

GCSE



WJEC GCSE in  
**SCIENCE**  
**(DOUBLE AWARD)**  
APPROVED BY QUALIFICATIONS WALES

# GUIDANCE FOR TEACHING

Teaching from 2016

This Qualifications Wales regulated qualification is not available to centres in England.



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## UNIT 1 – BIOLOGY 1

### 1.1 CELLS AND MOVEMENT ACROSS CELL MEMBRANES

	Spec Statement	Comment
(a)	the structure of animal and plant cells, including drawing and labelling diagrams and the function of the following parts: cell membrane, cytoplasm, nucleus, mitochondria, cell wall, chloroplast, vacuole	Know the role of the following structures: cell membrane: controls the entry and exit of substances cytoplasm: site of most cell reactions nucleus: contains chromosomes which carry genetic information and controls the activities of the cell mitochondrion: site of aerobic respiration cell wall containing cellulose: structural support for plant cells chloroplast: site of photosynthesis vacuole: contains a watery sugar solution (sap), a swollen vacuole pushes the rest of the cell contents against the cell wall, making the cell firm
(b)	the use of a light microscope to view animal and plant cells	Calculation of total magnification is achieved by the multiplication of the power of the eyepiece lens by the power of the objective lenses. <ul style="list-style-type: none"> <li>• how a slide is prepared, including that biological staining allows more detail of the cell to be seen</li> <li>• the limitations of light microscopy in studying cell structure: restriction in maximum magnification</li> <li>• a simple comparison with the electron microscope: greater magnification but can only be used to view dead tissue</li> </ul>
(c)	the differentiation of cells in multicellular organisms to become adapted for specific functions - specialised cells	Specialised cells are more efficient in performing specific functions than non-specialised cells.
(d)	the levels of organisation within organisms: tissues are groups of similar cells with a similar function and organs may comprise several tissues performing specific functions; organs are organised into organ systems, which work together to form organisms	
(e)	diffusion as the movement of substances down a concentration gradient; the role of the cell membrane in diffusion; Visking tubing as a model of living material; the results of Visking tubing experiments in terms of membrane pore and particle size	

(f)	diffusion as a passive process, allowing only certain substances to pass through the cell membrane in this way, most importantly oxygen and carbon dioxide	
(g)	osmosis as the diffusion of water through a selectively permeable membrane from a region of high water (low solute) concentration to a region of low water (high solute) concentration	Carry out practical work to show osmosis in living material. The results should be quantitative where possible, giving students opportunities to make calculations and analyse data in order to draw conclusions.
(h)	<b>active transport as an active process whereby substances can enter cells against a concentration gradient</b>	<b>Respiration provides the energy required in the form of ATP. (No detail is required of the process of ATP synthesis or how it is used to release energy)</b>
(i)	enzyme control of chemical reactions in cells; enzymes are proteins made by living cells, which speed up/catalyse the rate of chemical reactions	Enzymes are involved in all metabolic reactions building large molecules from small ones as well breaking down large molecules into small ones.
(j)	<b>how different enzymes are composed of different amino acids linked to form a chain which is then folded into a specific shape</b>	<b>The importance of specific amino acid sequences in determining protein structure and thus function.</b>
(k)	how the specific shape of the active site of an enzyme enables it to function, a simple understanding of 'lock and key' modelling and be able to interpret enzyme activity in terms of molecular collisions <b>resulting in the formation of enzyme-substrate complexes</b>	Apply knowledge of 'lock and key' to the analysis of simple, stylised diagrams of enzyme/substrate interactions.
(l)	the effect of temperature and pH on enzyme activity including the effect of boiling which denatures most enzymes	Understand the term optimum as a particular condition (such as temperature or pH) at which the rate of enzyme action is greatest as increased temperature results in increased collisions between enzymes and substrates. In a denatured enzyme the specific shape of the active site is destroyed and can no longer bind with its substrate, so no reaction occurs. Analyse data to show how enzyme action is affected by temperature and pH.

### SPECIFIED PRACTICAL WORK

- Examination of animal and plant cells using a microscope and production of scientific labelled diagrams
- Investigation into factors affecting enzymes

## Examination of animal and plant cells using a light microscope and production of labelled scientific diagrams from observation

### Introduction

Cheek cells are typical animal cells, they have a cell membrane, cytoplasm and a nucleus. Onion cells are plant cells, they have a cell wall, cell membrane, cytoplasm, nucleus and vacuole. This practical requires you to prepare cheek cell slides and onion cell slides. These slides can then be observed using a microscope.

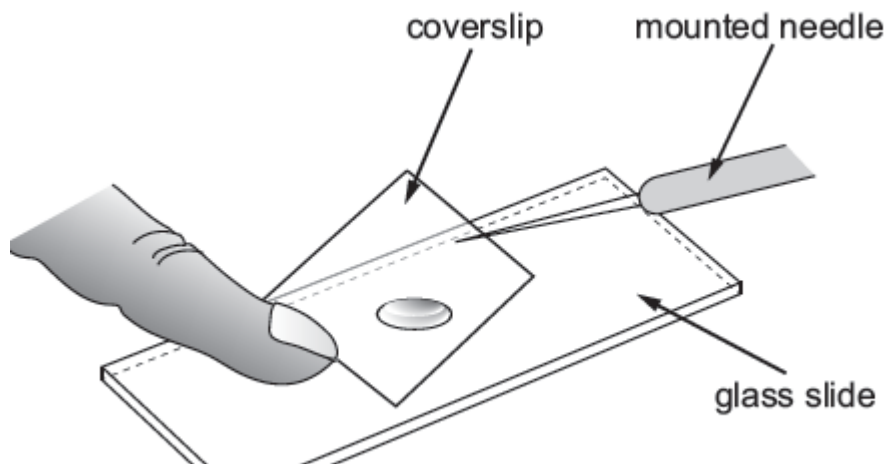
### Apparatus

light microscope  
 2 × glass slides  
 2 × cover slips  
 cotton wool bud  
 mounted needle  
 forceps  
 freshly cut onion  
 0.1 % methylene blue solution  
 iodine solution

#### Access to:

beaker of disinfectant

### Diagram of Apparatus



## Method

### Cheek Cells:

1. Put a drop of methylene blue on a glass slide.
2. Gently rub the inside of your cheek with a cotton bud.
3. Wipe the end of the cotton bud in the drop of methylene blue on the glass slide.
4. Place the cotton bud in the beaker of disinfectant.
5. Use the mounted needle to gently lower a coverslip onto the glass slide.
6. Using a light microscope, examine the slide using the  $\times 10$  objective lens.
7. Use the  $\times 40$  objective lens to identify some of the cell structures.
8. Draw a cell diagram. Identify and label: cell membrane, cytoplasm and nucleus.

## Analysis

1. Calculate the total magnification of the image seen by multiplying the power of the objective lens by the power of the eyepiece.
2. Your teacher will tell you the actual size of the cell, calculate the magnification of your diagram.

## Method:

### Onion Cells:

1. Using forceps, peel a thin layer of epidermis from the inside of a freshly cut onion piece.
2. Lay the epidermis onto a glass slide.
3. Add a drop of iodine solution to the onion epidermis on the glass slide.
4. Use the mounted needle to gently lower a coverslip onto the glass slide.
5. Using a light microscope, examine the slide using the  $\times 10$  objective lens.
6. Use the  $\times 40$  objective lens to identify some of the cell structures.
7. Draw a cell diagram. Identify and label: cell wall, cell membrane, cytoplasm and nucleus.

## Analysis

1. Calculate the total magnification of the image seen by multiplying the power of the objective lens by the power of the eyepiece.
2. Your teacher will tell you the actual size of the cell, calculate the magnification of your diagram.

## Teacher/Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Methylene blue is harmful and/or irritant	Splashing onto hand/skin/you whilst using Transfer from hand into eye when placing on slide	Wash off/wear gloves Wear eye protection.
Cheek cells are a biohazard	Transfer of infection from cheek cell to other people when handling	Only handle samples from your own body. After use, hygienically dispose of cotton buds and slides in a disinfectant such as Milton or Virkon.
Coverslips/ mounted needles are sharp	Coverslip/mounted needle could cut skin when placing on slide	Only use mounted needle by handle/only handle coverslip by the sides

Methylene blue and iodine solution are stains. Avoid contact with the skin. Iodine is a low hazard chemical as a dilute solution.

Suitable disinfectant would include Milton or Virkon which would need to be diluted to suitable concentrations.

If the lamp is not an integral part of the microscope, a desk lamp will be needed for each group.

Freshly cut onion is recommended. This should be prepared for student use in pieces approximately 1 cm<sup>2</sup>.

Students will need to be briefed regarding safe and effective microscope use prior to this practical activity. This practical activity is effective at developing microscope skills and biological drawing skills.

Students can calculate the total magnification of the image as the power of the objective lens multiplied by the power of the eyepiece. The actual size of the cells can be given to the students to enable them to calculate the magnification of their diagrams.

## Working scientifically skills covered

### 1. Development of scientific thinking

Appreciate the power and limitations of science and consider any ethical issues which may arise.

### 2. Experimental skills and strategies

Apply knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to this experiment.



Make and record observations and measurements using a range of apparatus and methods.

**3. Analysis and Evaluation**

Present observations and other data using appropriate methods.

## Investigation into factors affecting enzyme action

### Introduction

Iodine is an indicator that turns blue/black when starch is present, but is otherwise brown. In this investigation a blue/black solution of starch and iodine will change to brown as the enzyme amylase digests/breaks down the starch into sugar. The time taken for this reaction to occur is affected by temperature.

### Apparatus

test tube rack and six test tubes  
 marker pen  
 stopwatch  
 25 cm<sup>3</sup> measuring cylinder  
 10 cm<sup>3</sup> measuring cylinder  
 beaker of 1 % starch solution  
 dropper bottle of iodine solution  
 beaker of 10% amylase solution  
 spotting tile  
 dropping pipette

#### Access to:

water bath or alternative method of heating water

### Method

1. Measure 10 cm<sup>3</sup> of 1 % starch solution into a test tube.
2. Measure 2 cm<sup>3</sup> of 10% amylase solution into a second test tube.
3. Place both tubes into a water bath set at 20 °C for 3 minutes.
4. Place a drop of iodine in six wells of a spotting tile.
5. Remove both test tubes from the water bath. Pour the amylase into the starch/iodine solution and start the stopwatch.
6. Immediately, use the dropping pipette to place one drop of the mixture onto the first drop of iodine. Record the colour of the solution.
7. Repeat step 6 every minute for five minutes.
8. Repeat steps 1-7 at 30 °C, 40 °C, 50 °C, 60 °C.

### Analysis

1. Use your observations to reach a conclusion regarding the effect of temperature on enzyme action.
2. Evaluate your method and suggest possible improvements.

Teacher/Technician notes

Risk Assessment

Hazard	Risk	Control measure
10% amylase enzyme solution is an irritant	Amylase enzyme could get on to the skin when pouring into the test tube	Wash hands immediately if amylase gets on to them/ wear laboratory gloves
	Amylase enzyme could get transferred to the eyes from the hands when pouring	Wear eye protection.

10% bacterial amylase solution is a suggested concentration. Amylase varies in its effectiveness with source and age so it will be necessary to try out the experiment before presenting it to students to establish the optimum concentrations of starch and amylase to use.

Iodine solution is a stain. It is a low hazard chemical as a dilute solution, however contact with the skin should be avoided

The method as stated does not include repeats, but students should be encouraged to carry out an appropriate number, if time allows.

Students should be encouraged to look at reproducibility by looking at the results of other groups. Evaluation should include consideration of the end point of the reaction and possible improvements.

Students should design their own table, but a suggested table format is shown below.

Temperature of solution (°C)	Colour of solution					
	at start	after 1 minute	after 2 minutes	after 3 minutes	after 4 minutes	after 5 minutes
20						
30						
40						
50						
60						

## Working scientifically skills covered

**2. Experimental skills and strategies**

Apply knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to this experiment.

Evaluate methods and suggest possible improvements and further investigations.

**3. Analysis and Evaluation**

Evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

## 1.2 RESPIRATION AND THE RESPIRATORY SYSTEM IN HUMANS

	Spec Statement	Comment
(a)	aerobic respiration as a process that occurs in cells when oxygen is available; respiration as a series of enzyme-controlled reactions within the cell, that use glucose and oxygen to release energy and produce carbon dioxide and water; <b>energy is released in the form of ATP</b> and be able to state the word equation to describe aerobic respiration	Use germinating peas to show that energy is released as heat during respiration. This should include the role of Thermos flasks and disinfectant in the experiment.
(b)	anaerobic respiration as a process that occurs in the absence of oxygen; glucose being broken down to release energy and lactic acid; oxygen debt as a result of anaerobic respiration; <b>anaerobic respiration as a less efficient process than aerobic respiration because of the incomplete breakdown of glucose; less ATP is produced per molecule of glucose in anaerobic respiration than in aerobic respiration</b> and be able to state the word equation for anaerobic respiration in human cells	Lactic acid is harmful to the body. It has to be removed from cells and broken down following the resumption of aerobic respiration (to repay the oxygen debt). No knowledge of anaerobic respiration in yeast is required.
(c)	the need for and purpose of the respiratory system and be able to label the following structures on a diagram of a vertical section of the human respiratory system: nasal cavity, trachea, bronchi, bronchioles, alveoli, lungs, diaphragm, ribs and intercostal muscles	Large organisms require a complex respiratory system in order to obtain a sufficient volume of oxygen to maintain a high level of aerobic respiration and to remove an equivalent volume of waste carbon dioxide.
(d)	the function of mucus and cilia in the respiratory system	Mucus and cilia help protect the respiratory system. Particles and bacteria stick to mucus and cilia move the mucus out of the respiratory system to the back of the throat.

(e)	the mechanisms of inspiration and expiration, in terms of changes in thoracic volume and pressure brought about by movements of the diaphragm and rib cage; movement of air takes place due to differences in pressure between the lungs and outside the body	This includes how changes in the position of chest wall and diaphragm affect the lung volume in inspiration and in expiration (viewed from the side and the front).
(f)	the use of a bell jar model to illustrate inspiration and expiration and the limitations of this model	Compare and contrast diagrams of the bell jar model and the gross structures of the human respiratory system.
(g)	the structure of an alveolus and its blood supply and be able to label the following structures on a diagram: end of bronchiole, wall of alveolus, moist lining of alveolus, wall of capillary, red blood cells and plasma	The direction of movement of gases should be shown as arrows on the diagram.
(h)	the percentage composition of inspired and expired air and the reasons for the differences; how gases diffuse between alveolar air and capillaries; the adaptations of alveoli for gas exchange; the use of lime water to indicate the presence of carbon dioxide	The composition of inspired air: 21% Oxygen, 0.04% Carbon Dioxide, 78% Nitrogen, percentage of water vapour varies. The composition of expired air: 16% Oxygen, 4% Carbon Dioxide, 78% Nitrogen, saturated with water vapour. Describe how a simple 'huff and puff' apparatus, with lime water to detect carbon dioxide, is used to compare the carbon dioxide content of inspired and expired air and to explain experimental results. The adaptations of alveoli for gas exchange include large surface area, thin wall, moist lining and a rich blood supply. These adaptations maximise the rate of diffusion of oxygen and carbon dioxide.
(i)	the effects of smoking on cilia and mucus in the respiratory system and the consequences for the individual; the link between cigarette smoking and lung cancer and emphysema and the consequences of these conditions	There are chemicals in cigarette smoke which paralyse cilia and particles which clog the mucus which prevents their function. This increases the risk of disease in the respiratory system. Tar in tobacco smoke contains carcinogens which lead to lung cancer. Cigarettes also contain nicotine which is addictive. Cigarette smoke destroys lung tissue which leads to emphysema.

## 1.3 DIGESTION AND THE DIGESTIVE SYSTEM IN HUMANS

	Spec Statement	Comment
(a)	the need for digestion; the breakdown of large molecules into smaller molecules so they can be absorbed for use by body cells	
(b)	the digestion of larger insoluble molecules into their soluble products which can then be absorbed: fats made up of fatty acids and glycerol; proteins made up of amino acids; starch (a carbohydrate) made up of a chain of glucose molecules	
(c)	the tests for the presence of: starch using iodine solution; glucose using Benedict's reagent; protein using biuret solution	Positive results: Iodine: brown to blue/black Benedict's reagent: blue to brick red Biuret solution: blue to violet
(d)	the role of the following enzymes in digestion: carbohydrase; protease; lipase	Carbohydrase: starch to glucose Protease: protein to amino acids Lipase: fats and oils (lipids) to fatty acids and glycerol
(e)	the structure of the human digestive system and associated structures: the mouth, oesophagus, stomach, liver, gall bladder, bile duct, pancreas, small intestine, large intestine, anus and be able to label these on a diagram	
(f)	the role of the following organs in digestion and absorption: mouth, stomach, pancreas, small intestine, large intestine, liver	Know the role of the following organs: <ul style="list-style-type: none"> <li>• Mouth - starch digestion begins by carbohydrase/ amylase in saliva</li> <li>• Stomach - secretes protease</li> <li>• Pancreas - secretes lipase, proteases and carbohydrase into the small intestine</li> <li>• Small intestine - continued digestion of carbohydrates to glucose, proteins to amino acids, fats to fatty acids and glycerol and absorption of digested molecules</li> <li>• Large intestine - absorption of water</li> <li>• Liver - secretes bile</li> </ul>

(g)	how food is moved by peristalsis	Understand the action of contraction and relaxation of muscles in peristalsis in forcing food through the digestive system.
(h)	the function of bile, secreted by the liver and stored in the gall bladder, in the breakdown of fats	Bile emulsifies large droplets of fat into small droplets to increase the surface area for enzyme action. It also increases the pH in the small intestine to the optimum pH for lipase activity.
(i)	how soluble substances can be absorbed through the wall of the small intestine and eventually into the bloodstream and how Visking tubing can be used as a model gut, including the limitations of the model	This should be limited to knowledge of absorption by diffusion only. The small intestine has a relatively large surface area, created by villi, which contain blood vessels. It has a rich blood supply which maintains a steep diffusion gradient. Visking tubing can be used as a model gut but as it has no blood supply cannot maintain a diffusion gradient.
(j)	the fate of the digested products of fats, carbohydrates and proteins: fatty acids and glycerol from fats provide energy; glucose from carbohydrate provides energy or is stored as glycogen; amino acids from digested proteins are needed to build proteins in the body	
(k)	the need for a balanced diet, including: protein, carbohydrates and fats, minerals (iron), vitamins (vitamin C), fibre and water	A simple understanding that the dietary nutrients and water necessary to maintain good health will vary with age and activity levels. The functions of protein, carbohydrates and fats are given in (j). Iron is needed for the production of haemoglobin, vitamin C is needed to maintain healthy tissue and fibre provides bulk in the digestive system. Water is an essential part of many body functions and processes.
(l)	the fact that different foods have different energy contents and that energy from food, when it is in excess, is stored as fat by the body	The energy content of food eaten must be balanced with energy needs since excess energy will be stored as fat by the body. Excess stored fat leads to obesity.
(m)	the implications, particularly for health, of excess sugar, fat and salt in foods	Excess sugar can lead to type 2 diabetes, obesity, tooth decay. Excess fat can lead to obesity, heart disease and circulatory disease. Excess salt (sodium) can lead to high blood pressure.

### SPECIFIED PRACTICAL WORK

- Investigation into the energy content of foods



## Investigation of the energy content of foods

### Introduction

Different foods have different energy contents. The energy content of a food can be released when you set it alight. When you hold a burning food underneath a known volume of water, the temperature increase can be measured. A simple calculation can then be used to estimate the amount of energy stored within the food.

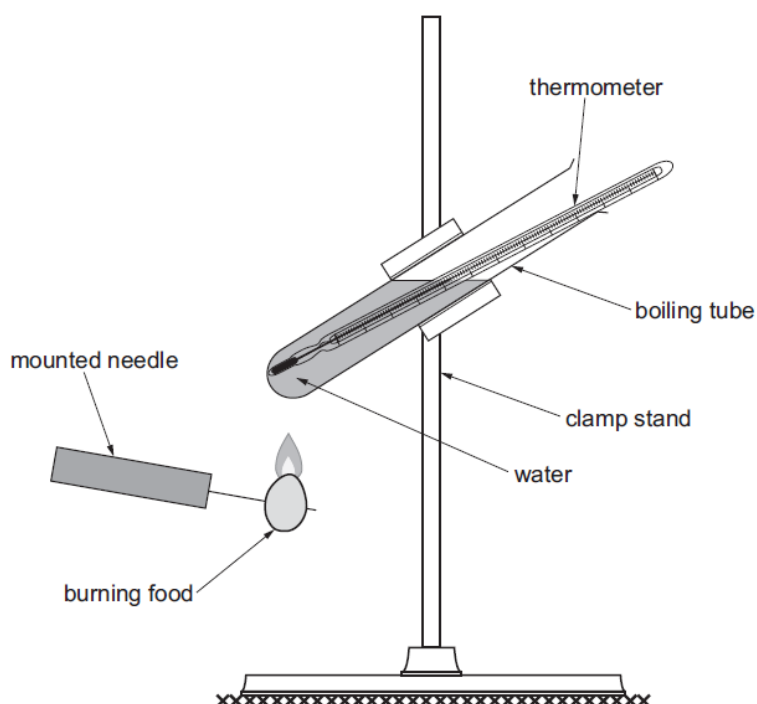
### Apparatus

25 cm<sup>3</sup> measuring cylinder  
 boiling tube  
 clamp stand, clamp and boss  
 thermometer  
 Bunsen burner  
 heat proof mat  
 mounted needle  
 samples of foods

#### Access to:

electronic balance  $\pm 0.1$  g

### Diagram of Apparatus



## Method

1. Measure 20 cm<sup>3</sup> of water into a boiling tube.
2. Clamp the boiling tube to the clamp stand.
3. Record the temperature of the water using a thermometer.
4. Choose a piece of food and record its mass.
5. Place food onto a mounted needle.
6. Hold the food in the Bunsen burner flame, until it catches alight.
7. As soon as the food is alight, hold it under the boiling tube of water. Keep the flame directly underneath the tube.
8. Hold the food in this position until it has burnt completely. If the flame goes out, but the food is not completely burnt, quickly light it again using the Bunsen burner and hold it directly underneath the boiling tube.
9. When the food has burned completely, and the flame has gone out, immediately record the temperature of the water.
10. Repeat steps 1-9 for other foods.

## Analysis

## Teacher/Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Fumes produced from burning foods or foods alone can cause allergic reactions	Risk of allergic reactions (skin rashes/breathing difficulties) or anaphylactic shock.	Do not use nuts as the food source.  Maintain good ventilation of the laboratory. Be prepared to administer first aid.
Hot apparatus can burn	Hot apparatus can burn skin when moving the apparatus	Leave apparatus to cool before moving
Hot water can scald/burn	Hot water can scald/burn skin/eyes when moving the apparatus/pouring water	Leave water to cool before moving  Wear eye protection
Bunsen burner flame can burn	Flame can burn the skin when igniting the crisp	Keep hands a safe distance from the flame
Burning food/dripping fat can burn	Burning food can burn the skin when heating water OWTTE	Keep hands a safe distance from the flame  Wear heat proof gloves

1. Calculate the increase in temperature each time.
2. Calculate the energy released from each food using the formula:

$$\text{Energy released from food per gram (J)} = \frac{\text{mass of water (g)} \times \text{temperature increase (}^\circ\text{C)} \times 4.2}{\text{mass of food sample (g)}}$$

3. Compare your results with the theoretical value on the food packet.
4. Evaluate your method and suggest how it could be improved.

4.2 J / kg °C is the value for the specific heat capacity of water. 1 cm<sup>3</sup> of water has a mass of 1 g.

A good range of data can be obtained from comparing the energy values of different crisps, e.g. wotsits, monster munch etc.

The method as stated does not include repeats, but students should be encouraged to carry out an appropriate number, if time allows.

This experiment can be used to compare the energy values quoted on food packaging with the data obtained from the experiment. Students can repeat results to determine repeatability and share results between pupil groups to determine reproducibility of data. This experiment is effective at evaluating the effectiveness of a method. Students can explain why the data obtained from the experiment is significantly different to the energy values quoted on food packaging. The idea of random and systematic errors can be explored.

Students should design their own table, but a suggested table format is shown below.

Type of food	Mass of food (g)	Temperature at start (°C)	Temperature at end (°C)	Temperature increase (°C)	Energy released per gram (J)

### Working scientifically skills covered

1. **Development of scientific thinking**  
Explain every day and technological applications of science: evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments
2. **Experimental skills and strategies**  
Make and record observations and measurements using a range of apparatus and methods.  
  
Evaluate methods and suggest possible improvements and further investigations.

**3. Analysis and Evaluation**

Carrying out and representing mathematical analysis

Evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

**4. Scientific vocabulary, quantities, units, symbols and nomenclature**

Use SI units and IUPAC chemical nomenclature unless inappropriate

## 1.4 CIRCULATORY SYSTEM IN HUMANS

	Spec Statement	Comment
(a)	the structure of a phagocyte and a red blood cell; be able to draw and label these cells	Drawings are only required to show the general shape of the blood cells. The following labels are required: red blood cell - cell membrane phagocyte - cell membrane, nucleus and cytoplasm
(b)	the functions of the four main parts of the blood: red cells, platelets, plasma, white cells	The functions include: red blood cells – contain haemoglobin for transport of oxygen; platelets – clotting; plasma – transport of carbon dioxide, soluble food, urea, hormones and the distribution of heat; white blood cells - defence against disease (No details of clotting mechanisms or immunity are required here)
(c)	the fact that the heart is made of muscle, which contracts to pump blood around the body	
(d)	the role of the coronary vessels in supplying the heart muscle with blood	The separate identification of coronary arteries and veins on diagrams will not be required.
(e)	the flow of blood to the organs through arteries and return to the heart through veins	
(f)	the structure of the heart: the left and right atria and ventricles, tricuspid and bicuspid valves, semi-lunar valves, pulmonary artery, pulmonary vein, aorta and vena cava and be able to label these on a diagram	Observe a dissected/ model of heart to include coronary arteries and internal structure. They should understand the significance of the difference in thickness of the muscle in the right and left ventricles.
(g)	the passage of blood through the heart including the functions of the valves in preventing backflow of blood	
(h)	a double circulatory system: involving one system for the lungs – pulmonary and one for the other organs of the body – systemic	

(i)	<p>the fact that in the organs, blood flows through very small blood vessels called capillaries; substances needed by cells pass/diffuse out of the blood to the tissues, and substances produced by the cells pass/diffuse into the blood, through the walls of the capillaries; the thin walls of the capillaries are an advantage for diffusion; capillaries form extensive networks so that every cell is near to a capillary carrying blood</p>	
(i)	<p>risk factors for cardiovascular disease and the effects of cardiovascular disease</p>	<p>These include high levels of fat and salt in the diet, high blood pressure, high blood cholesterol, smoking, genetic factors and a lack of exercise. Give a simple description of atheroma and its effects on the body.</p>

## 1.5 PLANTS AND PHOTOSYNTHESIS

	Spec Statement	Comment
(a)	the importance of photosynthesis, whereby green plants and other photosynthetic organisms use chlorophyll to absorb light energy and convert carbon dioxide and water into glucose, producing oxygen as a by-product and be able to state the word equation for photosynthesis	The chemical reactions of photosynthesis within the cell are controlled by enzymes. (Details of the enzymes involved in photosynthesis are not required.)
(b)	the conditions needed for photosynthesis to take place and the factors which affect its rate, including temperature, carbon dioxide and light intensity; <b>these as limiting factors of photosynthesis</b>	
(c)	the practical techniques used to investigate photosynthesis: the use of sodium hydroxide to absorb carbon dioxide; how to test a leaf for the presence of starch; how oxygen and carbon dioxide sensors and data loggers could be used	The steps within the method for testing a leaf for starch include: <ul style="list-style-type: none"> <li>• killing the leaf using boiling water</li> <li>• decolouration using ethanol,</li> <li>• washing to soften</li> <li>• testing with iodine</li> </ul> Understand the need for de-starching the leaf prior to the procedure.
(d)	the uses made by plant cells of the glucose produced in photosynthesis: respired to release energy; converted to starch for storage; used to make cellulose, proteins and oils	

### SPECIFIED PRACTICAL WORK

- Investigation into factors affecting photosynthesis

## Investigation of the factors affecting photosynthesis

### Introduction

Light is one of the factors which affects the rate of photosynthesis.

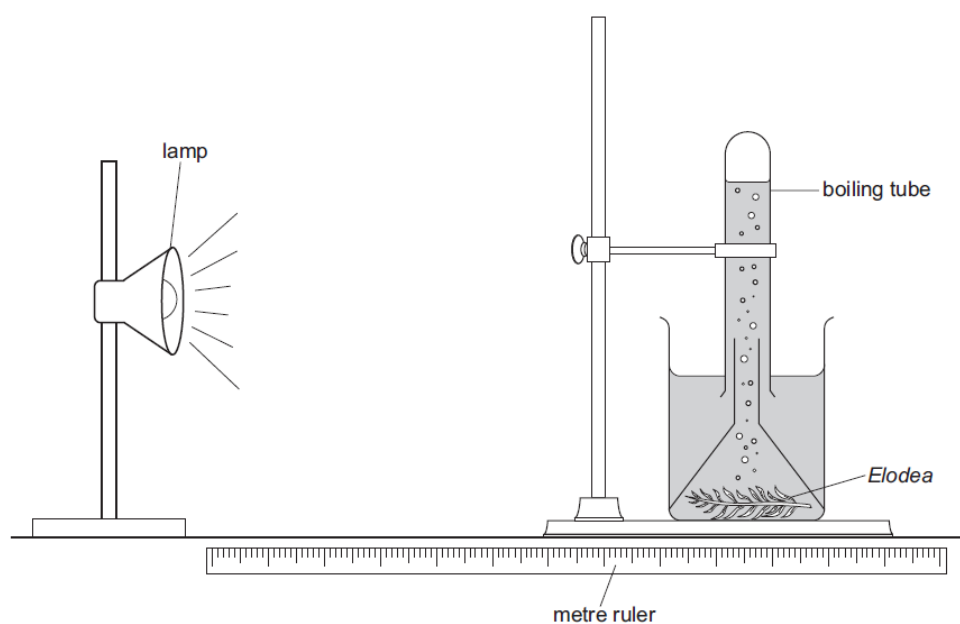
In this investigation a green plant named Canadian pondweed (*Elodea*) will produce bubbles of oxygen as a result of photosynthesis.

