

Scheme of Work

Cambridge Lower Secondary

Science 0893

Stage 9



This Cambridge Scheme of Work is for use with the Cambridge Lower Secondary Science Curriculum Framework published in September 2020 for first teaching in September 2021.

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# Introduction

This document is a scheme of work created by Cambridge Assessment International Education for Cambridge Lower Secondary Science Stage 9.

It contains:

* suggested units showing how the learning objectives in the curriculum framework can be grouped and ordered
* at least one suggested teaching activity for each learning objective
* a list of subject-specific language that will be useful for your learners
* some possible models and representations that are relevant to the learning objectives
* some possible misconceptions learners may have, or develop
* sample lesson plans.

You do not need to use the ideas in this scheme of work to teach Cambridge Primary Lower Secondary Stage 9. This scheme of work is designed to indicate the types of activities you might use, and the intended depth and breadth of each learning objective. These activities are not designed to fill all of the teaching time for this stage. You should use other activities with a similar level of difficulty, including those from endorsed resources.

The accompanying teacher guide for Cambridge Lower Secondary Science will support you to plan and deliver lessons using effective teaching and learning approaches. You can use this scheme of work as a starting point for your planning, adapting it to suit the requirements of your school and needs of your learners.

## Long-term plan

This long-term plan shows the units in this scheme of work and a suggestion of how long to spend teaching each one. The suggested teaching time is based on 90 total hours of teaching for Science Stage 9 at 3 hours a week. The actual number of teaching hours may vary according to your context.

| Unit and suggested order | Suggested teaching time | Unit and suggested order | Suggested teaching time | Unit and suggested order | Suggested teaching time |
| --- | --- | --- | --- | --- | --- |
| **Unit 9.1**  Chemical bonding | 11% (8 hours) | **Unit 9.4**  Sound and energy | 11% (10 hours) | **Unit 9.7**  Chemical reactions | 13% (12 hours) |
| **Unit 9.2**  Plant biology | 13% (12 hours) | **Unit 9.5**  Human biology | 9.5% (12 hours) | **Unit 9.8**  Species and their environments | 11% (10 hours) |
| **Unit 9.3**  Chemical structures and properties | 11% (10 hours) | **Unit 9.6**  Electricity | 11% (8 hours) | **Unit 9.9**  Earth and beyond | 9.5% (8 hours) |

## Sample lesson plans

You will find two sample lesson plans at the end of this scheme of work. They are designed to illustrate how the suggested activities in this document can be turned into lessons. They are written in more detail than you would use for your own lesson plans. The Cambridge Lower Secondary Science Teacher Guide has information on creating lesson plans.

## Other support for teaching Cambridge Lower Secondary Science Stage 9

Cambridge Lower Secondary centres receive access to a range of resources when they register. The Cambridge Lower Secondary support site at [**https://lowersecondary.cambridgeinternational.org**](https://lowersecondary.cambridgeinternational.org) is a password-protected website that is the source of the majority of Cambridge-produced resources for the programme. Ask the Cambridge Coordinator or Exams Officer in your school if you do not already have a log-in for this support site.

Included on this support site are:

* the Cambridge Lower Secondary Science Curriculum Framework, which contains the learning objectives that provide a structure for your teaching and learning
* grids showing the progression of learning objectives across stages
* the Cambridge Lower Secondary Science Teacher Guide, which will help you to implement Cambridge Lower Secondary Science in your school
* templates for planning
* worksheets for short teacher training activities that link to the teacher guide
* assessments provided by Cambridge
* a list of endorsed resources, which have been through a detailed quality assurance process to make sure they are suitable for schools teaching Cambridge Lower Secondary Science worldwide
* links to online communities of Cambridge Lower Secondary teachers.

## Resources for the activities in this scheme of work

We have assumed that you will have access to these resources:

* paper, graph paper, pens, pencils, rulers and calculators for learners to use
* clean water
* the internet.

Other suggested resources for individual units and/or activities are described in the rest of this document. You can swap these for other resources that are available in your school.

The Cambridge Lower Secondary Science Equipment List provides a list of recommended scientific equipment that your school should have access to in order to teach all stages of Cambridge Lower Secondary Science. It is available on the support site.

## Websites

There are many excellent online resources suitable for teaching Cambridge Lower Secondary Science. Since these are updated frequently, and many are only available in some countries, we recommend that you and your colleagues identify and share resources that you have found to be effective for your learners.

## Approaches to teaching Cambridge Lower Secondary Science Stage 9

There are three components to the Cambridge Lower Secondary Science Curriculum:

* four content strands (Biology, Chemistry, Physics, and Earth and Space)
* one skills strand (Thinking and Working Scientifically)
* one context strand (Science in Context).

When planning lessons, the three components should work together to enable you to provide deep, and rich, learning experiences for your learners.

We recommend you start your planning with a learning objective from one of the four content strands. This determine the focus of the lesson. Once there is a content learning objective lesson focus you can consider what Thinking and Working Scientifically learning objectives can be integrated into your teaching so learners are developing their scientific skills alongside their knowledge and understanding of science.

This approach is exemplified in this scheme of work by providing activities that cover the content learning objectives while also developing selected Thinking and Working Scientifically learning objectives. Some Thinking and Working Scientifically learning objectives are covered multiple times over the scheme of work which reflects the need for learners to have several opportunities to develop skills.

The selection, and frequency, of Thinking and Working Scientifically learning objectives in this scheme of work may match the needs of your learners. However, the selection of Thinking and Working Scientifically learning objectives needs suit the requirements of your school and needs of your learners. Any changes to what Thinking and Working Scientifically learning objectives are selected to be developed when teaching the content learning objectives will require activities to be reviewed and edited.

Once you are confident with the combination of content and Thinking and Working Scientifically learning objectives, you then have the option to integrate context into your lessons to show how the learning objectives and/or skills relate to the world the learners know and experience. The Science in Context learning objectives provide guidance on doing this. As including context is dependent on your learners and your context, the scheme of work does not give contextual links to an activity. Possible ways to contextualise units are provided in the unit introductions, aligned to the relevant Science in Context objectives.

Further support about integrating Thinking and Working Scientifically and Science in Context into lessons can be found in the Cambridge Lower Secondary Science Teacher Guide.

Models and representations

Scientists use models and representations to represent objects, systems and processes. They help scientists explain and think about scientific ideas that are not visible or are abstract. Scientists can then use their models and representations to make predictions or to explain observations. Cambridge Lower Secondary Science includes learning objectives about models and representations because they are central to learners’ understanding of science. They also prepare learners for the science they will encounter later in their education.

To support the integration of models and representations into your teaching, for each learning objective we have suggested possible models you may wish to use.

Misconceptions

Scientific misconceptions are commonly held beliefs, or preconceived ideas, which are not supported by available scientific evidence. Scientific misconceptions usually arise from a learner’s current understanding of the world. These ideas will informed by their own experiences rather than evidence. To support you in addressing misconceptions, for each learning objective in each unit we have suggested, where relevant, possible misconceptions to be aware of.

Due to the range of misconceptions that learners can hold not all misconceptions have been provided and you may encounter learners with misconceptions not presented in this scheme of work.

Misconceptions may be brought to the lesson by the learners, reinforced in the lesson, or created during a lesson. It is important that you are aware of misconceptions that learners may exhibit so that you can address them appropriately.

It is important to note that not all misconceptions are inappropriate based on the conceptual understanding learners are expected to have at different stages of their education. Therefore, some misconceptions may be validly held by learners at certain stages of their learning. A misconception of this type is known as an age-appropriate concept. Trying to move learners away from age-appropriate concepts too soon may give rise to other, more significant, misconceptions or barriers to their understanding of science. Over time age-appropriate concepts can become misconceptions when they start to interfere with the expected level of understanding learners need to have.

The misconceptions flagged in this scheme of work are considered to be either inappropriate concepts for a learner at this stage of understanding science or important age-appropriate concepts to be aware of so they are not challenged too early.

Health and safety

An essential part of this curriculum is that learners develop skills in scientific enquiry. This includes collecting primary data by experiment. Scientific experiments are engaging and provide opportunities for first-hand exploration of phenomena. However, they must, at all times, be conducted with the utmost respect for safety, specifically:

* It is the responsibility of the teacher in charge to adhere and conform to any national, regional and school regulation in place with respect to safety of scientific experimentation.
* It is the responsibility of the teacher in charge to make a risk assessment of the hazards involved with any particular class or individual when undertaking a scientific experiment that conforms to these regulations.

Cambridge International takes no responsibility for the management of safety for individual published experiments or for the management of safety for the undertaking of practical experiments in any given location. Cambridge International only endorses support material in relation to curriculum content and is not responsible for the safety of activities contained within it. The responsibility for the safety of all activities and experiments remains with the school.

The welfare of living things

Throughout biology, learners study a variety of living things, including animals. As part of the University of Cambridge, Cambridge International shares the approach that good animal welfare and good science work together.

Learners should have opportunities to observe animals in their natural environment. This should be done responsibly and not in a way that could cause distress or harm to the animals or damage to the environment.

If living animals are brought into schools then the teacher must ensure that any national, regional and school regulations are followed regarding animal welfare. In all circumstances, the teacher responsible must ensure all animals have:

* a suitable environment, including being housed with, or apart from, other animals (as required for the species)
* a suitable diet
* the opportunity to exhibit normal behaviour patterns
* protection from pain, injury, suffering and disease.

There is no requirement for learners to participate in, or observe, animal dissections for Cambridge Lower Secondary. Although dissection can provide a valuable learning opportunity, some learners decide not to continue studying biology because they dislike animal dissection. Several alternatives are available to dissection (such as models and diagrams) which you should consider during your planning.

If you decide to include animal dissection then animal material should be obtained from premises licensed to sell them for human or pet consumption, or from a reputable biological supplier. This approach helps to ensure animal welfare standards and also decreases the risk from pathogens being present in the material. Neither you nor your learners should kill animals for dissection.

When used, fresh material should be kept at 5 °C or below until just before use. Frozen material should be defrosted slowly (at 5 °C) without direct heat. All fresh or defrosted material should be used within 2 days. Preserved animal materials should only be handled when wearing gloves and in a well-ventilated room.

The responsibility for ensuring the welfare of all animals studied in science remains with the school.

# Unit 9.1 Chemical bonding

| Unit 9.1 Chemical bonding |
| --- |
| Outline of unit: |
| This unit covers fundamental ideas about chemical bonding including covalent and ionic bonding; it consolidates and builds upon learners’ prior knowledge of atomic structure. They will use their understanding of bonding to explain what a molecule is and consider various representations of molecules.  Learners will examine various types of models and develop skills in moving between multiple representations of substances. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * using the particle model of solids, liquids and gases * understanding that all matter is made of atoms * knowing the Periodic Table presents the known elements in an order * describing the atomic structure of elements using the Rutherford model * knowing that electrons have negative charge and protons have positive charge * knowing that the electrostatic attraction between positive and negative charge is what holds together individual atoms * describing the difference between elements, compounds and mixtures. |
| Suggested examples for teaching Science in Context: |
| ***9SIC.01*** *Discuss how scientific knowledge is developed through collective understanding and scrutiny over time.*  Learners can consider when the theory of bonding was first introduced and what it stated. They can then look at how subsequent discoveries, and thinking, altered our understanding of bonding over time. If doing this, ensure it is covered in an age-appropriate manner focusing on the history and general development of bonding, rather than the specific details learners may not have the prior understanding for. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
| --- | --- | --- | --- |
| **9Cm.02** Understand that a molecule is formed when two or more atoms join together chemically, through a covalent bond. | Molecule, diatomic, atom, covalent, bond | Diagrams of molecules can be used. Atoms can be represented as circles and the covalent bond represented by a line.  Physical models (e.g. molecular model kits) can also be used to represent molecules, with balls representing atoms and sticks representing covalent bonds. | Learners often confuse elements and compounds with molecules. For example, they may incorrectly state that oxygen, O2 cannot be a molecule as its atoms are the same.  This misconception is best prevented by showing learners lots of examples where the terms are used correctly, in sentences and alongside diagrams, models and formulae. |
| **9Cm.03** Describe a covalent bond as a bond made when a pair of electrons is shared by two atoms (limited to single bonds). | Covalent, bond, atom, electron, shell | Dot and cross models can be used to illustrate the sharing of electrons.  Learners can roleplay molecules with covalent bonds. Learners represent atoms. They each have a large hoop around their waste, representing electrons around the nucleus (their body). If they overlap hula hoops it represents the sharing of electrons which is a covalent bond. | There may be misconceptions where learners believe both atoms in the bond have an equal share of the pair of electrons. This misconception is stage appropriate and does not have to be addressed. |
| **9Cm.04** Describe an ion as an atom which has gained at least one electron to be negatively charged or lost at least one electron to be positively charged. | Ion, atom, electron, proton, neutron negative, positive, charge, subatomic, shell, Noble gas electron configuration | Lewis dot and cross models can be used to show the gain and loss of electrons.  Learners can roleplay forming ions. Learners, each one representing an atom, having a collection of balls which represent electrons. If they gain electrons they gain electrons (balls) from a learner representing an atom that loses electrons and on a piece of paper they write a number with the negative sign to show how many electrons they have gained (e.g. -2). Learners representing atoms that lose electrons write on their piece of paper how many electrons they have lost with a positive sign (e.g. +3).The atom given to a learner determines if gain or lose electrons due to the number of electrons in the outer shell. | It is common for learners to find it confusing that the loss of a particle can result in a positive charge. Learners should be encouraged to count the number of protons as single positive charges and electrons as single negative charges and look for an excess of either to determine the overall charge. |
| **9Cm.05** Describe an ionic bond as an attraction between a positively charged ion and a negatively charged ion. | Electrostatic, anion, cation, lattice, ionic, bond, ion, attraction, positive, negative, charge, electron, proton | Chemical jigsaw representations of positive and negative ions can be used to model ionic bonding.  To support learners an analogy that ionic bonding is like two magnets can be used, as a positive ion and negative ions attract due to their charges. However, the charge is caused by a movement of electrons between the atoms which form ions rather than magnetic fields. | Where analogies with magnets are drawn, learners may develop the misconception that an electrostatic attraction is of the same nature as a magnetic one. Clarify with learners that analogies/models have limitations. E.g. ‘Ionic bonding and magnetic attraction are two different phenomena but they can look similar (on the surface) |

# Unit 9.1 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
| --- | --- | --- |
| **9Cm.02** Understand that a molecule is formed when two or more atoms join together chemically, through a covalent bond. | **9TWSm.03** Use symbols and formulae to represent scientific ideas. | **What is a molecule?**  Split learners into groups for discussion. Give learners a range of diagrams showing molecules in various representations. These could include; diagrams with covalent bonds shown as lines and with atoms shown as spheres and dot and cross diagrams. Introduce learners to the key terminology, including the definition of a molecule.  Give each group a small selection of diagrams, including some diagrams of single atoms. Ask each group to determine whether each example is a molecule or not. They discuss what the diagrams show and how each one supports or refutes the definition of a molecule.  Ask groups to feed their ideas back to other groups, by each group nominating one learner as an ‘envoy’ who then moves to the other groups and shares ideas with the on behalf of their group. The learners then consider the new ideas within their groups.  Bring the ideas of learners together in a final class discussion; use this opportunity to correct any incorrect use of terminology. Use probing questions, such as:  *How are covalent bonds represented in the diagrams?*  *What types of atoms form covalent bonds?*  *What features of the diagrams were used in your decisions to classify a diagram as showing a molecule?*  **Resources:** Diagrams of molecules and atoms |
| **9Cm.03** Describe a covalent bond as a bond made when a pair of electrons is shared by two atoms (limited to single bonds). | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations. | **Physical modelling of electron sharing**  Introduce the dot and cross model of covalent bond formation.  *What does this model show?*  *What is each part of the model doing?*  Show some representations of molecules, including diagrams with covalent bonds show as lines, diagrams with atoms shown as dot and cross models, discussing what the dot and cross model represents. In addition, show how single bonds are represented in this model.  Assemble craft materials to make physical models of the dot and cross models. Making physical models is used here to stimulate discussion with learners about the strengths and limitations of the dot and cross model.  In this modelling exercise, the materials used for the outer shells (e.g. wire, string, pipe cleaners) should be threaded through two beads (two electrons) to represent a single bond. The models of simple molecules (e.g. methane, fluorine, hydrogen, ammonia, water) are suitable for this exercise.  Following the modelling exercise, lead a discussion with the whole class or individuals or small groups:  *How could your model be improved?*  *Are all atoms the same size? How could we represent this better in our models?*  *Are beads a good model for electrons?*  **Resources:** Diagrams of molecules using dot and cross models, craft materials |
| **9Cm.04** Describe an ion as an atom which has gained at least one electron to be negatively charged or lost at least one electron to be positively charged. | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations. | **What happens when an atom loses or gains electrons?**  Remind learners of their prior understanding of the atomic model, atomic structure and subatomic particles (neutrons, protons and electrons), with particular attention to the relative charges of the particles.  Ask learners:  *Why does an atom of calcium have no overall charge?*    Evaluate the answers given by learners; emphasise that the elements, as atoms, have no overall charge as the number of protons is equal to the number of electrons.  Show learners dot and cross models for some atoms, which clearly show the number of electrons in the outer shell.  Tell learners that an atom can gain or lose electrons in its outer shell until it achieves a Noble gas electron configuration. Show learners what a Noble gas electron configuration looks like and then provide some examples of atoms which gain or lose electrons to become charged ions in order to have a Noble gas electron configuration. For each example, model the counting of electrons and protons to determine the overall charge of the ion:  *How many electrons are there?*  *Are there more of fewer electrons than protons?*  *What is the charge of the ion?*  Define an ion with learners as an atom has a charge as the number of electrons is not equal to the number of protons.  Learners then consider how physical models of atoms can help demonstrate this concept. Learners use sets of counters in three different colours; One colour of counter should have stickers with + charges on to represent protons, the second colour should have stickers with – charges on to represent electrons, the final colour counters should be left plain and represent neutrons.  Learners assemble models of atoms based on the element symbols given in the Periodic Table. Once the atoms are assembled, learners should be guided that only counters representing electrons can be taken away. The balance of + and – counters can then be evaluated. More + counters mean there is an overall + charge on the ion and more – counters mean there is an overall – charge. Introduce that ions of + charge are cations and ions of – charge are anions.  Prompts to use with learners include:  Use the symbol in the Periodic Table to construct your atom.  Line up the protons and the electrons next to each other.  *If you take away one of the electron counters, how many protons and electrons are there now?*  *What charge will this ion have?*  Give learners plenty of exercises to develop a secure understanding before moving onto ionic bonding.  **Resources:** Diagrams of ions, coloured counters, copies of the Periodic Table |
| **9Cm.05** Describe an ionic bond as an attraction between a positively charged ion and a negatively charged ion. | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations. | **Modelling ionic attractions**  Show learners a diagram of a chemical substance which involves ionic bonds;  *What charge does the molecule have?*  *What charge do individual atoms have?*  Tell learners that substances containing ionic bonds have no overall charge; this means that the ions are arranged in a way which results in the number of + charges equalling the number of – charges. Discuss that ions of + charge are cations and ions of – charge are anions. The cations and anions are held together in a lattice by electrostatic attraction. The ratio of ions contained within the lattice determines the formula of the substance.  Give learners physical modelling components of ions where the shape of the positive ion components fit into the cavities in the negative ion components, similar to jigsaw pieces. Learners manipulate the components to model the formation of substances that have ionic bonds. They then observe the ratios of each ion in their constructed model to propose the formula for the ionic compound. Learners can discuss the analogy that an ionic lattice is like a three dimensional jigsaw puzzle.  Show learners representations of ionic structures (e.g. images of unit cells, exploded/expanded models and space filled models). Ask them to consider the limitations of the types of models they made:  *How do the models we made today relate to these images?*  *What is communicated well in the model we have used?*  *What is missing from our model?*  **Resources:** Physical models of ions, representations of ionic crystals |

