Chemistry

Upper Secondary Syllabus

Papua New Guinea
Department of Education

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Contents

Secretary's message

This Chemistry syllabus is to be used by teachers of Chemistry to teach Upper Secondary students (Grades 11 and 12) throughout Papua New Guinea. This syllabus builds upon science concepts, skills and attitudes learnt in Lower Secondary and provides a sound foundation for further learning.

The Upper Secondary Chemistry syllabus conforms to the National Education Plan's vision, which is that secondary education enables students to achieve their individual potential to lead productive lives as members of the local, national and international community. This stage of learning provides the opportunity for students engaging in experiments and laboratory work to develop deeper understanding in order to meet individual needs as well as local and global demands and challenges.

Teachers play a pivotal role by being innovative and creative and through keeping abreast of new information based on scientific research and innovative technological changes. The challenge for teachers of Chemistry is to engage student learning in realistic contexts for increased and better understanding. Engaging in such learning helps students appreciate the relevance of chemistry to human lives, including good health and activities in their environment.

A sound understanding of chemistry and its applications helps students appreciate the interdependence and interaction between all forms of matter, an appreciation that is vital for the future well-being of Papua New Guinea and the wider world.

The knowledge and skills gained in this Chemistry syllabus prepares students for higher cognitive chemistry learning, as well as providing the fundamental chemical concepts needed for students to appreciate common day-to-day chemical applications and practices.

This Chemistry syllabus incorporates fundamental chemistry units that provide the foundation for higher cognitive chemistry learning and prepare students continuing on to further education at tertiary level and other professional courses. Besides providing students with the conceptual background in chemistry needed to meet the challenges of academic and professional courses, the syllabus also equips them to appreciate and apply basic chemistry knowledge when faced with various changes to health, nutrition, environments, population, weather, industries and agriculture.

I commend and approve this syllabus as the official curriculum for Chemistry to be used in all schools with Grades 11 and 12 students throughout Papua New Guinea.

DR JOSEPH PAGELIO

Secretary for Education

Introduction

Chemistry helps us to understand the links between the macroscopic properties of the world and the subatomic particles and forces that account for those properties. Chemistry is an experimental science, making laboratory work an essential part of the syllabus. Practical work can be used to enable students to investigate the properties and reactions of substances and to provide opportunities for the learning and testing of principles and concepts.

Wherever possible, students should be given the opportunity to visit chemical industries to understand the chemical processes taking place in that particular chemical industry and how the negative effects of the waste products on the environment can be minimised. Such visits help the students to understand the economic importance of such industries as well as how such industries can be sustained without causing much environmental pollution. Engaging in such activities helps students to appreciate and find the relevance of chemistry in human activities.

Chemistry at Upper Secondary level draws upon and builds on the knowledge, understanding, skills and values developed in the Lower Secondary Science units, 9.5 Atoms and the Periodic Table, and 10.3 Chemical Reactions.

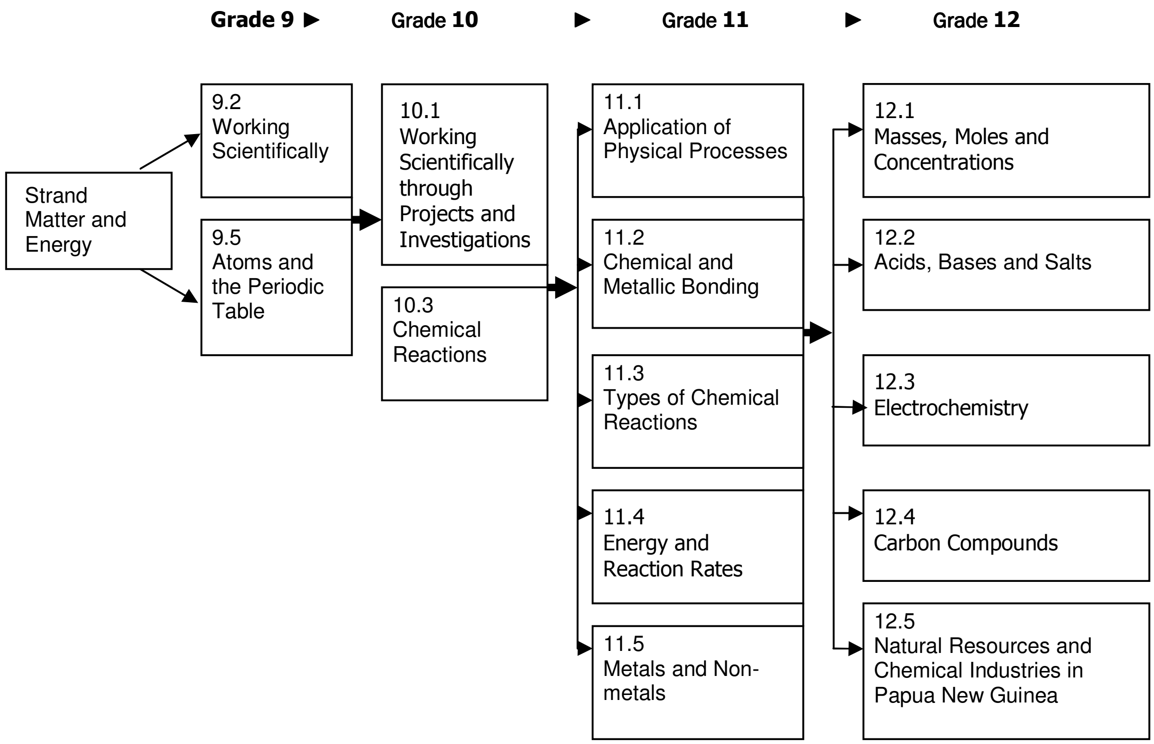
Lower Secondary Science	Lower Secondary Science	Upper Secondary Chemistry	
Strands	Units	Grade 11 units	Grade 12 units
1 The Nature of Science 3 Matter and Energy 4 Earth and Space • Strand 2, 'Life and Living', has some relevance to biochemistry with regards to processes such as respiration and fermentation	Atoms and the Periodic Table Working Scientifically through Projects and Investigations Chemical Reactions	Application of Physical Processes Chemical and Metallic Bonding Types of Chemical Reactions Energy and Reaction Rates Metals and Non-metals	Masses, Moles and Concentrations Acids, Bases and Salts Electrochemistry Carbon Compounds Natural Resources and Chemical Industries in Papua New Guinea

Chemistry is a specialised subject and requires a high level of cognitive competency. Having a high level of numeracy competency and basic level of language skills will help students to understand chemical processes better.

