STAWA DEPTH and BREADTH of CONTENT: Teacher Support Documents

Senior Secondary Science WACE 2015 – 2016: Chemistry - Unit 2

The STAWA Depth & Breadth of Content documents have been developed through the collaboration of teachers working in Department of Education, Catholic Education and Independent Schools.

Purpose

The STAWA Depth & Breadth of Content documents are intended to promote a shared understanding of the course content that improves moderation across schools, regions and systems/sectors.

Caution

The Depth and Breadth points of elaboration are interpretations. The ATAR syllabus content statements are the only parts of these documents that are mandated. Examiners are required to address the mandated statements only.

The STAWA Depth & Breadth of Content documents are a great example of teachers helping teachers for the benefit of all students.

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Leadership in Science Education

CHEMISTRY

ATAR Year 11

Unit 2 – Molecular interactions and reactions

Unit description

Students develop their understanding of the physical and chemical properties of materials, including gases, water and aqueous solutions, acids and bases. Students explore the characteristic properties of water that make it essential for physical, chemical and biological processes on Earth, including the properties of aqueous solutions. They investigate and explain the solubility of substances in water, and compare and analyse a range of solutions. They learn how rates of reaction can be measured and altered to meet particular needs, and use models of energy transfer and the structure of matter to explain and predict changes to rates of reaction. Students gain an understanding of how to control the rates of chemical reactions, including through the use of a range of catalysts.

Through the investigation of appropriate contexts, students explore how evidence from multiple disciplines and individuals have contributed to developing understanding of intermolecular forces and chemical reactions. They explore how scientific knowledge is used to offer reliable explanations and predictions, and the ways in which it interacts with social, economic and ethical factors.

Students use a range of practical and research inquiry skills to investigate chemical reactions, including the prediction and identification of products and the measurement of the rate of reaction. They investigate the behaviour of gases, and use the Kinetic Theory to predict the effects of changing temperature, volume and pressure in gaseous systems.

Learning outcomes

By the end of this unit, students:

- understand how models of the shape and structure of molecules and intermolecular forces can be used to explain the properties of substances, including the solubility of substances in water
- understand how kinetic theory can be used to explain the behaviour of gaseous systems, and how collision theory can be used to explain and predict the effect of varying conditions on the rate of reaction
- understand how models and theories have developed based on evidence from a range of sources, and the uses and limitations of chemical knowledge in a range of contexts

- use science inquiry skills to design, conduct, evaluate and communicate investigations into the properties and behaviour of gases, water, aqueous solutions and acids and bases, and into the factors that affect the rate of chemical reactions
- evaluate, with reference to empirical evidence, claims about chemical properties, structures and reactions
- communicate, predict and explain chemical phenomena using qualitative and quantitative representations in appropriate modes and genres

Unit content

This unit builds on the content covered in Unit 1.
This unit includes the knowledge, understandings and skills described below.

Science Inquiry Skills

Unit Content	Elaborations	Possible Activities	Assessment Opportunities
• identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes			
• design investigations, including the procedure(s) to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics			
• conduct investigations safely, competently and methodically for the collection of valid and reliable data, including:			

chromatography, measuring pH, rate of reaction, identification of the products of reactions, and determination of solubilities of ionic compounds to recognise patterns in solubility			
• represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and process data to identify trends, patterns and relationships; identify sources of random and systematic error; identify anomalous data; estimate the effect of error on measured results; and select, synthesise and use evidence to make and justify conclusions			
• interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments			
• communicate to specific audiences and for specific purposes using appropriate language, nomenclature and formats, including scientific reports			

Science as a Human Endeavour

Intermolecular forces and gases

Chromatographic techniques, including thin layer chromatography (TLC), gas chromatography (GC), and high performance liquid chromatography (HPLC), are used to determine the components of a wide range of mixtures in various settings. The decision to use a particular chromatographic technique depends on a number of factors, including the properties of the substances being separated, the amount of substance available for analysis and the sensitivity of the equipment. Chromatographic techniques have a wide range of analytical and forensic applications, including monitoring air and water pollutants, drug testing of urine and blood samples, and testing for food additives and quality.

