Government of Western Australia
School Curriculum and Standards Authority

# CHEMISTRY

## ATAR COURSE

Year 11 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. Chemistry 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 Chemistry 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

The Chemistry ATAR course 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 11 syllabus is divided into two units, each of one semester duration, which are typically delivered as a pair. The notional time for each unit is 55 class contact hours.

### Unit 1 – Chemical fundamentals: structure, properties and reactions

In this unit, students use models of atomic structure and bonding to explain the macroscopic properties of materials. Students develop their understanding of the energy changes associated with chemical reactions and the use of chemical equations to calculate the masses of substances involved in chemical reactions.

### Unit 2 – Molecular interactions and reactions

In this unit, students continue to develop their understanding of bonding models and the relationship between structure, properties and reactions, including consideration of the factors that affect the rate of chemical reactions. Students investigate the unique properties of water and the properties of acids and bases, and use chemical equations to calculate the concentrations and volumes of solutions involved in chemical reactions.

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 ATAR 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 ATAR 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 ATAR 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

Science 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 ATAR 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.

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 $<$, $>$, $\Delta$, $\approx$
- 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.

## Progression from the Year 7–10 curriculum

This syllabus continues to develop student understanding and skills from across the three strands of the Year 7–10 Science curriculum. In the Science Understanding strand, this syllabus draws on knowledge and understanding from across the four sub-strands of Biological, Physical, Chemical and Earth and Space Sciences.

In particular, this syllabus continues to develop the key concepts introduced in the Chemical Sciences sub-strand, that is, that the chemical and physical properties of substances are determined by their structure at an atomic scale; and that substances change and new substances are produced by the rearrangement of atoms through atomic interactions and energy transfer.

## 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 the Chemistry ATAR course.

### 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 the Chemistry ATAR course, 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 the Chemistry ATAR course.

## 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 the Chemistry ATAR course, the Sustainability cross-curriculum priority provides authentic contexts for exploring, investigating and understanding the function and interactions of chemical systems. The course 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 1 – Chemical fundamentals: structure, properties and reactions

## Unit description

Chemists design and produce a vast range of materials for many purposes, including for fuels, cosmetics, building materials and pharmaceuticals. As the science of chemistry has developed over time, there has been an increasing realisation that the properties of a material depend on, and can be explained by, the material's structure. A range of models at the atomic and molecular scale enable explanation and prediction of the structure of materials and how this structure influences properties and reactions. In this unit, students relate matter and energy in chemical reactions as they consider the breaking and reforming of bonds as new substances are produced. Students can use materials that they encounter in their lives as a context for investigating the relationships between structure and properties.

Through the investigation of appropriate contexts, students explore how evidence from multiple disciplines and individuals have contributed to developing understanding of atomic structure and chemical bonding. 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 science inquiry skills to develop their understanding of patterns in the properties and composition of materials. They investigate the structure of materials by describing physical and chemical properties at the macroscopic scale, and use models of structure and primary bonding at the atomic and sub-atomic scale to explain these properties. They are introduced to the mole concept as a means of quantifying matter in chemical reactions.

## Learning outcomes

By the end of this unit, students:

- understand how the atomic model and models of bonding explain the structure and properties of elements and compounds
- understand the concept of enthalpy, and apply this to qualitatively and quantitatively describe and explain energy changes in chemical reactions
- 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 of elements, compounds and mixtures and the energy changes involved in 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 includes the knowledge, understandings and skills described below.

### Science Inquiry Skills

- identify, research 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: the use of devices to accurately measure temperature change and mass, flame tests, separation techniques and heat of reaction
- 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 and estimate their effect on measurement 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

**Properties and structure of atoms**

Findings from a range of scientific experiments contributed to the understanding of the atom, enabling scientists, including Dalton, Thomson, Rutherford, Bohr and Chadwick to develop models of atomic structure and make reliable predictions about the mass, charge and location of the sub-atomic particles.