The number of bubbles of oxygen produced is affected by light intensity.

### Apparatus

250 cm<sup>3</sup> beaker  
 lamp  
 glass funnel  
 plasticine  
 test tube  
 8 cm length of pondweed (*Elodea*)  
 metre ruler  $\pm 1$  mm  
 sodium hydrogen carbonate powder  
 clamp stand, clamp and boss  
 spatula

### Diagram of Apparatus





## Method

1. Place the *Elodea* in a beaker containing 200 cm<sup>3</sup> of water.
2. Add one spatula of sodium hydrogen carbonate to the water.
3. Stick 3 small pieces of plasticine to the rim of the funnel and place it upside down over the plant.
4. Completely fill a test tube with water and carefully place over the end of the funnel with the end under the water, clamp into place.
5. Place the lamp 5 cm away from the apparatus.
6. Start the stopwatch and record the number of bubbles of oxygen produced in one minute.
7. Repeat the experiment with the lamp 10 cm, 15 cm, 20 cm, 25 cm and 30 cm from the apparatus.

## Analysis

1. Plot a graph of the distance against number of bubbles produced in 1 minute.
2. What conclusions can be reached from your results?
3. Evaluate your method and state how it could be improved.

## Teacher/Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Hot lamps can burn	Contact with skin will cause burns when handling/touching/moving apparatus	Do not touch lamp until it has cooled down.

If the plant is not producing bubbles then the stem might have started to 'heal' up, cutting off the end off may improve bubbling.

Begin the experiment with the lamp closer to the plant and move the plant further away as this seems to give better results.

*Cabomba caroliniana* (and *Elodea crispera*) are no longer available to buy. They have been banned for culturing or sale under European regulations controlling invasive non-native plants. CLEAPSS have worked with native plants (Hornwort and red Cabomba), and they are OK for use. The CLEAPSS method (see the link below) overcomes the problems of the native aquatic plants bubbling slowly.

<http://science.cleapss.org.uk/Resource-Info/GL184-Using-video-recording-to-measure-the-rate-of-photosynthesis.aspx>

If students have any difficulty in obtaining results, the link below can be used.

<http://www.reading.ac.uk/virtualexperiments/ves/preloader-photosynthesis-full.html>

The method as stated does not include repeats, but students should be encouraged to carry out an appropriate number, if time allows.

This experiment is ideal for a discussion of the limiting factors of photosynthesis and how they are controlled variables in this experiment. There is also a clear opportunity to discuss the limitations of the investigation such as the difficulty in controlling temperature.

Students should design their own table, but a suggested table format is shown below.

Distance from plant to lamp (cm)	Number of bubbles produced in one minute			
	Trial 1	Trial 2	Trial 3	Mean

### Working scientifically skills covered

#### 2. Experimental skills and strategies

Apply knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to this experiment.

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Make and record observations and measurements using a range of apparatus and methods.

Evaluate methods and suggest possible improvements and further investigations.

#### 3. Analysis and Evaluation

Evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

## 1.6 ECOSYSTEMS, NUTRIENT CYCLES AND HUMAN IMPACT ON THE ENVIRONMENT

Spec Statement	Comment	
(a)	<p>food chains and food webs showing the transfer of energy between organisms and involving producers; first, second and third stage consumers; herbivores and carnivores; decomposers</p>	<p>Radiation from the sun is the source of energy for living organisms. Green plants capture only a small percentage of the solar energy which reaches them. Candidates should be aware that alternative terms for the organisms in the trophic levels include: primary consumers, secondary consumers and tertiary consumers</p>
(b)	<p>the fact that at each stage in the food chain energy is used in repair and in the maintenance and growth of cells whilst energy is lost in waste materials and respiration</p>	<p>Draw and label pyramids of number and biomass (to include names and values at each trophic level). Analyse data in terms of: efficiency of energy transfer, numbers of organisms and biomass.</p>
(c)	<p>pyramids of numbers and biomass</p>	
(d)	<p><b>how to calculate the efficiency of energy transfers between trophic levels and how this affects the number of organisms at each trophic level</b></p>	
(e)	<p>the issues surrounding the need to balance the human requirements for food and economic development with the needs of wildlife</p>	<p>The rising human population is causing increased effects on the environment. This includes that more space is needed for housing, industry and agriculture. Where development is proposed, data collected by biologists is used in an assessment of environmental impact, including effects on endangered species. The assessment is used to decide whether the development should be allowed to go ahead, be refused or modified to reduce the effect on wildlife. Government agencies have an important role in monitoring, protecting and improving the environment.</p>

(f)	<p>the advantages and disadvantages of intensive farming methods, such as using fertilisers, pesticides, disease control and battery methods to increase yields</p>	<p>These include:</p> <p>advantages</p> <ul style="list-style-type: none"> <li>• increased yield of crops and high levels of meat production</li> </ul> <p>disadvantages</p> <ul style="list-style-type: none"> <li>• fertilisers and pesticides- can result in chemicals being washed from soils into waterways</li> <li>• disease control –excess use of antibiotics in farm animals could be present in meat and cause increased bacterial resistance</li> <li>• battery methods – negative impact on animal welfare and the duty of care to treat animals humanely</li> </ul>
(g)	<p>how indicator species and changes in pH and oxygen levels may be used as signs of pollution in a stream and how lichens can be used as indicators of air pollution</p>	<p>This should include analysis of first or second hand data from different habitats e.g. abundance and distribution of lichens.</p>
(h)	<p>the fact that some heavy metals, present in industrial waste and pesticides, enter the food chain, accumulate in animal bodies and may reach a toxic level</p>	<p>Bioaccumulation occurs when heavy metals or pesticides, which cannot be broken down in animals tissues, are washed into soils and rivers and pass through food chains. These chemicals reach a toxic level which can result in reduced fertility or death.</p>
(i)	<p>the fact that untreated sewage and fertilisers may run into water and cause rapid growth of plants and algae; these then die and are decomposed; the microbes, which break them down, increase in number and use up the dissolved oxygen in the water; animals which live in the water may suffocate</p>	<p>The term <i>eutrophication</i> is not required - if used by the candidate on examination papers, it is not usually sufficient as an answer. Candidates need to be able to explain this term if they use it.</p>

## UNIT 2 – CHEMISTRY 1

### 2.1 THE NATURE OF SUBSTANCES AND CHEMICAL REACTIONS

	Spec Statement	Comment
(a)	elements as substances that cannot be broken down into simpler substances by chemical means and as the basic building blocks of all substances	
(b)	elements as substances made up of only one type of atom	
(c)	compounds as substances made of two or more different types of atom that are chemically joined and having completely different properties to its constituent elements	
(d)	how to represent elements using chemical symbols and simple molecules using chemical formulae	
(e)	how to represent simple molecules using a diagram and key	Candidates should know that in a methane molecule, for example, the four hydrogen atoms surround a central carbon atom, rather than all being joined together in a row.
(f)	how to write the formulae of ionic compounds given the formulae of the ions they contain	A table of formulae for common ions (including compound ions) will be included in all examination papers but candidates should be able to apply their knowledge to any given ion.
(g)	relative atomic mass and relative molecular (formula) mass	<p>Candidates should be able to calculate relative molecular (formula) masses using <math>A_r</math> values from the Periodic Table*. The formal definition of relative atomic mass is not required <b>but higher tier candidates should know how <math>A_r</math> is different to mass number.</b></p> <p>* Note that the Periodic Table supplied will no longer include mass numbers</p>
(h)	the percentage composition of compounds	Candidates should be able to carry out a range of calculations based on the percentage by mass of each element present in a compound.

(i)	atoms/molecules in mixtures not being chemically joined and mixtures being easily separated by physical processes such as filtration, evaporation, chromatography and distillation	Candidates should understand the principles behind each separation method e.g. in chromatography they should understand that the more soluble a substance, the further it is carried by the solvent.
(j)	chromatographic data analysis and $R_f$ values	Candidates are expected to recall the expression used to calculate $R_f$ values.
(k)	chemical reactions as a process of re-arrangement of the atoms present in the reactants to form one or more products, which have the same total number of each type of atom as the reactants	
(l)	colour changes, temperature changes (exothermic/ endothermic) and effervescence as evidence that a chemical reaction has taken place	Candidates should know that these are indications that a chemical reaction has occurred. The only requirement for recall here is in respect of reactions that are covered within this unit e.g. the reaction of sodium and water is exothermic and effervesces.
(m)	how to represent chemical reactions using word equations	The emphasis here is on the skill of writing word equations. As above, detailed recall is related to other specification statements.
(n)	how to represent chemical reactions using balanced chemical equations where the total relative mass of reactants and products is equal	The emphasis here is on the skills of writing and balancing chemical equations. Again, detailed recall is related to other specification statements. Candidates should be able to use the state symbols (s), (l), (g) and (aq) but they will not be required to include them in equations unless they are specifically asked to do so.
(o)	the percentage yield of a chemical reaction	Candidates are expected to recall the expression used to calculate percentage yield.
(p)	<b>how to calculate the formula of a compound from reacting mass data</b>	<b>Candidates will not be expected to recall the methods used to collect this type of data but they should show an understanding of the principles involved when a description is provided. They should be able to deal with questions where the percentage composition of the compound is given, as well as examples where actual masses are provided. They should recognise that a formula calculated in this way is known as a simplest formula and as an empirical formula. Candidates <u>must</u> show their working in questions of this type and should be made aware that data collected may possibly suggest a formula different to that which they know to be correct, e.g. incomplete reaction of magnesium with oxygen could provide data that gives <math>Mg_2O</math> as the formula for magnesium oxide.</b>

(q)	<p>how to calculate the masses of reactants or products from a balanced chemical equation</p>	<p>Candidates should think of this as a progression from a balanced symbol equation – and appreciate that considering the masses of reactants and products is a good opportunity to check that an equation is correctly balanced. They will usually be given the balanced equation in examination questions on this section.</p>
(r)	<p>the Avogadro constant and the mole and how to convert amount of substance in grams to moles and vice versa</p>	<p>Candidates are expected to recall the relationship between number of moles and mass in grams. They are <u>not</u> required to recall the Avogadro constant.</p>

## 2.2 ATOMIC STRUCTURE AND THE PERIODIC TABLE

	Spec Statement	Comment
(a)	atoms containing a positively charged nucleus with orbiting negatively charged electrons	
(b)	atomic nuclei containing protons and neutrons	
(c)	the relative masses and relative charges of protons, neutrons and electrons	Candidates should know that protons and neutrons have the same mass of 1 atomic mass unit (amu) and that electrons have a negligible mass of approximately 2000 times less. Charges need only be described in terms of positive (+1), neutral (0) and negative (-1).
(d)	atoms having no overall electrical charge	Candidates should be able to build upon this idea to describe how ions form and explain the charges found on simple ions e.g. $\text{Na}^+$ , $\text{Mg}^{2+}$ , $\text{Cl}^-$ and $\text{O}^{2-}$ .
(e)	the terms atomic number, mass number and isotope	Candidates should be able to describe the difference between the atoms of different isotopes, in terms of the numbers of neutrons present but they are not expected to recall the mass numbers of any particular isotopes of any element. Mass number data will be included in any questions that require it as it is no longer included in the supplied Periodic Table.
(f)	how the numbers of protons, neutrons and electrons present in an atom are related to its atomic number and mass number	Candidates are expected to recall the definitions for both terms and to use them to identify the numbers of protons, neutrons and electrons in any given atom/ion. Question papers in Chemistry will not refer to proton number or nucleon number.
(g)	elements being arranged in order of increasing atomic number and in groups and periods in the modern Periodic Table, with elements having similar properties appearing in the same groups	Candidates should be able identify an element given its group and period, and vice versa. They should understand that elements with the same number of electrons in their outer shell undergo similar chemical reactions e.g. as seen in Group 1 and Group 7.
(h)	metals being found to the left and centre of the Periodic Table and non-metals to the right, with elements having intermediate properties appearing between the metals and non-metals in each period	Candidates should know that elements change from being metals to non-metals on going from left to right across the Periodic Table and that many of those in groups 3, 4 and 5 exhibit both metallic and non-metallic properties. The emphasis here should be on trends rather than recall of properties of individual elements.



(i)	the electronic structures of the first 20 elements	
(j)	how the electronic structure of any element is related to its position in the Periodic Table	Candidates should understand that the group number corresponds to the number of electrons in the outer shell and that the period number is the number of occupied electron shells.
(k)	the similarities and trends in physical and chemical properties of elements in the same group as illustrated by Group 1 and Group 7	<p>Candidates are expected to know that elements in the same group undergo the same type of reaction e.g. Group 1 elements react vigorously with water. They should know that Group 1 elements become more reactive down the group and that Group 7 elements become less reactive down the group. They should recall the following trends in melting/boiling points:</p> <ul style="list-style-type: none"> <li>• Group 1 melting/boiling points decrease down the group (lithium doesn't melt as it reacts with water)</li> <li>• Group 7 melting/boiling points increase down the group (states of chlorine, bromine and iodine at room temperature)</li> </ul>
(l)	many reactions, including those of Group 1 elements and many of those of Group 7 elements, involve the loss or gain of electrons and the formation of charged ions	Candidates should understand that elements with atoms containing full outer electron shells (Group 0) are unreactive and that other elements react in order to try to attain the same state. They should understand, for example, that the atoms of Group 1 metals lose one electron to do so, while those of Group 7 elements gain one electron. <b>Higher tier candidates should also understand that losing or gaining more than one electron is more difficult and that Group 2 elements are therefore less reactive than Group 1 elements (and Group 6 elements are less reactive than Group 7 elements).</b>
(m)	<b>the trends in reactivity of Group 1 and Group 7 elements in terms of their readiness to lose or gain an electron</b>	<b>Group 1 metals become more reactive down the group. The increasing size of the atom/distance from the positively charged nucleus makes it easier for the outer electron to be lost. Group 7 elements become less reactive down the group. The increasing size of the atom/distance from the positively charged nucleus results in a smaller force attracting the additional electron.</b>

(n)	the reactions of the alkali metals with air/oxygen, the halogens and water	<p>Candidates are expected to recall observations made during the reactions of lithium, sodium and potassium in each case:</p> <ul style="list-style-type: none"> <li>• Air/oxygen – tarnishing of freshly cut surface</li> <li>• Burning in air/oxygen – flame colours, white products</li> <li>• Halogens – flame colours, white products</li> <li>• Water – metals floating, movement on the water surface and whether or not a ball is formed, hissing sound, potassium <u>only</u> begins to burn (lilac flame)</li> </ul> <p>Observation includes sounds e.g. fizzing/hissing, but ‘hydrogen formed’ is not an observation.</p> <p>The tarnishing in air and reaction with water can be easily demonstrated in the laboratory but burning and reaction with halogens are best observed through video clips.</p> <p>In common with <u>all</u> specified reactions, candidates should be able to name all reaction products. They should know that the metal hydroxides formed during the reaction with water are alkalis.</p>
(o)	the test used to identify hydrogen gas	When a <u>lit splint</u> is placed into a jar/tube containing hydrogen gas, a <u>squeaky pop</u> is observed.
(p)	the reactions of halogens with alkali metals and with iron	Candidates should recall the colours of chlorine, bromine and iodine in their room temperature states. Recall of the observations made during the reactions with iron is <u>not</u> required but candidates should know that it is the iron(III) salt formed in each case. Video clips are a useful resource to observe these reactions.
(q)	<b>the relative reactivities of chlorine, bromine and iodine as demonstrated by displacement reactions</b>	<p><b>Candidates should appreciate that displacement reactions provide stronger evidence for the decreasing reactivity down Group 7 than that gained from the elements’ reactions with iron. Factors such as the halogens’ different states at room temperature can make it difficult to make a fair comparison of their reactivities by observation of their reactions with iron but they compete directly against one another in displacement reactions.</b></p> <p><b>Candidates should know that solutions of halides are colourless and that displacement of bromine and iodine results in the formation of an orange-brown solution.</b></p>

(r)	the properties and uses of chlorine and iodine	<p>Candidates should recall the properties of these elements and at least one widespread use of each.</p> <p>Chlorine – poisonous/toxic, kills bacteria; used in treatment of water supplies*, treatment of swimming pool water*, making household cleaners</p> <p>Iodine – poisonous/toxic, kills bacteria; used as antiseptic following hospital procedures</p> <p>* Candidates should understand that the quantities of chlorine used in the treatment of water supplies and in swimming pools is controlled and monitored to ensure that it is sufficient to kill bacteria and sterilise the water, without causing any harm to us.</p>
(s)	the identification of $\text{Li}^+$ , $\text{Na}^+$ , $\text{K}^+$ , $\text{Ca}^{2+}$ and $\text{Ba}^{2+}$ ions by flame tests and $\text{Cl}^-$ , $\text{Br}^-$ and $\text{I}^-$ ions by their reactions with silver nitrate solution (including ionic equations)	<p>The flame colours expected are as follows:</p> <ul style="list-style-type: none"> <li>• lithium – red (brick red will not be accepted)</li> <li>• sodium – yellow-orange</li> <li>• potassium – lilac</li> <li>• calcium – brick red</li> <li>• barium – apple green (green will not be accepted)</li> </ul> <p>Solutions of the halides produce different coloured precipitates on addition of <math>\text{Ag}^+(\text{aq})</math>:</p> <ul style="list-style-type: none"> <li>• chloride – white precipitate</li> <li>• bromide – cream precipitate</li> <li>• iodide – yellow precipitate</li> </ul> <p>Candidates should be able to name the insoluble compounds formed and recognise ‘spectator ions’ which take no part in the precipitation reaction. They should be able to write and interpret ionic equations e.g. <math>\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})</math> State symbols are an important feature of ionic equations for precipitation reactions but as with any questions on equations, candidates will be told to include them when a specific mark is allocated for this skill.</p>
(t)	the unreactive nature of the Group 0 gases and the uses of helium, neon and argon	<p>Candidates should recall the properties of these gases and at least one use of each.</p> <p>Helium – very low density, very unreactive; used in airships, weather balloons</p> <p>Neon – emits light when electric current passes through it; used in advertising signs</p> <p>Argon – very unreactive; used in light bulbs, as an inert atmosphere for welding</p>

## 2.3 WATER

	Spec Statement	Comment
(a)	the composition of water in 'natural' water supplies, including dissolved gases, ions, microorganisms and pollutants	Candidates should be aware that rainwater contains dissolved CO <sub>2</sub> (which lowers the pH) and O <sub>2</sub> . Groundwater contains ions such as Mg <sup>2+</sup> , Ca <sup>2+</sup> , Na <sup>+</sup> and K <sup>+</sup> from minerals dissolved as it permeates through rocks. Candidates will <u>not</u> be expected to name any microorganisms present in water. Candidates should be aware that man-made pollutants include fertilisers, pesticides and household and industrial waste. Natural pollutants include bacteria and viruses.
(b)	the need for a sustainable water supply to include reducing our water consumption, reducing the environmental impacts of abstracting, distributing and treating water	Candidates should show an understanding that water is a resource ever more in demand as a result of increasing population and industrialisation, and that climate change could potentially cause water shortages all over the world, including the UK. They should appreciate that as demand outstrips supply, the cost of water will increase and that measures to conserve water have economic benefits for domestic, commercial and industrial consumers.
(c)	the treatment of the public water supply using sedimentation, filtration and chlorination	Sedimentation – in reservoirs/tanks, larger solid particles settle under gravity Filtration – through layers of sand and gravel, removes smaller insoluble particles Chlorination – chlorine added to kill bacteria, prevents disease/makes it safe to drink Candidates are not expected to recall details of substances added to water at sedimentation and filtration stages.
(d)	the arguments for and against the fluoridation of the water supply in order to prevent tooth decay	Candidates are expected to know that fluoridation of water supplies is a controversial issue. They should be able to present the arguments for and against the process. Candidates should be aware that there is strong evidence to suggest that fluoride ions prevent tooth decay in young children. Significant amounts of fluoride ions are found naturally in the water in some areas but fluoride can also be ingested from toothpastes and mouthwashes. Candidates should be aware that the link between fluoride ions and a reduction in incidence of tooth decay has been established by surveying school children of various ages, and that the data is reliable because all school children are surveyed and only absentees on the day are excluded.

		<p>They should also understand that comparing data from one fluoridated area with that from one non-fluoridated area does not provide sufficient evidence to draw a valid conclusion, since other factors, such as social and economic backgrounds, also have an effect.</p> <p>Many people object to proposals to fluoridate water supplies for a number of reasons. Fluoride can be harmful in high concentrations, e.g. causing discolouring or decay of teeth (fluorosis). High fluoride intake has also been linked to stomach and bone cancers and to infertility.</p> <p>Some argue against fluoridation on the grounds that it is 'mass medication' and that no one should be forced to consume fluoride. It is important for candidates to realise that science cannot address ethical issues and therefore cannot answer the question as to whether or not it is correct to fluoridate water supplies. Science can only provide the facts and evidence required for people to form their own opinions. They should also be aware that information relating to the fluoridation of water supplies comes from many different sources and that some of these may be biased and may try to influence opinions.</p>
(e)	<p>desalination of sea water to supply drinking water including the sustainability of this process on a large scale</p>	<p>Candidates should know that the simplest method for desalination of sea water is distillation. This involves boiling sea water which uses large amounts of costly energy, preventing it from being a viable process in many parts of the world. Candidates should be aware that other methods are also used, e.g. the use of membrane systems, but they are not required to know any details of such methods. They should be able to discuss the potential of desalination as a source of drinking water in different parts of the world in terms of proximity to the sea, availability of 'cheap' energy and a country's wealth.</p>
(f)	<p>the separation of water and other miscible liquids by distillation</p>	<p>Candidates should know that pure liquids have distinct boiling points and recall that water boils at 100°C. Distillation allows a mixture of liquids to be separated as a result of their different boiling points. They should be able to name the important parts of a distillation apparatus and explain the separation process in terms of boiling and condensation. <b>Higher tier candidates should appreciate that it is not possible, for example, to obtain 'pure' ethanol (bp 78°C) from a mixture with water because some water evaporates at temperatures below its boiling point.</b></p>

(g)	simple methods to determine solubility and produce solubility curves	<p>Candidates should be familiar with the following methods:</p> <ul style="list-style-type: none"> <li>• Add known mass of solute (e.g. ammonium chloride) to a measured volume of water which will only dissolve a portion of the solute; filter, dry and weigh excess solute; determine solubility</li> <li>• Add slightly more weighed solute (e.g. potassium chlorate) than will dissolve to a measured volume of water at room temperature; heat solution until all solute dissolves; allow to cool and record temperature at which crystals first appear; repeat several times with increasing volumes of water; determine solubility at each temperature; plot solubility curve</li> </ul>
(h)	the interpretation of solubility curves	
(i)	the causes of hardness in water and how to distinguish between hard and soft waters by their action with soap	<p>Candidates should know that hardness in water is caused by the presence of <math>\text{Ca}^{2+}</math> and <math>\text{Mg}^{2+}</math> ions from dissolved calcium and magnesium compounds and that hard water forms a 'scum' and poor lather when shaken with soap solution. They should be able to describe in detail how the relative amount of hardness in different water samples can be determined, e.g. by measuring the volume of soap solution required to produce a given lather or by measuring the lather produced by a given volume of soap solution.</p>
(j)	the difference between temporary and permanent hardness	<p>Candidates should know that temporary hardness can be removed by boiling and that this leads to 'furring' of kettle elements as a result of formation of insoluble calcium carbonate. <b>Higher tier candidates should be able to explain this in terms of the removal of hydrogencarbonate ions.</b></p>

(k)	<p>the processes used to soften water to include boiling, adding sodium carbonate and ion exchange; the advantages and disadvantages of different methods of water softening <b>and the explanation of how these methods work</b></p>	<p>Boiling – no need for expensive equipment; only useful for small volumes and does not remove permanent hardness          Adding sodium carbonate (washing soda) – removes both temporary and permanent hardness; limescale is formed which can block washing machine pipes          Ion exchange – removes temporary and permanent hardness and is a continuous process, uses concentrated sodium chloride which is cheap and widely available; exchange columns are expensive</p> <p><b>Boiling causes hydrogencarbonate ions to decompose forming calcium carbonate on the heating element. Adding sodium carbonate (washing soda) removes hardness by precipitating calcium carbonate. Candidates should be able to write appropriate equations for these reactions.</b></p> <p><b>Ion exchange removes hardness because calcium (and magnesium) ions are exchanged for sodium ions on passing hard water through an ion exchange resin (two sodium ions needed for every calcium ion). Water coming from the resin contains sodium ions. All the sodium ions attached to an ion exchange resin are eventually ‘used up’ so no more hardness can be removed, but the resin can be ‘regenerated’ by being rinsed in a concentrated solution of sodium chloride.</b></p>
(l)	<p>the health benefits of hard water and its negative effects, e.g. on boiler elements</p>	<p>Candidates are expected to recall that calcium compounds dissolved in water have benefits for teeth and bones and also help reduce heart disease. Boilers and hot water pipes become ‘furred up’ as calcium carbonate precipitates – boilers become less efficient and pipes can become completely blocked.</p>

### SPECIFIED PRACTICAL WORK

- Determination of the amount of hardness in water using soap solution

## Determination of the amount of hardness in water using soap solution

### Introduction

Soft water readily forms **lather** with soap, but it is more difficult to form lather with hard water. Hard water contains dissolved calcium or magnesium compounds. This can 'fur up' kettles, boilers and pipes, which wastes energy and can be dangerous if the flow of water is impeded. The calcium ions and magnesium ions in hard water react with the soap to form scum, so more soap is needed to form a lather.

Temporary hard water contains calcium and magnesium hydrogen carbonate. Temporary hard water becomes soft on boiling (limescale). Permanent hard water does not become soft when it is boiled.

### Apparatus

100cm<sup>3</sup> conical flask and stopper  
 dropping pipette  
 50cm<sup>3</sup> measuring cylinder  
 water samples - A, B, C, D, boiled A, boiled B, boiled C, boiled D  
 stopwatch  
 soap solution

### Method

1. Measure 50cm<sup>3</sup> of water sample **A** into a conical flask.
2. Add 1cm<sup>3</sup> of soap solution, insert the stopper and shake vigorously for 5 seconds.
3. Repeat step 2 until a lather forms that lasts for 30 seconds. Record the total volume of soap solution added.
4. Repeat steps 1-3 with 50cm<sup>3</sup> samples of all other types of water.

### Analysis

1. Draw a bar chart of volume of soap solution against water sample.
2. Use your results to identify which samples are: soft water, temporary hard water and permanent hard water.



## Teacher / Technician notes

Wanklyn's or Clarke's soap solution can be used.

Suggested hard water concentration (and approximate volume of soap solution required)

- **A - Soft Water**

Unboiled	de-ionised water (1 cm <sup>3</sup> )
Boiled	de-ionised water (1 cm <sup>3</sup> )
  
- **B - Permanent Hard Water**

Unboiled	60% magnesium hard water, 40% calcium hard water (8 cm <sup>3</sup> )
Boiled	60% magnesium hard water, 40% calcium hard water (8 cm <sup>3</sup> )
  
- **C - Temporary Hard Water**

Unboiled	50% magnesium hard water, 50% calcium hard water (12 cm <sup>3</sup> )
Boiled	de-ionised water (1 cm <sup>3</sup> )
  
- **D - Permanent hard water**

Unboiled	calcium hard water (15 cm <sup>3</sup> )
Boiled	calcium hard water (15 cm <sup>3</sup> )
  
- Hard water solutions
  - Magnesium hard water – 0.45 g/dm<sup>3</sup> magnesium sulphate
  - Calcium hard water – 0.45 g/dm<sup>3</sup> calcium sulphate

Sample C is used to represent boiled temporary hard water to demonstrate that hardness has been removed. Teachers may want to create a further sample that contains a mixture of permanent hard water and temporary hard water to extend the experiment for more able students.

- **E - Permanent hard water**

Unboiled	calcium hard water (15 cm <sup>3</sup> )
Boiled	50% calcium hard water, de-ionised water (8 cm <sup>3</sup> )

Results are best recorded in a tally chart to enable students to record each time 1 cm<sup>3</sup> of soap is added to the solution.

Water sample	Tally chart of volume of soap solution added (cm <sup>3</sup> )	Total volume of soap solution added (cm <sup>3</sup> )

### Working scientifically skills covered

#### 1. Development of scientific thinking

Explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments.

#### 2. Experimental skills and strategies

Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

#### 3. Analysis and Evaluation

Translate data from one form to another.

Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

## 2.4 THE EVER-CHANGING EARTH

	Spec Statement	Comment
(a)	the large scale structure of the Earth in terms of solid iron core, molten iron outer core, mantle and crust	
(b)	the theory of plate tectonics and how it developed from Alfred Wegener's earlier theory of continental drift	<p>Candidates should know that the Earth's outer layer, called the lithosphere (the crust and the rigid upper part of the mantle), is broken into 7 or 8 major and many minor plates. These plates continuously move at a rate of a few centimetres per year in relation to one another.</p> <p>Candidates should know that Wegener suggested that all of the continents were once joined together in one supercontinent, called Pangaea, and that they have since drifted apart. This idea of 'continental drift' is based on the following observations:</p> <ul style="list-style-type: none"> <li>• Jigsaw-like fit of the edges of continents e.g. the west coast of Africa and the east coast of South America;</li> <li>• Similar rocks of the same age found on different continents;</li> <li>• Similar plant and animal fossils found on opposite sides of huge oceans.</li> </ul> <p>Wegener's theory did not include any attempt to explain how the continents moved and it was dismissed by more renowned scientists of the time. Convection currents in the mantle were proposed by some scientists as an explanation for plate movement as far back as the 1930s and this was generally accepted as being correct by the 1960s, but the exact mechanism remains a widely researched and much debated question. This is a very good example of how scientific ideas continually develop as new evidence is accumulated over time. Wegener's theory of continental drift was refined and became known as 'plate tectonics'.</p>

(c)	<p>the processes occurring at conservative, destructive and constructive plate boundaries where plates slide past one another, move towards one another and move apart respectively</p>	<p>Candidates should know that plotting the epicentres of major earthquakes and the sites of active volcanoes indicates the location of plate boundaries – regions where the edges of different plates are in contact. Plates move apart at a mid-ocean ridge; this is called a constructive plate boundary because volcanic activity produces new igneous rock. At a destructive plate boundary, one plate is pushed down into the mantle and melts to form magma, causing explosive volcanoes. Both of these boundary types are linked to earthquakes and volcanic activity. At a conservative plate boundary, where plates slide past each other, powerful earthquakes are generated but there are no volcanoes because melting does not occur. Candidates are not expected to recall the detailed structures of these boundary types.</p>
(d)	<p>the formation of the original atmosphere by gases, including carbon dioxide and water vapour, being expelled from volcanoes</p>	<p>Candidates should know that there are several theories that have been used to account for the formation of the Earth's early atmosphere, but many scientists agree that it is most likely to have formed from gases expelled by volcanoes. Carbon dioxide, water vapour and ammonia make up the greatest proportion of volcanic gases.</p>
(e)	<p>the present composition of the atmosphere and how the composition of the atmosphere has changed over geological time</p>	<p>Candidates should know that the surface of the Earth cooled over time and that water vapour present in the early atmosphere condensed forming the oceans. They should appreciate that this happened quickly, in geological terms, and that other changes took far longer. The percentage of carbon dioxide has decreased to a fraction of one percent as a result of a number of processes, the most important being photosynthesis. Photosynthesis began as green plants evolved, using up carbon dioxide and releasing oxygen into the atmosphere for the first time. The evolution of marine animals followed over hundreds of millions of years and much carbon dioxide was locked into limestone and chalk formed from their shells. More still was locked into fossil fuels formed many millions of years ago from the remains of simple marine organisms (crude oil and natural gas) and larger land plants (coal). Ammonia decomposed on reaction with oxygen forming nitrogen, which became the most abundant gas in the atmosphere.</p> <p>These changes occurred over billions of years and eventually led to the composition with which we are familiar:</p> <ul style="list-style-type: none"> <li>nitrogen 78%</li> <li>oxygen 21%</li> <li>argon (+ other noble gases) 0.9%</li> <li>carbon dioxide 0.04%</li> </ul>

(f)	the roles of respiration, combustion and photosynthesis in the maintenance of the levels of oxygen and carbon dioxide in the atmosphere	Candidates are expected to know that the composition of the atmosphere has remained stable for many millions of years. Photosynthesis uses carbon dioxide and produces oxygen, while respiration (animals & plants) and combustion use oxygen and produce carbon dioxide. The burning of ever more fossil fuels releases more and more of the 'locked-in' carbon dioxide into the atmosphere, disturbing the equilibrium that has existed for so long.
(g)	the environmental effects and consequences of the emission of carbon dioxide and sulfur dioxide into the atmosphere through the combustion of fossil fuels	<p>Candidates should know that enhanced global warming due to the increasing amounts of carbon dioxide produced by burning fossil fuels could cause:</p> <ul style="list-style-type: none"> <li>• Climate change e.g. hotter summers in some parts of the world (leading to droughts) and increased rainfall in others (flooding)</li> <li>• Higher rate of melting of ice caps, polar sea ice, glaciers</li> <li>• Rising sea levels</li> </ul> <p>They should know that fossil fuels contain many impurities, including many sulfur-containing compounds and that these produce sulfur dioxide on burning. Sulfur dioxide forms a solution of sulfuric acid on contact with water in the atmosphere and this falls as acid rain. Candidates should understand that 'clean' rain is weakly acidic (pH ~5.5) and that acid rain has a pH in the range of about 2-4. They should know that acid rain lowers the pH of lakes etc., damaging aquatic life and damaging forests and vegetation. They should know that it damages buildings (particularly those made of limestone [calcium carbonate]) and increases the rate of corrosion of metal structures such as bridges and statues.</p>
(h)	the measures used to address the problems of global warming and acid rain	Candidates should appreciate that there are no simple solutions to the environmental problems associated with burning fossil fuels. They should be able to suggest ways in which we can be more 'responsible consumers' of energy and describe alternative energy sources. They should be able to explain the use of weak alkalis to neutralise soil and lakes affected by acid rain. <b>Higher tier candidates should be familiar with the basic principles of 'carbon capture and storage' and 'sulfur scrubbing'. No detailed recall of these processes is expected.</b>

(i)	the air as a source of nitrogen, oxygen, neon and argon	Candidates should know that gases can be separated because they have different boiling points but they are not required to know the details of fractional distillation in this unit.
(j)	the tests used to identify oxygen gas and carbon dioxide gas	<p>When a <u>glowing splint</u> is placed into a jar/tube containing oxygen gas, it <u>re-lights</u>. (Please note that reference to a flame glowing more brightly is <u>not</u> acceptable as a test for oxygen gas.)</p> <p>When carbon dioxide gas is passed through <u>limewater</u> the solution turns <u>milky</u>. (Please note that reference to extinguishing a lit splint or flame is <u>not</u> acceptable as a test for carbon dioxide gas.)</p>

## 2.5 RATE OF CHEMICAL CHANGE

	Spec Statement	Comment
(a)	practical methods used to determine the rate of reaction – gas collection, loss of mass and precipitation (including using data-logging apparatus)	Candidates should recognise that a rate measures a change <u>over a given time</u> . They should be familiar with gas collection and mass loss methods of studying the rates of reactions such as acids and metals/carbonates, as well as the precipitation reaction of dilute hydrochloric acid and sodium thiosulfate.
(b)	the effect of changes in temperature, concentration (pressure) and surface area on rate of reaction	Candidates should know that the rate of reaction is increased by increasing temperature, concentration (pressure) and surface area. They should appreciate that decreasing solid particle size increases surface area.
(c)	the particle theory in explaining changes of rate as a result of changes in temperature, concentration (pressure) and surface area	Candidates should understand that particles of reactants must collide in order for a reaction to occur and that the greater the number of collisions in a given time, the faster the reaction/higher the rate. They should explain how changing concentration, temperature and surface area/particle size affect the collision rate. <b>Higher tier candidates should be familiar with the idea of a minimum energy required for ‘successful collisions’ where products are formed.</b>
(d)	catalysts as substances that increase the rate of a reaction while remaining chemically unchanged <b>and that they work by lowering the energy required for a collision to be successful (details of energy profiles are not required)</b>	Candidates are not expected to recall the names of any specific catalysts. They should know that the same catalyst does not work for all reactions and that although the catalyst used in any industrial process is not used up, it does need to be replaced regularly as it is affected by impurities and loses its activity over time. <b>Higher tier candidates should understand that catalysts increase the rate of a reaction by lowering the minimum energy required for ‘successful collisions’.</b>

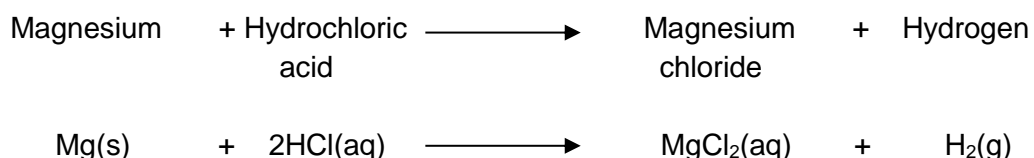
### SPECIFIED PRACTICAL WORK

- Investigation of the factors that affect the rate of a reaction using a gas collection method
- Investigation of the factors that affect the rate of the reaction between dilute hydrochloric acid and sodium thiosulfate

## Investigation of the factors that affect the rate of reaction using a gas collection method

### Introduction

Magnesium reacts with dilute hydrochloric acid to produce hydrogen. The equation for the reaction is as follows:



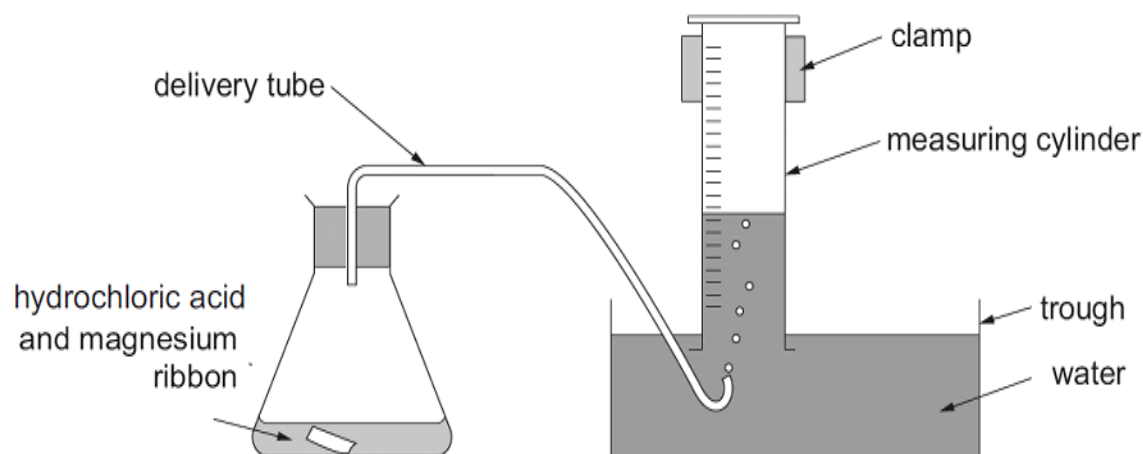
The rate at which the hydrogen gas is produced can be used to determine the rate of the reaction.

In this experiment you will study the effect of changing the concentration of the hydrochloric acid on the rate of the reaction.

### Apparatus

250 cm<sup>3</sup> conical flask  
 single-holed rubber bung  
 delivery tube to fit conical flask  
 trough or plastic washing-up bowl  
 100 cm<sup>3</sup> measuring cylinder  
 250 cm<sup>3</sup> measuring cylinder  
 clamp stand, boss and clamp  
 stopwatch  
 magnesium ribbon in 3 cm lengths  
 1 mol/dm<sup>3</sup> hydrochloric acid

### Diagram of Apparatus





## Method

1. Set up the apparatus as shown in the diagram.
2. Measure 20cm<sup>3</sup> of 1 mol/dm<sup>3</sup> hydrochloric acid using the 25 cm<sup>3</sup> measuring cylinder. Pour the acid into the 250 cm<sup>3</sup> conical flask.
3. Fill the other measuring cylinder with water, make sure that it stays filled with water when you turn it upside down and clamp above the trough.
4. Add a 3cm strip of magnesium ribbon to the flask, put the bung into the flask and start the stopwatch.
5. Record the volume of hydrogen gas given off every ten seconds. Continue timing until no more gas appears to be given off.
6. Repeat steps 2-5 using 10 cm<sup>3</sup> of the hydrochloric acid and 10 cm<sup>3</sup> of water to make the total volume used 20cm<sup>3</sup>.

## Analysis

1. Plot a graph of volume of hydrogen gas (*y*-axis) against time (*x*- axis), for both concentrations of hydrochloric acid and label the lines appropriately.

## Teacher / Technician notes

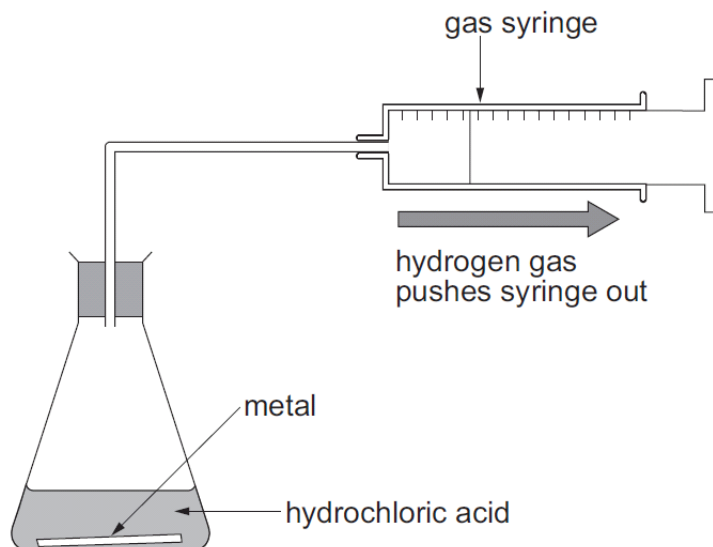
## Risk Assessment

Hazard	Risk	Control measure
Hydrochloric acid is an irritant	Hydrochloric acid could get onto the skin when adding to measuring cylinder	Wash hands immediately if any hydrochloric acid gets onto them / wear laboratory gloves.
	Hydrochloric acid could get transferred from the hands to the eyes/when pouring	Wear eye protection.

The magnesium ribbon should be clean and free from obvious corrosion or oxidation. Clean if necessary by rubbing lengths of the ribbon with an emery board to remove the layer of oxidation. To ensure that most of the magnesium surface is under the surface of the acid, it should be folded into a zigzag shape.

The bungs in the flasks need to be rubber. Corks are too porous and will leak. The tube through the bung should be a short section of glass, and then a flexible rubber tube can be connected. These can be pre-prepared before the reaction so all the student has to do is push the bung into the flask.

Gas syringes can be used instead of troughs of water and measuring cylinders. Syringes should not be allowed to become wet, or the plungers will stick inside the barrels. The apparatus set up for this procedure is shown in the diagram below:



Reagents:

- Hydrochloric acid – Refer to CLEAPSS hazcard 47A
- Magnesium ribbon – Refer to CLEAPSS hazcard 59A

A 3cm length of magnesium ribbon has a mass of 0.04 g and should yield 40cm<sup>3</sup> of hydrogen gas when reacted with this excess of acid.

If a graph of volume (y-axis) against time (x-axis) is drawn, the slope of the graph is steepest at the beginning. This shows that the reaction is fastest at the start. As the magnesium is used up, the rate falls. This can be seen on the graph, as the slope becomes less steep and then levels out when the reaction has stopped (when no more gas is produced).

No repeats have been included in the method, but students can compare results with other groups to make judgements on reproducibility.

### Working scientifically skills covered

#### 2. Experimental skills and strategies

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Make and record observations and measurements using a range of apparatus and methods.

#### 3. Analysis and Evaluation

Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

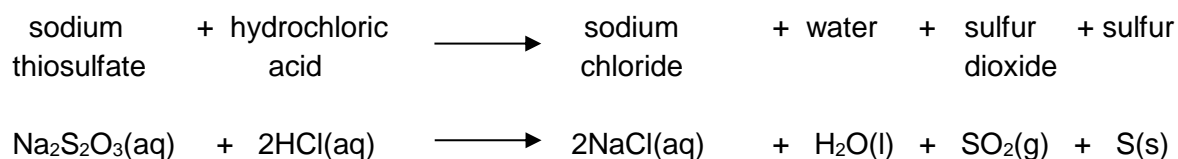
#### 4. Scientific vocabulary, quantities, units, symbols and nomenclature

Use scientific vocabulary, terminology and definitions.

## Investigation of the factors affecting the rate of reaction between dilute hydrochloric acid and sodium thiosulfate

### Introduction

Sodium thiosulfate reacts with hydrochloric acid to form a solid precipitate of sulfur. The formation of this precipitate makes the solution become cloudy, and so the rate at which this cloudiness appears can be used as a way to measure the rate of the reaction. The equation for this reaction is as follows:



The rate at which this precipitate forms can be changed by changing the conditions under which the reaction is carried out.

In this experiment you will study the effect of changing the temperature of the sodium thiosulfate solution.

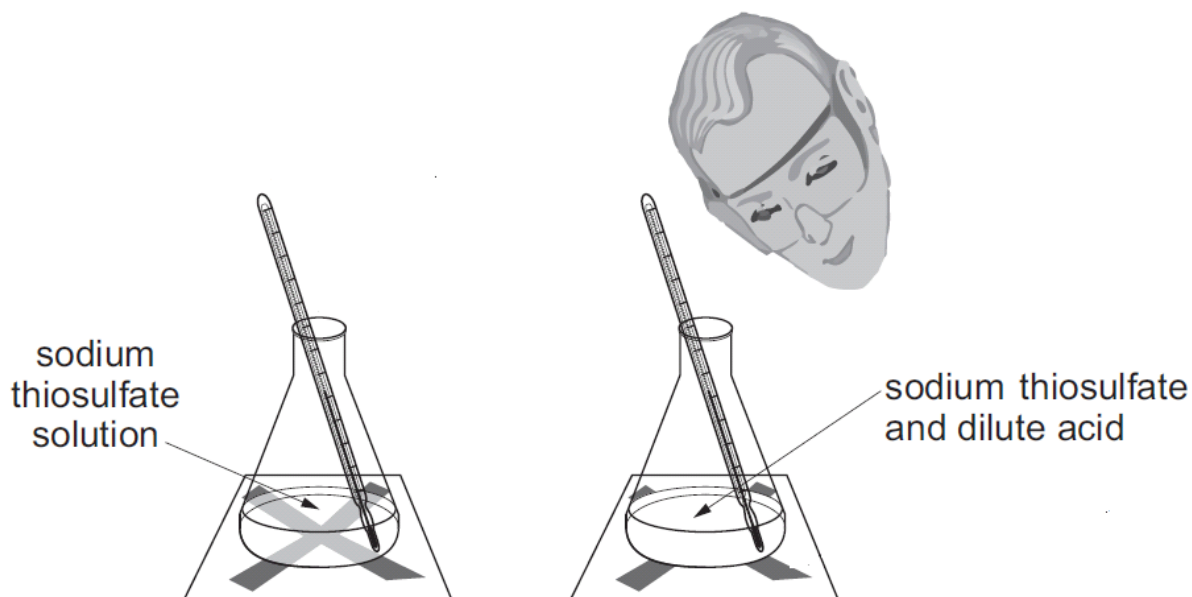
### Apparatus

10 cm<sup>3</sup> measuring cylinder  
 25 cm<sup>3</sup> measuring cylinder  
 250 cm<sup>3</sup> conical flask  
 white paper with cross marked on it  
 stopwatch  
 1 mol/dm<sup>3</sup> hydrochloric acid  
 thermometer

#### Access to:

40 g/dm<sup>3</sup> sodium thiosulfate solution at 5 °C  
 40 g/dm<sup>3</sup> sodium thiosulfate solution in a waterbath at 60 °C

## Diagram of Apparatus



## Method

1. Draw a cross on a square of white paper.
2. Measure 25 cm<sup>3</sup> of hot sodium thiosulfate using the 25 cm<sup>3</sup> measuring cylinder and pour into the conical flask. Record the temperature of the solution.
3. Using the 10 cm<sup>3</sup> measuring cylinder, measure out 5 cm<sup>3</sup> of the hydrochloric acid.
4. Place the conical flask onto the cross and add the hydrochloric acid. Swirl the flask to mix the contents and at the same time start the stopwatch.
5. Look down at the cross from above the mixture.
6. Stop the stopwatch as soon as the cross disappears.
7. Record the time taken for the cross to disappear.
9. Repeat steps 2 to 7 for different temperatures of sodium thiosulfate, made according to the table below.

Volume of sodium thiosulfate solution at 60 °C (cm <sup>3</sup> )	Volume of sodium thiosulfate solution at 5 °C (cm <sup>3</sup> )
25	0
20	5
15	10
10	15
5	20
0	25

## Analysis

1. Plot a graph of the temperature of sodium thiosulfate against the time taken for the cross to disappear

## Risk Assessment

Hazard	Risk	Control measure
Hydrochloric acid is an irritant.	Splashing onto hands/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Sodium thiosulfate is an irritant	Splashing onto hands/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Sulphur dioxide gas produced is an irritant	Inhalation of gas produced in reaction may cause damage/irritation to the lungs	Carry out in a well ventilated space/fume cupboard
Hot liquid can scald Hot apparatus can burn	Burns or scalds if the hot sodium thiosulphate is touched.	Keep maximum temperature to 60 °C. Leave to cool before moving

The crosses on the paper can be pre-prepared and laminated.

An alternative method can also be followed using the method set out on CLEAPSS card C195. It reduces the volume of reactants used so enabling more sets of equipment to be created.

## Reagents

- Hydrochloric acid – Refer to CLEAPSS hazcard 47A
- Sodium thiosulfate – Refer to CLEAPSS hazcard 95A

No repeats have been included in the method, but reproducibility can be checked by comparing results with other groups. As temperatures will vary across groups, the whole class data could be plotted onto one graph.

More able candidates could calculate and plot the rate of the reaction using  $\frac{1}{\text{time (s)}}$ .

Students should design their own table, but a suggested table format is shown below.

Recorded temperature (°C)	Time taken for cross to disappear (s)

## Working scientifically skills covered

### **2. Experimental skills and strategies**

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

### **3. Analysis and Evaluation**

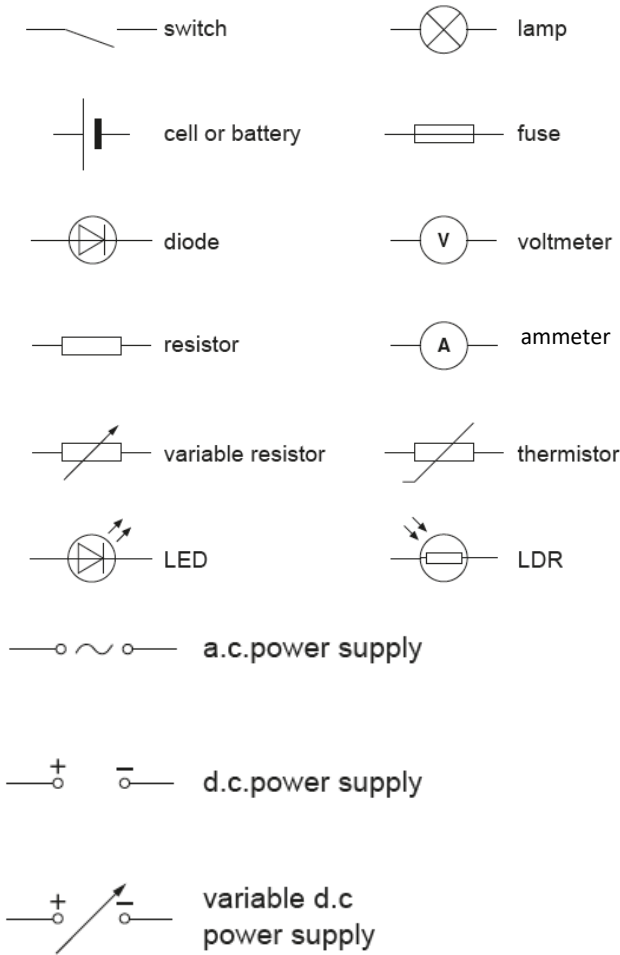
Represent distributions of results and make estimations of uncertainty.

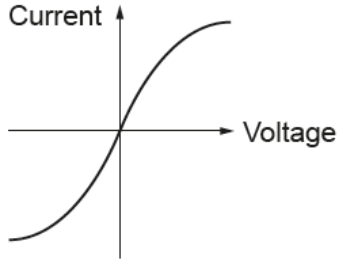
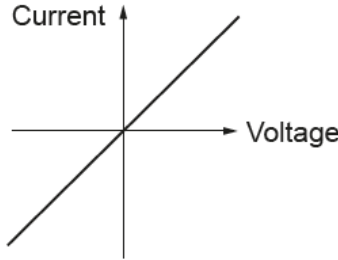
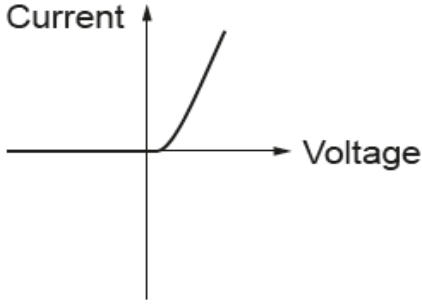
Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

## UNIT 3 – PHYSICS 1

### 3.1 ELECTRIC CIRCUITS

	Spec Statement	Comment
(a)	<p>the symbols of components (cell, switch, lamp, voltmeter, ammeter, resistor, variable resistor, fuse, LED, thermistor, LDR, diode) used in electrical circuits</p>	<p>Be able to draw circuit diagrams.</p>  <p>The diagram shows the following symbols and their labels:</p> <ul style="list-style-type: none"> <li>switch: a line with a diagonal slash</li> <li>lamp: a circle with a cross inside</li> <li>cell or battery: a long vertical line next to a shorter, thicker vertical line</li> <li>fuse: a rectangle with a diagonal slash</li> <li>diode: a triangle pointing to a vertical line</li> <li>voltmeter: a circle with a 'V' inside</li> <li>resistor: a rectangle</li> <li>ammeter: a circle with an 'A' inside</li> <li>variable resistor: a rectangle with a diagonal slash and an arrow pointing to it</li> <li>thermistor: a rectangle with a diagonal slash and a small circle at the end of the slash</li> <li>LED: a triangle pointing to a vertical line with two arrows pointing outwards</li> <li>LDR: a rectangle with a diagonal slash and two arrows pointing towards it</li> <li>a.c. power supply: a circle with a tilde symbol inside</li> <li>d.c. power supply: a circle with a '+' sign on top and a '-' sign on the bottom</li> <li>variable d.c. power supply: a circle with a '+' sign on top and a '-' sign on the bottom, with an arrow pointing to the circle</li> </ul>
(b)	<p>series circuits in which the current is the same throughout a circuit and voltages add up to the supply voltage; parallel circuits in which the voltage is the same across each branch and the sum of the currents in each branch is equal to the current in the supply</p>	<p>Including appreciation of types of household circuits e.g. ring main, household lighting circuits. Can be linked to topic 1.4 - domestic electricity.</p>

(c)	voltmeters and ammeters to measure the voltage across and current in electrical components in electrical circuits	Know that an ammeter must be connected in <b>series</b> and a voltmeter must be connected in <b>parallel</b> .
(d)	circuits to investigate how current changes with voltage for a component e.g. for a resistor (or wire) at constant temperature, a filament lamp and a diode	<p>The circuits could include a variable resistor or a variable power supply.</p> <p>Including knowledge of how:</p> <ul style="list-style-type: none"> <li>• <math>R</math> varies with <math>V</math> for a lamp because temperature is not constant</li> <li>• <math>R</math> varies with positive (forward bias) and negative voltages (reverse bias) for a diode and that normally a diode will not conduct until a particular voltage is reached.</li> </ul> <p>Current plotted on the <math>y</math>-axis and voltage on the <math>x</math>-axis.</p> <div style="display: flex; justify-content: space-around;">   </div> <div style="text-align: center; margin-top: 20px;">  </div>
(e)	the significance of and the relationship between current, voltage and resistance, $I = \frac{V}{R}$	The qualitative and quantitative relationships should be known. If $R$ is constant then $I \propto V$ . If $V$ is constant then $I \propto \frac{1}{R}$
(f)	how adding components in series increases total resistance in a circuit; adding components in parallel decreases total resistance in a circuit	



(g)	<p>how to calculate total resistance and total current in a series circuit, a <b>parallel circuit and circuits consisting of combinations of series and parallel connections;</b></p> $R = R_1 + R_2; \quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$	<p><b>Includes calculating current in a branch of a parallel circuit.</b>  <b>Includes calculating the p.d. across a resistor.</b>  <b>No limit to the number of parallel branches.</b>  <b>Final answers expressed as fractions will not be penalised.</b></p>
(h)	<p>power as energy transferred per unit time:  <math>E = Pt</math></p>	<p>Including the relationship between the units watts and joules i.e. <math>1 \text{ W} = 1 \text{ J/s}</math></p>
(i)	<p>the power transferred using:  power = voltage <math>\times</math> current  <math>P = VI</math>  <b>power = current<sup>2</sup> <math>\times</math> resistance = <math>P = I^2R</math></b></p>	<p><math>P = \frac{V^2}{R}</math> is not required</p>
(j)	<p>explain the design and use of circuits to explore the variation of resistance – including for lamps, diodes, ntc thermistors and LDRs</p>	<p>Including knowledge of how:</p> <ul style="list-style-type: none"> <li>• <math>R</math> varies with <math>T</math> for a ntc thermistor</li> <li>• <math>R</math> varies with light intensity for a LDR</li> </ul> <p>A multimeter could be used as an ohmmeter to explore the variation of resistance in a thermistor and LDR. Links with statement (d) in this section also.</p>

### SPECIFIED PRACTICAL WORK

- Investigation of the current-voltage ( $I$ - $V$ ) characteristics for a component

## Investigation of the current-voltage ( $I$ - $V$ ) characteristics of a component

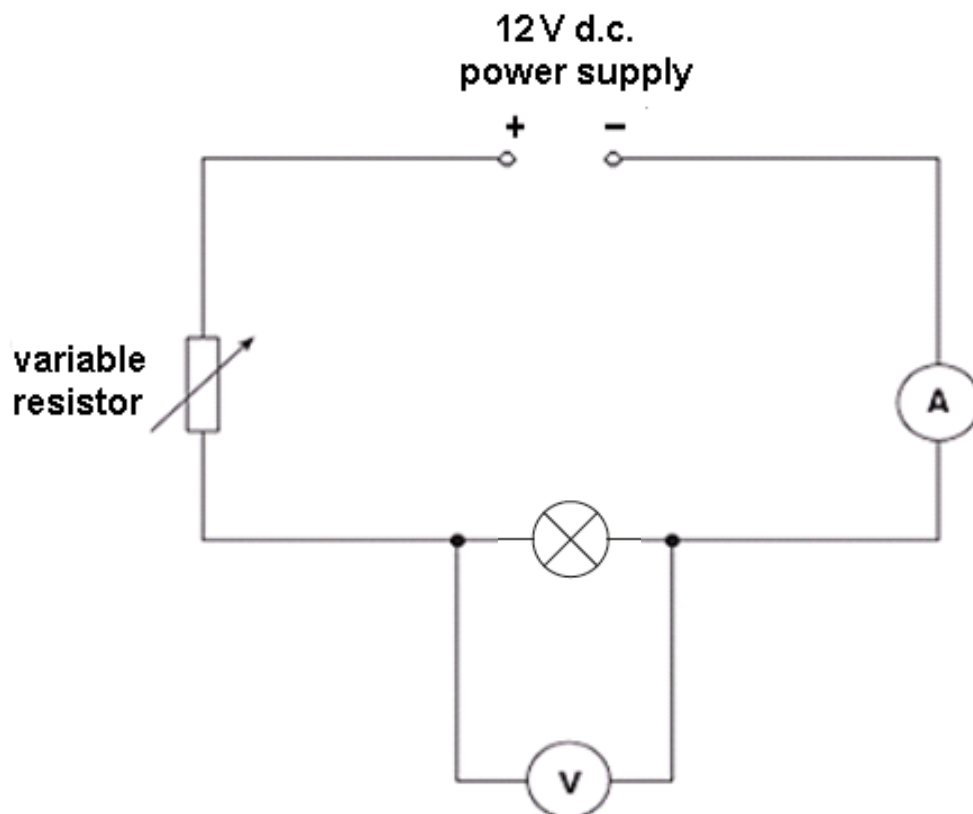
### Introduction

The voltage across and the current through a component can be measured and the results plotted on a graph to show the  $I$ - $V$  characteristic of the component.

