UNIT 1 CHEMISTRY

SUMMER SCHOOL

VCE SUMMER SCHOOL

Unit 1 Chemistry

Area of Study 1

How Do the Chemical Structures of Materials
Explain their Properties and Reactions?

Area of Study 2

How are Materials Quantified and Classified?

VCE Accreditation Period
2023 – 2027

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VCE SUMMER SCHOOL HEAD START LECTURES

STUDY DESIGN (2023 – 2027) – EDITION 1

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ABOUT THE COVER IMAGE
THE POWER OF ART

Engaging with art is essential to the human experience. Almost as soon as motor skills are developed, children communicate through artistic expression. Throughout each stage of our lives, art plays different and important roles. The arts have the power to bring joy, stir up emotions and influence our behaviour. Art crosses all divides. It breaks down cultural, social and economic barriers and plays a big role in how humans see and interact with others, and the world in general.

Art decreases stress levels and improves mental health and well-being, particularly in patients suffering chronic or terminal illness. It has the power to educate people and convey meaning in a way that can be appreciated by every person. Furthermore, it gives us the opportunity to travel through time and learn from the beliefs, dreams, habits, thoughts, culture and lives of people in different places and times.

The arts also challenge us with different points of view, encourages communication, promotes stronger critical thinking and problem-solving skills and unlocks the potential of the human mind. It is also closely linked to academic achievement, civic engagement and social and emotional development.

The benefits of art are significant and undeniable. Use it to benefit both your mental and physical health as you journey through your VCE.

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SECTION 1: UNIT 1 CHEMISTRY

COURSE OUTLINE & ASSESSMENT (2023 – 2027)

VCE CHEMISTRY STUDY DESIGN

UNIT 1: HOW CAN THE DIVERSITY OF MATERIALS BE EXPLAINED?

The development and use of materials for specific purposes is an important human endeavour. In this unit students investigate the chemical structures and properties of a range of materials, including covalent compounds, metals, ionic compounds and polymers. They are introduced to ways that chemical quantities are measured. They consider how manufacturing innovations lead to more sustainable products being produced for society through the use of renewable raw materials and a transition from a linear economy towards a circular economy.

Students conduct practical investigations involving the reactivity series of metals, separation of mixtures by chromatography, use of precipitation reactions to identify ionic compounds, determination of empirical formulas, and synthesis of polymers.

Throughout this unit students use chemistry terminology including symbols, formulas, chemical nomenclature and equations to represent and explain observations and data from their own investigations and to evaluate the chemistry-based claims of others.

A student-directed research investigation into the sustainable production or use of a selected material is to be undertaken in Area of Study 3. The investigation explores how sustainability factors such as green chemistry principles and the transition to a circular economy are considered in the production of materials to ensure minimum toxicity and impacts on human health and the environment. The investigation draws on key knowledge and key science skills from Area of Study 1 and/or Area of Study 2.

AREA OF STUDY 1

HOW DO THE CHEMICAL STRUCTURES OF MATERIALS EXPLAIN THEIR PROPERTIES AND REACTIONS?

In this area of study students focus on elements as the building blocks of useful materials. They investigate the structures, properties and reactions of carbon compounds, metals and ionic compounds, and use chromatography to separate the components of mixtures. They use metal recycling as a context to explore the transition in manufacturing processes from a linear economy to a circular economy.

The selection of learning contexts should allow students to develop practical techniques to investigate the properties and reactions of various materials. Students develop their skills in the use of scientific equipment and apparatus. Students may conduct flame tests to identify elements in the periodic table. They may model covalent, metallic and ionic structures using simple ball-and-stick models and may use computer simulations of the three-dimensional representations of molecules and lattices to better understand structures. They use solubility tables to experimentally identify unknown ions in solution.

They respond to challenges such as developing their own reactivity series by reacting samples of metals with acids, oxygen and water.

OUTCOME 1

On completion of this unit the student should be able to explain how elements form carbon compounds, metallic lattices and ionic compounds, experimentally investigate and model the properties of different materials, and use chromatography to separate the components of mixtures.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on pages 11 and 12 of the study design.

KEY KNOWLEDGE: OUTCOME 1

ELEMENTS AND THE PERIODIC TABLE

- The definitions of elements, isotopes and ions, including appropriate notation: atomic number; mass number; and number of protons, neutrons and electrons.

- The periodic table as an organisational tool to identify patterns and trends in, and relationships between, the structures (including shell and subshell electronic configurations and atomic radii) and properties (including electronegativity, first ionisation energy, metallic and non-metallic character and reactivity) of elements.

- Critical elements (for example, helium, phosphorus, rare-earth elements and post-transition metals and metalloids) and the importance of recycling processes for element recovery.

COVALENT SUBSTANCES

- The use of Lewis (electron dot) structures, structural formulas and molecular formulas to model the following molecules: hydrogen, oxygen, chlorine, nitrogen, hydrogen chloride, carbon dioxide, water, ammonia, methane, ethane and ethene.

- Shapes of molecules (linear, bent, pyramidal, and tetrahedral, excluding bond angles) as determined by the repulsion of electron pairs according to valence shell electron pair repulsion (VSEPR) theory.

- Polar and non-polar character with reference to the shape of the molecule.

- The relative strengths of intramolecular bonding (covalent bonding) and intermolecular forces (dispersion forces, dipole-dipole attraction and hydrogen bonding).

- Physical properties of molecular substances (including melting points and boiling points and non-conduction of electricity) with reference to their structure and bonding.

