Science

Chemistry

Rationale and aims

Rationale

The senior secondary Chemistry curriculum encompasses the three interrelated areas of science inquiry skills (incorporating skills and understanding of science as a way of knowing and doing), science as a human endeavour (incorporating knowledge and understanding of the personal, social, environmental, cultural and historical significance and relevance of science), and science understanding (incorporating knowledge and understanding of the biological, physical, and earth and space sciences). Building on students' science knowledge and skills acquired up to Year 10, the senior secondary Chemistry curriculum enables students to explore further chemical concepts, laws, principles and theories and their relevance to their everyday lives, and to solve problems and make evidence-based decisions related to present and future challenges. Chemistry involves the exploration and understanding of the nature of matter and chemical reactions. Many of the opportunities and challenges facing Australia, including measuring and controlling environmental impacts, the sustainability of resource use and the production of new and innovative products, involve chemistry. Chemists work in a variety of fields, including medicine, mining, pharmaceutics, manufacturing and forensic science.

Aims

The aim of the senior secondary Chemistry curriculum is to provide students with a solid foundation in science knowledge, understanding, skills and values on which further learning and adult life can be built. Students should be able to:

- draw on their curiosity and willingness to speculate about and explore the world to expand their interest in chemistry
- plan and undertake practical and other research investigations involving collection, collation and analysis of qualitative and quantitative data, interpretation of experimental outcomes and the use of models and simulations to visualise, explore and explain events
- engage in communication of and about chemistry, value evidence and scepticism, and critically evaluate the scientific claims made by others
- solve problems, and make informed, responsible and ethical decisions when considering local and global issues and applications of chemical concepts, techniques and technologies in daily life
- appreciate chemistry as both an independent and a collaborative human endeavour
- develop in-depth knowledge, understanding, skills and scientific values relating to chemistry
- appreciate the changing and expanding body of contemporary knowledge in chemistry.

Organisation

Content structure

The senior secondary Chemistry curriculum is organised around three interrelated strands: Science inquiry skills, Science as a human endeavour, and Science understanding.

Science inquiry skills

Scientific inquiry involves posing questions; formulating testable hypotheses; planning, conducting and critiquing investigations; collecting, analysing and interpreting evidence; and communicating findings. This strand is concerned with investigating ideas, evaluating claims, solving problems, drawing valid conclusions and developing evidence-based arguments. It also recognises that scientific explanations change as new or different evidence becomes available.

Science as a human endeavour

Science influences society through posing and responding to social and ethical issues, and science research is influenced by societal challenges or social priorities. This strand highlights the need for informed, evidence-based decision-making about current and future applications of science. It acknowledges that, in making decisions about science and its practices, moral, ethical and social implications must be taken into account. This strand also acknowledges that science has been advanced through, and is open to, the contributions of many different people from different cultures at different times in history. It identifies the historical aspects of science as well as contemporary science issues and activities, and that science offers rewarding career paths.

Science understanding

An understanding of science is evident when a person selects and integrates appropriate science knowledge in ways that explain and predict phenomena, and applies that knowledge to new situations and events. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established and continue to be challenged and refined by scientists over time. Science knowledge represents the building blocks of science understanding, but it is the dynamic nature of science understanding that will benefit citizens in an ever-changing world.

Links to K−10

The senior secondary Chemistry curriculum builds on the science knowledge and skills developed by students in Science up to the end of Year 10 and extends their learning in the K−10 biological, physical and earth sciences. The three organisational strands in Science K--−10, *Science understanding*, *Science as a human endeavour* and *Science inquiry skills* are continued into the senior secondary Chemistry curriculum. As with the Years K−10 science course, it is expected that teachers are able to show connections across these three strands in the exploration of chemical ideas, concepts and principles. The inquiry approach to science fostered throughout Years K−10 is strengthened in the senior years, with students formulating hypotheses generated from their own questions, and investigating and reporting on these. They also undertake an extended experimental investigation to explore an aspect of chemistry in depth.

Pathways

The senior secondary Chemistry curriculum provides pathways for students wishing to pursue further studies or those wishing to enter the workforce. While students may choose to specialise in chemistry, synergies between the four senior science courses provide opportunities for students to pursue multidisciplinary areas of science in addition to studying specific concepts through different discipline lenses. Concurrent study of Chemistry and Biology enhances students' understanding of various biochemical processes, for example enzyme function, bioenergetics and pharmaceutical development. Concurrent study of Chemistry and Earth and Environmental Science enables students to evaluate evidence for varying scientific viewpoints and theories, and enhance their decision-making capacity related to issues of local concern, for example monitoring environmental change, rate of change of chemical reactions occurring in the environment, and sustainability of natural resources. The concurrent study of Chemistry and Physics provides opportunities for students to engage in creative problem-solving relating to issues in society, for example enhancing efficiencies of energy conversions, developing novel ways of conserving energy in local and global applications, using the spectroscopic analysis of light emitted by distant stars to predict the nature of matter in the universe and using nuclear reactions as alternative energy sources.

In addition to providing pathways for further study or employment, the senior secondary Chemistry curriculum provides opportunities for all students to develop an understanding of chemical concepts and principles which will enable them to become more informed citizens who are able to make evidence-based decisions about the science-related issues which arise in their lives.