# Unit 9.2 Plant biology

| Unit 9.2 Plant biology |
| --- |
| Outline of unit: |
| In this unit, learners will learn more about photosynthesis including where it takes place and the summary word equation for the process. They will consider the role of light energy, chloroplasts and chlorophyll and understand that carbohydrates are made during photosynthesis.  Learners will investigate the pathway of water and mineral salts from the roots to the leaves in flowering plants and consider why plants need magnesium and nitrates.  The unit ends by learners studying the carbon cycle and the important roles that photosynthesis, respiration, feeding, decomposition and combustion have in the cycle.  During this unit, learners have opportunities for suggesting hypotheses, planning investigative work, carrying out risk assessments and practical work, drawing conclusions and evaluating investigations. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * knowing growth, nutrition and respiration are three of the characteristics of living organisms * describing the structure and functions of major parts of flowering plants such as roots, leaves and stems * identifying that plants get their energy from light and need water to grow * describing the ecological role some microorganisms have as decomposers * describing the structure of plant cells, the function of chloroplasts and sap vacuoles, and the structure and function of root hair cells * knowing that cells can be grouped together to form tissues and organs * knowing that air contains small amounts of carbon dioxide and that gas exchange in humans involves increased amounts of carbon dioxide being expired * knowing the summary word equation for aerobic respiration (glucose + oxygen -> carbon dioxide + water). |
| Suggested examples for teaching Science in Context: |
| ***9SIC.01*** *Discuss how scientific knowledge is developed through collective understanding and scrutiny over time.*  Learners can explore how our current understanding of photosynthesis has come about. The contributions of some key scientists over the past several hundred years can be discussed. For example, Joseph Priestly and the discovery of oxygen in 1774. Learners could also learn about the experiments of Melvin Calvin and his collaborators in the 1940s to work out how carbon (from carbon dioxide) becomes part of the carbohydrates formed by photosynthesis.  ***9SIC.05*** *Discuss how the uses of science can have a global environmental impact.*  Learners can discuss how using science allowed us to identify nitrates as key to plant growth. This resulted in humans artificially adding them to fertilisers. However overuse of nitrate in inorganic fertilisers has been scientifically proven to have a negative environmental impact e.g. high levels of nitrates in water run off can kill aquatic organisms. Learners could investigate the advantages and disadvantages of including nitrates in plant fertilisers. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
| --- | --- | --- | --- |
| **9Bp.05** Know that plants require minerals to maintain healthy growth and life processes (limited to magnesium to make chlorophyll and nitrates to make protein). | Plants, minerals, growth, life processes, magnesium, chlorophyll, nitrates, protein | Pictorial representations (e.g. diagrams, photographs) and online simulations may be used to show the effects of growing plants with and without magnesium and nitrates. | Some learners may confuse minerals required by plants for healthy growth with the term used to describe some rocks and ores. Explain that minerals, in the context of plant growth, are water-soluble substances that plants can absorb. It may help to remind learners that they have studied minerals in the context of animal diets.  Some learners may also believe that all plants require nitrates. Highlight to learners, that all plants require minerals and the exact mineral requirements depend on the plant. Legumes, for example, can survive without nitrates.  Some learners may confuse ‘chlorophyll’ with ‘chloroplast. Showing a diagram of a chloroplast containing chlorophyll may help. It may also be useful to explain that one of the meanings of the ending ‘plast’ means ‘organelle’. |
| **9Bp.06** Know that photosynthesis occurs in chloroplasts and is the process by which plants make carbohydrates, using the energy from light. | Photosynthesis, chloroplast, carbohydrate, light energy | Annotated diagrams of a chloroplast showing the summary reactants and products of photosynthesis, in the presence of light energy and chlorophyll, may be used.  Online, animated diagrams may help to consolidate the key ideas involved in the process of photosynthesis. | Quite complex terms appear in this learning objective: photosynthesis, chloroplasts and carbohydrates. Learners may find it helpful to have such terms broken down and explained when they are first introduced.  Not all learners will appreciate that energy from light is used in photosynthesis, but not used up. Remind learners that energy is never ‘used up’ but transferred into different forms of energy. In photosynthesis, light energy is mainly transferred into chemical energy in carbohydrates and thermal energy, when heat is lost to the environment. |
| **9Bp.07** Know and use the summary word equation for photosynthesis (carbon dioxide + water -> glucose + oxygen, in the presence of light and chlorophyll). | Equation, word equation, photosynthesis, carbon dioxide, water, glucose, oxygen, light energy, chlorophyll | Pictorial diagrams can be used to show the reactants and the products of the summary word equation for photosynthesis, along with the presence of light energy and chlorophyll (e.g. an outline of a leaf with arrows to show what is taken in and what is produced).  Simple atomic models can be used to show the reactants and products of the summary word equation for photosynthesis.  Online animations can be used to show the reactants and products of the summary word equation for photosynthesis. | Some learners might ask why the learning objective uses the term ‘summary word equation’; carefully explain that carbon dioxide and water do not actually react together and that glucose and oxygen are not made in the same reaction. Photosynthesis is actually a process that involves many reactions and the summary word equation just shows the key reactants and products.  Some learners may think that light energy and chlorophyll are reactants in photosynthesis. Emphasise that light energy and chlorophyll are needed for photosynthesis to happen but that the quantity of both energy and chlorophyll is not changed in the process. |
| **9Bs.01** Describe the pathway of water and mineral salts from the roots to the leaves in flowering plants, including absorption in root hair cells, transport through xylem and transpiration from the surface of leaves. | Pathway, mineral salts, water, stem roots, leaves, flowering plants, absorption, root hair cells, transport, xylem, transpiration | Pictorial diagrams showing the pathway for water and mineral salts from the roots to the leaves in plants can be used.  Pictorial diagrams that require labelling can add an element of interactivity. Labels could be processes (e.g. absorption, transport, transpiration) and/or parts of a flowering plant (e.g. root hair cell, xylem, leaf surface).  Animated diagrams of the pathway taken by water and mineral salts from roots to leaf surface may help show that this is a continual process.  Physical models can be bought/made that show the transport of water and mineral salts from root hair cells to leaf surface of a flowering plant.  Diagrams/photographs of microscopic sections through roots, stems and leaves can be used to show the main parts of flowering plants involved in the transport of water and mineral salts. | Learners may be confused about the use of the different terms used in related learning objectives, i.e. ‘minerals’ in 9Bp.05 and ‘mineral salts’ in this learning objective. Explain that these terms can be used interchangeably to some extent, but that ‘mineral salts’ usually implies compounds that are soluble in water.  A misconception could arise about the pathway of mineral salts. Mineral salts, dissolved in water, travel from the roots to the leaves, but they are not transpired from the surface of the leaves. Emphasise that only water is transpired. |
| **9ESc.01** Describe the carbon cycle (limited to photosynthesis, respiration, feeding, decomposition and combustion). | Carbon, carbon cycle, photosynthesis, respiration, feeding, decomposition, combustion | Diagrams of carbon cycles, with or without illustrations, can be useful to show the main five stages: photosynthesis, respiration, feeding, decomposition and combustion.  Diagrams showing different examples of carbon cycles can be used to illustrate the cycle in different habitats (e.g. woodland). | Learners should be familiar with all the terms in this learning objective apart from ‘combustion’. The process of combustion may need careful explanation, including why carbon appears as both a reactant and a product. |

# Unit 9.2 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
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| **9Bp.05** Know that plants require minerals to maintain healthy growth and life processes (limited to magnesium to make chlorophyll and nitrates to make protein). | **9TWSp.01** Suggest a testable hypothesis based on scientific understanding.  **9TWSp.04** Plan a range of investigations of different types to obtain appropriate evidence when testing hypotheses.  **9TWSa.03** Make conclusions by interpreting results, explain the limitations of the conclusions and describe how the conclusions can be further investigated.  **9TWSa.04** Evaluate experiments and investigations, including those by others, and suggest improvements, explaining any proposed changes. | **Mineral deficiency investigations**  Put learners into small groups of about 4, recap what they can remember about the need for minerals in a balanced diet for humans. Ask each group to write down the names of any minerals they can remember (calcium and iron are expected at Stage 8) and what they were needed for. Introduce magnesium and nitrates and explain the key roles that they play in plants; magnesium is required for chlorophyll and nitrates are required for proteins. Discuss how plants also use proteins for chlorophyll production and so plants deficient in either magnesium or nitrates may show similar visible indicators there is a mineral deficiency.  Show learners a short video of an investigation into what happens to plants when some minerals are not available. Choose a video that shows the equipment, method, the end effects of mineral deficiency on the plants and how the end effects are measured.  Ask questions:  *What was the aim of the investigation in the video?*  *What did the investigators find out?*  *What is the phrase used for when plants are missing a specific mineral?* (Answer: mineral deficiency)  *How did leaving out one mineral help the investigators find out why the plant needed that mineral?*  *In the investigation you have watched, what variables were controlled?*  Ask learners, in their groups, to design their own investigation to discover what happens when a locally available species of plant has no access to magnesium and nitrates. Discuss with learners the types of investigations they could use and which one may be the best to use. Their design should include a testable hypothesis for both magnesium deficiency and deficiency of nitrates. Use a class discussion to evaluate the methods; variables, reliability, and ease of data collection should be considered. Decide which method has the best design and which is most practicable (this may be the same design or two different designs).  **Note that the following investigation is a long-term investigation and may take a month or longer to obtain results. An alternative is suggested at the end of the activity.**  Provide materials for carrying out the chosen investigation into magnesium and nitrate deficiency. Seedlings or young plants of a locally available species of plant should be used, this can include water-living plants (e.g. duckweed). Learners will need a complete mineral nutrient solution (includes magnesium and nitrates); a mineral nutrient solution minus magnesium salts and a mineral nutrient solution minus nitrates. Equipment for water-living plants might include: beakers or jam jars and a loose lid to reduce evaporation. Equipment for seedlings might include: test tubes, cotton wool, aluminium foil to surround test tubes, pipette. It is possible to design a simple watering system, using wicks and reservoirs, to provide the mineral nutrient solutions to avoid the plants drying out between classes.  Learners carry out their investigation.  Make sure that all learners are involved; for example, each learner could set up one seedling under particular growing conditions Once the seedlings have grown to a measurable level the results can be collated and analysed.  *What do the results tell us?*  *What conclusions can we make?*  *What limitations are there to the conclusion?*  *How can the conclusions be further investigated?*  Learners can also suggest and explain improvements to the investigation.  Alternatively, if the required resources are not available, show learners a longer video of an investigation that explores the consequences of magnesium and nitrate deficiency on plants or ask them to use an online simulation that replicates a plant mineral deficiency investigation. Ask learners to interpret the results, make conclusions, explain the limitations of the conclusions and suggest how the conclusions might be further investigated.  Learners then compare and evaluate the methods of their planned investigation and the one they observed; they suggest and explain the improvements they would make.  **Resources:** A video of a plant mineral deficiency investigation, seedlings (young plants), mineral nutrient solutions, equipment as required (detailed in the activity) |
| **9Bp.06** Know that photosynthesis occurs in chloroplasts and is the process by which plants make carbohydrates, using the energy from light. | **9TWSc.06** Make an informed decision whether to use evidence from first-hand experience or secondary sources. | **The process of photosynthesis**  Hold a class discussion to establish what learners already know about photosynthesis.  Ask questions, such as:  *What sorts of organisms carry out photosynthesis?* (if required support learners in giving answers beyond ‘plants’, e.g. some bacteria, algae)  *What might plants need for photosynthesis to happen?*  *How many carbohydrates can you name?*  *What do carbohydrates all have in common?* (if required highlight to learners that there is a clue in the name ‘carbohydrate’)  Provide learners with an unlabelled diagram of a leaf cell. Ask the learners to label the chloroplasts and add arrows to show light entering the cells and the chloroplasts. The diagram can also be annotated to explain that carbohydrates are produced in the chloroplasts.  Ask learners, working in small groups, to discuss how they think scientists found out that chloroplasts are the site of photosynthesis. Divide the class into two groups, A and B. Group A discuss and plan what scientific experiments or investigations they can run that will confirm the finding that chloroplasts are the site of photosynthesis. Group B discuss using secondary sources of information to confirm the finding that chloroplasts are the site of photosynthesis. Both groups comes up with pros and cons of repeating experimental work or using secondary sources of information.  The groups present their cases. Collectively they agree if they should use secondary sources of information or do experimental work in the time they have left and with the resources they have available in school.  As a class, learners work towards the conclusion that this knowledge is the result of many different investigations over many years, often using sophisticated equipment not available to schools. Explain that it is an example of where scientific knowledge has been accepted by the scientific community and they do not need to repeat the investigations.  Learners use the remaining time to research that chloroplasts are the site of photosynthesis using secondary information sources.  **Resources:** Unlabelled diagram of leaf cells and chloroplasts, secondary information sources |
| **9Bp.07** Know and use the summary word equation for photosynthesis (carbon dioxide + water -> glucose + oxygen, in the presence of light and chlorophyll). | **9TWSm.03** Use symbols and formulae to represent scientific ideas. | **The summary word equation for photosynthesis**  Provide pairs of learners with the summary word equation for photosynthesis set out in the middle of a large piece of paper. Ask each pair to annotate the equation. Useful annotations could explain:   * where each reactant comes from and the route it takes to reach the chloroplasts * where each product is formed and what could happen to each product * where chlorophyll is found and why it is needed.   Ask learners questions about their annotated equations, such as:  *How much carbon dioxide is usually said to be in the air?*  *If plants take in carbon dioxide in the process of photosynthesis, what might happen to the carbon dioxide content of the air around plants? How might this be relevant to discussions about levels of carbon dioxide in the atmosphere?*  *What happens to the water on the leaves of plants when it has rained?*  *What might happen to the glucose made in photosynthesis?* (If required support learners by suggesting several possibilities.)  *Oxygen is made inside the chloroplasts within a plant cell inside a plant leaf. How does this oxygen reach the air outside a plant?*  After discussing these questions, give learners time to go back and add to their annotated equation.  **Resources:** Large sheets of paper |
| **9Bs.01** Describe the pathway of water and mineral salts from the roots to the leaves in flowering plants, including absorption in root hair cells, transport through xylem and transpiration from the surface of leaves. | **9TWSp.05** Make risk assessments for practical work to identify and control risks.  **9TWSa.04** Evaluate experiments and investigations, including those by others, and suggest improvements, explaining any proposed changes. | **The pathway of water and mineral salts in plants**  Show learners a short video of the movement of water through a plant. Choose one that shows water entering a plant through root hair cells, being transported through xylem and, finally, being transpired from the leaf surface. If the video has no voice-over, explain what is happening at each stage of the video.  Learners watch the same video a second time with the sound switched off; they work in small groups to produce a ‘voice-over’. If needed, show the video a third time. It may help some learners to have some key terms displayed (e.g. root hair cell, absorption, xylem, transpiration). Finally, show the silenced video again and allow the groups to provide the voice-over. Address any misconceptions and encourage the use of correct terminology. Groups not presenting their voice-over could provide constructive feedback.  Explain to learners that they are going to investigate one part of the pathway that water and mineral salts take. The investigation uses white flowers with a long stem (e.g. white carnations, *Dianthus caryophyllus*). Using a sharp knife (or scalpel) and a ceramic tile (or other suitable hard surface), cut the stems lengthwise from the end of the stem towards the flower. The cut can be halfway to the flower or can almost reach the flower. Place each of the two ends of the stem in different coloured water; the water can be coloured using food colouring and can be contained in containers (e.g. conical flasks, boiling tubes, cut up plastic bottles). Place foil (or cotton wool) around the top of the containers to reduce evaporation of the water.  Show learners a diagram of the investigation. Learners, working in pairs, carry out a risk assessment (using a template suitable to your local requirements about risk assessments) to identify and control risks associated with this investigation. Ask learners some questions to help them complete the risk assessments, such as:  *What hazards might be involved with cutting plant stems?*  *Why might food colouring be a hazard for some people?*  *Is there any part or product of a plant that might need considering during a risk assessment?*  The risk assessments might include:   * Sharp knives / scalpels could cut skin or damage work surfaces. Carry sharp knives / scalpels in a tray so that they are not left in unexpected places. Take care when handling sharp blades and always be aware of where the blade is. Do not hold the stem when someone else is cutting it. Cut the stems on a hard surface such as a ceramic tile. * Food colourings may be an irritant for some people. Use of alternative colourings may reduce the risk. * Plant sap may be a skin irritant. Wash hands after handling plants.   Provide learners with the equipment and materials needed and allow them to carry out the investigation. **Note that it may take several hours to get results.**  Flowers can be left for up to a week, as long as evaporation of the water is minimised, and photographs can be taken to record the changes.  Learners may be surprised that each colour is not restricted to the same side of the flower as the stem in the water of the same colour. Explain that xylem tissue has openings that allow water to move sideways between vessels, this allows the colours to mix.  Discuss with learners that the transpiration of water occurs at the flower, and any leaves present, so there is less water at the top of the stem. Water moves up the stem to equalise the water concentration in cells; it enters the bottom of the stem. Explain that the coloured water enters the bottom of the stem and, over time, the colour moves up the stem and into the flower; the colour does not evaporate with the water, remaining behind to colour the flower.  To finish, ask learners to evaluate the investigation undertaken and discuss if it effective. Ask learners if the investigation can be improved in anyway.  *Can you think how to make the investigation quantitative?*  Discuss learners’ responses and learners collectively agree how the investigation could be improved.  **Resources:** A short video of the movement of water through the plant, flowers, sharp knives, trays, ceramic tiles, food colourings, containers, foil, diagrams of the investigation, risk assessment template |
| **9ESc.01** Describe the carbon cycle (limited to photosynthesis, respiration, feeding, decomposition and combustion). | **9TWSc.01** Sort, group and classify phenomena, objects, materials and organisms through testing, observation, using secondary information, and making and using keys. | **The carbon cycle**  Provide learners a diagram of the carbon cycle and give them a few minutes to study it in pairs. Ask questions to check their understanding of the diagram and of the carbon cycle, such as:  *Where does the carbon cycle start?* (there is no start as it is a cyclical process)  *What might happen to the carbon cycle if no feeding happened?*  *What do the terms ‘decomposition’ and ‘combustion’ mean?*  *Which organisms carry out:*   * *photosynthesis* * *respiration* * *decomposition?*   Divide learners into five groups. Each group is responsible for researching one of the five key processes in the carbon cycle (photosynthesis, respiration, feeding, decomposition and combustion) and creating a poster about their process. The five posters can then be linked with arrows and used to create a large display of the carbon cycle.  Present learners, working in pairs, with a set of between 5-10 related statements about a particular organism, habitat or event; these can relate to your local area. Ask learners to sort the statements by matching them to one of the key processes of the carbon cycle. For example, a set of statements about a moorland habitat might include the following (with the key process given in brackets):   * Heather is an evergreen plant (keeps its leaves all year round) that is often found on moorlands. (photosynthesis) * Moorland is often managed by burning small areas of heather when the plants become old and woody. (combustion) * Burnt heather plants are usually replaced with young heather plants that provide a better food supply for game birds, such as grouse. (feeding) * In areas where there is a risk of fire spreading, heather can be managed by cutting. The cut heather will eventually break down due to the action of microbes and the resultant materials will be returned to the soil. (decomposition) * The microbes that break down heather cuttings do not work well in areas where there is reduced oxygen. (respiration)   **Resources:** Diagram of the carbon cycle, secondary information sources, sets of related statements |

# Unit 9.3 Chemical structures and properties

| Unit 9.3 Chemical structures and properties |
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| Outline of unit: |
| This unit provides learners with an opportunity to revisit the structure of the atom, build on prior their learning and to be introduced to electron arrangements. This new understanding is used to explain the chemical properties of chemical structures. Learners then consider the physical property of density.  Learners will have the opportunity to make observations of properties and propose trends. They will examine various types of models and develop skills in moving between multiple representations of substances. Learners will practise carrying out calculations, including rearranging formulae, choosing appropriate units and drawing conclusions from the data obtained. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * describing the particle model of solids, liquids and gases * knowing the Periodic Table presents the known elements in an order * describing the atomic structure of elements using the Rutherford model * knowing that electrons have negative charge and protons have positive charge * carrying out algebraic rearrangement of formulae (or substitution followed by rearrangement) * carrying out unit analysis. |
| Suggested examples for teaching Science in Context: |
| ***9SIC.01*** *Discuss how scientific knowledge is developed through collective understanding and scrutiny over time.*  This unit gives learners the opportunity to consider the historical development of atomic models. They could research the various models of the atom (e.g. the plum pudding model, the electron shell model) and highlight how our understanding has changed over time and how it has changed.  ***9SIC.05*** *Discuss how the uses of science can have a global environmental impact.*  Learners could consider the environmental impact of a range of chemicals based on their chemical and physical properties. These can include how the stability of chemicals affects how likely they are to last in the environment and therefore affects the impact they can have on the environment. Learners could also reflect on how science is used to predict and test the stability of chemicals and use that knowledge to make decisions about what chemicals should be controlled or used in different ways. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
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| **9Cm.01** Understand that the structure of the Periodic Table is related to the atomic structure of the elements and the Periodic Table can be used to predict an element’s structure and properties. | Periodic Table, electron, shell, atom, atomic structure, element, nucleus, property | All representations of the atom are models based on observation and mathematics. As part of this unit, learners will be introduced to, and use, the Bohr model of the atom.  The Periodic Table is itself a representation of how atoms are ordered. There are other forms of the Periodic Table learners could examine, discussing the strengths and limitations of each one. | The Bohr model of the atom is a simplification which is appropriate for Stage 9 learners. It is recommended that you are aware of the misconceptions (e.g. electrons exist in orbits, electrons are particles that can be isolated) but do not explain the limitations of the Bohr model at this stage as it may overcomplicate the concept and cause confusion to the class as a whole. |
| **9Cp.01** Understand that the groups within the Periodic Table have trends in physical and chemical properties, using group 1 as an example. | Periodic Table, group, trend, chemical property, physical property, reactivity | Drawings of the Bohr model, showing the positive nucleus at the centre of an atom surrounded by the shells of electrons, can help learners see the link between atomic structure and reactivity, as observed in chemical reactions. | Learners can overestimate the reactivity of group 1 elements, partly based on seeing fake videos. You should carefully check the reliability of resources used in school and also discuss with learners what they may have seen online. |
| **9Cp.04** Know that elements and compounds exist in structures (simple or giant), and this influences their physical properties. | Molecule, element, compound, structure, molecular,  simple, giant, crystal, physical property | All representations of molecules and giant structures are models. These may come in the form of: pencil and paper diagrams (e.g. lines representing the connections between atoms), physical models (e.g. balls connected with sticks) and animations or computer-simulated representations. | The formulae of compounds can lead learners to believe that all substances exist as molecules. For example, the formulae of NaCl and HCl both contain two atoms; the symbolic representation of the NaCl does not help learners to understand that NaCl exists as a giant lattice. This misconception is best prevented by showing learners a range of giant crystals and their associated symbolic representations. |
| **9Cp.02** Describe how the density of a substance relates to its mass in a defined volume. | Density, volume, mass, substance | Learners can use the particle models of solids, liquids and gases to explain the concept of density. | Learners often use the term ‘weight’ in place of ‘density’. They assume that heavier objects are denser without considering the volume of the object. A strong emphasis on the calculation of density and comparisons between different substances helps to prevent this misconception forming.  Learners can hold strongly to the idea that solids are always more dense than their liquid forms. Whilst this is a good general rule, it is not true for the most common substance learners encounter in chemistry lessons (water). Hydrogen bonding influences the structure of ice (solid water) so it has a lower density than liquid water and is able to float. At this stage, it is best to tell learners that water is a quite a special substance and show how the structure of ice means water expands when frozen and is less dense. |
| **9Cp.03** Calculate and compare densities of solids, liquids and gases. | Relative, density, solid, liquid, gas |
| **9Pf.01** Use density to explain why objects float or sink in water. | Density, float, sink | Learners can use the particle models of solids, liquids and gases to explain the concept of floating and sinking in relation to density. | Learners can find it hard to consider the relationship between two variables at once (e.g. weight, size, shape) as understanding the concept of density requires. They often attach more importance to one variable than the others. They may also apply simplistic thinking (e.g. heavy things sink and light things float). Careful scaffolding of activities and modelling of explanations helps to prevent this misconception.  Learners may also not understand that it is not just the density of a material that affects if an object float, but the average density including any cavities within the volume. This misconception can be addressed by discussing why large metal boats float and how the average density of the boat is reduced by having large internal voids/spaces filled with air. |

