of the particles, (b) the distance apart of the particles, and (c) the arrangements of the particles. Allow time for pairs to discuss their ideas and then ask them to redraw the three diagrams in the 'agreed diagrams' boxes on the handout. At this point pupils should select from the key words and phrases appropriate labels for their diagrams. Choose one pupil to draw their diagrams in suitable boxes on the board, adding key words and phrases. Conduct a whole-class review session to amend these drawings and labels until the whole group is satisfied with the drawings and use of key words.

Activity 3 (25 minutes). Give each pupil **handouts S18.3** (a set of statements) and **S18.4** (a set of diagrams). Tell pupils to work in pairs and decide quickly which statements are incorrect. Allow a few minutes and then take feedback. Tell the pairs to look at the diagrams and decide what each shows. After a few minutes take feedback. Finally tell the pairs to match the true statements to the diagrams. Explain that each true statement can be used once, more than once, or not at all.

Possible follow-up activities or homework

Ask pupils to write a short story describing what happens to some water particles as they become part of an ice lolly which a child then eats.

Plenary 10 minutes

Review the lesson using a few quick questions and answers. Then explain and illustrate wherever possible the limitations of the models used earlier:

- Particles are not always spherical.
- Some materials behave unusually (e.g. water, which is less dense as a solid) and the simple model does not explain that behaviour.
- Diagrams do not readily represent the forces between particles.

Particles: key words and phrases

With reference to particle size the key words are:

- bigger;
- smaller;
- same shape;
- different shape.

With reference to the distance apart of particles the key phrases are:

- distance apart increasing;
- distance apart decreasing.

With reference to the arrangement of particles the key words and phrases are:

- regular pattern;
- random.

During activity 2 of the main part of the lesson, pupils should use some or all of these labels in any way they wish on handout S18.2 in order to add extra detail about the particle arrangements in solids, liquids and gases.

Card loop game S18.1

Cooling a gas slows down the movement of its particles and the pressure will …	Squeezing air quickly in a bicycle pump raises the pressure and causes a rise in …
melting	*decrease*
The temperature at which a solid becomes a liquid is called the …	All matter is composed of …
temperature	*melting point*
All particles in a substance have kinetic energy and …	Condensation happens because …
particles	*move or vibrate*
Substances expand when heated because their particles …	In these two states of matter the particles are close together
the water particles move more slowly	*move further apart*
This type of substance does not have a fixed melting point	In these two states of matter the particles can move freely about
solids and liquids	*mixture*
Changing a gas to a liquid is called …	This gas forms about four fifths of air (80%)
liquids and gases	*condensation*

Squeezing a gas to turn it into a liquid is called …	This gas forms about one fifth of air (20%)
nitrogen	*compression*
Cooling a gas will cause its particles to move …	This gas forms about 0.5% of air
oxygen	*more slowly*
Freezing is the result of cooling a …	Heating a gas will cause its particles to …
carbon dioxide	*liquid*
Air particles striking the wall of a container cause …	When a gas is compressed its pressure will …
move more quickly	*air pressure*
These substances retain their shape	This substance is used in hydraulics because it does not easily compress
increase	*solids*
Particles in a solid do not …	Particles can be made to move further apart by …
water	*change position easily*

A liquid does not have a fixed shape because …	Changing a liquid to a gas is called …
heating	*the particles can move around each other easily*
Particles in a gas are …	Changing a liquid to a solid is called …
evaporation	*far apart*
This sort of substance is easily compressed	Changing a solid to a liquid is called …
solidification	*gas*