Unit structure

Content of the senior secondary Chemistry curriculum is outlined below:

Unit 1: Chemical patterns and reactions

In this unit, students will use an inquiry approach to investigate and develop their understanding of patterns in the structure and behaviour of materials, and the mechanisms and applications of chemical reactions.

This will include the study of: atomic theory and its applications; the organisation of elements in the periodic table based on their electronic structure; mechanisms and applications of chemical bonding; general types of chemical reactions and their uses; energy in chemical reactions; and factors affecting the rates of chemical reactions.

Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 2: Chemicals in the environment

In this unit, students will use an inquiry approach to investigate and develop their understanding of the physical and chemical properties of chemicals in the environment.

This will include the study of: the interrelationships between the structure, properties and uses of materials; properties of water and aqueous solutions; properties, behaviour and measurement of gases; and reactions of hydrocarbons and their uses.

Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 3: Using chemical processes

In this unit, students will use an inquiry approach to investigate and develop their understanding of chemical equilibrium and its applications in controlling chemical processes.

This will include the study of: concepts and applications of chemical equilibrium; reactions and uses of acids and bases; redox reactions and their uses; and concepts and applications of electrochemistry.

Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 4: Chemical analysis and synthesis

In this unit, students will use an inquiry approach to investigate and develop their understanding of the analysis and synthesis of useful materials in society.

This will include the study of: the interrelationships between the structure, properties and uses of organic materials; analytical techniques and chemical synthesis.

Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

General capabilities

The Australian Curriculum, Assessment and Reporting Authority (ACARA) has identified 10 general capabilities that will be specifically covered in the curriculum. In the senior secondary Chemistry curriculum, eight of these are considered inherent to science and so are explicitly included in the content descriptions and achievement standards. These are literacy, numeracy, information and communication technologies (ICT), thinking skills, creativity, teamwork, ethical behaviour and self-management. Each of these is embedded in the content descriptions of the Science inquiry skills strand and many are also incorporated into the Science as a human endeavour strand.

Literacy is an important capability in chemistry. Students will use and interpret the language of chemistry, including symbols, formulas, specific measurements of quantities, and chemical equations. They will be required to communicate their knowledge within and beyond the chemistry community, selecting and using formats appropriate to a purpose and audience, including written texts, multimodal representations and oral presentations. They will access, critically read, and extract information related to chemistry from a variety of sources, and acknowledge these sources appropriately.

Numeracy knowledge and skills are used and developed within the chemistry course in a range of situations, often through the measurement and analysis of results from investigations. Both qualitative and quantitative data will be collected and represented in appropriate formats. Students will be required to analyse numerical and graphical data in a range of situations which could include, for example, measuring the rates of chemical reactions, determining the structures and formulas of chemical compounds, and quantifying chemicals by mass, volume and concentrations. Students will apply the concept of error and uncertainty to their results and will evaluate the reliability of measurements in first- and second-hand data. They will be required to use skills of statistical analysis when using data from both their own experiments and secondary sources. Students will be required to use the concept of ratios extensively in their work with chemical formulas and equations, and should have an understanding of logarithmic scales when considering the pH scale.

Information and communication technologies (ICT) are relevant to teaching and learning in a large part of the senior secondary Chemistry curriculum. This will include the use of the internet to research concepts and applications as well as the use of digital learning objects such as animations and simulations to enhance students' understanding and engagement in chemistry. The use of the internet and local networks will facilitate a collaborative approach among students that models the methods of modern science. In practical investigations, ICT will aid students in tasks such as data collection and analysis through the use of probeware such as temperature, conductivity, pH meters, data logging and the use of spreadsheets. This enables students to use and analyse results efficiently, allowing for the development of valid conclusions, and also allows access to other potential areas for investigation. Simulations and modelling using digital technologies provide students with opportunities to experience situations which cannot be investigated through practical experiments in the classroom, especially in the area of structural analysis of chemicals. ICT offers opportunities to provide a range of media for communicating and sharing students' ideas and understandings both within and beyond the classroom.

Thinking skills are integral to the development of understanding in chemistry, including the ability to pose questions, make predictions, speculate, solve problems through investigation, make evidence-based decisions, analyse and evaluate evidence from their own and others' work and summarise information. Students will be encouraged to plan and conduct practical investigations as well as to select appropriate information from secondary sources and to evaluate the sources of information used to formulate conclusions. Students will also develop skills to evaluate claims based on the chemical sciences, for example in the media and advertising.

Creativity enables the development of ideas that are new to the individual. Students will develop skills that enable them to formulate creative questions, speculate, think in new ways about observations of the world around them and suggest solutions to chemically-based problems. In this course some of the students' understandings of the world around them will be taken to a deeper level, involving the development and amendment of existing understandings. Students will be encouraged to be flexible and open-minded as their own understandings of chemical concepts change and develop. Creative approaches to problem-solving may also be applied when students are required to perform experiments using limited resources or new methodologies. For example, they may be required to identify an appropriate solvent mix to separate and identify the chlorophyll pigments in autumn leaves.

Self-management is intrinsic to the ability to effectively carry out experiments and investigations. Specific self-management skills will be developed as students are encouraged to plan effectively for individual and collaborative activities, especially when using potentially harmful substances. Students will also apply self-management skills when reflecting on their own practices and learning. In this course the degree of guidance given to students will be reduced when compared with that experienced in earlier stages of schooling, requiring students to work as independent learners.