- The structure and bonding of diamond and graphite that explain their properties (including heat conductivity and electrical conductivity and hardness) and their suitability for diverse applications.

REACTIONS OF METALS

- The common properties of metals (lustre, malleability, ductility, melting point, heat conductivity and electrical conductivity) with reference to the nature of metallic bonding and the existence of metallic crystals.

- Experimental determination of a reactivity series of metals based on their relative ability to undergo oxidation with water, acids and oxygen.

- Metal recycling as an example of a circular economy where metal is mined, refined, made into a product, used, disposed of via recycling and then reprocessed as the same original product or repurposed as a new product.

REACTIONS OF IONIC COMPOUNDS

- The common properties of ionic compounds (brittleness, hardness, melting point, difference in electrical conductivity in solid and molten liquid states), with reference to the nature of ionic bonding and crystal structure.

- Deduction of the formula and name of an ionic compound from its component ions, including polyatomic ions (NH_4^+, OH^-, NO_3^-, HCO_3^-, CO_3^{2-}, SO_4^{2-} and PO_4^{3-}).

- The formation of ionic compounds through the transfer of electrons from metals to non-metals, and the writing of ionic compound formulas, including those containing polyatomic ions and transition metal ions.

- The use of solubility tables to predict and identify precipitation reactions between ions in solution, represented by balanced full and ionic equations including the state symbols: (s), (l), (aq) and (g).

SEPARATION AND IDENTIFICATION OF THE COMPONENTS OF MIXTURES

- Polar and non-polar character with reference to the solubility of polar solutes dissolving in polar solvents, and non-polar solutes dissolving in non-polar solvents.

- Experimental application of chromatography as a technique to determine the composition and purity of different types of substances, including calculation of R_f values.

AREA OF STUDY 2
HOW ARE MATERIALS QUANTIFIED AND CLASSIFIED?

In this area of study students focus on the measurement of quantities in chemistry and the structures and properties of organic compounds, including polymers.

The selection of learning contexts should allow students to develop practical techniques to quantify amounts of substances and to investigate the chemistry of organic compounds. Students develop their skills in the use of scientific equipment and apparatus. They perform calculations based on the generation of primary data, such as determining the empirical formula of an ionic compound or hydrated salt, and consider how the quality of data generated in experiments can be improved. They may construct models to visualise the similarities and differences between families of organic compounds. Students may use common substances in their experiments such as making glue from milk. They may investigate the environmental impact of the production of polymers: for example, the recycling of biodegradable polymers derived from natural resources such as biopolyethene (Bio-PE). Students respond to challenges such as investigating how changing formulations for polymers affects their structure and properties: for example, by creating slime.

OUTCOME 2

On completion of this unit the student should be able to calculate mole quantities, use systematic nomenclature to name organic compounds, explain how polymers can be designed for a purpose, and evaluate the consequences for human health and the environment of the production of organic materials and polymers.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on pages 11 and 12 of the study design.

KEY KNOWLEDGE: OUTCOME 2

QUANTIFYING ATOMS AND COMPOUNDS

- The relative isotopic masses of isotopes of elements and their values on the scale in which the relative isotopic mass of the carbon-12 isotope is assigned a value of 12 exactly.

- Determination of the relative atomic mass of an element using mass spectrometry (details of instrument not required).

- Avogadro's constant as the number 6.02×10^{23} indicating the number of atoms or molecules in a mole of any substance; determination of the amount, in moles, of atoms (or molecules) in a pure sample of known mass.

- Determination of the molar mass of compounds, the percentage composition by mass of covalent compounds, and the empirical and molecular formula of a compound from its percentage composition by mass.

FAMILIES OF ORGANIC COMPOUNDS

- The grouping of hydrocarbon compounds into families (alkanes, haloalkanes, alkenes, alcohols, carboxylic acids) based upon similarities in their physical and chemical properties, including general formulas and general uses based on their properties.

- Representations of organic compounds (structural formulas, semi-structural formulas) and naming according to the international union of pure and applied chemistry (IUPAC) systematic nomenclature (limited to non-cyclic compounds up to C8, and structural isomers up to C5).

- Plant-based biomass as an alternative renewable source of organic chemicals (for example, solvents, pharmaceuticals, adhesives, dyes and paints) traditionally derived from fossil fuels.

- Materials and products used in everyday life that are made from organic compounds (for example, synthetic fabrics, foods, natural medicines, pesticides, cosmetics, organic solvents, car parts, artificial hearts), the benefits of those products for society, and the health and/or environmental hazards they pose.

POLYMERS AND SOCIETY

- The differences between addition and condensation reactions as processes for producing natural and manufactured polymers from monomers.

- The formation of addition polymers by the polymerisation of alkene monomers.

- The distinction between linear (thermoplastic) and cross-linked (thermosetting) addition polymers with reference to structure and properties.

- The features of linear addition polymers designed for a particular purpose, including the selection of a suitable monomer (structure and properties), chain length and degree of branching.

- The categorisation of different plastics as fossil fuel based (HDPE, PVC, IDPE, PP, PS) and as bioplastics (PLA, Bio-PE, Bio-PP); plastic recycling (mechanical, chemical, organic), compostability, circularity and renewability of raw ingredients.

- Innovations in polymer manufacture using condensation reactions, and the breakdown of polymers using hydrolysis reactions, contributing to the transition from a linear economy towards a circular economy.