# Unit 9.3 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
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| **9Cm.01** Understand that the structure of the Periodic Table is related to the atomic structure of the elements and the Periodic Table can be used to predict an element’s structure and properties. | **9TWSm.01** Understand that models and analogies reflect current scientific evidence and understanding and can change. | **Atomic structure and properties**  Introduce learners to the Bohr model, describing the features at a basic level. For example:   * Electrons exist in shells at fixed distances from the nucleus. * Shells are filled from the inner shell. * Once a shell is full, electrons are added to the next shell out. * The capacities of the first three shells are 2,8,8 (although the pattern then changes, learners should be able to work out the atomic configurations for elements up to atomic number 20).   Discuss with learners the model, and link back to previous models of the atom; e.g. starting with the Dalton model (introduced in Stage 7), then the Rutherford model (introduced in Stage 8) and discuss how the models have changed over time. Discuss with learners what prompted the changes in thinking and if there is time learners can in class, or as a home activity, research the history of atomic models.  Ask learners to draw diagrams and deduce a shorthand notation for electron configurations of atoms from atomic number 1 to atomic number 20. Model using a shorthand notation if required (e.g. 2,1 for lithium or 2, 8, 3 for aluminium).  Ask learners to identify trends in the electron configurations they have drawn of elements across the periods and down the groups:  *What trends do we see as we go across a period?*  *What similarities do we see between elements in each group?*  *What similarities do we see between elements considered to be metals? How do their electronic structures differ from those of elements considered to be non-metals?*  Facilitate discussion about the force that keeps electrons in their shells; provide a basic explanation (i.e. the electrons in the shells are attracted to the protons in the nucleus).  Tell learners that many chemical reactions involve the loss or gain of electrons by atoms.  Ask learners to suggest what types of atoms will most easily lose electrons (large atoms) and gain electrons (small atoms).  **Resources:** Diagram of the Bohr model of the atom |
| **9Cp.01** Understand that the groups within the Periodic Table have trends in physical and chemical properties, using group 1 as an example. | **9TWSp.03** Make predictions of likely outcomes for a scientific enquiry based on scientific knowledge and understanding. | **The reactions of group 1 metals with water**  Explain to learners they are going to observe how water reacts with metals from the same group of the Periodic Table. They will use their observations to describe the common reactions of the group and the trend in reactivity down the group.  Demonstrate the reactions of group 1 metals (limited to small pieces of lithium, sodium and potassium) in a large tank, or ceramic basin, of cold water. If these metals are not available, show learners videos of the reactions (ensure any videos used are appropriate and do not over-exaggerate the reactivity of the metals)  Health and safety note: group 1 metals are flammable. They should be kept (stored under oil) in their bottles until needed. If demonstrating the reactivity of lithium, sodium and potassium with water ensure a full risk assessment is completed and you take appropriate safety measures as required by your school and country.  Ask learners to make notes as each demonstration proceeds. Encourage the use of scientific descriptions of observations. During the demonstration, highlight the key observations: floating of metals, movement around the surface of the water, production of gas and flames.  *What trend in reactivity did you observe?*  Learners use the observed trend to make predictions about how the metals lower down group 1 (rubidium, caesium and francium) would react with water.  *What do you think will happen? Why?*  Metals lower down group 1 can be demonstrated using videos; these should be selected from a reliable source as many fakes, showing different chemistry and/or levels of reactivity, exist. Do not demonstrate the reaction of rubidium, caesium and francium in the classroom.  Discuss with learners:  *Were your predictions accurate?*  *Do your observations support the trend identified for the earlier metals?*  Remind learners of the electron configuration of elements. Ask learners to draw the electron configurations of the group 1 elements, paying particular attention to the distance between electrons in the outer shell and the nucleus. Help learners to understand the link between the electron configuration of the group 1 atoms and how easy the outer electron can be lost.  *What happens to the size of the atom as we go down group 1?*  *What happens to the electron configuration as we go down group 1?*  Ask learners to suggest a relationship between the structure of the atoms as we go down group 1 and their reactivity with water. Encourage learners to write concise explanations of the relationship between the structure of an atom and its reactivity.  **Resources:** Small samples of lithium, sodium, potassium, large transparent tank, videos of the reactions of group 1 metals with water |
| **9Cp.04** Know that elements and compounds exist in structures (simple or giant), and this influences their physical properties. | **9TWSm.03** Use symbols and formulae to represent scientific ideas. | **Structures of elements and compounds**  Show learners a variety of models of both simple and giant structures. These can be formal models (made from molecular modelling equipment) or informal models (made from readily available craft or junk materials).  Discuss how these models represent the structures and how they relate to the other ways we represent chemical structures, e.g. chemical formulae and names.  Give groups/pairs of learners a short list of physical properties; ask them to discuss the models in terms of these properties, explaining their answers as they go. Physical properties could include:   * high/low melting boiling point * physical state at room temperature * electrical/thermal conductivity * crystallinity.   Give learners chemical formulae of simple and giant structures as well as equipment to make physical models of their structures (e.g. sticks, straws, discs, marshmallows). As learners make their models, ask:  *What does each part of your model represent?*  *Why have you used that structure?*  Instruct learners of specifics of links between structures and properties, with emphasis on key terms and scientific language. They should check their own explanations and refine them.  **Resources:** Models of simple and giant structures, model making equipment |
| **9Cp.02** Describe how the density of a substance relates to its mass in a defined volume. | **9TWSc.07** Collect, record and summarise sufficient observations and measurements, in an appropriate form. | **What is density?**  Help learners to think about the link between mass and volume. Ask a question, such as:  *Which is heavier, 1 kg of iron or 1 kg of feathers?* (they both have the same mass)  Learners may find it difficult to visualise the difference in volume of the iron and the feathers. If this is the case, show them a 1 kg weight and several pillows (with a total mass of 1 kg).  Introduce learners to the idea of density, including the formula to calculate it:  Emphasise the need for correct units, explaining that the use of standardised units makes it possible to compare the densities of different substances.  Provide learners with a range of objects with different densities; ideally these should be objects of the same size but made of different materials (e.g. cubes of different substances). Ask learners to rank the objects by volume and record the order. Learners then rank them by mass and record the order. Finally, learners calculate density and reorder the objects based on density. If learners use weighing scales (rather than a mass balance) ensure learners are clear about the difference between weights and mass.  If necessary, support learners with deriving the volume of the objects they have. Ask learners:  *What did you notice about the different ranking tasks?*  *What is the relationship between density, mass and volume?*  *What is high density?*  *What is low density?*  **Resources:** Cubes of different substances, means to measure mass |
| **9Cp.03** Calculate and compare densities of solids, liquids and gases. | **9TWSc.01** Sort, group and classify phenomena, objects, materials and organisms through testing, observation, using secondary information, and making and using keys.  **9TWSc.04** Take appropriately accurate and precise measurements, explaining why accuracy and precision are important. | **Measurement of the density of solids and liquids**  Provide learners with a range of solids (e.g. iron/steel block/mass, aluminium foil, carbon rod, piece of copper pipe, piece of expanded polystyrene) and liquids (e.g. water, ethanol, vegetable oil). Instruct learners to propose suitable ways of determining the volume of the substances. Provide a range of measuring tools for measuring mass and volume e.g. rulers, measuring tapes, measuring cylinders, sample bottles, mass balance.  Their strategies will depend on their mathematical understanding of calculating volumes and the shape of the solid materials provided to them. This activity provides an opportunity to develop mathematical reasoning and apply it in a scientific context. Encourage learners to consider the accuracy and precision of the measurements they will take.  Learners share their strategies and discuss the strengths and limitations of each strategy.  Once the volume is calculated, learners use a mass balance to measure and record the mass of each sample. Ensure learners are clear on the difference between weight and mass.  Ask learners to calculate the density of each sample, reminding them of the formula:    Ask learners to consider the accuracy and precision of the measurements taken. Discuss with the learners their calculated densities of the solids and liquids including evaluating how accurate their calculations were, this could include the use of a reference material and comparison with known values.  *How accurate do you think the measurements you took are?*  *What factors affect the accuracy of a measurement?*  *Are there differences in how you calculate the density for a solid and a liquid?*  *Is there a pattern in the results for the solids and liquids?* (This is an opportunity to demonstrate that liquids can have a greater density than a solid.)  Reiterate with learners how density is about the mass of a substance in a defined volume. This is the same for solids and liquids.  **Resources:** Samples of solids and liquids with different densities, measuring tools for mass and volume |
| **9Pf.01** Use density to explain why objects float or sink in water. | **9TWSc.01** Sort, group and classify phenomena, objects, materials and organisms through testing, observation, using secondary information, and making and using keys. | **Why do objects float and sink?**  Place learners in groups; provide each group with a sample of water of a different volume. Each group calculates the density of water by calculating the volume of their water sample (or give learners the volume data) and weighing the sample to find the mass. Ensure learners know the difference between weight and mass. Once all learners are done, compare their answers.  *Have you all got the same density?*  *What may make the density vary?*  *Were your samples of pure water?*  Tell learners that in reference tables the value for the density of water is given 1 g/cm3. Discuss why experimental results may vary from the data book value. For example, samples of water from the tap (as used in this experiment) contain dissolved substances and; therefore, have higher mass than pure water samples.  Provide learners with a list of objects and their densities. Ask them to predict which ones will float on pure water; they mark all those on the list with a density less than 1g/cm3.  Show learners an image of the Dead Sea and explain that the water contains so much salt that its density is much higher than pure water, i.e. 1.24g/cm3.  *Which objects will float in the Dead Sea that will not float in pure water?*  Learners run through their list of objects again, marking all the ones that will float in the Dead Sea. Discuss with learners any new additions.  *Why does that object now float?*  *What has changed?*  This activity can be extended by showing learners an image of Titan (a moon of Saturn). Explain that, based on observations of Titan, scientists believe that it has lakes and seas of liquid methane and ethane. Provide the density of liquid methane as 0.657 g/cm3.  *Which objects will float in a liquid methane lake on Titan?*  *Which objects will float in water on Earth but not in a liquid methane lake on Titan?*  Learners run through their list of objects again, marking all the ones that will float in liquid methane. Discuss any objects that sink in liquid methane but float in pure water. Explain that knowledge of the density of liquids and gases is important in building probes that will land on different planets during space exploration missions.  **Resources:** Mass balances, containers for water, list of objects and their densities, an image of the Dead Sea. |

# Unit 9.4 Sound and energy

| Unit 9.4 Sound and energy |
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| Outline of unit: |
| In this unit, learners draw and label waveforms, explore transverse and longitudinal waves and how they transfer energy. Learners will consider that sound travels as longitudinal waves and that electromagnetic waves travel as transverse waves. They will also learn about principles of wave interference using sound waves.  Learners go onto explore the theory of conservation of energy and begin to apply it to energy transfers and heat dissipation. As part of this learners will discuss and explain the difference between heat and temperature before considering transfer of energy by conduction convection and radiation and cooling by evaporation.  This unit provides opportunities for learners to carry out practical work and to consider models, including their strengths and limitations. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * describing how sound waves are transmitted by the vibration of particles * knowing light travels as waves * understanding sound and light waves can be reflected by some surfaces * knowing energy changes occur as a result of an event or process * knowing some energy is dissipated and becomes less useful during energy changes * describing how energy may be transferred mechanically with forces, electrically with an electric current and thermally by heating. |
| Suggested examples for teaching Science in Context: |
| ***9SIC.02*** *Describe how science is applied across societies and industries, and in research.*  Sound has many applications in industry and society including in medical technology. Learners can consider what technologies use sound, and how the sound waves are manipulated for example in ultrasound equipment.  ***9SIC.03*** *Evaluate issues which involve and/or require scientific understanding.*  Learners discuss energy efficiency and the role of house insulation. They can use their understanding of heat dissipation to discuss the pros and cons of house insulation and when it is appropriate to support or hinder heat dissipation.  **9*SIC.05*** *Discuss how the uses of science can have a global environmental impact.*  Scientific understanding about sound has allowed humans to develop new technologies, including the development of sonar and other underwater technologies. However some of these technologies have an impact on the marine environment and organisms. Learners can research and discuss the impact of underwater sounds from human activities. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
| --- | --- | --- | --- |
| **9Ps.01** Draw and interpret waveforms, and recognise the link between loudness and amplitude, pitch and frequency. | oscillation, transverse, longitudinal, compression, rarefaction, amplitude, frequency, wavelength, peak, trough, pitch, frequency, loudness, waveform | A ‘slinky’ toy (a compressed helical spring) can be used to model how a longitudinal wave (e.g. a sound wave) travels. In this model, each coil represents an air molecule. Each wave of compression represents a sound wave. Sound travels through the air (the wave moves), but the air (the coil) does not travel with the sound; like the coils, the air particles oscillate. | Some learners may think that waves transfer physical matter rather than energy. Using a length of rubber tubing, where the tube will allow a wave to propagate, will demonstrate that a transverse wave transfers energy without transferring matter.  Some learners may think that sound can travel through an empty space (a vacuum). This is a common misconception as many science fiction films show sound being transmitted through vacuum. It may be addressed by demonstrating, or showing a video, of sound in a bell jar under vacuum. |
| **9Ps.02** Use waveforms to show how sound waves interact to reinforce or cancel each other. | constructive interference, destructive interference, in phase, out of phase, superpose, superposition, reinforce, cancel, waveform | Superposition of waves can be modelled by dropping marbles into water at different locations and observing the wave patterns produced when two waves interact. | Learners may believe that waves have to be identical to interact. This can be disproved by showing a variety of diagrams of different waveforms interacting, including some interactions where the waveforms partially cancel or reinforce each other. |
| **9Pf.03** Know that energy is conserved, meaning it cannot be created or destroyed. | law of conservation of energy, chemical store, energy store, kinetic energy, thermal energy, gravitational potential, elastic potential energy, energy dissipation | Conservation of energy can be modelled using toy blocks (representing units of energy): the blocks can be transferred between different stores but they are not created or destroyed.  Learners could also be introduced to Sankey diagrams (without numbers) and use them to represent conservation of energy. | Learners often think that energy may be created and/or destroyed. This misconception is reinforced by the common misuse of language (e.g. The Sun ‘makes energy’ by nuclear fusion rather than ‘releases energy’). This misconception should be addressed throughout this unit by consistently modelling the correct use of language. |
| **9Pf.02** Describe the difference between heat and temperature. | thermal store, heat, energy transfer, temperature, joules (J), degrees Celsius (°C), kinetic theory, kinetic energy, solid liquid, gas | Kinetic theory can be used to model temperature, as temperature is a measure of the kinetic energy particles in a material or object have. Learners hold a cloth sheet (or blanket) on all sides with about ten lightweight balls placed in the centre. The balls initially represent the particles of a solid when the sheet is just gently moved: they are touching, form a regular pattern but are vibrating slightly. Jiggling the sheet a little more results in the balls breaking away from the pattern and their separation increases. Some balls may briefly fly into the air: this now represents the particles in a liquid. Shaking the sheet vigorously results in the balls being separated widely and being ejected from the sheet completely: this represents the particles of a gas.  The difference between heat and temperature can be shown by adding more balls to the sheet without changing the movement of the sheet. For example, quadrupling the number of balls (representing quadrupling the number of particles / mass) for the same amount movement would represent four times the amount of heat. | Learners may think that heat and temperature are the same thing. This misconception is reinforced by the common misuse of language e.g. The food should be cooked using a ‘high heat’ rather than ‘high temperature’. This misconception will be addressed through this unit.  Some learners may think that particles in a cold substance are not moving. The kinetic theory model should be used to address this misconception.  As water is commonly used to model an increase in kinetic energy of particles/atoms during a change of state, some learners may not realise other substances behave in a similar way. To address this, show other substances changing state and challenge learners to draw the particle diagrams for the changes. Gallium would melt on a learner’s gloved hand. Volatile liquids (e.g. petroleum ether, rubbing alcohol) that evaporate rapidly could also be used, taking care as they are flammable. |
| **9Pf.04** Know that thermal energy will always transfer from hotter regions or objects to colder ones, and this is known as heat dissipation. | temperature, heat thermal, dissipation, | Heat dissipation can be modelled using water and food colouring. Mix blue food colouring with cold water to represent a cold region of a substance. Add a few drops of red food colouring to hot water to represent a hot region. Gently pour the red, warm water on top of the blue, cold water. Over time, the red coloured water will spread throughout the entire body of water, changing the colour of the colder water.  Emphasise that the process of the red food colouring spreading is an example of diffusion which is caused by the water and food colouring particles’ movement. The process of heat dissipation is similar but can happen between remote materials and objects (e.g. between separate objects in an insulated container).  Heat dissipation can also be shown diagrammatically using colours to show different temperatures with arrows indicating the dissipation of heat. | Learners may think that energy is a substance that can ‘flow’ from place to place. Some models and experiments may reinforce this misconception. It may be addressed by evaluating the strengths and limitations of models and experiments when they are used. |
| **9Pf.05** Describe thermal transfer by the processes of conduction, convection and radiation. | conduction, convection, convection current, radiation, conductor, insulator, thermal transfer | The three different methods of heat transfer can be modelled using three bean bags given to learners. The bean bags can be returned to you by passing (conduction), carrying (convection), or throwing (radiation).  Conduction can be represented using a particle diagram of a solid being heated at one end. The particles at the end being heated vibrate more as energy is transferred to them. These particles collide with their neighbouring particles, transferring the energy to them and so transferring the energy throughout the material. Energy will transfer from one end to another until the thermal energy stores at each end are the same (both ends are at the same temperature).  Convection can be represented by a diagram showing a convection current of a fluid (liquid or gas) being heated from the bottom. Particles close to the thermal energy store get hot and start to vibrate more and move faster. They move further apart and become less dense. The hot fluid rises, and colder denser fluid takes up its place and is heated in turn. As the heated fluid rises it cools, becomes denser and sinks. This process continues until the fluid is the same temperature throughout.  Radiation can be represented by thermal images. | It is common for learners to state that ‘heat rises’ instead of stating that ‘hot fluids and gases rise’ when describing convection. It may be addressed by insisting on learners using correct terminology when describing heat transfer processes. The process of convection is also linked to density of a substance which has been previously covered.  Many learners believe that only ‘hot’ objects emit infrared radiation rather than all objects with a temperature higher than absolute zero. It may be addressed by showing thermal images of cooler objects and explaining the colour still represents heat. Black would represent absolute zero and a lack of heat being radiated by an object.  Learners may think that convection currents are caused by ‘potassium manganate VII’ because it has a ‘scientific sounding name’. Referring to it as a ‘dye’ can avoid this misconception. |
| **9Pf.06** Explain cooling by evaporation. | change of state, evaporation | Cooling by evaporation can be represented using the familiar example of sweating. Sweating can be modelled by dabbing a little cold water on the back of the hand using tissue paper / cotton wool and then blowing gently. | Some learners may think that when water evaporates it turns to steam, when it in fact becomes water vapour. This misconception should have been challenged at an earlier stage. However, if it remains, clarify that pure water does not boil until its temperature reaches100°C. Water evaporates at all temperatures between its freezing point and its boiling point; the rate of evaporation increases with temperature. |

