GCSE

WJEC GCSE in

APPLIED 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.

Contents

Contents

UNIT 1 - ENERGY, RESOURCES and the ENVIRONMENT

1.1 ENERGY AND LIFE –

1.1.1 THE CELL AND RESPIRATION

Applied Context
This section is common core content however learners can apply their knowledge in a number of fields including sport and medicine.

	Spec Statement	Comment
(a)	structure of animal and plant cells, and specialisation that results from being multicellular; function of the following parts: cell membrane, cytoplasm, nucleus, cell wall, vacuole, chloroplast	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 Specialised cells are more efficient in performing specific functions than non-specialised cells.
(b)	levels of organisation: aggregation of cells into tissues, and tissues into organs	Know that tissues are made up of many similar cells working together to perform a particular function. Organs are made up of many tissues working together to perform a function.
(c)	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	The pore size of the Visking tubing is large enough to allow water molecules through but restricts the movement of solute molecules.
(d)	diffusion as a passive process, allowing only certain substances to pass through the cell membrane in this way, most importantly oxygen and carbon dioxide	Understand that diffusion does not require energy. Oxygen and carbon dioxide are examples of substances that move across the cell membrane by diffusion.
(e)	**active transport which is an active process whereby substances can enter cells against a concentration gradient**	**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)**

(f)	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; the word equation to describe aerobic respiration	Understand that all cells require a constant supply of energy to carry out cell processes and so enable organs and systems to function. Symbol equations are not required here. Candidates should be aware that respiration is a series of enzyme-controlled reactions; however no enzyme names are required. Some energy from respiration is lost as heat. There is an opportunity for practical work here - 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.
(g)	anaerobic respiration as a process that occurs in the absence of oxygen; anaerobic respiration as a less efficient process than aerobic respiration, where lactate is formed; oxygen debt as a result of anaerobic respiration	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.

SPECIFIED PRACTICAL WORK

- Investigation of the factors that affect the rate of respiration

Investigation of the factors that affect the rate of respiration

Introduction

Yeast is a microorganism that carries out respiration. One factor that can affect the rate of respiration is the concentration of glucose. As yeast carries out respiration, bubbles of carbon dioxide are produced.

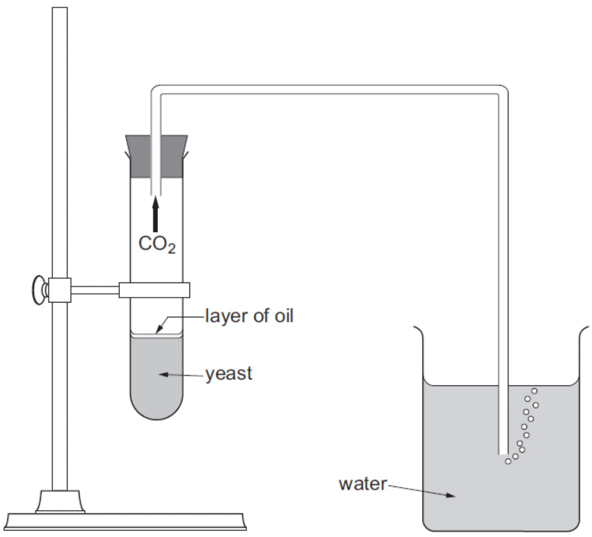
Apparatus

boiling tube
250 cm^3 beaker
clamp stand, clamp and boss
10 cm^3 measuring cylinder
bung and glass tubing (as shown in diagram)
stirring rod
pipette
stopwatch

Access to:

electronic balance ± 0.1 g
vegetable oil or equivalent
10 % yeast suspension
2, 4, 6, 8, 10 % glucose solutions

Diagram of Apparatus



Method

1. Place 10 cm^3 of yeast suspension into a boiling tube.
2. Place 10 cm^3 of 2% glucose solution into the same boiling tube.
3. Stir the contents gently with a stirring rod.
4. Using a pipette, place a few drops of oil on the top of the liquid so that it forms a thin layer.
5. Place the bung with glass tubing into the boiling tube.
6. Clamp the boiling tube in a clamp stand.
7. Fill a 250 cm^3 beaker with water.
8. Arrange the apparatus so that the end of the glass tube is underwater in the beaker as shown in the diagram.
9. Start the stopwatch when the first bubble appears, and then count the bubbles produced for 2 minutes.
10. Repeat steps 1-9 with 4, 6, 8 and 10 % glucose solution.

Analysis

1. Plot a graph of concentration of glucose (x- axis) against number of bubbles (y-axis).

Teacher/Technician notes

2, 4, 6, 8 and 10 % glucose solutions are suggested concentrations. It will be necessary to try out the experiment before presenting it to students to establish the optimum concentrations of glucose to use.

Yeast suspension should be made using warm water. This should be left to stand for 15 minutes before being used by students.

No repeat readings are planned but can be carried out if time permits.

Glass tubing can be fragile therefore plastic or rubber could be substituted as necessary.

Dried yeast can be used as an alternative to fresh yeast.

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.

   Evaluate methods and suggest possible improvements and further investigations.

3. Analysis and Evaluation

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

1.1 ENERGY AND LIFE –

1.1.2 OBTAINING THE MATERIALS FOR RESPIRATION

Applied Context
This section is common core content however learners can apply their knowledge in a number of fields including dietetics, sport and medicine.

	Spec Statement	Comment
(a)	the purpose of the respiratory system in providing oxygen and removing carbon dioxide	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.
(b)	the structure of the respiratory system to include the nasal cavity, trachea, bronchi, bronchioles, alveoli, lungs, diaphragm, ribs and intercostal muscles (knowledge of pleural membranes is not required)	Be able to label parts on a given diagram of a vertical section of the human respiratory system.
(c)	how air is breathed in and out (contraction/relaxation of the intercostal muscles and movement of the diaphragm causing pressure and volume changes, so air is sucked in or forced out of the lungs), and the changes that take place in the composition of the air	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). Candidates should know how gases diffuse between alveolar air and capillaries and know the adaptations of alveoli for gas exchange.
(d)	digestion as a process whereby large molecules are broken down into smaller molecules so they can be absorbed for use by body cells	
(e)	enzymes as proteins made by living cells that speed up/catalyse the rate of chemical reactions within the cells; specific enzymes being used for each reaction; optimum temperature and pH of enzymes; boiling destroying/denaturing enzymes	Enzymes are involved in all metabolic reactions building large molecules from small ones as well breaking down large molecules into small ones. 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.
(f)	**enzyme activity in terms of molecular collisions; the simple 'lock and key' model of enzyme action and formation of the enzyme - substrate complex at the active site**	**Apply knowledge of 'lock and key' to the analysis of simple, stylised diagrams of enzyme/substrate interactions.**

(g)	absorption of soluble substances through the wall of the small intestine and eventually into the bloodstream; the limitations of the model gut	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.
(h)	fats, made up of fatty acids and glycerol, proteins, made up of amino acids, and starch, made up of a chain of glucose molecules, that are insoluble; breakdown of fats, proteins and carbohydrates during digestion into soluble substances so that they can be absorbed	Use chemical models to show how compounds can be broken down into smaller units. Carbohydrase: starch to glucose Protease: protein to amino acids Lipase: fats and oils (lipids) to fatty acids and glycerol
(i)	the structure of the human digestive system, to include mouth, oesophagus/gullet, stomach, liver, gall bladder, bile duct, pancreas, small intestine, large intestine, anus	Recognise and label the digestive system on a given diagram
(j)	the role of the following organs in digestion: mouth, stomach, pancreas, small intestine, large intestine	Know the role of the following organs: • Mouth - starch digestion begins by carbohydrase/ amylase in saliva • Stomach - secretes protease • Pancreas - secretes lipase, proteases and carbohydrase into the small intestine • Small intestine - continued digestion of carbohydrates to glucose, proteins to amino acids, fats to fatty acids and glycerol and absorption of digested molecules • Large intestine - absorption of water
(k)	peristalsis as a process whereby food is moved along the digestive tract; the function of bile which is secreted by the liver and stored in the gall bladder, in the breakdown of fats	Understand the action of contraction and relaxation of muscles in peristalsis in forcing food through the digestive system. 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.
(l)	the fate of products of digestion: fatty acids and glycerol from fats and glucose from carbohydrate provide energy whilst amino acids from digested proteins are needed to build proteins in the body	

(m)	tests for the presence of starch using iodine solution, glucose using Benedict's reagent and protein using biuret solution	Positive results: Iodine: brown to blue/black Benedict’s reagent: blue to brick red Biuret solution: blue to violet

SPECIFIED PRACTICAL WORK

- Investigation into the factors affecting enzyme action

Investigation into the 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^3 measuring cylinder
10 cm^3 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^3 of 1 % starch solution into a test tube.
2. Measure 2 cm^3 of 10 % amylase solution into a second test tube.
3. Place both tubes into a water bath set at 20 ºC 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 ºC, 40 ºC, 50 ºC, 60 ºC.

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 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.

	Colour of solution					
Temperature of solution (°C)	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 MODERN LIVING AND ENERGY –

1.2.1 UNDERPINNING ENERGY CONCEPTS

Applied Context
It is important to understand energy transfer if we are to efficiently generate electricity or use energy in the home. Learners can apply their knowledge in a number of fields including electricity generation and sustainable development. This section is common core content.
This topic introduces some key scientific and mathematical concepts that will need to be applied to both the generation of electricity (1.2.2) and our use of energy (1.2.3).

	Spec Statement	Comment
(a)	how temperature differences lead to the transfer of energy	
(b)	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, transmission and use of energy	Including Sankey diagrams drawn to scale
(c)	mathematical equations to find useful information relating to both the generation and use of electricity: • $\%\text{efficiency} = \frac{\text{energy [or power] usefully transferred}}{\text{total energy [or power] supplied}} \times 100$ • power = voltage × current e.g. in relation to the power output of wind turbines, water turbines and solar panels and power consumption of household appliances • energy transfer = power × time	Manipulation of equations only on higher tier. On foundation tier, the equation will be given in the form required if it involves a change to the subject. Understand the relationship between watts and joules
(d)	how to investigate energy transfer and the efficiency of energy transfer in a range of contexts; the interpretation, analysis and evaluation of data and methods used in investigations. Investigations to include: • the energy output from a renewable source (e.g. energy output and the construction / location of a wind turbine) • the efficiency of an electric kettle	The efficiency of other electrical devices can be investigated
(e)	the terms 'sustainable' and 'carbon footprint' when applied to generation of electricity or the use of electricity and energy (e.g. natural gas)	Carbon footprint as a measure of the total amount of carbon dioxide and

		methane emissions of a defined population, system or activity

(f)	the measurement of the carbon footprint in terms of mass equivalent of carbon dioxide (kgCO2eq) and global warming potential of a gas; the use of the relationship: kgCO2eq = (mass of a gas) × (global warming potential of the gas)	comparison of the carbon dioxide equivalent of greenhouse gases using given data

SPECIFIED PRACTICAL WORK

- Investigation of the efficiency of energy transfer in electrical contexts

Investigation of the efficiency of energy transfer in electrical contexts

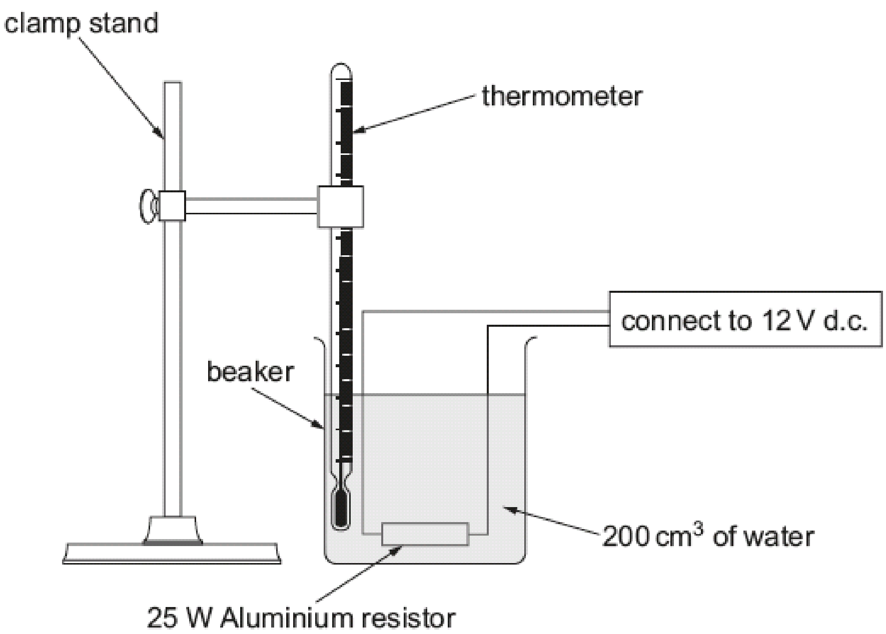
Introduction

A resistor can be used as a simple electrical immersion heater and the efficiency of the heat energy transferred to the water calculated.

Apparatus

25 W aluminium resistor for heating water
250 cm^3 beaker
clamp stand, boss and clamp
thermometer
connecting wires
12 V d.c. power supply
200 cm^3 water
stopwatch

Diagram of Apparatus



Method

1. Connect the circuit as shown. Ensure that the thermometer does not touch the resistor. Do not switch on the power supply until the resistor is fully immersed in the water.
2. Ensure that the power supply is set at 12 V.
3. Switch on the power supply and record the temperature of the water every 60 seconds for 600 seconds.

Analysis

1. Draw a graph of time (x-axis) vs temperature of the water (y-axis).
2. Calculate the efficiency of this method of heating water by using the following equations.

A) The useful energy output of the resistor can be calculated by:

Energy (J) = Power (W) × Time (seconds)

B) The energy gained by the water can be calculated by:

Energy (J) = Temperature rise (°C) × 840 (if 200 cm^3 of water is used)

The efficiency is then calculated from:

$$\text{\% efficiency} = \frac{\text{energy [or power] usefully transferred}}{\text{total energy [or power] supplied}} \times 100$$

Where:

- energy usefully transferred = answer to **B** (energy gained by the water)
- total energy supplied = answer to **A** (useful energy output of the resistor)

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Hot resistor can burn	Burning skin on the hot resistor when moving/handling	Allow apparatus to cool before touching

Suitable 25 W, 10 Ω aluminium resistors (it is easier to pre-solder leads to the resistors).

Power supplies should be set, fixed, at 12 V.

The calculations in this experiment will be made easier if students tabulate time in seconds not minutes.

Note: the temperature of the water will, probably, only increase by a few degrees during this experiment. Therefore it will be impractical to ask students to draw 'lines of best fit' on their plotted graphs.

More able students could suggest how the efficiency could be improved.

Working scientifically skills covered

2. **Experimental skills and strategies**
   Evaluate methods and suggest possible improvements and further investigations.

3. **Analysis and Evaluation**
   Carry out and representing mathematical analysis.

4. **Scientific vocabulary, quantities, units, symbols and nomenclature**
   Recognise the importance of scientific quantities and understand how they are determined.

   Use SI units and IUPAC chemical nomenclature unless inappropriate.

1.2 MODERN LIVING AND ENERGY –

1.2.2 GENERATING ELECTRICITY

Applied Context
This topic explores different ways of generating electricity and compares them for cost efficiency, reliability and environmental impact. Learners will also explore how electricity can be transferred from power stations to where it is used. Learners can apply their knowledge in a number of fields including electricity generation and sustainable development. This section is common core content.

	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) as a means of generating electricity on a national scale using secondary information	Consider economic, environmental and sustainability issues as well as generating capacities and start-up time.
(b)	the cost effectiveness of introducing domestic solar and wind energy equipment, including fuel cost savings and payback time by using data	Consider the reliability of output supply and the potential for meeting a household's demand
(c)	sustainability, carbon footprint, cost, reliability, environmental impact to compare different methods of power generation e.g. use data to assess their impact on the environment by considering atmospheric effects (acid rain and carbon dioxide emission), pollution including visual and noise pollution	Including output reliability and ability to meet domestic demand
(d)	the lifetime and the useful power produced by renewable energy devices and power stations e.g. solar cell, fuel cell, wind turbines and water turbines	
(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 electricity supply more reliable. Recognise power stations, 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)	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	Step up transformers increase voltage and decrease current – reduces energy losses in transmission lines making distribution more efficient. Step down transformers reduce voltage to safer levels for consumers.
(g)	the use of transformers 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)	
(h)	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	Links with statement (a) in this section

SPECIFIED PRACTICAL WORK

- Investigation of the factors affecting the output from a solar panel.

Investigation of the factors affecting the output from a solar panel

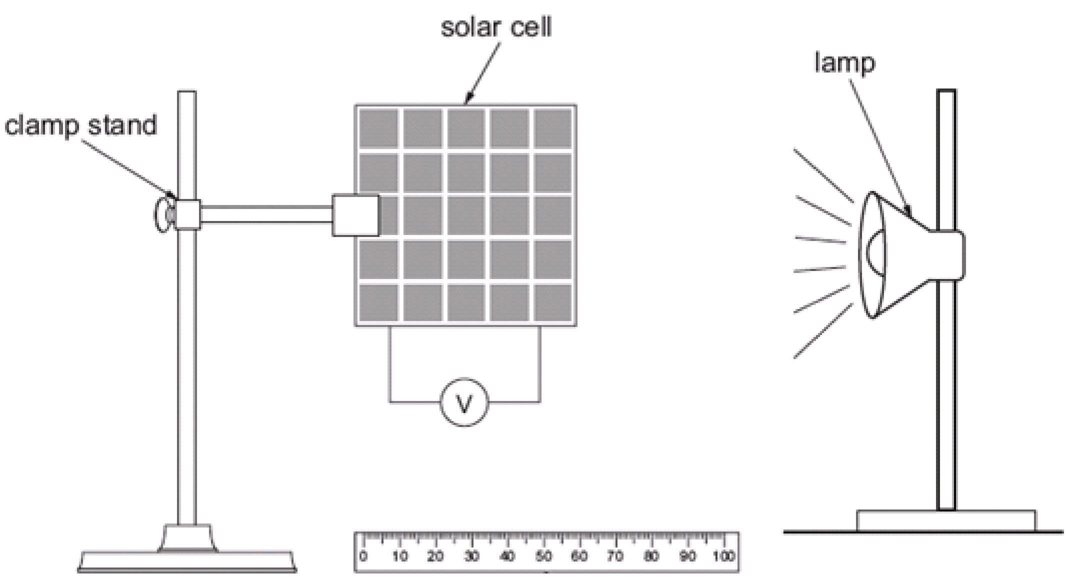
Introduction

Solar photovoltaic cells convert energy received from the sun into electricity. The output from a solar panel varies depending on the intensity of the radiation falling on it. In the UK in winter, the Earth's axis is tilted, reducing the intensity of the radiation reaching us. You can model this effect by moving a light source further away from a solar panel and measuring the voltage produced.

