Government of Western Australia
School Curriculum and Standards Authority

CHEMISTRY

ATAR COURSE

Year 12 syllabus

IMPORTANT INFORMATION

This syllabus is effective from 1 January 2017.

Users of this syllabus are responsible for checking its currency.

Syllabuses are formally reviewed by the School Curriculum and Standards Authority on a cyclical basis, typically every five years.

Content

Rationale

Chemistry is the study of materials and substances and the transformations they undergo through interactions and the transfer of energy. Chemists can use an understanding of chemical structures and processes to adapt, control and manipulate systems to meet particular economic, environmental and social needs. This includes addressing the global challenges of climate change and security of water, food and energy supplies, and designing processes to maximise the efficient use of Earth's finite resources. The Chemistry ATAR course develops students' understanding of the key chemical concepts and models of structure, bonding, and chemical change, including the role of chemical, electrical and thermal energy. Students learn how models of structure and bonding enable chemists to predict properties and reactions and to adapt these for particular purposes.

Students explore key concepts and models through active inquiry into phenomena, and through contexts that exemplify the role of chemistry and chemists in society. Students design and conduct qualitative and quantitative investigations, both individually and collaboratively. They investigate questions and hypotheses, manipulate variables, analyse data, evaluate claims, solve problems and develop and communicate evidence-based arguments and models. Thinking in chemistry involves using differing scales, including macro, micro and nano-scales; using specialised representations, such as chemical symbols and equations; and being creative when designing new materials or models of chemical systems. The study of chemistry provides a foundation for undertaking investigations in a wide range of scientific fields, and often provides the unifying link across interdisciplinary studies.

Some of the major challenges and opportunities facing Australia and the Asia-Pacific region at the beginning of the twenty-first century are inextricably associated with chemistry. Issues of sustainability on local, national and global levels are, and will continue to be, tackled by the application of chemical knowledge using a range of technologies. These include issues such as the supply of clean drinking water, efficient production and use of energy, management of mineral resources, increasing acidification of the oceans, and climate change.

Studying the Chemistry ATAR course provides students with a suite of skills and understandings that are valuable to a wide range of further study pathways and careers. An understanding of chemistry is relevant to a range of careers, including those in forensic science, environmental science, engineering, medicine, dentistry, pharmacy and sports science. Additionally, chemistry knowledge is valuable in occupations that rely on an understanding of materials and their interactions, such as art, winemaking, agriculture and food technology. Some students will use this course as a foundation to pursue further studies in chemistry, and all students will become more informed citizens, able to use chemical knowledge to inform evidence-based decision making and engage critically with contemporary scientific issues.

Aims

Chemistry aims to develop students':

- interest in and appreciation of chemistry and its usefulness in helping to explain phenomena and solve problems encountered in their ever-changing world
- understanding of the theories and models used to describe, explain and make predictions about chemical systems, structures and properties
- understanding of the factors that affect chemical systems, and how chemical systems can be controlled to produce desired products
- appreciation of chemistry as an experimental science that has developed through independent and collaborative research, and that has significant impacts on society and implications for decision making
- expertise in conducting a range of scientific investigations, including the collection and analysis of qualitative and quantitative data and the interpretation of evidence
- ability to critically evaluate and debate scientific arguments and claims in order to solve problems and generate informed, responsible and ethical conclusions
- ability to communicate chemical understanding and findings to a range of audiences, including through the use of appropriate representations, language and nomenclature.

Organisation

This course is organised into a Year 11 syllabus and a Year 12 syllabus. The cognitive complexity of the syllabus content increases from Year 11 to Year 12.

Structure of the syllabus

The Year 12 syllabus is divided into two units which are delivered as a pair. The notional time for the pair of units is 110 class contact hours.

Unit 3 – Equilibrium, acids and bases, and redox reactions

In this unit, students investigate the concept of reversibility of reactions and the dynamic nature of equilibrium in chemical systems; contemporary models of acid-base behaviour that explain their properties and uses; and the principles of oxidation and reduction reactions, including the generation of electricity from electrochemical cells.

Unit 4 – Organic chemistry and chemical synthesis

In this unit, students develop their understanding of the relationship between the structure, properties and chemical reactions of different organic functional groups. Students also investigate the process of chemical synthesis to form useful substances and products and the need to consider a range of factors in the design of these processes.

Each unit includes:

- a unit description – a short description of the focus of the unit
- learning outcomes – a set of statements describing the learning expected as a result of studying the unit
- unit content – the content to be taught and learned.

Organisation of content

Science strand descriptions

The Chemistry course has three interrelated strands: Science Inquiry Skills, Science as a Human Endeavour and Science Understanding which build on students' learning in the Year 7–10 Science curriculum. The three strands of the Chemistry course should be taught in an integrated way. The content descriptions for Science Inquiry Skills, Science as a Human Endeavour and Science Understanding have been written so that this integration is possible in each unit.

Science Inquiry Skills

Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting data; and communicating findings. This strand is concerned with evaluating claims, investigating ideas, solving problems, reasoning, drawing valid conclusions, and developing evidence-based arguments.

Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations.

In science investigations, the collection and analysis of data to provide evidence plays a major role. This can involve collecting or extracting information and reorganising data in the form of tables, graphs, flow charts, diagrams, text, keys, spreadsheets and databases. The analysis of data to identify and select evidence, and the communication of findings, involve the selection, construction and use of specific representations, including mathematical relationships, symbols and diagrams.

Through the Chemistry course, students will continue to develop their science inquiry skills, building on the skills acquired in the Year 7–10 Science curriculum. Each unit provides specific skills to be taught. These specific skills align with the Science Understanding and Science as a Human Endeavour content of the unit.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The Science as a Human Endeavour strand highlights the development of science as a unique way of knowing and doing, and explores the use and influence of science in society.