AREA OF STUDY 3

HOW CAN CHEMICAL PRINCIPLES BE APPLIED TO CREATE A MORE SUSTAINABLE FUTURE?

Knowledge of the structure and properties of matter has developed over time through scientific and technological research, leading to the production of a range of useful chemicals, materials and products for society. Chemists today, through sustainable practices, seek to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Chemists also learn from Aboriginal and Torres Strait Islander peoples about the ways that they sustainably modify and process raw materials using techniques developed over millennia.

Sustainability requires innovation in designing and discovering new chemicals, production processes and product management systems that will provide increased yield or performance at a lower cost while meeting the goals of protecting and enhancing human health and the environment.

In this area of study students undertake an investigation involving the selection and evaluation of a recent discovery, innovation, advance, case study, issue or challenge linked to the knowledge and skills developed in Unit 1 Area of Study 1 and/or Area of Study 2, including consideration of sustainability concepts (green chemistry principles, sustainable development and the transition towards a circular economy). Examples of investigation topics and possible research questions are provided below.

Students may select a research question related to the investigation topics included below or, in conjunction with their teacher, develop their own research question related to Unit 1 Area of Study 1 and/or Area of Study 2. Possible starting points when developing a research question may include visiting a chemical laboratory, local chemical manufacturer or industrial plant; announcements of recent materials science research findings; an interview with an expert involved in materials science or sustainability; an expert's published point of view; a public concern about an issue related to the production of a chemical or material; 'green field' research leading to new technologies; changes in government funding or policy or new government initiatives, such as incentives promoting the transition from a linear economy to a circular economy; case studies related to how Aboriginal and Torres Strait Islander peoples process natural materials for particular purposes; a TED talk; a YouTube presentation; or an article from a scientific publication.

Students apply critical and creative thinking and science inquiry skills to prepare a communication to explain the relevant chemical concepts associated with their investigation, critically examine the information and data available to answer the research question, and identify the sociocultural, economic, political, legal and ethical implications of the selected investigation in terms of sustainability.

INVESTIGATION TOPIC 1: ENDANGERED ELEMENTS IN THE PERIODIC TABLE

Today's chemists are involved in many branches of chemistry, covering all 118 elements in the periodic table. Some of these elements are now considered to be critical and endangered, particularly due to the prevalence of modern technologies that rely on many different scarce minerals. It has been estimated that 44 elements will soon be, or are already, facing supply limitations, making a future of continuing technological advancement uncertain.

Questions that may be explored in this investigation include:

- Which chemicals are used in the manufacture of fireworks, what is the environmental impact of the combustion of these chemicals to produce the colourful effects seen in fireworks displays, and what alternatives are available?

- Based on their usefulness for society, how would you compare the value of lanthanoids and actinoids with the value of other metal groups in the periodic table?

- Why is helium classified as a critical and endangered element, and how can it be saved given that its atmospheric recovery is almost impossible?

- How is indium mined and used in the manufacture of products such as LCD screen televisions and computer monitors, mobile phones or photovoltaic panels, and what alternatives are available if indium becomes scarce?

- How do the properties of the metalloids (such as germanium, antimony, tellurium) differ so much to their neighbours on the periodic table, and how have these properties made them highly important for society and consequentially scarce in supply?

- How are precious metals from electronic waste (e-waste) recycled and what are the environmental and economic benefits of these recovery processes?

INVESTIGATION TOPIC 2: PRODUCING AND USING 'GREENER' POLYMERS

Both natural and synthetic polymers play an important role in everyday life. The cells in animals and plants are built of, and metabolise, natural polymers. Proteins and carbohydrates in our food are both polymers. Synthetic polymers are used for a myriad of purposes in everyday life but may present challenges in terms of the by-products resulting from their manufacture or breakdown, and their persistence in the environment. The sustainability of polymers can be considered in terms of whether these plastics can be avoided by using different products or activities, reduced through design, or replaced by different materials.

Questions that may be explored in this investigation include:

- What are plant-based biopolymers and what are the impacts of their production on the environment?
- How do biodegradable and degradable polymers, compostable polymers and recyclable polymers differ in structure, production and environmental impacts?
- What is the difference between micropolymers and nanopolymers, and how are used plastic materials and litter managed and repurposed?
- Is the recycling of packaging products containing aluminium more sustainable than LDPE polymer-based packaging products?
- Why is the sale of plastic water bottles and single-use plastics banned in many countries?
- How do animal proteins compare with non-animal proteins for different applications, such as meat substitutes and non-animal leather?
- How do the chemical structures of elastomers differ from the structures of thermosetting and thermoplastic polymers, and what are the implications of the production of elastomers for society?
- What impact does the vulcanisation of rubber have on the environment and the communities where rubber is sourced and produced?
- What are the risks and benefits to the environment of the manufacturing, production and application of synthetic fibres for the textile industry (for example, synthetic grass, active wear, shoes and single-use plastics such as takeaway cups, containers, and electrical and electronic products such as mobile phone cords and USB flash drives)?

INVESTIGATION TOPIC 3: THE CHEMISTRY OF ABORIGINAL AND TORRES STRAIT ISLANDER PEOPLES' PRACTICES

Throughout history, people all over the world have hypothesised, experimented, made empirical observations, gathered evidence, recognised patterns, verified through repetition, and made inferences and predictions to help them to make sense of the world around them and their place within it. Recent research and discussion have confirmed many Aboriginal and Torres Strait Islander groups use the environment and its resources to solve the challenges they face in the different Australian climates in ways that are more sustainable than similar materials produced in Western society. Their solutions can be explained by a variety of organic and non-organic chemical processes.