Apparatus

solar panel
voltmeter ± 0.01 V
metre ruler ± 1 mm
12 V lamp and holder
12 V d.c. power supply
connecting leads
clamp stand, boss and clamp

Diagram of Apparatus



Method

1. Carefully clamp the solar panel in the boss.
2. Connect the solar panel to the voltmeter.
3. Place the lamp 20 cm from the solar panel.
4. Record the output voltage.
5. Repeat steps 3 to 4 increasing the distance by 20 cm each time, up to100 cm.
6. Repeat the experiment twice more.

Analysis

1. Calculate the mean voltage for each distance.
2. Plot a graph of mean voltage against distance.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Hot lamps can burn	Burning skin on hot lamp whilst moving it	Do not move lamp until cool

Solar panels are available to buy very cheaply from Rapid Electronics e.g. TruOpto OPL30A10101 Solar Module 3 V 100 mA 0.3 W order code 56-0124.

This task could be useful in developing planning skills as students could plan to investigate the effect of increasing cloud cover, by covering the solar panel with different thicknesses of tracing paper.

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.

   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.

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

1.2 MODERN LIVING AND ENERGY –

1.2.3 MAKING USE OF ENERGY

Applied Context
As energy is an expensive commodity, it is important that it is not wasted in industry and everyday life. Learners should consider how homes are heated, how to improve the efficiency of cars, how to reduce the carbon footprint. Learners can apply their knowledge in a number of fields including electricity generation and sustainable development. This section is common core content.

Spec Statement		Comment
(a)	processes by which energy can be transferred (conduction, convection or radiation)	No particulate explanation required. Convection arises from density changes.
(b)	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.
(c)	how energy loss from houses can be restricted e.g. loft insulation and double glazing; how data can be used to compare the economics of domestic insulation techniques	Link the 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.
(d)	the cost effectiveness and efficiency of different methods of reducing energy loss from the home, including loft insulation, cavity wall insulation, double-glazing and draught excluders to compare their effectiveness; the economic and environmental issues surrounding controlling energy loss	$\text{payback time} = \dfrac{\text{installation cost}}{\text{annual savings}}$
(e)	the efficiency of different vehicle engines (electric > diesel > petrol); how energy efficiency of vehicles can be improved (e.g. reduce aerodynamic losses/air resistance and rolling resistance, reduce idling losses, inertia losses)	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.
(f)	energy saving methods with respect to their impact on the carbon footprint	
(g)	mathematical equations to find the number of units and cost of electricity used: units used = power (kW) $\times$ time (h) total cost = cost of one unit $\times$ units used	Conversions between W and kW, minutes and hours, and hours and days.

SPECIFIED PRACTICAL WORK

Investigation of the methods of heat transfer

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

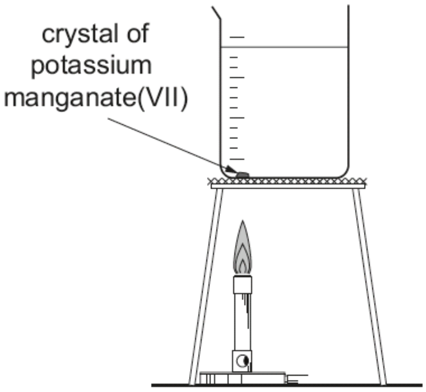
Convection:
2 × 250 cm^3 beaker
1 crystal of potassium manganate(VII)
10 cm^3 glass tube
tripod and gauze
heat proof mat
Bunsen burner
forceps

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

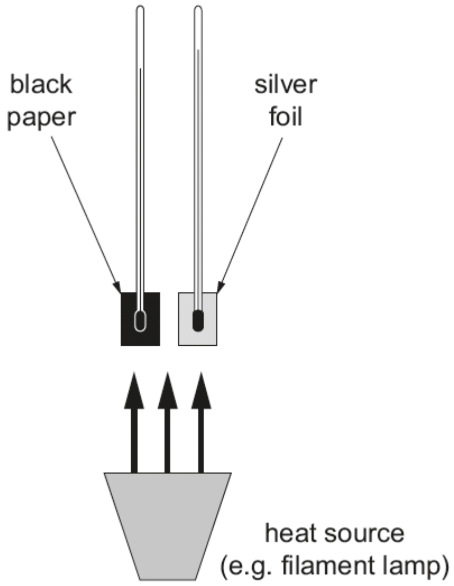
Conduction:
conductive ring
(aluminium, brass, copper and iron)
4 × wooden matches
Vaseline
clamp stand, clamp and boss
Bunsen burner
heat proof mat
stopwatch

Diagram of Apparatus

Convection Experiment

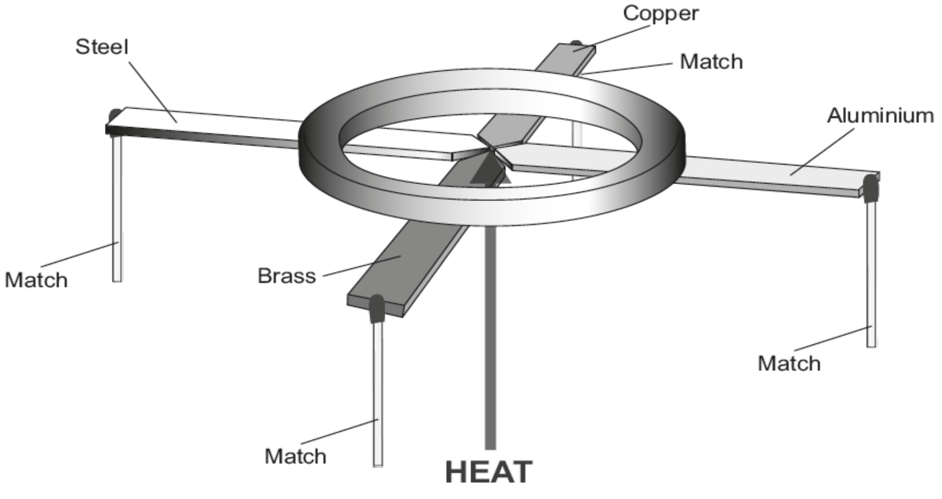


Radiation Experiment



Conduction Experiment

Conductive Ring Experiment



Method

Convection Experiment

1. Fill the beaker to ¾ 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.

Radiation Experiment

1. Use Sellotape to attach a 2 cm strip of black paper to the bulb of one thermometer.
2. In the same way attach a 2 cm strip of silver foil to the bulb of another thermometer.
3. Clamp the 2 thermometers **the same distance away** (about 10 cm) 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.

Conduction 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 which colour is the best absorber of heat.
2. Determine the order of conductivity of the metals.

Teacher / Technician Notes

Risk Assessment

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 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

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

This experiment can be demonstrated if only a limited number of conduction rings are available. A similar practical is undertaken by students in the specified practical in unit 3.1.

The expected order is :	**copper**	**(best conductor),**
	aluminium,	
	brass,	
	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.

If run as a class practical, 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. Students should be encouraged to use the smallest amount of Vaseline that is needed to attach each match to the ring.

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.

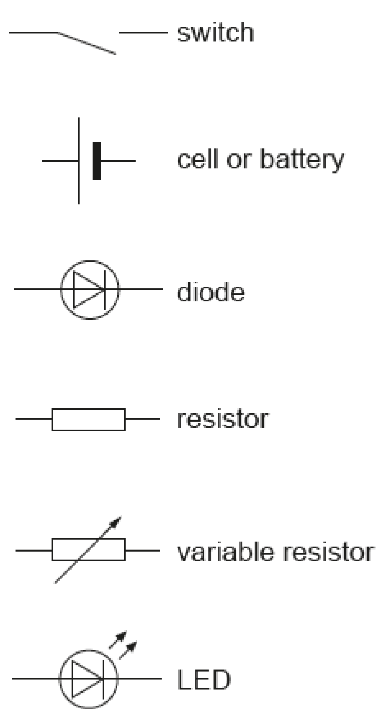
   Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

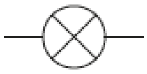
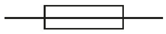
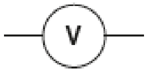
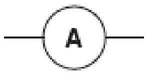
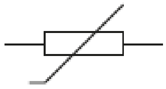
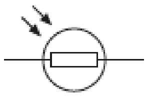
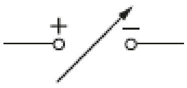
4. **Scientific vocabulary, quantities, units, symbols and nomenclature**
   Use scientific vocabulary, terminology and definitions.

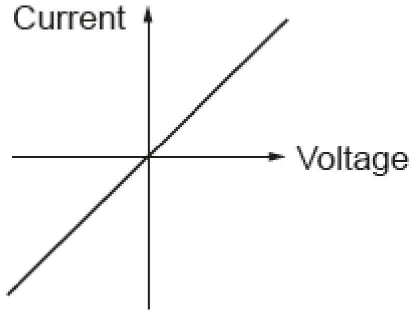
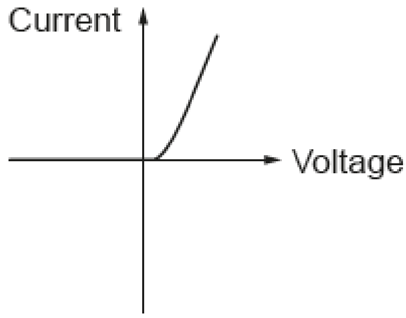
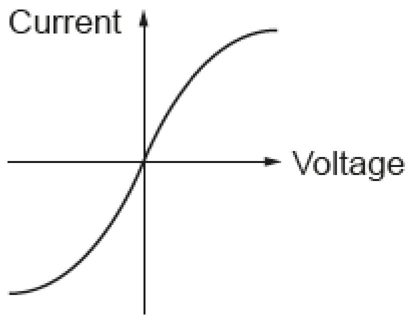
1.2 MODERN LIVING AND ENERGY –

1.2.4 BUILDING ELECTRIC CIRCUITS

Applied Context
A large number of electrical devices are now used in our homes, at work, or for leisure.
In this topic learners will explore simple electric circuits and understand how the construction of a circuit affects the current and voltage across components. They will also be introduced to key concepts and relationships that need to be considered when building a circuit. Learners can apply their knowledge in a number of fields including electrical engineering, electronics and communications. This section is common core content.

Spec Statement		Comment
(a)	the symbols of components (cell, switch, lamp, voltmeter, ammeter, resistor, variable resistor, fuse, LED, thermistor, LDR, diode) used in electrical circuits	Be able to draw circuit diagrams. 

		 lamp  fuse  voltmeter  ameter  thermistor  LDR a.c.power supply  d.c.power supply  variable d.c power supply
(b)	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	Including appreciation of types of household circuits e.g. ring main, household lighting circuits.
(c)	adding components in series or parallel to change the total resistance of a circuit; physical factors that affect the resistance of thermistors and LDRs	
(d)	voltmeters and ammeters to measure the voltage across and current through electrical components in electrical circuits	Know that an ammeter must be connected in series and a voltmeter must be connected in parallel

(e)	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;	The circuits would include a variable resistor. Including knowledge of how: • R varies with V for a lamp • R varies with positive and negative voltages for a diode and that normally a diode will not conduct until a particular voltage is reached. Current plotted on the y-axis and voltage on the x-axis.   
(f)	the significance of, and the relationship between current, voltage and resistance	The qualitative and quantitative relationships should be known If R is constant then $I \, \alpha \, V$. If V is constant then $I \alpha \frac{1}{R}$

(g)	how adding components in series increases total resistance in a circuit; how adding components in parallel decreases total resistance in a circuit	
(h)	how to calculate total resistance and current in a series circuit; how to select an appropriate fuse for a circuit; how to calculate the total resistance and total current in a parallel circuit	$R_T = R_1 + R_2$ ………………… A selection of fuse ratings will be given $1/R_T = 1/R_1 + 1/R_2$ …………………
(i)	mathematical equations to find useful information: $\text{current} = \dfrac{\text{voltage}}{\text{resistance}}$ $I = \dfrac{V}{R}$ power = voltage × current $P = VI$ **power = current² × resistance** $\boldsymbol{P = I^2R}$	Manipulation of equations only required on higher tier On foundation tier the equation will be given in the form required.

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

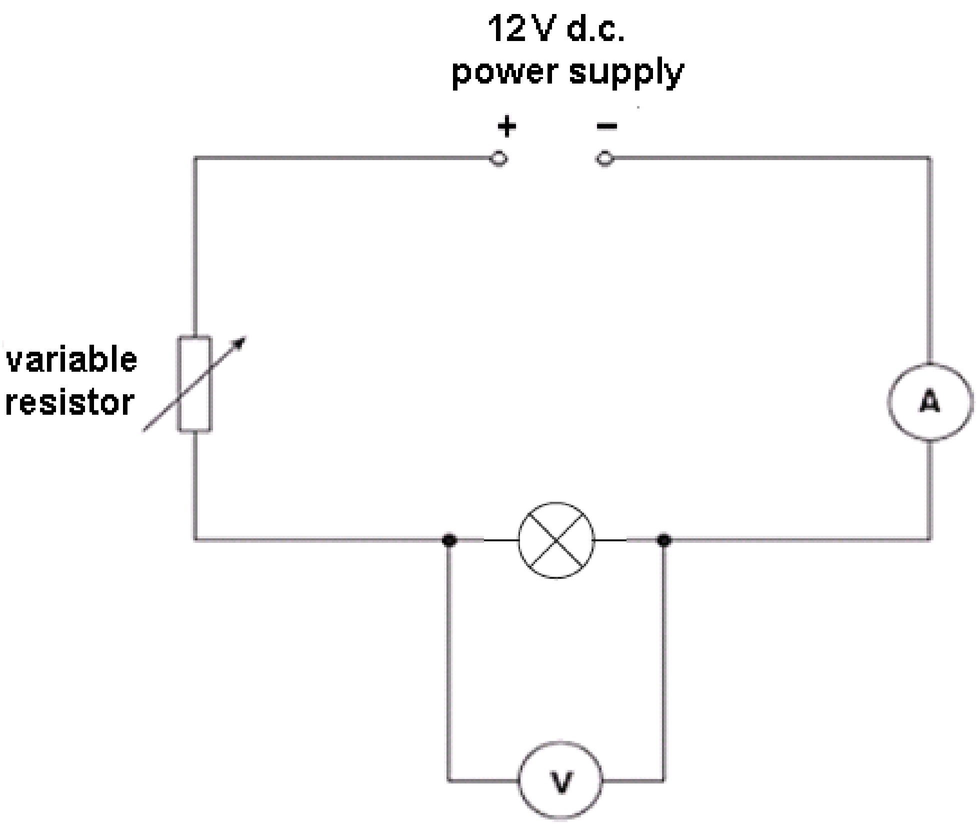
Introduction

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

12 V filament lamp
voltmeter ±0.01 V
ammeter ±0.01 A
connecting leads
12 V 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 IUOAC chemical nomenclature unless inappropriate.

1.3 OBTAINING RESOURCES FROM OUR PLANET–

1.3.1 OBTAINING CLEAN WATER

Applied Context
Water is a fundamental need of every living thing. In this topic learners are introduced to the composition of water and the need to treat water before it can be used by the public. Learners can apply their knowledge in a number of fields including the chemical industry and environmental monitoring. This section is common core content.

	Spec Statement	Comment
(a)	elements as substances that cannot be broken down by chemical means and as the building blocks of all substances; the symbols of elements; how to work out the formulae of simple compounds	Be able to construct formulae and interpret given chemical formulae i.e. name the elements; state the number of atoms of each element and the total number of atoms present.
(b)	the terms atomic number, mass number and isotope including their definition; the information obtainable from the atomic number and mass number to include number of protons, neutrons or electrons in a particular atom and the electronic structures of an atom; the difference between an atom and an ion	Comparison of the atomic structure of atoms of different elements / isotopes. Be able to calculate relative molecular (formula) masses using A_r values from the Periodic Table. The formal definition of relative atomic mass is not required **but higher tier candidates should know how A_r is different to mass number.** Recall the definitions for both terms and to use them to identify the numbers of protons, neutrons and electrons in any given atom/ion. Write and draw electronic configurations of atoms and ions.
(c)	the differences between elements and compounds in terms of elements being composed of one type of atom while compounds are made of two or more different types of atom that are chemically joined	Know that in a chemical reaction, atoms are rearranged but none are created or destroyed.
(d)	the composition of water in 'natural' water supplies, including dissolved gases, ions including metal ions, carbonates and nitrates, particulate matter, parasitic microorganisms, organic matter and pesticides	Rainwater contains dissolved CO_2 (which lowers the pH) and O_2. Groundwater contains ions such as Mg^{2+}, Ca^{2+}, Na^+ and K^+ from minerals dissolved as it permeates through rocks. Candidates will <u>not</u> be expected to name any microorganisms present in water. Be aware that man-made pollutants include fertilisers, pesticides and household and industrial waste. Natural pollutants include bacteria and viruses.