# Unit 9.4 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
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| **9Ps.01** Draw and interpret waveforms, and recognise the link between loudness and amplitude, pitch and frequency. | **9TWSm.01** Understand that models and analogies reflect current scientific evidence and understanding and can change. | **Describing and interpreting waveforms**  **Longitudinal waves**  Demonstrate a longitudinal (compression) wave using a ‘slinky’ by laying it out between you and a learner. This works best on a low friction surface; it may be done on the floor or on several tables placed end to end. Ensure the remaining learners can clearly see the slinky.  Oscillate the slinky backwards and forwards at a regular rate whilst the learner keeps the other end stationary. The learner should feel the motion of the wave in their hand.  Ask learners:  *What is being transferred by the wave?* (energy is transferred but matter is not – emphasise that the slinky does not move from you to the learner)  *In which direction is the oscillation?* (the oscillation is to and fro – in the same direction as the wave movement)  *In which direction is the energy transfer? (*from you to the learner)  Explain to learners that you are transferring energy to the slinky with your hand and that energy is transferred to the learner by the coils of the slinky.  State the definition of a longitudinal wave as being a wave in which the direction of oscillation is parallel to the direction of energy transfer.  Discuss with learners:   * the compressions; where the coils are closer together than normal * the rarefactions; where the coils are further apart than normal * how to measure the amplitude of the wave; half of the distance a coil moves to and fro * the wavelength of the wave; the distance between two compressions or two rarefactions.   Ask learners if they can point out any of the key parts of the waves.  Explain to learners that sound energy travels through the air in a similar way to energy travelling along the slinky. Emphasise that making a sound transfers energy to the air by forming compressions and rarefactions in the air. The sound wave transfers energy from the source of the sound (e.g. your vocal cords) to the sound receivers (the learners’ ears). Emphasise that the air molecules themselves do not travel from you to the learners (adding small pieces of paper to a few of the slinky’s coils makes it easier to see the motion of individual coils in the wave).  Ask:  *How could you model an increase to the loudness of the sound wave being produced?*  *How could you increase the frequency of compressions being produced?*  Now demonstrate a wave with a higher frequency (moving the slinky at a greater rate). Emphasise to learners that the compressions are now closer together; an increase in frequency causes a decrease in wavelength (for the same wave speed).  **Transverse waves**  Demonstrate a transverse wave using a slinky; lay the slinky out between you and a learner.  Oscillate the slinky left and right at a regular rate whilst the learner keeps the other end stationary. The learner should feel the motion of the wave in their hand.  Ask learners:  *What is being transferred by the wave? (*energy is transferred but matter is not – emphasise that the Slinky as a whole does not move from the teacher to the learner)  *In which direction is the oscillation/vibration? (*the oscillation is from side to side – at right angles to the wave movement)  *In which direction is the energy transfer? (*from you to the learner)  Emphasis that you transfer energy to the slinky by moving your hand from side to side. Ask learners to describe the direction of energy transfer in relation to the direction of oscillation.  State the definition of a transverse wave as being a wave in which the direction of oscillation is perpendicular (or 90 degrees) to the direction of energy transfer. This can be shown to learners using a diagram.  Ask learners:  *Where are the peaks?* (this will vary if learners stand on either side of the demonstration)  *Where are the troughs?* (on the opposite side of the wave to the peaks)  *How is the amplitude of the wave measured?* (from a peak or trough to the x-axis)  *What is a wavelength?* (the distance between two peaks or two troughs)  Modelling a transverse wave with a rubber tube is a demonstration to show that a wave transfers energy rather than matter. It is best carried out with a 5 m length of pressure tubing; if pressure tubing is unavailable, use rubber Bunsen burner tubing. Wrap one end around your hand 2-3 times and a learner does the same with the other end. Walk apart so the tubing is stretched by about 50%. With a single, sharp, up-and-down movement, create a transverse wave that travels along the tube to the learner. Try as they might, the learner will be unable to hold the tubing still.  Ask questions:  *How are transverse and longitudinal waves similar?* (both transfer energy from the source without transferring matter; both have an amplitude, a wavelength, a frequency and a speed)  *How are transverse and longitudinal waves different?* (the particles making up a longitudinal wave move to and fro, i.e. parallel to the direction of wave travel; the particles making up a transverse wave move side to side, i.e. at right angles to the direction of wave travel)  If available, sound waves can also be shown using an oscilloscope. Connect a signal generator to a loudspeaker and a microphone to an oscilloscope to show a wave trace. A better waveform will be obtained by connecting the signal generator directly to the oscilloscope, but it is better to show learners that sound from the loudspeaker picked up by the microphone causes the oscilloscope trace to change.  Emphasise to learners that:   * a sound wave is a longitudinal wave * the oscilloscope trace shows a transverse wave * the microphone changes the to-and-fro movement of air molecules into a small alternating voltage which the oscilloscope shows as an up-and-down movement of the trace.   Show learners how the trace changes as the sound volume and frequency change. If the equipment is not available, show and describe oscilloscope traces, showing a range of waveforms to which the learners can identify sounds with higher/lower loudness and amplitude and higher/lower frequencies/pitches, instead.  Discuss with learners that our understanding of sound has changed over time and the models reflect the understanding at the time. Show learners historical models relating to sound (e.g. particles moving from a sound source to an ear) and discuss how the models have changed over time.  **Resources:** slinky, oscilloscope, microphone, signal generator, loudspeaker, connecting leads, pressure tubing, images of historical models of sound |
| **9Ps.02** Use waveforms to show how sound waves interact to reinforce or cancel each other. | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations. | **Waves and superposition**  Show learners two waveforms.  *What will happen if these two waveforms happen at the same time in the same place?*  Discuss with learners that the two waveforms will interact, this is called ‘superposition’, and the waves will either reinforce or cancel each other. Discuss with learners that the superposition of waves can be physically modelled with transverse waves  Show learners a large, transparent tank filled halfway with water so the surface level of the water is clear when viewed from the side. Ensure the tank is as long as possible. Present two identical weights.  *What will happen when the weights are dropped in the water?* (they generate waves; if required, drop one weight to show the wave being generated)  *What will happen when the two waves meet?*  *How will they interact?*  Drop one weight at the same time as a learner drops the other so they enter the water simultaneously. Ask learners to sketch what they observe and add descriptions of their observations to their sketches.  Explain to learners that these waves, produced by two independent oscillating/vibrating sources, are in phase with each other. When two waves that are in phase with each other interact (collide) they constructively interfere (reinforce each other) and the individual wave amplitudes combine to create a larger amplitude (a bigger wave).  Repeat the demonstration but this time drop one weight slightly after the other. The learners observe and discuss how the interaction of the waves is different to the first demonstration.  Explain to learners that the waves are out of phase with each other. When the two waves interact (collide) they destructively interfere and the individual wave amplitudes combine to cancel each other out (no wave).  Discuss with learners the strengths and limitations of the model using water to model wave interactions of sound.  *What are the strengths of the model?*  *What are the limitations of the model?*  Provide a range of waveforms (in and out of phase, different amplitudes) and ask learners to draw the resulting wave interactions, labelling them as constructive or destructive interference.  For example:  Image result for superposition  If possible, to demonstrate sound interference, connect two identical loudspeakers to a signal generator. Set the loudspeakers about 1 m apart and the sound frequency to about 2000 Hz (so the wavelength is about 17 cm). Moving a sound level meter between the loudspeakers will detect loud and quiet regions. You could use a microphone connected to an oscilloscope as an alternative to a sound level meter. If the equipment is not available, show a video to learners demonstrating sound waves being reinforced and cancelled.  **Resources:** Weights, tank, signal generator, loudspeakers, sound level meter |
| **9Pf.03** Know that energy is conserved, meaning it cannot be created or destroyed. | **9TWSc.05** Carry out practical work safely, supported by risk assessments where appropriate.  **9TWSc.07** Collect, record and summarise sufficient observations  and measurements, in  an appropriate form. | **Conserving energy**  Show learners a candle and light it. Discuss the safety aspects of using any open flame in a science lesson.  Ask learners:  *Where does the energy for the candle flame come from?*  *In which form does candle wax store energy?*  *What happens to the chemical energy stored by the candle wax as the candle burns?*  *What happens to the total energy in the room as the candle burns?*  Listen to learners’ answers and, using their answers as a starting point, explain that the energy for the flame comes from the wax, which is a store of chemical energy. The chemical energy stored by the wax is changed into heat and light energy which are transferred to the surrounding environment. The total energy in the room remains constant because it is a closed system. Explain to learners that the law of conservation of energy states that energy can neither be created nor destroyed; it can only be transferred between energy stores.  Provide learners with clockwork toys; they wind them up and let them move. Learners then consider these questions, basing their answers on the candle example and their own observations of the clockwork toy.  *Where does the energy for the clockwork toy come from?*  *In which form is the store of energy?*  *What happens to the elastic potential energy store as the toy moves?*  *What happens to the total energy in the room as the toy moves?*  Explain to learners that scientists have proposed models to help explain the conservation of energy. Read the model created by Richard Feynman:  *Imagine a child, who has blocks which are absolutely indestructible, and cannot be divided into pieces. Each is the same as the other. Let us suppose that he has 28 blocks. His mother puts him with his 28 blocks into a room at the beginning of the day. At the end of the day, being curious, she counts the blocks very carefully, and discovers a phenomenal law—no matter what he does with the blocks, there are always 28 remaining! This continues for a number of days, until one day there are only 27 blocks, but a little investigating shows that there is one under the rug—she must look everywhere to be sure that the number of blocks has not changed. One day, however, the number appears to change—there are only 26 blocks. Careful investigation indicates that the window was open, and upon looking outside, the other two blocks are found. Another day, a careful count indicates that there are 30 blocks! This causes considerable consternation, until it is realized that a friend came to visit, bringing his blocks with him, and he left a few at the house. After the mother has disposed of the extra blocks, she closes the window, does not let the friend in, and then everything is going along all right, until one time she counts and finds only 25 blocks. However, there is a box in the room, a toy box, and the mother goes to open the toy box, and finds the missing blocks.*  Learners discuss the strength of the model. If beneficial to your learners act out the model to help consolidate it.  If required, remind learners of the model of energy they were taught in Stage 7 (either types of energy or stores of energy with pathways).  Set up a circus of examples for learners to practise identifying energy transfers. For each example they should decide whether they think energy is conserved. Before learners start the circus, discuss the safety aspects they have to consider, particularly for using flames or carrying out a chemical reaction.  Examples for the circus could include:   * conducting an exothermic reaction (e.g. burning magnesium) * plucking the string of a musical instrument (e.g. guitar, violin) * dropping a bouncy ball onto the floor * a simple circuit with a battery and lamp * a simple circuit with a battery and a buzzer * a gas burner (e.g. Bunsen burner) or match * a Bluetooth speaker, radio or CD player * an elastic band powered model aeroplane * a clockwork toy car * a battery powered toy car.   Throughout the circus of activities, the pairs of learners make observations and link them to their thoughts about energy transfers. Learners in pairs, comparing observations and notes, identify if the law of conservation of energy applies to each example. As a class, discuss any examples where any learners believe the law does not apply; explain how the energy has not destroyed or collected.  This activity can be extended by learners considering an endothermic reaction (e.g. dissolving ammonium chloride in water) or an endothermic process (e.g. ice melting).  **Resources:** Candle, clockwork toys, energy transfer circus equipment |
| **9Pf.02** Describe the difference between heat and temperature. | **9TWSc.03** Decide when to increase the range of observations and measurements, and increase the extent of repetition, to give sufficiently reliable data.  **9TWSc.04** Take appropriately accurate and precise measurements, explaining why accuracy and precision are important.  **9TWSp.04** Plan a range of investigations of different types to obtain appropriate evidence when testing hypotheses.  **9TWSa.02** Describe trends and patterns in results, identifying any anomalous results and suggesting why results are anomalous.  **9TWSa.05** Present and interpret results, and predict results between the data points collected | **Heat and temperature**  Explore learners’ understanding of temperature by providing a range of images (e.g. sun, hot bath, hot cup of tea, swimming pool, sparkler). Learners, working in pairs (or groups of three), rank the images in order of hottest to coldest based upon their experiences. After five minutes, discuss rankings with another group.  To explore learners understanding of the difference between heat and temperature, ask learners to describe (or name) something that has:   * a high temperature and a lot of heat (e.g. a furnace, the Sun, magma/lava) * a low temperature and a lot of heat (e.g. a heated swimming pool, a warm ocean current) * a low temperature and not have much heat (e.g. a cup of warm tea) * a high temperature and not much heat (e.g. a spark from a fire).   Provide groups of learners with stopwatches, thermometers and three 250 ml beakers filled with different volumes (50 ml, 100 ml, 150 ml) of water at the same temperature; the volume of water should be measured using measuring cylinders.  Ask learners to design their own investigation using the equipment provided to identify the relationship between heat and temperature. Learners share their plans and discuss which investigation type was chosen and why. Discuss with learners the importance of being accurate and precise and how they can be accurate and precise with their measurements in their investigations.  A possible investigation to run if learners have varied approaches or have flaws in their investigations: Learners suspend a thermometer in each beaker using a clamp stand, boss and clamp; the thermometer should not be touching the bottom of the beaker. They use stopwatches (or stop clocks) to time how long each beaker takes to reach 60°C, heating the beaker with a 4-5 cm Bunsen burner flame.  If the equipment required is limited or not available, the following data can be provided to learners in place of carrying out the investigation themselves:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Group A |  |  | Group B |  | | Volume of water (ml) | Time to reach 60OC (s) |  | Volume of water (ml) | Time to reach 60OC (s) | | 50 | 25 |  | 50 | 35 | | 100 | 40 |  | 100 | 110 | | 150 | 165 |  | 150 | 125 |   Using the experimental data (their own or provided) ask learners:  *What is the relationship between the volume of water in the beaker and the length of time needed to heat the water to 60OC?*  *Why does a larger amount of water take longer to heat up than a smaller volume?*  *What shape of graph would we expect if ‘time needed to heat the water to 60OC’ was plotted against ‘volume of water in the beaker’?*  If learners obtained their own data, discuss with learners if any of their data was anomalous. Discuss with learners why they may have anomalous results.  Discuss with learners why a larger volume of water takes longer to reach 60OC. Explain that this is because more heat energy is needed to heat the larger volume of water to 60OC.  Ask learners to plot a graph of their three results. Discuss the type of graph selected and what their graphs show. It is likely that few groups will obtain a straight-line graph as this investigation tends to yield variable results. Describe some of the variables that are difficult to control (e.g. draughts, heat losses from the beakers, height of the flame, position of the flame under the beaker, the position of the thermometer in the beaker). Learners, working in groups, list a series of strategies that would yield more reliable results.  Strategies could include:   * Using a wider range of water volumes in a larger beaker (e.g. 50 ml to 500 ml in a 600 ml beaker, increasing by 50 ml each time). * Using more water volumes between 0 ml and 150 ml (e.g. 25 ml to 150 ml, increasing by 25 ml each time). * Repeating each reading at least three times, discarding and repeating anomalous results. Take an average of the results within range. * Improving the equipment by using an insulated beaker that reduces heat losses. * Improving the procedure by keeping a constant flow of gas to the Bunsen burner and stirring the water.   Ask the learner groups to explain how their proposed improvements would increase the reliability of the data. If possible, learners carry out a refined investigation to generate more data and create a graph that is more meaningful.  Show learners an ideal graph and model using the graph to predict what other results/data points could be. Provide the graph to learners and ask them to identify likely experimental data they would expect from the graph. Discuss this is one way scientists check the validity of data; by interpreting a small set of data, making predictions and then seeing if their predictions are correct.  Recap with learners that:   * Heat is a measure of how much energy is transferred to a substance (which results in an increase in kinetic energy of the particles) and is measured in Joules (J). * Temperature is a measure of how hot something is (the average kinetic energy of the particles) and is measured in degrees Celsius (°C).   **Resources:** Images of objects at different temperatures, Bunsen burners, tripods, 250 ml beakers, measuring cylinders, thermometers (do not use mercury thermometers), stopwatches, clamp stands, bosses, clamps |
| **9Pf.04** Know that thermal energy will always transfer from hotter regions or objects to colder ones, and this is known as heat dissipation. | **9TWSa.02** Describe trends and patterns in results, identifying any anomalous results and suggesting why results are anomalous.  **9TWSa.05** Present and interpret results and predict results between the data points collected. | **Investigating cooling water**  Provide groups of learners with stopwatches, thermometers and several 200 ml beakers with lids (to reduce heat losses by evaporation) filled with 100 ml of water at different temperatures. Four kettles (or water baths) could be used to provide learners with water at the correct temperatures (30°C, 40°C, 50OC, 60OC). They monitor room temperature throughout the experiment.  Learners place four 200 ml beakers each with a lid (to reduce heat losses by evaporation) on heatproof mats and record the starting temperatures for each beaker. They record the temperature every 2 minutes, stirring between measurements, and, after 20 minutes they calculate the temperature drop for each beaker.  If the equipment required is limited or not available, the following data can be provided to learners in place of carrying out the investigation themselves:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Time (minutes) | Temperature of water (OC) | | | | | Beaker 1 | Beaker 2 | Beaker 3 | Beaker 4 | | 0 | 60 | 50 | 40 | 30 | | 2 | 55 | 46 | 37 | 29 | | 4 | 50 | 42 | 35 | 27 | | 6 | No data given for 6 minutes | | | | | 8 | 42 | 37 | 31 | 26 | | 10 | 39 | 34 | 30 | 25 | | 12 | 37 | 32 | 28 | 24 | | 14 | 34 | 31 | 27 | 24 | | 16 | 32 | 29 | 26 | 23 | | 18 | 31 | 28 | 25 | 23 | | 20 | 29 | 27 | 25 | 22 |   They plot a graph of temperature drop (y-axis) against time (x-axis) for each beaker on the same axes, drawing curves of best fit.  Ask learners interpret the results:  *What do your results tell you?*  If learners obtained their own data, discuss with learners if any of their data was anomalous. Discuss with learners why they may have anomalous results.  Discuss with learners that the higher the starting temperature of the beaker, the faster the temperature drops*.* Ask them to use their curves of best fit to determine the temperature drop for each beaker after 5 minutes and 15 minutes by interpolation.  Ask learners:  *Where has the energy from the water gone?*  Discuss with learners how the energy has transferred, and dispersed, into the surrounding environment. Explain that this is called heat dissipation and always occurs from hotter regions to colder ones.  Guide learners to determine from their graphs which beakers temperature reduced the fastest.  **Resources:** Beakers with lids, thermometers (do not use mercury thermometers), kettles, heatproof mats, stopwatches |
| **9Pf.05** Describe thermal transfer by the processes of conduction, convection and radiation. | **9TWSp.05** Make risk assessments for practical work to identify and control risks.  **9TWSc.05** Carry out practical work safely, supported by risk assessments where appropriate.  **9TWSc.07** Collect, record and summarise sufficient observations and measurements, in an appropriate form. | **Investigating thermal transfer processes**  Before carrying out the following practical activities, learners should identifying the major risks and what they need to do to mitigate them. Once risk assessments have been completed, accepted and appropriate safety equipment has been provided the learners can carry out the practical work. If you do not have the required equipment videos of each practical activity can be used which learners observe and comment on.  **Investigating conduction**  In groups learners, balance four rods of different metals (e.g. copper, steel/iron, brass, zinc, aluminium) on a tripod with their ends are/almost touching so that a 5-6 cm Bunsen flame, placed underneath, will heat each rod equally.  Before the Bunsen burner is lit, place a small amount of petroleum jelly / candle wax on the other end of each rod. Learners then apply a Bunsen flame to where all the rods are nearly touching. Learners record the time when the petroleum jelly / candle wax on each rod melts.  Ask learners:  *Which sample of petroleum jelly / candle wax melted first? Which one last?*  *Why is there a difference between them?*  Explain that most metals are relatively good conductors of heat, especially copper. Explain the process of heat conduction in terms of vibrations being passed from particle to particle. This can be demonstrated using a physical model. Several learners stand side-by-side in a line with linked arms. Gently ‘vibrate’ the end learner’s arm: the movement will quickly pass on to the other ‘particles’ in the line.  Explain that some solids (e.g. glass, plastic, wood) are poor conductors of heat compared with metals.  **Investigating convection**  Divide the learners into groups of 3-4; provide each group with a 600 ml (or 1000 ml) beaker and a single crystal of dye (potassium manganate VII). The water should be allowed to stand for a couple of minutes and be ready to heat before adding the crystal. Learners use forceps to pick up the crystal to avoid skin stains. They place the crystal in the water on one side of the beaker and apply heat, using a Bunsen flame, directly below the crystal. They observe what happens.  Ask learners:  *How does the water move?*  *Why does the water rise when it is heated?*  Explain that water expands slightly when heated and so becomes less dense. Lower density warm water rises through higher density cold water. The dye lets us see this, but does not change the water’s movement.  Discuss with learners that convection currents can also be observed in gases (e.g. air). Provide examples, such as: warm air currents can be felt rising 50 cm above a candle flame, birds and gliders can soar upwards on rising air currents called ‘thermals’.  **Investigating radiation**  A ‘Leslie cube’ is ideal for demonstrating heat transfer by radiation. Each of its four vertical faces has a different finish: blackened tinplate, roughened tinplate, varnished tinplate and polished tinplate. The cube is placed on a level surface and filled with boiling water, so each face is at the same temperature.  Ask learners:  *Will the temperature of each face be different or the same? (each face will be the same temperature, i.e. the temperature of the water)*  *Will each face emit the same amount of heat? (No. Shiny/polished faces emit heat less quickly than roughened/blackened faces)*  Use an infrared thermometer to measure the temperature of each vertical surfaces of the Leslie cube. These thermometers work well as they do not touch the surface of the cube, therefore eliminating conductive heating. Alternatively, suitable stands can be used to hold standard non-mercury thermometers (-10 to 110OC) very close to the Leslie cube without touching the four surfaces.  If learners are careful, they could place their hands 10-15 cm away from the different surfaces of the Leslie cube; they may be able to detect some difference in the energy transferred by each surface. Ensure learners take care to not put their hands too close to avoid burning themselves. They can discuss their own experiences where they have noticed thermal transfer by radiation.  **Resources:** Conductivity rods, petroleum jelly, tripods, Bunsen burners, heatproof mats, eye protection, 600 ml beakers, potassium manganate VII crystals, kettles, Leslie cubes, infrared thermometers |
| **9Pf.06** Explain cooling by evaporation. | **9TWSa.03** Make conclusions by interpreting results, explain the limitations of the conclusions and describe how the conclusions can be further investigated. | **Cooling by evaporation**  Explain the process of evaporation as the change of state from a liquid to a gas. It occurs when particles have enough energy to leave the surface of the liquid. This happens at all temperatures below the liquid’s boiling point.  Ask questions:  *What is the boiling point of pure water?* (100OC under standard conditions)  *How does the rate of evaporation change with temperature?* (the rate of evaporation increases with temperature)  *How is evaporation different from boiling?* (evaporation takes place at temperatures below the boiling point; boiling can only happen at the boiling point of the liquid)  *How is evaporation similar to boiling?* (both result in a liquid becoming a gas/vapour; the gas particles become much more spread out compared with the particles in the liquid)  Emphasise that evaporation is not the same as boiling. The boiling point of pure water is 100OC whereas pure water evaporates at all temperatures below 100OC.  Demonstrate heating a small metal block by placing a small metal block in a 1000 ml beaker, placing the beaker on a tripod and heating the beaker with a Bunsen burner. Alternative use a small saucepan over a mobile hob to heat the small metal block in water. Remove the small metal block from the water and watch the water evaporate from the block’s surface. Repeat this several times if required.  Ask questions:  *Why does the egg quickly become dry when it is taken out of water?* (the water evaporates from the surface of the shell)  *Where does the water go?* (it goes into the air as water vapour)  *How does it get into the air?* (heat from the egg passes to the liquid water on the shell giving the water molecules enough energy to break away from the liquid and become a vapour)  Cooling by evaporation can be represented using the familiar example of sweating. Explain that sweating is the body’s response to being in a hot place or generating heat by strenuous exercise. Sweating is one way for the body to lose unwanted heat, so cooling the body. Demonstrate to learners a way of modelling sweating; use tissue paper / cotton wool to dab a little cold water on the back of your hand and then blow gently. Get learners to try this and observe the cooling effect.  Ask questions:  *What does the water require in order to evaporate from your hand?* (water requires energy to give the surface water molecules enough energy to enter the gas phase)  *From where does the water on our hands get the energy to evaporate?* (from our skin)  *How does sweating cool us down?* (sweat glands secrete sweat onto our skin; the sweat takes energy from our skin to evaporate making our skin cooler)  In response to getting hot, our bodies produces sweat which gains energy from your skin and eventually evaporates. This process cools us down as there is a transfer of thermal energy from each individual’s body to their sweat.  Discuss with learners:  *What are the limitations of this experiment?*  *Could it be improved?*  Discuss with learners what experiment they could design to further investigate cooling by evaporation.  **Resources:** Small metal block, 1000 ml beaker, Bunsen burner, tripod, heatproof mat, gauze |

