The Australian
Curriculum

Subjects	Chemistry
Units	Unit 1, Unit 2, Unit 3 and Unit 4
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AUSTRALIAN CURRICULUM, ASSESSMENT AND REPORTING AUTHORITY

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Chemistry

Rationale and Aims

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, as 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 senior secondary Science 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, pharmacy and sports science. Additionally, chemistry knowledge is valuable in occupations that rely on an understanding of materials and their interactions, such as art, winemaking, agriculture and food technology. Some students will use this course as a foundation to pursue further studies in chemistry, and all students will become more informed citizens, able to use chemical knowledge to inform evidence-based decision making and engage critically with contemporary scientific issues.

Aims

Chemistry aims to develop students’:

- interest in and appreciation of chemistry and its usefulness in helping to explain phenomena and solve problems encountered in their ever-changing world
- understanding of the theories and models used to describe, explain and make predictions about chemical systems, structures and properties
- understanding of the factors that affect chemical systems, and how chemical systems can be controlled to produce desired products
- appreciation of chemistry as an experimental science that has developed through independent and collaborative research, and that has significant impacts on society and implications for decision making

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- 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.

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Organisation

Overview of senior secondary Australian Curriculum

ACARA has developed senior secondary Australian Curriculum for English, Mathematics, Science and History according to a set of design specifications. The ACARA Board approved these specifications following consultation with state and territory curriculum, assessment and certification authorities.

The senior secondary Australian Curriculum specifies content and achievement standards for each senior secondary subject. Content refers to the knowledge, understanding and skills to be taught and learned within a given subject. Achievement standards refer to descriptions of the quality of learning (the depth of understanding, extent of knowledge and sophistication of skill) expected of students who have studied the content for the subject.

The senior secondary Australian Curriculum for each subject has been organised into four units. The last two units are cognitively more challenging than the first two units. Each unit is designed to be taught in about half a 'school year' of senior secondary studies (approximately 50–60 hours duration including assessment and examinations). However, the senior secondary units have also been designed so that they may be studied singly, in pairs (that is, year-long), or as four units over two years.

State and territory curriculum, assessment and certification authorities are responsible for the structure and organisation of their senior secondary courses and will determine how they will integrate the Australian Curriculum content and achievement standards into their courses. They will continue to be responsible for implementation of the senior secondary curriculum, including assessment, certification and the attendant quality assurance mechanisms. Each of these authorities acts in accordance with its respective legislation and the policy framework of its state government and Board. They will determine the assessment and certification specifications for their local courses that integrate the Australian Curriculum content and achievement standards and any additional information, guidelines and rules to satisfy local requirements including advice on entry and exit points and credit for completed study.

The senior secondary Australian Curriculum for each subject should not, therefore, be read as a course of study. Rather, it is presented as content and achievement standards for integration into state and territory courses.

Senior secondary Science subjects

The Australian Curriculum senior secondary Science subjects build on student learning in the Foundation to Year 10 Science curriculum and include:

- Biology
- Chemistry
- Earth and Environmental Science
- Physics.

Structure of Chemistry

Units

In Chemistry, students develop their understanding of chemical systems, and how models of matter and energy transfers and transformations can be used to describe, explain and predict chemical structures, properties and reactions. There are four units:

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- Unit 1: Chemical fundamentals: structure, properties and reactions
- Unit 2: Molecular interactions and reactions
- Unit 3: Equilibrium, acids and redox reactions
- Unit 4: Structure, synthesis and design.

In Unit 1, students use models of atomic structure and bonding to explain the macroscopic properties of materials and to predict the products and explain the energy changes associated with chemical reactions. In Unit 2, they 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.

In Units 3 and 4, students further develop their knowledge of chemical processes introduced in Units 1 and 2, including considering energy transfers and transformations, calculations of chemical quantities, rates of reaction and chemical systems. In Unit 3, students investigate models of equilibrium in chemical systems; apply these models in the context of acids and bases and redox reactions, including electrochemical cells; and explain and predict how a range of factors affect these systems. In Unit 4, students use models of molecular structure, chemical reactions and energy changes to explain and apply synthesis processes, particularly with consideration of organic synthesis; and they consider current and future applications of chemical design principles.