(e)	the need for a sustainable water supply to include reducing our water consumption, reducing the environmental impacts of abstracting, distributing and treating water	Understand 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. 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.
(f)	the treatment of the public water supply using sedimentation, filtration, ozone dosing 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.
(g)	desalination of sea water to supply drinking water including the sustainability of this process on a large scale	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. 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.
(h)	the separation of water and other miscible liquids by distillation	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. **Higher tier candidates should appreciate that it is not possible to obtain 'pure ethanol' from a mixture with water because some water evaporates at temperatures below its boiling point.**
(i)	solubility curves including the drawing and interpreting of data on changes in solubility with temperature	Be familiar with the following methods: • 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. • 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.

(j)	the causes of hardness in water and distinguish between hard and soft waters by their action with soap	Know that hardness in water is caused by the presence of Ca^{2+} and Mg^{2+} 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. 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. **Higher tier candidates should be able to explain this in terms of the removal of hydrogencarbonate ions.**
(k)	the processes to soften water to include boiling, adding sodium carbonate and ion exchange; the advantages and disadvantages of different methods of water softening	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. **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.** **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.**
(l)	the impacts of hard water to include affects upon boilers, water pipes and health	Recall that boilers and hot water pipes become 'furred up' as calcium carbonate precipitates – boilers become less efficient and pipes can become completely blocked.

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

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

Method

1. Measure 50 cm^3 of water sample **A** into a conical flask.
2. Add 1 cm^3 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 50 cm^3 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^3)
  Boiled de-ionised water (1 cm^3)

- **B - Permanent Hard Water**
  Unboiled 60% magnesium hard water, 40% calcium hard water (8 cm^3)
  Boiled 60% magnesium hard water, 40% calcium hard water (8 cm^3)

- **C - Temporary Hard Water**
  Unboiled 50% magnesium hard water, 50% calcium hard water (12 cm^3)
  Boiled de-ionised water (1 cm^3)

- **D - Permanent hard water**
  Unboiled calcium hard water (15 cm^3)
  Boiled calcium hard water (15 cm^3)

- Hard water solutions
  - Magnesium hard water – 0.45 g/dm^3 magnesium sulphate
  - Calcium hard water – 0.45 g/dm^3 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^3)
  Boiled 50% calcium hard water, de-ionised water (8 cm^3)

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

Water sample	Tally chart of volume of soap solution added (cm^3)	Total volume of soap solution added (cm^3)

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.

1.3 OBTAINING RESOURCES FROM OUR PLANET –

1.3.2 OUR PLANET

Applied Context
This topic helps learners understand how raw materials such as metal ores, crude oil and gases such as oxygen are obtained from the Earth's crust or atmosphere and processed. They will also consider the benefits and environmental impacts of obtaining these materials. Understanding the chemical structure of these raw materials enables scientists to make the best use of them. Learners can apply their knowledge in a number of fields including the chemical industry and engineering. This section is common core content.

	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	The Earth's outer layer, (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. 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: • Jigsaw-like fit of the edges of continents e.g. the west coast of Africa and the east coast of South America; • Similar rocks of the same age found on different continents; • Similar plant and animal fossils found on opposite sides of huge oceans. 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'.

(c)	the process occurring at tectonic plate boundaries where plates slide past one another, move towards one another and move apart	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.
(d)	the composition of the original atmosphere to include gases from volcanoes such as carbon dioxide and water vapour	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.
(e)	the present composition of the atmosphere; how the composition of the atmosphere has changed over geological time	The surface of the Earth cooled over time and water vapour present in the early atmosphere condensed forming the oceans. 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. These changes occurred over billions of years and eventually led to the composition with which we are familiar: nitrogen 78% oxygen 21% argon (+ other noble gases) 0.9% carbon dioxide 0.04%

(f)	the periodic table as a tabular display of elements with elements arranged in periods and groups with elements in the same group having similar properties; the two main classes of elements with metals found to the left and centre of the periodic table and non-metals are to the right of the table; the similarities and trends of elements within a group as illustrated by data from group 1 and 7	Identify an element given its group and period, and vice versa. 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. Examine data about the physical and chemical properties of elements to establish trends within groups and to make predictions based on these trends (e.g. atomic number, melting point, boiling point, density and atomic radius). 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.
(g)	chemical reactions that involve transformation of one set of chemical compounds into another; that in a chemical reaction, atoms are re-arranged to make new products and no atoms are lost or gained; word and balanced symbol equations for simple chemical reactions (e.g. magnesium and oxygen, carbon and oxygen to form carbon dioxide, alkali metals and halogens)	The emphasis here is on the skills of writing and balancing chemical equations. 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.
(h)	methods to obtain raw materials from the Earth's crust or atmosphere, including metal ores via surface and subsurface mining, shale gas via fracking, crude oil via drilling, salt via solution mining or deep-shaft mining, gases such as oxygen or nitrogen from air via fractional distillation, biomass feedstock (e.g. for bioplastic production)	Detailed descriptions of extraction methods are not required.
(i)	the need to process most raw materials to produce useful materials, including separation of components and / or chemical transformation	
(j)	crude oil as a complex mixture of hydrocarbons which need separating to produce useful products; fractional distillation which utilises differences in boiling temperatures to separate fractions; each fraction as a less complex mixture which contain hydrocarbons with boiling points in the same range	Most fractions are used as fuels, others are further processed by cracking to make small, reactive molecules called monomers. Know the trends in boiling point and viscosity and link these with the number of carbon atoms.

(k)	cracking as a process to make more useful molecules including monomers	These monomers can be used to make plastics.
(l)	polymerisation reactions as processes that produce a polymer by linking monomers together into a repeating pattern	
(m)	bioplastics as produced from renewable sources such as vegetable oil or corn starch; the advantages and disadvantages of using plastics from renewable biomass sources	
(n)	ores as rocks that contain metals or compounds of metals	Appreciate that metals/metal compounds are obtained from the ground.
(o)	reduction processes used in metal extraction limited to reduction with carbon/carbon monoxide or electrolysis; reduction as a process in which oxygen is removed or electrons added and oxidation as a process in which oxygen is added or electrons removed; a metal's position in the reactivity series determining the reduction processes used; electrolysis reactions that involve an electric current flowing through a molten ionic compound or ionic compound in solution	Understand the process of iron extraction in the blast furnace and aluminium via electrolysis.
(p)	extraction of iron using a blast furnace and extraction of aluminium using electrolysis including the raw materials and reactions occurring in each process; word and balanced symbol equations for these reactions	Understand that the extraction of aluminium requires greater energy input than the extraction of iron and that the method used to extract the most reactive metals (including aluminium) is electrolysis
(q)	the use of electrolysis to electroplate objects; the main reasons for electroplating including reduction of abrasive wear, improve corrosion protection and aesthetics	Know that the article to be electroplated is made the cathode, and immersed in an aqueous solution containing ions of the required metal. The anode is usually a bar of the metal used for plating. During electrolysis metal is deposited on the article as metal from the anode goes into solution. Explain in terms of ion movement and electron gain/loss, using the terms electrode, anode, cathode and electrolyte. Suitable objects that are electroplated include jewellery, cutlery and cookery utensils.

(r)	the main costs of extracting and processing useful raw materials (labour, energy costs, demand)	Evaluate the cost and environmental impact of the extraction of metals from their ores compared to recycling.
(s)	the fate of discarded products, to include the expected life in the environment, persistence of plastics in the environment, the role of microbes in the breakdown of biodegradable plastics, the corrosion of metals	
(t)	the environmental, social and economic impacts of obtaining and processing raw materials e.g. the impacts of mining including spoil heaps; drilling for oil including oil spills; fracking; impact of using crops to produce raw materials for fuels/ producing bioplastics on food production; the effect on the world's oceans and marine life of waste plastics in the environment	

SPECIFIED PRACTICAL WORK

- Preparation of a biopolymer including the effect of a plasticiser.

Preparation of a biopolymer including the effect of a plasticiser

Introduction

In this practical you will make a plastic from potato starch and investigate the effect that adding a plasticiser has on the properties of the polymer that you make.

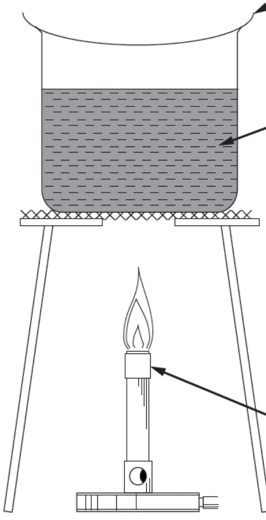
Apparatus

400 cm^3 beaker
250 cm^3 beaker
large watch glass
Bunsen burner
heat resistant mat
tripod
gauze
stirring rod
Petri dish or white tile
universal indicator paper
dropping pipette
25 cm^3 measuring cylinder
dilute hydrochloric acid (0.1 mol/dm^3)
dilute sodium hydroxide (0.1 mol/dm^3)
distilled water (about 500 cm^3)

Access to:

potato starch
food colouring
Propane-1,2,3-triol (glycerol), (2 cm^3)

Diagram of Apparatus



Method

1. Put 22 cm^3 of water into the beaker and add 4 g of potato starch, 3 cm^3 of hydrochloric acid and 2 cm^3 of propane-1,2,3-triol.
2. Put the watch glass on top of the beaker and heat the mixture using the Bunsen burner. Bring it carefully to the boil and then boil it gently for 15 minutes. Do not boil it dry.
3. Dip the stirring rod into the mixture and dot it onto the indicator paper to measure the pH. Add enough sodium hydroxide solution drop by drop to neutralise the mixture, testing after each addition with indicator paper. You will probably need to add about 3 cm^3.
4. Add a drop of food colouring and mix thoroughly.
5. Pour the mixture onto a petri dish or white tile and push it around with the glass rod so that there is an even covering.
6. Repeat steps 1-6 but leave out the propane-1,2,3-triol.
7. Label the mixtures and leave them to dry out. It takes about one day on a radiator or sunny windowsill, or two days at room temperature. Alternatively, use a drying cabinet. It takes about 90 minutes at 100 °C.

Analysis

1. Compare the two films.

Technician notes

Risk Assessment

Hazard	Risk	Control measure
Dilute hydrochloric acid/ Dilute sodium hydroxide solutions are irritants	Splashing on to hand/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Hot apparatus may cause burns	Moving the Bunsen burner may burn skin	Do not move Bunsen burner until cool

Reagents:

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

If access to a balance is difficult, then starch can be pre-weighed.

If you have a drying cabinet, the mixture should dry in about 90 minutes at 100 °C.

While using food colouring is optional, it does enhance the product and the colour it gives makes the plastic film look more like plastic. Only one drop is needed or the film is too dark.

Care should be taken not to let the substances boil dry, as they can spit and have a tendency to jump out of the beaker.

If you wish, you can prepare your own potato starch using the following method, which produces enough for one group.

1. Grate about 100 g of potato. The potato does not need to be peeled, but it should be clean. Put the potato into the mortar.
2. Add about 100 cm^3 of distilled water to the mortar, and grind the potato carefully.
3. Pour the liquid off through the tea strainer into the beaker, leaving the potato behind in the mortar.
4. Repeat steps 2 and 3 twice more.
5. Leave the mixture to settle in the beaker for 5 minutes.
6. Decant the water from the beaker, leaving behind the white starch which should have settled in the bottom. Put about 100 cm^3 of distilled water in with the starch and stir gently. Leave to settle again and then decant the water, leaving the starch behind.

When students compare the two films, the one without the propane-1,2,3-triol is far more brittle, the one with it shows more plastic properties.

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**
   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.

1.3 OBTAINING RESOURCES FROM OUR PLANET -
1.3.3 PRODUCING USEFUL COMPOUNDS IN THE LABORATORY

Applied Context
Chemical companies have to maximise the amount of product produced from starting materials. This topic introduces the basic chemistry and skills needed to prepare compounds in the laboratory. Learners will use their understanding of laboratory procedures to evaluate the suitability of a method. Learners can apply their knowledge in a number of fields including the chemical and pharmaceutical industries.

	Spec Statement	Comment
(a)	the reactions of acids with metals, metal oxides, hydroxides, carbonates and ammonia; the patterns that exist in these reactions and use these patterns to make predictions about the outcome of reactions	Be able to write word and balanced symbol equations of the reactions of acids with metals, metal oxides, hydroxides, carbonates and ammonia.
(b)	laboratory techniques to make useful salts, including insoluble salts (precipitation reactions e.g. copper carbonate) and soluble salts (e.g. copper sulfate, zinc sulfate, potassium nitrate, ammonium nitrate)	Write word and balanced symbol equations of these reactions.
(c)	laboratory procedures to evaluate the suitability of different methods of compound preparation, including the hazards in preparation, skills required, time, and success of the preparation	
(d)	chemical change to write word and symbol equations for simple neutralisation reactions (e.g. the formation of sodium chloride, potassium nitrate)	Be able to classify substances as acidic, alkaline or neutral in terms of the pH scale, including acid/alkali strength, use of indicators.

SPECIFIED PRACTICAL WORK

- Preparation of useful salts (e.g. zinc sulfate).

Preparation of useful salts (e.g. zinc sulfate)

Introduction

Zinc is important for growth and for the development and health of body tissues. Zinc sulfate is used to treat and to prevent zinc deficiency.
In this experiment you will produce the soluble salt, zinc sulfate from the reaction between a base, zinc oxide and sulfuric acid.

zinc oxide	+	sulfuric acid	⟶	zinc sulfate	+	water
$ZnO(s)$	+	$H_2SO_4(aq)$	⟶	$ZnSO_4(aq)$	+	$H_2O(l)$

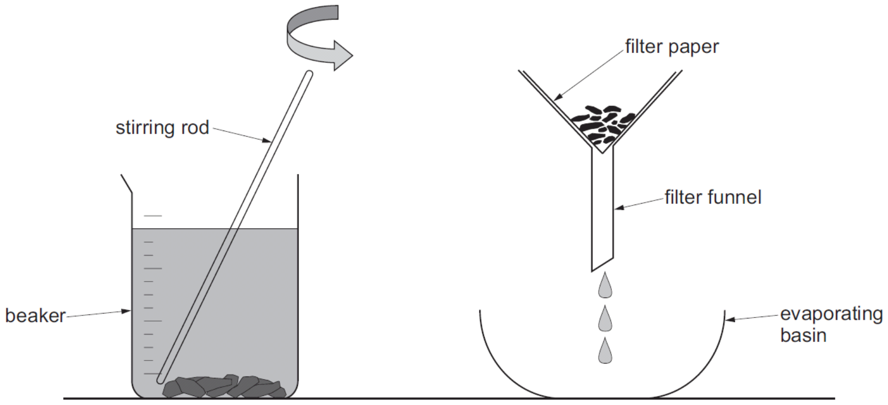
Apparatus

zinc oxide powder
1 mol/dm^3 sulfuric acid
filter paper
filter funnel
50 cm^3 measuring cylinder
250 cm^3 beaker
Bunsen burner
tripod and gauze
thermometer
evaporating basin

Access to:

electronic balance ±0.01 g

Diagram of Apparatus



Method

1. Weigh between 4.4 g and 5 g of zinc oxide onto a clean, dry filter paper. Record the mass used.
2. Measure 50 cm^3 of the 1 mol/dm^3 sulfuric acid into a 250 cm^3 beaker.
3. Heat the acid to approximately 50 °C.
4. Add the zinc oxide and stir.
5. Let the mixture cool then filter into an evaporating basin.
6. Boil the mixture in the evaporating basin until half the liquid has evaporated.
7. Leave to evaporate to dryness.
8. Scrape as much of the solid as possible onto a clean filter paper.
9. Record the mass obtained.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Sulfuric acid is an irritant	Splashing on to hand/skin/you whilst pouring Transfer from hand in to eye whilst pouring	Wash off/wear gloves Wear eye protection
Zinc sulfate is harmful	Splashing on to hand/skin/you whilst pouring Transfer from hand in to eye whilst pouring	Wash off/wear gloves Wear eye protection

Reagents:

- Zinc oxide - Refer to CLEAPSS hazcard 108B
- Zinc sulfate - Refer to CLEAPSS hazcard 108
- Sulfuric acid [1.0 mol/dm^3] - Refer to CLEAPSS hazcard 98A

This experiment provides a good opportunity to calculate percentage yield as an additional step.

If the mass is not to be weighed at the end, the quantities of zinc oxide and sulfuric acid could be halved.

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.

UNIT 2 - SPACE, HEALTH and LIFE

2.1 OUR PLANET -

2.1.1 OUR PLACE IN THE UNIVERSE

Applied Context
In this section learners will explore the changing Universe. Scientists use many different techniques to observe and search for patterns in the Universe in an attempt to understand and gather evidence concerning how it began, what it is now like, and how it is changing. Learners can apply their knowledge in a number of fields including communications and space exploration.