As science involves the construction of explanations based on evidence, the development of science concepts, models and theories is dynamic and involves critique and uncertainty. Science concepts, models and theories are reviewed as their predictions and explanations are continually re-assessed through new evidence, often through the application of new technologies. This review process involves a diverse range of scientists working within an increasingly global community of practice and can involve the use of international conventions and activities such as peer review.

The use and influence of science are shaped by interactions between science and a wide range of social, economic, ethical and cultural factors. The application of science may provide great benefits to individuals, the community and the environment, but may also pose risks and have unintended consequences. As a result, decision making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of stakeholder needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Science Understanding

Science understanding is evident when a person selects and integrates appropriate science concepts, models and theories to explain and predict phenomena, and applies those concepts, models and theories to new situations. Models in science can include diagrams, physical replicas, mathematical representations, word-based analogies (including laws and principles) and computer simulations. Development of models involves selection of the aspects of the system(s) to be included in the model, and thus models have inherent approximations, assumptions and limitations.

The Science Understanding content in each unit develops students' understanding of the key concepts, models and theories that underpin the subject, and of the strengths and limitations of different models and theories for explaining and predicting complex phenomena.

Safety

Chemistry learning experiences may involve the use of potentially hazardous substances and/or hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the *Work Health and Safety Act 2011,* in addition to relevant State health and safety guidelines.

Mathematical skills expected of students studying the Chemistry ATAR course

The Chemistry course requires students to use the mathematical skills they have developed through the Year 7–10 Mathematics curriculum, in addition to the numeracy skills they have developed through the Science Inquiry Skills strand of the Science curriculum.

Within the Science Inquiry Skills strand, students are required to gather, represent and analyse numerical data to identify the evidence that forms the basis of their scientific arguments, claims or conclusions. In gathering and recording numerical data, students are required to make measurements with an appropriate degree of accuracy and to represent measurements using appropriate units.

Students may need to be taught when it is appropriate to join points on a graph and when it is appropriate to use a line of best fit. They may also need to be taught how to construct a straight line that will serve as the line of best fit for a set of data presented graphically.

Students may need to be taught to interpret logarithmic scales and to use a calculator to substitute a value to evaluate a logarithmic expression, as they are required in pH calculations (Unit 3), but are not part of the Year 10 Mathematics curriculum.

It is assumed that students will be able to:

- perform calculations involving addition, subtraction, multiplication and division of quantities
- perform approximate evaluations of numerical expressions
- express fractions as percentages, and percentages as fractions
- calculate percentages
- recognise and use ratios
- transform decimal notation to power of ten notation
- change the subject of a simple equation
- substitute physical quantities into an equation using consistent units so as to calculate one quantity and check the dimensional consistency of such calculations
- solve simple algebraic equations
- comprehend and use the symbols/notations $<$, $>$, Δ, $\approx$
- translate information between graphical, numerical and algebraic forms
- distinguish between discrete and continuous data and then select appropriate forms, variables and scales for constructing graphs
- construct and interpret frequency tables and diagrams, pie charts and histograms
- describe and compare data sets using mean, median and inter-quartile range
- interpret the slope of a linear graph.

Representation of the general capabilities

The general capabilities encompass the knowledge, skills, behaviours and dispositions that will assist students to live and work successfully in the twenty-first century. Teachers will find opportunities to incorporate the capabilities into the teaching and learning program for Chemistry.

Literacy

Literacy is important in students' development of Science Inquiry Skills and their understanding of content presented through the Science Understanding and Science as a Human Endeavour strands. Students gather, interpret, synthesise and critically analyse information presented in a wide range of formats and representations (including text, flow diagrams, symbols, graphs and tables). They evaluate information sources and compare and contrast ideas, information and opinions presented within and between texts. They communicate processes and ideas logically and fluently and structure evidence-based arguments, selecting genres and employing appropriate structures and features to communicate for specific purposes and audiences.

Numeracy

Numeracy is key to students' ability to apply a wide range of Science Inquiry Skills, including making and recording observations; ordering, representing and analysing data; and interpreting trends and relationships. They employ numeracy skills to interpret complex spatial and graphic representations, and to appreciate the ways in which chemical systems are structured, interact and change across spatial and temporal scales. They engage in analysis of data, including issues relating to reliability and probability, and they interpret and manipulate mathematical relationships to calculate and predict values.

Information and communication technology capability

Information and communication technology (ICT) capability is a key part of Science Inquiry Skills. Students use a range of strategies to locate, access and evaluate information from multiple digital sources; to collect, analyse and represent data; to model and interpret concepts and relationships; and to communicate and share science ideas, processes and information.

Critical and creative thinking

Critical and creative thinking is particularly important in the science inquiry process. Science inquiry requires the ability to construct, review and revise questions and hypotheses about increasingly complex and abstract scenarios and to design related investigation methods. Students interpret and evaluate data; interrogate, select and cross-reference evidence; and analyse processes, interpretations, conclusions and claims for validity and reliability, including reflecting on their own processes and conclusions. Science is a creative endeavour and students devise innovative solutions to problems, predict possibilities, envisage consequences and speculate on possible outcomes as they develop Science Understanding and Science Inquiry Skills. They also appreciate the role of critical and creative individuals and the central importance of critique and review in the development and innovative application of science.

Personal and social capability

Personal and social capability is integral to a wide range of activities in Chemistry, as students develop and practise skills of communication, teamwork, decision making, initiative taking and self-discipline with increasing confidence and sophistication. In particular, students develop skills in both independent and collaborative investigation; they employ self-management skills to plan effectively, follow procedures efficiently and work safely; and they use collaboration skills to conduct investigations, share research and discuss ideas. In considering aspects of Science as a Human Endeavour, students also recognise the role of their own beliefs and attitudes in their response to science issues and applications, consider the perspectives of others, and gauge how science can affect people's lives.