Arrangements of particles S18.2

First draft

Particles in a solid

Particles in a liquid

Particles in a gas

Agreed diagrams

Particles in a solid

Particles in a liquid

Particles in a gas

True or false? S18.3

1 Particles are further apart when the substance is a gas.

2 Particles are all circular (or spherical).

3 Particles move faster when the substance is a gas.

4 Heating a liquid increases the distance between particles.

5 Heating a liquid makes it evaporate more quickly.

6 Heating a solid makes the individual particles expand.

7 Compressing a gas makes the particles move closer together.

8 All substances are made of particles.

Particle diagrams

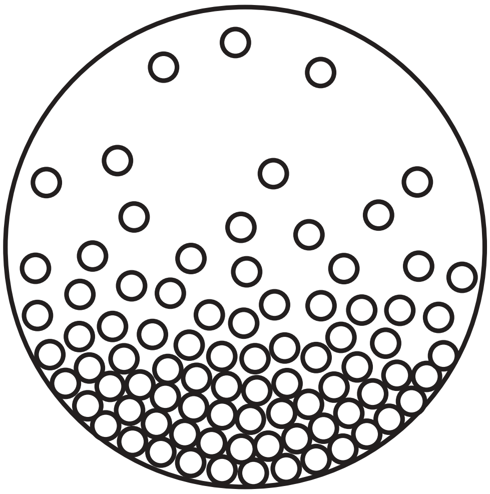


Figure 1

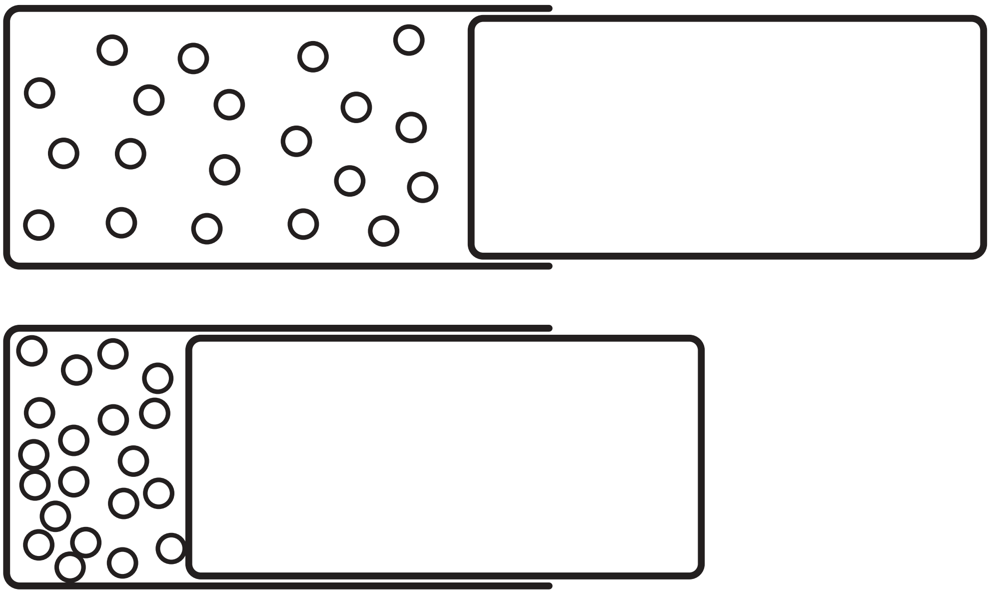


Figure 2

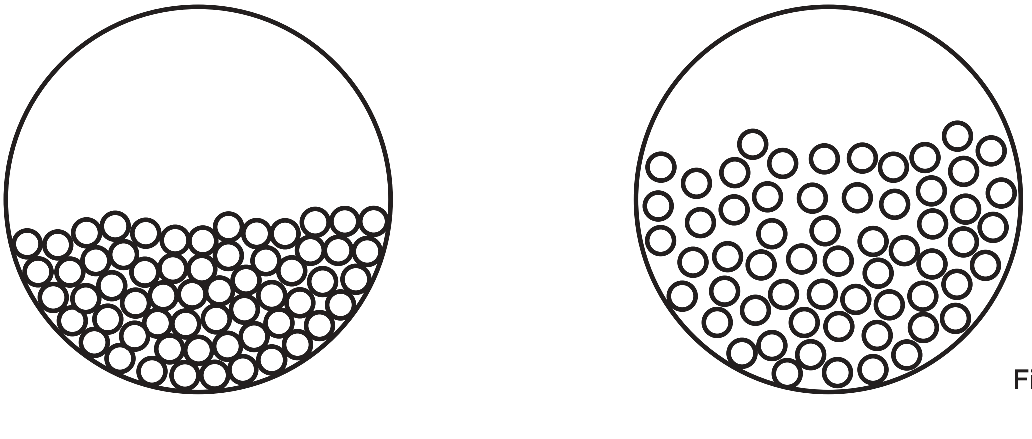


Figure 3

Lesson 19 Particles in chemical reactions

Objectives

Describe what happens to the particles in some simple chemical reactions

Be able to write word equations for some chemical reactions

Vocabulary

reaction, atom, molecule, element, compound, particle, chemical change, collision, diffusion, reactant, product