Each unit includes:

- Unit descriptions – short descriptions of the purpose of and rationale for each unit
- Learning outcomes – six to eight statements describing the learning expected as a result of studying the unit
- Content descriptions – descriptions of the core content to be taught and learned,organised into three strands:
  - *Science Inquiry Skills*
  - *Science as a Human Endeavour*
  - *Science Understanding (organised in sub-units).*

Organisation of content

The Australian Curriculum: Science has three interrelated strands: *Science Inquiry Skills, Science as a Human Endeavour* and *Science Understanding*. These strands are used to organise the Science learning area from Foundation to Year 12. In the Senior Secondary Science subjects, the three strands build on students' learning in the F-10 Australian Curriculum: Science.

In the practice of science, the three strands are closely integrated: the work of scientists reflects the nature and development of science, is built around scientific inquiry, and seeks to respond to and influence society. Students' experiences of school science should mirror this multifaceted view of science. To achieve this, the three strands of the Australian Curriculum: Science 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. The investigation design will depend on the context and subject of the investigation.

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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, prose, 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 senior secondary Science subjects, students will continue to develop generic science inquiry skills, building on the skills acquired in the F-10 Australian Curriculum: Science. These generic skills are described below and will be explicitly taught and assessed in each unit. In addition, each unit provides more specific skills to be taught within the generic science inquiry skills; these specific skills align with the *Science Understanding* and *Science as a Human Endeavour* content of the unit.

The generic science inquiry skills are:

- Identifying, researching and constructing questions for investigation; proposing hypotheses; and predicting possible outcomes
- Designing 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; conducting risk assessments; and considering ethical research
- Conducting investigations, including using equipment and techniques safely, competently and methodically for the collection of valid and reliable data
- Representing data in meaningful and useful ways; organising and analysing data to identify trends, patterns and relationships; recognising error, uncertainty and limitations in data; and selecting, synthesising and using evidence to construct and justify conclusions
- 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
- Selecting, constructing and using appropriate representations to communicate understanding, solve problems and make predictions
- Communicating to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes.

The senior secondary Science subjects have been designed to accommodate, if appropriate, an extended scientific investigation within each pair of units. States and territories will determine whether there are any requirements related to an extended scientific investigation as part of their course materials.

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.

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Across the senior secondary Science subjects, the same set of *Science as a Human Endeavour* content descriptions is used for Units 1 and 2 of the subjects; and another set for Units 3 and 4. This consistent approach enables students to develop a rich appreciation of the complex ways in which science interacts with society, through the exploration of *Science as a Human Endeavour* concepts across the subjects and in multiple contexts.

'Examples in context' will be developed to illustrate possible contexts related to *Science Understanding* content, in which students could explore *Science as a Human Endeavour* concepts. These will be made available to complement the final online curriculum. Each *Example in context* will be aligned to the relevant sub-unit in *Science Understanding* and will include links to the relevant *Science as a Human Endeavour* content descriptions.

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.

Science Understanding can be developed through the selection of contexts that have relevance to and are engaging for students. The Australian Curriculum: Science has been designed to provide jurisdictions, schools and teachers with the flexibility to select contexts that meet the social, geographic and learning needs of their students.

Organisation of achievement standards

The Chemistry achievement standards are organised by two dimensions: 'Chemistry Concepts, Models and Applications', and 'Chemistry Inquiry Skills'. They describe five levels of student achievement.

'Chemistry Concepts, Models and Applications' describes the knowledge and understanding students demonstrate with reference to the content of the *Science Understanding* and *Science as a Human Endeavour* strands of the curriculum. 'Chemistry Inquiry Skills' describes the skills students demonstrate when investigating the content developed through the strands of *Science Understanding* and *Science as a Human Endeavour*.

Senior secondary achievement standards have been written for each Australian Curriculum senior secondary subject. The achievement standards provide an indication of typical performance at five different levels (corresponding to grades A to E) following the completion of study of senior secondary Australian Curriculum content for a pair of units. They are broad statements of understanding and skills that are best read and understood in conjunction with the relevant unit content. They are structured to reflect key dimensions of the content of the relevant learning area. They will be eventually accompanied by illustrative and annotated samples of student work/ performance/ responses.