Science Understanding

Unit Content	Elaboration	Activities	Assessment opportunities
1. observable properties, including vapour pressure, melting point, boiling point and solubility, can be explained by considering the nature and strength of intermolecular forces within a covalent molecular substance	• State that van der Waal's forces may include dispersion forces, dipole-dipole forces and hydrogen bonding. • State and apply that van der Waal's forces are significant attractive forces between molecules in the solid and liquid states. • Define vapour pressure • Explain that observable properties, including vapour pressure, melting point, boiling point and solubility, can be explained by the considering the nature and strength of intermolecular forces between molecules.	**STAWA Stage 3 – Expt 8** **STAWA Stage 3 – Set 10**	
2. the valence shell electron pair repulsion (VSEPR) theory and Lewis structure diagrams can be used to explain, predict and draw the shapes of molecules	• Describe the valence shell electron pair repulsion (VSEPR) theory and use this theory, in combination with Lewis structures, to explain, predict and draw the shapes of simple molecules (limited to 5 atoms)		
3. the polarity of molecules can be explained and predicted using knowledge of molecular shape, understanding of symmetry,	• Relate the polarity of a covalent bond to the difference in electronegativity of the atoms involved in bond formation, leading to the unequal sharing of electrons in the bond. • State and apply that the conditions necessary for molecular polarity are bond polarity and molecular asymmetry.	**CWA2 – Chapter 3** **Lucarelli (3AB) – Set 4**	

and comparison of the electronegativity of atoms involved in the bond formation	• Predict and explain the molecular polarity of simple covalent molecular substances.		
4. the shape and polarity of molecules can be used to explain and predict the nature and strength of intermolecular forces, including dispersion forces, dipole-dipole forces and hydrogen bonding	• State and apply that dispersion forces will be present in all substances. • Describe and apply the relationship between the strength of dispersion forces and molecular shape and molecular size. • State that dipole-dipole forces result from the electrostatic attraction between polar molecules. • Identify nitrogen, oxygen and fluorine as highly electronegative elements and state that polar molecules involving these elements are likely to exhibit strong dipole-dipole attractions. • Identify hydrogen bonding as an extreme form of dipole-dipole interaction, and state that hydrogen bonding involves the attraction between the hydrogen atom attached to a nitrogen, oxygen and fluorine atom in one molecule and a nitrogen, oxygen or fluorine atom in another molecule. • Predict the nature and strength of intermolecular forces present between molecules from the shape and polarity of those molecules. • State and apply that, for molecules of similar size, hydrogen bonding is generally regarded as the strongest of the intermolecular forces.		

5. data from chromatography techniques, including thin layer chromatography (TLC), gas chromatography (GC), and high-performance liquid chromatography (HPLC), can be used to determine the composition and purity of substances; the separation of the components is caused by the variation in strength	• Define the following terms: stationary phase, mobile phase, retention time, retention factor, analyte/solute and eluent/solvent.
	• Relate the separation of mixtures in chromatography to solubility and absorption of components on the stationary phase.
	• Justify which chromatography technique is most appropriate to separate the components of a given mixture.
	• Outline, including the advantages and disadvantages, the following chromatography techniques:
	  ○ Thin layer chromatography (TLC)
	  ○ Gas chromatography (GC)
		STAWA Stage 3 – Invest 5 (ADAPT)
		
		Refer to the Royal Society of Chemistry (RSC) Website	

of the interactions between atoms, molecules or ions in the mobile and stationary phases	○ High performance liquid chromatography (HPLC) ○ Do not include detail of instrumentation or operation. • Calculate the retardation factor (R_f=(distance moved by component)/(distance moved by solvent front)) for TLC separations. • Interpret chromatograms to identify components present in a mixture.		
Science as a Human Endeavour Chromatographic techniques, including thin layer chromatography (TLC), gas chromatography (GC), and high performance liquid chromatography (HPLC), are used to determine the components of a wide range of mixtures in various settings. The decision to use a particular chromatographic technique depends on a number of factors, including the properties of the substances being separated, the amount of substance available for analysis and the sensitivity of the equipment. Chromatographic techniques have a wide range of analytical and forensic applications, including monitoring air and water pollutants, drug testing of urine and blood samples, and testing for food additives and quality.	• Describe examples of the application of chromatography. • Describe the sensitivity of each chromatography technique. • Identify the most appropriate chromatography technique for the monitoring of air and water pollution, drug testing of urine and blood samples and testing for food additives and quality. • Justify the use of a particular chromatography technique by considering the properties of the substances being separated, the amount of substance available for analysis and the sensitivity of the equipment.	Investigate aspirin using thin layer chromatography. Biotechnology Pharmaceuticals Analgesics Aspirin Paracetamol Drugs See RSC website Crime Scene investigation project	**Invest and Validation Test 2:** Solvent Composition
6. the behaviour of an ideal	• State the postulates of the Kinetic Theory of Matter.	**CWA1 – Chapter 7**	