### Science Understanding

- elements are represented by symbols
- atoms can be modelled as a nucleus, surrounded by electrons in distinct energy levels, held together by electrostatic forces of attraction between the nucleus and electrons; the location of electrons within atoms can be represented using electron configurations
- the ability of atoms to form chemical bonds can be explained by the arrangement of electrons in the atom and in particular by the stability of the valence electron shell
- the structure of the periodic table is based on the atomic number and the properties of the elements
- the elements of the periodic table show trends across periods and down main groups, including in atomic radii, valencies, 1$^{st}$ ionisation energy and electronegativity as exemplified by groups 1, 2, 13–18 and period 3

- flame tests and atomic absorption spectroscopy (AAS) are analytical techniques that can be used to identify elements; these methods rely on electron transfer between atomic energy levels and are shown by line spectra
- isotopes are atoms of an element with the same number of protons but different numbers of neutrons and are represented in the form $^{A}X$ (IUPAC) or X-A
- isotopes of an element have the same electron configuration and possess similar chemical properties but have different physical properties
- the relative atomic mass (atomic weight), $A_r$ is the ratio of the average mass of the atom to 1/12 the mass of an atom of $^{12}C$; relative atomic masses of the elements are calculated from their isotopic composition
- mass spectrometry involves the ionisation of substances and the separation and detection of the resulting ions; the spectra which are generated can be analysed to determine the isotopic composition of elements and interpreted to determine relative atomic mass

## Science as a Human Endeavour

**Properties and structure of materials**

Matter at the nanoscale can be manipulated to create new materials, composites and devices; the different characteristics of nanomaterials can be used to provide commercially available products. As products are designed on the basis of properties which are different from the bulk material, their use can be associated with potential risks to health, safety and the environment and this has led to regulations being developed to address new and existing nanoform materials.

## Science Understanding

- materials are pure substances with distinct measurable properties, including melting and boiling points, reactivity, hardness and density; or mixtures with properties dependent on the identity and relative amounts of the substances that make up the mixture
- pure substances may be elements or compounds which consist of atoms of two or more elements chemically combined; the formulae of compounds indicate the relative numbers of atoms of each element in the compound
- nanomaterials are substances that contain particles in the size range 1–100 nm and have specific properties relating to the size of these particles which may differ from those of the bulk material
- differences in the physical properties of substances in a mixture, including particle size, solubility, density, and boiling point, can be used to separate them
- the type of bonding within ionic, metallic and covalent substances explains their physical properties, including melting and boiling points, conductivity of both electricity and heat and hardness
- chemical bonds are caused by electrostatic attractions that arise because of the sharing or transfer of electrons between participating atoms; the valency is a measure of the bonding capacity of an atom

- ions are atoms or groups of atoms that are electrically charged due to a loss or gain of electrons; ions are represented by formulae which include the number of constituent atoms and the charge of the ion (for example, $O^{2-}$, $SO_4^{2-}$)
- ionic bonding can be modelled as a regular arrangement of positively and negatively charged ions in a crystalline lattice with electrostatic forces of attraction between oppositely charged ions
- the ionic bonding model can be used to explain the properties of ionic compounds, including high melting point, brittleness and non-conductivity in the solid state; the ability of ionic compounds to conduct electricity when molten or in aqueous solution can be explained by the breaking of the bonds in the lattice to give mobile ions
- the formulae of ionic compounds can be determined from the charges on the relevant ions (refer to Appendix 2)
- metallic bonding can be modelled as a regular arrangement of atoms with electrostatic forces of attraction between the nuclei of these atoms and their delocalised electrons that are able to move within the three dimensional lattice
- the metallic bonding model can be used to explain the properties of metals, including malleability, thermal conductivity, generally high melting point and electrical conductivity; covalent bonding can be modelled as the sharing of pairs of electrons resulting in electrostatic forces of attraction between the shared electrons and the nuclei of adjacent atoms
- the properties of covalent network substances, including high melting point, hardness and electrical conductivity, are explained by modelling covalent networks as three-dimensional structures that comprise covalently bonded atoms
- elemental carbon exists as a range of allotropes, including graphite, diamond and fullerenes, with significantly different structures and physical properties
- the properties of covalent molecular substances, including low melting point, can be explained by their structure and the weak intermolecular forces between molecules; their non-conductivity in the solid and liquid/molten states can be explained by the absence of mobile charged particles in their molecular structure
- molecular formulae represent the number and type of atoms present in the molecules (refer to Appendix 2)
- percentage composition of a compound can be calculated from the relative atomic masses of the elements in the compound and the formula of the compound
- hydrocarbons, including alkanes, alkenes and benzene, have different chemical properties that are determined by the nature of the bonding within the molecules
- molecular structural formulae (condensed or showing bonds) can be used to show the arrangement of atoms and bonding in covalent molecular substances
- IUPAC nomenclature is used to name straight and simple branched alkanes and alkenes from $C_1$- $C_8$
- alkanes, alkenes and benzene undergo characteristic reactions such as combustion, addition reactions for alkenes and substitution reactions for alkanes and benzene

## Science as a Human Endeavour

**Chemical reactions: reactants, products and energy change**

There are differences in the energy output and carbon emissions of fossil fuels (including coal, oil, petroleum and natural gas) and biofuels (including biogas, biodiesel and bioethanol). These differences, together with social, economic, cultural and political values, determine how widely these fuels are used.