### Apparatus

12V filament lamp  
 voltmeter  $\pm 0.01$  V  
 ammeter  $\pm 0.01$  A  
 connecting leads  
 12V d.c. power supply  
 variable resistor

### Diagram of Apparatus



## Method

1. Connect the circuit as shown in the diagram.
2. Adjust the variable resistor until the voltmeter reads 1 V.
3. Record the readings of voltage and current.
4. Adjust the variable resistor to increase the voltmeter reading to 2 V.
5. Record the readings of voltage and current.
6. Repeat steps 4 to 5, increasing the voltage by 1 V each time, until the voltmeter reads 12 V.

## Analysis

1. Plot a graph of current ( $y$ -axis) vs voltage ( $x$ -axis).

## Technician / Teacher notes

## Risk Assessment

Hazard	Risk	Control measure
Hot lamps can burn	Burning skin on hot lamps when moving/touching lamps	Allow lamp to cool before touching them.

Ray box lamps are suitable to use instead of 12 V lamps.

d.c. voltmeters and ammeters must be used.

If variable resistors are not available then a variable power supply could be used. Students should read the voltage directly from the voltmeter rather than using the settings on the power supply.

If students are constructing the circuits, it is advisable they should be checked for short circuits before use.

The graph should show a non-linear relationship.

More able students should be encouraged to discuss how the resistance of the filament changes due to the heating effect.

## Working scientifically skills covered

### 2. **Experimental skills and strategies**

Apply knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to the experiment.

Make and record observations and measurements using a range of apparatus and methods.

### 3. **Analysis and Evaluation**

Present observations and other data using appropriate methods.

Translate data from one form to another.

Carry out and represent mathematical analysis.

Interpret observations and other data, including identifying patterns and trends, making inferences and drawing conclusions.

### 4. **Scientific vocabulary, quantities, units, symbols and nomenclature**

Use SI units and IUPAC chemical nomenclature unless inappropriate.

## 3.2 GENERATING ELECTRICITY

	Spec Statement	Comment
(a)	the advantages and disadvantages of renewable energy technologies (e.g. hydroelectric, wind power, wave power, tidal power, waste, crops, solar and wood) for generating electricity on a national scale using secondary information	Consider economic, environmental and sustainability issues as well as generating capacities and start-up time. Links with statement (h) in this section.
(b)	the advantages and disadvantages of non-renewable energy technologies (fossil fuels and nuclear) for generating electricity	As above.
(c)	the processes involved in generating electricity in a fuel based power station	Including energy changes and the roles of turbines and generators.
(d)	Sankey diagrams to show energy transfers; energy efficiency in terms of input energy and energy usefully transferred in a range of contexts including electrical power generation and transmission: $\% \text{ efficiency} = \frac{\text{energy [or power] usefully transferred}}{\text{total energy [or power] supplied}} \times 100$	Including drawing Sankey diagrams to scale.  See section 2.3 – work and energy statement (h).
(e)	the need for the National Grid as an electricity distribution system including monitoring power use and responding to changing demand	Recognise the term base load. The role of different types of power stations in responding to changes in demand i.e. start-up times. Understand how the National Grid makes the electricity supply more reliable. Recognise power stations, step-up and step-down transformers, transmission lines and consumers on a diagram. Interpret graphs of demand through a time period. Importing and exporting of electricity to other European countries.

(f)	<p>advantages and disadvantages of using different voltages of electricity at different points in the National Grid to include transmission of electricity and use in the home, selecting and using the equation:  <math>\text{power} = \text{voltage} \times \text{current}; P = VI</math></p>	<p>Step-up transformers increase voltage and decrease current – reducing energy losses in transmission lines making distribution more efficient. Step-down transformers reduce voltage to safer levels for consumers.</p>
(g)	<p>the use of step-up and step-down transformers used in the transmission of electricity from the power station to the user in qualitative terms (they should be treated as voltage changers without any reference to how they perform this function)</p>	<p>See section 1.4 – domestic electricity statement (d).</p>
(h)	<p>efficiency, reliability, carbon footprint and output to compare different types of power stations in the UK including those fuelled by fossil fuels, nuclear fuel and renewable sources of energy</p>	<p>Involves the interpretation of given data.          Links with statement (a) in this section.</p>

### 3.3 MAKING USE OF ENERGY

	Spec Statement	Comment
(a)	how temperature differences lead to the transfer of energy thermally by conduction, convection and radiation	Conduction occurs well in metals and convection occurs in fluids.
(b)	the equation: $\text{density} = \frac{\text{mass}}{\text{volume}}$ and explain the differences in density between the three states of matter in terms of the arrangements of the atoms or molecules	Be able to work in both $\text{g/cm}^3$ and $\text{kg/m}^3$ but no conversions will be expected.
(c)	<b>conduction using a model of molecular motion and account for the better conduction in metals by the presence of mobile electrons</b>	Free electrons, de-localised electrons, mobile electrons are all suitable terms to use.
(d)	<b>convection in liquids and gases in terms of molecular behaviour and variations in volume and density</b>	For example: “when a section of liquid (gas) is heated the molecules gain energy and move more vigorously. As a result this section of the liquid increases in volume and its density decreases. This less dense liquid then rises and colder more dense liquid sinks to take its place. This process continues until all of the liquid is heated.” Learners need to be familiar with the term convection currents.
(e)	how energy loss from houses can be restricted e.g. loft insulation, double glazing, cavity wall insulation and draught excluders	Link method of heat transfer reduction to each method of insulation. Loft insulation and cavity wall insulation reduce heat loss by both conduction and convection. Be able to explain about the importance of “trapped air.” An awareness of the environmental benefits of house insulation is required.
(f)	the cost effectiveness and efficiency of different methods of reducing energy loss from the home, to compare their effectiveness; use data to compare the economics of domestic insulation techniques, including calculating the payback time; the economic and environmental issues surrounding controlling energy loss	$\text{payback time} = \frac{\text{installation cost}}{\text{annual savings}}$

(g)	how data can be obtained and used to investigate the cost of using a variety of energy sources for heating and transport	Consideration of the different costs of energy sources of vehicles and the range they allow: e.g. the fuel efficiency of cars, the cost-efficiency of oil-fired heating etc
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### SPECIFIED PRACTICAL WORK

- Investigation of the methods of heat transfer
- Determination of the density of solids and liquids (regular and irregular)



## Investigation of the methods of heat transfer

### Introduction

Heat can be transferred through materials (and indeed empty space) in different ways. This series of experiments explores the methods of heat transfer and aims to develop your understanding of the differences between conduction, convection and radiation.

### Apparatus

#### **Convection:**

2 × 250cm<sup>3</sup> beaker  
 1 crystal of potassium manganate(VII)  
 10 cm<sup>3</sup> glass tube  
 tripod and gauze  
 heat proof mat  
 Bunsen burner  
 forceps

#### **Radiation:**

filament lamp  
 2 × thermometers  
 1 small piece of black paper  
 1 small piece of silver foil  
 Sellotape  
 stopwatch  
 2 × clamp stand, clamp and boss

#### **Conduction:**

##### **EITHER**

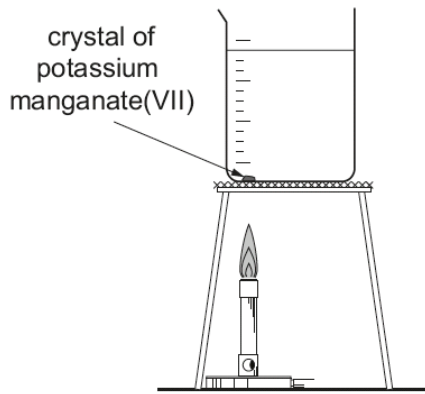
4 × metal rods  
 (aluminium, brass, copper and iron)  
 4 × drawing pins  
 Vaseline  
 tripod  
 Bunsen burner  
 heat proof mat  
 stopwatch

##### **OR**

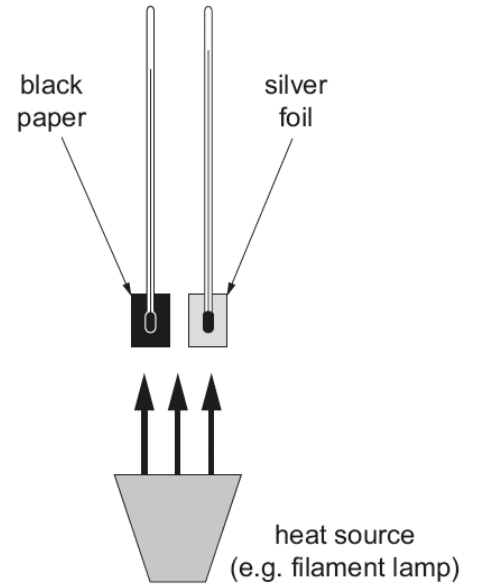
conductive ring  
 (aluminium, brass, copper and steel)  
 4 × wooden matches  
 Vaseline  
 clamp stand, clamp and boss  
 Bunsen burner  
 heat proof mat  
 stopwatch

Diagram of Apparatus

**Convection Experiment**

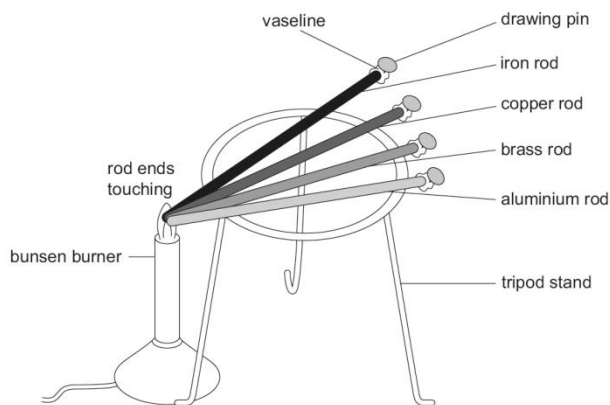


**Radiation Experiment**

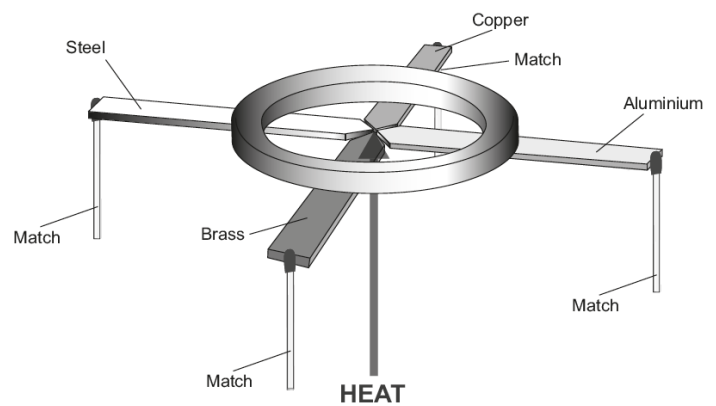


**Conduction Experiment**

**EITHER  
Metal Rods Experiment**



**OR  
Conductive Ring Experiment**



## Method

### Convection Experiment

1. Fill the beaker to  $\frac{3}{4}$  full of water.
2. Use forceps to pick up a single crystal of potassium manganate(VII) and drop it carefully through the glass tube to one side of the bottom of the beaker.
3. Place your finger on the top of the tube and remove carefully.
4. Light the Bunsen burner well away from the apparatus. Use the gas tap to get the smallest blue flame that you can.
5. Put the small Bunsen flame directly underneath the crystal and record your observations.

## Method

### Radiation Experiment

1. Use Sellotape to attach a 2cm strip of black paper to the bulb of one thermometer.
2. In the same way attach a 2cm strip of silver foil to the bulb of another thermometer.
3. Clamp the 2 thermometers **the same distance away** (about 10cm) from a filament lamp.
4. Record the temperatures shown by the two thermometers.
5. Switch on the lamp and record the temperatures again after 10 minutes.

## Analysis

1. Determine which colour is the best absorber of heat.

## Method

### Conduction Experiment

#### Metal Rods Experiment

1. Set up the apparatus as shown in the diagram above.
2. Attach a drawing pin to the end of each rod with a small blob of Vaseline.
3. The ends of the rods (without the drawing pins) should be brought together so that they can be heated equally (see diagram).
4. Heat the ends of the rods equally with a blue Bunsen flame.
5. Record the time taken for each rod to lose its drawing pin.

#### Conductive Ring Experiment

1. Clamp the conductive ring taking care to keep the clamp away from the mid-point of the ring.
2. Attach a wooden match to the outer end of each metal using a small blob of Vaseline.
3. Heat the centre point of the ring with a blue Bunsen flame.
4. Record how long it takes for each metal to lose its wooden match.

## Analysis

1. Determine the order of conductivity of the metals.

## Teacher / Technician Notes

## Risk Assessments

### Convection Experiment

Hazard	Risk	Control measure
Potassium manganate(VII) is harmful/oxidising	Could harm skin if touched	Use tweezers to drop a single crystal through the glass tube to bottom of beaker. Do not handle
Hot apparatus can burn	Burning fingers when moving apparatus	Allow apparatus to cool before any attempt to move it.  Hold tripod at bottom of a leg, Bunsen burner at base and gauze at the corner.

### Radiation Experiment

Hazard	Risk	Control measure
Hot filament lamp can burn	Burning fingers when moving lamp	Allow lamp to cool before any attempt to move it.

## Conduction Experiment

Hazard	Risk	Control measure
Hot metal rods can burn	Burning fingers when moving rods	Allow the rods to cool thoroughly before attempting to move them from the tripod
Hot tripod can burn	Burning fingers when moving tripod	Allow the tripod to cool. Do not touch the top. Move by holding bottom of a leg
Aluminium melting can burn	Molten aluminium falling on back of hand causing burning/injury	Do not overheat aluminium. Observe aluminium for signs of melting and remove heat. Do not hold the Bunsen when it is directly beneath end of aluminium rod

### Convection experiment

A small supply of potassium manganate (VII) crystals may be supplied in an evaporating basin (with some forceps) for shared use. Students should take care not to handle the crystals or get them on their clothes as it does stain. Please see the CLEAPPS card 48 on potassium manganate(VII) for further safety advice.

Strong heating does result in all the water becoming coloured very quickly. A small flame allows the convection to be seen much more easily. Students should adjust the gas tap to achieve the smallest blue flame that they can. If the flame goes out they should turn off the gas at the gas tap and then re-light the Bunsen burner and try again.

Students should be encouraged to describe their observations fully. It is not that the water all becomes coloured that is important but rather how this happens. They should be able to observe the convection currents in the water (as the purple colour rises, spreads across and sinks down the other side). They can then be encouraged to discuss / explain their observations.

### Radiation experiment

Infra-red lamps (perhaps used for microscope work) may be used as an alternative to filament lamps in the radiation experiment. The experiment works well if pieces of Sellotape are used to attach the foil/ paper. The temperature of the thermometer with the silver foil rises less despite the fact that the aluminium is a metal and a good conductor of heat. Alternatively, white paper could be used instead of the silver-coloured aluminium foil for a "fairer" experiment. Care should be taken to have the two thermometers (on the bench or clamped) at exactly the same distance from the heat source.

Students could be asked to predict what will happen. Some may suggest that the black paper will get hotter because it "attracts" more heat. This idea will need to be challenged in the discussion following the experiment.

Students should be encouraged to describe and explain their results. They should use relevant scientific terms such as heat waves, infra-red radiation, absorb and reflect.

## Conduction experiment

The expected order is :      **copper**                      **(best conductor),**  
    **aluminium,**  
    **brass,**  
    **iron/ steel**                      **(poorest conductor).**

Some groups may find aluminium to be the best conductor. It is often very close between copper and aluminium. Hopefully, a quick survey of each group's results will reveal more votes for copper than for aluminium as the best conductor.

The metal rods may roll off the tripod and onto the bench. Thick cloths should be available for the teacher to pick them up and place them onto the heat proof mat to avoid marking the benches.

The Vaseline makes this a potentially messy experiment. Students need access to soap and hot water to remove Vaseline from hands. A plentiful supply of paper towels should be available to wipe Vaseline from benches. Wooden splints may be used to transfer Vaseline from a small pot onto the drawing pin / metal rod. Students should be encouraged to use the smallest amount of Vaseline that is needed to attach each drawing pin to the rod.

This practical works well run as a circus of activities.

## Working scientifically skills covered

### 2. **Experimental skills and strategies**

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Make and record observations and measurements using a range of apparatus and methods.

### 3. **Analysis and Evaluation**

Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

### 4. **Scientific vocabulary, quantities, units, symbols and nomenclature**

Use scientific vocabulary, terminology and definitions.

## Determination of the density of liquids and solids (regular and irregular)

### Introduction

The density of a substance measures the mass it contains in a given volume. Density is calculated using the equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

### Apparatus

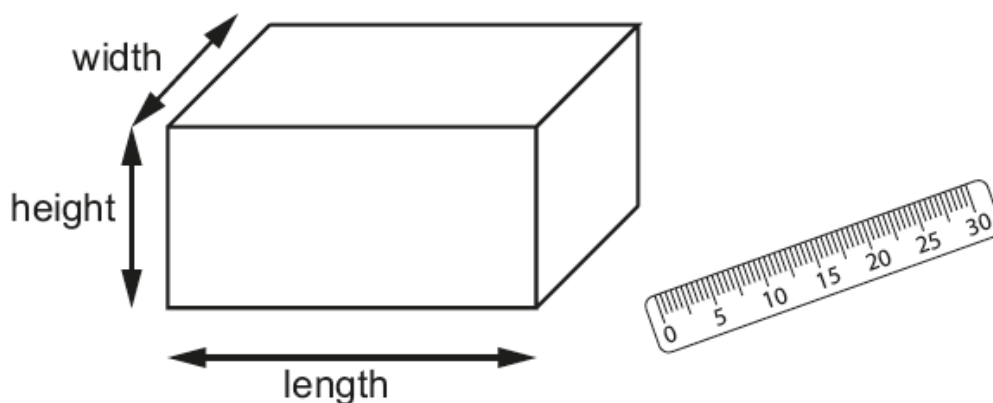
2 × regular shaped solids  
 2 × irregular shaped solids  
 30 cm ruler  
 50 cm<sup>3</sup> measuring cylinder  
 water

**Access to:**

electronic balance ± 0.1 g

### Measuring the density of a regular shaped solid

#### Diagram of Apparatus



## Method

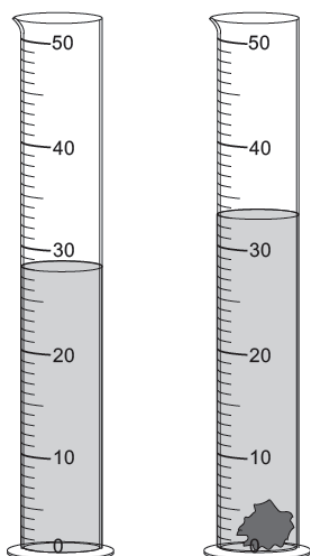
1. Record the mass of the solid.
2. Record the length, width and thickness of the solid using a ruler.
3. Repeat for cubes of different material.

## Analysis

1. Calculate the volume of the cube from:  $\text{volume} = \text{length} \times \text{height} \times \text{width}$ .
2. Calculate the density in  $\text{g/cm}^3$ .

## Measuring the density of an irregular shaped solid

### Diagram of Apparatus



## Method

1. Record the mass of the solid.
2. Fill the measuring cylinder with water up to  $20 \text{ cm}^3$  and record the volume.
3. Gently place the solid into the measuring cylinder and record the new volume.

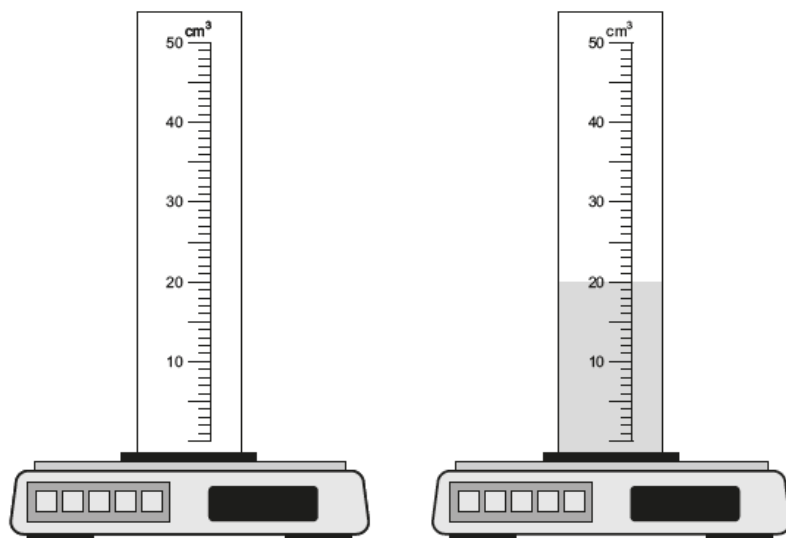
## Analysis

1. Calculate the volume of the solid by subtracting the original volume from the new volume.
2. Calculate the density in  $\text{g/cm}^3$ .



## Measuring the density of a liquid

### Diagram of Apparatus



### Method

1. Record the mass of the empty measuring cylinder.
2. Add 20 cm<sup>3</sup> of water to the measuring cylinder.
3. Record the mass of the measuring cylinder with the water.

### Analysis

1. Calculate the mass of the water by subtracting the mass of the measuring cylinder (without water) from the mass of the measuring cylinder with the water.
2. Calculate the density in g/cm<sup>3</sup>.

### Teacher / Technician notes

Small pieces of Blu-Tack or plasticine or small stones can be used as irregular shaped solids.

Students should be provided with a range of regular shaped common materials, e.g. cork, wood, steel, aluminium, polystyrene, rubber or plastic. However, care should be taken with the mass of the blocks to ensure balances are not damaged.

As an extension students could investigate how the addition of a salt such as sodium chloride to water changes its density.

This practical works well run as a circus of activities.

## Working scientifically skills covered

2. **Experimental skills and strategies**

Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

Make and record observations and measurements using a range of apparatus and methods.

3. **Analysis and Evaluation**

Carry out and representing mathematical analysis.

4. Scientific vocabulary, quantities, units, symbols and nomenclature

Use SI units and IUPAC chemical nomenclature unless inappropriate.

**Use an appropriate number of significant figures in calculation.**

### 3.4 DOMESTIC ELECTRICITY

	Spec Statement	Comment
(a)	the kilowatt (kW) as a convenient unit of power in the domestic context and the kilowatt hour (kWh) as a unit of energy	1 kWh is the electrical energy converted by a 1 kW appliance used for 1 hour. Be able to convert between kWh and joules.
(b)	the cost of electricity using the equations: units used (kWh) = power (kW) × time (h) cost = units used × cost per unit	Conversions between W and kW. Also between minutes/hours and hours/days and pence/£.
(c)	how data can be obtained either directly or using secondary sources (e.g. through the energy banding (A-G) and the power ratings of domestic electrical appliances) to investigate the cost of using them	Includes different types of lamps e.g. filament, halogen and LED. Includes payback time.
(d)	the difference between alternating current (a.c.) and direct current (d.c.)	An alternating current (a.c.) is one that continuously changes direction. Mains electricity is an a.c. supply. A direct current (d.c.) has a constant direction. Cells and batteries provide d.c. Graphical representation of a.c. and d.c. voltages on CRO screens. The UK mains supply is about 230 V and has a frequency of 50 cycles per second (50 Hz).  See section 1.2 – generating electricity statement (g).
(e)	the functions of fuses, miniature circuit breakers (mcb) and residual current circuit breakers (rccb) including calculations of appropriate fuse ratings	A selection of fuse ratings will be given.  Unlike fuses, mcb circuit breakers can be easily reset and use an electromagnet to open a switch if the current goes above a certain value. rccb circuit breakers switch off the circuit when there is a difference between the currents in the live and neutral wires of the appliance. They are more sensitive than mcb breakers. mcbs protect the circuit whilst rccbs protect the user.

(f)	<p>the ring main, including the functions of the live, neutral and earth wires</p>	<p>The structure and wiring of a 3 pin plug is not needed.</p> <p>The function of the live wire is to carry current to the house/appliance at a high voltage. The neutral wire completes the circuit and carries current away at low/zero voltage. The earth wire is a safety wire that can carry current safely into the ground if a fault develops in a metal framed appliance. Appliances with metal cases are usually earthed. If the casing becomes live, a large current can flow along the low-resistance earth wire and this high current will "blow" a fuse or trip a mcb.</p> <p>Switches and fuses are placed into the live wire.</p> <p>The ring main is a looped parallel circuit. There are several advantages of using a ring main circuit: - the cables can be made thinner because there are two paths for the current; - each part of the cable carries less current because the current flows two ways; - a ring main circuit is more convenient since sockets can be placed anywhere on the ring; - each socket has 230 V applied and they can be operated separately.</p>
(g)	<p>the cost effectiveness of introducing domestic solar and wind energy equipment, including fuel cost savings and payback time by using data</p>	<p>Including output reliability and ability to meet domestic demand feed-in tariffs.</p>
(h)	<p>how to investigate energy transfers in a range of contexts including interpreting and analysing data; evaluation of validity of the data and methods, e.g.</p> <ul style="list-style-type: none"> <li>• the energy output from a renewable source (e.g. wind turbine: construction and location)</li> <li>• efficiency of energy transfer (e.g. using an electric kettle)</li> </ul>	

### 3.5 FEATURES OF WAVES

	Spec Statement	Comment
(a)	the difference between transverse and longitudinal waves	Including definitions of both types of waves with comparison of the direction of vibrations and the direction of travel of the wave included.  Be able to give examples of a transverse wave and a longitudinal wave.
(b)	the description of a wave in terms of amplitude, wavelength ( $\lambda$ ), frequency ( $f$ ) and wave speed ( $v$ )	Know that amplitude is the maximum displacement from rest. No knowledge of period is required. Be able to define only the term frequency i.e. the number of cycles of a wave that occur in one second.
(c)	the graphical representation of a transverse wave, including labelling the wavelength and amplitude	Including constructing a wave diagram from given data.  Displacement – distance and displacement – time graphs are required.
(d)	diagrams showing plane wave fronts being reflected or refracted, e.g. as shown by water waves in a ripple tank	Only at plane boundaries required. Knowledge of the terms normal, angles of incidence / reflection / refraction required. Should know what happens to the speed / frequency / wavelength / direction of water waves as they move from deep to shallow water (and vice versa).
(e)	refraction in terms of the speed of waves on either side of a refracting boundary and the effect on the wavelength of the waves	Changes in wavelength are proportional to changes in wave speed.
(f)	the term "radiation" to both electromagnetic waves and to energy given out by radioactive materials	
(g)	the characteristics of radioactive emissions and short wavelength parts of the electromagnetic spectrum (ultraviolet, X-ray and gamma ray) as ionising radiation, able to interact with atoms and to damage cells by the energy they carry	No knowledge of alpha and beta is required here.

(h)	<p>the difference between the different regions of the electromagnetic spectrum [radio waves, microwaves, infra-red, visible light, ultraviolet, X-rays and gamma rays] in terms of their wavelength and frequency and know that they all travel at the same speed in a vacuum</p>	<p>Be able to name the 7 regions of the em spectrum. Have knowledge of the order in which the regions are arranged in terms of wavelength, frequency or energy. In a question – speed of light, <math>c = 3 \times 10^8 \text{ m s}^{-1}</math> will be given if needed.</p>
(i)	<p>the fact that all regions of the electromagnetic spectrum transfer energy and certain regions are commonly used to transmit information</p>	<p>Higher frequencies transmit higher energies. Awareness of the uses of the different regions of the em spectrum.</p>
(j)	<p>waves in terms of their wavelength, frequency, speed and amplitude</p>	<p>Including the relationship between wavelength and frequency i.e. inversely proportional and between amplitude and energy.</p>
(k)	<p>the equations: wave speed = wavelength <math>\times</math> frequency; <math>v = \lambda f</math> and <math display="block">\text{speed} = \frac{\text{distance}}{\text{time}}</math>applied to the motion of waves, including electromagnetic waves</p>	<p>Recognising expressions in standard form is expected on FT e.g. arranging values in a rank order. Calculations involving standard form will only be expected on HT.</p>
(l)	<p>communication using satellites in geosynchronous/geostationary orbit</p>	<p>Signal travels double the orbit height. Requires the use of microwaves to pass through the atmosphere. The use of more than 1 satellite is required. <b>A geosynchronous satellite has an orbit time of 24 h however the object in this orbit only returns to exactly the same position in the sky after a period of one day. A geostationary orbit is a particular type of geosynchronous orbit. The distinction being that while an object in geosynchronous orbit returns to the same point in the sky at the same time each day, an object in geostationary orbit never leaves that position. A base station can be in constant communication with a geostationary satellite but only once every 24 h with a geosynchronous satellite.</b></p>

### SPECIFIED PRACTICAL WORK

- Investigation of the speed of water waves

## Investigation of the speed of water waves

### Introduction

The speed of waves on the surface of water, created when the water is moved out of position, depends only on the depth of the water and the gravitational field strength. To measure the speed of the waves the time they take to travel a certain distance is measured and the following equation is applied.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

### Apparatus

rectangular apparatus tray with straight sides  
 stopwatch  
 large beaker  
 large measuring cylinder

### Diagram of Apparatus



### Method

1. Measure the length of the tray and record the result.
2. Add water to the tray to give a depth of 0.5 cm and record the volume used.
3. Lift the end of the tray up a few cm and gently replace on the desk.
4. Start the stopwatch when the wave produced hits the end of the tray.
5. Record how long it takes the waves to travel 3 lengths of the tray.
6. Repeat steps 3-5 four more times.
7. Repeat steps 2-6 increasing the depth each time by 0.5 cm up to 3.0 cm.