Through laboratory experiments and other hands-on learning activities, students learn to think scientifically and develop an attitude of questioning, investigating and providing explanations for natural phenomena being observed. Students can apply the skills learnt to solve certain everyday chemical problems they may encounter in their surroundings.

The units in the Upper Secondary Chemistry Syllabus are sequenced to guide teachers of Chemistry through the process of imparting basic chemistry knowledge and skills to students.

Overview of the study of Chemistry from Lower Secondary to Upper Secondary



Assessment is an important component of teaching for learning and is integrated into the learning and teaching activities of Chemistry. Continuous assessment in Chemistry provides feedback to students and the teacher on students' progress towards achieving the learning outcomes. It helps students improve their standards of achievement by knowing what they need to do well and where they need to improve. In Chemistry, teachers gather evidence from students' work during the course of the term and use those continuous assessments to improve their teaching and students' learning.

The teaching program should also include formal summative assessment of learning to gauge students' levels of achievement.

Chemistry is to be timetabled for 240–250 minutes per week in Grades 11 and 12.

Rationale

Papua New Guinea is endowed with vast amounts of natural resources, such as gold, copper, nickel, cobalt, petroleum, natural gas and forests. Papua New Guinea needs knowledgeable and skilled chemists and other professionals to bring about sustainable development. Being knowledgeable in chemistry and its applications is essential for many professions. Understanding of Chemistry will help students who want to become professionals such as chemists, chemical engineers, doctors, pharmacists, nurses, teachers or chemical industrialists.

The learning and applications of chemical knowledge are essential to formulate new products or processes, to develop natural resources, to provide remedies for chemical pollution, as well as to improve living standards. Chemistry provides students with the conceptual background of chemistry necessary to make them competent to meet the challenges of academic and professional courses comparable to the international level.

Chemistry knowledge has undergone tremendous change during the past decade. Many new areas such as synthetic materials, biomolecules, natural resources and industrial chemistry are becoming important and should be an integral part of any chemistry syllabus at this level.

Greater emphasis is now placed on the use of new nomenclature, symbols and formulations, the learning of fundamental concepts, and applications of chemistry concepts to industry and technology.

Chemical practices have existed in Papua New Guinea for thousands of years; for example, the extracting and mixing of dyes from plants for facial decorations and paintings, or the making of lime for many uses. Students recognise and appreciate the importance of preserving these traditional chemical practices. Their application in conjunction with modern scientific techniques may benefit our society.

Aims

The aims of the Chemistry syllabus are to develop in students:

- an understanding and appreciation of the methods and applications of chemistry and its development in the past, present and future contributions to life on earth and beyond
- the skills to engage safely in investigation techniques
- the capacity to work scientifically in the context of chemistry
- the ability to observe, collect, analyse and interpret data to explain certain chemical principles and laws
- an ability to manipulate and use laboratory apparatus effectively
- positive attitudes towards the study of matter and its interactions with the environment
- a capacity to work as part of a team engaging in cooperative activities for the development of Papua New Guinea
- individual potential to make a useful contribution to society
- an appreciation of traditional chemical practices
- proper responses with respect to opinions held by others while appreciating the importance of critically evaluating various scientific views.

Learning outcomes

The Chemistry learning outcomes identify the knowledge, skills, attitudes and values all students achieve or demonstrate at the end of Grade 12. The learning outcomes for Chemistry are listed below.

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
3. communicate findings of scientific investigations in different ways
4. analyse and interpret data, graphs and other forms of information relevant to topics studied
5. analyse and evaluate past and present scientific developments and their impacts on human beings and the environment and on the ethical decisions made
6. demonstrate an understanding of traditional knowledge and skills of chemistry practised over many years and explain their relevance today.

Note: While all ideas and concepts in Chemistry are linked, the table below indicates the connections that should be highlighted most.

Learning outcomes mapped against units										
Learning outcomes	**Units**									
	11.1	**11.2**	**11.3**	**11.4**	**11.5**	**12.1**	**12.2**	**12.3**	**12.4**	**12.5**
1. Demonstrate an understanding of fundamental scientific principles and models		✓		✓	✓		✓	✓	✓	✓
2. Apply scientific thinking, motor and process skills to investigate and find solutions to problems	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3. Communicate findings of scientific investigations in different ways			✓	✓	✓		✓	✓		✓
4. Analyse and interpret data, graphs and other forms of information relevant to topics studied	✓			✓		✓	✓			✓
5. Analyse and evaluate past and present scientific developments and their impacts on human beings and the environment and on the ethical decisions made					✓					✓
6. Demonstrate an understanding of traditional knowledge and skills of chemistry practised over many years and explain their relevance today										✓