Resources

Equipment to demonstrate the reaction between hydrochloric acid and ammonium hydroxide solution – long tube with bungs at each end, cotton wool, reactants (this standard demonstration can, if necessary, be found in *Classical chemistry demonstrations*, RSC, 1995, ISBN 1 87034 338 7)

Handout of S19.2 (one per pupil)

Handouts of S19.1 and S19.3 (cut out beforehand, one set of each per group of four)

Handouts of S19.4 and S19.5 (one each per group of four)

By the end of the lesson pupils should be able to:

- know and use correctly the words *atom*, *molecule*, *compound* and *particle*
- describe what happens to particles in a chemical reaction
- write word equations for simple chemical reactions

Possible follow-up activities or homework

Ask pupils to find and write four word equations for simple chemical reactions, leaving gaps for others to complete.

Starter 15 minutes

Introduce the objectives.

Set up the demonstration of the reaction between hydrochloric acid and ammonium hydroxide solution (see resources). As you work explain what you are doing and that the reaction will happen over the next few minutes. Then distribute copies of cards made from **handout S19.1** to each group of four pupils. Tell the groups first to sort the pictures into order of complexity, then to match the statements to the pictures and give a reason for each match, and finally to label the diagrams 'element', 'compound' or 'molecule' as appropriate.

Main activity 30 minutes

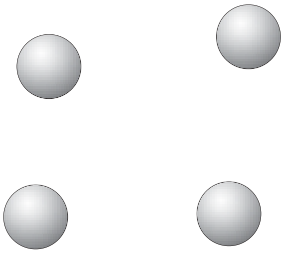
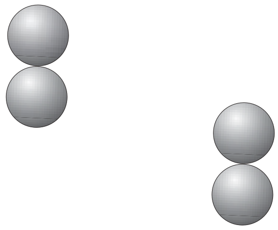
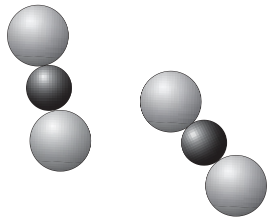
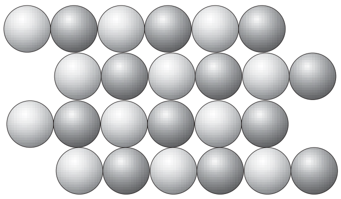
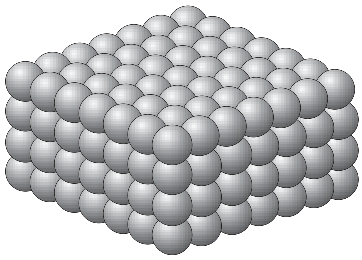
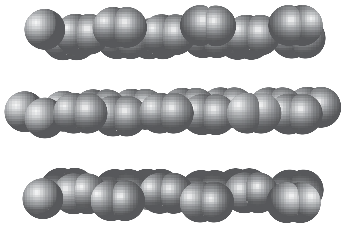
Activity 1 (15 minutes). Return to the demonstration which should have produced a visible reaction. Ask questions to elicit ideas of what has happened, the movement of particles, which moved the fastest, and explanations of the term *diffusion*. Give out **handout S19.2** which traces the reaction. Go through this to establish that no particles are left out of the reaction and no new ones introduced. Consolidate the idea of particles reacting using one or two further reactions, for example, oxygen and hydrogen to produce water, carbon and oxygen to produce carbon dioxide.

Activity 2 (15 minutes). Tell pupils to work in groups of four. Give each group a set of cards from **handout S19.3** and a copy of **handout S19.4** which has the instructions for the activity. Go through the instructions. While the pupils are working, circulate and question them on their understanding of what is happening to the particles in the reactions. Pupils who progress quickly could produce cards for other reactions of their own choice.