## Analysis

1. Calculate the mean speed of the waves using:

$$\text{mean speed} = \frac{\text{distance}}{\text{mean time}}$$

2. Plot a graph of depth against speed.

## Teacher / Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Wet floors are slippery	If water splashes on the floor during the experiment people may slip and be injured	Do not overfill the trays. Place tray down gently when producing waves. Mop up any spillages

Although straight sided trays are preferable, Gratnell trays work quite well in this experiment.

Pupils will need to be given the value for the volume of water required to fill the tray to a depth of 0.5 cm – in cm<sup>3</sup> this is numerically equal to half the surface area.

The data should give a smooth curve as the speed is proportional to  $\sqrt{\text{depth}}$ .

Students should plot a graph of depth against mean speed and be encouraged to plot a smooth curve of best fit (if they have measured carefully!) and to examine the quantitative relationship between the variables.

Students should be told that they need to use the length of tray  $\times 3$  in calculating the mean speed for each depth.

It is interesting to investigate the factor by which the depth must change to double the speed of the waves this could provide good extension opportunities for the more able.

Students should design their own table, but a suggested table format is shown on the next page.



		Time taken for waves to travel three lengths of the tray (s)						
Depth of water (cm)	Length of tray (cm)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean	Mean speed (cm/s)

Working scientifically skills covered

**2. Experimental skills and strategies**

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Make and record observations and measurements using a range of apparatus and methods.

Evaluate methods and suggest possible improvements and further investigations.

**3. Analysis and Evaluation**

Present observations and other data using appropriate methods.

Translate data from one form to another.

Carry out and representing mathematical analysis.

## UNIT 4 – BIOLOGY 2

### 4.1 CLASSIFICATION AND BIODIVERSITY

	Spec Statement	Comment
(a)	living organisms showing a range of sizes, features and complexity; the broad descriptive grouping into plants - non-flowering and flowering; animals - invertebrates and vertebrates	There is a range of living organisms and they are divided into major groups: non-flowering plants – do not produce flowers e.g. ferns and mosses; flowering plants – produce flowers; invertebrates – do not have a backbone e.g. insects; vertebrates – have a backbone.
(b)	the means by which organisms which have similar features and characteristics are classified into groups; the need for a scientific system for identification and the need for scientific as opposed to 'common' names	A systematic system helps in the understanding of the variety of living things, their trends and relationships. The classification system may be based on morphological features or DNA analysis. The five Kingdom classification uses morphological features and includes Bacteria, Single Celled organisms, Plants, Fungi, and Animals. Each organism has a scientific name to aid its identification and classification. This avoids the confusion and duplication caused by local or common names. The classification of any suitable example to species level should be used to illustrate the system, including use of the following hierarchical taxa: kingdom, phylum, class, order, family, genus, species.
(c)	the fact that organisms have morphological and behavioural adaptations which enable them to survive in their environment	
(d)	individual organisms needing resources from their environment e.g. food, water, light and minerals; how the size of a population may be affected by competition for these resources along with predation, disease and pollution	This would include competition between species (interspecific) and between members of the same species (intraspecific).

(e)	the term biodiversity: the variety of different species and numbers of individuals within those species in an area; why biodiversity is important; the ways in which biodiversity and endangered species can be protected including issues surrounding the use of legislation	<p>Biodiversity is important as it provides food, potential foods, industrial materials, new medicines and for human well-being.</p> <p>Biodiversity and endangered species can be conserved and protected by the following:</p> <ul style="list-style-type: none"> <li>• Convention on International Trade in Endangered Species</li> <li>• Sites of Special Scientific Interest</li> <li>• captive breeding programmes</li> <li>• national parks</li> <li>• seed/ sperm banks</li> <li>• local biodiversity action plans</li> </ul>
(f)	how quadrats can be used to investigate the abundance of species	Any suitable location could be used to show the effect of different environmental factors. This should include the use of line transects and random quadrat distribution. An understanding that the number/ distribution of quadrats used should be enough to give valid results.
(g)	the principles of sampling; the need to collect sufficient data	
(h)	<b>the principles of capture/recapture techniques including simple calculations on estimated population size</b>	<p><b>Candidates should know how to use the equation:</b></p> <p>population size =</p> $\frac{\text{number in 1}^{\text{st}} \text{ sample} \times \text{number in 2}^{\text{nd}} \text{ sample}}{\text{number in 2}^{\text{nd}} \text{ sample previously marked}}$ <p><b>When using capture-recapture data, assumptions made include: there is no death, immigration or emigration and that the marking technique does not affect chances of survival.</b></p> <p><b>Candidates will not be expected to recall the equation.</b></p>
(i)	the use of biological control agents and possible issues surrounding this; the introduction of alien species and their effects on local wildlife	<p>Candidates should know that some animals and plants have been introduced, deliberately and accidentally, into areas where they do not naturally occur and some have become invasive and caused problems. Invasive species may grow faster than native species and upset the natural eco-system. Native species may not be able to compete with them.</p> <p>Research into the use of biological control agents takes place, on a world-wide basis, in order to understand how best to control alien species. During the research, trials are needed to assess the effects of biological control agents particularly on non-targeted native species.</p>

### SPECIFIED PRACTICAL WORK

- Investigation into the distribution and abundance of organisms

## Investigation into factors affecting the abundance and distribution of a species

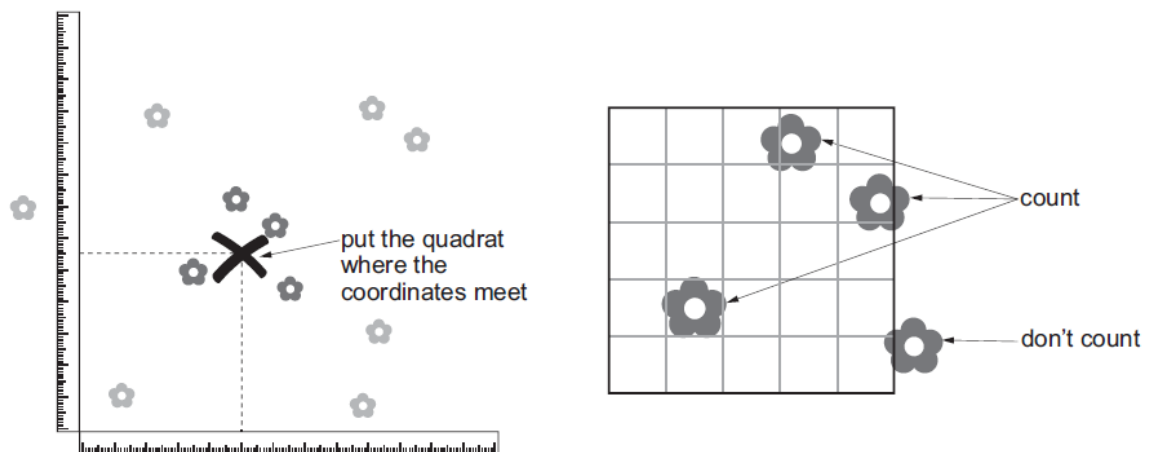
### Introduction

Daisies are a common plant species that can be found on a school field. Using quadrats for random sampling allows you to estimate the numbers of daisy plants growing in this habitat. This technique also reduces sampling bias. A simple calculation can then be used to estimate the total number of daisy species in the entire school field habitat.

### Apparatus

- 2 × 20m tape measures
- 2 × 20 sided dice
- 1 m<sup>2</sup> quadrat

### Diagram of Apparatus



## Method

1. Lay two 20 m tape measures at right angles along two edges of the area to survey.
2. Roll two 20 sided dice to determine the coordinates.
3. Place the 1 m<sup>2</sup> quadrat at the place where the coordinates meet.
4. Count the number of daisy plants within the quadrat. Record this result.
5. Repeat steps 2-4 for at least 25 quadrats.

## Analysis

1. Use the following equation to estimate the total number of daisy plants in the field habitat:

$$\text{Total number of daisy plants in the habitat} = \text{total number in sample} \times \frac{\text{total area (m}^2\text{)}}{\text{total sample area (m}^2\text{)}}$$

Where:

total area = 400 m<sup>2</sup>

total sample area = number of 1 m<sup>2</sup> quadrats used

## Teacher/Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Some plants have thorns which can cut skin or can sting	Cut/irritate skin when handling plants	Avoid touching plants when identifying or wear gloves
Uneven ground	Tripping/falling over when identifying plants	Wear suitable footwear

Students could compare data for mown and unmown areas.

This practical activity is effective at developing practical fieldwork skills. Students can discuss the need for a large sample of data in ensuring that there is confidence in a valid conclusion. Also, students can describe the importance of random sampling techniques in reducing/eliminating bias.

Alternative methods of generating coordinates can be used, such as using a random number generator or random number tables.

### Working scientifically skills covered

#### **2. Experimental skills and strategies**

Apply knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to this experiment.

Recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative

Make and record observations and measurements using a range of apparatus and methods.

#### **3. Analysis and Evaluation**

Carrying out and representing mathematical analysis.

## 4.2 CELL DIVISION AND STEM CELLS

	Spec Statement	Comment
(a)	chromosomes as linear arrangements of genes, found in pairs in body cells.	Since chromosomes are normally found in pairs in the nucleus of each body cell, the genes, which control particular characteristics, also come as pairs.
(b)	the functions of cell division by mitosis and meiosis	Cell division, by mitosis, enables organisms to grow, replace worn out cells and repair damaged tissues. Cell division by meiosis for the formation of gametes. The exact spelling of mitosis and meiosis is required.
(c)	the outcomes of mitotic and meiotic divisions and be able to compare these	Each mitotic division produces two daughter cells that are genetically identical and have the same number of chromosomes as the mother cell. Each meiotic division produces four daughter cells that are genetically different and have half the number of chromosomes of the mother cell.
(d)	the fact that if mitosis is uncontrolled, cancer can occur	A simple understanding that cancer is a result of uncontrolled mitosis.
(e)	stem cells: the cells in mature tissues have generally lost the ability to differentiate; some cells, in both plants and animals, do not lose this ability and these are called stem cells	The bodies of multicellular organisms consist of a variety of different cells that are adapted for particular functions. These different cells originate from undifferentiated stem cells that have the capacity to develop into specialised cells.
(f)	the potential of both adult and embryonic stem cells to replace damaged tissue	Stem cells are able to treat damaged or diseased tissue, providing a potent medical tool. The benefits of using your own stem cells include: no rejection, no need to find a donor, no need for tissue typing. However, the use of embryonic stem cells raises particular ethical issues.

### 4.3 DNA AND INHERITANCE

	Spec Statement	Comment
(a)	the structure of DNA as two long chains of alternating sugar and phosphate connected by bases; the chains are twisted to form a double helix; there are four types of base, A ( <b>adenine</b> ), T( <b>thymine</b> ), C ( <b>cytosine</b> ) and G ( <b>guanine</b> ); the order of bases forms a code for making proteins; the code determines the order in which different amino acids are linked together to form different proteins	DNA has a ladder-like structure, the bases forming the rungs. They should have an understanding of complementary base pairing - A ( <b>adenine</b> ) pairs with T ( <b>thymine</b> ) and that C ( <b>cytosine</b> ) pairs with G ( <b>guanine</b> ). <b>Each triplet code identifies a particular amino acid. In the cytoplasm, these triplet codes are used to identify and link amino acids together to form proteins.</b>
(b)	complementary base pairing between A and T, C and G <b>and the role of the triplet code during protein synthesis</b>	
(c)	the process of 'genetic profiling' which involves cutting the DNA into short pieces which are then separated into bands	The term genetic profiling should be used in place of genetic fingerprinting to avoid confusion with fingerprinting.
(d)	how 'genetic profiling' can be used to show the similarity between two DNA samples, the pattern of the bands produced can be compared to show the similarity between two DNA samples, for instance in criminal cases, paternity cases and in comparisons between species for classification purposes	
(e)	the benefits of DNA profiling, for example to identify the presence of certain genes which may be associated with a particular disease	The ethical issues linked with DNA profiling.
(f)	genes as sections of DNA molecules that determine inherited characteristics and that genes have different forms, called alleles, which are in pairs	



(g)	the following terms: gamete, chromosome, gene, allele, dominant, recessive, homozygous, heterozygous, genotype, phenotype, F1, F2, selfing	The terms gene and allele are <u>not</u> interchangeable.
(h)	single gene inheritance; be able to complete Punnett squares to show this; how to predict the outcomes of monohybrid crosses including ratios	
(i)	the fact that most phenotypic features are the result of multiple genes rather than single gene inheritance	
(j)	sex determination in humans: in human body cells, one of the pairs of chromosomes, XX or XY, carries the genes which determine sex, these separate and combine randomly at fertilisation	The use of Punnett squares to show the inheritance of sex chromosomes.
(k)	the artificial transfer of genes from one organism to another; the potential advantages, disadvantages and issues involved with this technology	Genetic modification includes that genes can be transferred from one species to another. Advantages would depend on the organisms in question, but may include disease resistance and increased yield. Disadvantages and issues may include effects on health and the environment.

## 4.4 VARIATION AND EVOLUTION

	Spec Statement	Comment
(a)	the variation in individuals of the same species having environmental or genetic causes; <b>variation being continuous or discontinuous</b>	The variation in height/length in organisms could be used to show that individuals of the same species are similar but they are never exactly the same. <b>Continuous and discontinuous variation should be illustrated graphically – bell shaped curve for continuous variation and discontinuous variation as discrete groups.</b>
(b)	sexual reproduction leading to offspring being genetically different from the parents, unlike asexual reproduction where genetically identical offspring called clones are produced from a single parent; sexual reproduction therefore giving rise to variation	In sexual reproduction - fertilisation produces a single cell with a new set of pairs of chromosomes. - this produces variation in the offspring i.e. offspring that are genetically different from the parents. In asexual reproduction a number of genetically identical offspring, clones, are produced from a single parent.
(c)	the facts that new genes result from changes, mutations, in existing genes; mutations occur at random; most mutations have no effect but some can be beneficial or harmful; mutation rates can be increased by ionising radiation	The greater the dose/exposure to ionising radiation the greater the chance of mutation. (No reference to specific ionising radiation is required.)
(d)	some mutations causing conditions which may be passed on in families, as is shown by the mechanism of inheritance of cystic fibrosis; the interpretation of family trees showing this; the issues surrounding the development and use of gene therapy in cystic fibrosis sufferers	Cystic fibrosis is an inherited disease that causes the production of thick mucus that blocks the bronchioles. It arises as a mutation and can be inherited as a recessive allele. The pattern of inheritance of this and other conditions in a family can be shown using family trees. Gene therapy has potential to treat this condition, but is not straightforward as the introduction of genes is not sufficient, they must be able to work within the body. There are also difficulties in targeting the appropriate cells and it is not a cure for the underlying condition. The genes can be introduced into the lung tissue via an inhaler.
(e)	heritable variation as the basis of evolution	Individual organisms in a particular species may show a wide range of variation because of differences in their genes (heritable variation).

(f)	<p>how individuals with characteristics adapted to their environment are more likely to survive and breed successfully; the use and limitations of a model to illustrate the effect of camouflage colouring in predator and prey relationships</p>	<p>Modelling, such as picking up different coloured cards from a suitable 'camouflage' background, may be used to illustrate the effect of camouflage colouring in prey and predator relationships. This has limitations as it cannot exactly reproduce the situation.</p>
(g)	<p>how the genes which have enabled these better adapted individuals to survive are then passed on to the next generation; natural selection as proposed by Alfred Russell Wallace and Charles Darwin; how the process of natural selection is sometimes too slow for organisms to adapt to new environmental conditions and so organisms may become extinct</p>	<p>The term natural selection should be understood. The term 'Survival of the fittest' should only be used with care as it must be qualified in the context of breeding i.e. survival of the fittest to breed. An understanding that Wallace and Darwin were both working on the ideas of evolution and natural selection at around the same time.</p>
(h)	<p>how evolution is ongoing as illustrated by antibiotic resistance in bacteria, pesticide resistance and warfarin resistance in rats</p>	
(i)	<p>the potential importance for medicine of our increasing understanding of the human genome</p>	<p>An understanding that the human genome is important because it uses information from DNA to develop new ways to treat, cure, or even prevent disease.</p>

### SPECIFIED PRACTICAL WORK

- Investigation into variation in organisms

## Investigation into variation in organisms

### Introduction

Snails of two closely related species of *Cepaea* are common in woodland and grassland in Britain. They show a pattern of variation known as polymorphism. This means that there are several different 'types'. The shell may be either yellow or pink/brown, and it may have dark stripes or be plain.

The four types of the snails are as follows:

- Pink/brown, plain
- Yellow, plain
- Pink/brown, striped
- Yellow striped



In this investigation photographs of snails from each area, woodland and grassland will be categorised and counted to determine which variations of snails are most common in each area.

### Apparatus

Images of snails (attached)

### Method

1. Arrange the photographs of the woodland snails face down and randomly select 50.
2. Categorise the snails selected into one of the 4 different variants and count the number of each.
3. Repeat steps 1- 2 for the grassland snails.

### Analysis

1. Draw a bar chart of your results.
2. Analyse your results to reach a conclusion on the effect of habitat on the variation of snails.

## Teacher/Technician notes

The photographs of snails need to be copied in colour and in sufficient quantities so that each group is able to collect 50 snails from each habitat, woodland and grassland.

Students should devise a tally chart to record data collected and calculation of the % of each type of snail should also be encouraged.

Snail Type	Woodland		Grassland	
	Numbers	%	Numbers	%
Plain yellow				
Striped yellow				
Plain pink				
Striped pink				

Further discussions could take place on evaluating the difference between this investigation and the reality of sampling snails in their environment, including the concept of sample size and the possible implications of some snails having better camouflage than others.

## Working scientifically skills covered

### 2. Experimental skills and strategies

Recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative

Make and record observations and measurements using a range of apparatus and methods.

### 3. Analysis and Evaluation

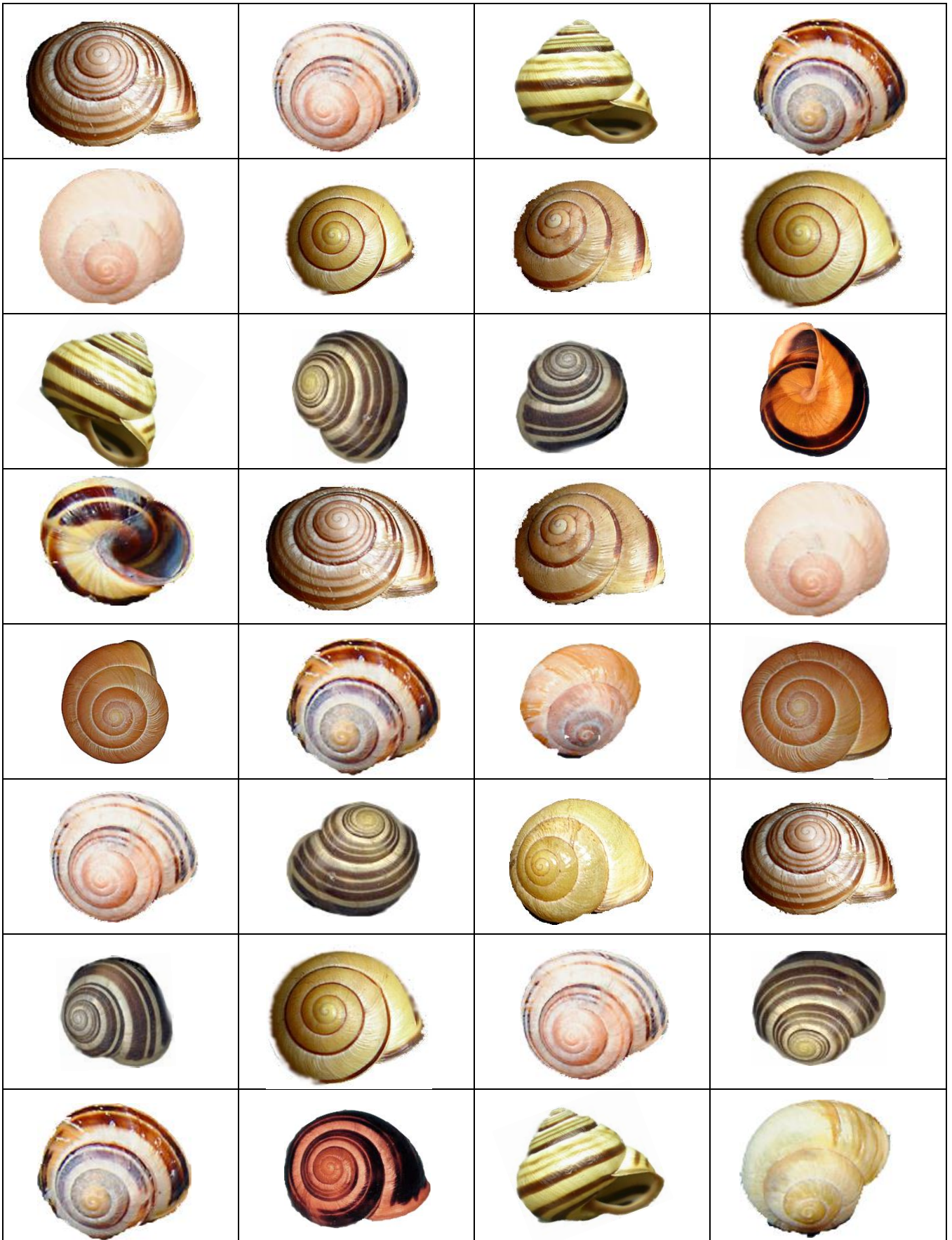
Presenting observations and other data using appropriate methods

Translating data from one form to another.

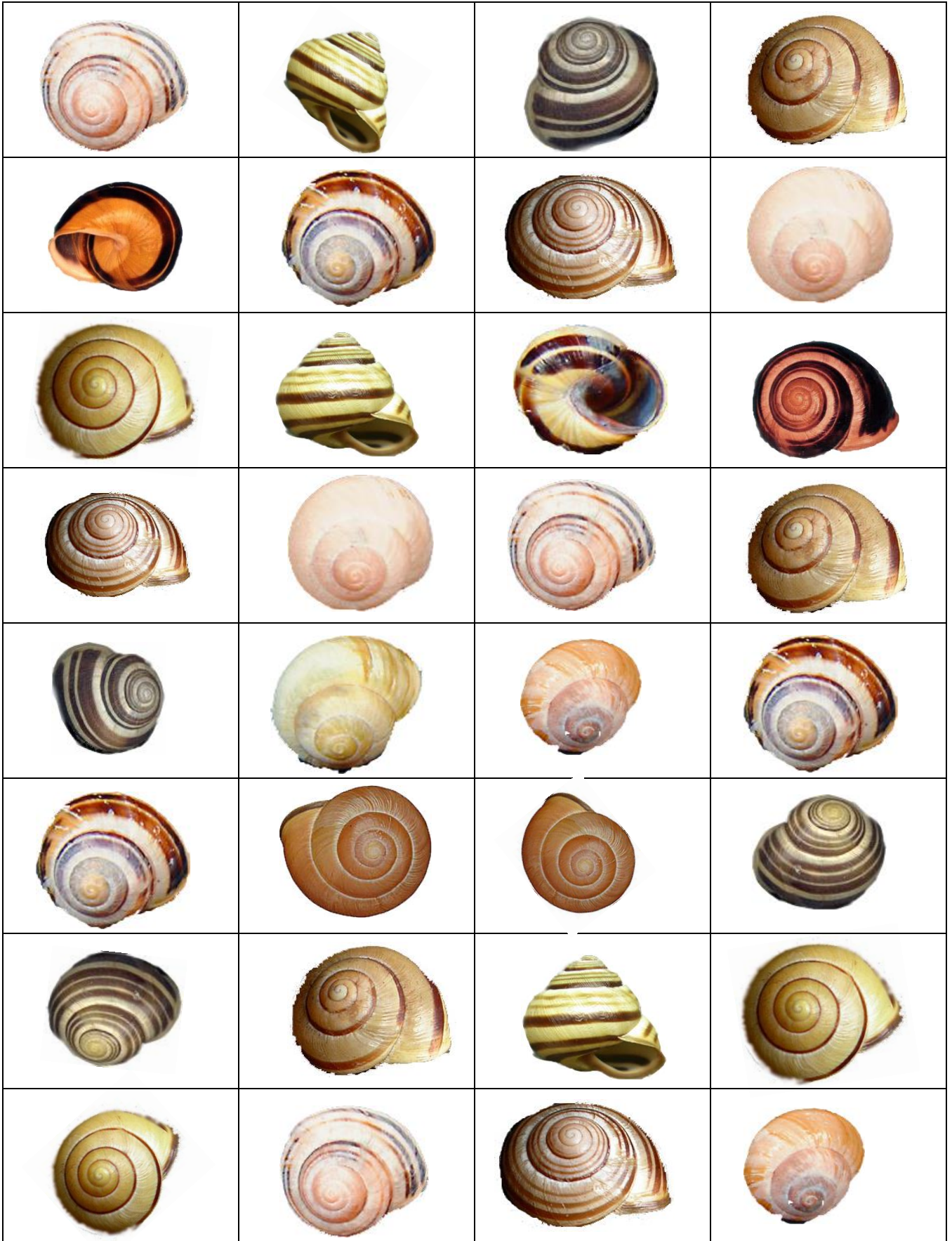
Carrying out and representing mathematical analysis.