The achievement standards will be refined empirically through an analysis of samples of student work and responses to assessment tasks: they cannot be maintained *a priori* without reference to actual student performance. Inferences can be drawn about the quality of student learning on the basis of observable differences in the extent, complexity, sophistication and generality of the understanding and skills typically demonstrated by students in response to well-designed assessment activities and tasks.

In the short term, achievement standards will inform assessment processes used by curriculum, assessment and certifying authorities for course offerings based on senior secondary Australian Curriculum content.

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ACARA has made reference to a common syntax (as a guide, not a rule) in constructing the achievement standards across the learning areas. The common syntax that has guided development is as follows:

- Given a specified context (as described in the curriculum content)
- With a defined level of consistency/accuracy (the assumption that each level describes what the student does well, competently, independently, consistently)
- Students perform a specified action (described through a verb)
- In relation to what is valued in the curriculum (specified as the object or subject)
- With a defined degree of sophistication, difficulty, complexity (described as an indication of quality)

Terms such as 'analyse' and 'describe' have been used to specify particular action but these can have everyday meanings that are quite general. ACARA has therefore associated these terms with specific meanings that are defined in the senior secondary achievement standards glossary and used precisely and consistently across subject areas.

Links to Foundation to Year 10

Progression from the F-10 Australian Curriculum: Science

The Chemistry curriculum continues to develop student understanding and skills from across the three strands of the F-10 Australian Curriculum: Science. In the *Science Understanding* strand, the Chemistry curriculum draws on knowledge and understanding from across the four sub-strands of Biological, Physical, Chemical and Earth and Space Sciences.

In particular, the Chemistry curriculum 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.

Mathematical skills expected of students studying Chemistry

The Chemistry curriculum requires students to use the mathematical skills they have developed through the F-10 Australian Curriculum: Mathematics, in addition to the numeracy skills they have developed through the *Science Inquiry Skills* strand of the Australian Curriculum: Science.

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

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

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

It is assumed that students will be able to competently:

- 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

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

Representation of General capabilities

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 genres, modes 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 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 Technolog*y *(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. Through exploration of *Science as a Human Endeavour* concepts, students assess the impact of ICT on the development of science and the application of science in society, particularly with regard to collating, storing, managing and analysing large data sets.

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.

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

Ethical understanding 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 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 Cross-curriculum priorities

While the significance of the cross-curriculum priorities for Chemistry varies, there are opportunities for teachers to select contexts that incorporate the key concepts from each priority.

Through an investigation of contexts that draw on *Aboriginal and Torres Strait Islander histories and cultures* students can 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.

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 could 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 could consider collaborative projects between Australian and Asian scientists and the contribution these make to scientific knowledge.

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

Safety

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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 or territory health and safety guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses, they will include more specific advice on safety.

For further information about relevant guidelines, contact your state or territory curriculum authority.

Animal ethics

Through a consideration of research ethics as part of *Science Inquiry Skills*, students will examine their own ethical position, draw on ethical perspectives when designing investigation methods, and ensure that any activities that impact on living organisms comply with the *Australian code of practice for the care and use of animals for scientific purposes 7th edition* (2004) (http://www.nhmrc.gov.au/guidelines/publications/ea16) .

Any teaching activities that involve the care and use of, or interaction with, animals must comply with the *Australian code of practice for the care and use of animals for scientific purposes 7th edition*, in addition to relevant state or territory guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses, they will include more specific advice on the care and use of, or interaction with, animals.

For further information about relevant guidelines or to access your local Animal Ethics Committee, contact your state or territory curriculum authority.

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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 and the development of ICT and other technologies 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, cultural 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.