	Spec Statement	Comment
(a)	the main parts of the electromagnetic spectrum including gamma rays, X-rays, ultraviolet, visible light, infra-red, microwaves and radio waves; the arrangement and scale of the electromagnetic spectrum in terms of frequencies, wavelengths and energies	Be able to name the 7 regions of the electromagnetic 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, $c = 3 \times 10^8$ m s^{-1} will be given if needed.
(b)	the relationship between the speed, frequency and wavelength of electromagnetic spectrum waves: wave speed = frequency $\times$ wavelength	Be aware of the units kHz, MHz, SI multipliers Manipulation of an equation only required on higher tier. On foundation tier, the equation will be given in the form required if it involves a change to the subject.
(c)	how theories about the Universe have changed over time to include the Steady State theory and Big Bang; differences in the two theories with reference to expansion of the Universe in the Big Bang theory; the Big Bang in which the Universe is believed to have started about 13.5 thousand million years ago; **how evidence from red shift and Cosmic Microwave Background Radiation (CMBR) is consistent with the Big Bang theory**	The wavelength of the early radiation in the form of short wavelength radiation (gamma rays) has become longer wavelength (microwave) radiation that presently pervades the Universe. This change (increase) in wavelength is believed to be due to the expansion of space. Be aware of diagrams showing line spectrums and how these change for galaxies moving at different rates. **Students should understand and describe the origin of CMBR and why the radiation is in the microwave region of the spectrum**

(d)	how images of the universe are taken by Earth based systems, and space craft and transmitted to Earth; how electromagnetic waves are used to study structures in the universe e.g. • X-ray images of stars • ultra violet images of the Sun, galaxies and the planets • visible light images of the Sun, the planets, moons and galaxies • infra-red images of the Sun, the planets and the Milky Way • microwave images of the Sun **and Cosmic Microwave Background Radiation (CMBR**) • radio wave images of stars • images of black holes	Be aware of the types of images listed.
(e)	the relative scale of the Universe, galaxies, and solar systems in terms of light years	Understand the difference in size of objects in the Universe. Recall that one light year is the distance that light will travel in 1 year.
(f)	absorption spectra to include how they are produced and provide information about stars and galaxies (composition and relative movement)	The idea that light of certain frequencies is absorbed by gases on the outside of stars/between stars and these correspond to the line emission spectrum of elements in those gases
(g)	the structure of our solar system to include the Sun, planets (rocky planets, gas giants, and dwarf planets), main moons, the asteroid belt, comets and the Oort Cloud	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.
(h)	the Sun to include the relative size and mass to the Earth; nuclear fusion as the source of solar energy; Sun spots; solar flares and their effect on Earth (e.g. on telecommunications)	
(i)	data to identify patterns and compare objects in the solar system (e.g. mean surface temperature, period of rotation, length of day, distance from Sun)	Be able to interpret given data

2.1 OUR PLANET -

2.1.2 WORLD OF LIFE

Applied Context

Learners should be able to apply the concepts in this section to appreciate the variety of life on Earth, describe how living things depend upon each other and how their evolution is driven by living and non-living factors. Learners can apply their knowledge in a number of fields including the ecology and environmental analysis.

Spec Statement		Comment
(a)	biodiversity as a measure of the health of a biological system over time	Biodiversity is important as it provides food, potential foods, industrial materials, new medicines and for human well-being.
(b)	how organisms (plants and animals) are adapted to their environment and how this allows them to compete for resources and mates; the use of data (numbers and distribution of organism, characteristics of organism) to investigate the success of an organism in an environment	Students should be able to draw conclusions from charts, graphs or tables
(c)	strategies that organisms use to avoid adverse environmental conditions, such as hibernation and migration	Students should be given examples of organisms who migrate and hibernate
(d)	classification of organisms (plants, animals, microorganisms) that have similar features in a logical way	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.
(e)	different groups of organisms being distinguished according to characteristic features; genetic sequencing as a tool to confirm and sometimes reclassify species; classifications not necessarily being demonstrated as external features and characteristics	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.

(f)	the use of scientific names (binomial system developed by Linnaeus) as opposed to ‘common’ names	Scientific names are used for organisms so that each has a scientific name to aid its identification and classification and so avoid confusion and duplication caused by local or common names.
(g)	natural selection and its importance as a driving force for evolution; variation which occurs naturally; individuals with advantageous traits being more likely to be reproductively successful; genes of these individuals being passed on to future generations	Individual organisms in a particular species may show a wide range of variation because of differences in their genes (heritable variation). 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. Students should be able to explain the process of natural selection in given examples.

SPECIFIED PRACTICAL WORK

- Investigation into factors affecting the distribution and abundance of a species.

Investigation into factors affecting the distribution and abundance of a species

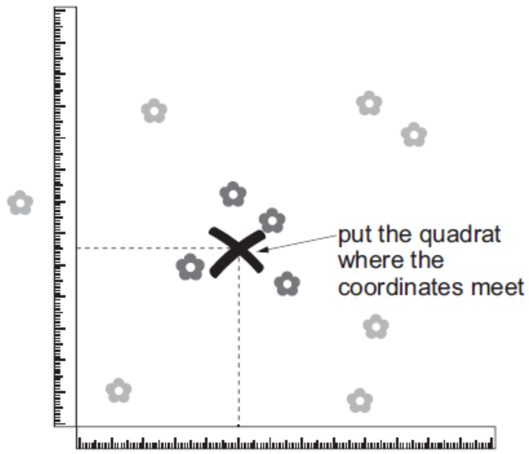
Introduction

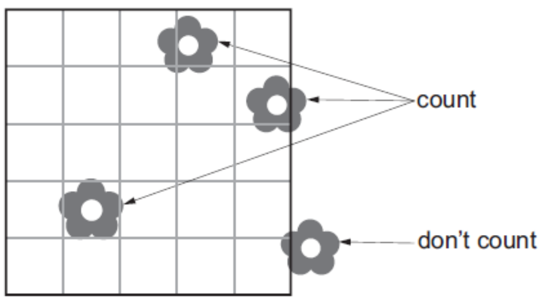
Daisies are a common plant species that can be found on a school field. Using quadrats for random sampling allows you to estimate the numbers of daisy plants growing in this habitat. This technique also reduces sampling bias. A simple calculation can then be used to estimate the total number of daisy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

Apparatus

2 × 20 m tape measures
2 × 20 sided dice
1 m^2 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^2 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:

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

Where:
total area = 400 m^2
total sample area = number of 1 m^2 quadrats used

Teacher/Technician notes

Risk Assessment

Hazard	Risk	Control measure
Some plants have thorns which can cut skin or sting	Can irritate skin when handling plants	Avoid touching plants when identifying/wear gloves
Tripping	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.

2.1 OUR PLANET -

2.1.3 TRANSFER AND RECYCLING OF NUTRIENTS

Applied Context
Learners will consider how ecosystems are in balance and how living organisms are dependent on their environment and each other for survival. They will also gain an appreciation of the impact that humans have on the Earth and the importance of sustainable developments for future generations. Learners can apply their knowledge in a number of fields including environmental monitoring, energy and biotechnology.

Spec Statement		Comment
(a)	food chains and food webs to show the transfer of useful energy between organisms; types of feeding (e.g. herbivore, carnivore); pyramids of numbers and biomass	Be aware that alternative terms for the organisms in the trophic levels include: primary consumers, secondary consumers and tertiary consumers. Be able to construct food chains, food webs and pyramids from given information
(b)	interdependency of organisms; plants that depend on invertebrates and other animals for pollination, seed dispersal, protection from grazers etc; animals that depend on plants either directly or indirectly for food, shelter etc; predation, disease and competition that cause large numbers of organisms to die; microorganisms that play an important role in the cycling of nutrients	This would include competition between species (interspecific) and between members of the same species (intraspecific). Be able to interpret predator-prey relationships.
(c)	radiation from the Sun being the source of energy for most ecosystems/communities of living organisms; capture of a small percentage of the solar energy by green plants which reaches them in a process known as photosynthesis	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.
(d)	loss of energy at each stage in the food chain due to waste materials and as heat during respiration	Analyse data in terms of: efficiency of energy transfer, numbers of organisms and biomass.

(e)	the carbon cycle (that carbon is recycled via photosynthesis, food chains, respiration and combustion); the role of bacteria and fungi in transferring carbon by feeding on waste materials from organisms and dead plants and animals, respiration and release of carbon dioxide into the atmosphere	Micro-organisms digest materials from their environment for growth and other life processes. These materials are returned to the environment either in waste products or when living things die and decay. When decay is prevented, fossil fuels such as coal, oil and gas are formed and these store energy in carbon compounds. Carbon is taken up by green plants in photosynthesis and is passed to animals when they eat the plants. Some of this carbon then becomes part of carbohydrates, fats and proteins which make up their bodies. Animals and plants release carbon dioxide during respiration
(f)	the effect of human activity (via burning fossil fuels, clearing forests) upon the levels of carbon dioxide in the atmosphere	Be able to interpret information showing the similarity between how CO_2 and mean global temperature have changed over time. Greenhouse gases allow for sufficient warming of the planet for liquid water to be present. Human activity beyond this is leading to climate change Evaluate effects of human activity on carbon dioxide levels.
(g)	the greenhouse effect caused by the Earth absorbing and emitting electromagnetic radiation that is absorbed by some gases (e.g. methane and water vapour) in the atmosphere, so keeping it warmer than it would otherwise be	
(h)	the greenhouse effect as being important to stabilize conditions for life but an enhanced greenhouse effect may have significant impact on climate, ice sheets and sea levels and agriculture	
(i)	proposed solutions to global warming to reduce human impact on the climate (e.g. reducing dependence on fossil fuels via reducing energy consumption, using alternative non-carbon sources of energy, carbon capture)	Be able to interpret data in tabular form and from charts and graphs to compare different sources of energy, and relate to carbon footprint
(j)	nutrients that are released during decay, e.g. nitrates, and that these nutrients are then taken up by other organisms resulting in nutrient cycles; that the processes which remove materials are balanced by processes which return materials in a stable community	The principle of cycling of elements is required. Knowledge of the nitrogen and phosphate cycles is not required.

(k)	**that nitrogen is also recycled through the activity of soil bacteria and fungi acting as decomposers, converting proteins and urea into ammonia; ammonia is converted to nitrates which are taken up by plant roots and used to make new protein**	**This includes the factors that affect bacterial action and influence the decomposition process in compost heaps and landfill sites e.g. temperature, oxygen, pH, heavy metals.** **Nitrogen fixation occurs in bacteria in root nodules of legume plants or free living bacteria in the soil. Some other bacteria break down the nitrate in the soil, returning nitrogen to the atmosphere. These are called denitrifying bacteria and they prefer to live in waterlogged/ unploughed soil.** **Names of bacterial species is not required**

2.2 PROTECTING OUR ENVIRONMENT

Applied Context
Learners will consider how the way we live affects the world around us. They will also gain an appreciation of the importance of sustainable development for future generations. Learners can apply their knowledge in a number of fields including environmental monitoring, energy and biotechnology.

	Spec Statement	Comment
(a)	how heavy metals from industrial waste and mining enter the food chain; how pesticides can enter the food chain; how heavy metals and pesticides can accumulate in animal bodies and may reach a toxic level and so have harmful effects (bioaccumulation)	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. Note that the term bioaccumulation is not sufficient as an answer without explanation to its meaning.
(b)	the rapid growth of photosynthesisers, plants and algae, in water due to untreated sewage and fertilisers; death of plants and algae, and the microbes which break them down, increase in number and further use up the dissolved oxygen in the water; animals, including fish, which live in the water may suffocate	The term eutrophication is not sufficient as an answer on examination papers. Candidates need to be able to explain this term if they use it.
(c)	environmental issues relating to the disposal of plastics, in terms of their non-biodegradability, increasing pressure on landfill for waste disposal; how recycling addresses these issues as well as the need to carefully manage the use of natural resources	Evaluation of how the need for and disposal of materials is affecting biodiversity
(d)	destruction of habitat due to increased land use for building, quarrying, dumping and agriculture, so causing loss of species and a reduction in biodiversity	
(e)	some of the measures to ensure sustainability such as the impact of reduce, reuse, recycle schemes or the use of biodegradable materials in packaging; problems associated with unsustainable disposal of waste in landfill sites	Biodegradable products break down into substances that may be useful (for example in compost). Non-degradable products use productive land in landfill, and partial breakdown produces toxic materials that may leak into the environment.

(f)	production of environmentally toxic substances by households (sewage and waste containing toxic substances such as batteries, used low energy light bulbs, old mobile phones); the impact of these waste products on the environment; how science helps manage the disposal of sewage (sewage treatment and the role of microbes in treating sewage)	Be aware of methods to minimise disposal of environmentally toxic substances.
(g)	environmental monitoring using living (e.g. lichens to monitor air pollution, invertebrate animals as water pollution indicators) and non-living indicators (pH and oxygen levels in streams to monitor water pollution)	This should include analysis of first or second hand data from different habitats e.g. abundance and distribution of lichens.
(h)	the need for, and issues surrounding sustainable development; the problem of increased consumption of resources and their continued supply	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. Biodiversity and endangered species can be conserved and protected by the following: • Convention on International Trade in Endangered Species • Sites of Special Scientific Interest • captive breeding programmes • national parks • seed/ sperm banks local biodiversity action plans.
(i)	maintenance of biodiversity using captive breeding programmes, seed banks and protected areas	
(j)	issues surrounding the creation of nature reserves and the need for corridors between reserves to allow movement and prevent isolation between populations of species	
(k)	reclamation of land previously used for industry and landfill and its importance for sustainable development	

SPECIFIED PRACTICAL WORK

- Investigation into how indicator species and changes in pH and oxygen levels may be used as signs of pollution

Investigate how indicator species and changes in pH and oxygen levels may be used as signs of pollution

Introduction

This is a fieldwork exercise that involves sampling water from streams (ideally) or ponds, in two different situations. Sample data are provided which could be used to discuss the process if you cannot carry out the practical work.

Apparatus

large container
indicator species sheet
animal keys
plastic trough or enamel dish (deep enough for water at a depth of 3-5 cm without spilling)
net
disposable gloves

Diagram of Apparatus

Method

1. Identify two locations to be tested e.g. these may be two different areas in the same river.
2. Collect some water in a large container – about 2-3 cm deep.
3. Collect samples of invertebrates using the net and transfer them to the tray. Try to use the same technique each time you collect the sample – holding the net the same way for the same amount of time. Scoop up some of the material from the bottom of the stream, or stir up the bottom and place the net downstream.
4. Study the organisms in the tray and try and identify the invertebrates against the chart – 'Invertebrate indicators of pollution'. If you cannot identify an invertebrate, take a picture or make a drawing to help identify it later on.
5. Record the number of each invertebrate that has been caught.
6. After identifying and counting the invertebrates, pour them and the water gently back into the stream.
7. Repeat steps 1-6 at the second location.

Analysis

1. Compare the invertebrates from each location and make a judgement as to the level of pollution in each.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Wet ground is slippery	May slip / trip and cause injury	Appropriate footwear to be worn
Disease causing microbes in water can cause illness	May get into body through abrasions and cause harm or may be transferred from hand to mouth	Cover all abrasions with plasters and wear gloves. Do not touch eyes / nose / mouth

There are a number of precautions that should be taken whilst conducting fieldwork (see risk assessment). Before working outside, prepare a risk assessment of the area and put any necessary risk control measures in place.

See CLEAPSS Supplementary Risk Assessment SRA 09 09/06 School ponds for more details. See also the guidance leaflet 'Group safety at water margins' which is downloadable from: http://www.rospa.com/leisuresafety/Info/WaterSafety/groupsafety-watermargins.pdf

Refer to CLEAPSS handbook section 17 for more information on planning safe outdoor activities, and to CLEAPSS supplementary risk assessment *Practical activities in the school grounds* (SRA 08, October 2006). Some elements of these ideas are listed in the safety notes for Biodiversity in your backyard.

You should also refer to your Local Authority or employer's guidelines for working outside the classroom in planning these activities.

This investigation will depend on the access you have to a safe enough area for collecting water samples. If you do not have a suitable area for students to assess, or do not have time for students to collect their own samples, you could collect samples yourself and keep the invertebrates in a tray of water for a day or so. A video or digital camera would be useful to make a record of the animals found, especially to keep information for later identification of unfamiliar invertebrates.

An example set of data from two streams is provided for analysis and discussion. You could work through this before or after students collect invertebrates from their own water samples.

Discourage students from trying to catch fish. Encourage them to treat all living things with the respect they deserve.

These indicator animals are usually quite easy to find if the students have a bit of patience. They are all delicate and so students must handle them with care.

The pictures given are typical of the invertebrates you are likely to find. Be aware that there are other species in each group, so the organisms you find may look different. The Field Studies Council key to freshwater invertebrates (link below) provides a more comprehensive list with colour illustrations: https://www.field-studies-council.org/

Identification clues:
Mayfly nymphs have three tails, whereas stonefly nymphs have two.
Caddis fly larvae collect bits of twig and stone around themselves to make a protective case. If any pieces of twig or stone seem unusually mobile, they are probably caddis fly larvae.

As well as an exercise in pollution monitoring, students can study ways in which living things are adapted to survive in their natural habitat. This follows on from considering why some organisms live only in unpolluted streams, while others survive despite pollution.

Sample results from two streams

Species	Total in sample	
	Stream A	Stream B
Mayfly nymph	4	0
Caddis fly larva	30	0
Freshwater shrimp	70	1
Water louse	34	4
Bloodworm	10	45
Sludge worm	2	100

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.

   Evaluate risks both in practical science and the wider societal context, including perception of risk in relation to data and consequences.

2. **Experimental skills and strategies**
   Recognise when to apply a knowledge of sampling techniques to ensure that any samples collected are representative.

   Evaluate methods and suggest possible improvements and further investigations.

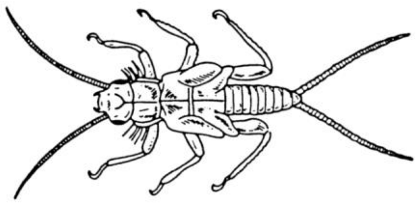
3. **Analysis and Evaluation**
   Translate data from one form to another.

Invertebrate indicators of pollution

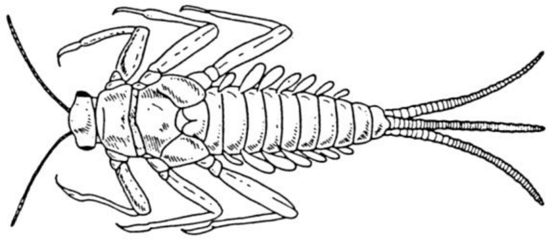
Different invertebrates will live in the water according to how polluted it is.
Unpolluted water is clear and also contains plenty of oxygen.
Polluted water may by cloudy, but more importantly, it often contains less oxygen.