Interpreting observations and other data, including patterns and trends, making inferences and drawing conclusions

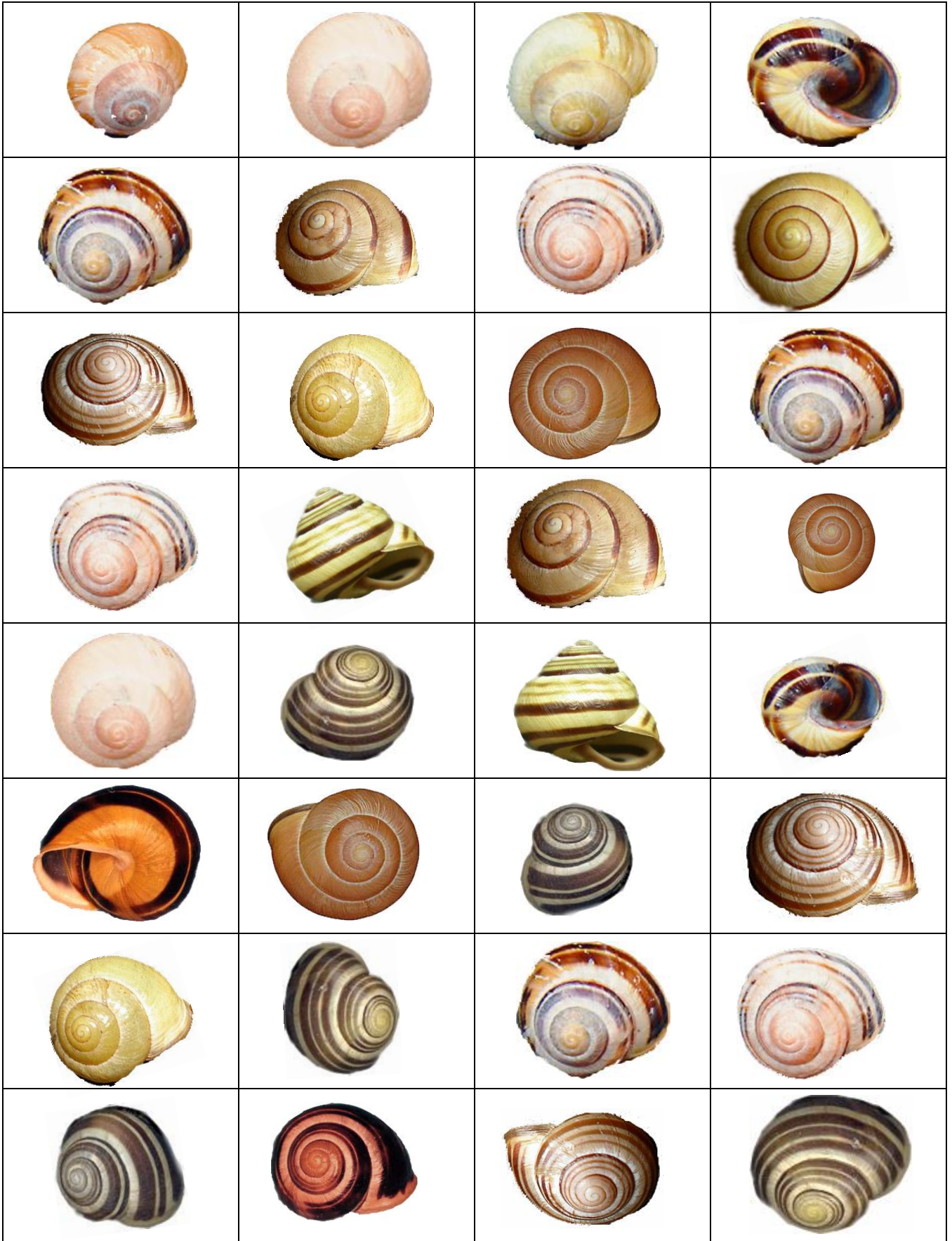
Woodland snails 1



Woodland snails 2

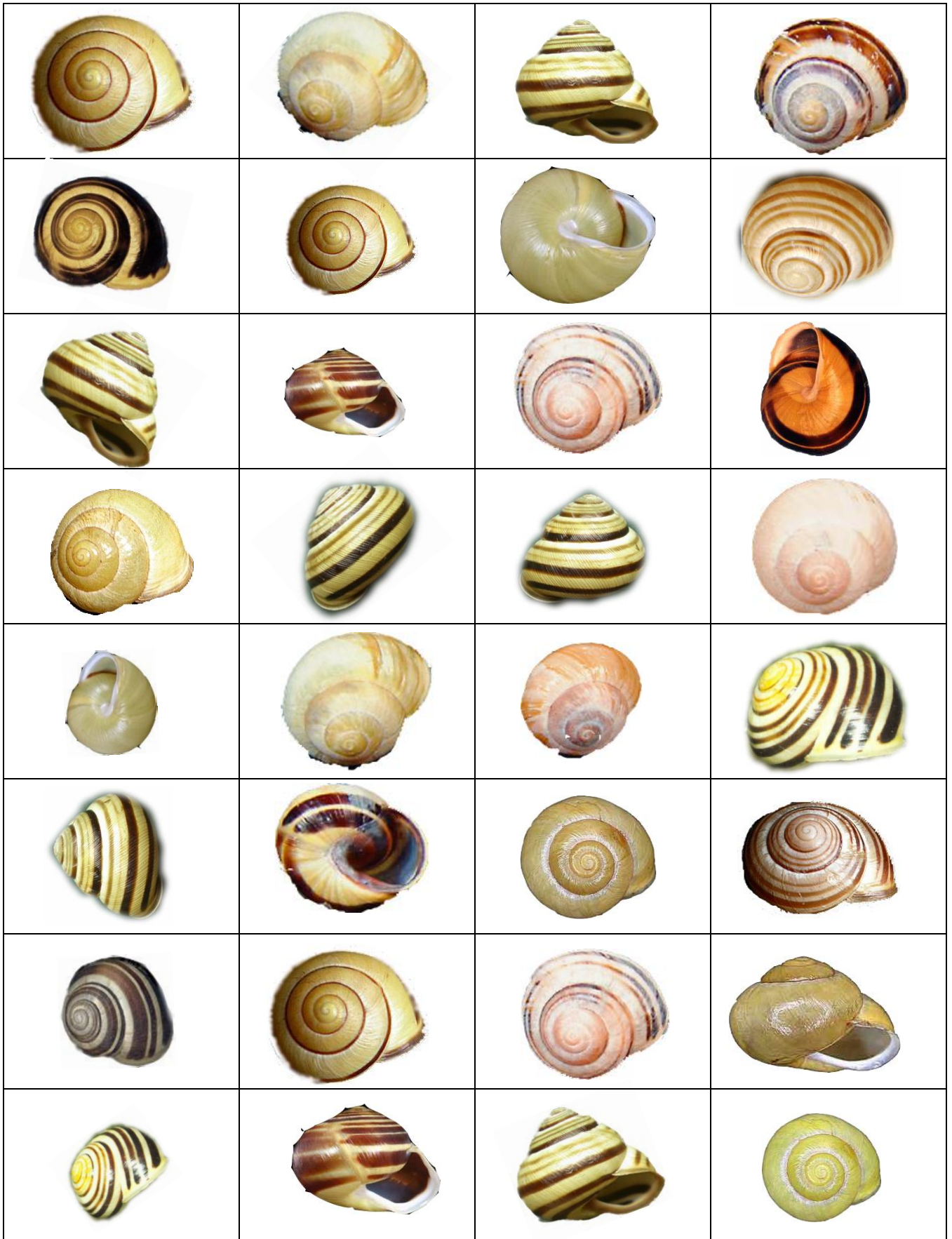


Woodland snails 3





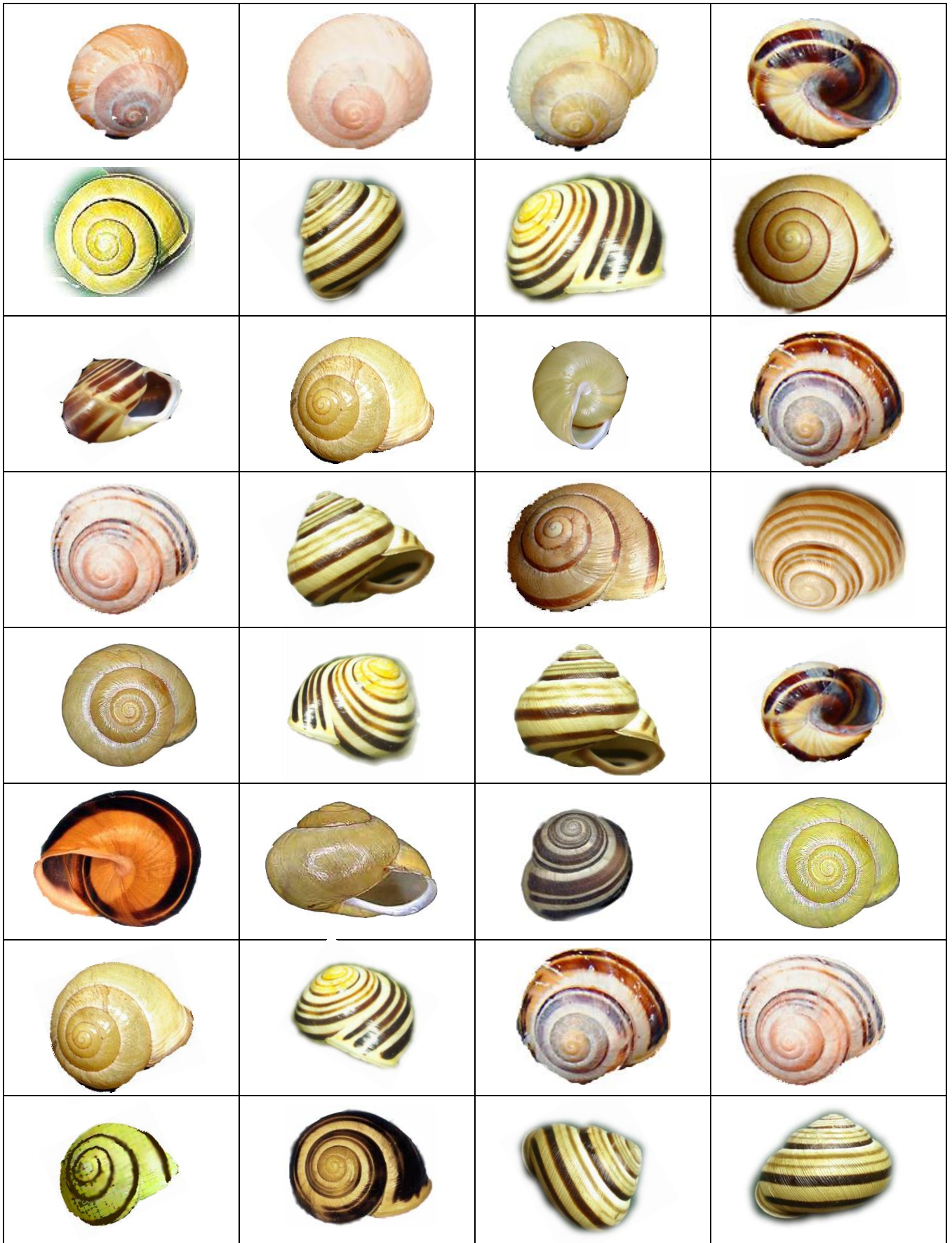
Grassland snails 1



Grassland snails 2



Grassland snails 3



## 4.5 RESPONSE AND REGULATION

Spec Statement		Comment
(a)	sense organs as groups of receptor cells which respond to specific stimuli: light, sound, touch, temperature, chemicals and then relay this information as electrical impulses along neurones to the central nervous system	
(b)	the brain, spinal cord and nerves forming the nervous system; the central nervous system consisting of the brain and spinal cord	
(c)	the properties of reflex actions: fast, automatic and some are protective, as exemplified by the withdrawal reflex, blinking and pupil size	
(d)	<b>the components of a reflex arc: stimulus, receptor, coordinator and effector; be able to label a diagram of a reflex arc to show: receptor, sensory neurone, relay neurone in spinal cord, motor neurone, effector and synapses</b>	<b>Candidates need to be able to indicate, on a diagram of a reflex arc, the direction of travel of the impulse.</b>
(e)	the reasons why animals need to regulate the conditions inside their bodies to keep them relatively constant and protected from harmful effects – homeostasis	Metabolism operates only within a narrow range of temperature and pH and requires appropriate nutrients and water.
(f)	hormones as chemical messengers, carried by the blood, which control many body functions	
(g)	the need to keep glucose levels within a constant range, so that when the blood glucose level rises, the pancreas releases the hormone insulin, a protein, into the blood, which causes the liver to reduce the glucose level by converting glucose to insoluble glycogen and then storing it	

(h)	diabetes as a common disease in which a person has a high blood glucose level; type 1 diabetes caused by the body not producing insulin; type 2 diabetes caused by the body cells not properly responding to the insulin that is produced; the causes of both types of diabetes; treatments for diabetes	The detection of glucose in urine is a symptom of diabetes. Candidates should test artificially prepared urine samples for the presence of glucose using Benedict's solution. The methods of treating diabetes include regularly injecting insulin, a low sugar and low carbohydrate diet and possible transplant of pancreatic tissue.
(i)	the structure of a section through the skin: hair, erector muscle, sweat gland, sweat duct, sweat pore, blood vessels; be able to label these structures on a diagram	
(j)	the role of these structures in temperature regulation: change in diameter of blood vessels, sweating, erection of hairs; shivering as a means of generating heat	
(k)	<b>the principles of negative feedback mechanisms to maintain optimum conditions inside the body as illustrated by the control of glucose levels by insulin and glucagon and by the control of body temperature</b>	<b>Any change from the balance in optimal internal conditions results in the body's hormonal and nervous systems compensating for the change and restoring the balance.</b>
(l)	the fact that some conditions are affected by lifestyle choices; the effects that alcohol and drug abuse have on the chemical processes in people's bodies; the incidence of diabetes (type 2) and the possible relationship with lifestyle	Alcohol changes various chemical processes in the body including reaction time. It may cause people to become dependent on, addicted to and suffer withdrawal symptoms without it. It can also cause long-term physical damage e.g. liver, circulatory and heart diseases. Some drugs are misused e.g. illegal drugs and these drugs affect people's bodies. The link between obesity and type 2 diabetes.

### SPECIFIED PRACTICAL WORK

- Investigation into factors affecting reaction time

## Investigation into factors affecting reaction time

### Introduction

If you notice a ball moving towards your head, the time it takes from when you first notice the ball to when your arm reaches up to catch it is an example of reaction time. Even though nervous impulses travel very quickly through your nervous system, your body doesn't react instantly. In this activity, you will conduct a simple, measurable experiment to study reaction time and investigate the hypothesis that reaction time improves with practice.

### Apparatus

30 cm ruler

### Diagram of Apparatus



## Method

1. Ask your first volunteer to sit in the chair with good upright posture and eyes looking across the room.
2. Have the volunteer place their forearm (the part of the arm from elbow to hand) so it extends over the edge of the table.
3. Ask the volunteer to place their thumb and index (pointer) finger on either side of the bottom of the vertically placed ruler. The number “1” should be on the bottom, the “30” near the top.
4. Let your volunteer practice holding the ruler with those two fingers.
5. Now, ask your volunteer to remove their fingers from the ruler while you continue to hold it so that the bottom of the ruler is at a height of 2 cm above the fingers.
6. Tell your volunteer that you will release the ruler without warning. Their job will be to catch it with their thumb and forefinger as soon as they sense it dropping.
7. Drop the ruler. When your volunteer catches it, record the number on the ruler displayed just over the thumb. The lower the number, the faster the reaction time.
8. Conduct five trials with the same volunteer, dropping the ruler from 2 cm above their fingers each time.
9. Repeat the experiment with at least five other volunteers and record your results in a suitable table

## Analysis

1. Use the conversion table below to convert the distance measured to a reaction time for each volunteer

Catch distance (cm)	Reaction time (milliseconds)	Catch distance (cm)	Reaction time (milliseconds)
1	50	16	180
2	60	17	190
3	70	18	190
4	80	19	200
5	90	20	200
6	100	21	210
7	120	22	210
8	130	23	220
9	140	24	220
10	140	25	230
11	150	26	230
12	160	27	230
13	160	28	240
14	170	29	240
15	170	30	250

2. Discuss the extent to which your results support the hypothesis.

Teacher / Technician notes

A possible alternative activity could be to compare the volunteer's dominant hand with their non-dominant hand.

Students should design their own table, but a suggested table format is shown below.

Volunteer	Trial 1		Trial 2 etc	
	Distance (cm)	Reaction time (ms)	Distance (cm)	Reaction time (ms)

Working scientifically skills covered

**2. Experimental skills and strategies**

Use scientific theories and explanations to develop hypotheses

Evaluate methods and suggest possible improvements and further investigations.

**3. Analysis and Evaluation**

Translate data from one form to another.

Interpret observations and other data, including patterns and trends, making inferences and drawing conclusions.

Present reasoned explanations including relating data to hypotheses.

Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.



## 4.6 DISEASE, DEFENCE AND TREATMENT

Spec Statement		Comment
(a)	the harmless nature of most micro-organisms, many performing vital functions; some micro-organisms called pathogens, cause disease	
(b)	the fact that pathogens include micro-organisms such as bacteria, viruses, protists and fungi; the basic structure of a bacterial cell and virus	Bacterial cells consist of a cell wall, cell membrane and cytoplasm, no distinct nucleus. Viruses consist of a number of genes surrounded by a protein coat.
(c)	the types of organisms which can cause communicable diseases: viruses, bacteria and fungi; the means by which they can be spread: by contact, aerosol, body fluids, water, insects, contaminated food	
(d)	the means by which the body defends itself from disease: intact skin forming a barrier against micro-organisms; blood clots to seal wounds; phagocytes in the blood ingesting micro-organisms; lymphocytes producing antibodies and antitoxins	<p>Blood clots seal wounds to prevent entry of microbes. White cells in the blood help to defend the body against microbes by</p> <ul style="list-style-type: none"> <li>• ingesting bacteria</li> <li>• producing antibodies which inactivate particular bacteria or viruses</li> <li>• producing antitoxins which counteract the toxins released by bacteria.</li> </ul> <p>The community of microorganisms on the skin, the skin flora, make it difficult for pathogens to become established.</p>
(e)	an antigen as a molecule that is recognised by the immune system; foreign antigens triggering a response by lymphocytes, which secrete antibodies specific to the antigens; the function of antibodies	One type of white blood cell, called a lymphocyte, multiplies to form clones of cells. These secrete antibodies specific to the foreign antigen that is present. Antibodies eventually assist in the destruction of the cells bearing the foreign antigen.

(f)	<p>how vaccination can be used to protect humans from infectious disease; the factors influencing parents in decisions about whether to have children vaccinated or not</p>	<p>Candidates should consider the consequences for individuals and society of when individuals decide not to be vaccinated. There should be an awareness of the influence of the media.</p>
(g)	<p><b>the fact that a vaccine contains antigens derived from a disease-causing organism; how a vaccine will protect against infection by that organism, by stimulating the lymphocytes to produce antibodies to that antigen; how vaccines may be produced which protect against bacteria and viruses</b></p>	<p>Vaccines generally use ‘non-active’ microorganisms, antigens or parts of antigens to stimulate an immune response (the details of individual vaccines and the detail of vaccine production are not required).</p>
(h)	<p><b>how after an antigen has been encountered, memory cells remain in the body and antibodies are produced very quickly if the same antigen is encountered a second time; how this memory provides immunity following a natural infection and after vaccination; the highly specific nature of this response</b></p>	<p><b>The specific response is relatively slow if the body has not previously encountered the relevant antigen. However, antibodies are produced very quickly and in large numbers if the same antigen is encountered a second time.</b></p>
(i)	<p>the fact that antibiotics, including penicillin, were originally medicines produced by living organisms, such as fungi; how antibiotics help to cure bacterial disease by killing the infecting bacteria or preventing their growth but do not kill viruses</p>	<p>Antibiotics are now often chemically modified and so are semi-synthetic or synthetic.</p>
(j)	<p>how some resistant bacteria, such as MRSA, can result from the over use of antibiotics; effective control measures for MRSA</p>	<p>Some bacteria have become resistant to antibiotics. The use of antibiotics in animal feed, in some countries, could be discussed as well as over-prescription for humans.</p> <p>MRSA control measures could include:</p> <ul style="list-style-type: none"> <li>• hand washing</li> <li>• thorough cleaning of hospital wards</li> <li>• use of alcohol gels</li> </ul> <p>MRSA screening</p>

(k)	<p>how some conditions can be prevented by treatment with drugs or by other therapies</p>	<p>An understanding that some conditions can be prevented by good hygiene, clean water, improved diet, and vaccination. Some can be treated by drugs such as antibiotics. (No detail of individual diseases is required)</p>
(l)	<p>how new drug treatments may have side effects and that extensive, large scale, rigorous testing is required; the associated risks, benefits and ethical issues involved in the development of new drug treatments, including the use of animals for testing drugs and whether this is superseded by new technologies</p>	<p>All drugs may have side effects. New drugs, including medicinal drugs, may cause side effects that do not show up until lots of people use them.</p>

## UNIT 5 – CHEMISTRY 2

### 5.1 BONDING, STRUCTURE AND PROPERTIES

	Spec Statement	Comment
(a)	the properties of metals, ionic compounds, simple molecular covalent substances and giant covalent substances	Candidates should know the general properties of each of these substance types including, for example, qualitative descriptions of melting/boiling points, conductivity and solubility in water.
(b)	the 'sea' of electrons/lattice of positive ions structural model for metals in explaining their physical properties	Candidates should use this model to explain why, in general, metals have high melting/boiling points, are good conductors of heat and electricity and are malleable and ductile. <b>Higher tier candidates would also be expected to explain the trend in melting points of sodium, magnesium and aluminium, for example.</b>
(c)	electronic structure in explaining how ionic bonding takes place (and how this is represented using dot and cross diagrams)	Questions involving dot and cross diagrams are familiar to all and nothing new is expected here. It should be emphasised to candidates that the dot/cross notation should be used to ensure that it is completely clear which electrons have been transferred in forming ions and that no electrons should appear to be in two places at once.
(d)	the accepted structural model for giant ionic structures in explaining the physical properties of ionic compounds	Candidates should use this model to explain why ionic compounds have high melting/boiling points, are soluble in water and conduct electricity when dissolved or in molten form. <b>Higher tier candidates would also be expected to explain the difference in melting/boiling points of sodium chloride and magnesium oxide, for example, in terms of the greater charges giving rise to greater attraction/stronger ionic bonds.</b>
(e)	electronic structure in explaining how covalent bonds are formed (and how this is represented using dot and cross diagrams)	These too are familiar diagrams and the point regarding use of the dot/cross notation to show from which atom a given electron has come should again be emphasised. <b>Higher tier candidates would also be expected to draw diagrams for molecules that contain double or triple bonds.</b>
(f)	the intermolecular bonding structural model for simple molecular structures in explaining the physical properties of simple molecular substances	Candidates should use this model to explain why simple molecular substances have low melting/boiling points and do not conduct electricity, even in molten form.

<p>(g)</p>	<p>the properties of diamond, graphite, fullerenes, carbon nano-tubes and graphene and how these are explained in terms of structure and bonding</p>	<p>Candidates should recognise each of these as giant structures containing covalent bonds. Candidates should recognise that the very high melting points of diamond and graphite are a result of the strong covalent bonding present. Their differing hardness, brittleness, lubricating and conducting properties are a result of each carbon atom in diamond being strongly bonded to four others whilst each one in graphite forms only three strong bonds. Candidates should explain these differences in terms of the graphite carbon atoms' fourth 'delocalised' or 'free' electron. Candidates should also know that fullerenes are cage structures made entirely of carbon atoms.</p> <p><b>Buckminsterfullerene</b> is the most widely-known fullerene. Its molecules are spherical and contain 60 carbon atoms. Research into the use of fullerenes as drug delivery systems in the body, in lubricants and as catalysts is on-going. Candidates should know that carbon nano-tubes have important properties – conductors/semi-conductors, high strength but very low density – and explain these in terms of free electrons, bond strength. Carbon nano-tubes are made from single layers from a graphite structure, known as graphene layers, rolled into tubes. It should be noted that carbon nano-tubes have a much smaller scale structure than carbon fibres and are <u>not</u> what is used in the manufacture of bikes and tennis rackets. Graphene has been shown to be the strongest material ever tested and also the best electrical conductor but although claims have been made that it will transform technology in the future, there are as yet no commercially available 'graphene products'.</p>
<p>(h)</p>	<p>individual atoms not having the same properties as bulk materials as demonstrated by diamond, graphite, fullerenes, carbon nano-tubes and graphene having different properties despite all containing only carbon atoms, and by nano-scale silver particles exhibiting properties not seen in bulk silver</p>	

(i)	the properties and uses of nano-scale particles of silver and titanium dioxide	Candidates should know that nano-sized silver particles are antibacterial, antiviral and antifungal and that they are used in plasters, antiseptic sprays, refrigerator linings, socks, deodorant sprays and so on. Nano-sized titanium dioxide particles are used in some sun screens as they absorb and reflect UV light but are also transparent so more appealing to consumers. Self-cleaning glass is coated with nano-scale titanium dioxide particles. These catalyse the breakdown of dirt in the presence of UV light and also cause water to spread out in a thin film, rather than forming droplets on the surface. The combined effort of sunshine and rainwater cleans the windows!
(j)	<b>the possible risks associated with the use of nano-scale particles of silver and titanium dioxide, and of potential future developments in nanoscience</b>	<b>Candidates should appreciate that nanomaterials currently used have been tested to ensure that they cause no damage to individuals or the environment, but that their long-term effects are as yet unknown. Some people have expressed concern that nano-scale silver (deodorants) and titanium dioxide (sun screens) are applied to the skin and can therefore be easily absorbed into the body. While it has been shown that these uses are safe in the short term, there is no certainty that exposure over many years will not result in problems.</b>
(k)	the properties and uses of smart materials including thermochromic pigments, photochromic pigments, polymer gels, shape memory alloys and shape memory polymers	<p>Candidates must show an understanding that these materials have <i>properties that change</i> when a <i>change occurs in their environment</i> <u>and</u> that this change is <i>reversible</i>.</p> <p>They should know that the following smart materials change as follows.</p> <ul style="list-style-type: none"> <li>• Thermochromic pigments – change colour with changing temperature</li> <li>• Photochromic pigments – change colour with changing light intensity</li> <li>• Polymer gels e.g. hydrogels – absorb/expel water and swell/shrink (up to 1000 times their volume) due to changes in pH or temperature</li> <li>• Shape memory alloys – regain original shape when heated</li> <li>• Shape memory polymers – regain original shape when heated</li> </ul> <p>In relating the use of a smart material to its properties, the emphasis here should be the ability to identify situations where the properties of particular smart materials may be desirable, rather than the recall of a specific number of uses.</p>

## 5.2 ACIDS, BASES AND SALTS

Spec Statement		Comment
(a)	substances as acidic, alkaline or neutral in terms of the pH scale, including acid/alkali strength	Candidates should understand that acids and alkalis can be classified as being either strong or weak and how universal indicator and the pH scale are used to for this purpose. They should recall the colours, approximate pH values and associated acid/alkali strength e.g. orange > pH ~3/4 > weak acid.
(b)	solutions of acids containing hydrogen ions and alkalis containing hydroxide ions	Candidates should know that acids are a source of H <sup>+</sup> ions whereas alkalis are a source of OH <sup>-</sup> ions.
(c)	the reactions of dilute acids with metals and how these relate to the metals' position in the reactivity series	<p>Candidates should know that when an acid reacts with a metal, a solution of the metal salt and hydrogen gas are produced. They should explain the reactions of metals with acids in terms of their position in the reactivity series, in relation to hydrogen. This section can be linked to topic 5.3(b) in which the reactivity series is used in relation to displacement reactions and metal extraction. Candidates should be able to describe in detail how crystals of soluble salts, such as zinc sulfate, can be prepared by the reaction of metals and acids.</p> <p>In common with <u>all</u> specified reactions, candidates should be able to name products and write word and balanced symbol equations describing those reactions.</p>
(d)	the neutralisation of dilute acids with bases (including alkalis) and carbonates	Candidates should know that metal oxides and metal hydroxides are known as bases and that an alkali is a soluble base. They should know that the reactions of acids with bases always produce a metal salt and water and that acids and carbonates produce carbon dioxide gas in addition to a salt and water. They should know that neutralisation reactions are exothermic and that effervescence (fizzing) is observed when an acid reacts with a carbonate.
(e)	<p>neutralisation as the reaction of hydrogen ions with hydroxide ions to form water</p> $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$	<b>Candidates should understand that neutralisation reactions can be summarised by this ionic equation.</b>

(f)	the acid/carbonate reaction as a test for acidic substances and $\text{CO}_3^{2-}$ ions	Effervescence (fizzing) is observed when an acid reacts with a carbonate. Note that 'carbon dioxide formed' is <u>not</u> an observation.
(g)	the preparation of crystals of soluble salts, such as copper(II) sulfate, from insoluble bases and carbonates	Candidates should know the method used to prepare crystals of soluble salts from the reaction of acids with insoluble bases and carbonates: <ul style="list-style-type: none"> <li>• excess base/carbonate to use up all acid;</li> <li>• filtration to remove excess base;</li> <li>• evaporation of water to form crystals.</li> </ul> They should know that small crystals can be formed quickly by heating to evaporate until about $\frac{1}{3}$ of the solution remains and leaving to cool. Allowing the filtered solution to evaporate slowly over a period of days results in the formation of larger crystals.
(h)	the names of the salts formed by hydrochloric acid, nitric acid and sulfuric acid	
(i)	the test used to identify $\text{SO}_4^{2-}$ ions	White precipitate forms when barium chloride solution is added to a solution containing sulfate ions. The ionic equation is also required.
(j)	titration as a method to prepare solutions of soluble salts and to determine relative concentrations of solutions of acids/alkalis	Candidates should know the method used to prepare crystals of soluble salts from the reaction of acids with alkalis: <ul style="list-style-type: none"> <li>• indicator and fixed volume of acid/alkali in flask;</li> <li>• exact volume of alkali/acid needed for neutralisation is measured and recorded;</li> <li>• same fixed volume of acid/alkali in clean flask and exact volume of alkali/acid needed for neutralisation is added but with <u>no</u> indicator;</li> <li>• evaporation of water to form crystals.</li> </ul> All candidates should be able to compare relative concentrations of acid/alkali on the basis that if, for example, $25\text{cm}^3$ of NaOH requires $30\text{cm}^3$ of HCl to neutralise it, the alkali must be of higher concentration than the acid.

### SPECIFIED PRACTICAL WORK

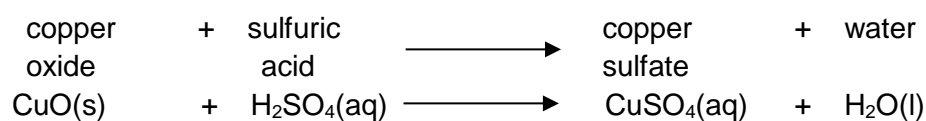
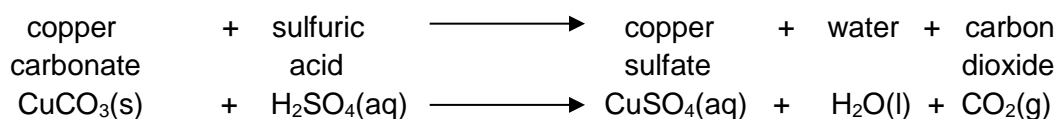
- Preparation of crystals of a soluble salt from an insoluble base or carbonate
- Titration of a strong acid against a strong base using an indicator



## Preparation of crystals of a soluble salt from an insoluble base or carbonate

### Introduction

In this experiment you will make crystals of copper sulfate. This can be done using either copper carbonate or copper oxide.



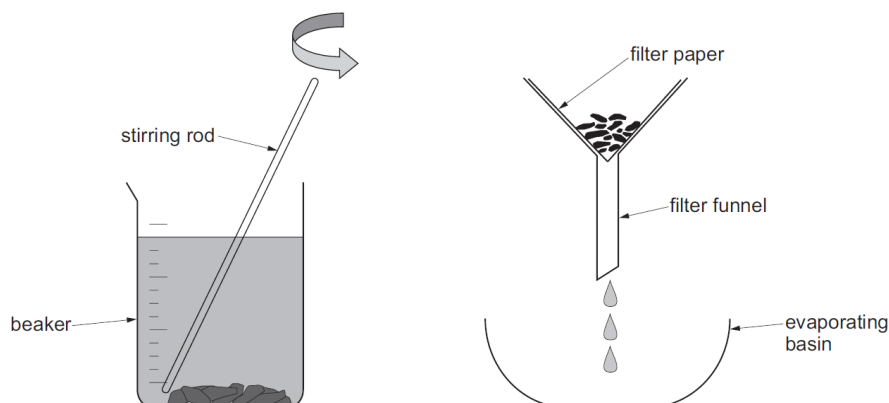
### Apparatus

100 cm<sup>3</sup> beaker  
 stirring rod  
 filter funnel and paper  
 evaporating basin  
 50 cm<sup>3</sup> measuring cylinder  
 0.5 mol/dm<sup>3</sup> H<sub>2</sub>SO<sub>4</sub>  
 copper(II) oxide or copper carbonate  
 spatula  
 indicator paper

#### Access to:

electronic balance  $\pm 0.1$  g

## Diagram of Apparatus



## Method

1. Measure 50 cm<sup>3</sup> of sulfuric acid and pour into the beaker.
2. Measure approximately 4g copper (II) oxide **or** 5g copper(II) carbonate. (This does not need to be precise as the solid will be in excess.)
3. Add the solid to the acid and stir thoroughly.
4. To ensure all the acid has reacted, touch the glass rod onto a piece of indicator paper. If it is acidic continue stirring.
5. If the solution is neutral, pour the mixture into the filtration apparatus above the evaporating basin.
6. Allow to evaporate for several days until dry.