Teamwork is an important aspect of science at a number of levels, both personal and organisational. At times students will be required to work together, sharing ideas and discussing and debating their work in order to develop and consolidate their knowledge. They will study examples of chemists working in teams, both harmoniously and discordantly, to develop chemical ideas or products, or undertake research in a specific branch of chemistry. The focus in this course will be on developing harmonious, collaborative methods of student inquiry in their own learning and for future work applications.

Ethical behaviour is considered in relation to both experimental science and the acquisition and use of scientific information, including when working independently, in teams or in an online environment. In carrying out investigations students are encouraged to gather evidence honestly and ethically, considering the implications of the investigation, especially in the areas of safety and environmental impact. Students will also develop skills to evaluate claims based on science. This will enable them to make more valid judgments about social, environmental and personal issues that involve chemistry. There will also be opportunities for students to discuss the ethical implications of applications of chemistry in areas such as medicine, environmental management and the use of resources.

Cross-curriculum dimensions

The cross-curriculum dimension of sustainability is addressed in the content descriptions of the senior secondary Chemistry curriculum. Knowledge and understanding of the natural environment is incorporated within the content descriptions for the Science understanding strand. It includes atmospheric chemical processes, properties and uses of water, the effect of acidity on environmental situations, and the interaction of chemicals with a range of forms of radiation. Sustainability as a social and environmental issue is incorporated in the Science as a human endeavour strand in areas such as acid rain, use of fuels, management strategies for the control of greenhouses gases, depletion of atmospheric ozone, and treatment of waste. Important skills associated with sustainability, including researching areas such as the use of fuels and evaluating claims and arguing ideas, are incorporated within the Science inquiry skills strand.

The cross-curriculum dimensions of Indigenous history and culture, and Asia and Australia's engagement with Asia provide engaging and rich contexts for science learning.

Unit 1 - Chemical patterns and reactions

In this unit, students will use an inquiry approach to investigate and develop their understanding of patterns in the structure and behaviour of materials, and the mechanisms and applications of chemical reactions. This will include the study of: atomic theory and its applications; the organisation of elements in the periodic table based on their electronic structure; mechanisms and applications of chemical bonding; general types of chemical reactions and their uses; energy in chemical reactions; and factors affecting the rates of chemical reactions. Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Atomic theory and its applications, including:

• the structure of atoms in terms of subatomic particles (protons, neutrons and electrons) and energy levels (shells and subshells) for electrons

• atomic number, mass number, isotopes, calculation of relative atomic mass

• the mole concept, percentage composition by mass, Avogadro's constant.

The organisation of elements in the periodic table based on their electronic configuration, including:

• relationship between electronic configuration and position in the periodic table

• trends and patterns within the periodic table, including atomic number, atomic radius, ionisation energy, metallic/non-metallic character, types of compounds formed and chemical reactivity

• use of the periodic table to predict the formation and use of new compounds (for example, global impact of development and use of alternatives to chlorofluorocarbons as refrigerants).

Mechanisms and applications of chemical bonding, including:

• formation of chemical bonds between atoms through the transfer and/or sharing of valence electrons

• models of bonding to explain structure, properties and uses of elements and compounds, including ionic substances, metals (pure and alloys) and covalent substances (molecules, network lattices and layer lattices)

• diagrammatic representations of ionic and covalent bonding, including Lewis (electron dot) diagrams of the arrangement of electrons

• naming and chemical formulas for ionic and covalent substances

• composite materials and the development of new materials (for example, glass-reinforced plastics, nanomaterials).

Reaction types and their uses, including:

• direct combination (synthesis), chemical decomposition (analysis), displacement, double displacement and combustion, and examples of their everyday applications

• representation of chemical reactions using balanced chemical equations

• prediction of the products of chemical reactions based on knowledge of the general types of chemical reactions.

Energy in chemical reactions, including:

• explanation of energy changes in chemical reactions in terms of stored chemical energy and bond energy, including the use of ?H notation to represent changes in enthalpy

• energy profile diagrams of energy changes during exothermic and endothermic chemical reactions, including activation energy and the formation of transition states

• everyday applications of exothermic and endothermic reactions.

Factors affecting the rates of chemical reactions, including:

• qualitative consideration of the distribution of molecular energies in gases and liquids

• collision theory to explain changes in rates of chemical reactions by variations in concentration, temperature and pressure

• catalysis and mechanisms by which homogeneous and heterogeneous catalysts can increase or decrease the rate of a chemical reaction

• use of a range of catalysts, including enzymes, surface catalysts and zeolites in everyday situations (for example, in our bodies, the petrochemical industry, food production)

• application of ‘green chemistry’ principles used to minimise environmental impacts of chemical reactions and processes (for example, efficient use of energy, waste minimisation, hazard reduction, and use of renewable resources).

Science as a human endeavour

The nature and practice of chemistry, including:

• the dynamic nature of the body of chemical knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• the role of chemists in the production of materials from mixtures using new and innovative separation and purification methods, and their ethical responsibility in applying green chemistry principles (for example, minimising toxicity, maximising biodegradability, choice of safe solvents)

• applications of rates of chemical reactions to improve production yields (for example, food chemistry, the use of fuels)

• dependence of decisions made to control the rate of chemical reactions of chemical processes on the situation (for example, reactions of acids in the environment, redox reactions used in extraction of metals).