Questions that may be explored in this investigation include:

- Which plants are important to Aboriginal and Torres Strait Islander peoples for their medicinal properties, how are the plants processed before they are used, and what are the active ingredients (for example, the terpineols, cineoles and pinenes as the active constituents of tea trees and eucalyptus resin)?

- What are the chemical processes that occur when Aboriginal and Torres Strait Islander peoples detoxify poisonous food items: for example, the preparation of nardoo as a food source by heating, and the detoxification of cycad seeds through the removal of cycasins?

- How do Aboriginal and Torres Islander peoples utilise animal fats, calcination and plant pigments to vary the properties of the paints they make, and how does this compare to Western paint production processes and materials?

- How do binders and fixatives work to allow Aboriginal and Torres Islander peoples' paintings to be preserved for thousands of years?

- How do Aboriginal and Torres Islander peoples' glue formulations parallel the use of modern epoxy resins, and how sustainable are the chemical processes involved in producing these materials?

- How are plant-based toxins such as saponins used in Aboriginal and Torres Strait Islander peoples' fishing practices, and how is this similar to other First Nation Peoples' fishing practices around the world?

- Kakadu plums have long been a component of Aboriginal and Torres Islander Peoples diets. What active ingredients do they contain that may make them a 'super food'?

INVESTIGATION TOPIC 4: THE SUSTAINABILITY OF A COMMERCIAL PRODUCT OR MATERIAL

In Australia, new materials that are useful for society tend to be produced through a linear economy in which products are purchased, used and then thrown away. Increasingly, manufacturing companies are moving towards a circular economy, which seeks to reduce the environmental impacts of production and consumption while enabling economic growth through more productive use of natural resources and creation of less waste.

Research questions that may be explored in this investigation include:

- What is 'green steel' and what are the implications of its production for human health and the environment?

- Research a metal mined in Australia: for example, gold, copper or lithium. How is the metal processed and what are its useful properties? To what extent has the metal production and use moved towards a circular economy over the last decade? What innovations have led to the production of the metal being more sustainable over time?

- Select a commercial product that is available in different formulations: for example, vinegar (fermented, synthetic); salt (river salt, sea salt, iodised salt, Himalayan salt); cleaning products (soaps and detergents); oil (fish oil, coconut oil, olive oil); or milk (whole milk, skim milk, low-fat milk, A2 milk, plant milks such as almond, soy and coconut). What ingredients are in the product? How do the ingredients compare in the different product formulations? How is the product made? To what extent does the production of the product involve a linear economy or a circular economy? How does the production and use of the product impact human health and the environment?

- Select a product whose composition has changed over time: for example, hair comb (tortoiseshell to polymer); dental fillings (from silver amalgam and gold to porcelain and composite resin fillings); contact lenses (glass to polymers); paints (lead-based to oil-based and water-based); and tennis racquet strings (from cat gut to nylon and polyester). How have the properties and efficacies of the products changed over time? To what extent have the manufacturing processes become 'greener'?

- Examine the life cycle of a new product or material: for example, unbreakable glass inspired by seashells; new nanomaterials for the treatment of skin infections; and ultra-thin self-healing polymers to make water-resistant coatings. What is the relationship between the properties, structure and the nature and strength of the chemical bonding in the product or material? What are the raw materials used to make the product or material? How is the product or material manufactured? How are the by-products of production treated and managed? Is the product recyclable? Can any wastes during production or at the end of the product's use be repurposed into a useful product or material?

OUTCOME 3

On completion of this unit the student should be able to investigate and explain how chemical knowledge is used to create a more sustainable future in relation to the production or use of a selected material.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on pages 11 and 12 of the study design.

KEY KNOWLEDGE: OUTCOME 3

SCIENTIFIC EVIDENCE

- The distinction between primary and secondary data.
- The nature of evidence and information: distinction between opinion, anecdote and evidence; and scientific and non-scientific ideas.
- The quality of evidence, including validity and authority of data and sources of possible errors or bias Methods of organising, analysing and evaluating secondary data.
- The use of a logbook to authenticate collated data.

SUSTAINABILITY

- Sustainability concepts and principles: green chemistry principles, sustainable development, and the transition from a linear economy towards a circular economy.
- Identification of sustainability concepts and principles relevant to the selected research question.

SCIENTIFIC COMMUNICATION

- Chemical concepts specific to the investigation: definitions of key terms; and use of appropriate chemical terminology, conventions and representations.
- Characteristics of effective science communication: accuracy of chemical information; clarity of explanation of chemical concepts, ideas and models; contextual clarity with reference to importance and implications of findings; conciseness and coherence; and appropriateness for purpose and audience.
- The use of data representations, models and theories in organising and explaining observed phenomena and chemical concepts, and their limitations.
- The influence of social, economic, legal and/or political factors relevant to the selected research question.
- Conventions for referencing and acknowledging sources of information.

ASSESSMENT

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study, including the key knowledge and key skills listed for the outcomes, should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessments at Units 1 and 2 are school-based. Assessment instruments should be aligned with the VCE assessment principles. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision. For this unit students are required to demonstrate three outcomes. As a set these outcomes encompass the areas of study in the unit.