## Teacher / Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Sulfuric acid is an irritant	Splashing onto hand/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Copper sulfate is a harmful irritant	Splashing on to hand/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear protection
Hot apparatus can burn	Contact with skin will cause burns when handling/touching/moving apparatus	Leave apparatus to cool before moving.

Reagents:

- Copper(II) oxide - Refer to CLEAPSS hazard card 26
- Copper(II) carbonate - Refer to CLEAPSS hazard card 26
- Sulfuric acid [0.5 mol/dm<sup>3</sup>] - Refer to CLEAPSS hazard card 98A
- Copper sulfate solution - Refer to CLEAPSS hazard card 26

50 cm<sup>3</sup> of copper sulfate solution requires medium to large evaporating basins. Quantities can be reduced to suit available equipment. However it is vital that the solid is always in excess.

It can be emphasised that the reason for adding the insoluble base in excess is to ensure all of the acid has reacted and that a pure sample of the salt can thus be obtained.

At method point 6, it is possible to heat the evaporating basin to reduce the volume of copper sulfate solution by approximately a third using a Bunsen burner. This will reduce the time needed to reach dryness.

There is also scope for extension work – the mass of the base added could be weighed accurately and recorded. The mass of excess could then be obtained and thus the number of moles of copper sulfate produced could be calculated.

## Working scientifically skills covered

### 2. Experimental skills and strategies

Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

Apply a knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to the experiment.

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

## Titration of a strong acid against a strong base using an indicator

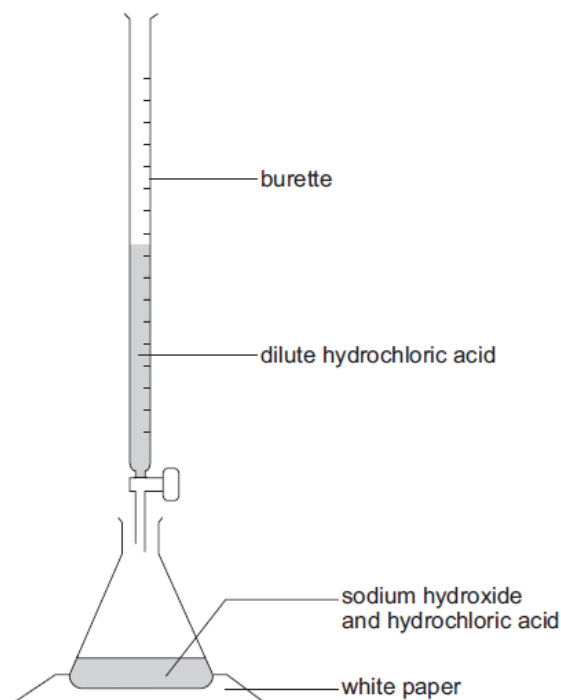
### Introduction

In this experiment sodium hydroxide is neutralised with hydrochloric acid to produce the soluble salt, sodium chloride in solution. An indicator is used to show when neutralisation has occurred. The solution could then be concentrated and crystallised to produce sodium chloride crystals.

### Apparatus

burette  
 measuring cylinder  
 100cm<sup>3</sup> conical flask  
 small filter funnel  
 white paper  
 dilute sodium hydroxide  
 dilute hydrochloric acid  
 indicator  
 clamp stand, boss and clamp or burette stand

### Diagram of Apparatus



## Method

1. Use the small funnel to fill the burette with acid. Run a little acid out into a waste beaker to fill the part of the burette that is below the tap. Record the starting volume of acid in the burette.
2. Accurately measure  $25\text{ cm}^3$  of sodium hydroxide solution into a conical flask.
3. Add 2 drops of indicator.
4. Add  $0.1\text{ cm}^3$  of acid at a time, swirl the flask after each acid addition. Keep adding acid until the indicator changes colour. Record the final volume of acid in the burette.
5. Repeat steps 1-4 twice more.

## Analysis

1. Calculate the volume of acid that was needed to neutralise the alkali in each repeat.
2. Calculate the mean volume of dilute hydrochloric acid needed to neutralise  $25\text{ cm}^3$  sodium hydroxide solution.
3. What do your results tell you about the concentration of the alkali?

## Teacher / Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Sodium hydroxide is an irritant	Sodium hydroxide spilling onto hands when filling burette or measuring volume of liquids	Wear gloves Wash hands immediately after contact with solutions
	Sodium hydroxide splashing into eyes when filling burette	Wear eye protection

### Reagents:

- Hydrochloric acid – Refer to CLEAPSS hazcard 47A
- Sodium hydroxide – Refer to CLEAPSS hazcard 31

Sodium hydroxide and hydrochloric acid solutions do not need to be made up to a high degree of accuracy, but should be reasonably close to the same concentration and less than  $0.5\text{ mol/dm}^3$ .

Burette stands and clamps are designed to prevent crushing of the burette by over-tightening, which may happen if standard jaw clamps are used.

A white tile can be used to go under the titration flask, instead of white paper.

Students need training in using burettes correctly, including how to clamp them securely and fill them safely. You should consider demonstrating burette technique, and give students the opportunity to practise this. Students do not need the acid volume to start on 0 in the burette, but must ensure that the reading is not above zero.

In this experiment a pipette is not essential and measuring cylinder is acceptable. However, a pipette and filler could be used to increase accuracy if desired.

There is an opportunity here with more able students to do quantitative measurements leading to calculations but the primary aim is to introduce students to the titration technique to produce a neutral solution.

Indicators you can use include screened methyl orange (green in alkali, violet in acid) and phenolphthalein (pink in alkali, colourless in acid).

At the end of the experiment the solution can be left to crystallise slowly in a warm room to produce large crystals or heated to half the volume of solution with a Bunsen burner and allowed to cool.

Students should design their own table, but a suggested table format is shown below.

	Trial			Mean
	1	2	3	
Final volume of acid in burette (cm <sup>3</sup> )				
Initial volume of acid in burette (cm <sup>3</sup> )				
Titre (volume added) (cm <sup>3</sup> )				

## Working scientifically skills covered

### 2. Experimental skills and strategies

Apply a knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to the experiment.

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Make and record observations and measurements using a range of apparatus and methods.

**3. Analysis and Evaluation**

Translate data from one form to another.

Carry out and representing mathematical analysis.

**4. Scientific vocabulary, quantities, units, symbols and nomenclature**

**Use an appropriate number of significant figures in calculation.**

### 5.3 METALS AND THEIR EXTRACTION

	Spec Statement	Comment
(a)	ores found in the Earth's crust as the source of most metals and that these metals can be extracted using chemical reactions	Candidates should know that ores are minerals found in the Earth's crust and that they contain metal compounds, from which these metals can be extracted. They should be able to identify metals present in given ores from their chemical formulae.
(b)	some unreactive metals (e.g. gold) being found in their native form and that the difficulty involved in extracting metals increases as their reactivity increases	Gold and silver are examples of metals that are found native. Candidates should know that the most reactive metals are extracted by electrolysis while those towards the middle of the reactivity series can be chemically reduced. They may be required to use information such as, "X is more/less reactive than carbon..." to suggest a method of extraction for any metal. There is a link here with topic 5.2(c) where candidates may have to use information such as, "X is more/less reactive than hydrogen..." to suggest whether or not a metal will react with dilute acid. Candidates should have an awareness of the approximate position of common metals (and carbon and hydrogen) in the reactivity series but detailed recall is <u>not</u> required.
(c)	the relative reactivities of metals as demonstrated by displacement (e.g. iron nail in copper(II) chloride solution) and competition reactions (e.g. thermit reaction)	The emphasis is on the understanding of the processes and not on recall of colours of elements, compounds or solutions, although information of this nature these may be given in a question.
(d)	reduction and oxidation in terms of removal or gain of oxygen	Candidates should be able to recognise loss or gain of oxygen in any given reaction. They should be precise in their descriptions e.g. iron(III) oxide – <u>not</u> iron – is reduced in the blast furnace.
(e)	the industrial extraction of iron in the blast furnace, including the combustion, reduction, decomposition and neutralisation reactions	Candidates are expected to name each of the raw materials are added to the furnace and to explain why they are needed: <ul style="list-style-type: none"> <li>• Iron ore – source of iron</li> <li>• Coke – as a fuel and to produce carbon monoxide for the reduction</li> <li>• Limestone – to remove impurities (slag formation when limestone breaks down and reacts with sand from the rocks)</li> <li>• Hot air – provides oxygen so that coke can burn</li> </ul>



		<p>Candidates should be able to write word and balanced symbol equations for the combustion of carbon, reduction of iron(III) oxide by carbon monoxide, decomposition of calcium carbonate and the neutralisation reaction between calcium oxide and silicon dioxide.</p> <p>Candidates should have an understanding that the process is continuous with new raw materials added and products removed all the time due to the time and cost associated with getting the furnace up to temperature.</p>
(f)	electrolysis of molten ionic compounds e.g. lead(II) bromide (including electrode equations)	<p>Candidates should know that for electrolysis to proceed, compounds must be melted to release their ions. They should explain electrolysis in terms of positive ions moving towards the cathode where they gain electrons (are reduced) and negative ions moving towards the anode where they lose electrons (are oxidised). Candidates should be able to write balanced equations for the processes taking place at the electrodes.</p>
(g)	reduction and oxidation in terms of gain or loss of electrons	<p>Candidates should be able to recognise gain or loss of electrons in any given reaction e.g. <math>\text{Pb}^{2+}</math> ions are reduced during the electrolysis of lead(II) bromide because they gain electrons to form Pb atoms; <math>\text{Br}^-</math> ions are oxidised because they lose electrons. Defining reduction and oxidation in terms of electrons is useful when reactions do not involve oxygen.</p>
(h)	the industrial extraction of aluminium using electrolysis, including the use of cryolite to dissolve alumina	<p>Candidates should know that alumina (aluminium oxide) dissolves in molten cryolite at a temperature much lower than its melting point, therefore saving energy. They should be able to write balanced equations for the processes occurring at the anode and cathode.</p> $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$ $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$ <p>They should also understand that the oxygen formed reacts with the carbon anodes, forming carbon dioxide gas and requiring these to be replaced frequently.</p>

(i)	the properties and uses of iron (steel), aluminium, copper and titanium	<p>Candidates are expected to recall some common uses of steel, aluminium, copper and titanium and explain these uses in terms of the following properties:</p> <ul style="list-style-type: none"> <li>• steel – hard, strong</li> <li>• aluminium – strong, low density, good conductor of heat and electricity, resistant to corrosion</li> <li>• copper – very good conductor of heat and electricity, malleable and ductile, attractive colour and lustre</li> <li>• titanium – hard, strong, low density, resistant to corrosion, high melting point.</li> </ul>
(j)	the general properties of transition metals, including their ability to form ions with different charges	<p>Candidates should know that the transition metals are found in the centre of the Periodic Table and that they display the typical metallic properties of high melting and boiling points, malleability, high density, good electrical and thermal conductivity. They have a number of other properties. Many transition metals are useful catalysts (e.g. iron in the manufacture of ammonia, platinum in catalytic converters). They can form more than one type of ion e.g. <math>\text{Fe}^{2+}/\text{Fe}^{3+}</math> and their compounds are often coloured.</p> <p><b>Higher tier candidates should know the characteristic colours of compounds containing the following ions:</b></p> <p><b><math>\text{Fe}^{2+}</math> – pale green</b>  <b><math>\text{Fe}^{3+}</math> – brown</b>  <b><math>\text{Cu}^{2+}</math> – blue</b></p>
(k)	an alloy being a mixture made by mixing molten metals, whose properties can be modified by changing its composition	<p>Candidates should know that steel is much harder and stronger than iron and is therefore more useful. Different types of steel are made by varying the carbon content and by adding other metals but candidates are not required to recall the names, compositions or properties of any other alloys.</p>

(i)	<p>factors affecting economic viability and sustainability of extraction processes e.g. siting of plants, fuel and energy costs, greenhouse emissions and recycling</p>	<p>Candidates should be aware that the primary reason for siting plants near to the coast is for the importing of raw materials and <u>not</u> the export of products.</p> <p>Other factors that affect the siting of plants include:</p> <ul style="list-style-type: none"> <li>• A site away from built up areas;</li> <li>• A town or city within commuting distance to accommodate the workforce;</li> <li>• Good transport links for transporting the product to buyers;</li> <li>• A direct electricity supply (a power station close by) in the case of aluminium.</li> </ul> <p>The energy costs associated with aluminium production are very high and when Wylfa Power Station was decommissioned, Anglesey Aluminium closed. When it was running the plant accounted for around 10-15% of all the electricity used in Wales. Without a power station close by, guaranteeing the direct supply of electricity, this became unsustainable and the plant closed. Candidates should be aware that although all the raw materials for iron extraction can be found in Wales and that Wales has a long history of iron and steel production, the plant at Port Talbot imports iron ore, coal to make coke and limestone from other countries. Using raw materials from Wales is not sustainable on an economic (cost) or environmental (quarrying) basis.</p> <p>Candidates should appreciate that recycling metals is more sustainable as it conserves the raw materials and uses much less energy. Recycling aluminium requires approximately 5% of the energy used to extract the metal from bauxite. The reduction in energy for recycling means that less electricity is needed and so there are smaller associated greenhouse emissions.</p>
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### SPECIFIED PRACTICAL WORK

- Determination of relative reactivities of metals through displacement reactions

## Determination of relative reactivities of metals through displacement reactions

### Introduction

Some metals are more reactive than others. In this experiment, a piece of metal is added to a solution of a compound of another metal. A more reactive metal displaces a less reactive metal from its compound. By carrying out this experiment, you will be investigating the competition reactions of metals and produce a reactivity series of the metals.

### Apparatus

dimple tray

100 cm<sup>3</sup> beaker

4 × dropping pipettes

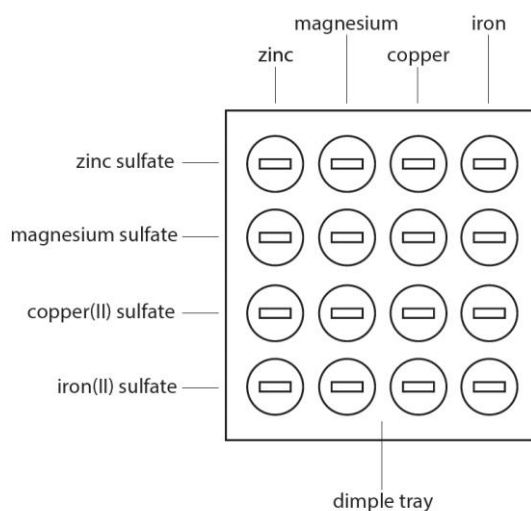
5 cm<sup>3</sup> of each of the following at 0.1 mol/dm<sup>3</sup>

- zinc sulfate
- magnesium sulfate
- copper(II) sulfate
- iron(II) sulfate

Approximately 1 cm length/square sample of the following metals.

- zinc
- magnesium
- copper
- iron

### Diagram of Apparatus



## Method

1. Using a dropping pipette, put a little zinc sulfate in four of the depressions of the dropping tile. Do this for each solution in turn. Do not overfill dimples.
2. Put a piece of metal in each of the solutions, using the apparatus diagram as a guide.
3. Observe and record the changes in the solutions or metal samples.

## Analysis

1. Use your results to construct a reactivity series for the metals used. Write equations for any reactions that occurred.

## Teacher / Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Zinc and copper sulfate are irritants	Splashing onto hand/skin/you whilst pouring  Transfer from hand into eye	Wear eye protection  Wash hands when solutions spilt on to hands

### Reagents

- Zinc sulfate - Refer to CLEAPSS hazcard 108
- Magnesium sulfate - Refer to CLEAPSS hazcard 59B
- Copper(II) sulfate - Refer to CLEAPSS hazcard 27B
- Iron(II) sulfate - Refer to CLEAPSS hazcard 38
- Zinc foil - Refer to CLEAPSS hazcard 107
- Magnesium ribbon - Refer to CLEAPSS hazcard 59A
- Copper foil - Refer to CLEAPSS hazcard 26
- Iron(II) sulfate - Refer to CLEAPSS hazcard 38

Solutions may be dispensed in small beakers to each group of students or in small dropper bottles.

Students may need two dimple trays per group, if trays do not contain 16 dimples.

Metals should be approximately 1 cm lengths/squares of ribbon or foil cleaned with an emery cloth and as similar in size as possible.

Students will need to record which metals react with the solutions. A table may be useful. Use a  $\checkmark$  to show reactivity and a  $\times$  to show no reaction. The metals with the most ticks are the most reactive.

Students should design their own table, but a suggested table format is shown below.

	Zinc	Magnesium	Copper	Iron
Zinc sulfate				
Magnesium sulfate				
Copper(II) sulfate				
Iron(II) sulfate				

You can point out to students that there is no need to carry out the zinc/zinc sulfate, magnesium/magnesium sulfate reactions, etc or allow them to decide for themselves if these reactions are likely to lead to a positive result.

Remind students that they are looking for metal displacement, some solutions are slightly acidic so bubbles of hydrogen can be seen. Explain that this doesn't count as displacement. Students may need to be given guidance of the sort of observations they may expect to see.

It may be best to get the class to tell you what they think the order of reactivity is while they still have the evidence in front of them, so that discrepancies can be resolved.

There are many ways of carrying out this series of reactions. The one described here uses a dimple tray, but it can be adapted with test tubes. The advantages of the dimple tray are the small amounts of chemical involved and the way the results are displayed.

### Working scientifically skills covered

#### 2. Experimental skills and strategies

Make and record observations and measurements using a range of apparatus and methods.

#### 3. Analysis and Evaluation

Present observations and other data using appropriate methods.

Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

## 5.4 CHEMICAL REACTIONS AND ENERGY

	Spec Statement	Comment
(a)	exothermic and endothermic reactions in terms of temperature change and energy transfer to or from the surroundings	Candidates should know that in an exothermic reaction energy is transferred to the surroundings, resulting in a temperature increase. Similarly, they should know that in an endothermic reaction energy is taken in from the surroundings, resulting in a temperature decrease. The emphasis here should be on interpretation of experimental data to identify exothermic and endothermic reactions. There is no requirement for candidates to recall examples of endothermic reactions but they do need to know that combustion and neutralisation reactions are exothermic.
(b)	energy profiles for exothermic and endothermic reactions	Candidates should be able to sketch energy profile diagrams for exothermic and endothermic reactions, labelling the reactants, products, activation energy and the overall energy change.
(c)	the activation energy as the energy needed for a reaction to occur	Candidates should know that this is the minimum amount of energy required to start a reaction.
(d)	the use of bond energy data to calculate overall energy change for a reaction and to identify whether it is exothermic or endothermic	Candidates should be able to calculate the total amount of energy required to break bonds and the total amount released in forming bonds during a given reaction, and use those values to find the overall energy change for the reaction. They should explain that a reaction is exothermic because more energy is released in forming bonds than is required to break bonds, rather than by stating simply that the overall energy change has a negative value. <b>Higher tier candidates should also be able to apply their understanding to more complex questions, e.g. where the given data is used to calculate a bond energy value.</b>

## 5.5 CRUDE OIL, FUELS AND ORGANIC CHEMISTRY

	Spec Statement	Comment
(a)	crude oil as a complex mixture of hydrocarbons that was formed over millions of years from the remains of simple marine organisms	Candidates should know that hydrocarbons are compounds that contain carbon and hydrogen only. They should understand that carbon atoms have the ability to form bonds with other carbon atoms resulting in the formation of chains of carbon. Crude oil consists of dozens of hydrocarbons with carbon chains of varying lengths.
(b)	the fractional distillation of crude oil	Candidates should know that crude oil is boiled/vaporised before it enters the fractionating column and that the hydrocarbons present condense at different heights in the column. The lower the boiling point, the higher in the column a compound is collected.
(c)	fractions as containing mixtures of hydrocarbons (alkanes) with similar boiling points	Candidates should know that fractions are mixtures containing hydrocarbon compounds that have similar boiling points and that these have similar chain lengths. They are not expected to recall details such as the range of chain lengths present in the constituent hydrocarbons of different fractions but they should know the uses of the following fractions: petroleum gases; gasoline/petrol; naphtha; kerosene; diesel; lubricating oil; fuel oil; bitumen.
(d)	the trends in properties of fractions with increasing chain length and the effect on their usefulness as fuels	Candidates should know that the longer the chain lengths of the hydrocarbons present in a fraction, the higher its boiling point. They should also recall the effect of chain length on different fractions' colour (colourless – yellow – brown), viscosity, ease of ignition and cleanliness of burn.
(e)	the global economic and political importance and social and environmental impact of the oil industry	Candidates should know that decisions made about the use of crude oil impact on all aspects of life, and all over the world. They should know that burning fuels causes global warming and acid rain, which of course don't only affect the countries using the energy. Rapidly growing economies in China and India will consume greater amounts of energy year on year and supplying that energy using crude oil is not sustainable in the long term. Growing demand drives prices upwards, affecting individuals' heating and travel costs but also indirectly causing inflation e.g. in food prices. Candidates should also consider that many important products (e.g. plastics, medicines) are made using components of crude oil and that people will eventually have to decide between burning the remaining reserves of oil and using it for other purposes.



(f)	the combustion reactions of hydrocarbons and other fuels	Candidates should know that the combustion of any fuel requires oxygen (from the air) and that burning hydrocarbons produces carbon dioxide and water. All combustion reactions are exothermic.
(g)	how to determine experimentally the energy per gram released by a burning fuel	Candidates should be able to describe the steps of a simple experiment to determine the amount of energy released by a fuel. They are not required to recall the equation used in the subsequent calculations but they should be able to calculate values from given data.
(h)	the combustion reaction of hydrogen and its use as an energy source including its advantages and disadvantages as a fuel	<p>Candidates should know that when hydrogen burns, it forms water only. Candidates should know that hydrogen is used as a rocket fuel and in hydrogen fuel cells that are now being utilised to power cars. It is expected that candidates are able to discuss the advantages and disadvantages of its use as a fuel.</p> <ul style="list-style-type: none"> <li>• Advantages – produced from water therefore renewable and water is the only product of its combustion so burning hydrogen does not contribute towards global warming or acid rain.</li> <li>• Disadvantages – requires large amounts of electricity to produce hydrogen from water by electrolysis (how is this generated?), storage requires bulky and heavy pressurised containers and is potentially hazardous as it forms an explosive mixture with air.</li> </ul>
(i)	the fire triangle in fire-fighting and fire prevention	Candidates should understand the fire triangle and how it is used in fire prevention and fire-fighting. They should be able to suggest methods to prevent and extinguish fires in a range of situations and explain their reasoning.
(j)	the cracking of some fractions to produce smaller and more useful hydrocarbon molecules, including monomers (alkenes) which can be used to make plastics	Candidates should know that the cracking process involves heating fractions obtained from crude oil to a high temperature in the presence of a catalyst. This causes the hydrocarbon molecules present to decompose forming smaller molecules, including an alkene. There is greater demand for the smaller hydrocarbons, and alkenes such as ethene, are the starting material for the production of many plastics.

(k)	the general formula $C_nH_{2n+2}$ for alkanes and $C_nH_{2n}$ for alkenes	Candidates should be able to apply their understanding of these formulae to identify unfamiliar formulae as those of alkanes or alkenes and to write molecular formulae for compounds containing any given number of carbon atoms
(l)	the names and molecular and structural formulae for simple alkanes and alkenes	<p>Candidates should know that carbon atoms must always have four bonds. Alkanes contain single bonds between the carbon atoms only and are said to be <u>saturated</u>. The alkenes contain a double covalent bond between two carbon atoms and are said to be <u>unsaturated</u>.</p> <p>Candidates are expected to recall the names and molecular and structural formulae of the alkanes methane, ethane, propane, butane and pentane, and the alkenes ethene and propene.</p>
(m)	<b>isomerism in more complex alkanes and alkenes</b>	<p><b>Candidates should be able to identify isomers from the structural formulae of given hydrocarbons and draw true isomers of a given molecular formula. They should be able to draw structural formulae for all isomers of <math>C_4H_{10}</math> and <math>C_5H_{12}</math> but are not required to name them. They should know how carbon atoms in the longest chain are numbered and therefore draw structural formulae for but-1-ene and but-2-ene (names required). They do not need to know about E-Z isomers of but-2-ene but they should know that propene with a methyl group attached to the second carbon atom is a third isomer with the molecular formula <math>C_4H_8</math>.</b></p> <p><b>Candidates will not be required to use or interpret skeletal formulae.</b></p>
(n)	the addition reactions of alkenes with hydrogen and bromine and the use of bromine water in testing for alkenes	<p>Candidates should know that these reactions involve addition of two atoms across the C=C bond in an unsaturated compound thus forming a saturated compound. They should know that one atom is added to each of the carbon atoms involved. Candidates should know that addition of hydrogen forms an alkane and that addition of bromine forms a colourless 'bromoalkane'. They will not be required to name the bromoalkane.</p> <p>Bromine water is used in the test for alkenes as it is safer and easier to handle than bromine. It turns from orange/brown to colourless when added to an alkene.</p> <p>Candidates should be able to represent these reactions using structural formulae in balanced equations.</p>

(o)	<p>the addition polymerisation of ethene and other monomers to produce polythene, poly(propene), poly(vinylchloride) and poly(tetrafluoroethene)</p>	<p>Candidates should know that monomers are small, reactive molecules that can be joined together to make a polymer. They should know that this process is called polymerisation. They should understand that the reactivity of a monomer arises from the presence of its double bond, and that as polymerisation happens one of the bonds breaks to allow the molecule to join to another.</p> <p>Candidates should be able to draw the structural formulae of the ethene, propene, vinylchloride and tetrafluoroethene monomers and describe the reactions forming their respective polymers in the form of an equation using 'n' monomer molecules.</p>
(p)	<p>the general properties of plastics and the uses of polythene, poly(propene), poly(vinylchloride) and poly(tetrafluoroethene)</p>	<p>Candidates should know that plastics are generally flexible, strong, good thermal and electrical insulators, resistant to corrosion, have low density and do not rot. They should be able to select suitable plastics for specific uses, given their properties, and to evaluate their usefulness when compared with traditional materials.</p> <p>Candidates are required to recall the following uses of the named plastics and to link them to their properties:</p> <ul style="list-style-type: none"> <li>• polythene – bags, plastic bottles</li> <li>• poly(propene) – ropes, crates</li> <li>• poly(vinylchloride) – drain pipes, window frames</li> <li>• poly(tetrafluoroethene) – non-stick pans</li> </ul>
(q)	<p>the environmental issues relating to the disposal of plastics, in terms of their non-biodegradability, increasing pressure on landfill for waste disposal, and how recycling addresses these issues as well as the need to carefully manage the use of finite natural resources such as crude oil</p>	<p>Candidates should understand that disposing of plastics in landfill is not desirable because these sites are rapidly being filled and any plastic items will not decompose for hundreds of years.</p> <p>They should also be able to explain that burning plastics is not a particularly good solution to the problem because of the carbon dioxide gas and various toxic fumes they release when they burn.</p> <p>Candidates should appreciate that recycling waste plastic reduces the amount of waste either ending up in landfill or being burned. Equally important are the benefits of conserving crude oil reserves and, because recycling uses less energy than production, reducing fossil fuel use.</p>

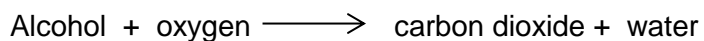
### SPECIFIED PRACTICAL WORK

- Determination of the amount of energy released by a fuel

## Determination of the amount of energy released by a fuel

### Introduction

Fuels react with oxygen when they burn, releasing energy. You will burn four different alcohols and compare the energy they give off.



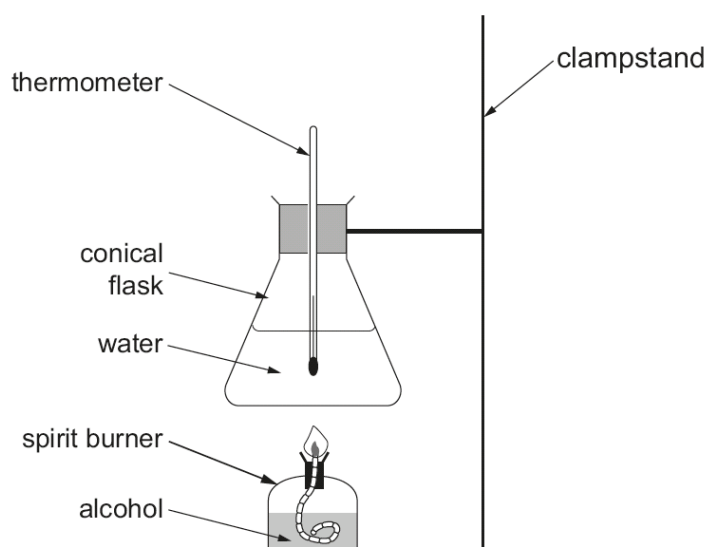
### Apparatus

clamp stand, clamp and boss  
 250cm<sup>3</sup> conical flask  
 100cm<sup>3</sup> measuring cylinder  
 thermometer

#### Access to:

electronic balance  $\pm 0.01$  g  
 4  $\times$  spirit burners containing methanol, ethanol, propanol, butanol

### Diagram of Apparatus



## Method

1. Measure 100 cm<sup>3</sup> of water into the conical flask.
2. Clamp the flask at a suitable height so the spirit burner can be placed below it (as shown in the diagram - make sure that the thermometer does not touch the bottom of the flask).
3. Record the temperature of the water.
4. Record the mass of the spirit burner (including the lid and alcohol).
5. Place the spirit burner under the conical flask and light it.
6. Allow the burner to heat the water until the temperature rises by about 40 °C. Record the temperature of the water.
7. Extinguish the flame carefully and record the mass of the burner.
8. Repeat steps 1-7 with each of the other alcohols.