Unit sequence and structure

Grade 11 units	Grade 12 units
11.1 Application of Physical Processes *6–7 weeks* • Diffusion • Behaviour of gases • Pure and impure substances • Separation of mixtures • Solubility of solids and gases in water **11.2 Chemical and Metallic Bonding** *6–7 weeks* • Electron shell diagrams of atoms and ions • Trends in the periodic table • Chemical bonding • Metallic bonding **11.3 Types of Chemical Reactions** *6–7 weeks* • Indicators of chemical changes • Types of reactions • Exothermic and endothermic reactions **11.4 Energy and Reaction Rates** *4–5 weeks* • Factors affecting rates of reactions • Energy diagrams **11.5 Metals and Non-metals** *6–7 weeks* • Properties of metals, metalloids and non-metals • Uses of metals and metal alloys • Chemistry of nitrogen and nitrogen compounds • Chemistry of sulfur and sulfur compounds • Chemistry of phosphorous and phosphate fertilisers	**12.1 Masses, Moles and Concentrations** *7–8 weeks* • Isotopes • Relative formula mass and percentage composition • Moles • Empirical and molecular formula • Stoichiometry • Solutions **12.2 Acids, Bases and Salts** *4–5 weeks* • Common acids and bases • Properties of acids and bases • Strong and weak acids and bases • Dissociation constants and pH calculations • Acid-base titration to detect the end point (volumetric analysis) **12.3 Electrochemistry** *5–6 weeks* • Electrolysis • Galvanic cells **12.4 Carbon Compounds** *6–7 weeks* • Homologous series • Hydrocarbons • Alcohols • Aldehydes • Ketones • Carboxylic acids and esters **12.5 Natural Resources and Chemical Industries in Papua New Guinea** *9–10 weeks* • Crude oil • Metallic ores • Production of ethanol • Production and uses of vegetable oils • Traditional chemical practices • Industrial chemical pollution

Grade 11 units

11.1 Application of Physical Processes

6–7 weeks

Context

Why does ice melt and water vapour become dew? Is it possible to obtain pure water from sewage? How can you separate salt and water from sea water? Why does solubility of sugar increase as temperature increases?

Knowledge

Students have learnt the basic concepts of physical changes in the Upper Primary Science course. They have also learnt the arrangement of particles in solids, liquids and gases.

In this unit students learn the behaviour of gases and use the different physical separation methods to separate mixtures. They further investigate the solubilities of gases (CO_2 and O_2) in water and their effects on aquatic life. Students use the concept of particle theory to explain the phase changes of substances during heating and cooling, the behaviour of gases, and solubility of solids and selected gases in water.

Learning outcomes

Students can:

2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
4. analyse and interpret data, graphics and other forms of information relevant to topics studied.

To achieve the learning outcomes, students:

- apply the particle theory to explain the behaviour of gases and liquids
- investigate and collect data on melting and boiling points and plot heating and cooling curves of pure and impure substances
- demonstrate an understanding of various physical separation techniques and apply the concept to separate different mixtures
- define the terms ‘solubility’, ‘solute’, ‘solvent’, ‘saturated’, ‘unsaturated’ and ‘supersaturated’ solutions
- investigate and collect data on solubilities of various salts and gases and plot solubility curves
- calculate the solubilities of substances using solubility curves as well as given data.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

> ***Warning!***
> *Poisonous gases produced. Conduct experiment in fume cupboard.*

Diffusion

- define 'diffusion'
- diffusion of:
  - solids in water (potassium permanganate)
  - gases (hydrogen chloride gas and ammonia gas) using Graham's law

$$\frac{Rate\ of\ diffusion\ of\ Gas\ A}{Rate\ of\ diffusion\ of\ Gas\ B} = \frac{\sqrt{Molar\ mass\ of\ Gas\ B}}{\sqrt{Molar\ mass\ of\ Gas\ A}}$$

Behaviour of gases

- the gas laws to calculate the unknown quantity:
  - Boyle's law: equation P1V1 = P2V2
  - Charles's law: equation T1V2 = T2V1
  - combined gas law: equation $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
  - ideal gas law: equation PV = nRT; (universal gas constant, R = 8.314 J/K.mol)

Pure and impure substances

- elements, compounds and mixtures
  - classify elements, compounds and mixtures as pure and impure substances
- differentiate between:
  - elements
  - compounds
  - mixtures
- classify mixtures as homogeneous or heterogeneous mixtures
- plot and interpret heating and cooling curves of pure substances and mixtures

Separation of mixtures

- separation using the techniques of:
  - magnetic separation
  - filtration
  - crystallisation
  - centrifuging
  - simple distillation
  - fractional distillation
  - chromatography
  - solvent extraction

- link to traditional techniques of separations (salt from the sea)

Solubility of solids and gases in water

- solubility of substances in water
  - unsaturated solution
  - saturated solution
  - supersaturated solution
  - factors affecting solubility of solids in water
- calculation of:
  - solubility using given data
  - solubility using solubility curves
- solubility of gases (O_2 and CO_2) in water
- factors affecting solubility of gases in water

Warning!
Poisonous gases produced. Conduct experiment in fume cupboard.

Laboratory work

1. Investigate physical separation of substances (for example, salt from sand, salt from ammonium chloride, extracting pure water from sea water).
2. Heat ice to obtain its melting and boiling points and compare it to heating a mixture of ethanol and water to obtain its boiling point. Show the effect of impurities on the melting and boiling points of a substance.
3. Conduct experiments on heating and cooling of ice and naphthalene and plot their heating and cooling curves.
4. Conduct an experiment on the dissolution of solids in water (for example, NaCl or sugar) at various temperatures and plot solubility curves.
5. Use a separating funnel to separate a mixture of oil and water.
6. Investigate rate of diffusion, using potassium permanganate and water, hydrogen chloride gas and ammonia gas in the tube.
7. Use paper chromatography to separate dyes from ink.

11.2 Chemical and Metallic Bonding

6–7 weeks

Context

Do you ever stop to think about why some substances behave differently from others? Why some substances can conduct electricity, while other substances do not? Why is water so different from its constituent elements of hydrogen and oxygen?