Ethical understanding

Ethical understanding is a vital part of science inquiry. Students evaluate the ethics of experimental science, codes of practice, and the use of scientific information and science applications. They explore what integrity means in science, and they understand, critically analyse and apply ethical guidelines in their investigations. They consider the implications of their investigations on others, the environment and living organisms. They use scientific information to evaluate the claims and actions of others and to inform ethical decisions about a range of social, environmental and personal issues and applications of science.

Intercultural understanding

Intercultural understanding is fundamental to understanding aspects of Science as a Human Endeavour, as students appreciate the contributions of diverse cultures to developing science understanding and the challenges of working in culturally diverse collaborations. They develop awareness that raising some debates within culturally diverse groups requires cultural sensitivity, and they demonstrate open-mindedness to the positions of others. Students also develop an understanding that cultural factors affect the ways in which science influences and is influenced by society.

Representation of the cross-curriculum priorities

The cross-curriculum priorities address contemporary issues which students face in a globalised world. Teachers will find opportunities to incorporate the priorities into the teaching and learning program for Chemistry.

Aboriginal and Torres Strait Islander histories and cultures

Through an investigation of contexts that draw on Aboriginal and Torres Strait Islander histories and cultures, students appreciate the role of Aboriginal and Torres Strait Islander Peoples' knowledge in developing richer understandings of the chemical diversity in the Australian environment, for example, the chemical properties of plants used for bush medicines, or mineral ores used for decoration or artwork, and how items in the natural environment were used before modern materials became available.

Asia and Australia's engagement with Asia

Contexts that draw on Asian scientific research and development and collaborative endeavours in the Asia Pacific region provide an opportunity for students to investigate Asia and Australia's engagement with Asia**.** Students examine the important role played by people of the Asia region in such areas as medicine, materials science, nanotechnology, energy security and food security. They consider collaborative projects between Australian and Asian scientists and the contribution these make to scientific knowledge.

Sustainability

In Chemistry, the Sustainability cross-curriculum priority provides authentic contexts for exploring, investigating and understanding the function and interactions of chemical systems. Chemistry explores a wide range of chemical systems that operate at different time and spatial scales. By investigating the relationships between chemical systems and system components, and how systems respond to change, students develop an appreciation for the ways in which interactions between matter and energy connect Earth's biosphere, geosphere, hydrosphere and atmosphere. Students appreciate that chemical science and its applications provide the basis for decision making in many areas of society and that these decisions can impact on the Earth system. They understand the importance of using science to predict possible effects of human and other activity, such as ocean acidification, mineral extraction or use of fossil fuels, and to develop management plans, alternative technologies or approaches, such as green chemistry, that minimise these effects and provide for a more sustainable future.

Unit 3 – Equilibrium, acids and bases, and redox reactions

Unit description

The idea of reversibility of reaction is vital in a variety of chemical systems at different scales, ranging from the processes that release carbon dioxide into our atmosphere to the reactions of ions within individual cells in our bodies. Processes that are reversible will respond to a range of factors and can achieve a state of dynamic equilibrium. In this unit, students investigate acid-base equilibrium systems and their applications. They use contemporary models to explain the nature of acids and bases, and their properties and uses. This understanding enables further exploration of the varying strengths of acids and bases. Students investigate the principles of oxidation and reduction reactions and the production of electricity from electrochemical cells.

Through the investigation of appropriate contexts, students explore the ways in which models and theories related to acid-base and redox reactions, and their applications, have developed over time and through interactions with social, economic and ethical considerations. They explore the ways in which chemistry contributes to contemporary debate in industrial and environmental contexts, including the use of energy, evaluation of risk and action for sustainability, and they recognise the limitations of science in providing definitive answers in different contexts.

Students use science inquiry skills to investigate the principles of dynamic chemical equilibrium and how these can be applied to chemical processes and systems. They investigate a range of electrochemical cells, including the choice of materials used and the voltage produced by these cells. Students use the pH scale to assist in making judgements and predictions about the extent of dissociation of acids and bases and about the concentrations of ions in an aqueous solution.

Learning outcomes

By the end of this unit, students:

- understand the characteristics of equilibrium systems, and explain and predict how they are affected by changes to temperature, concentration and pressure
- understand the difference between the strength and concentration of acids, and relate this to the principles of chemical equilibrium
- understand how redox reactions, galvanic and electrolytic cells are modelled in terms of electron transfer
- understand how models and theories have developed over time and the ways in which chemical knowledge interacts with social and economic considerations in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into the properties of acids and bases, redox reactions and electrochemical cells, including volumetric analysis
- evaluate, with reference to empirical evidence, claims about equilibrium systems and justify evaluations
- communicate, predict and explain chemical phenomena using qualitative and quantitative representations in appropriate modes and genres.

Unit content

An understanding of the Year 11 content is assumed knowledge for students in Year 12. It is recommended that students studying Unit 3 and Unit 4 have completed Unit 1 and Unit 2.

This unit includes the knowledge, understandings and skills described below. This is the examinable content.

Science Inquiry Skills

- 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: acid-base properties, using acid-base volumetric analysis techniques, effects of changes to equilibrium systems, and constructing electrochemical cells
- 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 and distinguish between random and systematic errors, and estimate their effect on measured results; discuss how the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions
- interpret a range of scientific 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

Chemical equilibrium systems

Levels of carbon dioxide in the atmosphere are rising and have a significant impact on global systems, including surface temperatures. The increasing level of carbon dioxide in the atmosphere causes more carbon dioxide to dissolve in the ocean producing carbonic acid and leading to increased ocean acidity. This is predicted to have a range of negative consequences for marine ecosystems such as coral reefs. Calcification is the process which results in the formation of calcium carbonate structures in marine organisms. Acidification shifts the equilibrium of carbonate chemistry in seawater, decreasing the rate and amount of calcification among a wide range of marine organisms. The United Nations Kyoto Protocol and the Intergovernmental Panel on Climate Change aim to secure a global commitment to reducing greenhouse gas emissions over the next few decades.