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Content Descriptions

Science Inquiry Skills (Chemistry Unit 1)

Identify, research and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH001)

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 (ACSCH002)

Conduct investigations, including the use of devices to accurately measure temperature change and mass, safely, competently and methodically for the collection of valid and reliable data (ACSCH003)

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 (ACSCH004)

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 (ACSCH005)

Select, construct and use appropriate representations including chemical symbols and formulae, molecular structural formulae, physical and graphical models of structures, chemical equations and thermochemical equations, to communicate conceptual understanding, solve problems and make predictions (ACSCH006)

Select and use appropriate mathematical representations to solve problems and make predictions, including calculating percentage composition from relative atomic masses and using the mole concept to calculate the mass of reactants and products (ACSCH007)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH008)

Science as a Human Endeavour (Units 1 and 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSCH009)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSCH010)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSCH011)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSCH012)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSCH013)

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Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSCH014)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH015)

Science Understanding

Properties and structure of atoms

Trends in the observable properties of elements are evident in periods and groups in the periodic table (ACSCH016)

The structure of the periodic table is based on the electron configuration of atoms, and shows trends, including in atomic radii and valencies (ACSCH017)

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; atoms can be represented using electron shell diagrams (all electron shells or valence shell only) or electron charge clouds (ACSCH018)

Flame tests and atomic absorption spectroscopy are analytical techniques that can be used to identify elements; these methods rely on electron transfer between atomic energy levels (ACSCH019)

The properties of atoms, including their ability to form chemical bonds, are explained by the arrangement of electrons in the atom and in particular by the stability of the valence electron shell (ACSCH020)

Isotopes are atoms of an element with the same number of protons but different numbers of neutrons; different isotopes of elements are represented using atomic symbols (for example, ${}^{12}_{6}\mathrm{C}$, ${}^{13}_{6}\mathrm{C}$) (ACSCH021)

Isotopes of an element have the same electron configuration and possess similar chemical properties but have different physical properties, including variations in nuclear stability (ACSCH022)

Mass spectrometry involves the ionisation of substances and generates spectra which can be analysed to determine the isotopic composition of elements (ACSCH023)

The relative atomic mass of an element is the ratio of the weighted average mass per atom of the naturally occurring form of the element to $\frac{1}{12}$ the mass of an atom of carbon-12; relative atomic masses reflect the isotopic composition of the element (ACSCH024)

Properties and structure of materials

Materials are either pure substances with distinct measurable properties (for example, melting and boiling point, reactivity, strength, density) or mixtures with properties dependent on the identity and relative amounts of the substances that make up the mixture (ACSCH025)

Differences in the properties of substances in a mixture, such as particle size, solubility, magnetism, density, electrostatic attraction, melting point and boiling point, can be used to separate them (ACSCH026)

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The type of bonding within substances explains their physical properties, including melting and boiling point, conductivity of both electricity and heat, strength and hardness (ACSCH027)

Nanomaterials are substances that contain particles in the size range 1–100 nm and have specific properties relating to the size of these particles (ACSCH028)

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 number of bonds that an atom can form (ACSCH029)

Ions are atoms or groups of atoms that are electrically charged due to an imbalance in the number of electrons and protons; 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-}) (ACSCH030)

The properties of ionic compounds (for example, high melting point, brittleness, ability to conduct electricity when liquid or in solution) are explained by modelling ionic bonding as ions arranged in a crystalline lattice structure with forces of attraction between oppositely charged ions (ACSCH031)

The characteristic properties of metals (for example, malleability, thermal conductivity, electrical conductivity) are explained by modelling metallic bonding as a regular arrangement of positive ions (cations) made stable by electrostatic forces of attraction between these ions and the electrons that are free to move within the structure (ACSCH032)

Covalent substances are modelled as molecules or covalent networks that comprise atoms which share electrons, resulting in electrostatic forces of attraction between electrons and the nucleus of more than one atom (ACSCH033)

Elemental carbon exists as a range of allotropes, including graphite, diamond and fullerenes, with significantly different structures and physical properties (ACSCH034)

Carbon forms hydrocarbon compounds, including alkanes and alkenes, with different chemical properties that are influenced by the nature of the bonding within the molecules (ACSCH035)

Chemical reactions: reactants, products and energy change

All chemical reactions involve the creation of new substances and associated energy transformations, commonly observable as changes in the temperature of the surroundings and/or the emission of light (ACSCH036)

Endothermic and exothermic reactions can be explained in terms of the Law of Conservation of Energy and the breaking and reforming of bonds; heat energy released or absorbed can be represented in thermochemical equations (ACSCH037)

Fuels, including fossil fuels and biofuels, can be compared in terms of their energy output, suitability for purpose, and the nature of products of combustion (ACSCH038)

A mole is a precisely defined quantity of matter equal to Avogadro's number of particles; the mole concept and the Law of Conservation of Mass can be used to calculate the mass of reactants and products in a chemical reaction (ACSCH039)

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Chemistry

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Unit 2: Molecular interactions and reactions

Unit Description

In this unit, 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 and the development of ICT and other technologies 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, cultural 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 multiple disciplines, 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 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.