Knowledge

Students have learnt about atoms and chemical changes in Lower Secondary. In this unit, students learn that the combination of atoms of various elements leads to the formation of new substances. Chemical bonding focuses on the formation of ionic and covalent compounds. Metallic bonds are studied to explain why metals and non-metals differ in their physical properties. Students demonstrate an understanding that different compounds can be categorised as ionic, covalent molecular and giant covalent structures, according to the kind of bond that binds the atoms to form that compound.

This unit describes how atoms combine to form ionic compounds, covalent compounds and metallic substances. Students examine the properties of the three types of bonds (ionic, covalent and metallic) through research and suitable simple experiments. Students can also write chemical formula to represent the new substance(s) formed.

Learning outcomes

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems.

To achieve the learning outcomes, students:

- demonstrate an understanding of the patterns of arrangement of electrons in atoms and describe the electron arrangement in terms of shells and subshells (s, p, d, f)
- explain trends and relationships between elements in terms of atomic structure and bonding
- explain that the position of an element in the periodic table reflects its electron configuration
- draw diagrams (shell or Lewis dot) to show how ions can be formed by atoms gaining or losing electrons
- draw electronic shell diagrams to show the formation of ionic and covalent compounds
- differentiate between ionic, covalent and metallic bonds

- explain the formation of coordinate (dative) bonds
- discuss the allotropes of carbon (graphite and diamond)
- explain polarity and formation of hydrogen bonds
- describe the concept of metallic bonding, using diagrams.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Electron shell diagrams of atoms and ions

- shell diagrams showing shell and subshells (s, p, d and f) for first 30 elements of the periodic table
- students must know the patterns in assigning electrons onto the shells or orbitals using the octet rule, $2n^2$
- shell diagrams to show the formation of ions

Trends in the periodic table

- explanations of:
  - electronegativity
  - electropositivity
  - reactivity series
  - radius of atoms and ions
  - metallic properties
  - electron affinity
  - ionisation energy

Chemical bonding

- ionic bonding
  - ionic bonding as repeating three-dimensional lattice of ions
  - formation of ionic bonds
  - electron shell diagrams of ionic compounds
  - properties of ionic compounds
- covalent bonding
  - covalent bonds
  - electron shell diagrams of covalent compounds
  - properties of covalent compounds
  - polar and non-polar molecules
  - coordinate (dative) bonding
  - allotrope of carbon
  - giant covalent (network) bonding (graphite versus diamond)
- reasons why:
  - graphite is soft whereas diamond is hard
  - graphite conducts electricity whereas diamond does not, although both are made of carbon

– diamond has higher melting and boiling point than graphite

Metallic bonding

- metallic bonds as three-dimensional lattices of ions in a sea of negatively charged electrons
- physical properties of metallic substances

Laboratory work

1. Conduct experiments to demonstrate and relate the physical and chemical properties of metals to their chemical bonds.
2. Conduct experiments to show that molten aqueous ionic compounds conduct electricity.
3. Conduct experiments to show the existence of ions; for example, potassium permanganate in water.

11.3 Types of Chemical Reactions

6–7 weeks

Context

Have you ever wondered how lime is produced or why a piece of wood burns? Are there any differences in the burning of wood and melting of ice? How can you show that there are some differences in the burning of wood and melting of ice? Did you know that all living things are able to survive because of the chemical reactions that go on within and around them?

Knowledge

Students have learnt the concept of writing chemical formulas and chemical equations in units 9.5 and 10.3. In this unit, students identify various chemical reactions and write balanced chemical equations. Students classify chemical reactions into different types of chemical reactions. For example, burning wood is an example of a combustion reaction.

Learning outcomes

Students can:

2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
3. communicate findings of scientific investigations in different ways.

To achieve the learning outcomes, students:

- identify and name types of chemical reactions
- write balanced chemical equations with states for various chemical reactions
- write gross ionic and net ionic equations and identify spectator ions
- explain whether a given chemical species is undergoing an oxidation or reduction process
- define and describe the types of chemical reactions as exothermic or endothermic.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Indicators of chemical changes

- change of temperature
- formation of precipitate
- change of colour
- disappearance of solids (not merely due to dissolution)
- gas given off

Types of reactions

Synthesis or combination reactions

- writing balanced chemical equations for reactions of:
  - metal + oxygen gas
  - metal + sulfur
  - metal + halogen
  - non-metal (carbon and sulfur) + oxygen gas

Neutralisation reactions

- writing balanced chemical equations for reactions of:
  - acids + aqueous ammonia solution
  - acids + carbonates
  - acids + metal oxides
  - acids + metal hydroxides
  - acids + hydrogen carbonates
- writing ionic and net ionic equations

Displacement reactions

- discuss Reactivity Series
- writing balanced chemical equations, ionic equations and net ionic equations for:
  - metals + aqueous salts
  - acids + metals
  - halogen + soluble metal halides

Precipitation reactions

- writing balanced chemical equations, ionic equations and net ionic equations for:
  - reaction of two aqueous metal salts
  - reactions of metal and aqueous metal salt solutions

Decomposition reactions

- writing balanced chemical equations for the decomposition of:
  - carbonates
  - hydroxides
  - metal hydrogen carbonates

Combustion

- writing balanced chemical equations for the combustion of:
  - hydrocarbons (methane, ethane, propane and butane)
  - magnesium ribbon
  - sulfur
  - carbon

Exothermic and endothermic reactions

- defining and listing examples of:

– exothermic reaction
– endothermic reaction

Warning!
Poisonous gases produced. Conduct experiment in fume cupboard.

Laboratory work

1. Investigate various types of reactions (such as synthesis, neutralisation and displacement).
2. Investigate reactions between acids and carbonates, alkalis and metal salts.
3. Investigate burning of hydrocarbons and heating of limestone may be considered.
4. Conduct practical experiments on the formation of precipitates in single and double displacement reactions. Use physical separation methods to obtain precipitate.