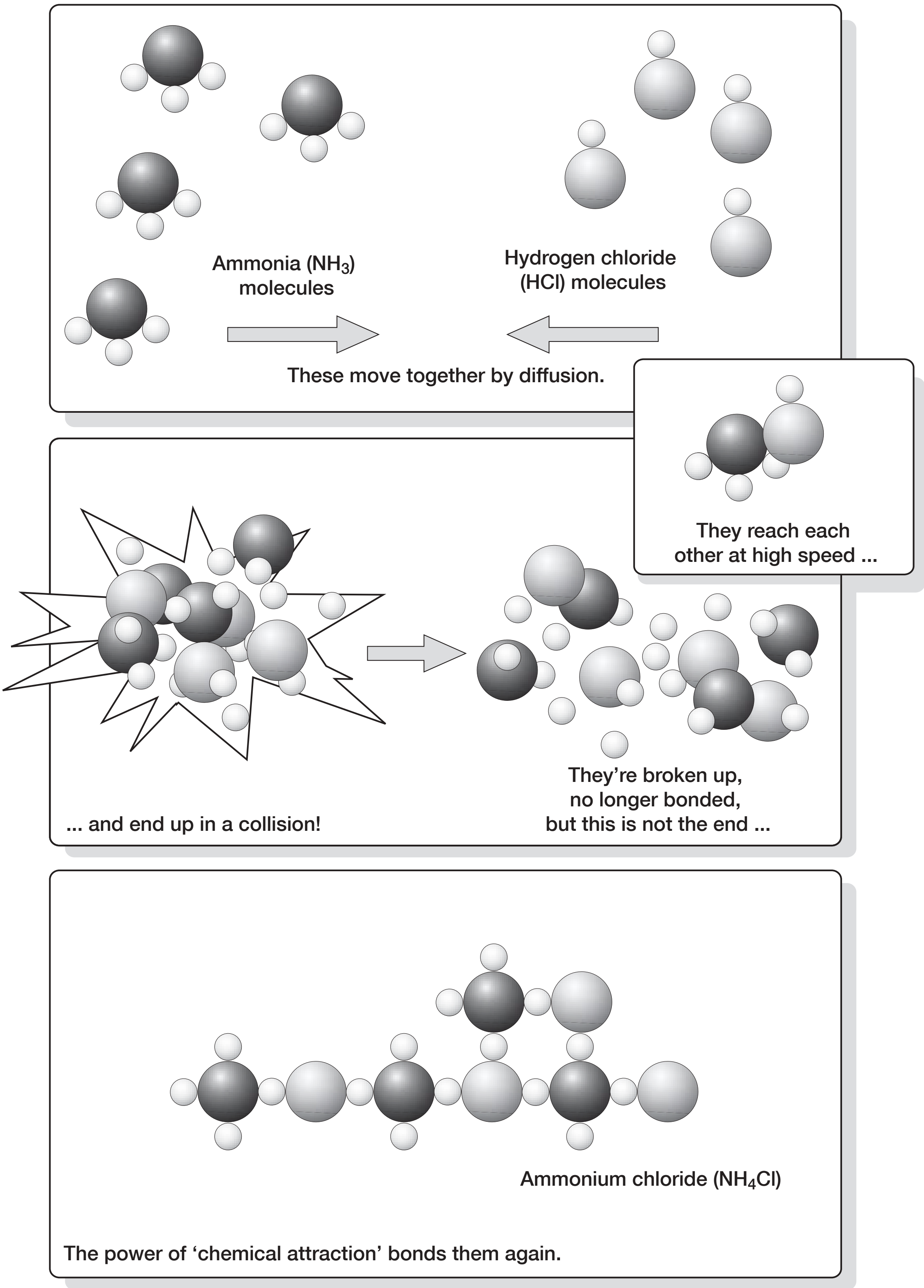
Plenary 15 minutes

This is a 'hot-seat' activity. Tell pupils to remain in their groups of four. Issue copies of **handout S19.5** to each group; this contains a set of questions. Each group selects one person to be in the 'hot seat' who has to answer the first four questions and give any explanations that the group asks for. Rotate the hot seat for the next group of four questions, and so on. After 10–12 minutes the teacher assumes the hot seat to answer any questions the groups found difficult.