Suitable tasks for assessment in this unit may be selected from the following:

OUTCOME 1 AND OUTCOME 2

For each outcome, at least one task selected from:

- A report of a laboratory or fieldwork activity, including the generation of primary data.
- Comparison and evaluation of chemical concepts, methodologies and methods, and findings from at least two student practical activities.
- Reflective annotations of one or more practical activities from a logbook.
- A summary report of selected practical investigations.
- Critique of an experimental design, chemical process or apparatus.
- Analysis and evaluation of generated primary and/or collated secondary data.
- A modelling or simulation activity.
- A media analysis/response.
- Problem-solving involving chemical concepts, skills and/or issues.
- A report of an application of chemical concepts to a real-world context.
- Analysis and evaluation of a chemical innovation, research study, case study, socio-scientific issue, secondary data or a media communication, with reference to sustainability (green chemistry principles, sustainable development and/or the transition to a circular economy).
- An infographic.
- A scientific poster.

**If multiple tasks are selected for Outcome 1 and/or Outcome 2, they must be different.
The same task cannot be selected more than once across Outcomes 1 and 2.**

OUTCOME 3

A response to a question involving the production or use of a selected material, including reference to sustainability

PRACTICAL WORK

Practical work is a central component of learning and assessment and may include activities such as laboratory experiments, fieldwork, simulations, modelling and other direct experiences as described in the scientific investigation methodologies on page 13. A minimum of 10 hours of class time should be devoted to student practical activities and investigations across Areas of Study 1 and 2. For Area of Study 3, a minimum of seven hours of class time should be devoted to undertaking the investigation and communicating findings.

UNIT 2: HOW DO CHEMICAL REACTIONS SHAPE THE NATURAL WORLD?

Society is dependent on the work of chemists to analyse the materials and products in everyday use. In this unit students analyse and compare different substances dissolved in water and the gases that may be produced in chemical reactions. They explore applications of acid-base and redox reactions in society.

Students conduct practical investigations involving the specific heat capacity of water, acid-base and redox reactions, solubility, molar volume of a gas, volumetric analysis, and the use of a calibration curve.

Throughout the unit students use chemistry terminology, including symbols, formulas, chemical nomenclature and equations, to represent and explain observations and data from their own investigations and to evaluate the chemistry-based claims of others.

A student-adapted or student-designed scientific investigation is undertaken in Area of Study 3. The investigation involves the generation of primary data and is related to the production of gases, acid-base or redox reactions, or the analysis of substances in water. It draws on the key science skills and key knowledge from Unit 2 Area of Study 1 and/or Area of Study 2.

AREA OF STUDY 1
HOW DO CHEMICALS INTERACT WITH WATER?

In this area of study students focus on understanding the properties of water and investigating acid-base and redox reactions. They explore water's properties, including its density, specific heat capacity and latent heat of vaporisation. They write equations for acid-base and redox reactions, and apply concepts including pH as a measure of acidity. They explore applications of acid-base reactions and redox reactions in society.

The selection of learning contexts should allow students to develop practical techniques to investigate the properties of water and acid-base and redox reactions. Students develop their skills in the use of scientific equipment and apparatus. They may demonstrate their understanding of concentration using coloured solutions such as ammonium molybdate. Students explore pH: for example, by making their own indicators from natural materials, developing their own pH scale and comparing the accuracy of their indicators with commercial indicators. They may investigate redox reactions by comparing corrosion rates of iron in tap water and sea water or building simple cells to power a diode. They respond to challenges such as investigating the action of soda water on seashells and linking their findings to socio-scientific issues such as ocean acidification.

AREA OF STUDY 2
HOW ARE CHEMICALS MEASURED AND ANALYSED?

In this area of study students focus on the analysis and quantification of chemical reactions involving acids, bases, salts and gases. They measure the solubility of substances in water, explore the relationship between solubility and temperature using solubility curves, and learn to predict when a solute will dissolve or crystallise out of solution. They quantify amounts in chemistry using volumetric analysis, application of the ideal gas equation, stoichiometry and calibration curves.

The selection of learning contexts should allow students to develop practical techniques to investigate substances that may be dissolved in water or found in soils, particularly salts, acids and bases, as well as gases. Students develop their skills in the use of scientific equipment and apparatus. They use precipitation reactions to purify water: for example, by using iron or aluminium compounds to precipitate and remove phosphorus from wastewater. They perform acid-base titrations, such as comparing the ethanoic acid concentrations of vinegar, mayonnaise and tomato sauce. They construct calibration curves to analyse unknown concentrations of substances, such as the amount of nitrates or phosphates in water or soil samples. Students respond to challenges such as determining the set of standards required in setting up a calibration curve in colorimetry.

AREA OF STUDY 3
HOW DO QUANTITATIVE SCIENTIFIC INVESTIGATIONS DEVELOP OUR UNDERSTANDING OF CHEMICAL REACTIONS?

Many of the 17 goals in the United Nations' 2030 Agenda for Sustainable Development relate to ensuring that people have access to potable water, clean air and good quality soil to meet their basic needs. The quality of water, air and soil must be monitored closely to ensure that human health and the environment are not compromised.

In this area of study students adapt or design and then conduct a scientific investigation related to chemical equations and/or analysis, which must include the generation of primary data. They develop a research question related to the production of gases, acid-base or redox reactions or the analysis of substances in water, and adapt or design and then conduct a scientific investigation to generate appropriate quantitative data. Students organise and interpret the data and reach a conclusion in response to their research question.