Science Understanding

- collision theory can be used to explain and predict the effects of concentration, temperature, pressure, the presence of catalysts and surface area of reactants on the rates of chemical reactions
- chemical systems include physical changes and chemical reactions and may be open (which allow matter and energy to be exchanged with the surroundings) or closed (which allow energy, but not matter, to be exchanged with the surroundings)
- observable changes in chemical reactions and physical changes can be described and explained at an atomic and molecular level
- over time, in a closed system, reversible physical and chemical changes may reach a state of dynamic equilibrium, with the relative concentrations of products and reactants defining the position of equilibrium
- the characteristics of a system in dynamic equilibrium can be described and explained in terms of reaction rates and macroscopic properties
- the reversibility of chemical reactions can be explained in terms of the activation energies of the forward and reverse reactions
- the effect of changes of temperature on chemical systems initially at equilibrium can be predicted by considering the enthalpy changes for the forward and reverse reactions; this can be represented on energy profile diagrams and explained by the changes in the rates of the forward and reverse reactions
- the effects of changes in concentration of solutions and partial pressures of gases on chemical systems initially at equilibrium can be predicted and explained by applying collision theory to the forward and reverse reactions
- the effects of changes in temperature, concentration of species in solution, partial pressures of gases, total volume and the addition of a catalyst on equilibrium systems can be predicted using Le Châtelier's Principle
- equilibrium law expressions can be written for homogeneous and heterogeneous systems; the equilibrium constant (K), at any given temperature, indicates the relationship between product and reactant concentrations at equilibrium
- the relative amounts of reactants and products (equilibrium position) can be predicted qualitatively using equilibrium constants (K_c)

Science as a Human Endeavour

Acids and bases

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory scope. Davy initially proposed that acids were substances that contained replaceable hydrogen (hydrogen that could be partly or totally replaced by metals) and bases were substances that reacted with acids to form salts and water. The Arrhenius model, which includes only soluble acids and bases, identified acids as substances which produce hydrogen ions in solution and bases as substances which produce hydroxide ions in solution. Subsequently, the Brønsted-Lowry model describes acid-base behaviour in terms of proton donors and proton acceptors. This approach includes a wider range of substances and can be more broadly applied.

Science Understanding

- acids are substances that can act as proton (hydrogen ion) donors and can be classified as monoprotic or polyprotic, depending on the number of protons available for donation
- the strength of acids is explained by the degree of ionisation at equilibrium in aqueous solution which can be represented by chemical equations and acidity constants (K_a)
- the relationship between acids and bases in equilibrium systems can be explained using the Brønsted-Lowry model and represented using chemical equations that illustrate the transfer of protons between conjugate acid-base pairs
- the hydrolysis of salts of weak acids and weak bases can be represented using equations; the Brønsted-Lowry model can be applied to explain the acidic, basic and neutral nature of salts derived from bases and monoprotic and polyprotic acids
- buffer solutions are conjugate in nature and resist changes in pH when small amounts of strong acid or base are added to the solution; buffering capacity can be explained qualitatively; Le Châtelier's Principle can be applied to predict how buffers respond to the addition of hydrogen ions and hydroxide ions
- water is a weak electrolyte; the self-ionisation of water is represented by $K_w = [H^+][OH^-]$ where $K_w = 1.0 \times 10^{-14}$ at 25 °C
- K_w can be used to calculate the concentration of hydrogen ions or hydroxide ions in solutions of strong acids or bases
- the pH scale is a logarithmic scale and the pH of a solution can be calculated from the concentration of hydrogen ions using the relationship $pH = -\log_{10}[H^+]$
- acid-base indicators are weak acids, or weak bases, in which the acidic form is a different colour from the basic form
- volumetric analysis methods involving acid-base reactions rely on the identification of an equivalence point by measuring the associated change in pH, using appropriate acid-base indicators or pH meters, to reveal an observable end point
- data obtained from acid-base titrations can be used to calculate the masses of substances and concentrations and volumes of solutions involved

Science as a Human Endeavour

Oxidation and reduction

Spontaneous redox reactions can be used as a source of electrical energy, including primary, secondary and fuel cells. Fuel cells are a potential lower-emission alternative to the internal combustion engine and are already being used to power various modes of transport. Organisations, including the International Partnership for Hydrogen and Fuel Cells in the Economy, have been created to foster global cooperation on research and development, common codes and standards, and information sharing on infrastructure development.

Science Understanding

- oxidation-reduction (redox) reactions involve the transfer of one or more electrons from one species to another
- oxidation involves the loss of electrons from a chemical species, and reduction involves the gain of electrons by a chemical species; these processes can be represented using half-equations and redox equations (acidic conditions only)
- a range of reactions involve the oxidation of one species and reduction of another species, including metal and halogen displacement reactions, combustion and corrosion
- the species being oxidised and reduced in a redox reaction can be identified using oxidation numbers
- the relative strength of oxidising and reducing agents can be determined by comparing standard electrode potentials, and can be used to predict reaction tendency
- electrochemical cells, including galvanic and electrolytic cells, consist of oxidation and reduction half-reactions connected via an external circuit through which electrons move from the anode (oxidation reaction) to the cathode (reduction reaction)
- galvanic cells produce an electric current from a spontaneous redox reaction
- the electric potential difference of a cell under standard conditions can be calculated from standard electrode potentials; these values can be used to compare the voltages generated by cells constructed from different materials
- electrochemical cells can be described in terms of the reactions occurring at the anode and cathode, the role of the electrolyte, salt bridge (galvanic cell), ion migration, and electron flow in the external circuit
- cell diagrams can be used to represent electrochemical cells
- electrolytic cells use an external electrical potential difference to provide the energy to allow a non-spontaneous redox reaction to occur; electrolytic cells are used in a range of industrial situations, including metal plating and the purification of copper

Unit 4 – Organic chemistry and chemical synthesis

Unit description

This unit focuses on organic chemistry and the processes of chemical synthesis by which useful substances are produced for the benefit of society. Students investigate the relationship between the structure, properties and chemical reactions of different organic functional groups and the vast diversity of organic compounds. Students also develop their understanding of the process of chemical synthesis to form useful substances and products and the need to consider a range of factors in the design of these processes.