Pollution level

A Clean water

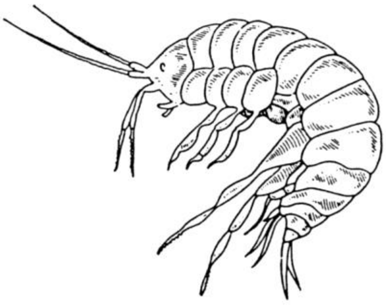


Stonefly nymph (about 10 mm)

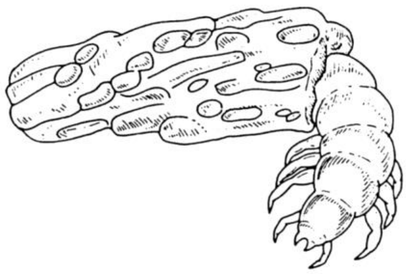


Mayfly nymph (about 20 mm)

B Some pollution

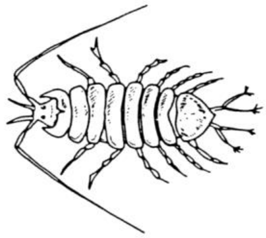


Freshwater shrimp (about 20 mm)



Caddis fly larva (about 10 mm)

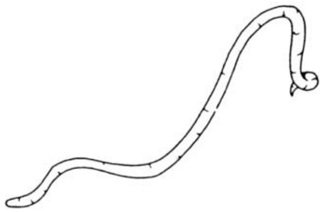
C Moderate pollution

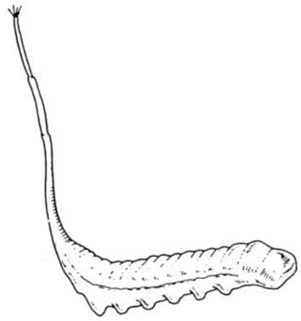


Water louse (about 10 mm)

Bloodworm (about 20 mm)

D High pollution





Sludgeworm (about 120 mm)

Rat-tailed maggot (up to 55 mm)

E Very high pollution – no life

2.3 HEALTH, FITNESS AND SPORT -

2.3.1 FACTORS AFFECTING HUMAN HEALTH

Applied Context
Human health is affected by a number of factors including inheritance, lifestyle and the environmental factors. Geneticists are trying to improve treatments to develop cures for genetic disorders. Nutritionists and dieticians help to improve health by controlling energy and nutrient intake. Health professionals need to be aware of how our bodies respond to internal and external changes and how we regulate out internal systems, in order to treat problems like diabetes. Learners can apply their knowledge in a number of fields including sport, nutrition and medicine.

	Spec Statement	Comment
(a)	chromosomes that contain DNA molecules which determine inherited characteristics and are found in pairs; genes as sections of DNA molecules that determine inherited characteristics and are found in pairs since chromosomes are normally found in pairs; different forms of genes called alleles that cause variation	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 structure of a DNA molecule as two strands coiled to form a double helix, joined by weak bonds between complementary base pairs, A bonds with T, C bonds with G (full names not required)	DNA has a ladder-like structure, the bases forming the rungs. They should have an understanding of complementary base pairing - A pairs with T and that C pairs with G.
(c)	Punnett squares to explain the outcomes of monohybrid crosses; the terms genotype, phenotype, recessive, dominant and allele; some changes in alleles that cause inherited diseases(e.g. Huntington's and Cystic Fibrosis); the implications of genetic screening and subsequent counselling, and the ethical problems posed by an individual's prior knowledge of the probability of such a genetic disease	Be able to produce and interpret genetic crosses as well as family tree diagrams. Inherited disease may be recessive or dominant. Although these are exemplified by cystic fibrosis and Huntington's disease, other conditions may be used which apply the same principles of inheritance. The terms gene and allele are not interchangeable.

(d)	new genes that result from changes (mutations) in existing genes; mutations that may be harmless, beneficial or harmful and may be passed on from parents to offspring	The greater the dose/exposure to ionising radiation the greater the chance of mutation. (No reference to specific ionising radiation is required.)
(e)	chromosome abnormalities in humans e.g. Down's syndrome	Some conditions are due to altered chromosome number e.g. Down's syndrome
(f)	the short term and long term impact of excessive alcohol consumption on the body and society; addiction as a consequence of sustained alcohol consumption	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.
(g)	how to calculate daily energy requirements and the body mass index (BMI) using: $BMI = \frac{mass}{height^2}$	Use of this data in terms of the advice offered by nutritionists. Calculation and interpretation of BMI is required.
(h)	the limitations of BMI, particularly for children and athletes; the causes, social and economic impact, and long term harmful effects of anorexia and obesity	Be aware of the limitations of BMI and how it could lead to incorrect advice.
(i)	the effects of smoking on the body and society	Physiological effects such as: lung disease, circulatory disease. 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. Social effects such as cost to NHS, rise in e-cigarettes, taxation

(j)	how epidemiological studies inform our knowledge of the impact of lifestyle (e.g. smoking, alcohol consumption, diet) on health; the ideas of correlation and cause appropriately and suggest factors that increase the chance of an outcome; why individual cases do not provide convincing evidence of, for or against, correlation; test design (sample sizes, how well samples match); the use of data to develop an argument that a factor does/does not increase the chance of an outcome	Link to statement (f), (g), (h) and (i) in this section.
(k)	the terms Guideline Daily Amount (GDA) and Recommended Daily Allowance (RDA) and their relevance to a controlled diet; the use of data to assess the energy requirement of individuals; the need for accurate information to be given on food labelling and be able to interpret food labels, including food traffic lights, use by dates, quantities and energy values of nutrients and other components of food, including salt and sugar	Be able to interpret GDA and RDA data. Know the effects of excessive consumption of sugar, fat, salt and other food additives. Discuss available data about nutritional content in highly processed food compared to less processed foods.
(l)	the effect of insufficient salt intake (muscle cramps, dizziness, electrolyte disturbance) and the risks with excessive intake (high blood pressure, stroke)	
(m)	the adverse health risks associated with obesity, especially the effect of obesity on the cardiovascular system and the risks of diabetes; the implications of obesity to society (impact on NHS and resources)	Consider the effects to the individual and society.

(n)	the role of insulin in glucose homeostasis; diabetes as a common disease in which a person has a high blood glucose level; type 1 diabetes due to the body not producing enough insulin; type 2 diabetes due to the body cells not properly responding to the insulin that is produced	Understand the concept of negative feedback. Insulin and glucagon are hormones produced by the pancreas, and are transported in the blood. Glucose can be stored in the liver and muscles in the form of glycogen.
(o)	how type 1 and type 2 diabetes can be controlled; diagnosis of diabetes by the presence of glucose in urine	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.
(p)	the effect of pollutants on human health, (e.g. atmospheric pollutants linked with asthma, heavy metals)	How allergens are linked to asthma. Effects of heavy metals e.g. lead and mercury on human health.

SPECIFIED PRACTICAL WORK

- Investigation of 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.

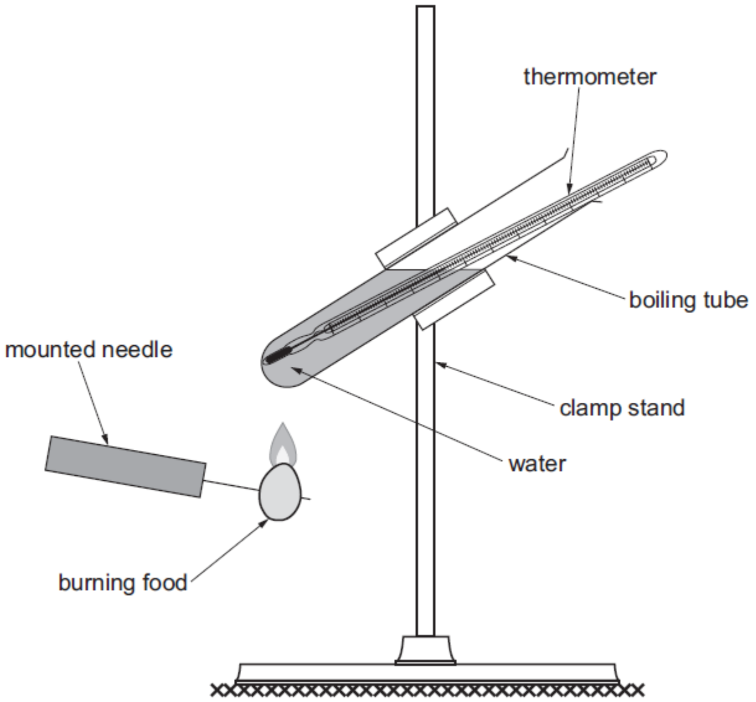
Apparatus

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

Access to:

electronic balance ±0.1 g

Diagram of Apparatus



Method

1. Measure 20 cm^3 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

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

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

3. Compare your results with the theoretical value on the food packet.

4. Evaluate your method and suggest how it could be improved.

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 whilst handling/burning	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 OWTTE	Keep hands a safe distance from the flame Wear heat proof gloves

4.2 J / kg °C is the value for the specific heat capacity of water. 1 cm^3 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 (ºC)	Temperature at end (ºC)	Temperature increase (ºC)	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 IUOAC chemical nomenclature unless inappropriate

2.3 HEALTH, FITNESS AND SPORT -

2.3.2 DIAGNOSIS AND TREATMENT

Applied Context
Medical scientists develop methods to diagnose and treat disease. Scientists have discovered that ionising radiation can be very helpful to us, as well as very harmful. They have found out that certain parts of the electromagnetic spectrum can also be used in diagnosis. This topic looks at imaging methods to diagnose disease and progresses to study ways to treat disease. Learners can apply their learning in medical and fitness fields.

Spec Statement		Comment
(a)	the role of the electromagnetic spectrum in diagnosis of disease and injury	Link to statement (d), (e) and (f) in this section.
(b)	drug treatments that have positive effects and possible side effects on the patient as exemplified by aspirin as a common treatment of patients suffering cardiovascular disease (positive: reduces the risk of blood clots occurring and so the chances of a heart attack; negative: prolonged treatment with aspirin can cause bleeding in the patient's stomach and stomach ulcers)	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.
(c)	the stringent testing that new drugs undergo before they can be released for general use; animal testing and clinical trials; ethical decisions with differences of opinion on what is acceptable	The use of the terms blind, double blind and placebo in the context of drug development should be understood. Consider reasons for and against the use of animals in the testing of new drugs.
(d)	ionising radiation; radioactive emissions from radioisotopes (such as iodine-131) and short wavelength parts of the electromagnetic spectrum (ultraviolet, X-ray and gamma ray)	Radiation can refer to any waves or particles emitted from a source. Ionising radiations cause the removal of electrons from atoms.
(e)	formation of images by a gamma camera detecting gamma rays, used in diagnosing cancer; delivery of radioisotopes by drugs that carry the radioisotope to target organs in the body	Tracers are specially formulated substances which collect in a specific part of the body. These substances emit faint gamma ray signals which are detected using a gamma camera.

(f)	the differences between, alpha, beta and gamma radiation, to include that α and *β* are particles **(*α* a helium nucleus and is a high velocity electron ejected from the nucleus of a decaying atom)** while *γ* radiation is electromagnetic radiation, their relative penetrating and ionising power	Understand the difference in risk for alpha, beta or gamma sources outside or inside the body. link with statement (g) in this section 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.
(g)	the interaction between ionising radiation and atoms or molecules, damaging the DNA of cells; cancer cells being more susceptible to damage from ionising radiation and die or reproduce more slowly; some healthy cells being affected by the treatment	Understand that ionising radiation kills living cells and because of this can be used to treat cancer. Healthy cells could be damaged due to mutations in the DNA.
(h)	radiotherapy using ionising radiation in the treatment of cancer; the difference between external radiotherapy which uses an external source of X-rays that are targeted at a tumour and internal radiotherapy which uses a radioisotope, such as iodine-131, taken as a drink or injected into a vein; radioisotopes used in internal radiotherapy that constantly emit ionising radiation but these emissions halve in a short period of time (e.g. the ionising radiation emissions from iodine-131 half every 8 days); the concept of half-life	Be able to select a suitable isotope for a given application and explain their choice. 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.
(i)	use of data to select the most suitable radioisotope for a medical purpose	Candidates should decide on suitability of sources depending on type of radiation emitted, its penetrating power, ionising power, damage to healthy cells and half-life
(j)	chemotherapy as a type of cancer treatment, in which medicine is used to kill cancer cells by damaging them, so they can't reproduce and spread and is often used in conjunction with radiotherapy	

(k)	medical imaging as a technique that uses electromagnetic radiation or sound waves to create images of the human body to reveal, diagnose or examine disease	Links to statement (l)-(o) in this section.
(l)	the use of ultrasound in the diagnosis of diseases and safe monitoring during pregnancy; the production of ultrasound images by sound bouncing off a boundary between two different structures of different density	Ultra-sound uses high frequency sound waves.
(m)	X-rays that are used in both X-ray examinations and CAT scanners; X-ray images as two-dimensional while those taken using a CAT scanner are three-dimensional; CAT scan images formed by processing together a large number of two-dimensional X-ray images taken around an axis; absorption of X-rays by denser objects in the human body (e.g. bones) but not by softer material	
(n)	MRI scans that use strong magnetic fields to form images of the body	The magnetic field is varied throughout the body to allow the position of the source of radio waves emitted from the body to be determined
(o)	uses of X-rays, CAT scans, ultrasound and MRI	No reference to contrast media required.

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	**500**
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.

2.3 HEALTH, FITNESS AND SPORT -

2.3.3 FIGHTING DISEASE

Applied Contex
Treatment of infection and disease is extremely important, and as our life expectancy increases, new diseases will arise. Medical scientists have developed vaccinations, which can prevent life-threatening infections. Learners can apply their knowledge to the health, medicinal and pharmaceutical industries.

	Spec Statement	Comment
(a)	microorganisms, to include some microorganisms that are harmless and perform vital functions, and some microorganisms, called pathogens, that cause diseases; the barrier against microorganisms formed by intact skin; defence of the body by: blood clots to seal wounds; white cells in the blood that ingest microorganisms and produce antibodies and antitoxins; competition of pathogens with the body's natural population of microorganisms	Blood clots seal wounds to prevent entry of microbes. White cells in the blood help to defend the body against microbes by: • ingesting bacteria • producing antibodies which inactivate particular bacteria or viruses • producing antitoxins which counteract the toxins released by bacteria. The community of microorganisms on the skin, the skin flora, make it difficult for pathogens to become established.
(b)	protection of humans from infectious disease by vaccination; factors influencing parents in decisions about whether to have children vaccinated or not, including the need for sound scientific evidence and the effect of the media and public opinion	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.
(c)	antigens as molecules that are recognised by the immune system; antigen response by some white blood cells, lymphocytes, which secrete antibodies specific to the antigen; 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.
(d)	vaccines that contain antigens (or parts of antigens) that are derived from disease-causing organisms; protection against infection by vaccines due to stimulating antibody production to protect against bacteria and viruses	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).

(e)	memory cells that are produced following natural infection or vaccination that produce specific antibodies very quickly if the same antigen is encountered a second time	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.
(f)	measles as a condition that most people suffer only once, but flu occurs many times in a lifetime	How occurrence of disease has changed as a result of increased use of vaccinations. The high mutation rate of the influenza virus.
(g)	antibiotics, including penicillin, that were originally medicines produced by living organisms, such as fungi; treatment of bacterial disease by antibiotics that kill the infecting bacteria or prevent their growth	
(h)	resistance resulting from overuse of antibiotics, such as MRSA; effective control measures for MRSA	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. MRSA control measures could include: • hand washing • thorough cleaning of hospital wards • use of alcohol gels • MRSA screening

SPECIFIED PRACTICAL WORK

- Investigation into the effect of antibiotics on bacterial growth

Investigation of the effect of antibiotics on bacterial growth

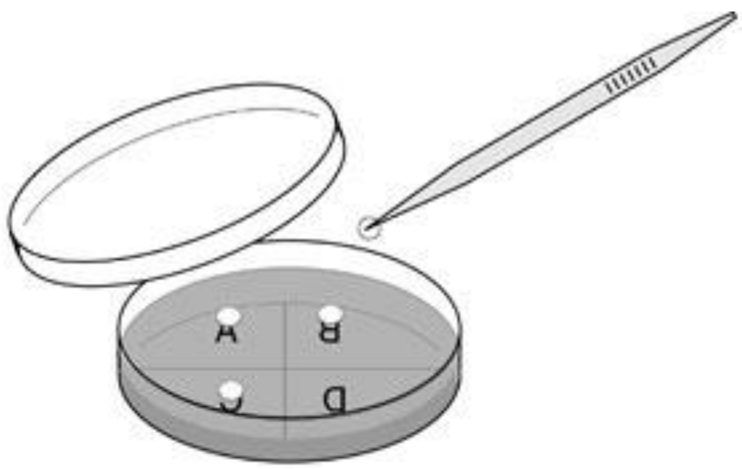
Introduction

Antimicrobials are agents that are able to kill bacteria or halt their growth. They are widely used in medicine to treat bacterial infections. In this experiment you will test different anti-microbial agents to assess how they affect bacterial growth.