## Science Understanding

- chemical reactions can be represented by chemical equations; balanced chemical equations indicate the relative numbers of particles (atoms, molecules or ions) that are involved in the reaction
- chemical reactions and phase changes involve enthalpy changes, commonly observable as changes in the temperature of the surroundings and/or the emission of light
- endothermic and exothermic reactions can be explained in terms of the Law of Conservation of Energy and the breaking of existing bonds and forming of new bonds; heat energy released or absorbed by the system to or from the surroundings, can be represented in thermochemical equations
- fossil fuels (including coal, oil, petroleum and natural gas) and biofuels (including biogas, biodiesel and bioethanol) can be compared in terms of their energy output, suitability for purpose, and the nature of products of combustion
- the mole is a precisely defined quantity of matter equal to Avogadro’s number of particles
- the mole concept relates mass, moles and molar mass and, with the Law of Conservation of Mass; can be used to calculate the masses of reactants and products in a chemical reaction

# 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

- 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

- 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
- the valence shell electron pair repulsion (VSEPR) theory and Lewis structure diagrams can be used to explain, predict and draw the shapes of molecules

- the polarity of molecules can be explained and predicted using knowledge of molecular shape, understanding of symmetry, and comparison of the electronegativity of atoms involved in the bond formation
- 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
- 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 of the interactions between atoms, molecules or ions in the mobile and stationary phases
- the behaviour of an ideal gas, including the qualitative relationships between pressure, temperature and volume, can be explained using the Kinetic Theory
- 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

## 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

- 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
- 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 (mol $L^{-1}$) and the mass of the solute per litre of solution (g $L^{-1}$) or parts per million (ppm)
- 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
- 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
- the Arrhenius model can be used to explain the behaviour of strong and weak acids and bases in aqueous solutions
- indicator colour and the pH scale are used to classify aqueous solutions as acidic, basic or neutral

- pH is used as a measure of the acidity of solutions and is dependent on the concentration of hydrogen ions in the solution
- 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 reactants; ionic equations represent the reacting species and products in these reactions
- the mole concept can be used to calculate the mass of solute, and solution concentrations and volumes involved in a chemical reaction

## 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

- varying the conditions under which chemical reactions occur can affect the rate of the reaction
- the rate of chemical reactions can be quantified by measuring the rate of formation of products or the depletion of reactants
- 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
- 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
- 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
- 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

# 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 11 syllabus and the weighting for each assessment type.

### Assessment table – Year 11

| Type of assessment | Weighting |
|---|---|
| **Science inquiry**<br>Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting data; and communicating findings.<br>**Practical**<br>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.<br>**Investigation**<br>Investigations are more extensive activities, which can include experimental testing; chemical analyses; and comprehensive scientific reports.<br>The assessed component of tasks of these types should be conducted in a supervised classroom setting.<br>Students must complete at least one investigation in each unit. | 25% |
| **Extended response**<br>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.<br>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.<br>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**<br>Tests are structured tasks designed so that students can apply their understanding and skills in chemistry to analyse, interpret, solve problems and construct scientific arguments. | 15% |
| **Examination**<br>Typically conducted at the end of each semester and/or unit. In preparation for Unit 3 and Unit 4, the examination should reflect the examination design brief included in the ATAR Year 12 syllabus for this course. | 50% |

Teachers are required to use the assessment table to develop an assessment outline for the pair of units (or for a single unit where only one is being studied).

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. In the assessment outline where a single unit is being studied, each assessment type must be included at least once.

The set of assessment tasks must provide a representative sampling of the content for Unit 1 and Unit 2.

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 (or for a unit where only one unit is being studied). 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 11 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.