Contemporary research and applications of chemistry, including:

• the influence of chemical reactions and processes on our daily lives (for example, fuels, cosmetics, solutions, colloids)

• the influence of ‘green chemistry’ principles on the management of chemical processes and to minimise use of non-renewable resources, including appropriate selection of catalysts (for example, use of the catalytic metathesis process to manufacture herbicides, develop fuels and polymers with special properties, and develop pharmaceuticals)

• development of new materials with enhanced functionality (for example, improving performance of sporting equipment, aerospace materials research)

• application of chemistry in industrial processes, including the use of specialised catalysts (for example, the work of Ian Wark in the development of froth flotation methods for separating minerals from their ores).

The development of ideas in chemistry, including:

• historical development of the model of atomic theory, including the nature of the evidence to support changing ideas and the limitations of different models

• current attempts to produce 'super heavy' synthetic elements (for example, element 118)

• historical development of the periodic table from Mendeleev to Seaborg, including the justification of alternative models

• research and developments in technologies which have led to our current knowledge of the structure of materials and attempts to produce new materials for specific purposes

• use of biomimicry as inspiration to solve chemistry-based ecological problems based on physical and/or chemical reactions (for example, CSIRO's development of a synthetic insecticide which attaches to the insect's hormone receptors to cause premature moulting and subsequent death)

• historical experiments and human stories related to development of ideas in chemistry, demonstrating application of scientific values and endeavour.

Science inquiry skills

Design and perform investigations and experiments based on chemical patterns and reactions, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• comparing chemical and physical properties of elements, compounds and mixtures

• comparing and evaluating separation methods

• measuring and comparing energy changes in exothermic and endothermic reactions (for example, the reactions used in applications such as cold packs and heat pads)

• testing different materials and material composites for specific properties or for specific uses

• comparing the effect of different factors on the rates of chemical reactions.

Develop skills in performing investigations and experiments, including:

• using chemical concepts to guide hypotheses which link to the design of investigations

• selecting and using appropriate scientific equipment and techniques for specific observational and measurement tasks (for example, probes, meters, ICT)

• analysing quantitative data relating to rates of chemical reactions using mathematical and graphical methods

• evaluating procedures and processes used in investigations and suggesting specific changes to improve the reliability and validity of results

• formulating explanations consistent with experimental evidence and scientific theories

• working ethically when carrying out experiments and collaborative research with others.

Engage in critical, creative, innovative and reflective thinking, including:

• problem-solving issues relating to the use of chemical reactions (for example, the use of fuels, product safety, production of metals)

• evaluating the validity of results and proposing possible areas for further investigation.

Analyse and synthesise information relating to chemistry, including:

• researching, reading critically and synthesising information from a range of sources relating to chemical reactions and applications of chemistry (for example, the use of fuels, processing of food, uses of materials), and acknowledging and commenting on the validity of the information sources

• using and interpreting models and simulations to aid understanding and communication of chemical concepts (for example, collision theory).

Communicate ideas and findings, including:

• using correct scientific language and conventions, including correct chemical symbols and units of chemical quantities when reporting methods, calculations,

• creating and presenting structured reports of experimental and investigative work

• discussing results and findings with others in order to develop understanding and evaluate conclusions

• sharing and exchanging information, including through ICT, in collaborative endeavours, and observing social protocols, ethical use of information and security of information

• communicating chemical ideas within and beyond the chemistry community, and selecting and using formats appropriate to a purpose and audience.

Unit 2 - Chemicals in the environment

In this unit, students will use an inquiry approach to investigate and develop their understanding of the physical and chemical properties of chemicals in the environment. This will include the study of: properties of water and aqueous solutions; interrelationships between the structure, properties and uses of materials; properties, behaviour and measurement of gases; and reactions of hydrocarbons and their uses. Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Interrelationships between the structure, properties and uses of materials, including:

• the prediction and explanation of molecular shapes based on the VSEPR theory

• influence of molecular shape on determining intermolecular bonding

• carbon's unique ability to form a range of chain and cyclic molecules containing single and multiple covalent bonds, and fullerene clusters

• IUPAC naming of straight-chain, branched and cyclic hydrocarbons up to C10

• calculation of the empirical formulas of compounds from their composition by mass and determination of molecular formulas from empirical formulas

• significance of structural and geometric isomerism in hydrocarbons in terms of bonding

• determination of polarity in molecules based on molecular shape and differences in electronegativities

• intermolecular forces, including dispersion forces (van der Waal's forces), dipole?dipole forces and hydrogen bonding

• effects of intermolecular forces on properties of substances, including vapour pressure, melting and boiling points, solubility and the use of solvents

• absorption of energy by chemical bonds within molecules, and the application of this property in everyday situations (for example, greenhouse gases, microwave cooking).

Properties of water and aqueous solutions, including:

• water as a vital resource for life on Earth due to its involvement in a wide range of chemical, biological and environmental processes

• explanation of the unique properties of water in terms of structure, bonding and intermolecular forces

• specific heat capacity of water

• application of calorimetry to measure energy changes in chemical reactions in solution calorimetry

• physical and chemical processes that affect the properties of aqueous solutions (for example, acidity, salinity)

• calculation of concentrations of solutions using moles per litre (mol L^{-1}), grams per litre (g L^{-1}), parts per million (ppm), milligrams per litre (mg L^{-1}), percentage by mass (% (m/m))

• precipitation reactions, including the use of solubility rules to predict the formation of precipitates and the use of ionic equations to represent precipitation reactions

• solubility of organic and inorganic substances in water, and dependence of solubility on bonding within the substance and the intermolecular forces between these substances and water

• chemical indicators of water pollution, including environmental monitoring techniques

• chemistry associated with a human-induced chemical change related to water quality (for example, salinity, eutrophication, water pollution), including cause, effect and remediation and/or conservation strategies.