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Content Descriptions

Science Inquiry Skills (Chemistry Unit 2)

Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH040)

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 (ACSCH041)

Conduct investigations, including measuring pH and the rate of formation of products, identifying the products of reactions, and testing solubilities, safely, competently and methodically for the collection of valid and reliable data (ACSCH042)

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 (ACSCH043)

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 (ACSCH044)

Select, construct and use appropriate representations, including physical and graphical models of molecules, energy profile diagrams, electron dot diagrams, ionic formulae, chemical formulae, chemical equations and phase descriptors for chemical species to communicate conceptual understanding, solve problems and make predictions (ACSCH045)

Select and use appropriate mathematical representations to solve problems and make predictions, including using the mole concept to calculate the mass of chemicals and/or volume of a gas (at standard temperature and pressure) involved in a chemical reaction, and using the relationship between the number of moles of solute, concentration and volume of a solution to calculate unknown values (ACSCH046)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH047)

Science as a Human Endeavour (Units 1 and 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review, and reproducibility (ACSCH048)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSCH049)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSCH050)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSCH051)

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The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSCH052)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSCH053)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH054)

Science Understanding

Intermolecular forces and gases

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 substance (ACSCH055)

The shapes of molecules can be explained and predicted using three-dimensional representations of electrons as charge clouds and using valence shell electron pair repulsion (VSEPR) theory (ACSCH056)

The polarity of molecules can be explained and predicted using knowledge of molecular shape, understanding of symmetry, and comparison of the electronegativity of elements (ACSCH057)

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 (ACSCH058)

Data from chromatography techniques (for example, thin layer, gas and high-performance liquid chromatography) can be used to determine the composition and purity of substances; the separation of the components is caused by the variation of strength of the interactions between atoms, molecules or ions in the mobile and stationary phases (ACSCH059)

The behaviour of gases, including the qualitative relationships between pressure, temperature and volume, can be explained using kinetic theory (ACSCH060)

Aqueous solutions and acidity

Water is a key substance in a range of chemical systems because of its unique properties, including its boiling point, density in solid and liquid phases, surface tension, and ability to act as a solvent (ACSCH061)

The unique properties of water can be explained by its molecular shape and hydrogen bonding between molecules (ACSCH062)

The concentration of a solution is defined as the amount of solute divided by the amount 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}) (ACSCH063)

The presence of specific ions in solutions can be identified using analytical techniques based on chemical reactions, including precipitation and acid-base reactions (ACSCH064)

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The solubility of substances in water, including ionic and molecular substances, can be explained by the intermolecular forces between species in the substances and water molecules, and is affected by changes in temperature (ACSCH065)

The pH scale is used to compare the levels of acidity or alkalinity of aqueous solutions; the pH is dependent on the concentration of hydrogen ions in the solution (ACSCH066)

Patterns of the reactions of acids and bases (for example, reactions of acids with bases, metals and carbonates) allow products to be predicted from known reactants (ACSCH067)

Rates of chemical reactions

Varying the conditions present during chemical reactions can affect the rate of the reaction and in some cases the identity of the products (ACSCH068)

The rate of chemical reactions can be quantified by measuring the rate of formation of products or the depletion of reactants (ACSCH069)

Collision theory can be used to explain and predict the effect of concentration, temperature, pressure and surface area on the rate of chemical reactions by considering the structure of the reactants and the energy of particles (ACSCH070)

The activation energy is the minimum energy required for a chemical reaction to occur and is related to the strength of the existing chemical bonds; the magnitude of the activation energy influences the rate of a chemical reaction (ACSCH071)

Energy profile diagrams can be used to represent the enthalpy changes and activation energy associated with a chemical reaction (ACSCH072)

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 (ACSCH073)

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Units 1 and 2 Achievement Standards

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Chemistry concepts, models and applications

A	B	C	D	E
For the chemical systems studied, the student:	*For the chemical systems studied, the student:*	*For the chemical systems studied, the*	*For the chemical systems studied, the*	*For the chemical systems studied,*