Through the investigation of appropriate contexts, students explore the ways in which models and theories have developed over time and through interactions with social, economic and ethical considerations. They explore the ways in which chemistry contributes to contemporary debate regarding current and future uses of local, regional and international resources, evaluate the risk and action for sustainability, and they recognise the limitations of science in providing definitive answers in different contexts.

Students use science inquiry skills to investigate the principles and application of chemical structure in organic chemistry, and of chemical synthesis processes. They make predictions based on knowledge of types of chemical reactions, and investigate chemical reactions qualitatively and quantitatively.

Learning outcomes

By the end of this unit, students:

- understand how the presence of functional groups and the molecular structure of organic compounds are related to their properties
- understand addition, condensation and oxidation reactions, and predict the products of these reactions
- understand how knowledge of chemical systems is used to design synthesis processes
- understand how models and theories have developed over time, and the ways in which chemical knowledge interacts with social and economic considerations in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into reactions to identify organic compounds, including analysis of secondary data derived from chemical analysis
- evaluate, with reference to empirical evidence, claims about organic synthesis and chemical design, and justify evaluations
- 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 3.

This unit includes the knowledge, understandings and skills described below. This is the examinable content.

Science Inquiry Skills

- 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 properties of organic compounds containing different functional groups and using chemical synthesis processes
- represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and analyse data to identify patterns and relationships; identify and distinguish between random and systematic errors, and estimate their effect on measured results; discuss how the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence from a range of sources 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, genres and modes, including scientific reports

Science as a Human Endeavour

Properties and structure of organic materials

The Protein Data Bank (PDB) houses an international repository of structural data of proteins. The information is accessed and contributed to by scientists worldwide. The function of a protein is closely linked to its structure.

Science Understanding

- organic molecules have a hydrocarbon skeleton and can contain functional groups, including alkenes, alcohols, aldehydes, ketones, carboxylic acids, esters, amines and amides; functional groups are groups of atoms or bonds within molecules which are responsible for the molecule’s characteristic chemical properties
- structural formulae (condensed or showing bonds) can be used to show the arrangement of atoms and bonding in organic molecules that contain the following functional groups: alkenes, alcohols, aldehydes, ketones, carboxylic acids, esters, amines and amides
- functional groups within organic compounds display characteristic chemical properties and undergo specific reactions; these reactions include addition reactions of alkenes, redox reactions of alcohols, and acid-base reactions of carboxylic acids; these reactions can be used to identify the functional group present within the organic compound

- IUPAC nomenclature is used to name organic species, including those with a parent chain of up to 8 carbon atoms with simple branching and one of the following functional groups: alkenes, alcohols, aldehydes, ketones, carboxylic acids, esters, amines and amides
- isomers are compounds with the same molecular formulae but different structures; different types of isomerism include chain and position structural isomerism and cis-trans isomerism
- all alcohols can undergo complete combustion; with oxidising agents, including acidified MnO_4^- or $Cr_2O_7^{2-}$ oxidation of primary alcohols produces aldehydes and carboxylic acids, while the oxidation of secondary alcohols produce ketones; these reactions have characteristic observations and can be represented with equations
- alcohols can react with carboxylic acids in a condensation reaction to produce esters and can be represented with equations
- organic compounds display characteristic physical properties, including boiling point and solubility in water and organic solvents; these properties can be explained in terms of intermolecular forces (dispersion forces, dipole-dipole interactions and hydrogen bonds) which are influenced by the nature of the functional groups
- empirical and molecular formulae can be determined by calculation and the structure of an organic compound established from the chemical reactions they undergo, and other analytical data
- addition reactions can be used to produce polymers, including polyethene and polytetrafluoroethene
- the structure of an addition polymer can be predicted from its monomer and the structure of an addition polymer can be used to predict the monomer from which it was derived
- condensation reactions can be used to produce polymers, including polyamides and polyesters
- the structure of a condensation polymer can be predicted and drawn from its monomer(s) and the structure of a condensation polymer can be used to predict the monomer(s) from which it was derived
- α-amino acids can be represented using a generalised structure
- the characteristic properties of α-amino acids include the formation of zwitterions and the ability to react to form amide (peptide) bonds through condensation reactions
- α-amino acids undergo condensation reactions to form polypeptides (proteins) in which the α-amino acid monomers are joined by peptide bonds
- the sequence of α-amino acids in a protein is called its primary structure
- secondary structures of proteins, (α-helix and β-pleated sheets) result from hydrogen bonding between amide and carbonyl functional groups; hydrogen bonding between amide and carbonyl functional groups within a peptide chain leads to α-helix structures while hydrogen bonding between adjacent polypeptide chains leads to β-pleated sheets
- the tertiary structure of a protein (the overall three-dimensional shape) is a result of folding due to interactions between the side chains of the α-amino acid in the polypeptide, including disulfide bridges, hydrogen bonding, dipole-dipole interactions, dispersion forces and ionic interactions

Science as a Human Endeavour

Chemical synthesis

Scientific knowledge can be used to design alternative chemical synthesis pathways, taking into account sustainability, local resources, economics and environmental impacts (green chemistry), including the production of ethanol and biodiesel.