gas, including the qualitative relationships between pressure, temperature and volume, can be explained using the Kinetic Theory	• Use the Kinetic Theory to explain the characteristic properties of gases. • Explain gas pressure in terms of the Kinetic Theory. • State that temperature changes is due to a change in kinetic energy. • Explain the significance of the distribution of kinetic energies of molecules of gas samples at different temperatures. • Explain the qualitative relationships between pressure, temperature and volume using the Kinetic Theory. • Describe the properties of an ideal gas in relation to the Kinetic Theory and state why real gases deviate from ideal gas behaviour. • From data provided, plot pressure/volume, temperature/volume and pressure/temperature graphs for gases and interpret the results.	**Lucarelli (2AB) – Set 1**	
7. the mole concept can be used to calculate the mass of substances and volume of gases (at standard temperature and pressure) involved in a chemical reaction	• Perform mass/gas volume and gas volume/gas volume calculations using the mole as the unifying concept at standard pressure and temperature (STP).	**STAWA Stage 2 – Sets 18, 19 & 20** **Lucarelli (2AB) – Set 17, 21,22**	**Test 5:** Calculations

Science as a Human Endeavour

Aqueous solutions and acidity

The supply of potable drinking water is an extremely important issue for both Australia and countries in the Asian region. Water sourced from groundwater and seawater undergoes a number of purification and treatment processes (such as desalination, chlorination, fluoridation) before it is delivered into the supply system. Chemists regularly monitor drinking water quality to ensure that it meets the regulations for safe levels of solutes. Heavy metal contamination in ground water is monitored to ensure that concentrations are at acceptable levels. Several methods can be used to reduce heavy metal contamination; the method used is influenced by economic and social factors.

Science Understanding

Unit Content	Elaboration	Activities	Assessment opportunities
8. the unique physical properties of water, including melting point, boiling point, density in solid and liquid phases and surface tension, can be explained by its molecular shape and hydrogen bonding between molecules	• Define surface tension. • Explain the properties of water, including melting and boiling point, density in solid and liquid phases, and surface tension, in terms of its molecular shape and the presence of hydrogen bonding between the molecules.		
9. solutions can be classified as saturated, unsaturated or supersaturated; the concentration of a solution is defined as the quantity of solute dissolved in a quantity of solution; this can be represented in a variety of ways, including by the number of moles of the solute per litre of solution	• Define the terms saturated solution, unsaturated solution and supersaturated solution. • State and apply that the concentration of a saturated solution is a measure of solubility. • Classify solutions, based on the solubility of the solute, as unsaturated, saturated or supersaturated. • Define concentration of a solution as the quantity of solute dissolved in a quantity of solution. • Perform calculations relating the mass of solute and the mass of solution to the concentration of a solution in parts per million (ppm).	**CWA1 – Chapter 8** **STAWA Stage 2 – Sets 22 &23** **Lucarelli (2AB) – Set 6** **Lucarelli (2AB) – Set 19**	**SHE**- Solubility curves for different substances

(mol L-1) and the mass of the solute per litre of solution (g L-1) or parts per million (ppm)	• Perform calculations relating the mass of solute and the volume of solution to the concentration of solution in grams per litre (g L^{-1}). • Perform calculations relating the number of moles of solute and the volume of solution to the concentration of solution in moles per litre (mol L^{-1})		
10. the presence of specific ions in solutions can be identified by observing the colour of the solution, flame tests and observing various chemical reactions, including precipitation and acid-base reactions	• Qualitative Analysis • Use the colours of ions to infer and describe the products of reactions. • Apply the solubility rules (as per the data sheet) to predict if precipitation will occur when two dilute solutions of different ionic compounds are mixed. • Use flame tests to identify the presence of certain metal ions (see unit 1). • Apply the solubility rules and use acid-base reactions to determine the presence of specific ions.	**STAWA Stage 2 – Set 13** **Lucarelli (2AB) – Set 20** Heinemann AQA workbooks	

11. the solubility of substances in water, including ionic and polar and non-polar molecular substances, can be explained by the intermolecular forces, including ion-dipole interactions between species in the substances and water molecules, and is affected by changes in temperature	• Classify solutes as ionic, polar or non-polar.
	• Identify ion-dipole interactions as the electrostatic force of attraction between polar molecules and ions.
	• State and apply the influence of the large number of ion-dipole interactions that occur between ions and water molecules in explaining the solubility of ionic solutes in water.
	• Explain and predict, in terms of the interactions between solute particles, between water molecules and between solute particles and water molecules,
	  ○ the general solubility of ionic compounds,
	  ○ the general insolubility of non-polar solutes,
	  ○ the general solubility of polar solutes.
	• State that the solubility of a solute in water depends on temperature.
	• From data provided, plot temperature/solubility graphs and interpret the results.
		Investigations 13 &14 STAWA Exploring Chemistry Stage 3	