# Appendix 1 – Grade descriptions Year 11

| | |
|---|---|
| **A** | **Understanding and applying concepts**<br>Applies chemical models and principles to accurately explain complex phenomena in detail, for example factors affecting reaction rates, and strengths of intermolecular forces.<br>Clearly links multiple concepts to explain relationships in detail, for example molecular polarity with bond polarity.<br>Applies models to explain, in detail, the properties of substances and systems.<br>Accurately applies scientific knowledge to the specifics of unfamiliar contexts or examples.<br>Selects, evaluates and uses scientific information from a variety of sources, including chemical formulae and balanced equations to solve problems and to support a point of view.<br>Applies mathematical procedures that may involve rearranging formulae to solve complex problems.<br>Performs multiple-step calculations accurately using correct units and significant figures. |
| | **Science Inquiry Skills**<br>Formulates a testable hypothesis that states the relationship between dependent and independent variables.<br>Designs investigations to identify dependent and independent variables, and control appropriate variables. Describes the experimental method in detail and accurately collects data.<br>Processes data accurately and provides relevant suggestions to improve its validity and reliability.<br>Organises data logically and presents it in a range of forms, including graphs, tables and charts to reveal patterns and relationships.<br>Explains trends using data, including numerical data when appropriate, as evidence to draw conclusions that relate to the hypothesis.<br>Communicates detailed and relevant information and concepts logically and coherently, using correct terminology and appropriate conventions. |

| | |
|---|---|
| **B** | **Understanding and applying concepts**<br>Applies chemical models and principles to accurately explain simple, and some complex, phenomena.<br>Presents explanations of concepts logically and/or sequentially, with some provision of supporting examples.<br>Applies models to explain the properties of substances and systems using diagrams where appropriate, for example linking the physical properties of substances to their bonding types.<br>Applies scientific knowledge to unfamiliar contexts or examples, sometimes lacking detail.<br>Selects, evaluates and uses scientific information, including chemical formulae and balanced equations to solve problems and present a point of view.<br>Applies mathematical procedures that may involve rearranging formulae to solve straightforward, and some complex, problems.<br>Solves multistep calculations using correct units and significant figures with only minor inaccuracies. |
| | **Science Inquiry Skills**<br>Formulates a testable hypothesis that states the relationship between dependent and independent variables.<br>Designs investigations to identify dependent and independent variables, and control appropriate variables. Describes the experimental method and accurately collects data.<br>Processes data and suggests ways to improve its validity and reliability. Presents data in a range of forms, including graphs, tables and charts to reveal patterns and relationships.<br>Describes trends and uses evidence to draw conclusions that relate to the hypothesis.<br>Communicates detailed information and concepts logically, using correct terminology and appropriate conventions. |

| | |
|---|---|
| **C** | **Understanding and applying concepts**<br>Applies chemical models and principles on some occasions to describe some phenomena.<br>Presents arguments or statements supported by some evidence. Develops responses which lack detail and may include irrelevant information.<br>Describes trends or relationships.<br>Describes properties of substances and systems.<br>Develops responses to unfamiliar contexts which are generic and lack specific application of scientific knowledge.<br>Selects some scientific information to solve straightforward problems.<br>Selects formulae to solve straightforward problems. Provides working which is limited or unclear. |
| | **Science Inquiry Skills**<br>Formulates a testable hypothesis that links dependent and independent variables.<br>Designs investigations to identify and control some variables, briefly outlines the experimental method and collects data.<br>Processes data and makes general suggestions for improving the investigation. Presents data using basic tables and graphs.<br>Describes trends in the data and draws simple conclusions that may not be linked back to the hypothesis.<br>Communicates information and concepts, without detail, using some correct terminology and appropriate conventions. |

| | |
|---|---|
| **D** | **Understanding and applying concepts**<br>Incorrectly applies chemical models and principles to describe properties and phenomena.<br>Presents statements of ideas with limited development of an argument and little use of evidence. Links cause and effect in limited/simple situations.<br>Describes properties of substances and systems with some irrelevant or incorrect information.<br>Inconsistently applies principles to unfamiliar contexts.<br>Makes little use of scientific information to solve straightforward problems.<br>Inconsistently solves simple calculations. |
| | **Science Inquiry Skills**<br>Provides a statement that identifies one or more relevant variables without making links between them.<br>Identifies a limited number of controlled variables.  Does not distinguish between the dependent, independent and controlled variables. Describes a method which lacks detail.<br>Presents data that is unclear, insufficient and lacks appropriate processing. Includes anomalous results in the data without identifying them as anomalous.<br>Identifies trends in the data incorrectly or overlooks trends.<br>Offers simple conclusions that are not supported by the data or are not related to the hypothesis.<br>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. |