Science Understanding

- chemical synthesis to form products with specific properties may require the construction of reaction sequences with more than one chemical reaction and involves the selection of particular reagents and reaction conditions in order to optimise the rate and yield of the product
- quantities of products in a chemical synthesis reaction can be calculated by comparing stoichiometric quantities with actual quantities and by determining the limiting reagent
- the percentage yield of a chemical synthesis reaction can be calculated by comparing theoretical versus actual product quantities
- reagents and reaction conditions are chosen to optimise yield and rate for chemical synthesis processes, including in the production of ammonia (Haber process), sulfuric acid (Contact process) and biodiesel (base-catalysed and lipase-catalysed methods)
- enzymes are protein molecules which are biological catalysts and can be used on an industrial scale to produce chemicals that would otherwise require high pressure or temperature conditions to achieve an economically viable rate, including fermentation to produce ethanol versus hydration of ethene
- chemical synthesis processes may involve the construction of reaction sequences with more than one chemical reaction, including the hydration of ethene to form ethanol and the subsequent reaction of ethanol with acetic (ethanoic) acid to produce ethyl ethanoate
- the base hydrolysis (saponification) of fats (triglycerides) produces glycerol and the salt of a long chain fatty acid (soap)
- the structure of soaps contains a non-polar hydrocarbon chain and a carboxylate group; the structure of the anionic detergents derived from dodecylbenzene contains a non-polar hydrocarbon chain and a sulfonate group
- the cleaning action of soaps and detergents can be explained in terms of their non-polar hydrocarbon chain and charged group; the properties of soaps and detergents in hard water can be explained in terms of the solubilities of their calcium salts
- industry produces a vast range of plastics, including addition polymers (polyethene, polytetrafluoroethene) and condensation polymers (nylon and polyethylene terephthalate [PET]) which have different properties and uses

School-based assessment

The Western Australian Certificate of Education (WACE) Manual contains essential information on principles, policies and procedures for school-based assessment that needs to be read in conjunction with this syllabus.

Teachers design school-based assessment tasks to meet the needs of students. The table below provides details of the assessment types for the Chemistry ATAR Year 12 syllabus and the weighting for each assessment type.

Assessment table – Year 12

Type of assessment	Weighting
Science inquiry Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting data; and communicating findings. **Practical** Practical work can involve a range of activities, such as practical tests; modelling and simulations; qualitative and/or quantitative analysis of second hand data; and brief summaries of practical activities. **Investigation** Investigations are more extensive activities, which can include experimental testing; chemical analyses; and comprehensive scientific reports. The assessed component of tasks of these types should be conducted in a supervised classroom setting. Students must complete at least one investigation over a pair of units.	20%
Extended response Tasks requiring an extended response can involve selecting and integrating appropriate science concepts, models and theories to explain and predict phenomena, and applying those concepts, models and theories to new situations; interpreting scientific and media texts and evaluating processes, claims and conclusions by considering the quality of available evidence; and using reasoning to construct scientific arguments. Assessment can take the form of answers to specific questions based on individual research, and interpretation and evaluation of chemical information in scientific journals, media texts and/or advertising. Appropriate strategies should be used to authenticate student achievement on an out-of-class assessment task. For example, research completed out of class can be authenticated using an in-class assessment task under test conditions.	10%
Test Tests typically consist of multiple choice questions, and questions requiring short and extended answers. This assessment type is conducted in supervised classroom settings.	20%
Examination Typically conducted at the end of each semester and/or unit and reflecting the examination design brief for this syllabus.	50%

Teachers are required to use the assessment table to develop an assessment outline for the pair of units.

The assessment outline must:

- include a set of assessment tasks
- include a general description of each task
- indicate the unit content to be assessed
- indicate a weighting for each task and each assessment type
- include the approximate timing of each task (for example, the week the task is conducted, or the issue and submission dates for an extended task).

In the assessment outline for the pair of units, each assessment type must be included at least twice.

The set of assessment tasks must provide a representative sampling of the content for Unit 3 and Unit 4.

Assessment tasks not administered under test/controlled conditions require appropriate validation/authentication processes.

Grading

Schools report student achievement in terms of the following grades:

Grade	Interpretation
A	Excellent achievement
B	High achievement
C	Satisfactory achievement
D	Limited achievement
E	Very low achievement

The teacher prepares a ranked list and assigns the student a grade for the pair of units. The grade is based on the student's overall performance as judged by reference to a set of pre-determined standards. These standards are defined by grade descriptions and annotated work samples. The grade descriptions for the Chemistry ATAR Year 12 syllabus are provided in Appendix 1. They can also be accessed, together with annotated work samples, through the Guide to Grades link on the course page of the Authority website at www.scsa.wa.edu.au

To be assigned a grade, a student must have had the opportunity to complete the education program, including the assessment program (unless the school accepts that there are exceptional and justifiable circumstances).

Refer to the WACE Manual for further information about the use of a ranked list in the process of assigning grades.

ATAR course examination

All students enrolled in the Chemistry ATAR Year 12 course are required to sit the ATAR course examination. The examination is based on a representative sampling of the content for Unit 3 and Unit 4. Details of the ATAR course examination are prescribed in the examination design brief on the following page.

Refer to the WACE Manual for further information.

Examination design brief – Year 12

Time allowed

Reading time before commencing work: ten minutes

Working time for paper: three hours

Permissible items

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination

Provided by the supervisor

A Chemistry data booklet

Additional information

The weighting of calculations in the examination is within the range 15–20%. Calculations are included in Section Two and Section Three.

Instructions to the candidate state: When calculating numerical answers, the candidate must show working or reasoning clearly. Numerical answers should be expressed to the appropriate number of significant figures and include units where applicable.