Science as a Human Endeavour			
The supply of potable drinking water is an extremely important issue for both Australia and countries in the Asian region. Water sourced from groundwater and seawater undergoes a number of purification and treatment processes (such as desalination, chlorination, fluoridation) before it is delivered into the supply system. Chemists regularly monitor drinking water quality to ensure that it meets the regulations for safe levels of solutes. Heavy metal contamination in ground water is monitored to ensure that concentrations are at acceptable levels. Several methods can be used to reduce heavy metal contamination; the method used is influenced by economic and social factors.	• Define potable water as water suitable for human consumption. • Explain the process of desalination used at the Kwinana desalination plant. • Describe and explain the chemistry of chlorination. • Describe and explain the chemistry of fluoridation. • Explain the role of chlorination and fluoridation in water quality. • Describe methods for monitoring water quality, such as conductivity measurements, pH measurements etc. • Describe methods for the removal of heavy metal contamination such as precipitation. • Relate methods of removing heavy metal contamination to economic and social factors.	Investigations 13 &14 STAWA Exploring Chemistry Stage 3 Scitech for potable drinking	**Investig & Validation Test 1:** Water Quality research, practical & validation test
12. the Arrhenius model can be used to explain the behaviour of strong and weak acids and bases in aqueous solutions	• Describe the Arrhenius model of acid-base behaviour. • Write equations to illustrate that acids are sources of $H^+(aq)$ and bases are sources of $OH^-(aq)$ • Distinguish between the terms 'strong' and 'weak' when applied to degree of ionisation or dissociation of acids and bases in aqueous solution. • Identify strong acids including HCl, H_2SO_4, HNO_3 and strong bases as group 1 and 2 oxides and hydroxides. • Identify common weak acids including CH_3COOH, H_3PO_4 and	**CWA1 – Chapter 1** **Lucarelli (2AB) – Sets 26 & 27**	

	weak bases including NH_3 and Na_2CO_3. • Distinguish between terms 'concentrated' and 'dilute'. • Distinguish between the terms ionisation and dissociation. • Identify substances as acidic or basic based on physical properties.		
13. indicator colour and the pH scale are used to classify aqueous solutions as acidic, basic or neutral	• Identify the colour of universal indicator in acidic, basic or neutral solutions. • Use pH numbers to identify whether a solution is acidic, basic or neutral.	**STAWA Stage 3 – Expt 9** **STAWA Stage 3 – Invests 6 & 7** **STAWA Stage 3 – Sets 15 & 16**	
14. pH is used as a measure of the acidity of solutions and is dependent on the concentration of hydrogen ions in the solution	• Define the pH scale a measure of the hydrogen ion concentration of a solution. • State the expression for the ionisation constant for water $K_w = [H^+][OH^-]$, which equals 1 x 10^{-14} at 298 K. • State that the concentrations of $H^+(aq)$ and $OH^-(aq)$ in pure water are equal to 1.0 x 10^{-7} mol L^{-1} at 298 K. • State that the concentrations of $H^+(aq)$ and $OH^-(aq)$ are equal in a neutral solution. • State and apply the relationship between pH and acidity and alkalinity in aqueous solutions. • Define 'pH' as –log 10$[H^+(aq)]$ and calculate the pH of strong acid solutions and strong base solutions.	**STAWA Stage 2 – Expt 19, 20 & 21** **STAWA Stage 2 – Invest 12**	
15. patterns of the reactions of acids and bases, including reactions of acids with bases, metals and carbonates and the reactions of bases with acids and ammonium salts, allow products and observations to be predicted from	• Write equations (ionic where appropriate) to demonstrate the chemical properties of acids for their reactions with bases, metals and carbonates. (may also include hydrogen carbonates, sulfites) • Write equations (ionic where appropriate) to demonstrate the chemical properties of bases for their reactions with acids and ammonium salts. • Predict the observations and products of the reactions of acids with bases, metals and carbonates.	**STAWA Stage 2 – Expts 22, 23 & 24** **STAWA Stage 2 – Invest 3 & 14**	**Test 3: Aqueous Solutions and Acidity**

reactants; ionic equations represent the reacting species and products in these reactions	• Predict the observations and products of the reactions of bases with acids and ammonium salts.		
16. the mole concept can be used to calculate the mass of solute, and solution concentrations and volumes involved in a chemical reaction	• Solve problems interrelating mass, molar mass, number of moles of solute and concentration and volume of solution.	**STAWA Stage 2 – Sets 22 & 23**	