# Unit 9.5 Human biology

| Unit 9.5 Human biology (12 hours) |
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| Outline of unit: |
| This unit starts with learners considering excretion in the context of the human renal system. Learners then study reproduction (another characteristic of living organisms) in the human context; they focus on gametes and fertilisation while exploring the role of DNA, genes and chromosomes. The inheritance of biological sex is studied in terms of XX and XY chromosomes. Finally, learners discuss how fetal development is influenced by maternal health including her diet and whether she drinks alcohol, smokes or uses drugs (legal or illegal).  During this unit, learners have opportunities for describing the strengths and limitations of models as well as understanding that models reflect current scientific evidence and they can change when new evidence is discovered. Learners also have opportunities to use symbols to represent scientific ideas when using information about XX and XY chromosomes and to interpret data about fetal development in relation to maternal health. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * knowing the seven characteristics of living organisms including excretion * explaining how the structure of some specialised cells are related to their functions * describing the functions of the cell nucleus * knowing that animals, including humans, produce offspring that have a combination of features from their parents * describing how human growth, development and health can be affected by lifestyle, including diet and smoking * knowing that blood contains blood cells and dissolved substances. |
| Suggested examples for teaching Science in Context: |
| ***9SIC.03*** *Evaluate issues which involve and/or require scientific understanding.*  Learners can discuss the need for two kidneys and some of the ethics involved in donating kidneys to those who have no functioning kidneys. They can consider if the ethics change depending on if the donor is living or deceased. This could be approached by giving learners a ‘for’ or ‘against’ position and the opportunity to use secondary information sources to carry out some research and discuss their ideas. This could be followed with a class debate on the pros and cons of donating a kidney and, more generally, organ donation.  ***9SIC.02*** *Describe how science is applied across societies and industries, and in research.*  Knowledge about the effects of maternal smoking, diet and drugs on fetal development has greatly advanced in recent years and advice resulting from research into these areas is now much more readily available. Learners can discuss the different ways in which advice can be given so that it reaches as many parents and prospective parents as possible. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
| --- | --- | --- | --- |
| **9Bs.02** Describe the structure of the human excretory (renal) system and its function (limited to kidneys filtering blood to remove urea, which is excreted in urine). | Excretory system (renal system), excretion, kidney, filtration, urea, urine | Learners could use a combination of the following models:   * physical models illustrating the anatomy of the kidneys and associated renal system * coloured diagrams illustrating the human excretory system * animations showing the process of filtration of blood by the kidneys and the formation of urine * physical filtration models to represent a kidney (e.g. simple sieves; filter funnels and filter paper) can be used to show that dissolved substances (e.g. urea) will pass through a filter while insoluble substances and large components (e.g. blood cells) will not pass through. | Some learners may need guidance on what the term ‘excretion’ means in terms of the human renal system; ‘excretion’ can sometimes be confused with ‘egestion’. Explain that excretion always means getting rid of products made in the body whereas egestion means is the process of voiding undigested food.  Some learners may have the idea that urine and faeces are analogous. Explain that urine is produced from urea that has been absorbed into the blood and then is excreted. Faeces are largely made of waste materials that have not been absorbed into the blood and are egested.  The idea that ‘dirty’ blood is filtered to make the blood ‘clean’ may be held by some learners. Ensure that correct terminology is used and emphasise the idea that filtering removes a waste product (urea) from the blood but the blood itself if not ‘dirty’.  Any confusion between ‘urea’ and ‘urine’ can be overcome by showing learners how urea dissolves to form a solution of urine. If urea is not available, solid sugar can be dyed with a little yellow food colouring and then dissolved. |
| **9Bs.03** Know that chromosomes contain genes, made of DNA, and that genes contribute to the determination of an organism's characteristics. | DNA, genes, chromosomes, organisms, characteristics | Learners can use coloured diagrams or animations to show the relationships between DNA, genes and chromosomes. | Some learners may be confused by the relative sizes of DNA, genes and chromosomes. Explain that genes are smaller than chromosomes; the extremely long DNA molecules (often said to be about 3m per cell) are packaged into chromosomes. Making DNA models will help learners understand the relationships between DNA, genes and chromosomes.  Learners might have a simplistic view of the relationship between genes and characteristics, thinking either that genes decide everything or genes are irrelevant. Discuss with learners there is a range of different ways genes contribute to characteristics and some genes do not have a direct impact on an organisms characteristics while others are vital to an organism’s survival. Examples of genes and their role in human biology can highlight the variation. |
| **9Bp.01** Describe the fusion of gametes to produce a fertilised egg with a new combination of DNA. | Fusion, gametes, fertilisation, egg, DNA | Physical models of male gametes, female gametes and fertilised eggs will help learners appreciate the relative size and structures of these cells.  Coloured diagrams, showing some simple chromosome structures of gametes and the fertilised egg, will help learners appreciate that fertilised eggs have a new combination of DNA.  Animations can help learners understand the processes of fusion and fertilisation, as well as the formation of a new combination of DNA within a fertilised egg. | The idea of fusion is different from just ‘meeting’ and it is helpful to make this clear to learners, so that they fully understand how the fertilised egg has a new combination of DNA. Ensure that the term ‘fusion’ is used wherever appropriate and that learners understand this term. Also ensure learners understand gametes contain DNA from the parents. |
| **9Bp.02** Describe the inheritance of sex in humans in terms of XX and XY chromosomes. | Inheritance, sex, chromosomes,  XX chromosomes,  XY chromosomes, male, female, parent, offspring | Learners can use sets of cards, individually marked with an X or a Y, to model chromosomes and to work out the chances of a fertilised egg forming a baby boy or girl.  Pedigree diagrams and Punnet squares can be used to show the inheritance of X and Y chromosomes. | XX and XY and their role in humans can be confused (especially if learners find out about sex determination in other species such as birds). Provide plenty of opportunities for learners to link the pairs of chromosomes to the correct sex.  Biological sex and gender are not the same thing in terms of scientific language. Clarify the difference and try to use the terms correctly to encourage learners to do the same. |
| **9Bp.08** Discuss how fetal development is affected by the health of the mother, including the effect of diet, smoking and drugs. | Fetus, fetal development, health, diet, smoking, medicine, drugs | Videos that discuss how the health of a mother affects fetal development are useful in portraying real life examples that learners may relate to, but such videos should be previewed to make sure that they are appropriate for learners. | Learners may have misconceptions about diet including that there are ‘unhealthy’ foods and ‘healthy’ foods. When discussing diet, make sure that learners appreciate that a diet being considered ‘unhealthy’ is about the quality and/or quantity of each item. For example, some foods considered healthy may be unhealthy if eaten in excess. This is important when addressing the misconception pregnant women require more food due to being pregnant when no extra calories are required in the first 6 months and only an extra 10% are required in the last 3 months.  Some learners may not understand how a pregnant woman smoking may affect her fetus. This can be addressed by showing data about the effects of maternal smoking on fetal health. Learners could also be given diagrams that show how substances in a mother’s blood can cross the placenta and enter fetal blood.  Some learners may think that only illegal drugs may harm a fetus. Explain that there are common, legally available drugs, including alcohol and medicines, that can affect the health of a fetus if taken by the mother. |

# Unit 9.5 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
| --- | --- | --- |
| **9Bs.02** Describe the structure of the human excretory (renal) system and its function (limited to kidneys filtering blood to remove urea, which is excreted in urine). | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations. | **Structure and function of the human excretory system**  Show learners a short video about the structure and function of the human excretory system. Ask the class questions, based on the video, such as:  *What products does the human body excrete?*  *Where might these products have come from?*  *What components of the human excretory (renal) system can you name?*  *Suggest some reasons why the human body has two kidneys.*  *What might happen if the kidneys stop working properly?*  Ask learners to place cut-out kidney shapes in the correct position on an outline of the human body; a life-size body outline could be prepared by drawing round one of the learners. Once the kidneys have been placed correctly, ask the learners to consider the strengths and limitations of this simple model. For example: the model is simple and visual (strengths); the 2-dimensional nature of the model does not show that the kidneys are towards the back of the body or how the kidneys relate to the bladder and circulatory system (limitations).  Use an anatomical model of a kidney to show learners where blood enters a kidney and where the blood and filtered products leave the kidney. Alternatively, a real kidney from an animal, may be dissected as classroom demonstration or by learners. If you do carry out dissections ensure a full risk assessment is complete and you comply with local health and safety standards and please refer to the notes on dissection on page 8 of this scheme of work.  Check learners’ understanding of the principles of filtration. Consolidate their understanding by setting up a simple filtration system model that represents filtration within the kidneys. ‘Blood’ could be made by combining three components: sand (urea molecules), dried peas (blood cells) and water (plasma). Pour the ‘blood’ through a sieve over a container and show learners that the ‘urea’ passed through the sieve but the ‘blood cells’ were too large to pass through. Learners, working in small groups, make a table showing the strengths and limitations of the sieve demonstration as a model for kidney filtration. Collate the responses and discuss as a whole class; ensure that the key ideas are understood, i.e. kidneys filter blood to remove urea, urea is excreted.  **Resources:** A video on the structure and function of the human excretory system, outline of the human body, cut-out kidney shapes, anatomical model of a kidney, sand, dried peas, sieve |
| **9Bs.03** Know that chromosomes contain genes, made of DNA, and that genes contribute to the determination of an organism's characteristics. | **9TWSm.01** Understand that models and analogies reflect current scientific evidence and understanding and can change. | **DNA, genes and chromosomes**  Show learners an animation that explains the relationships between DNA, genes and chromosomes. Provide pairs of learners with simple DNA model kits to create their own DNA molecules which show part of the DNA molecule; they attach labels to show different genes. If possible, attach the completed DNA models together to make one long DNA model molecule that could be used as part of a classroom display. Alternatively, learners can use printed templates of DNA and colour suitable lengths of the completed models to represent one, two or three genes (depending on the template used).  Explain to learners that they have made a model of part of a DNA molecule that contains a number of genes. Explain that a real DNA molecule will contain hundreds or thousands of genes. Introduce the idea that genes contribute to the determination of an organism’s characteristics. Provide some examples of human characteristics controlled by a single gene (e.g. red-green colour blindness). Show learners some examples of different genes and match them to different characteristics. Highlight that even a small change can have a large impact. Also discuss how many characteristics may not be immediately observable e.g. differences in genes affect the production of hormones, how the immune system responds to illness, and other differences that are not observable by the human eye.  Ask learners questions, such as:  *How can such a long DNA molecule fit into the nucleus of a cell (with 45 other DNA molecules in humans)?*  *If the DNA molecule has to be folded, what might the folded structure be called?*  Explain that DNA molecules are folded and form structures called chromosomes.  Show learners a video that describes how the structure of DNA and the functions of genes were discovered, including what scientists thought controlled the characteristics of organisms before and after these discoveries. Make a ‘timeline’ using string (or coloured wool), starting in the year 1900 to the present day. Learners add information, based on the video and other secondary information sources, to the timeline to show how scientific ideas have changed. Extend the timeline to the future and encourage learners to add ideas about what scientists might discover in the future (e.g. are there genes for ‘criminality’?)  Discuss with learners that our understanding is now more refined and we have better clarity of the structure and purpose of genetic material. Highlight that in size order; chromosomes are largest, they are made of folded DNA and sections of the DNA molecule which have a specific function are called genes.  **Resources:** An animation of the relationships between DNA, genes and chromosomes; DNA model kits, a video of the discovery of the structure of DNA and the functions of genes, string |
| **9Bp.01** Describe the fusion of gametes to produce a fertilised egg with a new combination of DNA. | **9TWSc.01** Sort, group and classify phenomena, objects, materials and organisms through testing, observation, using secondary information, and making and using keys. | **Fusion of gametes to produces a fertilised egg**  Show the class a short animation about how gametes fuse to produce a fertilised egg with a new combination of DNA. Check learners’ understanding by asking questions, such as:  *What do you think the term ‘fused’ means?*  *Why would it be incorrect to say that the gametes ‘met’ rather than ‘fused’?*  *What does the term ‘fertilised’ mean?*  *How could you describe what a ‘gamete’ is without using the term ‘gamete’?*  Give learners, working in pairs, a set of diagrams representing the stages in the fusion of gametes to produce a fertilised egg with a new combination of DNA. Each stage should be shown in a separate diagram; ideally the diagrams should be cut up and separate from the other stages. Ask learners to sort the diagrams so that they show the correct sequence and annotate each stage to explain what is happening.  Explain that the female gamete remains still or moves slowly, but the male gamete moves towards the female gamete relatively quickly and the gametes merge together or ‘fuse’. Once all the ‘chromosomes’ are together in what was the female gamete, explain that fertilisation has now taken place. Explain that the fusion of the two gametes has created a fertilised egg with a new combination of chromosomes (and genes and DNA) from that of the parents who produced the gametes.  Show learners diagrams illustrating the development of monozygotic twins (one egg fusing with one sperm and the resultant zygote splitting to form two separate embryos) and dizygotic twins (two eggs each fusing with a separate sperm). Learners can explain which embryos have the same combination of chromosomes and which have different combinations.  **Resources:** An animation of gamete fusion, a set of diagrams of the stages of gamete fusion |
| **9Bp.02** Describe the inheritance of sex in humans in terms of XX and XY chromosomes. | **9TWSm.03** Use symbols and formulae to represent scientific ideas. | **XX and XY chromosomes**  Hold a class discussion about the differences between male and female humans, both before and after puberty. Ensure the correct use of biological terms. Outline the role of the X and Y chromosomes in humans, so that learners understand that males have X and Y chromosomes in the nucleus of most cells, but females have two X chromosomes. Explain that X and Y are symbols that represent chromosomes that determine sex in humans. Show simple diagrams that illustrate how gametes have only one sex chromosome, always an X in female gametes but X or Y in male gametes, and that when gametes fuse, the fertilised egg will have two sex chromosomes, XX or XY.  Ask learners to work in pairs. Provide each learner in each pair with a set of small paper squares or cards, each individually marked with an X or a Y. In each pair, one learner, representing the mother, has only X cards which represent the X chromosomes in the female gamete. The other learner (the ‘father’) has X cards and Y cards, representing the possible sex chromosomes in the male gamete; the set of X and Y chromosomes should be thoroughly mixed so they are in random order. With the cards arranged face down, so the X and Y symbols cannot be seen, in a pile in front of each learner, learners take turns to enact ‘fertilisation’ and produce a ‘fertilised egg’.  Ask pairs to keep records of the sex chromosomes turned up, the sex chromosomes of the ‘fertilised egg’ and the sex of the future ‘baby’ by completing a results table. This is a quick activity, so pairs could work with 30 or more cards and calculate how many male and how many female ‘babies’ they created. The results of all the pairs can be added together to see how close the ratio is to 50:50. Ask questions to ensure that learners understand the inheritance of sex in terms of XX and XY chromosomes:  *Which gamete determines the sex of a baby?*  *What percentage of male gametes carry a Y chromosome?*  *What is the probability (in %) is it that a baby is a girl?*  *Did your results show 50% boy babies and 50% girl babies? If not, why might this be?*  *Did the collated class results show 50% boy babies and 50% girl babies? If not, why might this be?*  *Why are the collated class results different from the results of each pair?*  *If a couple has three girl babies, what are the chances of the fourth baby being a boy?*  Learners use secondary information sources to research questions relating to this learning objective. For example, what genes are on the Y chromosome and how do they determine the sex of a future baby? What is the difference between ‘sex’ and ‘gender’? Discuss with learners that it is not always possible to gather evidence from first hand investigations or experience and why we may want to use secondary information sources. Discuss bias in secondary sources and how to select a reliable and valid source of information.  **Resources:** Sets of X and Y cards, results tables |
| **9Bp.08** Discuss how fetal development is affected by the health of the mother, including the effect of diet, smoking and drugs. | **9TWSa.03** Make conclusions by interpreting results, explain the limitations of the conclusions and describe how the conclusions can be further investigated. | **Factors affecting fetal development**  Divide the class into four groups and allocate each group one aspect of how maternal health may be affected: diet or alcohol or smoking or drugs.  Give each group data about the effect of diet or alcohol or smoking or drugs on the health of a pregnant woman or on the development of her fetus. Within their groups, learners work in pairs to study the data and produce conclusions that can be reported to the group and then to the rest of the class. Explain that tentative conclusions are acceptable. If there are gaps in the data, learners can be asked to predict the missing information. Discuss with learners how their conclusions could be further investigated e.g. controlled medical trials. Discuss the risks and ethics of gathering data with human test subjects, in particular pregnant women.  If possible, invite a medical practitioner (e.g. a nurse, a midwife) into the class to give a talk about how maternal health can affect fetal development. Alternatively, show learners a video that describes the effects of maternal diet, smoking and drugs (including alcohol) on fetal development and ask appropriate questions, such as:  *What effects might the diet of a mother have on the development of her fetus?*  *In what ways can fetal development be affected by smoking, alcohol or by drugs?*  *What signs might medical practitioners look for to decide if a fetus is or is not developing properly?*  **Resources:** Data about the effect of diet, smoking and drugs (including alcohol) on maternal and fetal health |

# Unit 9.6 Electricity

| Unit 9.6 Electricity |
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| Outline of unit: |
| This unit extends learners’ knowledge and understanding of electricity by making and testing the current in different parts of parallel circuits. They extend their knowledge of circuit diagrams by drawing parallel circuits and their knowledge of electrical components and circuit symbols by using fixed and variable resistors. Learners will be introduced to using a voltmeter to measure the voltage in series and parallel circuits; they learn to calculate resistance from voltage and current using the formula *R = V / I*. Learners use this relationship gain an understanding of how factors such as voltage and resistance affect the flow of current in circuits.  This unit provides opportunities for learners to make circuits and investigate current and resistance. It also gives opportunities to discuss the strengths and limitations of models used to describe and explain electricity. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * describing electric current as a flow of electrons around a circuit * knowing that the current in a series circuit can be modelled * using diagrams and conventional symbols to represent, make and compare circuits that include cells, wires, switches, lamps and buzzers * measuring the current in series circuits with an ammeter * explaining that an electrical device will not work if there is a break in the circuit and describing how a simple switch is used to open and close a circuit * investigating how changing the number or type of components in a series circuit can change the current * knowing that some materials are good electrical conductors, especially metals, and some are good electrical insulators. |
| Suggested examples for teaching Science in Context: |
| ***9SIC.01*** *Discuss how scientific knowledge is developed through collective understanding and scrutiny over time.*  Learners can consider the history of electronics and how our understanding of voltage, current and resistance has improved over time. They can discuss how this understanding allowed us, with other technologies, to develop more refined electronics which enable our modern devices to function. For example, learners can look at the work of Benjamin Franklin, Georg Ohm, Nikola Tesla, Thomas Edison and Otis Boykin.  ***9SIC.02*** *Describe how science is applied across societies and industries, and in research.*  The controlled use of electricity (including current, voltage and resistance) is important in modern society and in a range of industrial processes. Learners could look at how electricity is produced, distributed and used and how voltage, current and resistance are controlled in different societies and industries. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
| --- | --- | --- | --- |
| **9Pe.04** Use diagrams and conventional symbols to represent, make and compare circuits that include cells, switches, resistors (fixed and variable), ammeters, voltmeters, lamps and buzzers. | Cell, battery, fixed resistor, variable resistor, ammeter, voltmeter, lamp, buzzer | Learners will use conventional symbols throughout this unit to represent components within electrical circuits.  Learners will use circuit diagrams throughout this unit. A circuit diagram is a topological model of a circuit. It shows each component in position relative to others and wires are conventionally shown as vertical and horizontal lines. | Learners may confuse certain symbols and their names (e.g. cell and battery, and resistor and variable resistor). This may be addressed by making the differences between symbols and their meanings explicit, and having the symbols displayed in the classroom.  Learners may have difficulty in translating circuit diagrams to physical circuits and *vice versa.* This may be addressed by practice, assessment (by peers or teacher) and feedback. |
| **9Pe.03** Calculate resistance (resistance = voltage / current) and describe how resistance affects current. | Voltage, current, resistance | Voltage, current and resistance can be modelled using a loop of rope. The teacher pulling the rope represents a cell/battery that transfers energy to the loop. The faster the loop is moving the greater the current, i.e. more electrons pass per second. Please note that a limitation of the model is that electrons do not move in the same direction as the conventional current. At Stage 9, you may choose to identify the differences between conventional current and electrons as charge carriers.  Resistance can also be modelled using the rope model. The more circuit components (learners holding the rope gently) added to the rope the slower the current will move (i.e. the more resistance the lower the current).  Resistance can be modelled mathematically by considering and rearranging the equation:  resistance = voltage / current  Diagrams can be used to consolidate and represent their understanding. | Learners may have difficulty describing and understanding electricity because of its abstract nature. For example, if you chose to introduce the concept, they may struggle with the idea that conventional current travels in the opposite direction to electrons in a wire. Good use of models (e.g. the rope model) are invaluable for supporting concept development and addressing misconceptions.  Learners may also believe that batteries ‘store’ voltage and this is what flows in a circuit. This misconception can be explored by looking at what a cell (a battery) is and what it is made of. There is no need to discuss electrochemical reactions (which are not required at this stage). |
| **9Pe.01** Describe how current divides in parallel circuits. | Series. parallel, current | The division of currents in parallel circuits can be modelled using two loops of rope, one shorter than the other. The teacher, representing the cell, holds two ropes; one learner holds onto the shorter loop of rope and another learner holds the longer loop of rope. The teacher pulls both ropes, transferring energy to the loops, and the loops move through the learners’ hands. Each learner represents one circuit component and offers the same resistance to the speed of their rope and therefore the current. The cell therefore is operating at twice the current than if a single loop was used. | Learners often have difficulty understanding that the current flowing into a junction must equal the current flowing out of it. The rope model is a good way to demonstrate this idea. In addition, learners can develop this concept through carrying out an investigation of current in a parallel circuit. |
| **9Pe.02** Know how to measure current and voltage in series and parallel circuits, and describe the effect of adding cells and lamps. | Voltage, volts, current, amps, series, parallel | The rope model can be extended to show the impact of more cells and/or more lamps in an electrical circuit. Learners can be added to represent more cells in a circuit; they increase the amount of pull (energy) transferred to the loop of rope. Learners can be added to represent lamps in the circuit: they increase the resistance to the movement of the loop making the loop move more slowly, representing a lower current.  Online simulators may be used to show how current and voltage may be measured in a series circuit. |