Research questions may relate to different scientific methodologies. Pattern seeking may be utilised in investigating questions such as 'Is there a relationship between salinity concentration and the rate of rusting of iron?'. Controlled experiments may be designed to investigate questions such as 'Why is isopropyl alcohol measured as %(v/v) while chlorine bleach is measured in ppm, and what concentrations of isopropyl alcohol and chlorine bleach are required to disinfect surfaces?'. Students may also investigate product, process or system development, such as formulating a UV-stable natural indicator.

The student-adapted or student-designed scientific investigation relates to knowledge and skills developed in Unit 2 Area of Study 1 and/or Area of Study 2.

SECTION 2: AREA OF STUDY 1

HOW DO THE CHEMICAL STRUCTURES OF MATERIALS EXPLAIN THEIR PROPERTIES & REACTIONS?

AREA OF STUDY 1:HOW DO THE CHEMICAL STRUCTURES OF MATERIALS EXPLAIN THEIR PROPERTIES AND REACTIONS?

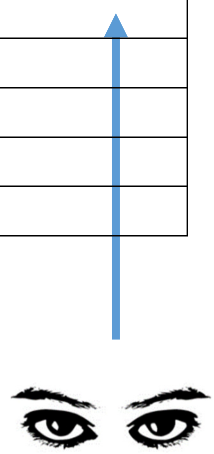
SIZE AND CHEMISTRY

Chemistry deals in a world where we use evidence, sometimes visual evidence, from things we can see to make judgments about the interactions and re-arrangements in a world that is too small for us to see.

Many developments are now being made in nanoscience. This is just a term that gives us an indication of the size of particle that is being used in that area. Nanoscience works on a scale which is smaller than the eye can perceive which makes it both challenging and exciting. Structures that are that small can exhibit physical properties far different from larger counterparts.

Below is a table of the metric prefix notations used to describe relative sizes. This table uses that metre, but the prefixes and what they mean to a specific unit is constant across the whole of the metric system.

Prefix	Symbol	Value compared to standard metre
Picometre	pm	10^{-12} m (0.000000000001 m)
Nanometre	nm	10^{-9} m (0.000000001 m)
Micrometre	μm	10^{-6} m (0.000001 m)
Millimetre	mm	10^{-3} m (0.001 m)
Metre	m	1 m
Kilometre	km	10^{3} m (1000 m)
Megametre	Mm	10^{6} m (1000000 m)



Approximate limit of the human eye (≈100 μm)

QUESTION 1
Convert the following units of length.

(a) 100 μm to mm

(b) 23 mm to nm

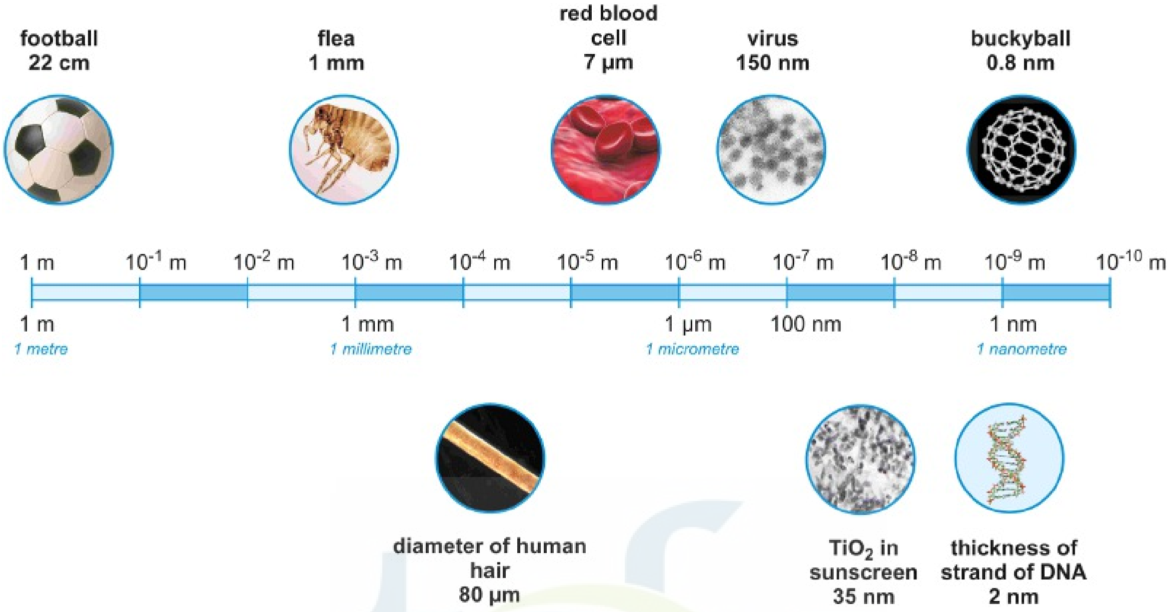
(c) 0.0080 m to μm

(d) 17 km to mm

THE NANOSCALE

- A millimetre is one thousandth of a metre (1mm = 10^{-3} m)
- A micrometre is one millionth of a metre (1μm = 10^{-6} m)
- A nanometre is one billionth of a metre (1nm = 10^{-9} m)