Science as a Human Endeavour

Rates of chemical reactions

Catalysts are used in many industrial processes in order to increase the rates of reactions that would otherwise be uneconomically slow. Catalysts are also used to reduce the emission of pollutants produced by car engines. Motor vehicles have catalytic converters which are used to catalyse reactions that reduce the amount of carbon monoxide, unburnt petrol and nitrogen oxides that are emitted.

Science Understanding

Unit Content	Elaboration	Activities	Assessment opportunities
17. varying the conditions under which chemical reactions occur can affect the rate of the reaction	• Describe the effect of each of the following factors on the rates of chemical reactions: ○ Concentration of reactants ○ State of sub-division of reactants ○ Temperature ○ Catalyst	**CWA1 – Chapter 11** **Lucarelli (2AB) – Set 15**	
18. the rate of chemical reactions can be quantified by measuring the rate of formation of products or the depletion of reactants	• Define reaction rate in terms of the change in the quantity of reactants or products per unit time.	**CWA1 – Chapter 12** **STAWA Stage 2 Expts 16, 17, 18** Expt - Acid carbonate reactivity - measuring loss over time **STAWA Stage 2 – Invest 9**	

		SIS opportunity – research assignment on catalysts, surface area, temperature	

19. collision theory can be used to explain and predict the effects of concentration, temperature, pressure, the presence of catalysts and surface area on the rate of chemical reactions	• Explain the Collision Theory of reaction rates identifying that as prerequisites for any successful reaction:
	    ○ the reacting particles must have an appropriate collision orientation, and
	    ○ the reacting particles must collide with sufficient energy.
	• Use the collision theory and a potential energy diagram, where appropriate, to explain the effect of the following factors on rates of chemical reactions:
	    ○ Concentration of reactants
	    ○ State of sub-division of reactants
	    ○ Temperature
	    ○ Catalyst
		Lucarelli (2AB) – Set 16	

20. the activation energy is the minimum energy required for a chemical reaction to occur and is related to the strength and number of the existing chemical bonds; the magnitude of the activation energy influences the rate of a chemical reaction	• Define activation energy as the minimum energy required for a chemical reaction to occur. • State and apply that the activation energy is related to the strength and number of bonds between the atoms of the reactants. • State and apply that the magnitude of the activation energy influences the rate of a chemical reaction. • Distinguish between heat of reaction and activation energy to explain why a highly exothermic reaction can be slow or not proceed at all at room temperature.		

21. energy profile diagrams, which can include the transition state and catalysed and uncatalysed pathways, can be used to represent the enthalpy changes and activation energy associated with a chemical reaction	• Define the transition state/activated complex in a reaction as the highest energy state for the reacting system which
	    ○ Corresponds to some stage in the reaction at which bond breaking and bond formation is taking place,
	    ○ Is unstable, having no more than a temporary existence,
	and explain its significance.
	• Draw and interpret potential energy diagrams for exothermic and endothermic processes showing the transition state,		

	activation energy, catalysed and uncatalysed pathways, and heat of reaction.		
22. catalysts, including enzymes and metal nanoparticles, affect the rate of certain reactions by providing an alternative reaction pathway with a reduced activation energy, hence increasing the proportion of collisions that lead to a chemical change	• Describe catalysts as agents which increase the rate of chemical reactions by providing an alternative reaction pathway with a lower activation energy and are not permanently consumed in the reaction. • Describe enzymes as biological catalysts and give examples. • Explain how enzymes act as biological catalysts e.g. lock and key model. • State and explain how changes in temperature and pH affect enzyme activity.	Demonstrate the effects of concentration, temperature, and catalysts on the rate of a chemical reaction.	
Science as a Human Endeavour Catalysts are used in many industrial processes in order to increase the rates of reactions that would otherwise be uneconomically slow. Catalysts are also used to reduce the emission of pollutants produced by car engines. Motor vehicles have catalytic converters which are used to catalyse reactions that reduce the amount of carbon monoxide, unburnt petrol and nitrogen oxides that are emitted.	• Relate the role of catalysts to economic viability of industrial processes and give examples. • Explain how catalytic converters reduce the amount of carbon monoxide, unburnt petrol and nitrogen oxides that are emitted.		