# Unit 9.6 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
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| **9Pe.04** Use diagrams and conventional symbols to represent, make and compare circuits that include cells, switches, resistors (fixed and variable), ammeters, voltmeters, lamps and buzzers.  NOTE: There are multiple opportunities throughout this unit to cover this learning objective. | **9TWSm.03** Use symbols and formulae to represent scientific ideas. | **Circuit diagrams and symbols**  Revise the circuit symbols for cells, switches, ammeters, lamps and buzzers and remind learners that, in circuit diagrams, connecting wires are conventionally shown as vertical and horizontal lines. Emphasise that circuit symbols and diagrams are representations that make it easier to interpret complex circuits.  Provide learners with the components needed to make simple circuits (cells, switches, ammeters, lamps, buzzers and wires) and challenge them to make three circuits from circuit diagrams and then draw three circuit diagrams from circuits they create. As an alternative to the practical activity, provide learners with photographs of different circuits and ask them to draw the corresponding circuit diagrams.  Ask learners:  *Why are conventional symbols used in circuit diagrams?*  *Why are wires conventionally shown as vertical and horizontal lines in circuit diagrams?*  Discuss how using a set of common and conventional symbols means scientists from different areas find it easier to interpret what others mean and to replicate circuits made by others.  Introduce learners to the conventional symbols for a fixed and a variable resistor. Explain these symbols will be used throughout the unit.  **Resources:** Cells, switches, ammeters, lamps, buzzers, wires, circuit diagrams |
| **9Pe.03** Calculate resistance (resistance = voltage / current) and describe how resistance affects current. | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations.  **9TWSc.04** Take appropriately accurate and precise measurements, explaining why accuracy and precision are important. | **Modelling current and introducing resistance**  Make a circuit comprising a cell, an ammeter and a lamp. Record the value of the current. Then, add a second and a third lamp, recording the new value for the current each time. Show learners that the current in the circuit reduces each time an additional lamp is added.  Model a circuit using a single loop of speckled rope (at least 3 m) looped between you and one learner. The learner represents a short length of resistance wire and you represent a cell (or battery) that transfers energy to the circuit. Show that pulling the loop of rope faster represents a higher current. Now add two or three learners into the circuit. Explain that their hands increase the friction; pulling the rope with the same force results in the rope moving slower. (Avoid friction burns by controlling the speed and making sure learners do not hold on too tightly.)  Ask learners:  *How does the speckled rope model explain the results of the demonstration where additional lamps were added to the circuit?*  *What does the increase friction represent?*  *What are the strengths and limitations of this model?*  Discuss how more learners represent more lamps and a slower rope represents lower current. In the circuit with more lamps there is greater resistance and so the current is lower. Discuss that in a circuit all components the current goes through have resistance and there are many scientists and engineers around the world looking at how to minimise or maximise resistance to best suit our needs.  Introduce the equation: *R = V / I*  This equation is a mathematical model for discussing and quantifying resistance.  Model how to solve a resistance calculation:  *e.g. What is the resistance of a 12V light bulb which has a current of 3A flowing through it?*  Provide a range of additional questions. For example:  *Calculate the current passing through a 10Ω resistor if the voltage across is 240V.*  *If another resistor of 10Ω was added to the circuit, calculate the new current. Comment on your answer.*  (Current = voltage / resistance, Current = 240 / (10+10), Current = 240 / 20, Current = 12A, the resistance has doubled, and the current has halved.)  Learners construct a circuit comprising a variable voltage power supply, an ammeter, a voltmeter, a 50 cm length of resistance wire (e.g. nichrome) and some connecting wires (including some with crocodile clip ends). This is a good time to introduce the circuit symbol for a fixed resistor. If the power supply is not variable, add a high power, low resistance variable resistor to the circuit to adjust the voltage across the wire.  Learners investigate how the current in the wire varies with voltage They plot a graph of voltage (in volts) on the vertical axis against current (in amperes) on the horizontal axis. Explain that this is unusual as the independent variable (in this case, the voltage) is usually plotted on the horizontal axis.  If learners do not have access to the equipment required, or they get anomalous results due to errors in the circuit design, set up or measurement, provide them with the following data to use.   |  |  | | --- | --- | | Voltage (volts) | Current (amperes) | | 2.0 | 0.23 | | 4.0 | 0.47 | | 6.0 | 0.70 | | 8.0 | 0.93 | | 10.0 | 1.15 |   Learners should now have a graph showing a straight line through the origin. Explain the significance of the line: the gradient is equal to the change in voltage divided by the change in current (*ΔV / ΔI*). The line is straight because the resistance of the wire is constant.  Show learners a simple circuit containing a variable resistor and a lamp. Highlight how a variable resistor is a component where we can change the resistance without replacing the component. Demonstrate the effect of changing the resistance of the variable resistor and then ask learners:  *What effect does the new component have on the current in the circuit?* (it can vary the current)  *What effect does the new component have on the lamp in the circuit?* (it can vary the brightness)  *What might change in the new component to change the current in the circuit?* (resistance)  **Resources:** Speckled rope, Cells, lamps, ammeters, voltmeters, resistance wire, wires, variable resistor |
| **9Pe.01** Describe how current divides in parallel circuits.  **9Pe.02** Know how to measure current and voltage in series and parallel circuits, and describe the effect of adding cells and lamps. | **9TWSa.03** Make conclusions by interpreting results, explain the limitations of the conclusions and describe how the conclusions can be further investigated. | **Parallel circuits**  Set up two identical circuits compromising of cells, an ammeter and one lamp. To one circuit add a second lamp in series and to the other circuit add a second lamp in parallel to the first lamp. Ask learners:  *What happens when the second lamp is added in each circuit?*  *How do the two circuits compare?*  Draw attention to how in the parallel circuit both lamps are the same brightness while in the series the second is dimmer.  Unscrew a lamp in the series circuit and then unscrew a lamp in the parallel circuit. Ask learners:  *How is the parallel circuit different from a series circuit?*  Highlight that in a series circuit, unscrewing a lamp causes both lamps to go out as there is a break in the circuit, however in the parallel circuit, the current passes through one lamp or the other so even unscrewing one lamp the other remains on.  To the parallel circuit add two ammeters to the circuit as below:    Learners should observe that A1 = A2 + A3. State the rule: The total current flowing into a junction must equal the total current flowing out of a junction. (Kirchhoff’s First Law)  Now model a parallel circuit with two lengths of rope (one five-metre and one three-metre loop of rope). Hold both ropes (to represent the cell) whilst one learner holds onto the shorter loop of rope and another holds the longer loop of rope. Pull both ropes transferring energy to the loop. The loop moves through each of the learners representing the current flowing through two lamps.  Ask learners:  *What do the two ropes represent?*  Discuss how each rope represents the current through one lamp, the two ropes together represent the sum of the currents passing through the lamps  **Resources:** Cells, lamps, ammeters, wires, rope |
| **9Pe.02** Know how to measure current and voltage in series and parallel circuits, and describe the effect of adding cells and lamps. | **9TWSa.01** Evaluate the strength of the evidence collected and how it supports, or refutes, the prediction. | **Measuring current and voltage in series and parallel circuits**  Demonstrate how to measure the voltage across a lamp. Provide learners in groups of 4 with equipment (cells, switches, voltmeters, lamps, connecting wires) to make and test a circuit with three lamps in series to determine the four values for voltage: V1 to V4 in the circuit.  Ask learners to predict the results;  *What results do you predict you will get?*  Learners then collect their results and compare against their predictions.  *Were your predictions correct?*  *Is the evidence collected strong enough to support or refute your prediction?*  Discuss if all the data in the class shows a clear outcome and how scientists require a large body of evidence before making conclusions.  Challenge learners to use their results to devise a new rule to describe voltage in a series circuit. Discuss how the sum of the voltages across the components in a series circuit is equal to the voltage across the cells.  If learners do not have access to equipment the following typical results can be provided:   |  |  | | --- | --- | | Voltmeter | Voltage reading (Volts) | | V1 | 6.16 | | V2 | 2.04 | | V3 | 2.06 | | V4 | 2.04 |   Ask learners:  *What would happen to the voltage across each lamp if the voltage of the power supply were doubled?* (the voltage across each lamp would double or the sum of the voltages across the lamps would double)  *What would happen to the current through each lamp if the voltage of the power supply was doubled?* (the current through each lamp would increase, the current would not double as the resistance of the lamp increases)  *What would happen to the voltage across each lamp if a fourth, identical lamp was added?* (the voltage across each lamp would be smaller but would still add up to the voltage of the power supply)  *What would happen to the current through each lamp if a fourth lamp was added in series?* (the current would reduce because adding a fourth lamp would increase the total resistance of the circuit)  Now extend the investigation of voltage to a parallel circuit such as the one below.  Ask learners to predict the results;  *What results do you predict you will get?*    Learners construct the circuit and collect the voltage data.  Learners then collect their results and compare against their predictions.  *Were your predictions correct?*  *Is the evidence collected strong enough to support or refute your prediction?*  Challenge learners to devise a new rule to describe voltage in a parallel circuit. Discuss how the voltage across each parallel circuit branch is equal to the voltage across the cells.  If learners do not have access to equipment the following typical results can be provided:   |  |  | | --- | --- | | Voltmeter | Voltage reading (Volts) | | V1 | 6.16 | | V2 | 6.14 | | V3 | 6.15 |   Ask learners to consider how voltage is affected by components in series and parallel circuits. Learners write a summary statement about their observations.  **Resources:** Cells, switches, voltmeters, lamps, wires |

# Unit 9.7 Chemical reactions

| Unit 9.7 Chemical reactions |
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| Outline of unit: |
| In this unit, learners will learn about chemical reactions and how mass and energy are conserved in them. They will be introduced to displacement reactions and learn how to prepare common salts and then purify the final product. Learners will also consider what factors can affect the rate of reaction including concentration, surface area of reactants and temperature. Throughout the unit learners will use symbols to represent and describe chemical reactions.  Learners will have the opportunity to plan investigations using their prior knowledge and reference materials. They will also carry out standard practical procedures, revisiting previous understanding of separation techniques. They will consider how the particle model is extended to collision theory when looking at chemical reactions. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * defining what a chemical reaction is * identifying evidence for chemical changes taking place (e.g. colour changes, production of a gas, temperature changes) * describing and using the particle model of solids, liquids and gases * explain dissolving as a solute dissolving in a solvent * using separation techniques, such as filtration and evaporation. |
| Suggested examples for teaching Science in Context: |
| ***9SIC.02*** *Describe how science is applied across societies and industries, and in research.*  A wide range of salts are manufactured worldwide for domestic and industrial use (e.g. de-icing, water softening, food production and preservation). Learners could suggest acid-base pairs for the production of these and research their uses.  ***9SIC.05*** *Discuss how the uses of science can have a global environmental impact.*  Chemical reactions can involve multiple reactants and often take place in solution (i.e. with a solvent); some reactants and solvents can be toxic or harmful. Learners could discuss and research how scientists test chemicals for toxicity, and design chemicals to reduce their toxicity. Learners could also research the production of some common household chemicals and consider the environmental impact of the chemical reactions required to form the product.  Learners can investigate how some chemicals will continue to react in the environment and the impact these reactions have including the formation of products which have an adverse environmental impact. For example, the reaction of chlorofluorocarbons (CFCs) in the atmosphere leading to ozone depletion and that some CFC replacements react in the atmosphere to create ‘forever chemicals’, the impact of which is not yet understood. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
| --- | --- | --- | --- |
| **9Cc.01** Use word equations and symbol equations to describe reactions (balancing symbol equations is not required). | Reactant, product, word equation, symbol equation, reaction, formulae | Learners will use word and symbol equations throughout this unit which are representations of chemical processes. | Chemical names may seem arbitrary to learners as they may lack familiarity with them. Explain chemical names and link them to their chemical formulae, their historical origins and/or their naming conventions.  Learners may try to turn a word equation into a symbol equation before they understand how to construct chemical formulae correctly. For example, Magnesium chloride is not MgCl but MgCl2 as magnesium forms 2+ ions and chlorine 1- ions. Reassure learners that, at this stage they will be given any difficult formulae. |
| **9Cc.05** Understand that in chemical reactions mass and energy are conserved. | Chemical, reaction, reactants, products, conservation, mass, energy | Molecular models, such as balls and sticks, can be used to show how atoms are rearranged in chemical reactions rather than lost or gained. Care must be taken to ensure examples of all types of products are modelled, including gaseous products. | Learners can find it hard to understand the abstract concepts of the conservation of mass and energy. This can lead to strongly held misconceptions. Practical work is useful in preventing these misconceptions. For example, learners may think that mass is not conserved in chemical reactions involving colourless gases (reactants or products). Learners can explore the law of conservation of mass by observing a reaction in a closed system where gases can be observed and measured. |
| **9Cc.02** Identify examples of displacement reactions and predict products (limited to reactions involving calcium, magnesium, zinc, iron, copper, gold and silver salts). | Displacement, reaction, reactivity, products, salts | Learners can use analogies to help conceptualise displacement. For example, displacement reactions are like when substitutes are made in a football game. The substitutes replace other players and change the composition of the team. | Learners may think that the reactivity series is limited to metals; this misconception can be unhelpful when learners meet the electrochemical series in later learning. Show learners lots of different versions of the reactivity series, especially those which contain carbon and hydrogen (e.g. the extraction of metals). |
| **9Cc.03** Describe how to prepare some common salts by the reactions of metals with acids, and metal carbonates with acids, and purify them, using filtration, evaporation and crystallisation. | Salts, reaction, acid, metal, carbonate, purification, filtration, evaporation, crystallisation | Learners can use or draw diagrams of the particle model of solids, liquids and gases when describing the various purification techniques.  Learners can also use the particle model, word equations and symbol equations to demonstrate their understanding of the reaction of metals with acids, and metal carbonates with acids. | Learners may believe that crystallisation is a reaction rather than a purification technique.  Adding a specific solvent to a solution will cause the crystallisation of substances that are not soluble in it. Explain this is not a reaction, as there is no rearrangement of atoms, but separating out substances based on their properties. |
| **9Cc.04** Describe the effects of concentration, surface area and temperature on the rate of reaction, and explain them using the particle model. | Concentration, collision, surface area, temperature, rate of reaction, particle model | The particle model, as a diagram or as a physical model using balls (e.g. marbles, snooker balls) in a tray, can be used to model collisions. Learners could consider how the rate of collisions, and therefore reactions, are affected by concentration, surface area and temperature. | Learners may confuse the meanings of ‘rate’ and ‘speed’ and also mix them up with ‘time’. Mixing up the terminology of rate and speed is a common misconception for younger learners; it is easily corrected with careful feedback. In order to prevent learners getting the time of a reaction mixed up with the rate of a reaction, discuss several scenarios. For example, learners could consider the time a person takes to make pancakes (in minutes) and the speed they make pancakes (in pancakes per minute). |

# Unit 9.7 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
| --- | --- | --- |
| **9Cc.01** Use word equations and symbol equations to describe reactions (balancing symbol equations is not required).  NOTE: This learning objective can be reinforced throughout the entire unit. | **9TWSm.03** Use symbols and formulae to represent scientific ideas. | **Representing chemical reactions**  Give pairs, or groups, of learners a range of names of substances on cards including commonly used names (e.g. salt, water) and systematic chemical names (e.g. sodium chloride, dihydrogen monoxide). Ask them to discuss the names and group them in whatever patterns they feel appropriate, explaining their reasoning. Bring them back together as a class and discuss reasons groupings based on common names and systematic names.  Demonstrate to learners how to read a formula, explaining that the subscript numbers denote the number of atoms of each element. Provide formulae of the substances provided earlier on cards and ask learners to match the formulae against the systematic names already used.  *How do we represent the number of each atom in a substance?*  *How do we represent each type of atom in a substance?*  Discuss with learners each atom is given a symbol as shown on the Periodic Table of elements. All chemical formulae are based on these.  Explain to learners the key naming conventions including:   * the use of mono, di, bi, and tri as prefixes in naming stems. For example, sodium bicarbonate, dihydrogen monoxide, carbon monoxide, tricalcium phosphate. * the use of ~ide and ~ate endings. For example, sodium bicarbonate, tricalcium phosphate, iron sulfide.   Relate the naming of substances to the number of atoms, or chemical groups, and common chemical groups. Provide learners with worksheets with chemical formulae to name.  Demonstrate a reaction to the learners, e.g. burning magnesium or reacting acetic acid with sodium bicarbonate. Discuss with learners the products formed from the reaction and show how the reaction can be shown as a word equation and as a symbol equation.  Time permitting, provide learners with more examples of word and symbol reactions to read or write. Explain to learners there will be more opportunities throughout the unit to use and write word and symbol equations.  **Resources:** Substance cards; some with common name, some with systematic name and some with formulae, chemical formulae naming worksheets. |
| **9Cc.05** Understand that in chemical reactions mass and energy are conserved. | **9TWSc.05** Carry out practical work safely, supported by risk assessments where appropriate.  **9TWSc.07** Collect, record and summarise sufficient observations and measurements, in an appropriate form. | **Exploring the conservation of mass and energy**  Define the laws of conservation of mass and conservation of energy.  *What does conservation mean?*  *What do you recall about energy?*  Discuss with learners some examples of the conservation of energy in a closed system (e.g. heat dissipating from a hot object into the surrounding environment). Explain that the conservation of energy and mass applies to all chemical reactions; mass and energy are always conserved although it isn’t always easy to identify all the product and energy transfers.  Explain to learners that they will carry out two types of chemical reaction and observing the mass as they work. Alternatively, demonstrate the experiments to the class. Ask learners to keep an eye on the mass readings and to record any changes they see. If the equipment is not available, provide learners with descriptions/diagrams of the practical procedures and sample results.  Provide pairs of learners with equipment to carry out the experiments: mass balances, 0.5-1.0 M hydrochloric acid solution, 0.5-1.0 M sodium hydroxide solution, universal indicator / litmus indicator solution (or indicator paper or pH probe), 0.1-0.25 M copper sulfate solution, test tubes, small beakers.  Learners should identify hazards and complete risk assessments before carrying out the practical work themselves. Ensure that sodium hydroxide (an irritant) is used at the lowest concentration and smallest quantities possible.  Example 1: Acid and alkali  Learners place a small beaker on the mass balance. Pour dilute hydrochloric acid solution into a test tube, to a depth of approximately 1 cm and put it in the beaker. Add dilute sodium hydroxide solution to a second test tube to a depth of approximately 1 cm, add 2 drops of indicator solution and put it into the beaker. Note the reading on the balance. Pour the acid into the test tube with the alkali and indicator, placing both test tubes back in the beaker. Learners note any visual changes and the reading on the balance.  Example 2: Precipitation  Learners place a small beaker on the mass balance. Pour dilute copper sulfate solution (clear blue) into a test tube, to a depth of approximately 1 cm and put it in the beaker. Add dilute sodium hydroxide solution (colourless) to a second test tube to a depth of approximately 1 cm and put it into the beaker. Note the reading on the balance. Pour the sodium hydroxide into the test tube with the copper sulfate solution, placing both test tubes back in the beaker. Learners note any visual changes and the reading on the balance.  Ask learners to write a summary of their results and a conclusion that refers to the law of conservation of mass. Discuss with the class, any observed variations in mass:  *What variations in mass are acceptable?*  *What may cause variations in the mass observed?* (minor spills, environmental conditions affecting the balances, human error)  Discuss with learners how they could monitor the conservation of energy within a chemical reaction.  *What are the barriers to observing the conservation of energy?*  Discuss how monitoring conservation of energy is difficult to due to energy being transferred to many different types or stores which are hard to monitor.  **Resources:** Mass balances, dilute hydrochloric acid solution, dilute sodium hydroxide solution, indicator solution, dilute copper sulfate solution, test tubes, small beakers |
| **9Cc.02** Identify examples of displacement reactions and predict products (limited to reactions involving calcium, magnesium, zinc, iron, copper, gold and silver salts). | **9TWSp.01** Suggest a testable hypothesis based on scientific understanding.  **9TWSp.03** Make predictions of likely outcomes for a scientific enquiry based on scientific knowledge and understanding.  **9TSWa.05** Present and interpret results and predict results between the data points collected.  **9TWSa.04** Evaluate experiments and investigations, including those by others, and suggest improvements, explaining any proposed changes. | **Exploring displacement reactions**  Give each learner a copy of the reactivity series of metals (limited to calcium, magnesium, zinc, iron, copper, gold and silver). Define the term ‘displacement reaction’.  Tell learners that they will be provided with samples of magnesium, zinc, iron and copper and the solutions of their salts. Ask them to plan an investigation to confirm the order of their reactivity using their prior knowledge of the substances and/or the reference material provided. Their plan should cover:   * the sequence and scale of reactions, including their predictions of what might happen in each reaction * the variables that must be controlled to ensure a valid result * an appropriate table to record and present their results * a complete risk assessment for their investigation.   Question prompts may include:  *What will the independent, dependent and control variables be?*  *What risks do you need to account for?*  *How will your record your data?*  Learners swap their plans and peer review them.  Provide learners with test tubes or spotting tiles, pieces of metals (magnesium, zinc, iron, copper) and  10 ml of dilute solutions of the metal salts (1 M iron (III) chloride solution, prepared in hydrochloric acid; 0.2-0.4 M copper sulfate solution; 1 M zinc sulfate solution; 1M magnesium chloride solution).  Learners carry out their planned investigation, record and present their results in a suitable format and propose a conclusion. Learners then present their conclusions to the wider class and a whole class discussion identifies if each group arrived at the same conclusion. If there are differences in conclusions discuss the differences and why they may occur.  Ask learners to use their prior knowledge, and a copy of the reactivity series, to predict the results of displacement reactions of other metals (calcium, gold and silver).  Learners then evaluate their investigations and discuss how they could be improved. Using the experimental data, and judgements on differences between the work undertaken, learners made annotated edits to their original investigation plans with specific mention of why they each improvement is being suggested. Learners then share their improvements and as a whole class identify if there are any common improvements they would make if they did the investigation a second time.  **Resources:** A copy of the reactivity series of metals, samples of metals, dilute solutions of metal salts, test tubes or spotting tiles |
| **9Cc.03** Describe how to prepare some common salts by the reactions of metals with acids, and metal carbonates with acids, and purify them, using filtration, evaporation and crystallisation. | **9TWSc.02** Decide what equipment is required to carry out an investigation or experiment and use it appropriately.  **9TWSc.05** Carry out practical work safely, supported by risk assessments where appropriate. | **Preparing salts**  Introduce the term ‘salts’ to learners. Ask learners:  *What salts can you name?*  Learners may only name sodium chloride and struggle to name other salts. Introduce that salts in chemistry refer to the compound made when an acid is neutralised by a base. Salts are ionic compounds. The positive ion (cation) comes from the base and the negative ion (anion) comes from the acid. Sodium chloride is one salt and there are others, all of which can be produced by chemical reactions.  There are several way to make salts through chemical reactions. Two to be aware of at Stage 9 are;  Metal + acid 🡪 salt + hydrogen  Metal carbonate + acid 🡪salt + carbon dioxide + water  Remind learners that hydrogen and carbon dioxide can be tested so these by products can be identified. Discuss with learners that is the reaction occurs in solution, as you expected, then the salt may be dissolved in the solution. Explain that the learners will carry out reactions to make some salts and then retrieve the salt through filtration, evaporation and crystallisation. Where possible, provide learners with a range of equipment and have them choose the appropriate equipment to use for each reaction.  Example of metal carbonate (copper carbonate) and acid reaction to form a salt:  Provide learners with the experimental procedure for each reaction, including the purification step. Learners should identify hazards and complete risk assessments before carrying out the practical work themselves. Ensure that dilute sulfuric acid (an irritant) is used at the lowest concentration and smallest volumes possible. Learners should be supervised when heating the mixture and learners should make certain there is an excess of base present in order to avoid heating acidic solutions.  Describe and explain the experimental steps to learners, emphasising the reasons why each stage is carried out as described. Make sure all learners are clear about the safety precautions required and the steps they will need to take if an accident or spillage occurs.  Provide sufficient apparatus for pairs of learners to carry out the reactions, including boiling tubes, boiling tube racks, measuring cylinders, spatulas, beakers, filter papers, filter funnels, evaporating basins, Bunsen burners (or alternative), tripods and gauze. Provide small quantities of metals and metal carbonates and 0.5-1.0 M sulfuric acid.  Learners use a measuring cylinder to measure 10 cm3 of dilute sulfuric acid solution and transfer the liquid to a boiling tube. They add the copper carbonate powder, half a spatula at a time, until the effervescence stops and a solid is observed at the bottom of the tube. They warm the reaction mixture by placing the boiling tube in a beaker of boiling water. If the mixture goes clear then they add more copper carbonate until a solid is observed at the bottom of the tube. They filter the mixture, add the filtrate to an evaporating basin and heat it until the volume has been reduced by half. The learners leave the basin in a safe place to crystallise; they observe the crystals in a follow up lesson.  If there is not sufficient equipment carry out the reactions as demonstrations or show learners videos.  Ask learners to summarise their practical work by producing a series of annotated diagrams with explanations. Discuss with learners:  *Why was an excess of copper carbonate used?*  *How did we know an excess of copper carbonate was present?*  *Why were bubbles produced when the copper carbonate reacted with the sulfuric acid?*  *Why was the mixture heated?*  *Which components were separated by the filtration step?*  *Why was the mixture evaporated by half rather than to dryness?*  NOTE: The example reaction provided is one example of several. For learners to fully meet the learning objective they need to make a range of salts through a range of metals and metal carbonates reacting with acids. Ensure any other reactions you, or learners, carry out are appropriate and safe for a school science laboratory setting.  **Resources:** Boiling tubes, boiling tube racks, measuring cylinders, spatulas, beakers, filter papers, filter funnels, evaporating basins, Bunsen burners, tripods, gauze, copper carbonate solid, dilute sulfuric acid solution |
| **9Cc.04** Describe the effects of concentration, surface area and temperature on the rate of reaction, and explain them using the particle model. | **9TWSp.05** Make risk assessments for practical work to identify and control risks. | **Studying the rate of reaction**  Tell learners that they will be studying the reaction between magnesium ribbon and hydrochloric acid. Introduce them to the word equation:  Magnesium + hydrochloric acid 🡪 magnesium chloride + hydrogen  Provide learners with reference materials for the hazards (e.g. hazard cards) for the reactants and products. Help learners to carry out a risk assessment by asking the class questions, such as:  *What are the details of the activity to be undertaken?*  *What are the hazards?*  *What is the chance of something going wrong?*  *How serious would it be if something did go wrong?*  *How can the risk(s) be controlled for this activity? How can it be done safely? Does the procedure need to be altered? Should eye protection be worn?*  Provide learners with the experimental procedure and model how to complete the risk assessment template. If necessary, provide guidance to learners about appropriate concentrations of acid. Help learners to make a suitable choice for an endpoint that can be observed when the reaction is complete.  Provide learners with the appropriate equipment to carry out the practical work: magnesium ribbon, stock acid solution (0.8-2.0 M hydrochloric acid), measuring cylinders, stop watches, thermometers, boiling tubes, beakers.  Learners will then carry out three sets of experiments:   * Learners react magnesium in 5 different dilutions of hydrochloric acid (0.8M, 1.0M, 1.4, 1.6M, 2.0M) and record how long each reaction occurs for. Learners discuss their findings and create a conclusion for the effect concentration of acid has on the rate of the reaction * Learners carry out the reaction under four different temperatures, recorded with a thermometer. For example, one cool temperature using hydrochloric acid that has been refrigerated, one room temperature and two above room temperature through gentle heating of the hydrochloric acid in a water bath to reach a desired temperature before adding the magnesium. Learners record how long each reaction occurs for. They then discuss their findings and create a conclusion for the effect temperature of acid has on the rate of the reaction Note: Heating acid can be dangerous and learners should not heat it past 60oC. * Learners change the surface area of the magnesium strip by using three samples; one with a strip cut into small pieces with scissors, the second leaving a strip as is, and the third folding a strip up into layers. The learners then carry out three reactions with these sample. Learners record how long each reaction occurs for. They then discuss their findings and create a conclusion for the effect surface area of the magnesium has on the rate of the reaction. Note: learners should not cut magnesium ribbon themselves in case of sparks igniting the ribbon.   Discuss with the class if any of their findings were surprising and agree common conclusions from each set of experiments.  Show learners the particle model and discuss with learners why the rate of reaction changed when the concentration, temperature of surface area changed. Model to learners using the particle model how:   * Increasing the concentration introduces more particles of one reactant, increasing the number of collisions between reactants * increasing the temperature means reactants have more energy, increasing the number of collisions * increasing he surface area of the magnesium changes the available contact between the reactants, increasing the number of collisions   Learners draw their own particle model diagrams and write their own explanations to explain their experimental findings.  **Resources:** Reference material for hazards, a risk assessment template, magnesium ribbon, stock acid solution, measuring cylinders, stop watches, thermometers, boiling tubes, beakers. |