## Analysis

1. Calculate the temperature rise for each fuel.
2. Calculate the mass of each alcohol burnt.
3. Calculate the energy released for each alcohol using the following equation:

$$\text{Energy released from alcohol per gram (J)} = \frac{\text{mass of water (g)} \times \text{temperature increase (}^\circ\text{C)} \times 4.2}{\text{mass of alcohol (g)}}$$

## Teacher / Technician notes

## Risk Assessment

Hazard	Risk	Control measure
Alcohols are harmful and highly flammable	Alcohols could ignite if left near naked flame	Ensure spirit burners are kept away from lit Bunsen burners
The hot flask could burn/hot water could scald	Burning could result if hot beaker handled. Scalding could result if hot water spilled on skin	Allow hot beaker to cool before disassembling the apparatus

Methanol - Refer to CLEAPSS hazard card 40B

Ethanol - Refer to CLEAPSS hazard card 40A

Propanol - Refer to CLEAPSS hazard card 84A

Butanol - Refer to CLEAPSS hazard card 84B

Pentanol should not be used as a fume cupboard is needed - Refer to CLEAPSS hazard card 84C.

Spirit burners should not be used for more than one alcohol. Make sure that the wick fits tightly in the holder and the holder sits tightly in the container.

Students should not fill or refill spirit burners.

An extension activity could be to plot a graph of the number of carbon atoms in the alcohol against the energy released per gram.

No repeats are planned in this experiment, but can be carried out if time allows.

Alternatively, groups can compare results to discuss reproducibility. Students should design their own table, but a suggested table format is shown below.

Alcohol	Initial mass of burner (g)	Final mass of burner (g)	Change in mass of burner (g)	Initial temperature (°C)	Final temperature (°C)	Temperature increase (°C)	Energy released per gram (J)

### Working scientifically skills covered

**1. Development of scientific thinking**

Explain every day and technological applications of science: evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments.

**2. Experimental skills and strategies**

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Evaluate methods and suggest possible improvements and further investigations.

**3. Analysis and Evaluation**

Carrying out and representing mathematical analysis

Evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

**4. Scientific vocabulary, quantities, units, symbols and nomenclature**

Use SI units and IUPAC chemical nomenclature unless inappropriate

## UNIT 6 – PHYSICS 2

### 6.1 DISTANCE, SPEED AND ACCELERATION

Spec Statement		Comment
(a)	motion using speed, velocity and acceleration	An understanding of the distinction between scalar (speed) and vector (velocity) quantities is needed.
(b)	speed-time and distance-time graphs	Be able to describe the motion represented by a motion graph including calculations where appropriate such as speed or mean speed for a distance-time graph and acceleration or <b>distance travelled (higher tier only) for a velocity-time graph.</b> Calculations will be required for curved sections of graphs as estimations and an understanding of the motion of the object will be expected. See section 2.2 – Newton’s laws statement (d). Links with statements (c) & (d) in this section.
(c)	the equations: $\text{speed} = \frac{\text{distance}}{\text{time}}$ and $\text{acceleration (or deceleration)} = \frac{\text{change in velocity}}{\text{time}}$	
(d)	velocity-time graphs to determine acceleration <b>and distance travelled</b>	Links with statements (b) & (c) in this section.
(e)	the principles of forces and motion to the safe stopping of vehicles, including knowledge of the terms reaction time, thinking distance, braking distance and overall stopping distance and discuss the factors which affect these distances	Be able to state how different factors affect thinking or braking distance.
(f)	the physics of motion together with presented data and opinions to discuss traffic control arising from the above, e.g. the need for speed limits and seat belts	Need to appreciate that the greater the speed of a vehicle the greater the stopping distance and so in urban areas speed limits are important.

## 6.2 NEWTON'S LAWS

	Spec Statement	Comment
(a)	the concept of inertia, that mass is an expression of the inertia of a body	Understand that inertia is a resistance to a change in motion and that objects with greater mass have greater inertia and so a greater resultant force will be required to change its motion.
(b)	Newton's first law of motion <b>and be able to state it</b>	For FT need to understand that balanced forces do not change the motion of an object. <b>For HT should also state Newton's first law: that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external resultant force.</b>
(c)	how unbalanced forces produce a change in a body's motion and that the acceleration of a body is directly proportional to the resultant force and inversely proportional to the body's mass	Be able to calculate the resultant force by considering the forces acting on an object. Be able to recognise direct or inverse proportion from tabulated or graphical data. Apply understanding to situations where mass is not constant e.g. a rocket on take-off.
(d)	Newton's second law of motion, <b>and be able to state it</b> , in the form: resultant force = mass $\times$ acceleration; $F = ma$	Need to be able to recognise it is Newton's second law. <b>Can be stated in words or as an equation.</b>
(e)	the distinction between the weight and mass of an object, the approximation that the weight of an object of mass 1 kg is 10 N on the surface of the Earth and use data on gravitational field strength in calculations involving weight ( $W = mg$ ) and gravitational potential energy:  weight (N) = mass (kg) $\times$ gravitational field strength (N/kg)	That weight is the force of gravity acting on an object whereas mass is the amount of matter in an object. Candidates should know that mass is measured in kg and weight is measured in N. See section 2.3 – work and energy.
(f)	forces and their effects to explain the behaviour of objects moving through the air, including the concept of terminal speed	This could apply to either vertical or horizontal motion. Good examples are the explanation of a skydiver's motion and a vehicle reaching maximum speed. Need to be able to explain how terminal speed is attained. The term terminal speed will be used rather than terminal velocity.



<b>(g)</b>	<p>Newton's third law of motion <b>and be able to state it</b></p>	<p><b>State Newton's third law: if a body A exerts a force on body B then body B exerts an equal and opposite force on body A.</b></p> <p>Be able to apply their knowledge of Newton's third law in different situations e.g. rocket propulsion, gravitational force of the Earth on a body and of the body on the Earth.</p>
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### **SPECIFIED PRACTICAL WORK**

- Investigation of the terminal speed of a falling object

## Investigation of the terminal speed of a falling object

### Introduction

When objects fall through the air, they accelerate until they reach a maximum speed - known as the terminal speed. You are going to investigate how the terminal speed of a falling object depends upon its mass. You are going to use paper cake cases. These are quite light and have a relatively large area. They reach their terminal speed after falling a very short distance.

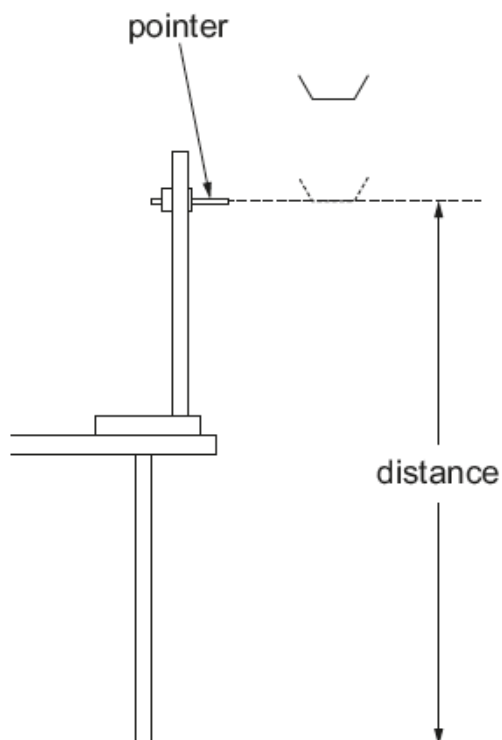
### Apparatus

6 × paper cake cases  
 stopwatch  
 2 × metre rulers  $\pm 1$  mm  
 clamp stand, boss and clamp  
 pointer (e.g. pencil)

#### Access to:

electronic balance  $\pm 0.1$  g

### Diagram of Apparatus



## Method

1. Set up a pointer in the clamp stand and adjust its height to a convenient level above the floor, e.g. 150 cm. Record this height accurately.
2. Take a single cake case and record its mass.
3. Drop the cake case from a height well above (e.g. about 20 cm) the pointer and record the time it takes to fall from the level of the pointer to the floor.
4. Repeat step 3 another four times.
5. Repeat steps 2-4 with 2, 3, 4, 5 and 6 cake cases in a stack.

## Analysis

1. Calculate the terminal speed of each stack of cake cases using:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

2. Plot the number of cake cases against the terminal speed.

## Teacher / Technician notes

Cake cases are readily available from local shops / supermarkets.

Students will need to use the equation:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

to calculate the terminal speed of each stack of cake cases. We assume that the cakes cases have reached their terminal speed by the time they pass the pointer.

Students should design their own table, but a suggested table format is shown below.

Number of cake cases	Mass of cake cases (g)	Time taken for paper cake case to fall (s)						Terminal speed (m/s)
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean	
1								
2								
3								
4								
5								
6								

Students could discuss the repeatability and reproducibility of the results obtained, evaluate the method used and suggest improvements. They could also discuss whether the cakes cases have actually reached their terminal speed as they pass the pointer and how this may be investigated.

### Working scientifically skills covered

#### **2. Experimental skills and strategies**

Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Make and record observations and measurements using a range of apparatus and methods.

#### **3. Analysis and Evaluation**

Carry out and representing mathematical analysis.

Represent distributions of results and make estimations of uncertainty.

Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

## 6.3 WORK AND ENERGY

	Spec Statement	Comment
(a)	the fact that, when a force acts on a moving body, energy is transferred although the total amount of energy remains constant	Links with statement (c) in this section.
(b)	the equation: work = force $\times$ distance moved in the direction of the force ; $W = Fd$	Calculations will not be required where the force is at an angle to the direction of motion. Need to be able to recognise situations where no work is done as there is no motion in the direction of the force. Need to be able to link $W = Fd$ with changes in kinetic or gravitational potential energy to calculate the mean resistive force acting. See statement (e) in this section.
(c)	the fact that work is a measure of the energy transfer, i.e. that work = energy transfer (in the absence of thermal transfer)	In situations where thermal transfer does occur calculations may be required. See statement (e) in this section.
(d)	the fact that an object can possess energy because of its motion (kinetic energy) and position (gravitational potential energy) and deformation (elastic energy)	Various contexts could be discussed, e.g. an aeroplane, a falling object, a stretched rubber band, a catapult etc.
(e)	<p><b>the equations for kinetic energy and changes in gravitational potential energy:</b></p> <p><b>kinetic energy</b> = <math>\frac{\text{mass} \times \text{velocity}^2}{2}</math> ; <b>KE</b> = <math>\frac{1}{2}mv^2</math></p> <p><b>change in potential energy</b> = mass <math>\times</math> <b>gravitational field strength</b> <math>\times</math> <b>change in height</b></p> <p><b>PE = mgh</b></p>	See statements (a), (b) and (c) in this section.  <b>PE = mgh</b>

(f)	<p>the relationship between force and extension for a spring and other simple systems; force = spring constant <math>\times</math> extension; <math>F = kx</math></p>	<p>Simple systems could include springs connected together (series or parallel) but not a combination. Be able to predict the effect on the extension and energy stored in a spring of different spring constant in a given situation. No explanation of the term spring constant is required.</p>
(g)	<p><b>the work done in stretching by finding the area under the force-extension (<math>F</math>-<math>x</math>) graph;</b> <b><math>W = \frac{1}{2}Fx</math> for a linear relationship</b></p>	<p>Force plotted on the <math>y</math>-axis and extension on the <math>x</math>-axis.</p>
(h)	<p>how energy efficiency of vehicles can be improved (e.g. by reducing aerodynamic losses/air resistance and rolling resistance, idling losses and inertial losses)</p>	<p>Be able to give examples of how to reduce losses e.g. aerodynamic losses reduced by more streamlined designs. Rolling resistance is reduced by having correctly inflated tyres and using materials which don't heat up as much as they are squashed. Stop – start systems reduce idling losses. Inertial losses are reduced by having lighter cars. Link to the design of the vehicle and not driving style. See section 1.2 – generating electricity statement (d).</p>
(i)	<p>the principles of forces and motion to an analysis of safety features of cars e.g. air bags and crumple zones</p>	<p>Discussion of momentum is not required here so answer can be expressed in terms of <b>work done</b>: i.e. an air bag and a crumple zone increase the distance over which the energy is transferred, so reducing the force.</p>

### SPECIFIED PRACTICAL WORK

- Investigation of the force-extension graph for a spring

## Investigation of the force-extension graph for a spring

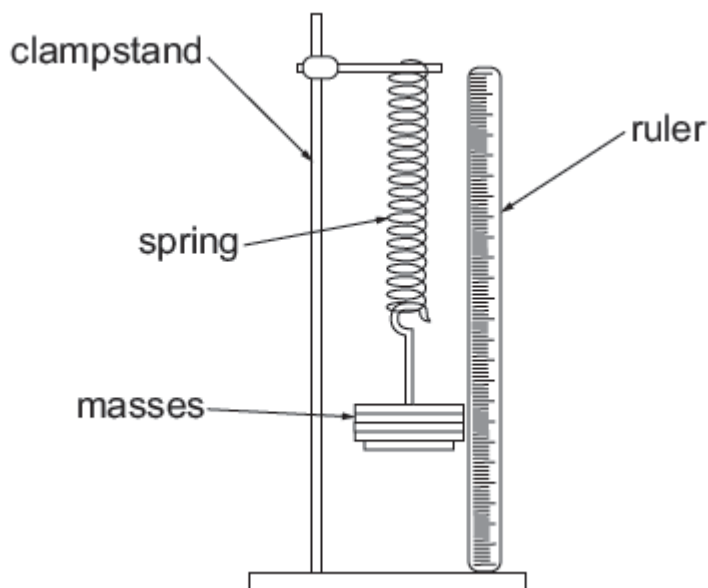
### Introduction

When a force is applied to a spring its length increases. The extension of the spring is found by subtracting the original length of the spring from its length with the force applied. Hooke's Law states that the extension is directly proportional to the force applied provided that the elastic limit is not exceeded. You will investigate if the spring obeys Hooke's law.

### Apparatus

spring  
 100g mass hanger  
 6 × 100g masses  
 clamp stand, boss and clamp  
 metre ruler  $\pm 1$  mm

### Diagram of Apparatus



### Method

1. Record the original length of the spring.
2. Suspend the spring from the clamp and attach the 100g mass hanger.
3. Record the new length of the spring.
4. Add a further 100g to the spring and record the new length.
5. Repeat steps 2-3 until a total mass of 700g has been added.
6. Repeat steps 1-5 once more.

## Analysis

1. Calculate the mean length for each mass added.
2. Calculate the extension for each mass added.
3. Plot a graph of force ( $y$ -axis) against extension ( $x$ -axis). ( $100\text{ g} = 1\text{ N}$ )
4. Determine whether the spring obeys Hooke's law or not.

## Teacher / Technician Notes

Students may be asked to measure the length of the spring itself and not the loops at each end. Including one, or indeed, both loops, will make no difference to their final values for extension. However, students must be consistent in making the same measurement throughout the investigation.

Students should be encouraged to measure and record each result to the nearest 0.1 cm (1 mm). If the result is 9 cm they should write 9.0 in their table.

Students should be asked to *gently* place the masses onto the spring and to ensure that the spring is stationary each time when measuring its new length.

Students should load the spring up to a limit of 700 g. This will ensure that the elastic limit is not exceeded and the springs are not over-stretched. The teacher could demonstrate the effect of further increasing the force applied.

A graph should then be plotted of force ( $y$ -axis) against extension ( $x$ -axis). The line of best fit expected is a straight line through the origin. This proves that the spring obeys Hooke's Law.

Students should design their own table, but a suggested table format is shown below.

Mass (g)	Force (N)	Length (cm)		Mean length (cm)	Extension (cm)
		1	2		



## Working scientifically skills covered

**2. Experimental skills and strategies**

Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

**3. Analysis and evaluation**

Translate data from one form to another.

Carry out and representing mathematical analysis.

Present reasoned explanations including relating data to hypotheses.

**4. Scientific vocabulary, quantities, units, symbols and nomenclature**

Interconvert units

**Use an appropriate number of significant figures in calculation.**

## 6.4 STARS AND PLANETS

(a)	Spec Statement	Comment
	<p>the main features of our solar system: their order, size, orbits and composition to include the Sun, terrestrial planets and gaseous giant planets, dwarf planets, comets, moons and asteroids</p>	<p>Need to be able to recall the order of the planets including the position of the asteroid belt. Know which planets are rocky and which are gaseous and know that the asteroid belt comprises many rocky asteroids and dwarf planets. Appreciate that comets have highly elliptical orbits, passing far out of our solar system. Also appreciate that most of the planets, including some dwarf planets, have moons which orbit them.</p>
	<p>the features of the observable universe (planets, planetary systems, stars and galaxies) and the use of appropriate units of distance: kilometres, astronomical units (AU) and light years (l-y)</p>	<p>Understand the difference in size of the objects listed. Recall that a planetary system (solar system) comprises a star and all the objects which orbit it and that a galaxy is a large collection of stars. Recall that 1 A.U. is the mean distance from the Sun to the Earth and that 1 light year is the distance that light will travel in 1 year. Be able to convert distances in light years into metres and be able to infer what a light minute or light second is.</p>
	<p>the main observable stages in the life cycle of stars of different masses, using the terms: protostar, main sequence star, red giant, supergiant, white dwarf, supernova, neutron star and black hole</p>	<p>Describe the life cycle of stars from protostars to low mass main sequence stars like our Sun (to red giant and white dwarf) and high mass stars (to supergiant, supernova and neutron star or black hole). Describe the life cycle of stars from protostars to low mass main sequence stars like our Sun (to red giant and white dwarf) and high mass stars (to supergiant, supernova and neutron star or black hole).</p>
	<p>the fact that the stability of stars depends upon a balance between gravitational force and a combination of gas and radiation pressure and that stars generate their energy by the fusion of increasingly heavier elements</p>	<p>In main sequence the forces acting on a star are balanced. Gravitational inward forces match outwards gas and radiation pressure forces. When the hydrogen reduces the star will begin to fuse helium and then other increasingly heavier elements to maintain fusion. The star will begin to swell as the combination of gas and radiation pressure exceeds the gravitational force and the forces become unbalanced. Eventually the gravitational force exceeds the combination of gas and radiation pressure and the star shrinks.</p>

(e)	the return of material, including heavy elements, into space during the final stages in the life cycle of giant stars	Appreciate that heavy elements which are created in fusion in large stars are ejected during supernovae.
(f)	the origin of the solar system from the collapse of a cloud of gas and dust, including elements ejected in supernovae	Recall that gravitational forces cause the matter to get closer together creating the Sun and the planets. Use of the term nebula is not required. During formation rocks tended to gather close to the Sun and formed the rocky planets whilst gaseous substances gathered together at distances further away and formed the gas planets.
(g)	<b>the Hertzsprung-Russell (H-R) diagram as a means of displaying the properties of stars, depicting the evolutionary path of a star</b>	<b>Be able to interpret the H-R diagram to predict the path in the life cycle of a star.</b>

## 6.5 TYPES OF RADIATION

	Spec Statement	Comment
(a)	the terms nucleon number ( $A$ ), proton number ( $Z$ ) and isotope, and relate them to the number of protons and neutrons in an atomic nucleus	Be able to explain what is meant by the term isotope. Define isotopes of the same element has having equal numbers of protons but differing numbers of neutrons in their nuclei.
(b)	radioactive emissions as arising from unstable atomic nuclei because of an imbalance between the numbers of protons and neutrons	Candidates will not be given credit for stating that an atom is radioactive because “it has too many neutrons.”
(c)	the fact that waste materials from nuclear power stations and nuclear medicine are radioactive and some of them will remain radioactive for thousands of years	The implications of this for the safe disposal of nuclear waste should be understood. Appreciation that this is due to the long half-lives of some radioactive substances.
(d)	background radiation and be able to make an allowance for it in measurements of radiation	See statement (i) in the section below.
(e)	the random nature of radioactive decay and that it has consequences when undertaking experimental work, requiring repeat readings to be made or measurements over a lengthy period as appropriate	Understand that small variations in count rate are to be expected as radioactive decay is a random process.
(f)	the differences between alpha, beta and gamma radiation in terms of their penetrating power, relating their penetrating powers to their potential for harm and discussing the consequences for the long term storage of nuclear waste	Understand the difference in risk for alpha, beta or gamma sources outside or inside the body. Different methods of disposal of nuclear waste should be considered along with their advantages and disadvantages.  Links with statement (c) in this section.
(g)	alpha radiation as a helium nucleus, beta radiation as a high energy electron and gamma radiation as electromagnetic	No credit will be given for stating that an alpha particle is “helium” or a “helium atom” or a “helium ion”. Recognise an alpha particle as being a group of two neutrons and two protons.

(h)	<p><b>producing</b> and balancing nuclear equations for radioactive decay using the symbols <math>{}^4_2\text{He}^{2+}</math> or <math>{}^4_2\alpha</math> for the alpha particle and <math>{}^0_{-1}\text{e}</math> and <math>{}^0_{-1}\beta</math> for the beta particle</p>	<p>Recall of the symbols is required.</p>
(i)	<p>natural and artificial sources of background radiation, respond to information about received dose from different sources (including medical X-rays) and discuss the reasons for the variation in radon levels</p>	<p>Be able to identify if sources are natural or man-made. Understand that background radiation varies with altitude as at higher altitudes there will be more cosmic radiation. Know that radon originates from rocks especially granite so the type of rock in an area determines the amount of radon. Know how householders can be protected from radon.</p>

## 6.6 HALF-LIFE

Spec Statement		Comment
(a)	the random nature of radioactive decay and to model the decay of a collection of atoms using a constant probability of decay, e.g. using a large collection of dice, coins or a suitably programmed spreadsheet	Links with statement (b) in this section.
(b)	how to plot or sketch decay curves for radioactive materials, understand that a given radioactive material has a characteristic half-life and determine the half-life of a material from the decay curve	Plot smooth curves of best fit when producing decay curves. Be able to draw suitable horizontal and vertical construction lines onto the decay curve in order to show a clear determination of the half-life.
(c)	how to perform simple calculations involving the activity and half-life of radioactive materials in a variety of contexts, e.g. carbon dating	Be able to calculate the activity after a certain number of half-lives, or calculate half-life from given data on changes to activity. Define half-life as the time taken for the number of radioactive nuclei / mass / activity to reduce to one half of its initial value.
(d)	the different uses of radioactive materials, relating to the half-life, penetrating power and biological effects of the radiation e.g. radioactive tracers and cancer treatment	Be able to select a suitable isotope for a given application and explain their choice.

### SPECIFIED PRACTICAL WORK

- Determination of the half-life of a model radioactive source, e.g. using dice

## Determination of the half-life of a model radioactive source

[e.g. using cubes or dice]

### Introduction

Radioactive decay is a random process. The number of radioactive atoms present in a given sample will halve in a fixed time period depending on the probability of decay for that particular radioisotope. This is known as the half-life of the substance. This is a simulation in which radioactive atoms are represented by cubes. The cubes are considered to be decayed when they land with a particular face upwards.

### Apparatus

50 × cubes with one face shaded  
 margarine tub  
 tray

### Diagram of Apparatus



### Method

1. Count the cubes to ensure that you have 50 and put them into the margarine tub.
2. Shake the tub and gently throw the cubes into the plastic tray.
3. Record the number of cubes that have landed with the shaded face upwards and remove from the tray.  
 [These represent the radioactive atoms that have decayed.]
4. Put the cubes remaining in the tray back into the margarine tub.  
 [These represent the radioactive atoms that have NOT yet decayed.]
- 5 Repeat steps 2 and 3 another 9 times.

## Analysis

1. Use the results from the whole class to plot a graph of the number of radioactive atoms remaining ( $y$ -axis) against the number of throws ( $x$ -axis).
2. Use the graph to determine the half-life of the cubes.

## Teacher / Technician Notes

Students should design their own table, but a suggested table format is shown below.

Throw	Number decayed	Number remaining
0	0	50
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

The third column may be calculated by subtracting the number decayed from the total number of cubes.

Note that rather than calculate the mean results, students should simply calculate the total class results. This effectively increases the sample size from 50 to 500. The results may be collated by providing the following grid for students, e.g. on a white board/ excel spreadsheet:



Throw	Number remaining											
	Gp 1	Gp 2	Gp 3	Gp 4	Gp 5	Gp 6	Gp 7	Gp 8	Gp 9	Gp10	TOTAL	
0	50	50	50	50	50	50	50	50	50	50	50	<b>500</b>
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

The graph should be a good approximation to an exponential decay curve. Students are asked in the analysis section to find how many throws were required to reduce the number of cubes to half the original number and then half again etc (fractions of a throw are allowed) and the concept of half-life introduced.

The half-life should be determined from the graph. The graph will start at 500 (at 0 throws). A horizontal line should be drawn from 250 to the curve and then a vertical line drawn downwards from this point on the curve. The half-life is the intercept on the number of throws axis. A second value should be obtained, e.g. by drawing a horizontal line from 125 to the curve and then a vertical line downwards. The second value of half-life is then determined by subtracting the “250 intercept” from the “125 intercept”. A mean value for the half-life can then be determined by adding the 2 values and dividing by 2.

Note that lines could be drawn onto the graph to determine the half-life using other pairs of numbers, e.g. 400 to 200 and 200 to 100.

### Working scientifically skills covered

#### 1. Development of scientific thinking

Use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts.

#### 2. Experimental skills and strategies

Recognise when to apply a knowledge of sampling techniques to ensure that any samples collected are representative

Make and record observations and measurements using a range of apparatus and methods.

#### 3. Analysis and Evaluation

Translate data from one form to another.

Carry out and representing mathematical analysis.

Represent distributions of results and make estimations of uncertainty.

## EQUATIONS

A list of equations will be included at the start of each examination paper. FT learners will not be expected to change the subject of an equation. However, they may be expected to recognise and use them in other formats i.e. a version of the equation may be given to them in a question which is different to the version that appears on the list of equations at the start of the paper. For example, on page 2 the power equation appears in the form: power = voltage  $\times$  current. So if the question asked the learner to calculate the voltage then the equation would be given to them in the question as: voltage =  $\frac{\text{power}}{\text{current}}$  because it is in a

different form to that on page 2.

HT learners will be expected to rearrange equations.

### FOUNDATION TIER – EQUATION LIST

#### UNIT 3 – PHYSICS 1

current = $\frac{\text{voltage}}{\text{resistance}}$	$I = \frac{V}{R}$
total resistance in a series circuit	$R = R_1 + R_2$
energy transferred = power $\times$ time	$E = Pt$
power = voltage $\times$ current	$P = VI$
% efficiency = $\frac{\text{energy [or power] usefully transferred}}{\text{total energy [or power] supplied}} \times 100$	
density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$
units used (kWh) = power (kW) $\times$ time (h) cost = units used $\times$ cost per unit	
wave speed = wavelength $\times$ frequency	$v = \lambda f$
speed = $\frac{\text{distance}}{\text{time}}$	

### SI multipliers

Prefix	Multiplier
m	$1 \times 10^{-3}$
k	$1 \times 10^3$
M	$1 \times 10^6$

### HIGHER TIER – EQUATION LIST

#### UNIT 3 – Physics 1

current = $\frac{\text{voltage}}{\text{resistance}}$	$I = \frac{V}{R}$
total resistance in a series circuit	$R = R_1 + R_2$
total resistance in a parallel circuit	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$
energy transferred = power $\times$ time	$E = Pt$
power = voltage $\times$ current	$P = VI$
power = current <sup>2</sup> $\times$ resistance	$P = I^2R$
% efficiency = $\frac{\text{energy [or power] usefully transferred}}{\text{total energy [or power] supplied}} \times 100$	
density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$
units used (kWh) = power (kW) $\times$ time (h) cost = units used $\times$ cost per unit	
wave speed = wavelength $\times$ frequency	$v = \lambda f$
speed = $\frac{\text{distance}}{\text{time}}$	

## SI multipliers

Prefix	Multiplier
p	$1 \times 10^{-12}$
n	$1 \times 10^{-9}$
$\mu$	$1 \times 10^{-6}$
m	$1 \times 10^{-3}$

Prefix	Multiplier
k	$1 \times 10^3$
M	$1 \times 10^6$
G	$1 \times 10^9$
T	$1 \times 10^{12}$

FOUNDATION TIER – EQUATION LIST  
UNIT 6 – Physics 2

speed = $\frac{\text{distance}}{\text{time}}$	
acceleration [or deceleration] = $\frac{\text{change in velocity}}{\text{time}}$	$a = \frac{\Delta v}{t}$
acceleration = gradient of a velocity-time graph	
resultant force = mass $\times$ acceleration	$F = ma$
weight = mass $\times$ gravitational field strength	$W = mg$
work = force $\times$ distance	$W = Fd$
force = spring constant $\times$ extension	$F = kx$

**SI multipliers**

Prefix	Multiplier
m	$1 \times 10^{-3}$
k	$1 \times 10^3$
M	$1 \times 10^6$

HIGHER TIER – EQUATION LIST  
UNIT 6 – Physics 2

speed = $\frac{\text{distance}}{\text{time}}$	
acceleration [or deceleration] = $\frac{\text{change in velocity}}{\text{time}}$	$a = \frac{\Delta v}{t}$
acceleration = gradient of a velocity-time graph	
distance travelled = area under a velocity-time graph	
resultant force = mass $\times$ acceleration	$F = ma$
weight = mass $\times$ gravitational field strength	$W = mg$
work = force $\times$ distance	$W = Fd$
kinetic energy = $\frac{\text{mass} \times \text{velocity}^2}{2}$	$KE = \frac{1}{2}mv^2$
change in potential energy = mass $\times$ gravitational field strength $\times$ change in height	$PE = mgh$
force = spring constant $\times$ extension	$F = kx$
work done in stretching = area under a force-extension graph	$W = \frac{1}{2}Fx$

**SI Multipliers**

Prefix	Multiplier
p	$1 \times 10^{-12}$
n	$1 \times 10^{-9}$
$\mu$	$1 \times 10^{-6}$
m	$1 \times 10^{-3}$

Prefix	Multiplier
k	$1 \times 10^3$
M	$1 \times 10^6$
G	$1 \times 10^9$
T	$1 \times 10^{12}$