Apparatus

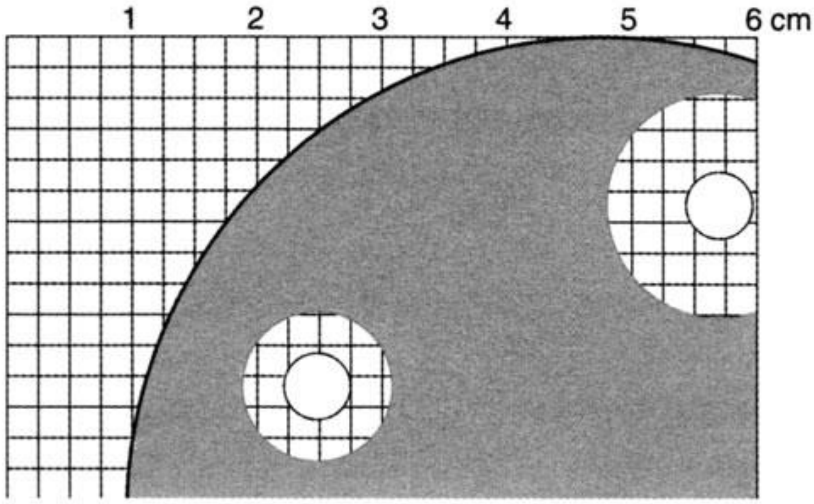
Bunsen burner
1 × pre-prepared agar plate seeded with bacteria
4 × antimicrobial agents, labelled A, B, C and D
4-8 × paper discs (Whatman antibiotic assay paper discs/ or new filter/ chromatography paper cut with a hole punch then sterilised by autoclaving)
sterile forceps
adhesive tape
marker pen
disinfectant solution and cloth

Diagram of Apparatus



Method

1. Wash your hands with the soap or handwash. Wipe down the working area thoroughly with the disinfectant.
2. Work very close to a lit Bunsen burner. Flame the forceps and use them to pick up a filter paper disc and dip the disc into antibiotic A.
3. Allow them to dry for 5 minutes on an open, sterile Petri dish, next to a lit Bunsen burner.
4. Repeat step 3 for antibiotics B, C and D.
5. Use the agar plate that has already been prepared and seeded with bacteria.
6. Turn the dish upside down. Divide the base into four sections by drawing a cross with the marker pen. Label the sections A, B, C, D
7. Flame the forceps and then use them to pick up antibiotic disc **A**. Raise the lid of the Petri dish at an angle and place the disc onto the agar in the centre of section A.
8. Repeat step 5 for the other 3 discs. Make sure the discs are placed in the centre of each section.
9. Label the agar plate with your name and date. Tape the lid securely. Incubate inverted for 2-3 days at 20-25 °C.
10. Observe the plates without opening them.
11. Record the width of the clear zone around each antimicrobial. A piece of squared paper under the agar plate might be helpful here.



Analysis

1. Which antimicrobial agent was the most efficient in your investigation? Give reasons for your answer.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Bacteria can be pathogenic	Contracting infection from touching bacteria on open plate	Wash hands after placing discs Seal plate after placing discs
Bunsen burner flame and Forceps can burn	Burning skin when sterilising forceps	Care must be taken to keep hands a safe distance away from the flame. Do not touch tip of forceps after flaming

Detailed instructions are given on the link below.
http://www.nuffieldfoundation.org/practical-biology/investigating-anti-microbial-action

Making agar and pouring plates

a Calculate the quantity required and prepare just enough agar for the investigation – around 15 cm^3 for normal depth in a 90 mm Petri dish. Any surplus will keep for 6-12 months in tightly-sealed screw-top bottles if sterile.

b Weigh out the agar medium powder containing the gel and chosen nutrients, add water and sterilise the mixture for the time, and at the temperature, specified by the manufacturer.

c Heat agar and water at 95 °C to dissolve the agar. Always use a water bath to boil agar, and never add agar to boiling water.

d Stopper flasks with a well-fitting plug of non-absorbent cotton wool. Cover with greaseproof paper or aluminium foil before sterilising by autoclaving.

e After autoclaving, transfer to a water bath to equilibrate at 50 °C. Stack plates after pouring to minimise condensation except in the top plate(s).

f Warm the Petri dishes before pouring to minimise condensation.

g Keep poured plates in a sealed plastic bag until needed to reduce dehydration of the media.

Making a spread plate

1 Sterile spreaders are used to distribute inoculum of *Bacillus subtilis* over the surface of prepared agar plates. You can sterilise a wrapped glass spreader in a hot air oven or sterilise by flaming with alcohol.

2 To flame a spreader with alcohol:

- **a** Dip the lower end of the spreader into a small volume of alcohol (70% IDA) contained in a vessel with a lid (either a screw cap or aluminium foil) or in a glass (not plastic) Petri dish with a lid. Keep the alcohol container covered and 1 metre away from the Bunsen burner flame.
- **b** Pass quickly through a Bunsen burner flame to ignite the alcohol. Ensure the spreader is pointing downwards when and after igniting the alcohol to avoid burning yourself.
- **c** Remove the spreader from the flame and allow the alcohol to burn off. The burning alcohol will sterilise the glass.
- **d** Do not put the spreader down on the bench.

3 Cotton wool swabs can be used instead of glass spreaders. They may be preferable as they avoid the need for using alcohol as a sterilising agent. Prepare them by rolling small pieces of absorbent cotton wool around one end of a cocktail stick. Wrap individually in aluminium foil or place inside a universal bottle to sterilise in an autoclave or pressure cooker. These sterile swabs can then be dipped into the solution or culture to be transferred, rubbed on the surface of the agar plate, and immediately disposed of into disinfectant. (Note: Cotton buds from a pharmacist are not sterile and may be impregnated with an antimicrobial agent.)

4 Use agar plates with a well-dried surface so that the inoculum dries quickly. Dry the surface of agar plates by incubating for several hours (perhaps overnight) or put them in a hot air oven (at 55-60 °C) for 30-60 minutes with the two halves separated and the inner surfaces directed downwards.

The antibiotics can be bought as ready made discs or solutions can be made from everyday ingredients. Many types of toothpaste contain low concentrations of anti-microbials, and mouthwashes claim plaque-killing potential.

The ten spices with the most potent antibacterial effects are garlic, onion, allspice, oregano, thyme, cinnamon, tarragon, cumin, cloves and lemon grass. Many spices with relatively weak antibacterial effects become much more potent when combined; examples are in chili powder (typically a mixture of red pepper, onion, paprika, garlic, cumin and oregano) and five-spice powder (pepper, cinnamon, anise, fennel and cloves). Lemon and lime juice, while weak inhibitors themselves, also have synergistic effects.

It is also possible to investigate different dilutions of a particular anti-microbial.

Students should be made aware of aseptic techniques before starting the practical activity. It is possible that students can prepare their own pour plates and inoculate them if you wish.

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**
   Apply 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**
   Presenting observations and other data using appropriate methods.

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

2.3 HEALTH, FITNESS AND SPORT -

2.3.4 EXERCISE AND FITNESS IN HUMANS

Applied Context
Healthcare scientists working in fields related to exercise and fitness need to understand the organ systems in the body and the need for personal fitness. They need to compare physiological parameters of individuals to assess fitness. Learners can apply their learning in medical and fitness fields.

	Spec Statement	Comment
(a)	the need for energy to do work (muscle contraction)	
(b)	the role of the nervous system comprised of the central nervous system (the brain and spinal cord) and the peripheral nervous system in muscle contraction; nerve impulses as electrical signals carried by nerve cells, or neurones	Candidates should be able to recognise and label a diagram of a reflex arc
(c)	action of antagonistic muscles (e.g. biceps and triceps)	Describe the action of antagonistic muscles.
(d)	a synovial joint and its parts (cartilage, ligaments, synovial fluid and synovial membrane)	Label a diagram showing a synovial joint (e.g. the knee) and describe the function of cartilage, ligaments, synovial fluid and synovial membrane.) In a synovial joint: • Cartilage – reduces friction • Synovial fluid - lubricates joints • Synovial membrane – produces synovial fluid • Ligaments - join bones to bones • Tendons - join muscles to bone
(e)	disease (limited to osteoarthritis) and injury (e.g. torn ligaments) that can result in limited movement of joints; replacement of badly damaged joints by artificial joints	
(f)	the different types of fractures of bones: simple, compound and green stick	Use of X-ray images to study fracture types would be useful in this section.
(g)	the locations of a fixed joint (skull), hinge joint (elbow, knee), and ball and socket joint (shoulder, hip)	Know a joint is where bones meet.

(h)	distance-time and velocity-time graphs to analyse movement (walking, running, cycling)	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 **distance travelled (higher tier only) for a velocity-time graph.** Calculations will be required for curved sections of graphs as estimations and an understanding of the motion of the object will be expected.
(i)	mathematical equations to find useful information relating to movement: $\text{speed} = \frac{\text{distance}}{\text{time}}$ $\text{acceleration}\left(\text{or deceleration}\right) = \frac{\text{change in velocity}}{\text{time}}$	Manipulation of an equation only required on higher tier. On foundation tier, the equation will be given in the form required if it involves a change to the subject. Units of speed – m/s Units of acceleration - m/s^2
(j)	velocity-time graphs to determine acceleration and distance travelled	Acceleration is the gradient of velocity-time graph. Distance travelled is the area under the line of the Velocity-time graph.
(k)	structure and function of the human cardiovascular system to include the heart, ventricles, valves, atria, veins, arteries, capillaries and double circulatory system (names of valves not required)	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.

(l)	how the structure of blood vessels is related to function (arteries have thick, muscular walls, veins have thinner walls and valves to prevent backflow of blood, capillaries are one cell thick to allow exchange of substances); composition of blood and functions of red blood cells (containing haemoglobin), white blood cells, plasma and platelets	Compare the relative thickness of the blood vessel walls and the size of the lumen in arteries and veins. Veins contain valves. Know the difference in function between the main types of blood vessels (arteries, veins and capillaries) and why the purse can be felt at an artery. The functions of blood 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 for defence against disease. (No details of clotting mechanisms or immunity are required here)
(m)	measurements to monitor pulse rate, breathing rate and recovery time	Opportunity for practical work here.
(n)	physiological effects of exercise on breathing (short term effects: breathing rate increases to provide the oxygen and remove carbon dioxide. Long term effects: the body becomes more efficient at transporting oxygen)	
(o)	physiological effects of exercise on heart rate and recovery time (short term effects: heart rate increases, cardiac output increases. Long term effects: heart muscle strengthened, heart muscle becomes more efficient)	Recovery time gets shorter.

SPECIFIED PRACTICAL WORK

- Determination of the acceleration of a moving object

Determination of the acceleration of a moving object

Introduction

An object moving down an inclined ramp will accelerate. The velocity of the object as it leaves the ramp can be used to calculate the mean acceleration of the object using the formula:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

Since the object starts from rest at the top of the ramp this means that:

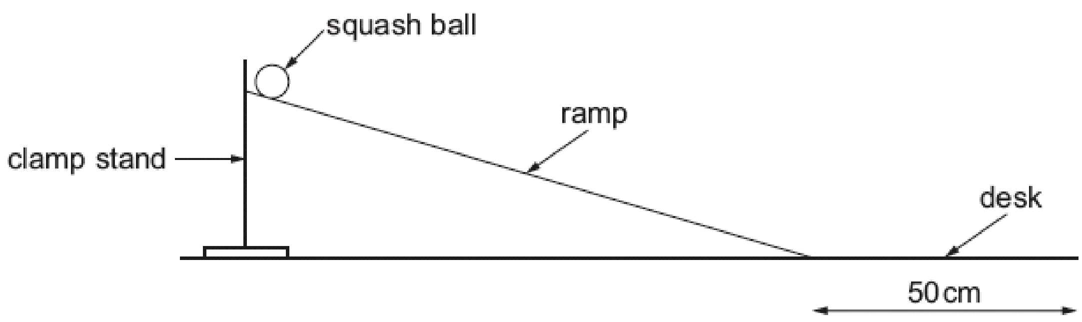
$$\text{acceleration} = \frac{\text{velocity at bottom of ramp}}{\text{time to reach bottom of ramp}}$$

The velocity at the bottom of the ramp can be calculated from the time the object takes to travel a certain distance along the bench.

Apparatus

ramp
squash ball
metre ruler ± 1 mm
stopwatch
clamp stand, clamp and boss

Diagram of Apparatus



Method

1. Set the height of the ramp to 10 cm above the desk.
2. Measure a distance of 50 cm from the end of the ramp and mark this point.
3. Release the squash ball from the top of the ramp starting the stopwatch as you do.
4. When the squash ball reaches the bottom of the ramp press the lap button on the stopwatch.
5. Stop the stopwatch when the squash ball reaches the 50 cm mark.
6. Record the time taken for the ball to travel down the ramp (lap time) and the total time.
7. Repeat steps 1-6 increasing the height in 5 cm intervals each time up to 25 cm.
8. Repeat the experiment twice more.

Analysis

1. Calculate the time taken for the ball to travel 50 cm along the bench; this is the total time – the lap time.
2. Calculate the velocity at the bottom of the ramp using the formula

$$\text{velocity} = \frac{0.5}{\text{mean time taken to travel 50 cm along the bench}}$$

3. Calculate the acceleration using the formula

$$\text{acceleration} = \frac{\text{velocity at bottom of ramp}}{\text{mean time to reach bottom of ramp}}$$

4. Plot a graph of ramp height against acceleration.

Teacher / Technician notes

Self-adhesive trunking which is widely available in DIY stores can be stuck onto metre rules to make effective ramps which work well with squash balls.

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

Height (cm)	Time to reach bottom of ramp (s)			Mean time to reach bottom of ramp (s)	Time to travel 50 cm along bench (s)			Mean time to travel 50 cm (s)	Velocity (m/s)	Acceleration (m/s^2)
	Trial 1	Trial 2	Trial 3		Trial 1	Trial 2	Trial 3			

This investigation is good for developing evaluation skills and students could be encouraged to judge the repeatability and reproducibility of their results. Data could be compared against doing the same experiment with data loggers and sources of error considered.

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**
   Evaluate methods and suggest possible improvements and further investigations.

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.

4. **Scientific vocabulary, quantities, units, symbols and nomenclature**
   Recognise the importance of scientific quantities and understand how they are determined.

UNIT 3 – FOOD, MATERIALS and PROCESSES

3.1 MATERIALS FOR A PURPOSE

Applied Context
This topic helps learners understand why a material is selected for a purpose. Learners should be able to make applications in a range of fields including sports equipment, safety equipment, cars, aircraft, medicine including artificial veins and joints. This section should be delivered as far as possible in terms of the knowledge, understanding and skills that material scientists use to carry out their work.

	Spec Statement	Comment
(a)	ionic bonding as strong electrostatic attraction between ions of opposite charge**; how the charge on an ion depends upon the position of an element in the periodic table (restricted to main group elements);** covalent bonding as the sharing of electrons between non-metal atoms to form molecules	In ionic compounds the strong electrostatic attraction between ions of opposite charge gives the compounds a close regular structure. The strong force of attraction makes it difficult to separate the ions, which is why ionic compounds have a high melting point. Covalent compounds share electrons and these compounds are easy to boil and melt. This is because the bonds that hold the atoms together in a covalent compound are strong but the bonds that hold the molecules together are weak. Use of dot and cross diagrams to represent ionic and covalent bonding.
(b)	the properties of ionic compounds to include high melting points, solubility in water (many, but not all, are soluble in water), electric conduction when molten or in solution	Use of data related to ionic compounds.
(c)	**metallic bonding as the strong attraction between closely packed positive metal ions and a 'sea' of delocalised electrons; how the characteristic properties of metals are related to metallic bonding;** the properties of metals to include awareness that there are important exceptions to the characteristic properties of metals (e.g. lead is a soft metal; mercury is a liquid at room temperature)	**This model should be used to explain why, in general, metals have high melting and boiling points, are good conductors of heat and electricity and are malleable and ductile.** Use of data to compare and identify different metals.

(d)	the main classes of materials (metals and alloys, polymers, ceramics, composites) and examples of each class of material	The characteristic properties of metals (high tensile strength, thermal conductivity, flexibility and hardness). Metals are malleable, can be hammered into shape and rolled into sheets. Alloys are a mixture of two or more elements, of which at least one is a metal. The characteristic properties of polymers are (low density, flexibility and low thermal conductivity). Some examples include: • *aluminium alloys* – used in aircraft frames, bicycle frames • *stainless steel* – used in exhaust systems, chemical tankers, surgical instruments, surgical implants, MRI scanners • *titanium and its alloys* – used in the building of high-performance bicycle frames, aircraft frames and replacement hip joints Ceramics are hard, brittle solids with very high melting points, low thermal conductivity and high resistance to chemical attack. Ceramics are used, for example, as heat-resistant tiles on space shuttles and catalytic converters, in pottery products and specialist industrial materials (e.g. lining furnaces). Composites are a combination of materials. Carbon fibre is an example of a composite material used to make bicycle frames, tennis rackets, badminton rackets, and the shafts of golf clubs. Link the properties of polymers to the model of their bonding (compounds made up of large long-chained molecules with strong covalent bonds between the atoms in the chain and weaker forces of attraction between the chains).
(e)	alloys, to include the definition of an alloy and differences in malleability, hardness and strength between alloys and pure metals	Use of data to distinguish between alloys and their properties. Link to statement (d) in this section.
(f)	allotropes of carbon to include the idea of giant molecules, the structure of **diamond,** graphite, graphene, carbon fibres, fullerenes and carbon nanotubes; how the properties of the giant molecules **diamond**, graphite and carbon nanotubes are related to bonding & structure; uses/potential uses of **diamond**, carbon fibre composites, graphite, graphene and carbon nanotubes (Note: the principles underpinning the semiconducting properties of materials are beyond the scope of a GCSE course)	Recognise each of these as giant structures containing covalent bonds. Carbon nanotubes should be considered as single layers from a graphite structure rolled into a tube shape. Typical diagrams to illustrate the molecular structures and therefore the properties of the allotropes of carbon. Relate the properties of these giant molecules to number of bonds and delocalised electrons.