The properties, behaviour and measurement of gases, including:

• reactions of gases that affect the composition of the atmosphere, including sources and effects of pollutant gases including chlorofluorocarbons and greenhouse gases

• qualitative treatment of the effect of changes to pressure, volume and temperature on the behaviour of gases, as explained by kinetic theory

• vapour pressure and its relationship to the boiling point of liquids

• molar volume of gases and its use in converting between amount (in moles) and volume of gases under standard conditions

• use of the ideal gas equation in stoichiometric calculations involving gases at a range of temperatures and pressures

• chemical indicators of air pollution, including environmental monitoring techniques

• chemistry associated with a human-induced chemical change related to gases in the environment (for example, ozone depletion, urban air pollution), including cause, effect and remediation strategies.

Reactions of hydrocarbons and their uses, including:

• types, uses and sustainability of energy sources, including black and brown coal, natural gas, biochemical fuels and nuclear fission products

• prediction of enthalpy changes in reactions based on given values of bond energies

• comparison of energy efficiencies in generation of heat by combustion of hydrocarbons and biofuels

• mechanism and use of addition reactions in the synthesis of substances, including alcohols, haloalkanes and polymers

• initiation of chemical reactions by electromagnetic radiation (for example, use of ultraviolet light in the production and reactions of ozone and the conversion of alkanes to haloalkanes)

• application of the mole concept and the use of stoichiometry to calculate masses of reactants and products in hydrocarbon reactions

• environmental consequences of the use of hydrocarbons (for example, effects on air quality due to the combustion of fossil fuels, disposal of polymer waste management and the non-biodegradability of polymers).

Science as a human endeavour

The nature and practice of chemistry, including:

• the dynamic nature of the body of chemical knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• involvement of scientists in recent scientific developments relating to the environment (for example, production of biofuels, the treatment of water) and how these advances often result from collaborations between scientists

• making informed decisions about the environment based on chemical knowledge (for example, conservation of atmospheric ozone, treatment of salinity).

Contemporary research and applications of chemistry, including:

• effects of chemical reactions on the environment (for example, use of fuels, acidification of oceans, acid rain, effects of greenhouses gases in the atmosphere, depletion of atmospheric ozone)

• applications of ‘green chemistry’ principles to better manage chemical processes and to minimise use of non-renewable resources, including design of chemicals with maximum efficacy and minimum toxicity (for example, replacement of organotonin compounds as antifoulant agents to remove growth on the hulls of ships with alternative, less toxic chemicals)

• developments in nanochemistry and applications relating to catalysis and properties of materials

• use of new technologies in developments in chemistry (for example, the production of polymer materials, reverse osmosis for the desalination of water)

• involvement of different groups in society (for example, industry, agriculture, environmental agencies) in debates relating to the use of natural and processed resources.

The development of ideas in chemistry, including:

• the contribution of chemists from Australia and elsewhere to an understanding of molecular structure (for example, Sir Ronald Nyholm's work in the development of the VSEPR theory, X-ray crystallography methods pioneered by Sir Lawrence Bragg, Sir Harry Kroto's discovery of fullerenes)

• historical experiments and human stories related to the development of ideas in chemistry, demonstrating application of scientific values and endeavour.

Science inquiry skills

Design and perform investigations and experiments based on chemicals in the environment, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• measuring heat produced from fuels and comparing with theoretical values

• using addition reactions to distinguish between saturated and unsaturated compounds

• predicting and comparing solubility of substances in a range of solvents

• measuring the molar volume of gases

• investigating the application of Graham’s law by comparing the effusion rates of gases

• using precipitation reactions to identify compounds.

Develop skills in performing investigations and experiments, including:

• using chemical concepts to guide hypotheses which link to the design of investigations

• selecting and using appropriate scientific equipment and techniques for specific observational and measurement tasks (for example, using probes, meters and ICT)

• analysing quantitative data using mathematical methods (for example, concentrations of solutions, energy changes in reactions, gas pressures)

• evaluating procedures and processes employed in investigations and suggesting specific changes to improve the reliability and validity of results

• formulating explanations consistent with experimental evidence and chemical theories

• working ethically when undertaking experiments and collaborative research with others.

Engage in critical, creative, innovative and reflective thinking, including:

• problem-solving issues relating to chemistry (for example, treatment of water, advantages and disadvantages of different fuels)

• evaluating the validity of results and scientific arguments and proposing possible areas for further investigation.

Analyse and synthesise information relating to chemistry, including:

• evaluating claims in advertising relating to products (for example, water filters, low emission cars, household heaters)

• analysing media reports about chemistry and the environment (for example, climate change, water resources, recycling of plastics, use of fuels)

• researching, reading critically and synthesising information from a range of sources, including popular science journals and the internet, relating to environmental chemistry (for example, the use of hydrocarbons, water treatment, atmospheric chemistry), and acknowledging and commenting on the validity of the information sources

• using and interpreting models and simulations to aid understanding and communication of chemical concepts (for example, the shapes of molecules, intermolecular forces).