11.4 Energy and Reaction Rates

4–5 weeks

Context

The ripening of pawpaw takes place over a number of weeks and the baking of bread takes a while, but an explosion of dynamite is very fast. Why are some reactions faster than others? Can we change the rate of a reaction to our advantage?

Knowledge

Students have realised in units 10.3 and 11.3 that some reactions are much faster than others. In this unit, students develop increased understanding of why reactions have different rates. Students use energy diagrams to explain the energy changes in chemical reactions. Students measure the time required for a reaction to be completed, and carry out simple experiments to determine the factors that influence the rate of reactions. Students also draw energy diagrams of exothermic and endothermic reactions, and calculate enthalpy change and activation energy.

Learning outcomes

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
3. communicate findings of scientific investigations in different ways
4. analyse and interpret data, graphs and other forms of information relevant to topics studied.

To achieve the learning outcomes, students:

- investigate the factors that influence the rate of a reaction
- measure volume, mass or temperature to determine the rate of reaction
- draw energy diagrams of exothermic and endothermic reactions.
- calculate bond energy.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Factors affecting rates of reactions

- Particle Collision theory
- factors affecting the rate of reactions, such as
  - concentration

- temperature
- surface area
- pressure (in case of gaseous reactants)
- catalyst

Energy diagrams

- energy diagrams of exothermic and endothermic reactions—activation energy (E_{act}), formation energy (F), potential energy of reactants and products, activation complex or transition state, enthalpy change or heat of reaction (ΔH)
- position of equilibrium of a reaction by applying Le Chatelliers principles in the production of chemicals (ammonia by Haber process)
  - energy diagram of a reversible reaction
  - energy diagram of a reaction in the absence and presence of a catalyst
- Bond energy
  - calculate heat of reaction (ΔH) using bond energy

Warning! *Hazardous acids and corrosive chemicals. Conduct experiments with care.*

Laboratory work

1. Investigate the effects of concentration, temperature, and catalysts on the rate of chemical reaction.
2. Carry out reaction on powdered magnesium and magnesium ribbon with hydrochloric acid and measure hydrogen gas produced.

11.5 Metals and Non-metals

6–7 weeks

Context

Many known substances can generally be classified into metal and non-metals, depending on their physical and chemical properties. How can it be shown that a given substance is a metal or a non-metal? What are some of the physical and chemical properties that can be used to distinguish metal from non-metals?

Knowledge

Students have learned in Unit 9.5 about the position of metals and non-metals on the periodic table and have also learnt about the basic properties of metals and non-metals. In this unit they further study the physical and chemical properties of metals and non metals. Using these concepts, they explain the physical states of metals and non metals at room temperature and pressure. In this unit students can explain the properties of metals and non metals. They also understand the usefulness of metals and metal alloys, as well as of some non-metal compounds in artificial fertilisers.

Learning outcomes

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
3. communicate findings of scientific investigations in different ways
5. analyse and evaluate past and present scientific developments and their impacts on human beings and the environment and on the ethical decisions made.

To achieve the learning outcomes, students:

- demonstrate an understanding of the physical and chemical properties of metals and non-metals using the concept of chemical bonding
- demonstrate an understanding of the uses of metals and metal alloys
- explain the chemistry of nitrogen and some of its compounds
- explain the chemistry of sulfur and some of its compounds
- explain the chemistry of phosphorous and some of its compounds.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Properties of metals, metalloids and non-metals

- the physical and chemical properties of metals, metalloids, non-metals
- corrosion of iron and steel: methods of rust prevention

Uses of metals and metal alloys

- uses of metals and metal alloys in human civilisation, emphasising:
  - important alloys and their uses (stainless steel, brass, bronze)
  - composition of important alloys

Chemistry of nitrogen and nitrogen compounds

- the chemistry of:
  - nitrogen
  - nitrogen cycle
  - Haber process
  - production of nitrogen fertilisers
  - environmental effects of nitrogen fertilisers (eutrophication)

Chemistry of sulfur and sulfur compounds

- the chemistry of:
  - sulphur
  - allotropes of sulfur
  - sulfur dioxide
  - production of sulfuric acid
  - acid rain

Chemistry of phosphorous and phosphate fertilisers

- the chemistry of:
  - phosphorous
  - production of phosphate fertilisers
  - environmental effects of phosphate fertilisers (eutrophication)

Chemistry of halogens

- the chemical and physical properties of:
  - fluorine
  - chlorine
  - bromine
  - iodine

Warning!
Group one metals give violent reaction with air, water and acids. Always use safety glasses.

Laboratory and practical work

1. Investigate reaction of acids with metals.
2. Investigate reactions (such as combustion) of carbon and sulfur.
3. Investigate corrosion of iron.
4. Investigate physical properties of metals.

Grade 12 units

12.1 Masses, Moles and Concentrations

7–8 weeks

Context

Have you ever stopped to consider the amount of sugar you add to your cup of tea or coffee? Think about how much sugar, coffee or tea we have to add to a cup of hot water to give the right taste and effect.

Knowledge

Students have learned about solutes, solvents and solutions in Upper Primary and about units of measurement of mass, such as milligrams, grams, kilograms and tonnes, in Physics, Unit 11.1.

In this unit students study the masses of different isotopes and calculate their relative atomic molecular masses (RAM) and percentage of different elements in a given compound. They also study the mole concept and how to calculate empirical and molecular formula. Using the knowledge acquired, students are able to calculate concentration of solutions.

In this unit students study methods of calculating mass, moles and concentration of solutions. Students also calculate the relative atomic mass and relative molecular masses from isotope data and further calculate empirical and molecular formula and the percentage composition.

Learning outcomes

Students can:

2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
4. analyse and interpret data, graphs and other forms of information relevant to topics studied.