# Unit 9.8 Species and their environments

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| Unit 9.8 Species and their environments | | | |
| Outline of unit: | | | |
| In this unit, learners consider variation within a species and relate this to genetic differences between individuals. Learners also study the scientific theory of natural selection and how it relates to genetic changes over time.  This understanding of species then supports learners when they investigate what could happen to the population of a species (including extinction) when there is an environmental change. Learners then describe the historical and predicted future impacts of climate change, including sea level change, flooding, drought and extreme weather events. Finally, learners consider the consequences of asteroid collision with the Earth, including climate change and mass extinctions.  During this unit, learners have opportunities to make predictions of likely outcomes for a scientific enquiry based on scientific knowledge and understanding, and to decide what equipment is required to carry out an investigation. Learners also have opportunities to collect, record and summarise sufficient observations in an appropriate form and to evaluate the strength of the evidence collected. | | | |
| Recommended prior knowledge or previous learning required for the unit: | | | |
| Learners will benefit from previous experience of:   * knowing the definition of the term ‘species’ * understanding that different ecosystems exist on the Earth * describing how different organisms are adapted to their habitats * describing how new and/or invasive species can affect other organisms and an ecosystem * creating and interpreting food chains and food webs * explaining the difference between climate and weather * knowing there is evidence that the Earth's climate exists in a cycle between warm periods and ice ages, and the cycle takes place over long time periods * knowing that planetary systems can contain asteroids. | | | |
| Suggested examples for teaching Science in Context: | | | |
| ***9SIC.04*** *Describe how people develop and use scientific understanding as individuals and through collaboration, e.g. through peer-review.*  Learners can explore how some people (e.g. Charles Darwin, Alfred Russel Wallace) developed the ideas of natural selection and how these ideas were then presented to scientists of the time (e.g. in open meetings). Learners could also compare how new scientific ideas might be treated today in terms of electronic journal submission and confidential peer-review.  ***9SIC.03*** *Evaluate issues which involve and/or require scientific understanding.*  Learners can consider how every human being is unique, i.e. we have individual DNA that allow us to be identified from traces that we leave everywhere we go. The cheek cells (containing DNA) of an individual can be collected by wiping a cotton swap inside their cheek; this is useful to find criminals and to absolve innocent people. Learners can evaluate whether it is a good or bad idea to keep a DNA database of everyone. | | | |
| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
| **9Bp.03** Describe variation within a species and relate this to genetic differences between individuals. | Variation, species, genetic differences | Diagrams and drawings can be used to provide examples of variation existing within a species, e.g. blood groups in humans and the number of spines on holly (*Ilex aquifolium*) leaves.  Animations and videos can be used to show variations within a range of species and how these are linked to genetic differences between individuals. | Some learners may consider variation within a species only by comparing differences in appearance. To avoid this, provide a wide range of examples including variations beyond simple physical appearance (e.g. blood groups, allergies). Some learners may also link variation in physical characteristics with variation in genes. Highlight, that large variation in genes does not always result in large variation in physical characteristics.  Learners may confuse variation within a species with variation between species. Check that learners understand the concept of a species and remind them that this learning objective focuses on how individuals of the same species may differ from each other. |
| **9Bp.04** Describe the scientific theory of natural selection and how it relates to genetic changes over time. | Scientific theory, natural selection, genetic change, species | Online, interactive simulations of natural selection are available, both for real organisms (e.g. the peppered moth, *Biston betularia*) and fictional organisms (e.g. animals from computer games).  Videos and animations can describe the scientific theory of natural selection and how it relates to genetic changes over time. | The meaning of a scientific theory is not the same as the meaning of ‘theory’ in everyday language. Clearly explain the difference in the terms to learners: in everyday language, a theory means a guess or speculation; in science, a theory means a comprehensive explanation supported by evidence. |
| **9Be.01** Describe what could happen to the population of a species, including extinction, when there is an environmental change. | Population, species, extinction, environmental change | Animations, videos and simulations are useful to show what might happen to populations of species when there is an environmental change. | Some learners may think that extinct species can be brought back to life. Make it clear that extinction means that there are no more organisms alive from a species and, currently, scientists cannot reintroduce extinct species.  Due to the impact humans are having on the environment, learners may believe that extinction is a result of humans rather than a natural process and is happening all the time. Discuss examples of species that went extinct without human interaction or a global event e.g. the extinction of the stegosaurus that went extinct around 100 million years ago, before the mass extinction event 66 million years ago. |
| **9ESc.02** Describe the historical and predicted future impacts of climate change, including sea level change, flooding, drought and extreme weather events. | Prediction, impact, climate change, sea level, flooding, drought, extreme weather | Learners can study graphs displaying historical data about climate change, sea level change, flooding, drought and extreme weather events. They can use lines of extrapolation to make predictions about the future.  Online simulations can be used to demonstrate past and possible future impacts of climate change.  Computer modelling can be used to predict future impacts of climate change (e.g. sea level changes). Some computer modelling is quite complex and may need simplifying for learners. | The terms climate and weather can be confused by learners. Clearly explain that weather is the short–term (minutes, hours, days or weeks) state of the atmosphere and is affected by factors, such as temperature, rainfall, wind. Climate is considering weather over a longer period and may be considered as the weather of a place averaged out over many years, often thirty years.  Learners may be confused between global climate change (i.e. warming) and regional climate change that can be warming or cooling. Be clear which type of climate change is being discussed.  Some learners may need help with understanding how reliable predictions can be. Explain that complex predictions, such as the predicted future impacts of climate change depend on many factors, each of which contains its own errors and uncertainties. Explain that, as new evidence arises, predictions can change. |
| **9ESs.01** Describe the consequences of asteroid collision with the Earth, including climate change and mass extinctions. | Consequences, asteroid, collision, Earth, climate change, mass extinctions | Animations are useful to show possible consequences of asteroid collision with the Earth.  Computer simulations can show the consequences of collisions, by different sized asteroids, on the Earth. | Some learners may think that all asteroids are the same size. Explain that some asteroids are as small as pebbles while others can be hundreds of kilometres in diameter. It may help to show learners pictures of asteroids and ask them to draw diagrams showing their shapes and relative sizes. Learners may find it reassuring that an asteroid has to be relatively large to impact the Earth, as asteroids are broken up by entry into the Earth’s atmosphere. |

# Unit 9.8 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
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| **9Bp.03** Describe variation within a species and relate this to genetic differences between individuals. | **9TWSc.07** Collect, record and summarise sufficient observations and measurements, in an appropriate form. | **Variation within species**  Check that learners can use the term ‘species’ correctly and confidently. Ask learners, working in pairs, to choose a species to investigate. Encourage the class, as a whole, to cover a wide range of species so that learners appreciate that variation within species is not confined to one kingdom, such as the animal kingdom. If domesticated species are included, discuss the reasons for the greater variation seen in domesticated species (i.e. human selection). Once pairs have collected information about variation within their chosen species, they record their findings as a poster. Provide each learner with a ‘Species and Examples’ worksheet; they complete the table with names of species and examples of variations mentioned in the posters.  Hold a class discussion about whether the variations illustrated by the posters are can be explained by genetic differences. Ask learners:  *Could any of the variations be due to the environment? If ‘yes’, suggest how? If ‘no’, suggest why not?*  *Which variations must be due to genetic differences?*  *If a hen lays a clutch of eggs and some of the chicks are different in colour to the hen, how might the differences be explained?*  *A gardener plants seeds to grow marigold plants and finds that some plants have small, dark yellow flowers and other plants have large, pale yellow flowers. Suggest at least two explanations for what the gardener observes.*  **Resources:** Secondary information sources; species and examples worksheet |
| **9Bp.04** Describe the scientific theory of natural selection and how it relates to genetic changes over time. | **9TWSp.03** Make predictions of likely outcomes for a scientific enquiry based on scientific knowledge and understanding. | **Natural selection**  Explain the difference, giving examples, in the meaning of the word ‘theory’ in everyday use and in a scientific context:   * In everyday use, a theory means little more than a guess (e.g. she has a theory that wasps are becoming more of a nuisance when you eat outdoors). * In a scientific context, a scientific theory is supported by evidence (e.g. the theory of natural selection). In addition, a scientific theory is a testable hypothesis for which scientists seek evidence to disprove or refine.   Introduce the learners to the definition of ‘natural selection’, providing one example of natural selection that has taken place over time. For example, tell learners the story of how the modern horse developed from the Eohippus (small, size of a dog, forest-dwelling) over 50 million years. Illustrate the story with pictures that show the changes in the shape of the hooves and the length of the legs. Explain that over time occasional animals underwent genetic changes. Some of the features which resulted from the genetic changes helped those animal to survive and breed. These genetic changes were passed on to their offspring. Over time more genetic changes happened and the genes that created new (advantageous) characteristics became more common as offspring who have them are more likely to survive and breed. Eventually there were enough changes that a distinct species could be identified. Keep examples and descriptions to natural selection, avoiding changes that humans have brought about (e.g. tiny ponies, huge working horses).  Give pairs of learners a series of pictures illustrating stages in the development of the modern horse over time. Ask them to arrange the pictures in order and write an account, in their own words, of the role of natural selection in the development of the modern horse.  Learners can role-play a situation to model the process of natural selection. This works best outside but can also be played in a large indoor space. Prepare lengths of wool of different colours (e.g. 20 each of dark brown, light brown, green, yellow and red) with some colours that will blend into the background better than others, these represent worms. Scatter the ‘worms’ randomly over an area; if learners are involved in this process, ask them to move places so that they lose sight of where they put the ‘worms’. Tell learners they are going to be birds who have to catch as many worms as they can in a given time.  Ask learners to predict which colour ‘worms’ will be the easiest to catch. Remind learners to be careful not to knock into other ‘birds’ and give them a short time (e.g. 15 seconds) to collect as many ‘worms’ as they can. Count how many ‘worms’ of each colour have been caught and calculate the percentage of each colour. Explain that all caught ‘worms’ are considered to be eaten ‘worms’.  Ask learners to consider if this model was real:  *How can you explain that the worms are all the same species, but individuals can be different colours?*  *What colour of worm was caught most? Why?*  *What colour of worms was caught least? Why?*  *What colour worms are most likely to survive to produce offspring? What colour would their offspring be?*  *After many generations, what colour would most of the worms of this species be?*  *What is the name of the process by which, over time, a species can change a characteristic?*  Discuss with learners their answers and how by variants of species which are less suitable to an ecosystem die leaving the surviving variants of species continue to change over time to form new species. This is the process of natural selection.  This activity can be extended by asking learners to explore how natural selection has operated in other living organisms, such as the deer mouse (*Peromyscus maniculatus*) and antibiotic-resistant bacteria (*Staphyloccus aureus*).  **Resources:** Statements using the word ‘theory’, series of pictures of the development of the horse over time, wool of different colours |
| **9Be.01** Describe what could happen to the population of a species, including extinction, when there is an environmental change. | **9TWSc.02** Decide what equipment is required to carry out an investigation or experiment and use it appropriately. | **The impact of environmental changes on the population of a species**  Ask questions to consolidate learners’ understanding, such as:  *What environmental changes can you name?*  *How might one of these environmental changes affect a species?*  *How might the same environmental change affect a different species?*  *Which environmental changes are most likely to lead to the extinction of a population of a species? Which are least likely?*  Discuss how an environmental change can affect multiple species in different ways as some species will be better suited to survive and environmental change. The effect on a species is normally a change in the population, the number of individuals of a species that are alive.  Give each learner a fact sheet which details a species, what habitat they live in, and what they eat. Ideally give all learners different examples, although you may like to give several learners a factsheet about an apex predator. Each learner then receives counters to represent their population. Have prepare a set of cards detailing environmental changes that could happen. Select a card at random and learners predict whether the species they have will gain population, stay the same, will drop in population or will go extinct. If the population of a species increases learners gain more counters and if the population of a species decreases learners lose counters (you decide the number of counters gained or lost). When you select a card discuss with learners what the impact could be and how it may affect a range of species potentially even all species. Select a minimum number of cards, more if time allows, and at the end discuss the final population sizes of the species.  *Which species have gone extinct?*  *Which species have thrived?*  *Which species have decreased in population size?*  *Which species have stayed the same?*  Learners watch a short video that shows some of the methods used to monitor the populations of species.  Outline a theoretical scenario of an environmental change that is likely to affect a particular population of a species (with local detail, if possible) and explain to learners that they are going to plan how to monitor the impact of the environmental change on the species.  For example, tell learners that a new road is going to be built through a scientifically important site (e.g. a national nature reserve) where a rare butterfly is found and a particular plant grows that both the adult and larvae of the butterfly prefer to feed on. Put learners into groups (6-7 learners) and tell them that they are going to investigate the impact of the road by counting the population of butterflies and of the plant, before and after the road is built. Ask each group to decide what equipment would be required to carry out the investigation, bearing in mind that the butterfly is a protected species so it cannot be caught. As a class, compile a final list using inputs from all the groups. (Example species from the UK context are the Adonis blue butterfly, *Polyommatus bellargus,* and the horseshoe vetch, *Hippocrepis comosa.*)  Learners then consider their own local environment and design and carry out an investigation to monitor a local species, an insect species with short lifespan would be ideal, over a long period of time (e.g. the rest of the academic year) monitoring environmental conditions e.g. rainfall, temperature, human activity and how the environmental conditions affect the population of the species.  **Resources:** Species fact sheets, counters, environmental change cards, a video of species monitoring, a scenario about an environmental change, |
| **9ESc.02** Describe the historical and predicted future impacts of climate change, including sea level change, flooding, drought and extreme weather events. | **9TWSa.01** Evaluate the strength of the evidence collected and how it supports, or refutes, the prediction. | **Climate change**  Hold a class discussion about climate change based on what learners already know or have heard. Use this as an opportunity to dispel any misconceptions, asking questions, such as:  *What information have you seen or heard about climate change?*  *What do you understand by the term climate change?*  *What is the difference between climate and extreme weather?*  *If our climate changes and the Earth gets warmer, what would you expect to happen to sea levels?*  *Why would some areas flood but other areas be short of water?*  Discuss with learners how climate change does not just relate to changing temperature and how the climate has changed, and will continue to change, over time. Discuss how climate change is linked to extinction events or the extinction of individual species.  If possible, invite a speaker from a local university/college to give a talk and answer questions. Alternatively, show learners a video about climate change, having checked it for scientific accuracy. Learners could also play a computer simulation where they can change the climate and watch the effects on sea levels, flooding, drought and extreme weather events. Hold a question and answer session after the video or computer simulation activity.  Provide groups of 2-3 learners with data (tables, graphs) about historical and predicted future impacts of climate change on sea level, flooding, drought and extreme weather events. Ask groups to study the data, including its source, and draw conclusions. They should also attempt to evaluate the strength of historical evidence by asking questions about the data (e.g. how old is it? who collected it? how many readings were taken? could mistakes have occurred?) and the reliability of predictions by considering what would happen to the prediction if some of the assumptions were changed. Learners may need a framework of questions to work through; these should be tailored to the data they have been provided.  Hold a class ‘workshop’ on climate change and invite each group to present their findings.  Explain the limitations of the models used, discussing the accuracy and uncertainty of climate models. Be careful to only give information from reliable sources so that learners are clear about the known science behind climate change.  **Resources:** A video about climate change; climate change data (historical and predictions) |
| **9ESs.01** Describe the consequences of asteroid collision with the Earth, including climate change and mass extinctions. | **9TWSc.07** Collect, record and summarise sufficient observations and measurements, in an appropriate form. | **The consequences of an asteroid collision with Earth**  Show learners a short animation about asteroids and their possible collisions with the Earth. Ask questions, to establish learners’ understanding, such as:  *What is an asteroid?*  *How are asteroids different from planets?*  *How frequently do asteroids collide with the Earth?*  Tell learners that they are going to make a film about the possible consequences of asteroid collision with the Earth, including climate change and mass extinctions. Divide the class into three groups and allocate each group a topic:   * Asteroid collision with the Earth * Possible impacts of a collision on climate change * Possible impacts of a collision on mass extinction.   Explain that each group will use secondary information sources to carry out research on their topic, collect and record their findings and then summarise their findings by writing a film script. Ensure learners consider looking at the evidence of previous asteroid impacts, small and large, which informs the models used to predict the impact of future impacts. If research time is limited, provide fact sheets to the groups. Learners could use drawings or pictures to supplement their film scripts. The learners then record their scripts, with the final product being viewed by the class or it can be given as a live documentary.  Consolidate learners’ knowledge and understanding by giving individuals a set of questions with true/false answers and once complete discuss the answers as learners self or peer mark the questions.  **Resources:** Animation about asteroids and possible collisions with the Earth, secondary information sources or fact sheets, true or false questions |

# Unit 9.9 Earth and beyond

| Unit 9.9 Earth and beyond |
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| Outline of unit: |
| This unit covers important ideas about tectonic processes on Earth and how they have shaped our continents and oceans. Learners will apply their understanding of convection to the movement of tectonic plates and will examine the variety of evidence for this theory.  The unit then covers ideas about the formation of the Moon. It considers different hypotheses and how evidence from samples of Moon rock and the relative movement of the Earth and Moon led to the development of the collision theory (Giant impact hypothesis). The unit concludes with learning about nebulae and the theory of star formation from nebular collapse.  This unit provides learners with opportunities to consider scientific evidence and how it is used to prove or disprove a hypothesis. Learners will also consider a range of models throughout the unit. |
| Recommended prior knowledge or previous learning required for the unit: |
| Learners will benefit from previous experience of:   * describing the structure of the Earth using different models including a chemical model (crust, mantle, core) and a physical model (layers that do or do not flow) * describing the model of plate tectonics, in which a solid outer layer (made up of the crust and uppermost mantle) moves because of flow lower in the mantle * understanding that earthquakes, volcanoes and fold mountains often occur near to the boundaries of tectonic plates * knowing the planets in the Solar System orbit the Sun, and the Moon is a natural satellite of the Earth * describing how the planets in the Solar System formed from debris remaining after the formation of the Sun * describing gravity as a force of attraction between any two objects. |
| Suggested examples for teaching Science in Context: |
| ***9SIC.01*** *Discuss how scientific knowledge is developed through collective understanding and scrutiny over time.*  This unit provides learners many opportunities for considering how scientific knowledge has changed over time through collective understanding and scrutiny. For example, the development of the collision theory (Giant impact hypothesis) based on evidence from the composition of Moon rocks, Moon structure and the relative movement of the Earth and Moon.  ***9SIC.04*** *Describe how people develop and use scientific understanding as individuals and through collaboration, e.g. through peer-review.*  Learners could research Alfred Wegener who developed the Theory of Continental Drift based on the shapes of the continents. He could not explain a mechanism for the drift and his ideas were not initially accepted by other scientists. Once other scientists discovered new evidence to support continental drift (e.g. seafloor spreading, fossil evidence) the theory was developed into the theory of plate tectonics and many more scientists began to accept the theory. |

| Learning objective | Key vocabulary | Possible models and representations | Possible misconceptions |
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| **9ESp.02** Explain why the jigsaw appearance of continental coasts, location of volcanoes and earthquakes, fossil record and alignment of magnetic materials in the Earth's crust are all evidence for tectonic plates. | Tectonic plate, continent, crust, volcano, earthquake, boundary, fault, fossil record, alignment, magnetic materials | The movement of present-day continents from the paleocontinent of Pangea can be modelled using a jigsaw diagram of the continents. This can be supported by using animations available online.  Maps are 2D representations of the Earth. World maps showing active volcanoes and earthquakes can be used to provide evidence for tectonic plate margins. | Learners may have misconceptions, such as:   * tectonic plates are formed of crust only * all of the mantle can flow * the mantle flows like water * continents cannot move * the Earth has remained the same over time * continents move quickly * continents are the same as tectonic plates * volcanoes and earthquakes can only happen at plate boundaries.   Models can be used to address misconceptions such as these. For example, a broken biscuit floating on the syrup, can help to explain the movement of continents.  The concept of the geological timescale can be communicated by using 24 hours to represent 200 million years:   * The extinction of the dinosaurs occurred at about 16:00. * Humans appeared around 23:58. * The industrial revolution started at about one tenth of a second before midnight.   You may also like to refer to the misconceptions given in the introduction to Unit 7.7. in the Stage 7 scheme of work. |
| **9ESp.01** Explain the movement of tectonic plates in terms of convection currents. | Convection, convection current, tectonic plate, plate tectonics, viscous, viscosity, convergent, divergent | Physical models can be used to represent plate divergence caused by a convection current.  A 600 ml beaker of thick, light-coloured syrup is cooled for several hours in a fridge to increase its viscosity. It is placed on a tripod with a broken biscuit placed on the surface. Heating the syrup with a 4 cm Bunsen flame causes a plume of syrup to rise towards the surface. As it rises, the plume displaces colder syrup near the surface and the biscuit pieces separate. |
| **9ESs.02** Describe the evidence for the collision theory for the formation of the Moon. | Collision theory, impact, debris, coalesce, isotope | The collision of a Mars-sized object with a young Earth can be shown using a computer simulation available online. | Some learners may believe that the Earth and Moon has remained the same over time. Provide evidence that changes have occurred. For example, Mars once had liquid water (based on erosion evidence); comets collide with planets (e.g. Shoemaker-Levy 9 colliding with Jupiter in 1994). |
| **9ESs.03** Know that nebulae are clouds of dust and gas and can act as stellar nurseries. | Nebula, nebulae, nebular, star, stellar, gravity, gravitational collapse, supernova, supernovae, hydrogen, helium, protostar, fusion, interstellar space | The formation of stars in a nebula can be shown using a video of a computer simulation available online.  Star formation in nebulae may be modelled using a cotton sheet that is sprinkled with something granular (e.g. rice, salt, sugar). Stones can then be placed on the sheet to represent gravity pulling the grains in. Shake the sheet and the grains will go into the ‘dimples’ created by the stones; this represents the ‘clumping’ of materials and gases. This model offers only a partial explanation of stellar formation in nebulae; explain to learners that the physics involved in the process is the model cannot convey the complex physics involved. | Learners may believe that stars are unchanging. This misconception may be addressed by providing evidence for stellar evolution and looking at the life cycle of a star from birth to death. |