Communicate ideas and findings, including:

• using correct scientific language and conventions, including correct units of chemical quantities when reporting methods, calculations, conclusions and explanations

• creating and presenting structured reports of experimental and investigative work

• discussing results and findings with others in order to develop understanding and evaluate conclusions

• sharing and exchanging information, including through ICT, in collaborative endeavours, and observing social protocols, ethical use of information and security of information

• communicating chemical ideas within and beyond the chemistry community, and selecting and using formats appropriate to a purpose and audience.

Unit 3 - Using chemical processes

In this unit, students will use an inquiry approach to investigate and develop their understanding of chemical equilibrium and its applications in controlling chemical processes. This will include the study of: concepts and applications of chemical equilibrium; the behaviour and uses of acids and bases; the mechanism, uses and control of acid-base and redox reactions; and concepts and applications of electrochemistry. Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Concepts and applications of chemical equilibrium, including:

• reversible reactions and dynamic chemical equilibrium

• comparison of chemical and physical equilibrium systems

• qualitative and quantitative analysis of homogeneous and heterogeneous equilibrium situations involving solids, liquids, aqueous solutions and gases, including the use of equilibrium constant expressions

• qualitative predictions and quantitative analysis of responses of systems at equilibrium to change, including applications of Le Châtelier’s principle in industrial, environmental and biological situations (for example, increasing yields in the commercial production of sulfuric acid, ethane or nitric acid)

• steady state and equilibrium systems in biological and environmental situations which consist of a number of interrelated chemical processes.

Acid-base reactions and their uses, including:

• explanations of the behaviour of acids and bases using conceptual models, including the Brønsted?Lowry theory and the Lewis theory of acids and bases

• use of ionic equations to represent reactions of acids and bases

• weak and strong acids/bases in terms of chemical equilibrium

• qualitative and quantitative methods for testing acidity and determining concentrations of acids and bases, including the use of chemical indicators, volumetric titrations and use of stoichiometry

• calculation of pH for solutions of strong acids and strong bases

• effects of pH changes on chemical reactions occurring in everyday environmental and biological situations

• calculation of equilibrium quantities of substances involved in acid-base reactions, including amount (in moles), mass, concentration, solution volume and gas volume

• analysis of data from volumetric analysis experiments involving acid-base reactions.

Redox reactions and their uses, including:

• definition of oxidation and reduction (redox) reactions in terms of electron transfer

• oxidation number and its use in identifying redox reactions

• use of redox reactions in a range of biological, environmental and industrial applications

• representation of oxidation and reaction processes using half-equations

• equations, including ionic equations where appropriate, for a range of redox reactions, including reactions of metals, halogens, metal salts and metal oxides

• the use of the reactivity series of metals to predict reaction tendency

• relative strength of oxidising and reducing agents based on electrode potentials, and the use of this information in the prediction of reaction tendencies

• calculation of equilibrium quantities of substances involved in redox reactions, including amount (in moles), mass, concentration, solution volume and gas volume

• analysis of data from volumetric analysis experiments involving redox reactions.

Concepts and applications of electrochemistry, including:

• principles of electrochemical cells (including electrolytic and galvanic cells), including the function of the anode, cathode and the electrolyte

• calculation of standard cell potentials based on standard electrode potentials

• comparison of the materials and reactions involved in rechargeable and non-rechargeable electrochemical cells

• uses and operation of specific types of electrochemical cells for specific purposes (for example, lithium cells used in portable appliances due to their light weight; specialised electrolytic cells to produce useful chemicals for society such as chlorine, aluminium or gold; electroplating baths

• corrosion as an electrochemical process and the use of electrochemical methods to reduce metal corrosion

• application of Faraday's laws in electrochemistry.

Science as a human endeavour

The nature and practice of chemistry including:

• the dynamic nature of the body of chemical knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• application by chemical engineers of the concepts and laws of chemical equilibrium to industrial processes

• the range of careers in the fields of industrial and environmental chemistry

• use of quantitative chemical analysis in a range of areas (for example, environmental monitoring, food analysis, water testing)

• applications of redox and acid-base reactions in a variety of situations in the home and in industry, including how these reactions are controlled and/or monitored (for example, corrosion prevention, neutralisation).

Contemporary research and applications of chemistry, including:

• influence of a variety of factors, including equilibrium considerations, on the choices regarding the manufacture and use of a chemical, or chemical process for a particular task (for example, cost, safety, environmental impact, environmentalists, consumer demand, energy considerations, shifting equilibrium positions)

• equilibrium applications of 'green chemistry' principles to better manage chemical processes and to minimise use of non-renewable resources, including selection of appropriate chemicals to improve energy efficiencies of chemical reactions, resulting in economic and environmental advantages (for example, use of cryolite as the electrolyte in the production of aluminium from alumina in the Hall-Héroult process which operates at lower temperatures than earlier metal production processes)

• use of technological advances to increase the efficiency and sustainability of chemical processes in industrial and environmental situations (for example, production of chemical products, treatment of waste)

• use of electrochemical cells in modern technologies (for example, communication technology, photovoltaic cells, transport)

• the greater use of microelectronic devices in the home, at work and in medical applications, enabled by the development of modern electrochemical cells.