To achieve the learning outcomes, students:

- define isotopes of atoms and calculate the relative atomic masses of various isotopic elements
- calculate the relative formula mass and the relative molecular mass of a given compound
- calculate percentage composition and mass of elements in a given compound
- calculate the number of moles in a given mass and the mass from a number of moles
- calculate the number of particles in a given mass of a substance using Avogadro’s number

- write balanced chemical equations and find stoichiometric ratios of the reactants and products
- calculate and prepare solutions using different units of concentration and further dilute to lower concentrations
- identify limiting reagent and the reagent in excess through stoichiometric calculations
- calculate theoretical and percentage yields of substances in a given chemical reaction.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Isotopes

- definition of isotopes
- relative atomic mass (RAM)
- calculation of:
  - relative atomic mass (RAM)
  - percentage abundance of isotopes

Relative formula mass and percentage composition

- calculation of:
  - relative formula and molecular masses
  - percentage composition of element(s) in a given compound
  - mass of an element in a given mass of a compound

Moles

- definition and calculation of:
  - moles of elements and compound
  - mass given the moles of the substance
  - Avogadro's number (N_A) and number of particles $(N_A = 6.02 \times 10^{23})$.

Empirical and molecular formula

- definition and calculation of:
  - empirical formula from percentage elemental composition
  - empirical formula from mass elemental composition
  - molecular formula from empirical ratio of elements
  - molecular formula from mass elemental composition

Stoichiometry

- writing balanced chemical equations and interpretation of the coefficients in terms of mole ratios
- carrying out stoichiometric calculations to find the products produced and reactants used in terms of moles and mass

- calculating the moles, mass and volume of reactants and products of gases at standard temperature and pressure (STP) and room temperature and pressure (RTP)
- carrying out stoichiometric calculations to determine the limiting reagent and the reagent in excess
- finding the theoretical and percentage yields

Solutions

- preparation of:
  - standard solution
  - dilute solutions ($C_1V_1 = C_2V_2$)
- measurement and calculation of concentration in:
  - mol/L (molarity)—$Concentration\ (Molarity) = \frac{moles}{volume\ (L\ or\ dm^3)}$
  - g/L
  - mg/L (ppm = parts per million)
  - calculate unknown concentration and volume from an acid-base reaction using:

    B x M_a x V_a = A x M_b x V_b, where

    M_a = molarity of acid, V_a = volume of acid
    M_b = molarity of base, V_b = volume of base
    A = the coefficient in front of acid
    B = the coefficient in front of base

Laboratory work

1. Compare actual mass of a precipitate formed by a chemical reaction with the mass calculated from the equation.
2. Prepare standard solutions and dilute standard solutions.
3. Conduct acid-base reactions using titration.

12.2 Acids, Bases and Salts

4–5 weeks

Context

Do you know that acids occur in many foods and drinks, and even in your stomach? Have you noticed that bases are usually used as household cleaning detergents?

Knowledge

Students have learned about acids and bases in Upper Primary and some reactions of acids and bases in Lower Secondary. They have also learnt about reactions of acids and bases in 11.3 Types of Chemical Reactions.

In this unit students increase their understanding of acids, bases and salts. They learn about acids, bases and salts that occur in nature, as well as their synthesised forms. They also carry out acid-base reactions in the laboratory to quantitatively describe what happens during acid-base reactions.

Learning outcomes

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
3. communicate findings of scientific investigations in different ways
4. analyse and interpret data, graphs and other forms of information relevant to topics studied.

To achieve the learning outcomes, students:

- demonstrate an understanding of chemical properties of acids and bases
- investigate the differences between strong and weak acids as well as strong and weak bases by discussing their dissociation in water
- discuss and explain dissociation constant (K_w) of water
- calculate the pH and pOH of a given solution
- conduct volumetric analysis (titration) experiments using the different indicators to detect the end point of the titrations
- demonstrate an understanding of titration and pH curves by plotting them.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Common acids and bases

- classification of acids as mineral (inorganic) or organic
  - common acids and their uses
- common bases and their uses

Properties of acids and bases

- Arrhenius, Bronsted-Lowry and Lewis definitions of acids and bases
- chemical properties of acids and bases

Strong and weak acids and bases

- definition of and differences between:
  - strong and weak acids
  - strong and weak bases
  - dilute and concentrated acids
  - dilute and concentrated bases
  - monoprotic, diprotic and triprotic acids
  - amphoteric and amphiprotic substances

Dissociation constants and pH calculations

- calculation of:
  - K_w of $H_2O = [H^+][OH^-] = 10^{-14}$ where [ ] = concentration
  - pH ($pH = -\log_{10} [H^+]$)
  - pOH ($pOH = 14 – pH$) or $pOH = -\log[OH^-]$
  - $[H^+]$ = antilog[-pH] or 10^{-pH}
  - $[OH^-]$ = antilog[-pOH]
  - writing ionisation equation and relating [H+] and [OH-] to find the acid and base concentration

Acid-base titration to detect the end point (volumetric analysis)

- determining the end point of acid-base reaction by using:
  - indicators (phenolphthalein and methyl orange indicator)
  - pH meter
  - conductrimetric titration—use conductivity meter or ammeter
- determine
  - the quantity of acids and bases used in a neutralisation reaction
  - unknown concentrations using volumetric analysis

Warning!
To dilute, always add acid to water. Do not add water to concentrated acid.

Laboratory work

1. Investigate the common properties of acids and bases.
2. Use indicator to detect end point in volumetric analysis (a universal indicator can be prepared in the laboratory by taking the juice of red cabbage)
3. Use pH meter to detect end point of titration.
4. Use conductivity meter or measure current in an electrolyte to determine the end point of titration.

12.3 Electrochemistry

5–6 weeks

Context

Energy transformation in electrochemical reactions has been a vital process in human history. This chemical process has been used to produce electrical energy to drive diverse machines to do work and also purify impure metals. Electrochemical cells are divided into galvanic or voltaic cells and electrolytic cells. Do you know that batteries in torches, watches and mobile phones are examples of galvanic cells? Do you also know that the copper concentrate (about 30% copper) produced by Papua New Guinea can be refined to 99.99% pure by electrolysis process?