Particles in chemical reactions: starter S19.1

		
		
The **compound** sodium chloride – a solid at room temperature consisting of a giant lattice of sodium and chlorine particles	The **element** argon – a gas at room temperature consisting of atoms	The **element** oxygen – a gas at room temperature consisting of atoms
The **compound** carbon dioxide (CO_2) – a gas at room temperature consisting of molecules	The **element** iron – a solid at room temperature consisting of a lattice of many atoms	The **element** carbon – a solid at room temperature consisting of a giant lattice

Ammonia and hydrogen chloride reaction S19.2



Reaction cards

Reactants: iron sulfur	Product: iron sulfide	Black solid mass
Reactants: magnesium hydrochloric acid	Products: magnesium chloride hydrogen	Vigorous bubbling, magnesium 'disappears'
Reactants: calcium carbonate hydrochloric acid	Products: calcium chloride water carbon dioxide	Bubbling, calcium carbonate 'disappears'
Reactants: sodium water	Products: sodium hydroxide hydrogen	Sodium floats and moves on water, sodium fizzes
Reactants: magnesium oxygen	Product: magnesium oxide	Blinding white flame, white ash left
Reactants: sulfur oxygen	Product: sulfur dioxide	In a gas jar, fumes of pungent gas appear
Reactants: iron copper sulfate	Products: iron sulfate copper	A red-brown colour appears around the iron; the blue solution turns colourless

iron + sulfur → iron sulfide
magnesium + hydrochloric acid → magnesium chloride + hydrogen
calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide
sodium + water → sodium hydroxide + hydrogen
magnesium + oxygen → magnesium oxide
sulfur + oxygen → sulfur dioxide
iron + copper sulfate → iron sulfate + copper

Reaction cards: instructions S19.4

The set of cards from handout S19.3 contains information for seven different chemical reactions. These are:

- a reaction between two elements;
- a reaction between a metal and water;
- a reaction between a metal and an acid;
- a reaction between a metal carbonate and an acid;
- burning a metal;
- burning a non-metal;
- a displacement reaction.

For each type of reaction, look through the cards and identify:

- the reactants,
- the products, and
- the word equation,

and put the cards into sets, one set per reaction.

The remaining cards have information about observations you could make during or after the reaction. Match each observation card to the correct reaction and add it to the set.

If you have time, make up your own cards for further examples of reactions.

Hot-seat questions S19.5

1 Why does a splint disappear on burning?

2 Why does the mass of a beaker containing magnesium and hydrochloric acid go down during the reaction?

3 What product would you expect to see when a balloon of hydrogen is burnt?

4 Why don't you see the product you expect for question 3?

5 What is the test for hydrogen?

6 What is the white ash left when magnesium is burnt in air?

7 Why is there no fizzing when an acid is reacted with a base (or alkali)?

8 How can you tell there has been a chemical change?

9 What is the red/brown colour formed when iron is reacted with copper sulfate solution?

10 What is the word equation for the reaction between carbon and iron oxide?

11 What is the name of the process that describes the movement of particles from one place to another?

12 What is the name of chemicals that take part in a reaction?

13 What is the test for carbon dioxide?

14 Why does a candle go down when it burns?

15 Why does the magnesium seem to disappear when it reacts with acid?

16 If you react 1 g of iron with 1 g of sulfur, what would be the mass of the iron sulfide produced?

Lesson 20 Conduction, convection, radiation and evaporation

Objectives

Explain convection, conduction and radiation as means of energy transfer

Relate these to some everyday examples

Relate the energy transfer to that involved in evaporation

Vocabulary

conduction, convection, radiation, particles, energy, energy transfer, density, vibration

Resources

Equipment and materials as appropriate for practicals (see notes on page 89)

Radiant heat source

Handouts of S20.1 (a few copies) and S20.2 (one per pair)

By the end of the lesson pupils should be able to:

- explain conduction and convection using ideas of particle movement and energy transfer
- explain that radiation is energy transfer through waves
- begin to explain energy transfer in evaporation

Starter 10 minutes

Show the pupils two mugs of tea: one just made and very hot, and one 'you made earlier' and cold. Explain that earlier today the cold tea was as hot as the hot tea is now. Ask them to work in pairs to generate some key words and phrases to describe where the heat has gone. Elicit all ideas that will give you evidence about pupils' levels of understanding or misunderstanding.