The development of ideas in chemistry, including:

• development of theories of acid-base behaviour over time based on increasing experimental evidence

• development of descriptions of redox reactions over time, from the consideration of loss or gain of oxygen through to explanations based on the transfer of electrons

• historical experiments and human stories related to the development of ideas in chemistry, demonstrating application of scientific values and endeavour.

Science inquiry skills

Design and perform investigations and experiments related to equilibria, acid-base reactions, redox reactions and electrochemical cells, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• comparing the effect of varying strengths and concentrations of acids on the rate and extent of acid-base reactions

• determining concentrations of acidic and/or basic solutions using volumetric analysis (for example, concentration of laboratory acids and bases, the quantities of acids in foods, quantities of base in antacid medicines and cleaning materials)

• comparing the reactions of a range of oxidising and reducing agents, including the prediction of reaction tendency

• comparing voltage produced from a range of electrochemical cells, including comparison with predicted theoretical values

• investigating the effect of concentration of the electrolyte on the cell potential

• investigating factors (for example, surface area of electrodes and electrolyte concentration) that affect the formation of products in electrolytic cells

• identifying causes of corrosion and evaluating the effectiveness of different methods of corrosion prevention.

Develop skills in performing investigations and experiments, including:

• using chemical concepts and models to develop testable hypotheses

• performing volumetric analysis experiments using accurate and safe procedures to determine concentrations and quantities of acids and bases

• selecting and using the most appropriate equipment and methods for a specific task (for example, selection of indicator and use of a primary standard in volumetric analysis) in order to minimise experimental error

• using digital technology to record, analyse and present experimental data, both first-hand and second-hand, where appropriate

• integrating statistical methods when analysing data (for example, calculations of means, determination of degree of uncertainty in experimental results)

• evaluating primary and secondary data in terms of the processes and equipment used to collect the data

• using primary and secondary quantitative data to calculate chemical quantities

• comparing the validity of alternative explanations based on experimental results.

Engage in critical, creative, innovative and reflective thinking, including:

• contributing evidence-based opinions and information to discussions about issues involving chemistry (for example, acid rain, corrosion resistance)

• reflecting on methods used in experiments and suggesting modifications to improve accuracy of results

• justifying areas and ideas for future investigation.

Analyse and synthesise information relating to chemistry, including:

• researching, reading critically and synthesising information relating to acid-base and redox chemistry from a range of sources, and acknowledging and commenting on the validity of the information sources

• using models and simulations to explain and communicate chemical concepts (for example, theories of acid-base behaviour and redox reaction mechanisms).

Communicate ideas and findings, including:

• using correct scientific language and conventions when describing methods, conclusions and explanations

• describing quantitative data and findings to the appropriate degree of accuracy, including the correct use of units

• creating and presenting structured reports of experimental and investigative work

• sharing and exchanging information, including through ICT, in collaborative endeavours, and observing social protocols, ethical use of information and security of information

• communicating chemical ideas within and beyond the chemistry community, and selecting and using formats appropriate to a purpose and audience.

Unit 4 - Chemical analysis and synthesis

In this unit, students will use an inquiry approach to investigate and develop their understanding of the analysis and synthesis of useful materials in society. This will include the study of: the interrelationships between the structure, properties and uses of organic materials; analytical techniques and chemical synthesis. Students will reflect on how knowledge in chemistry in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Interrelationships between the structure, properties and uses of organic materials, including:

• organic functional groups including alcohols, carboxylic acids, esters, aldehydes, ketones, amines, amino acids and amides

• effects of functional groups on the chemical properties of a range of compounds (for example, pharmaceuticals, biochemical substances, surfactants, solvents)

• condensation reactions as synthesis reactions that produce a main organic product and a small molecular by-product

• use of condensation reactions in the production of organic molecules (for example, esters, dipeptides, polyesters, polyamides) and in the synthesis of biopolymers and their synthetic analogues (for example, proteins and nylon)

• hydrolysis reactions of organic compounds (for example, hydrolysis of esters and polyesters, saponification of fats and oils)

• optical isomerism in organic molecules, including identification of molecules that display optical isomerism and chirality

• specificity of optical isomers in biological systems (for example, medicinal differences in the optical isomers phentermine and dextromethamphetamine)

• variation in the chemical properties of substances due to differences in the structure and shape of molecules (for example, comparisons of the reactions of primary, secondary and tertiary alcohols; aldehydes and ketones; alcohols and ethers)

• formation of a range of fullerene clusters (buckyballs and carbon nanotubes) by carbon atoms, and the uses of these and other nanomaterials (for example, as catalysts; in the production of specialised materials).

Analytical techniques, including:

• principles and applications of two analytical techniques involving the interaction between the sample and a stationary/mobile phase (for example, electrophoresis, paper chromatography, thin layer chromatography, high performance liquid chromatography, gas chromatography), including interpretation of qualitative and quantitative data

• principles and applications of two analytical techniques involving the interaction between the sample and electromagnetic radiation (for example, colorimetry, atomic absorption/emission spectroscopy, infrared spectroscopy, mass spectroscopy, nuclear magnetic resonance spectroscopy, visible and ultraviolet spectroscopy) including interpretation of qualitative and quantitative data

• strengths and limitations of analytical techniques in practical situations

• factors in determining the selection of an appropriate analytical technique, or combination of techniques, for a particular analytical task.