Knowledge

Students have some learning about electricity in Unit 9.6 and learned about ions in Unit 10.3 at Lower Secondary. This unit further develops concepts of electrons and ions and the spontaneous and non-spontaneous oxidation-reduction in galvanic and electrolytic cells. It also helps the students to appreciate the practical applications of these reactions in everyday life.

Students construct simple galvanic cells and electrolytic cells to measure voltage, current and the mass deposited during the reaction. Students use electrical energy to carry out chemical reactions in electrolytic cells to purify impure metals.

Learning outcomes

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
3. communicate findings of scientific investigations in different ways.

To achieve the learning outcomes, students:

- define electrochemistry and differentiate between galvanic cells and electrolytic cells
- investigate and explain the concepts and applications of electrolytic cells
- investigate and explain the concepts and applications of galvanic cells
- demonstrate an understanding of cell potentials and standard potentials by defining and calculating potentials.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Electrolysis

Electrolytic cells

- construction of an electrolytic cell
- half equations for reactions at the anode and cathode and overall equation in electrolytic cells
- identifying reacting chemical species as oxidant or reductant
- factors affecting the performance of electrolytic cells (such as the concentration of electrolyte, type of electrolyte, types of electrodes and magnitude of applied current or voltage)

Electrolysis using inert electrodes

- molten salts (NaCl)
- dilute aqueous salts (KCl)
- concentrated aqueous salts (KCl)
- dilute acids (for example, H_2SO_4)

Application of electrolysis

- investigate using inert electrodes
  - electrolysis of brine
  - manufacture of aluminium from bauxite
- investigate using reactive electrodes in
  - refining of metal (such as impure copper)
  - electroplating

Galvanic cells

- cell potential
- standard cell potential
- galvanic cells:
  - construction of galvanic cells with and without salt bridge
  - factors affecting performance of galvanic cells (such as concentration of electrolyte, type of electrolyte and electrodes)
  - writing half equations for spontaneous reactions at the anode and cathode
  - examination of dry cells and car batteries

Laboratory work

1. Construct simple galvanic and electrolytic cells.
2. Conduct electrolysis of a dilute acid (H_2SO_4).
3. Electroplating of copper onto silver coin.
4. Investigate the electrolysis of aqueous salts using different reactive and inert electrodes.
5. Purification of blistered copper.

> ***Warning!***
> *Be aware of electric shocks. Take precautions when harmful and flammable gases such as chlorine and hydrogen are produced.*

12.4 Carbon Compounds

6–7 weeks

Context

Plants and animals are made up of carbon and its compounds. The banana that we eat consists of a compound of carbon, hydrogen and oxygen, called ‘carbohydrates’. In general, organic substances are compounds of carbon and other elements, mainly nitrogen, hydrogen and oxygen. Have you ever wondered about the composition of petrol, kerosene and cooking gases? Are you aware that carbon is the greatest component in living things?

Knowledge

Students have acquired knowledge of carbon in units 11.2 and 11.4. In this unit students study compounds of carbon and various categories of carbon compounds. Students write general formula, draw structures and name the hydrocarbons, alcohols, aldehydes, ketones and carboxylic acids using the International Union of Pure and Applied Chemists (IUPAC) naming system.

Learning outcomes

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems.

To achieve the learning outcomes, students:

- understand the general pattern of the structure of carbon compounds
- write formulae, draw structures and name, according to IUPAC system:
  - hydrocarbons (aliphatic and aromatic)
  - alcohols
  - aldehydes
  - ketones
  - carboxylic acids
  - esters
  - amines

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Homologous series

- definition of ‘homologous series’

Hydrocarbons

- writing formulae, drawing structures and naming from C1 to C10 according to IUPAC system:
  - alkanes [C_nH_{2n+2}]
  - alkenes [C_nH_{2n}]
  - alkynes [C_nH_{2n-2}]
  - benzene
  - differentiating between saturated and unsaturated hydrocarbon compound
- importance of the patterns behind the formulas of simple organic molecules
- combustion of alkanes and alkenes

Alcohols

- writing formulas, drawing structures and naming from C1 to C7 according to IUPAC system:
  - primary alcohols [$C_nH_{2n+1}OH$]
  - secondary alcohols [$C_nH_{2n+1}OH$]
  - tertiary alcohols [$C_nH_{2n+1}OH$]

Aldehydes

- writing general formulas, drawing structures and naming from C1 to C7 according to IUPAC system

Ketones

- writing general formulas, drawing structures and naming from C3 to C7 according to IUPAC system

Carboxylic acids and esters

- writing general formulas, drawing structures and naming from C1 to C7 according to IUPAC system:
  - carboxylic acids
  - esters made from acid and alcohol
  - amines

Laboratory and practical work

1. Construct simple molecules using models.

12.5 Natural Resources and Chemical Industries in Papua New Guinea

9–10 weeks

Context

Papua New Guinea is endowed with many natural resources. How can we develop this country by exploiting these resources in a sustainable way? Can it prosper economically unless we develop chemical industries?

Knowledge

In previous units of Upper Secondary Chemistry, students have learned basic principles of chemistry. In this unit they learn about natural resources and the importance of developing them in a sustainable way. They study selected chemical industries and traditional chemical practices, and learn about pollution caused by producing and using chemicals and burning fossil fuels. Students learn through investigating natural resources, chemical industries, traditional chemical practices and industrial pollution.

Learning outcomes

Students can:

1. demonstrate an understanding of fundamental scientific principles and models
2. apply scientific thinking, motor and process skills to investigate and find solutions to problems
3. communicate findings of scientific investigations in different ways
4. analyse and interpret data, graphs and other forms of information relevant to topics studied
5. analyse and evaluate past and present scientific developments and their impacts on human beings and the environment and on the ethical decisions made
6. demonstrate an understanding of traditional knowledge and skills of chemistry practised over many years and explain their relevance today.