Section	Supporting information
Section One **Multiple-choice** 25% of the total examination 25 questions Suggested working time: 50 minutes	Nil
Section Two **Short answer** 35% of the total examination 8–12 questions Suggested working time: 60 minutes	The questions can require the candidate to respond with equations, descriptions, short calculations, diagrams, tables, graphs and/or flow charts.
Section Three **Extended answer** 40% of the total examination 5–7 questions Suggested working time: 70 minutes	Each question has parts and is based on a scenario. Stimulus materials for scenarios can take the form of technical or historical passages or experimental data, and can include images, diagrams, graphs and/or charts. Questions can require the candidate to respond with written responses, multi-step calculations or flowcharts, either singly or in combination.

Appendix 1 – Grade descriptions Year 12

A	**Understanding and applying concepts** Applies chemical models and principles to comprehensively and consistently explain complex phenomena. Supports responses with a range of appropriate examples and diagrams or structures that clearly represent concepts. For example action of soap, and electrochemical cells. Clearly links multiple concepts to explain relationships in detail with support of relevant examples and equations. For example, selection of indicators based on any hydrolysis of ions at the equivalence point. Accurately applies scientific knowledge to explain, in detail, unfamiliar contexts or examples. Selects and accurately evaluates scientific information from a variety of sources to present logical, well-developed responses which are supported by relevant, detailed evidence. Applies mathematical procedures that may involve rearranging formulae to solve complex problems. Performs multiple-step calculations accurately, expressing answers consistently using correct units and significant figures.
	Science inquiry skills Formulates a hypothesis that states the relationship between dependent and independent variables. Designs investigations to identify dependent and independent variables, and control appropriate variables. Describes the experimental method in detail and accurately collects data. Organises data logically and accurately processes data. Present~~s~~ data in a range of forms, including graphs, tables and charts to reveal patterns and relationships. Comprehensively explains trends using data, including numerical data when appropriate, as evidence to draw conclusions that relate to the hypothesis. Evaluates the experimental method and provides specific relevant suggestions to improve the validity and reliability of the data collected. Correctly identifies and distinguishes between systematic and random errors. Communicates detailed and relevant information and concepts logically and coherently, using correct terminology and appropriate conventions.

B	**Understanding and applying concepts** Applies chemical models and principles to accurately explain simple, and some complex, phenomena. Supports responses with appropriate examples and diagrams or structures that represent concepts. Presents explanations of concepts, for example properties of substances and systems, logically and/or sequentially, with some provision of supporting examples and equations. Applies scientific knowledge to explain unfamiliar contexts or examples, sometimes lacking detail. Selects and evaluates scientific information from a variety of sources to present logical responses which are supported by relevant evidence. Applies mathematical procedures that may involve rearranging formulae to solve straightforward, and some complex, problems. Solves multiple-step calculations using correct units and significant figures with only minor inaccuracies.
	Science inquiry skills Formulates a hypothesis that states the relationship between dependent and independent variables. Designs investigations to identify dependent and independent variables, and control appropriate variables. Describes the experimental method and accurately collects data. Organises data logically and usually processes data accurately. Presents data in a range of forms, including graphs, tables and charts to reveal patterns and relationships. Explains trends using some numerical data, where appropriate, and uses evidence to draw conclusions that relate to the hypothesis. Evaluates the experimental method and provides relevant suggestions to improve the validity and reliability of the data collected. Correctly identifies and distinguishes between systematic and random errors. Communicates information and concepts logically, using correct terminology and appropriate conventions.

C	**Understanding and applying concepts** Applies chemical models and principles on some occasions to describe simple phenomena. Provides examples in some responses. Draws simple diagrams or structures that lack detail. Explains simple cause and effect such as increasing boiling points for homologues series of hydrocarbons due to increase in strength of dispersion forces. Links concepts at a superficial level only. Responses lack detail and may include irrelevant information. Provides responses to unfamiliar contexts which are generic and lack specific application of scientific knowledge. Selects some scientific information to provide generalised responses or statements supported by some evidence. Applies mathematical procedures to solve straightforward problems. Selects formulae to solve straightforward problems. Provides working which is limited or unclear.
	Science inquiry skills Provides a statement that links dependent and independent variables without giving their relationship. Designs investigations to identify and control some variables, briefly outlines the experimental method and collects data. Organises and processes data with some errors or omissions. Presents data using basic tables and appropriate graphs. Describes trends in the data and draws simple conclusions that may not be linked back to the hypothesis. Provides general suggestions to improve the investigation. Identifies errors but does not consistently distinguish errors as systematic or random. Communicates information and concepts in general terms, using some correct terminology and appropriate conventions.

D	**Understanding and applying concepts** Inconsistently applies chemical models and principles to describe properties and phenomena. Selects poor examples or omits examples. Presents diagrams or structures that are incomplete or incorrect. Links cause and effect in simple situations. Shows limited recall of facts. Responses contain multiple errors, inconsistencies, misconceptions and do not address the key elements of the question. Inconsistently applies principles to familiar and unfamiliar contexts. Presents statements of ideas with limited development of a response. Provides limited supporting evidence. Performs simple calculations with errors and omissions. Provides working out which is confused and lacks the use of appropriate units and significant figures.
	Science inquiry skills Provides a statement that identifies one or more relevant variables without making links between them. Identifies a limited number of controlled variables. Does not distinguish between the dependent, independent and controlled variables. Describes an experimental method which lacks detail. Presents data that is unclear, insufficient and lacks appropriate processing. Inconsistently identifies errors and expresses them in general terms with limited relevance. Communicates information using everyday language with frequent errors in the use of conventions.

E	Does not meet the requirements of a D grade and/or has completed insufficient assessment tasks to be assigned a higher grade.