(g)	characteristic properties of polymers to include awareness that there are important exceptions to these characteristic properties (e.g. Kevlar® is relatively hard and strong); how the properties of polymers are related to bonding and structure to include reference to the extent of cross-linking between chains, strong covalent bonding within chains and the weak forces between chains	Link the properties of polymers to the model of their bonding (compounds made up of large long-chained molecules with strong covalent bonds between the atoms in the chain and weaker forces of attraction between the chains.) *for example,* polymers are used in materials for sports clothing, for example as the foam inner layer of cycle helmets. Use of data to analyse the properties of polymers.
(h)	how carbon fibre can be mixed with polymers to form a material which is an example of a composite material	Link to statement (d) in this section.
(i)	practical procedures to include planning to test the properties of a material and interpreting the significance of the data obtained. Properties are to include: • stiffness/flexibility • toughness/brittleness • tensile (breaking) strength • hardness • density • durability • shock absorption • thermal conductivity • electrical conductivity	Opportunities for practical work here.
(j)	mathematical equations to find useful information about the properties of materials: $\text{density} = \dfrac{\text{mass}}{\text{volume}}$ $\text{stress} = \dfrac{\text{force}}{\text{cross-sectional area}}$ Hooke's Law force = constant $\times$ extension	Manipulation of an equation only required on higher tier. On foundation tier, the equation will be given in the form required if it involves a change to the subject.
(k)	how to assess the suitability of a material for a purpose to include using information on a material's properties (as described by the terms in 3.1(i), resistance to corrosion and biological inertness), cost, environmental impact and sustainability	Use of data to assess material suitability. Link to statement (d) in this section.

(l)	materials to explain why a combination of properties often makes a material suitable for a particular purpose; developments in materials to explain why materials used in sports equipment, clothing, car/aircraft parts, and surgery have changed over time	Describe and explain examples which show how the development of new materials has led to changes in equipment over time, resulting in changes in performance. Link to statement (d) in this section

SPECIFIED PRACTICAL WORK

- Investigation of the thermal conductivity of metals

Investigation of the thermal conductivity of metals

Introduction

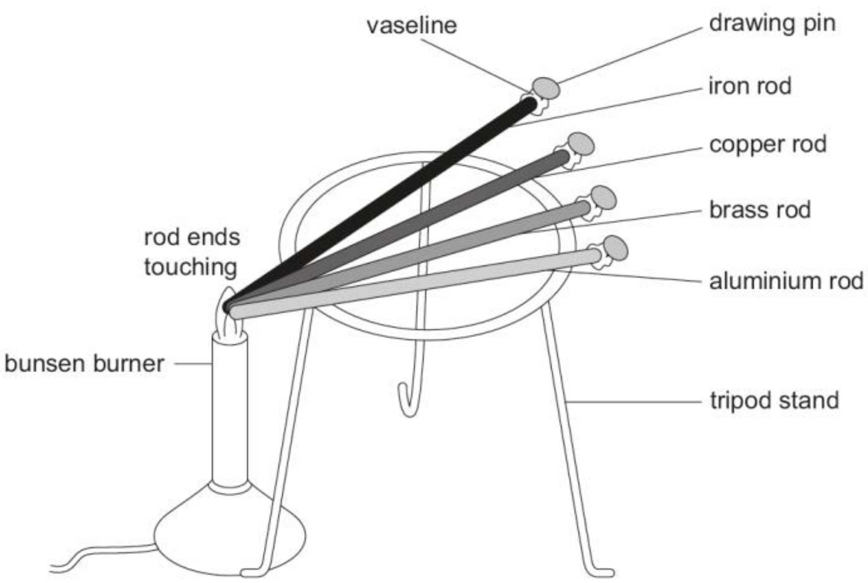
Metals are better conductors of heat than non-metals. However, some metals are much better conductors than others. In this investigation the thermal conductivity of 4 metals is compared and the metals can then be placed in order from the best conductor of heat to the poorest.

Apparatus

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

Diagram of Apparatus

Metal Rods Experiment



Method

1. Set up the apparatus as shown in the diagram.
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.

Analysis

1. Determine the order of conductivity of the metals.

Teacher / Technician Notes

Risk Assessment

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

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

The practical can be extended by adding four drawing pins to the underside of each rod and recording the time for each to fall.

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.

3.2 FOOD FOR THE FUTURE -

3.2.1 PRODUCING FOOD

Applied Context
The production of food requires a number of the scientific skills and techniques. Scientists need to consider how we can produce high quality food for the future but also maximise food output. Biotechnologists continuously research and develop ways of producing food. Learners can apply their learning in food science and processing, nutrition and health.

Spec Statement		Comment
(a)	the materials required by plants to support life processes	Include the materials required for photosynthesis as well as mineral requirement.
(b)	the general structure of a leaf	Recognise the structure of a leaf and be able to label the following structures: cuticle, epidermis, stomata, palisade layer, spongy layer, xylem and phloem; the structure of stomata to include guard cells and stoma; the fact that stomata can open and close to regulate transpiration and allow gas exchange. No details of the mechanism of stomatal opening are required.
(c)	photosynthesis, whereby green plants use chlorophyll to absorb light energy and convert carbon dioxide and water into glucose, producing oxygen as a by-product; the word equation for photosynthesis (details of the enzymes involved in photosynthesis are not required)	The chemical reactions of photosynthesis within the cell are controlled by enzymes. (Details of the enzymes involved in photosynthesis are not required.)
(d)	the conditions required for photosynthesis and the factors which affect its rate, including temperature, carbon dioxide and light intensity; **the concept of limiting factors**	Use of first hand data to show the need for carbon dioxide and the effect of light intensity on the rate of photosynthesis.
(e)	the fate of the glucose produced in photosynthesis (glucose may be respired to provide energy, converted to starch for storage or used to make cellulose and proteins which make up the body of plants)	
(f)	plant nutrient requirements and the effects of deficiencies on plant growth: lack of nitrates results in poor growth, deficiency of potassium results in yellowing of the leaf and deficiency of phosphate results in poor root growth; use of NPK fertilisers	Candidates should know that nutrients can be replaced by either natural (manure) or chemical fertilisers.

(g)	the differences (methods of production, yield, cost of production) between intensive and organic farming; the impact of pesticides and fertilisers on the environment; the differences of opinion on the ethics of these methods of food production	Use of data to compare different methods of production.
(h)	food products being grown in controlled environments to increase productivity; **hydroponics as a method of growing where soil is replaced by a mineral solution pumped around the plant roots**	Candidates should understand how controlled environments are used in intensive farming and be able to compare these with the techniques used in organic farming (for example, use of natural pests such as ladybirds or parasitic wasps and mechanical methods of weed control). **Hydroponics as an alternative growth method.**
(i)	artificial transfer of genes from one plant species to another to increase crop yield or improve product quality; potential disadvantages and issues involved	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. Candidates should be able to discuss the economic, social and ethical issues concerning genetic engineering and suggest possible long-term problems.
(j)	selective breeding in plants; potential of plants to be selectively bred in order to produce desirable traits; disadvantages of selective breeding to include a reduction in variation and increased susceptibility to disease	Selective breeding involves selecting the parents with desired traits, crossing them, selecting from their offspring and then repeating the process over several generations. Candidates should consider the impact of selective breeding and genetic engineering on the methods of food production over time.

SPECIFIED PRACTICAL WORK

- Investigation of the factors affecting photosynthesis

Investigation of the factors affecting photosynthesis

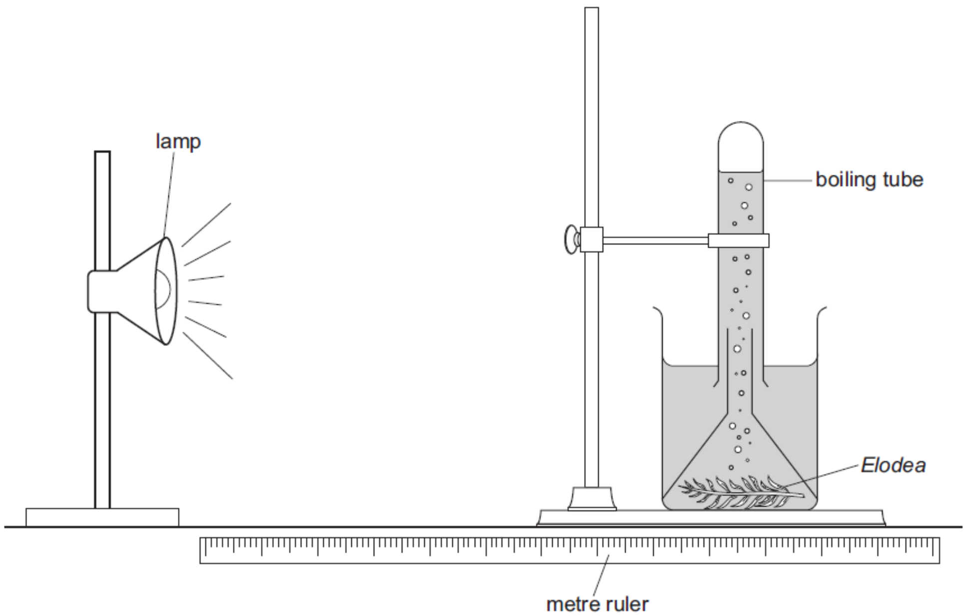
Introduction

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^3 beaker
lamp
glass funnel
plasticine
test tube
8 cm length of pondweed (*Elodea)*
metre ruler ± 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^3 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 {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 caroliana (and *Elodea crispa*) 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.

	Number of bubbles produced in one minute			
Distance from plant to lamp (cm)	**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.

3.2 FOOD FOR THE FUTURE -

3.2.2 FOOD PROCESSING AND SPOILAGE

Applied Context
The food industry requires a number of the scientific skills and techniques. Food scientists need to ensure that food is processed so that it is safe and appealing to the consumer. Learners can apply their learning in food science and processing, nutrition and health.

Spec Statement		Comment
(a)	bacteria, yeast, and other fungi in food production (bread, wine, beer, yoghurt and cheese)	Describe the uses of microorganisms in food production: • bacteria produce lactic acid and the production of yoghurt and cheese from milk. • yeast fermentation produces carbon dioxide that produces carbon dioxide gas which makes dough rise. • yeast is used in fermenting sugar(maltose) to make beer and in fermenting the sugars in grape juice to make wine. Learners should be aware of the word equation for fermentation.
(b)	the different stages in the processing of yoghurt, cheese and beer and interpretation of information regarding these processes	Opportunity for practical work (making yoghurt here).
(c)	the optimum conditions for growth of bacteria (suitable temperature, moisture, food source) and the significance of this in food production	Opportunity for practical work to demonstrate bacterial growth. Bacteria can be grown on nutrient agar in a Petri dish. Petri dishes and nutrient agar should be sterilised before use. An inoculating loop, sterilised before and after use by heating it to red heat in a Bunsen flame, is used to transfer bacteria. The Petri dish lid prevents microorganisms from the air contaminating a culture and vice versa. In schools, after inoculation the lid of the Petri dish should be secured in place by strips of adhesive tape for safety reasons. Inoculated agar plates are incubated to allow the bacteria to grow. In school laboratories incubation at 25°C is used which encourages growth of the culture without growing pathogens. For safety reasons plates and equipment should be sterilised after use. Relation of the optimum conditions for bacterial growth to regulations required by the food industry (warmth, moisture and food source). Link to statement (j) in this section.
(d)	pasteurisation as a process which slows microbial growth in foods including beer, milk and fruit juice	Pasteurisation as a process where foods are exposed to high temperatures to slow bacterial growth.

(e)	pasteurisation of milk by heating sufficiently to kill some pathogens, and production of semi-skimmed and skimmed milk	Semi-skimmed milk and skimmed milk as 'reduced fat' alternatives to whole milk.
(f)	homogenisation of milk by pumping it at high pressure through narrow tubes, affecting the size of fat globules in milk, resulting in an emulsion	Milk often is homogenized, a treatment that prevents a cream layer from separating out of the milk. The milk is pumped at high pressures through very narrow tubes, breaking up the fat globules.
(g)	food spoilage due to bacterial and fungal action, that may be accelerated by storage conditions	Link to statement (c) in this section.
(h)	ways in which the growth of bacteria is slowed down or stopped (refrigeration, freezing, heating, drying, salting, smoking, pickling (lowering pH))	Ways in which the growth of bacteria can be slowed down or stopped: • refrigeration – slows down but does not stop bacterial growth • freezing – stops bacteria multiplying but does not kill them • heating – heating then rapid cooling kills nearly all microorganisms • cooking – kills microorganisms • drying – removes water so bacteria cannot digest and absorb the food source • salting – bacteria lose water from their cells so they dehydrate and cannot reproduce • pickling – addition of vinegar to lower pH and inactivate microorganisms. Use of data to compare growth of bacteria in different conditions.
(i)	how food preparation areas are kept free of bacteria (personal hygiene, disinfectants, detergents, sterilisation, disposal of waste, control of pests e.g. insects, mice and rats)	Link to statement (c) in this section. How food preparation areas are kept free of bacteria: • good personal hygiene • wearing protective clothing • use of disinfectants on surfaces • using detergents to wash up • sterilisation using high temperatures or gamma rays • correct disposal of waste • control of pests such as insects or mice
(j)	how cross contamination of food can be prevented	Include storage and preparation methods.

(k)	food poisoning which is caused by the growth of microorganisms, usually bacteria, and by the toxins they produce when they grow (*Campylobacter sp., E.coli, Salmonella sp*.); the common symptoms for food poisoning (stomach pains, vomiting, diarrhoea)	Know examples of bacteria which cause food poisoning.
(l)	data on the growth of microorganisms (colony counts, turbidity)	Interpret data from agar plates and turbidity experiments.
(m)	potential impact of the contamination of food products, with bacteria (e.g. by commercial food preparation outlets)	Consider the impact to individuals and society.

3.3 SCIENTIFIC DETECTION

Applied Context
Analytical scientists work in a wide range of different industries and agencies. Examples include monitoring water pollution, food analysis, drug testing in athletes, and genetic profiling from crime scenes. This topic is designed to help learners understand the way in which an analytical scientist works so as to enable them to tackle problems and answer questions. Learners can apply their learning in forensics, water treatment, environmental and pharmaceutical industries.

	Spec Statement	Comment
(a)	how samples are collected which are representative (e.g. water samples from streams/rivers, landfill sites or household water supplies)	
(b)	analytical techniques to classify a method as qualitative, semi-quantitative or quantitative	Explain the difference between qualitative, quantitative and semi-quantitative tests.
(c)	**the mole to include the use of the mole to count particles, how to use relative atomic masses to calculate relative molecular mass, how to calculate the number of moles from mass and relative molecular mass**	**Candidates should understand that a mole is a term describing a specific number. They should know that, for example, 12g of carbon and 56g of iron both contain this number of atoms. Terms such as particles, atoms and molecules should be used very carefully in this context, e.g. 2g of hydrogen gas, H_2, contains 2 moles of hydrogen atoms but 1 mole of hydrogen molecules.** **The molar mass is simply the relative molecular (formula) mass, expressed in grams.** **This relationship can be used to calculate a molar mass (and relative atomic/molecular mass) when mass and number of moles are known.**
(d)	chromatographic methods to include the separation of species in a mixture, the calculation of R_f values, the use of R_f values / retention times (t_R) to identify components in a mixture, the dependence of the R_f/t_R upon the conditions of the analysis (temperature, nature of stationary phase and mobile phase, flow rate of mobile phase in instrumental analysis) and applications of each method; **the separation of molecules in chromatography in terms of the differences in the relative attraction of different molecules for a mobile and stationary phase** (Chromatographic methods to include paper chromatography, TLC, HPLC, GLC)	In chromatography substances are separated by the movement of a solvent (the mobile phase) through a medium (the stationary phase). **Understand that chromatography depends on the relative attractions of molecules of a solute to the solvent and the medium.** Analysis of simple chromatograms. Candidates should use the following equation to compare samples: $Rf = \frac{distance\ travelled\ by\ substance}{distance\ travelled\ by\ solvent}$ Experimental details of gas-liquid chromatography, and high pressure liquid chromatography are not required. Candidates will be expected to interpret traces to identify a match between an unknown and known substance.

(e)	colorimetry to find concentration of species (e.g. nitrate) using calibration curves (quantitatively) or by comparing to coloured test strips (e.g. nitrate, pH chlorine, lead) (semi-quantitatively) (see Table 3.3)	Please refer to table 3.3 in specification.
(f)	DNA to include that it is found in the nucleus of all cells; that is unique to individuals (except for identical twins) which allows for 'genetic profiling'; genetic profiling for identification in criminal and paternity cases; DNA profiles to include comparing DNA profiles for matches (see Table 3.3)	The term genetic profiling should be used in place of genetic fingerprinting to avoid confusion with fingerprinting. The ethical issues linked with DNA profiling.
(g)	qualitative, quantitative and semi-qualitative analytical procedures to include: selecting an appropriate procedure for an analysis, displaying data (table, bar graph, line graph), processing data (by manipulating and rearranging equations, plotting and using calibration curves, interpreting qualitative data) and drawing valid conclusions (Table 3.3 details techniques)	Related to table 3.3
(h)	sources of error in terms of both random errors and systematic errors	In relation to procedures given in the content and specified practical activities.

SPECIFIED PRACTICAL WORK

- Titration of a strong acid against a strong base using an indicator
- Identification of unknown substances using paper chromatography
- Identification of unknown ionic compounds using flame tests and chemical tests for ions

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

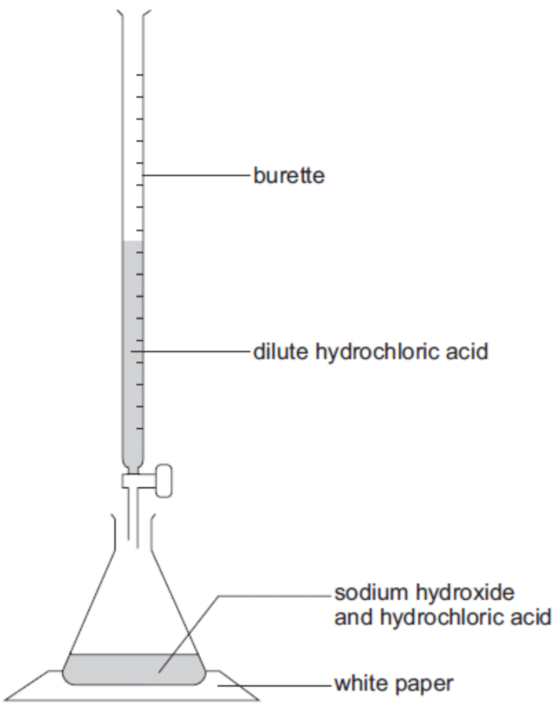
Introduction

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
100 cm^3 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 cm^3 of sodium hydroxide solution into a conical flask.
3. Add 2 drops of indicator.
4. Add 0.1 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 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 irritant	Sodium hydroxide spilling onto hands when filling burette or measuring volume of liquids	Wear gloves Wash hands immediately after contact with solutions
	Hydrochloric acid or 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 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			
	1	2	3	Mean
Final volume of acid in burette (cm^3)				
Initial volume of acid in burette (cm^3)				
Titre (volume added) (cm^3)				

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.