To achieve the learning outcomes, students:

- demonstrate an understanding of natural resources and the importance of developing them in a sustainable way
- demonstrate an understanding of important chemical industries in Papua New Guinea by discussing an overview of the processes
- investigate and understand traditional chemical practices in Papua New Guinea
- investigate pollution caused by producing and using chemicals and burning fossil fuels, with special reference to global warming and climate change.

Content

Students acquire knowledge and skills through the learning and teaching of this content.

Crude oil

- carbon cycle
- fossil fuels (crude oil or natural gas)
- refining crude oil (including reforming and cracking)
- combustion of fossil fuel
- production of plastics (polymerisation)
- advantages and disadvantages of plastics

Metallic ores

- extraction of copper, gold and silver, nickel and cobalt
- environmental consequences of mining

Production of ethanol

- fermentation (SP Brewery)
- fermentation and distillation (Ramu Sugar Ltd)
- chemical and physical properties of ethanol
- harmful effects of ethanol and methanol

Production and uses of vegetable oils

- extraction of oil from seeds and nuts (coconut, oil palm, peanut, karuka)
- saponification (soap production)
- biodiesel production

Traditional chemical practices

- lime production; salt production
- traditional dyes; traditional medicine

Industrial chemical pollution

- environmental effects of:
  - mining activities
  - production and use of chemicals, including plastics
  - complete and incomplete fossil fuel combustion (greenhouse effect)
  - persistent organic pollutants (agro and industrial chemicals; for example, DDT, CFCs)

Laboratory and practical work

1. Produce soap.
2. Extract natural oil from pandanus nut, coconut or marita.
3. Ferment alcohol.
4. Undertake excursion to an industry located in the local area.

Assessment components, weightings and tasks

The internal assessment mark for Chemistry is based on the Grade 11–12 syllabus only. Final assessment is based on a range and balance of assessment instruments guided by the recommended components and weightings. The components, weightings and tasks for Grades 11 and 12 units are detailed below.

Components, weighting and tasks: Grade 11

Component	Weighting	Tasks
Written tests	150	May include multiple-choice items, short answers, extended responses
Practical testing skills (Laboratory practical report)	50	These tasks can include elements within class, particularly in the presentation phase. Tasks may be undertaken over a period of time. The communication may be written or oral
Practical investigative skills (Project)	100	Statistical interpretation, graphical skills, calculations. These can utilise contemporary or hypothetical situations. Should include group-based tasks, although it may incorporate individual elements in the reporting phase. The tasks can include written reports from group research, seminars, group presentations, multimedia presentations
Marks	**300**	

Components, weighting and tasks: Grade 12

Component	Weighting	Tasks
Written tests	150	May include multiple-choice items, short answers, extended responses
Practical testing skills (Laboratory practical report)	100	Tasks may include student research on aspects of a topic, reported through a prepared essay or an in-class task or presentation
Practical investigative skills (Project)	50	Statistical interpretation, graphical skills and calculations. These can utilise theoretical, contemporary or hypothetical situations
Marks	**300**	

Assessment, examinations and certification

Assessment and reporting practices described here are detailed further in the *National Assessment and Reporting Policy for Papua New Guinea* (2003) and in other support materials produced by the Department of Education.

Assessment

The main purpose of assessment is to improve student learning.

Assessment needs to be *for* learning as well as *of* learning. It is used to evaluate and improve learning and teaching, report achievement and provide feedback to students on their progress.

Assessment measures students' achievement of learning outcomes as described in the syllabus. It is the ongoing process of identifying, gathering and interpreting information about students' achievement of the learning outcomes.

Learning and teaching using an outcomes approach requires teachers to plan their teaching and assess learner performance in relation to outcomes, using criteria derived from those outcomes. Assessment involves focusing less on whether a learner has 'passed' or 'failed' and more on what outcomes a learner has achieved and in which areas further support is required.

Assessment in Chemistry

A student's achievement in Chemistry at the end of Grade 12 will be assessed against the learning outcomes. Assessment of student progress towards achieving these learning outcomes is cumulative throughout Grades 11 and 12.

It is important that teachers plan the learning and teaching sequence so that there is a balanced spread of assessment during the year. Some tasks, such as investigations or case studies, can be designed so that they are completed over a period of time rather than at the end of the unit. Other tasks can be done immediately the relevant section of the unit or topic has been covered.

Assessment for certification

A student's overall achievement in Chemistry will be both internally and externally assessed. The final mark awarded to each student will be a combination of the internal assessment mark provided by the school and the examination mark.

Internal assessment

Internal assessment provides a measure of a student's achievement based on a wider range of syllabus content and outcomes than may be covered by the external examination alone.

For Chemistry the internal assessment marks will provide a summation of each student's achievements in Grades 11 and 12. The assessment tasks used to determine the internal assessment mark must comply with the components, weightings and types of tasks specified in the tables on page 31. A variety of tasks gives students the opportunity to demonstrate all the learning outcomes in different ways to improve the validity and reliability of the assessment.

All schools must meet the requirements for internal assessment as specified in the Grade 12 *Assessment, Examination and Certification Handbook.*

External examination

The external examination provides a measure of student achievement of those aspects of the learning outcomes that can be reliably measured in an examination setting. Questions for the external examination in Chemistry will be developed using the outcomes, knowledge and skills in the syllabus.

Recording

All schools must meet the requirements for maintaining and submitting student records as specified in the Grade 12 *Assessment, Examination and Certification Handbook.*

Certification

Candidates will be awarded the national certificate only if they meet all requirements for internal and external assessment. Eligibility rules for the award of certificates are specified in the Grade 12 *Assessment, Examination and Certification Handbook.*