# Unit 9.9 Suggested activities

| Learning objective | Thinking and Working Scientifically opportunities | Suggested teaching activities and resources |
| --- | --- | --- |
| **9ESp.02** Explain why the jigsaw appearance of continental coasts, location of volcanoes and earthquakes, fossil record and alignment of magnetic materials in the Earth's crust are all evidence for tectonic plates. | **9TWSa.02** Describe trends and patterns in results, identifying any anomalous results and suggesting why results are anomalous. | **Evidence for tectonic plates**  Show learners a world map showing where earthquakes have occurred in the last 10-20 years, and a similar map showing volcanic eruptions.  Ask learners:  *What similarities and differences are there between the maps?* (most earthquakes and volcanoes occur along well-defined lines on the maps)  *What do these lines represent?* (the lines of earthquakes and volcanoes suggest these are boundaries of tectonic plates)  Determine what learners understand by the term ‘tectonic plate’. Correct any misconceptions such as the plates being breaks in the Earth’s crust only (rather than a solid layer made up of the crust and the uppermost mantle). It may help to draw a diagram showing the relationship between the chemical and physical models of the Earth described in Stage 7.  *Why do earthquakes occur near the boundaries of tectonic plates?*  *Why do volcanoes occur near the boundaries of tectonic plates?*  *Are there any anomalous results?*  *Why might earthquakes and volcanoes occur in other places?*  Although the focus of this learning objective is on those earthquakes and volcanoes that occur near the boundaries of tectonic plates, you may like to point out and explain some anomalous examples.   * Earthquakes can occur in other places (for example the Gujarat earthquake of 2001), especially at faults in the Earth’s outer solid layer. The boundaries of tectonic plates are the largest examples of faults (and so are the sites of the largest earthquakes). * The dominant theory to explain volcanoes that occur away from plate boundaries (e.g. the Yellowstone super-volcano and the Hawaiian islands) is the hotspot theory (by Canadian geophysicist John Tuzo-Wilson). This states that there are some exceptionally hot fixed areas in the mantle which melt the tectonic plates which move above them.   A jigsaw of the continents is a model that can be used to help learners visualise how the positions of the continents has changed over a long period of time to the present day, as the tectonic plates have moved.  Learners should work in pairs, or groups of three, for this activity. Provide each learner group with cut outs of the continents, ideally showing the continental shelves. Learners then match the shapes of the continents to form a single super-continent (some gaps may remain between continents as erosion has taken place over time). Discuss with learners how this ‘jigsaw’ model is evidence that the continents sit on tectonic plates and movement of the tectonic plates separated out a single super-continent and how the continents are still moving. This can be reinforced by showing learners an animation of the continents moving over time.  Discuss with learners that if we accept the movement of land masses due to tectonic plates, then what evidence from fossils they might expect.  Discuss with learners the example of mesosaurus fossils that have been found in Southern Africa and Eastern South America. There are several explanations for why this may be including the species evolving independently on separate continents (which is unlikely), a population swimming or being transported between the continents or the continents at one point being physically connected to allow the species to spread across what would become two continents. Ask learners to research other examples where the fossil records indicates the continents were once joined. Learners share their findings to build up a class evidence base that the fossil record collaborates the theory of tectonic plates.  Show learners a topographical map of the Atlantic Ocean floor in which the Mid-Atlantic Ridge is clearly visible. Explain that the Mid-Atlantic Ridge was discovered in 1872 but was confirmed in 1925 using sonar technology. A detailed map showing the full structure of the ridge was not made until 1950. The discovery of other mid-ocean ridges led to the theory of seafloor spreading, which supported the theory of plate tectonics.  Now show learners a map of the magnetic stripes on either side of the Mid-Atlantic Ridge. When magma emerges from the Earth’s crust the magnetic materials in the liquid rock align to the Earth’s magnetic field. As the Earth’s magnetic poles switch over long periods of time, this means where new rock is being regularly formed e.g. at the boundary of tectonic plates you get rock with magnetic material which are aligned to the geographical north, followed by rock with magnetic material aligned to the geographical south and so on as the magnetic materials align to the change in the Earth’s magnetic poles over time. Explain the magnetic stripes were discovered during the 1950s; they represent as further evidence for seafloor spreading which is a key part of proving a mechanism for tectonic plates.  Discuss with learners it was not until the 1960s when the tectonic plate theory became accepted and this was due to the volume and nature of the evidence in its favour.  Summarise the learning by emphasising that theories in science are not always accepted quickly. It may take the collection of much more evidence over many years before other scientists accept the new theory.  **Resources:** World maps showing the location of earthquakes and volcanic eruptions, a jigsaw of the continents, a map of the Mid-Atlantic Ridge, a magnetic stripe map of the Mid-Atlantic Ridge |
| **9ESp.01** Explain the movement of tectonic plates in terms of convection currents. | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations. | **Modelling convection currents in the mantle**  Show learners a map of the world which includes the lines showing plate boundaries. Ask learners:  *How do the tectonic plates move?*  *What causes the movement?*  Discuss with learners their answers. We can find out by considering our existing knowledge and using a model. Recap with learners the structure of the Earth particularly that there is a solid outer layer and below that viscous layer that can flow.  Provide learners with the equipment and set up to model these layers in a beaker. Learners, in groups of three, pour light coloured syrup (that has been cooled for several hours to increase its viscosity) into a 600ml beaker so there is a layer no deeper than 200ml. On top of the syrup is a broken biscuit. Discuss with learners that the syrup represents the part of the mantle that can flow and the biscuit the solid outer layer (crust and upper mantle).  Learners then place the beaker on a tripod and apply a 4 cm Bunsen flame to the bottom of the beaker. A plume of heated syrup rises and I the process displaces colder syrup near the surface and the biscuit pieces separate. Do not allow learners to heat the syrup above about 50OC because hot syrup causes serious burns.  Draw learners’ attention to the slow convection current within the syrup as shown by small air bubbles moving.  If you do not have the resources available then videos showing this model can be found online.  Ask learners:  *What is causing the movement of the biscuit?* (this is a good opportunity to revise understanding of convection currents)  *What are the strengths of this model?*  *What are the limitations of this model?*  The model shows how a convection current in a viscous liquid or layer can cause movement of a solid resting on its surface. Discuss some of the limitations of the model (e.g. the rising syrup does not form new biscuit at the surface).  Explain that convection currents in the mantle cause seafloor spreading. Show learners images of divergent boundaries (e.g. the East African Rift, the Red Sea Rift, the Iceland Rift) or pillow lava forming at a mid-ocean ridge.  Ask learners:  *If there are places where tectonic plates are moving apart and making new crust, why isn’t the Earth growing in size?*  Explain that, in the 1960s, a scientist called Harry Hammond Hess proposed that the ocean floor spreads on either side from a mid-ocean ridge rather like a conveyor belt. Other geologists realised that some ocean crust was being pushed under continents causing the formation of mountain chains and deep ocean trenches. When the crust is pushed under the continents it becomes part of the mantle.  Show learners an animation of a convergent boundary between oceanic crust and continental crust. Draw their attention to the ocean trench and mountains that form. Identify some convergent boundaries on a tectonic map of the world, such as where the Nazca Plate meets the South America Plate forming the Andes and the Peru-Chile (Atacama) Trench. Show an image of the Himalayas and explain that they began to form about 50 million years ago, when the Indian Plate collided with the Eurasian Plate and, they are still forming.  Ask learners to summarise the evidence for convection currents causing the movement of tectonic plates, and to describe how the tectonic plates move.  **Resources:** 600ml beakers, syrup, Bunsen burners, heatproof mats, biscuits |
| **9ESs.02** Describe the evidence for the collision theory for the formation of the Moon. | **9TWSm.01** Understand that models and analogies reflect current scientific evidence and understanding and can change.  **9TWSp.02** Describe examples where scientists' unexpected results from enquiries have led to improved scientific understanding. | **Comparing theories for the formation of the Moon.**  Introduce the lesson by discussing learners’ understanding of the origins of the Solar System:  *How did the planets form?* (from debris left over from the formation of the Sun)  *Why is our Moon so unusual?* (only two inner planets have moons, our Moon is far larger than the two moons that orbit Mars)  Explain that, over time, our understanding of how the Earth and Moon formed has changed, giving some examples of hypotheses:   * Capture hypothesis – One early theory was that the Earth captured a small planet which became our Moon. * Accretion hypothesis – A second theory was that the Earth and Moon formed together from the same accretion (debris) disc. * Collision (Giant impact) hypothesis – Scientists’ current understanding is that a Mars-sized protoplanet (named Theia) struck the Earth creating a molten Earth and a debris field in space that coalesced to form the Moon.   Ask questions:  *If the Moon was a small planet captured by the Earth how would their chemical compositions compare?* (we would expect the composition of the Moon to be very different from the Earth’s composition)  *If the Moon and Earth formed from the same accretion (debris) disc, how would their chemical compositions compare?* (we would expect the composition of the Moon to be almost identical to the Earth’s composition)  Explain that the Apollo missions brought back 2200 samples of Moon rock (weighing a total of 382 kg). Analysis of the composition of many types of Moon rock has shown :   * The Moon's surface was once molten. This was an unexpected result for scientists as there is no evidence of any volcanic or tectonic activity on the Moon. * The stable-isotope ratios of lunar (Moon) and terrestrial (Earth) rock are very similar, but not identical.   Ask learners in pairs to discuss:  *Which theory/hypothesis does this evidence support? Why?*  Listen to learners thoughts and confirm the evidence supports the collision theory.  Explain to learners that there is further supporting evidence for the Collision Theory*:*   * the Earth's spin and the Moon's orbit have similar orientations – this supports an oblique impact by a large object * there is evidence in other star systems of similar collisions, resulting in accretion (debris) discs * the Moon has a relatively small iron core – the Moon formed mainly from debris from the outer layers of the Earth which have less iron than the core. * the Moon has a lower density than the Earth – the Moon formed mainly from debris from the outer layers of the Earth which are less dense than the core.   If possible, show learners a simulation of the impact between Theia and Earth.  Explain to learners that there is some evidence that the Moon formed in a different way. Collision Theory cannot explain:   * Why is there no evidence that a large part of the Earth’s surface was molten? Why is there no evidence for a magma ocean like that discovered on the Moon? Either the Collision Theory is wrong, or all evidence has been obliterated by erosion and plate tectonics. * Why is there little evidence of material from Theia, the protoplanet that collided with the young Earth? Either the Collision Theory is wrong, Theia had a similar chemical composition to the Earth, or we have yet to find the evidence.   Ask learners:  *Why are we not fully sure how the Moon formed?* (no single hypothesis is fully supported by evidence)  Explain to learners that, in 2012, Robin M. Canup proposed a new hypothesis. He suggests the Earth and Moon formed together from the impact of two protoplanets, each larger than Mars. The two protoplanets coalesced to create the Earth and a debris disc from which the Moon formed.  Ask learners:  *How is Robin M. Canup’s Giant impact hypothesis supported by evidence?* (all pieces of evidence support his theory apart from the lack of evidence of a magma ocean on Earth)  Give learners a worksheet which provides has a table with the evidence in the first column against theories, as titles for the other columns. Learners tick the blank cell in each theory to show which evidence supports the theory.  **Resources:** A simulation of the impact between Theia and Earth, worksheet with all evidence |
| **9ESs.03** Know that nebulae are clouds of dust and gas, and can act as stellar nurseries. | **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and limitations. | **The formation of stars**  Show learners some images of nebulae; good examples can be found on the Hubble telescope website.  Ask learners:  *What do you think nebulae are?*  *When do you think they were discovered? (nebulae were not discovered until after the invention of the telescope, the first nebula was observed by Charles Messier, a French astronomer, in 1764)*  Explain that a nebula is a cloud of gas and dust in interstellar space (the space between stars and a long way from their gravitational pull). Give learners some interesting facts about nebulae:   * The gas and dust that make a nebula come from a variety of sources, some nebulae are formed from hydrogen and helium left over from the Big Bang and heavier elements produced by supernovae (huge stars that explode at the ends of their lives), other nebulae are formed from dead stars. * The density of a typical nebula is only 100 to 10,000 particles per cm3; this is a million times less than that of a typical vacuum on Earth. * A nebula the size of the Earth would only weigh a few kilograms. * A typical nebula is one light year across – about 9 000 000 000 000 km or nine thousand billion km. * Nebulae are made visible by fluorescence caused by radiation from stars.   Explain that a nebula has gravity and can slowly collapse to become denser and hotter. If it collapses enough, it can form a protostar (a ball of hot gas without a nuclear fusion reaction at its centre). A protostar will continue to collapse under its gravity and heat up more and more. Once the temperature and pressure at the centre of the protostar are high enough, nuclear fusion begins and the protostar becomes a real star.  Stellar formation may be modelled using a sheet of material that is sprinkled with something granular (e.g. rice). The sheet with sprinkled grains represents the nebulae. Place stones on the sheet to model gravity pulling the grains in. Shake the sheet to cause the grains to collect in the ‘dimples’ created by the stones. Explain to learners that this represents the ‘clumping’ of materials and gases.  Learners use secondary information sources to research the nature of nebulae and star formation. They summarise their findings by creating a flowchart that explains the sequence of formation of a star from a nebula.  Explain that a star lifecycle can take millions or billions of years and so scientists cannot observe the whole process. They have observed many stars at different stages in their lifecycle and used that information to deduce a sequence for stellar evolution. To model this process, you could provide learners with a series of pictures showing amphibian metamorphosis and challenge them to sequence them. This would be a particularly powerful model were the photographs to include anomalies (e.g. a lizard, a fully grown axolotl.)  **Resources:** Images of nebulae, sheet, rice, secondary information sources, pictures of amphibian metamorphosis |

# Sample Lesson 1

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| --- | --- |
| CLASS: | |
| DATE: | |
| **Learning objectives** | **9Cp.01** Understand that the groups within the Periodic Table have trends in physical and chemical properties, using group 1 as an example.  **9TWSa.02** Describe trends and patterns in results, identifying any anomalous results and suggesting why results are anomalous.  **9TWSp.03** Make predictions of likely outcomes for a scientific enquiry based on scientific knowledge and understanding. |
| **Lesson focus /**  **success criteria** | I can describe observations about the reactions of Group 1 metals with water  I can describe and explain the trends in reactivity  I can link the trend in reactivity to the electron configuration of Group 1 metals |
| **Prior knowledge / Previous learning** | Learners will build on prior knowledge about the structure of the atom, the Periodic Table, chemical properties, and physical properties.  They will benefit from knowing the distinction between chemical and physical properties and knowing how these can be observed. Learners should also know how to represent the electron configuration of some elements. |

**Plan**

| **Lesson** | **Planned activities** | **Notes** |
| --- | --- | --- |
| **Introduction** | Ask learners to give the electron configuration of some elements for the starter activity. Check understanding.  Lead a discussion, asking learners to describe some observations that may be made when a chemical reaction occurs. Learners may suggest: colour change, temperature change, bubbles of gas, formation of a precipitate (solid). If not all of these are given by learners, prompt and fill in gaps as appropriate.  Ask them to suggest how the reactions of more reactive elements might differ from those with lower reactivity. Define with learners the term ‘reactivity’ to ensure it is being used appropriately throughout the lesson.  Explain to learners they are going to observe how water reacts with three metals (lithium, sodium and potassium) that all belong to group 1 of the Periodic Table. They should use their observations to describe the common reactions of the group and describe the trend in reactivity down the group. |  |
| **Main activities** | Demonstrate the reactions of lithium, sodium and potassium in a large basin of cold water one by one. Ask learners to make notes as each demonstration proceeds. Encourage the use of scientific descriptions of observations, modelling the language expected.  During the demonstration, highlight the key observations: floating of metals, movement around the surface of the water, production of gas, flames.  *What trend in reactivity did you observe?*  Remind learners about their prior understanding of the electron configuration of elements. Ask learners to draw the electron configurations of the group 1 elements they observed in the demonstration, paying particular attention to the location of the nucleus and the distance between electrons in the outer shell and the nucleus. Discuss with learners that the metal loses electrons during its reaction with water. Help learners to make links between the ease of loss of the electron in the outer shell of the group 1 atoms and the electron configuration.  Ask learners:  *What happens to the size of the atom as we go down group 1?*  *What happens to the electron configuration as we go down group 1?*  Learners use the observed trend to make predictions about how the metals lower down group 1 (rubidium, caesium and francium) would react with water.  *What do you think will happen? Why?*  Metals lower down group 1 (rubidium, caesium and francium) reacting with water are observed using videos.  Discuss with learners:  *Were your predictions accurate?*  *Do your observations support the trend identified for the earlier metals?*  Ask learners to suggest a relationship between the structure of the atoms as we go down group 1 and their reactivity with water. Encourage learners to write concise explanations of the relationship between the structure of an atom and its reactivity. | Resources: Small samples of Li, Na, K (the size of a rice grain), large glass tank of water, safety screens to protect learners and goggles to protect yourself.  Ensure samples of the Group 1 metals are handled with care at all times and are kept safe (e.g. in oil). Follow all local and regional health and safety requirements.  Resources: Reliable videos of the reactions of R, Cs and Fr with water |
| **End/Close/ Reflection/Summary** | Ask learners to swap their explanations and peer review. Encourage sharing of clear and concise explanations. Work as whole class to create a definitive class explanation which can be displaced for future reference. |  |

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| **Reflection Use the space below to reflect on your lesson. Answer the most relevant questions for your lesson.** |
| *Were the learning objectives and lesson focus realistic? What did the learners learn today? What was the learning atmosphere like? What changes did I make from my plan and why?*  *If I taught this again, what would I change?*  *What two things went really well (consider both teaching and learning)?*  *What two things would have improved the lesson (consider both teaching and learning)?*  *What have I learned from this lesson about the class or individuals that will inform my next lesson?* |
| **Next steps**  **What will I teach next, based on learners’ understanding of this lesson?** |

# Sample Lesson 2

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| --- | --- |
| **CLASS:** | |
| **DATE:** | |
| **Learning objectives** | **9Pe.04** Use diagrams and conventional symbols to represent, make and compare circuits that include cells, switches, resistors (fixed and variable), ammeters, voltmeters, lamps and buzzers.  **9TWSm.02** Describe some important models, including analogies, and discuss their strengths and weaknesses.  **9TWSm.03** Use symbols and formulae to represent scientific ideas. |
| **Lesson focus /**  **success criteria** | I can identify which circuit symbols represent different circuit components  I can draw circuits using conventional symbols  I can make a circuit from a given circuit diagram |
| **Prior knowledge / Previous learning** | Learners will benefit from previous experience using circuit diagrams and conventional symbols. This lesson acts as a recap of prior learning to ensure they can access the rest of the unit.  Learners will also benefit from knowing; how to measure current in series circuits with an ammeter, an electrical device will not work if there is a break in the circuit, how a simple switch is used to open and close a circuit, and how changing the number or type of components in a series circuit can change the current. |

**Plan**

| **Lesson** | **Planned activities** | **Notes** |
| --- | --- | --- |
| **Introduction** | Provide learners with a series of symbols that represent different objects or ideas. For example, the symbol for a chemical element, the hazard symbol for a poisonous substance, a road sign, a mathematical operator (e.g. %).  Ask learners:  *Why do we use symbols in society?*  Discuss with learners their responses and how symbols are visual representations without words, they are commonly understood by most people irrespective of whatever language is spoken/used. | Resources: Images of symbols |
| **Main activities** | Introduce the main activity by showing learners one or more circuit diagrams including the conventional symbols for the components that they encountered during Stage 7 (i.e. cells, wires, switches, lamps, buzzers and ammeters).  Ask learners:  *Why are conventional symbols used in circuit diagrams?* (so that scientists from different areas find it easier to understand and interpret circuit diagrams)  *Why are connecting wires conventionally shown as vertical and horizontal lines in circuit diagrams?* (this makes it easier to interpret circuit diagrams and make circuits using them)  Provide learners with 4 circuit diagrams (each containing at least 2 components) and the equipment to make the circuits. Make sure the first two circuits are simpler than the final two circuits. Whist learners are making their circuits, circulate around the groups to offer guidance to those groups that need it. Provide more complex circuit diagrams to the faster groups, if appropriate.  Once you are satisfied that learners are secure with making circuits, have 4 circuits made up around the room for learners to practise drawing circuit diagrams.  Introduce learners to the circuit symbols for a fixed resistor and a variable resistor and show them the physical components. Explain that resistors limit the current flowing in a circuit. Get them to practise using the symbols for the fixed resistor and variable resistor by drawing some circuit diagrams that contain them.  Introduce the symbol for a voltmeter and explain how it is connected in a circuit, explaining that it measures a quantity called ‘voltage’. Explain that voltage is a measure of how much energy the electric current has and it is measured in volts (V). Explain that voltmeters are always connected in parallel (rather than in series). Show learners the connection on a circuit diagram and in a physical circuit.  Learners practise making a circuit that contains a resistor, an ammeter and a voltmeter to ensure they can connect the voltmeter correctly. Once again, circulate around the groups to check their circuits are correct, offering guidance where needed. | Resources: Range of circuit diagrams  Cells, wires, switches, lamps, buzzers, ammeters  Resistors, variable resistors, voltmeters  Photographs of 4 electrical circuits if needed |
| **End/Close/ Reflection/Summary** | Show learners a series circuit (or a photograph of a series circuit) containing a lamp, a variable resistor and an ammeter. Show them three circuit diagrams for the circuit that are topologically identical. For example:    Ask learners:  *Which circuits diagrams are correct, and which are incorrect?* (all the diagrams are correct, they are just different representations of the same circuit. Even with the placement of the components in different places the sequence is still correct) | A circuit containing three components.  Three circuit diagrams that are topologically identical. |

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| **Reflection Use the space below to reflect on your lesson. Answer the most relevant questions for your lesson.** |
| *Were the learning objectives and lesson focus realistic? What did the learners learn today? What was the learning atmosphere like? What changes did I make from my plan and why?*  *If I taught this again, what would I change?*  *What two things went really well (consider both teaching and learning)?*  *What two things would have improved the lesson (consider both teaching and learning)?*  *What have I learned from this lesson about the class or individuals that will inform my next lesson?* |
| **Next steps**  **What will I teach next, based on learners’ understanding of this lesson?** |

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