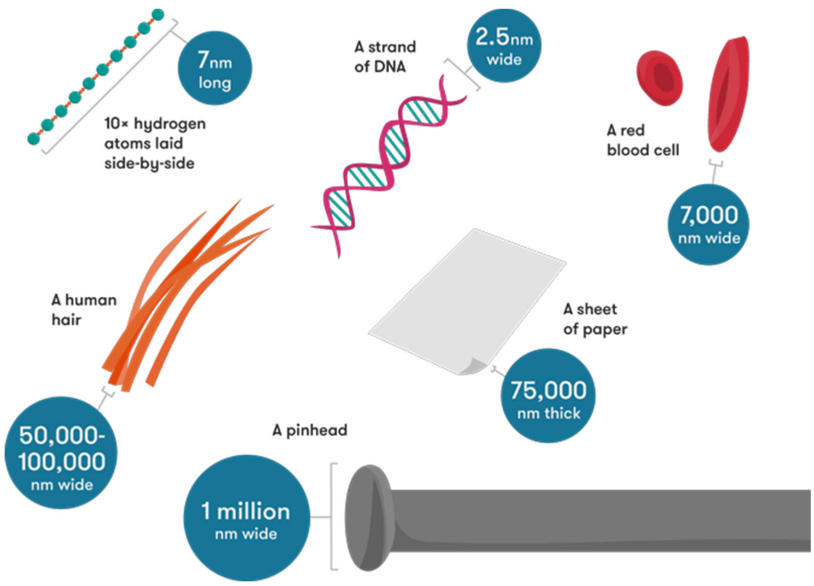
The nanoscale is used to describe objects that are about 1-100 nm wide.



A scale to show the relative dimensions of various objects.

http://www.essentialchemicalindustry.org/materials-and-applications/nanomaterials.html

The examples outlined below show how small the nanoscale is.



https://www.science.org.au/curious/nanoscience

IMPORTANT DEFINITIONS

ATOMS

Atoms are the basic building blocks of all substances. The atom is composed of a dense positively charged **nucleus** containing **protons** (positively charged particles) and **neutrons** (neutrally charged particles) and which are collectively referred to as **nucleons**. Negatively charged particles known as **electrons** orbit the centrally positioned nucleus.

ELEMENTS

Elements are made up of one type of atom. Every one of these atoms has the same number of protons in their nuclei. An element is a fundamental substance and cannot be broken down into smaller substances by chemical methods.

COMPOUNDS

Compounds are made up of more than one type of atom or element that are bonded together. Compounds can be broken down into simpler substances by chemical methods.

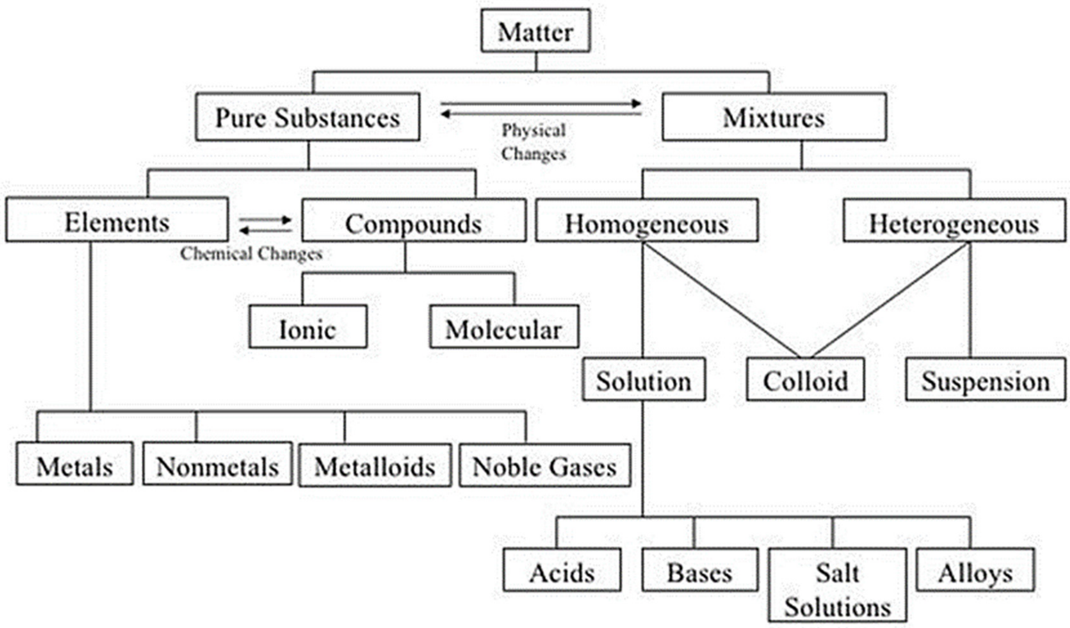
MOLECULES

Molecules are **non metallic** entities that are made up of two or more atoms that are **covalently** bonded in fixed proportions.