Introduce the objectives and explain that pupils are going to improve their understanding of conduction, convection and radiation and their accurate use of these key words. Explain too that you are going to use the word *energy* throughout this lesson so that the pupils can think about energy transferring from one place to another.

Main activity 40 minutes

Conduction. Demonstrate practical 1 (see notes on page 89). Ask pupils to predict which blob of butter or wax will melt first. While the bar is heating model the particle movement using pupils as described in the notes. Then tell the class you now have two pieces of evidence for energy moving through materials: (i) energy moved along the bar to the butter or wax; (ii) energy moved through the mug to the air and the table. Ask pupils to work in pairs and write a sentence to describe how they think the energy moved. Say that the sentence must include the word 'particle'. Support and encourage the pairs as necessary but allow them to write their own ideas. After a few minutes tell pairs to join as fours to compare sentences. The four should produce an agreed new sentence written large on A4 paper.

Convection. Demonstrate practical 2 (see notes on page 89). Ask pupils to predict whether the ice will melt quickly. Then demonstrate practical 3. Explain that you now have three pieces of evidence which require a different explanation from that for conduction: (i) the ice did not melt quickly but the water at the top of the tube got very hot, perhaps even boiled; (ii) the colour of the dissolving potassium permanganate crystal was seen to rise up the side of the beaker, move across the top and then begin to fall; (iii) the air above the hot mug of tea is warmer than air around. Repeat the sentence-writing activity from above by asking the pupils to write a sentence to explain how the energy moved, again requiring the pupils to include the word 'particle'. Give out and go through **handout S20.1** if any groups are stuck.

Radiation. Remind pupils that energy from the Sun warms us up on a sunny day, but that the Sun is 149 million kilometres (93 million miles) away in space. Then demonstrate a radiant heat source allowing the pupils to feel the heat. Explain that we now have three more pieces of evidence: (i) energy transferred from the Sun through space; (ii) energy transferred quite quickly from the radiant source; (iii) energy transferred in a similar way from the mug of tea. (You may also want to remind them about thermal imaging cameras.) Repeat the sentence-writing exercise but this time explain that pupils cannot use the word 'particle' because there are no particles in most of space.

Allow the class to go around and look at the three sentences written by each group. Tell them that they can modify any of their sentences if they wish. At this point gather all the conduction sentences and display them at the front. Use questions and answers to derive a single sentence which describes energy transfer by conduction. Write this on the board or OHT. Repeat for convection and radiation.

Possible follow-up activities or homework

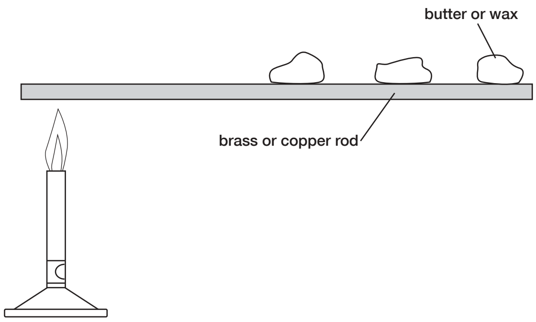
Ask pupils to explain why loft insulation and double glazing are effective ways of preventing heat loss from a house.

Plenary 10 minutes

Give out **handout S20.2** which illustrates steam coming from a boiling kettle and three children's explanations. Ask pupils to work in pairs and think about the three sentences that describe the energy transfer and particle movement. Tell them to decide which statement is correct and why. Allow 5 minutes and then take feedback by asking one pair for their ideas, and then allowing others to make further points or ask questions.

Conduction, convection and radiation practicals

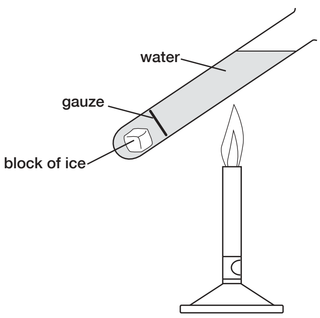
Practical 1



Position the Bunsen at one end of the brass or copper rod.