Chemical synthesis, including:

• design of synthesis processes, including the choice of reagents and conditions, based on precipitation, addition, condensation, acid-base or redox reactions

• production, isolation and purification of organic compounds (for example, preparation of esters, production of aspirin and other pharmaceuticals) and calculation of predicted and actual yields

• production of synthetic polymers based on polymerisation reactions

• the multi-step synthesis of a selected organic compound involving conversions of functional groups (for example, synthesis of Relenza)

• design of synthesis methods, including consideration of the use of energy, the use of renewable resources as reactants, hazard reduction, and waste minimisation.

Science as a human endeavour

The nature and practice of chemistry, including:

• the dynamic nature of the body of chemical knowledge which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve

• advances in science knowledge and understanding through modern chemical analysis (for example, development of pharmaceuticals such as the Relenza vaccine; identification of chemical compounds in space; biochemistry; forensic science and solving current as well as 'cold' criminal cases; materials science and the synthesis of new materials)

• comparisons of a range of chemistry-related courses and careers (for example, organic chemistry, pharmacy, forensics, and biochemistry).

Contemporary research and applications of chemistry, including:

• the effects of different structures and isomerism on properties and uses of substances (for example, uses of optical isomers of thalidomide, artificial sweeteners, enzymes)

• applications of 'green chemistry' principles to better manage chemical processes, including minimising reaction end-product waste (for example, the pharmaceutical company Pfizer's achievement of a 60% reduction in the quantities of raw materials used to manufacture sertraline, the active ingredient in the antidepressant Zoloft®, by developing a single-step synthesis pathway to replace the previous three-step process)

• applications of 'green chemistry' principles to better manage chemical processes and to minimise use of non-renewable resources (for example, development by US researchers of a biodegradable material consisting of flax yarn embedded in a soy protein polymer resin which has tensile properties comparable to steel)

• developments in nanochemistry and applications relating to chemical synthesis methods

• future directions for the development and use of materials (for example, molecular self-assembly, conducting polymer materials, biofuels, anti-viral agents)

• the work of chemists from Australia and elsewhere in the development of applications of polymer science (for example, Alan MacDiarmid's work on electrically conducting polymers, Robert Gilbert's methods of emulsion polymerisation, CSIRO and David Solomon's development of the technology used to create polymer banknotes).

The development of ideas in chemistry, including:

• challenges to the prevailing chemical understanding of the time (for example, cyanic acid as prepared by Friedrich Woehler was noted as having the same elemental composition but different properties from fulminic acid as prepared by Justus von Liebig, which challenged the understanding at the time that chemical compounds could only be different if they had different elemental compositions)

• research, including research that has been awarded a Nobel prize, which has resulted in an increased knowledge of structures of a range of substances (for example, John Cornforth's work on structure of enzymes, Frederick Zanger's determination of the primary structures of insulin and DNA)

• the development of chemical analytical methods, including the contribution of Australian scientists (for example, Sir Alan Walsh and atomic emission spectroscopy, Ross Taylor and spectral analysis)

• the development of chemical synthesis methods (for example, Arthur Birch's work on reduction reactions)

• historical experiments and human stories related to the development of ideas in chemistry, demonstrating application of scientific values and endeavour.

Science inquiry skills

Design and perform investigations and experiments based on the analysis and synthesis of chemical substances, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• distinguishing between organic compounds (for example, primary, secondary and tertiary alcohols; aldehydes and ketones; saturated and unsaturated polymers)

• predicting and identifying the reaction products of a range of organic compound reactions

• synthesising and isolating organic compounds (for example, esters, polymers)

• evaluating the effectiveness of surfactants

• producing a biodiesel fuel from used cooking oil

• production of azo dyes

• comparing the properties of different polymers (for example, hydrogels, polymers used in clothing and packaging).

Develop skills in performing investigations and experiments, including:

• selecting and using the most appropriate methods for a specific task in order to minimise experimental error

• evaluating primary and secondary data in terms of the methods used to collect the data

• formulating evidence-based explanations and relating these to theoretical concepts

• comparing the validity of alternative explanations based on experimental results.

Engage in critical, creative, innovative and reflective thinking, including:

• contributing evidence-based opinions and information to discussions about issues (for example, the use of solvents, polymers and pharmaceuticals in everyday situations)

• justifying areas and ideas for future investigation in relation to links between the structure and properties of substances

• reflecting on developments related to the understanding of chemical structure and the application of this knowledge in a range of situations.

Analyse and synthesise information relating to chemistry, including:

• researching, reading critically and synthesising information from a range of sources, including outputs from instrumental analysis, and acknowledging and commenting on the validity of the information sources

• using models and simulations to explain and communicate chemical concepts, including structures of organic molecules and mechanisms of organic reactions.

Communicate ideas and findings, including:

• using correct scientific language and conventions when describing methods, conclusions and explanations

• selecting and using appropriate methods for representing a range of chemical structures

• creating and presenting structured reports of multi-step experimental and investigative work

• sharing and exchanging information, including through ICT, in collaborative endeavours, and observing social protocols, ethical use of information and security of information

• communicating chemical ideas within and beyond the chemistry community, and selecting and using formats appropriate to a purpose and audience.