Appendix 2

Students should be able to recognise and write the formula of the following ions and molecules:

Ion name	Formula
ammonium	NH_4^+
caesium	Cs^+
hydrogen	H^+
lithium	Li^+
potassium	K^+
rubidium	Rb^+
silver	Ag^+
sodium	Na^+
barium	Ba^{2+}
calcium	Ca^{2+}
cobalt(II)	Co^{2+}
copper(II)	Cu^{2+}
iron(II)	Fe^{2+}
lead(II)	Pb^{2+}
magnesium	Mg^{2+}
manganese(II)	Mn^{2+}
nickel(II)	Ni^{2+}
strontium	Sr^{2+}
zinc	Zn^{2+}
aluminium	$A\ell^{3+}$
chromium(III)	Cr^{3+}
iron(III)	Fe^{3+}

Ion name	Formula
bromide	Br^-
chloride	$C\ell^-$
cyanide	CN^-
dihydrogenphosphate	$H_2PO_4^-$
ethanoate (acetate)	CH_3COO^-
fluoride	F^-
hydrogencarbonate	HCO_3^-
hydrogensulfate	HSO_4^-
hydroxide	OH^-
iodide	I^-
nitrate	NO_3^-
nitrite	NO_2^-
permanganate	MnO_4^-
carbonate	CO_3^{2-}
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
hydrogenphosphate	HPO_4^{2-}
oxalate	$C_2O_4^{2-}$
oxide	O^{2-}
sulfate	SO_4^{2-}
sulfide	S^{2-}
sulfite	SO_3^{2-}
nitride	N^{3-}
phosphate	PO_4^{3-}

Common molecules that have non-systematic names:

Molecule name	Formula
ammonia	NH_3
water	H_2O
hydrogen peroxide	H_2O_2
ethanoic acid	CH_3COOH
hydrochloric acid	$HC\ell$
nitric acid	HNO_3

carbonic acid	H_2CO_3
sulfuric acid	H_2SO_4
sulfurous acid	H_2SO_3
phosphoric acid	H_3PO_4

Appendix 3 – Glossary

This glossary is provided to enable a common understanding of the key terms in this syllabus.

Algebraic representation	A set of symbols linked by mathematical operations; the set of symbols summarise relationships between variables.
Anomalous data	Data that does not fit a pattern; outlier.
Data	The plural of datum; the measurement of an attribute, for example, the volume of gas or the type of rubber. This does not necessarily mean a single measurement: it may be the result of averaging several repeated measurements. Data may be quantitative or qualitative and be from primary or secondary sources.
Evidence	In science, evidence is data that is considered reliable and valid and which can be used to support a particular idea, conclusion or decision. Evidence gives weight or value to data by considering its credibility, acceptance, bias, status, appropriateness and reasonableness.
Genre	The categories into which texts are grouped; genre distinguishes texts on the basis of their subject matter, form and structure (for example, scientific reports, field guides, explanations, procedures, biographies, media articles, persuasive texts, narratives).
Green chemistry	Chemistry that aims to design products and processes that minimise the use and generation of hazardous substances and wastes. Principles of green chemistry include prevention of waste; atom economy; design of less toxic chemicals and synthesis methods; use of safer solvents and auxiliaries; design for energy efficiency; use of renewable feedstocks; reduction of unnecessary derivatives; use of catalytic reagents rather than stoichiometric reagents; design for degradation; design of in-process analysis for pollution prevention; and safer chemistry for accident prevention.
Hypothesis	A scientific statement based on the available information that can be tested by experimentation. When appropriate, the statement expresses an expected relationship between the independent and dependent variables for observed phenomena.
Investigation	A scientific process of answering a question, exploring an idea or solving a problem that requires activities such as planning a course of action, collecting data, interpreting data, reaching a conclusion and communicating these activities. Investigations can include observation, research, field work, laboratory experimentation and manipulation of simulations.
Law	A statement describing invariable relationships between phenomena in specified conditions, frequently expressed mathematically.
Measurement error	The difference between the measurement result and a currently accepted or standard value of a quantity.
Media texts	Spoken, print, graphic or electronic communications with a public audience. Media texts can be found in newspapers, magazines and on television, film, radio, computer software and the internet.
Mode	The various processes of communication – listening, speaking, reading/viewing and writing/creating.
Model	A representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea.
Primary data	Data collected directly by a person or group.
Primary source	Report of data created by the person or persons directly involved in observations of one or more events, experiments, investigations or projects.

Random error	Uncontrollable effects of the measurement equipment, procedure and environment on a measurement result; the magnitude of random error for a measurement result can be estimated by finding the spread of values around the average of independent, repeated measurements of the quantity.
Reliable data	Data that has been judged to have a high level of reliability; reliability is the degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute, achieving similar results for the same population.
Reliability	The degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute, achieving similar results for the same population.
Representation	A verbal, visual, physical or mathematical demonstration of understanding of a science concept or concepts. A concept can be represented in a range of ways and using multiple modes.
Research	To locate, gather, record, attribute and analyse information in order to develop understanding.
Research ethics	Norms of conduct that determine ethical research behavior; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics.
Risk assessment	Evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities. Requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate.
Secondary data	Data collected by a person or group other than the person or group using the data.
Secondary source	Information that has been compiled from records of primary sources by a person or persons not directly involved in the primary event.
Significant figures	The use of place value to represent a measurement result accurately and precisely.
Simulation	A representation of a process, event or system which imitates a real or idealised situation.
System	A group of interacting objects, materials or processes that form an integrated whole. Systems can be open or closed.
Systematic error	The contribution to the uncertainty in a measurement result that is identifiable and quantifiable, for example, imperfect calibration of measurement instruments.
Theory	A set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena. Theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power.
Uncertainty	Range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment.
Validity	The extent to which tests measure what was intended; the extent to which data, inferences and actions produced from tests and other processes are accurate.