Identification of unknown substances using paper chromatography

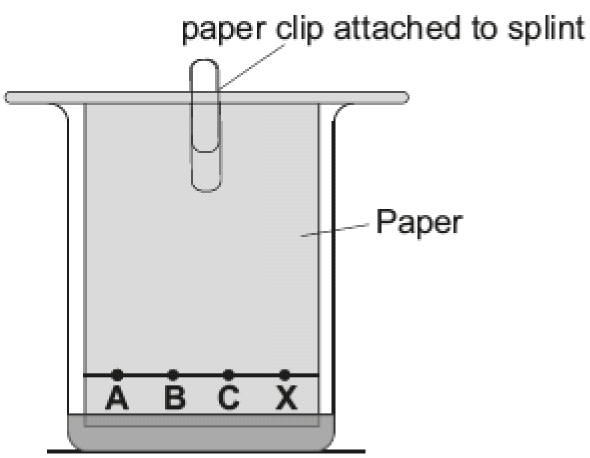
Introduction

Black ink is a mixture of colours and different black inks contain different amounts and types of coloured dyes and thus give a different pattern in a chromatograph. Chromatography is used in forensic science. In this experiment you will examine a ransom note and ink from three pens. The objective is to identify which pen's ink matches the ransom note.

Apparatus

3 × black pens (water soluble)
part of a ransom note
beaker
splint
paper clip
chromatography paper
dimple tray (or small watch glass)
dropping pipette
capillary tube

Diagram of Apparatus



Method

1. On a rectangular piece of chromatography paper, draw a line **in pencil,** 1 cm from a short edge and mark 4 evenly spaced points.
2. **In pencil**, label under the points **A,B,C** and **X**.
3. Mark a spot with each pen labelled A, B and C on each of the corresponding points.
4. Take the sample of the ransom note and place in the well of a dimple tray.
5. Add a small amount (1-2 drops) of water to the sample. The ink should come out of the paper.
6. Use a small capillary tube to apply some of this ink to the point labelled X.
7. Attach the chromatography paper to the splint with a paper clip.
8. Place some water into the beaker making sure that the water does not go over the spot line on the chromatography paper.
9. Suspend the chromatography paper in the beaker and allow the water to travel up until it almost touches the splint.
10. Remove the chromatography paper and allow to dry.

Analysis

1. Identify which pen has the same ink as on the ransom note.

Teacher / Technician notes

Whatman chromatography paper is available in a long roll and can be pre-cut into strips of approximately 6-7 cm for the class.

Pens should all be black and water soluble, fibre tip pens work better than ball point pen as a greater amount of ink is released. Permanent markers and some whiteboard pens are not suitable as they are insoluble in water.

It is important that the minimum amount of water is used to dissolve the ink from the sample note.

Beaker can be 100 or 250 cm^3.

Extension activity – calculate the R_f values for the ransom note. Students will need to mark the position of the solvent front in order to do this. The dyes do not completely separate and this can be a discussion point in evaluation.

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

Identification of unknown ionic compounds using flame tests and chemical tests for ions

Introduction

Scientists need to identify the compounds that they are working with. To do this we use a series of chemical tests that allow us to identify the different metal or non-metal ions that are present in a compound.
These tests include:

- Flame tests
- Tests for carbonate
- Tests for Group 7 ions

Flame test

Dip a damp wooden splint into the solid sample being tested. Put the sample into the hottest part of a Bunsen flame (air-hole open).

Result

Ion	Flame colour
potassium, K^+	lilac
sodium, Na^+	yellow
calcium, Ca^{2+}	brick red
lithium, Li^+	red

Test for a carbonate ion, CO_3^{2-}

Add dilute hydrochloric acid. Pipette the gas formed into the limewater.

Result

Fizzes when acid is added

Gas formed turns limewater milky

Test for Group 7 ions, Cl^-, Br^- and I^-

Make a solution by dissolving the sample in water.
Add silver nitrate solution.

Result

Ion	Precipitate colour
chloride, Cl^-	white
bromide, Br^-	cream/pale yellow
iodide, I^-	yellow

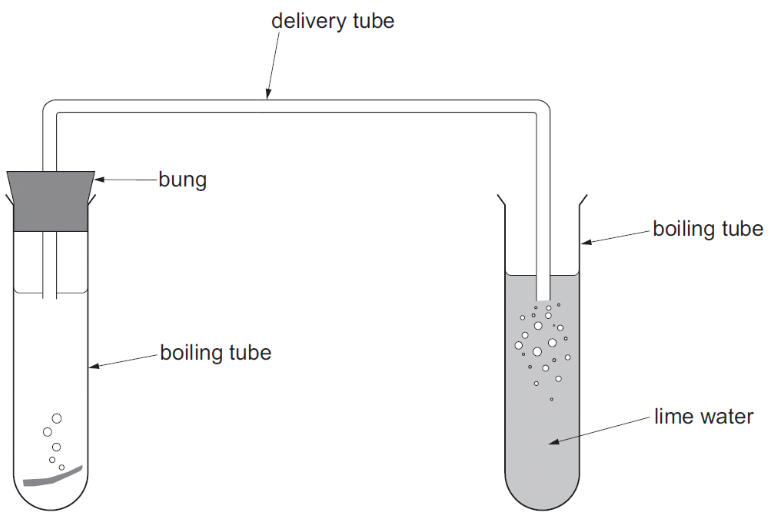
You will be provided with 5 solid compounds, labelled A, B, C, D and E.

You will use these tests to identify the five compounds you have been given.

Apparatus

5 × damp wooden splints
Bunsen burner
heat proof mat
12 × test tubes
1 × dropping pipette
5 × spatulas
silver nitrate solution
dilute hydrochloric acid
limewater

Diagram of Apparatus



Method - Flame test

1. Take a damp wooden splint and dip it into sample A.
2. Hold the splint in the roaring (blue) Bunsen burner flame.
3. Record the flame colour obtained.
4. Repeat for each of the samples with a separate damp splint.

Method – Test for carbonate ions

1. Add one of the samples to a test tube.
2. Half fill a second tube with limewater.
3. Add hydrochloric acid to the sample and quickly attach the bung and side arm tube.
4. Record what happens to the limewater.

Method – Test for Group 7 ions

1. Test each of the samples that did not give a positive result for the carbonate ion for the presence of a Group 7 ion.
2. Add a small amount of the solid to a test tube.
3. Add de-ionised water to each solid to create a solution.
4. Add silver nitrate to the solution using a dropping pipette.
5. Record the colour of the precipitate formed.

Analysis

1. Use the reference tables to identify each of the unknown compounds.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Hydrochloric acid is an irritant	Hydrochloric acid could get onto the skin when adding to test tube	Wash hands immediately if any hydrochloric acid gets onto them / wear laboratory gloves.
	Hydrochloric acid could get transferred from the hands to the eyes	Wear eye protection.
Limewater is corrosive	Limewater could get onto the skin when adding to test tube	Wash hands immediately if any limewater gets onto them / wear laboratory gloves.
	Limewater could get transferred from the hands to the eyes	Wear eye protection.
Silver nitrate is irritant	Silver nitrate could get onto the skin when adding to test tube	Wash hands immediately if any silver nitrate gets onto them / wear laboratory gloves.
	Silver nitrate could get transferred from the hands to the eyes	Wear eye protection.
Hot apparatus can burn	Burns to skin when moving Bunsen burner	Do not touch Bunsen burner until cool

In this experiment it is important that the splints are soaked in de-ionised water not tap water.

Each splint should be no shorter than 10 cm.

An alternative to the damp splints is to use nichrome wires held in a bung or between tongs.

Reagents for flame tests:
Calcium chloride – Refer to CLEAPSS hazcard 19A
Lithium chloride - Refer to CLEAPSS hazcard 47B
Sodium carbonate – Refer to CLEAPSS hazcard 95A
Potassium iodide – Refer to CLEAPSS hazcard 47B
Potassium bromide – Refer to CLEAPSS hazcard 47B

Other reagents:
Hydrochloric acid – Refer to CLEAPSS hazcard 47A
Limewater – Refer to CLEAPSS hazcard 18
Silver nitrate – Refer to CLEAPSS hazcard 87

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

Sample	Flame test observation	Carbonate test observation	Group 7 test observation	Name of Compound
A				
B				
C				
D				
E				

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.

   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 SI units and IUPAC chemical nomenclature unless inappropriate.

3.4 CONTROLLING PROCESSES -

3.4.1 CONTROLLING CHEMICAL REACTIONS

Applied Context
The chemical industry provides many of the chemicals that people need for modern life. The chemical industry today is developing new processes for manufacturing these chemicals more efficiently and with less impact on the environment. This topic explores how the rate of reaction depends upon the conditions of a chemical reaction. It also explores thermal runaway reactions and how these have contributed to a number of serious accidents. Learners can apply their learning in pharmaceutical and chemical fields.

Spec Statement		Comment
(a)	how the energy stored in a chemical system changes when a reaction occurs resulting in an endothermic reaction (process causing the temperature of the surroundings to decrease) or exothermic reaction (process causing the temperature of surroundings to increase)	They should describe reactions as exothermic/endothermic in terms of the relative amounts of energy required to break bonds and energy released in forming bonds during a reaction.
(b)	how concentration / pressure, temperature, particle size and surface area affect the reaction rate in terms of collisions between molecules and activation energy	The rate of reaction is increased by increasing temperature, concentration (pressure) and surface area. Appreciate that decreasing solid particle size increases surface area. 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 the concentration, temperature and surface area/particle size affect the collision rate. **Higher tier candidates should be familiar with the idea of 'successful collision' where products are formed.**
(c)	how a catalyst changes the rate of a chemical change while remaining chemically unchanged itself in terms of the energy required for a collision to be successful	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 over time. **Higher tier candidates should understand that catalysts increase the rate of a reaction by lowering the minimum energy required for 'successful collisions'**

(d)	how to carry out experiments to study how factors affect rate (e.g. using a light sensor and data logger to follow the precipitation of sulfur during the reaction between sodium thiosulfate and hydrochloric acid); data to draw conclusions, and critically evaluate the method of data collection, the quality of the data and to what extent the data supports the conclusion	Recognise that a rate measures a change over a given time. Be familiar with gas collection and mass loss methods of studying rates of reaction such as acids and metals/carbonates, as well as the precipitation reaction of dilute hydrochloric acid and sodium thiosulfate.
(e)	the economic and environmental importance of developing new and better catalysts, in terms of increasing yields, preserving raw materials, reducing energy costs etc.	Yield is referred to here in its broadest sense i.e. the amount of product that can be made per day/month/year. Consideration of position of equilibrium is well beyond the scope of the specification.
(f)	the need to control exothermic reactions which accelerate with an increase in temperature; the danger of thermal runaway in chemical reactions including the definition of a thermal runaway reaction and how thermal runaway reactions can occur; how thermal runaway contributed to disasters such as Texas City disaster (1947) and Bhopal disaster (1984)	

SPECIFIED PRACTICAL WORK

- Investigation of the factors that affect the rate of reaction

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:

sodium thiosulfate	+	hydrochloric acid	$\longrightarrow$	sodium chloride	+	water	+	sulfur dioxide	+	sulfur	
$Na_2S_2O_3(aq)$	+	$2HCl(aq)$	$\longrightarrow$	$2NaCl(aq)$	+	$H_2O(l)$	+	$SO_2(g)$	+	$S(s)$	

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.

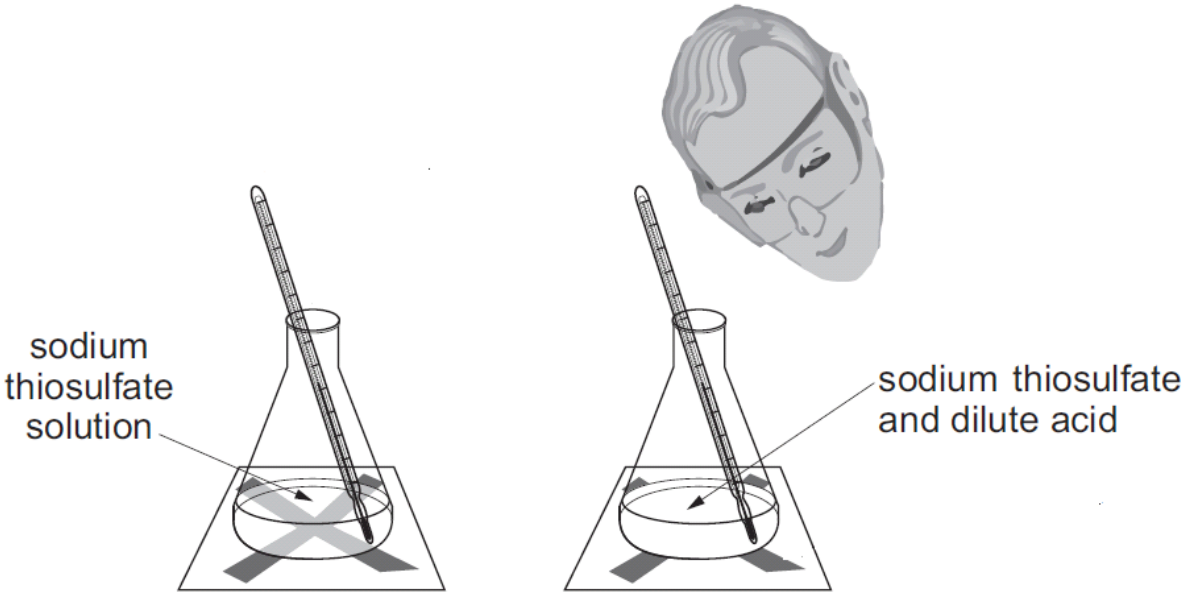
Apparatus

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

Access to:

40 g/dm^3 sodium thiosulfate solution at 5 °C
40 g/dm^3 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^3 of hot sodium thiosulfate using the 25 cm^3 measuring cylinder and pour into the conical flask. Record the temperature of the solution.
3. Using the 10 cm^3 measuring cylinder, measure out 5 cm^3 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^3)	Volume of sodium thiosulfate solution at 5 °C (cm^3)
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.

Teacher / Technician notes

Assessment

Hazard	Risk	Control measure
Hydrochloric acid is an irritant.	Splashing on to hand/skin/you whilst pouring Transfer from hand in to eye when pouring	Wash off/wear gloves Wear eye protection
Sodium thiosulfate is an irritant	Splashing on to hand/skin/you whilst pouring Transfer from hand in to eye when pouring	Wash off/wear gloves Wear eye protection
Sulphur dioxide gas produced is an irritant	Inhalation of gas may cause damage/irritation to the lungs	Carry out in a well ventilated space/fume cupboard
Hot liquid can scald/burn 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

1. **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.

2. **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.

3.4 CONTROLLING PROCESSES -

3.4.2 CONTROLLING NUCLEAR REACTIONS

Applied Context
Nuclear reactions are used to generate electricity. This topic looks at how we can control a nuclear reaction so that we can generate electricity. It also examines why a small number of accidents have happened and compares the relative risk of generating electricity using nuclear power with other forms of electricity generation. Learners can apply their learning in the fields of electricity generation and health and safety.

	Spec Statement	Comment
(a)	nuclear fission to include how a uranium nucleus is split by being hit with a neutron releasing energy and neutrons, and the difference of nuclear fusion which occurs in stars and involves two nuclei joining to form a larger nucleus and energy; nuclear symbols of the form ${}^{A}_{Z}X$ in the context of nuclear fission and nuclear fusion, and use data to produce and balance nuclear equations	**producing** and balancing nuclear equations for radioactive decay using the symbols ${}^{4}_{2}He^{2+}$ or ${}^{4}_{2}\alpha$ for the alpha particle and ${}^{0}_{-1}e$ and ${}^{0}_{-1}\beta$ for the beta particle.
(b)	calculations involving the activity and half-life of radioactive materials	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. 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.
(c)	how the uncontrolled decay of uranium starts a chain reaction including the idea of an explosion as a chain reaction out of control	

(d)	how a nuclear reactor is constructed including fuel rods, moderator, control rods, coolant and concrete shields	Be able to label a diagram and describe the components of a nuclear reactor. Appreciate that nuclear fuels do not produce gases that cause global warming, but the waste materials produced by them are radioactive. Radioactive emissions are harmful to life so the waste from nuclear power stations has to be stored in a safe place until the radiation falls to safe levels.
(e)	how nuclear reactors are kept safe to include using control rods placed in the reactor to control the number of available neutrons and the circulation of coolant to prevent the temperature of the reactor becoming too high	Control rods are arranged to absorb neutrons so that for every two or three neutrons that are released from a fission reaction, only one (on average) goes on to produce further fission. The effect of raising and lowering control rods should be understood along with the way in which a reactor is completely shut down. The moderator slows down fast moving neutrons to enable absorption by U-235 nuclei to occur.
(f)	how a failure in following safety protocols and control mechanisms has led to a small number of nuclear accidents (e.g. Three Mile Island, Chernobyl, Fukushima)	
(g)	the consequences of a nuclear accident to the environment and human health; the relative risks of different methods of power generation to health and the environment (e.g. coal, oil, nuclear)	Consideration of the short- and long-term effects of nuclear accidents. Comparisons with accidents resulting from other methods of power generation.