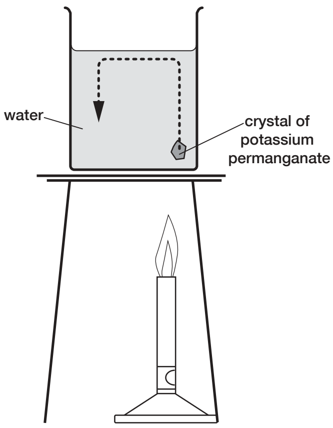
While the rod is heating, ask pupils to role-play the demonstration. Assemble a line of pupils standing close together with their arms tightly linked. The one at the end takes the part of the Bunsen, two or three pupils in the line are the butter or wax and the others are the rod. The 'Bunsen' vibrates, which induces greater vibration of the 'particles' along the line to model the energy transfer down the rod.

Practical 2



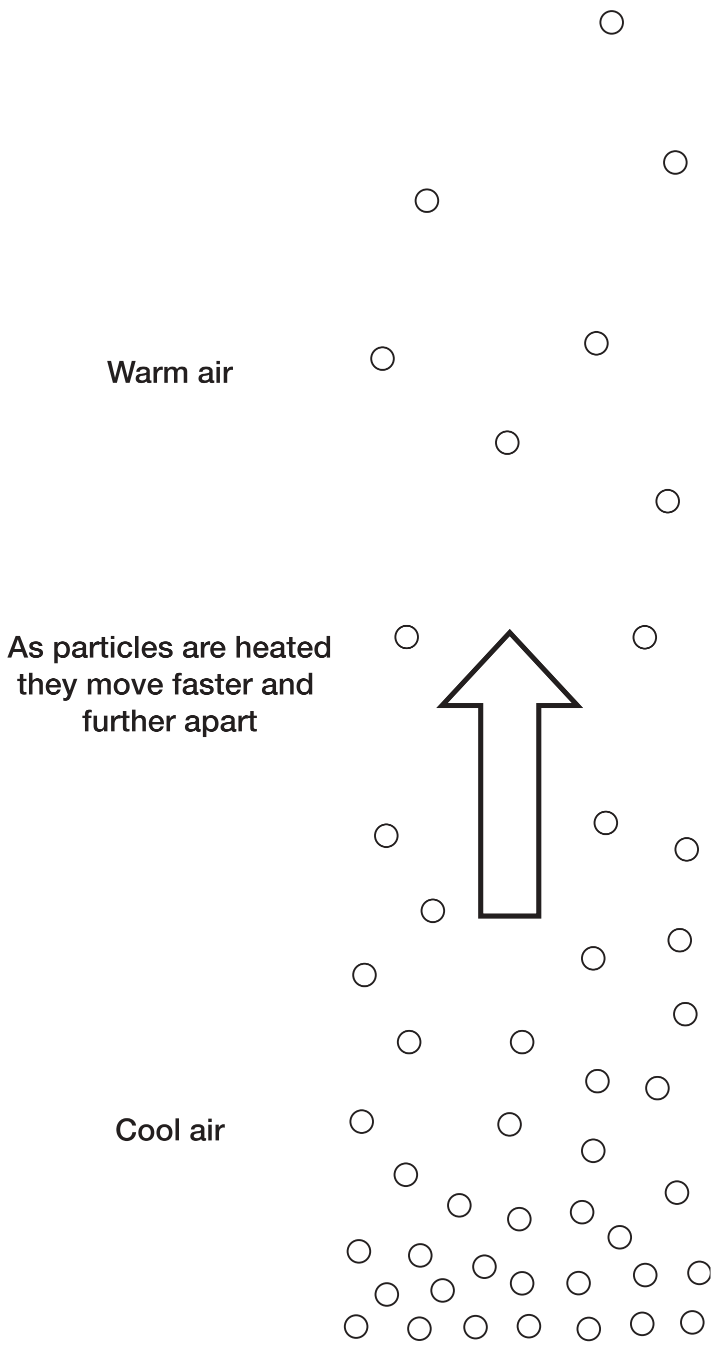
Place the Bunsen halfway between the gauze and the meniscus. Heat the water gently and angle the test tube away from pupils.

Practical 3



Make sure that the crystals are placed in the beaker with as little disturbance to the water as possible. Drop them down a plastic or glass tube held in the water with the end near the bottom.

Convection


Warm air
As particles are heated they move faster and further apart
Cool air

Energy transfer in boiling water S20.2