For example:

Molecular Elements: Cl_2, O_2
Molecular Compounds: H_2O, SO_2

CLASSIFICATION OF MATTER



ATOMIC STRUCTURE

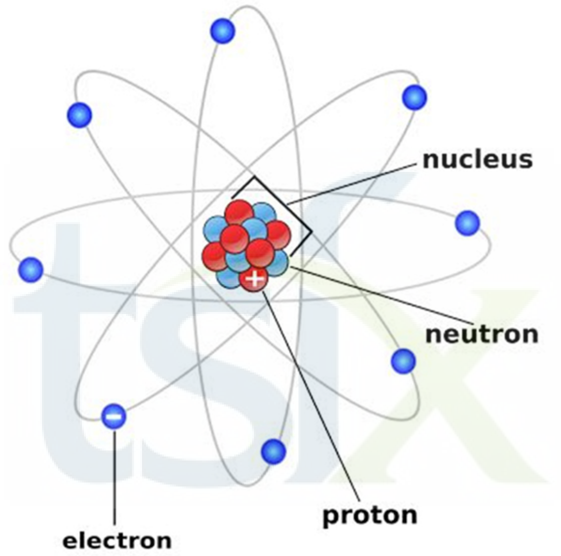
THE CURRENT MODEL OF THE ATOM

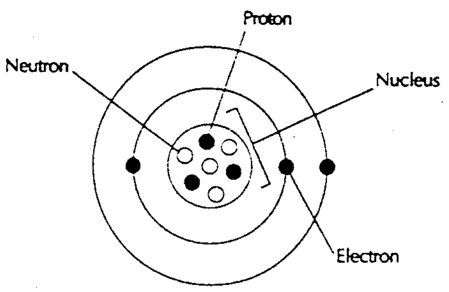
The current model of an atom has a dense positively charged **nucleus** in the centre of the atom, with most of the atom being empty space.

Each atom consists of three types of particles:

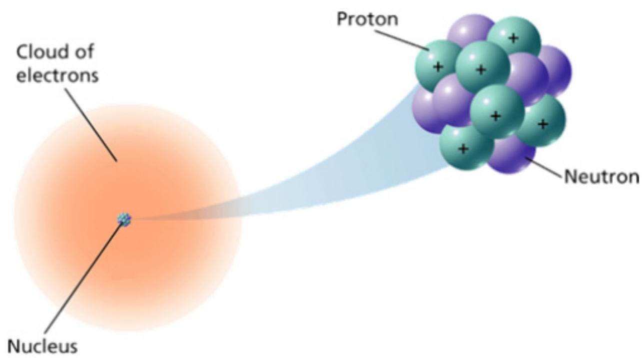
- Protons (positively charged particles)
- Neutrons (neutrally charged particles)
- Electrons (negatively charged particles)

The positively charged nucleus contains all of the protons and neutrons and is surrounded by negatively charged electrons that surround the central mass.





Traditional picture of an atom with electrons orbiting the nucleus.



A more accurate representation – the electrons are found in electron clouds which surround the nucleus.

Protons, neutrons and electrons are collectively called **subatomic particles**.

- The relative mass of a proton (relative to that of a proton) is equal to 1 unit.
- The relative mass of a neutron (relative to that of a proton) is equal to 1 unit.
- Electrons are tiny, light particles with a relative mass of approximately $\frac{1}{1836}$ unit (relative to that of a proton).

The protons and neutrons account for most of the mass of an atom and electrons occupy most of the space.

Subatomic Particle	Location	Charge
Proton	Nucleus	Positive
Electron	Electron clouds around the nucleus	Negative
Neutrons	Nucleus	Neutral

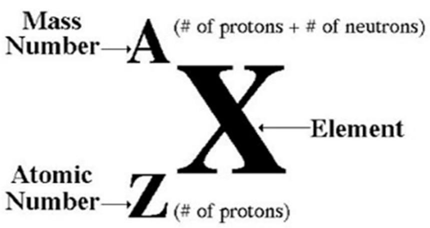
CHARACTERISTICS OF ATOMS

All atoms have numerous characteristics in common.

- All atoms of the same element contain the same number of protons and electrons.
- All atoms are therefore neutrally charged.
- All atoms of an element have the same number of protons but they can have different numbers of neutrons. Such atoms are called **isotopes.**

REPRESENTING ELEMENTS

Elements are represented using the following notation:



Where: **X** represents the element's symbol.

A represents the **mass number** (the total number of protons and neutrons in an atom's nucleus).

Z represents the **atomic number** (the number of protons in an atom's nucleus).

QUESTION 2

The symbol for the isotope U-238 is $^{238}_{92}U$. What can be deduced from this symbol?

A This isotope has 54 more neutrons than protons in the nucleus.
B All atoms of uranium have 238 protons.
C All atoms of uranium contain 146 neutrons.
D All atoms of uranium contain 92 protons in their shells.

QUESTION 3

The atom with the same number of neutrons as ^{54}Cr is:

A ^{50}Ti
B ^{51}V
C ^{53}Fe
D ^{55}Mn

QUESTION 4

Complete the following table:

Atomic Number	Name of Isotope	Chemical Symbol	No. of Protons	No. of Neutrons	No. of Electrons	Mass Number of Isotope
4	**Beryllium-9**					
		$^{14}_{7}N$				
			17			**35**
82						**208**
		^{48}Ti	**22**			
			19	**20**		

ISOTOPES

- Most elements occur in nature as a mixture of isotopes.

- Isotopes describe atoms of an element that have the same number of protons but different numbers of neutrons i.e. The atomic numbers of such elements are the same, but the mass numbers differ.

  For example:

  There are two chlorine isotopes: Chlorine-35 and Chlorine-37

$^{35}_{17}Cl$ contains:	$^{37}_{17}Cl$ contains:
17 protons	17 protons
18 neutrons	20 neutrons
17 electrons	17 electrons

- Chemists have used experimental data to determine the relative masses of different isotopes. The standard of relative mass is the common isotope of carbon, ^{12}C, which has a relative mass of 12 units.

QUESTION 5

Neon consists of two different isotopes with masses of 20 and 22. If each neon atom contains 10 protons, write each isotope in A – Z notation.

Solution