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Chemistry concepts, models and applications

• analyses how structure, bond strength and energy transfers and transformations are interrelated in chemical systems • analyses how a range of factors affect atomic or molecular interactions and change the structure and properties of systems • explains the theories and model/s used to explain the system and the aspects of the system they include • applies theories and models of systems and processes to explain phenomena, interpret complex problems, and make reasoned, plausible predictions in unfamiliar contexts *For the chemical science contexts studied, the student:*	• explains how structure, bonding and energy transfers and transformations are interrelated in chemical systems • explains how a range of factors change the structure and properties of chemical systems • describes the theories and model/s used to explain the system • applies theories and models of systems and processes to explain phenomena, interpret problems, and make plausible predictions in unfamiliar contexts *For the chemical science contexts studied, the*	*student:* • describes how structure, bonding and energy transfers are related in chemical systems • describes how some factors change the structure and properties of chemical systems • describes a theory or model used to explain the system • applies theories or models of systems and processes to explain phenomena, interpret problems, and make plausible predictions in familiar contexts	*student:* • describes structure and bonding in substances • describes how some factors affect chemical systems • identifies aspects of a theory or model related to the system • describes phenomena, interprets simple problems, and makes simple predictions in familiar contexts *For the chemical science contexts studied, the student:* • describes the role of communication and new	*the student:* • identifies observable properties of substances • identifies observable changes to chemical systems • identifies aspects of a theory or model related to parts of the system • describes phenomena and makes simple predictions in familiar, simple contexts *For the chemical science contexts studied, the student:*

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Chemistry concepts, models and applications

• analyses the roles of collaboration, debate and review, and technologies, in the development of chemical science theories and models • evaluates how chemical science has been used in concert with other sciences to meet diverse needs and inform decision making, and how these applications are influenced by interacting social, economic and ethical factors	*student:* • explains the role of collaboration, debate and review, and technologies, in the development of chemical science theories and models • explains how chemical science has been used to meet diverse needs and inform decision making, and how these applications are influenced by social, economic and ethical factors	*For the chemical science contexts studied, the student:* • describes the role of collaboration and review, and technologies, in the development of chemical science theories or models • discusses how chemical science has been used to meet needs and inform decision making, and some social, economic or ethical implications of these applications	and new evidence in developing chemical science knowledge • describes ways in which chemical science has been used in society to meet needs, and identifies some implications of these applications	• identifies that chemical science knowledge has changed over time • identifies ways in which chemical science has been used in society to meet needs

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Chemistry inquiry skills

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For the chemical science contexts studied, the student:	*For the chemical science contexts studied, the*	*For the chemical science contexts*	*For the chemical science contexts*	*For the chemical science contexts*

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Chemistry inquiry skills

	student:	studied, the student:	studied, the student:	studied, the student:
• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data, and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories, and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies, and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories, and provides evidence for conclusions • evaluates processes and claims, provides a critique with reference to evidence, and identifies possible improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies, and sources of error • selects data to demonstrate relationships linked to chemical science knowledge, and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends, and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

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Unit 3: Equilibrium, acids and redox reactions

Unit Description

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

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

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

Learning Outcomes

By the end of this unit, students:

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

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Content Descriptions

Science Inquiry Skills (Chemistry Unit 3)

Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH074)

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 (ACSCH075)

Conduct investigations, including using volumetric analysis techniques and constructing electrochemical cells, safely, competently and methodically for the collection of valid and reliable data (ACSCH076)

Represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and process data to identify trends, patterns and relationships; identify and distinguish between random and systematic errors, and estimate their effect on measured results; discuss how the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSCH077)

Interpret a range of scientific texts, and evaluate processes, claims and conclusions by considering the quality of available evidence, including confidence intervals in secondary data; and use reasoning to construct scientific arguments (ACSCH078)

Select, construct and use appropriate representations, including half-equations, balanced chemical equations, equilibrium constants and expressions, pH, oxidation numbers, standard electrode potentials and cell diagrams, to communicate conceptual understanding, solve problems and make predictions (ACSCH079)

Select and use appropriate mathematical representations to solve problems and make predictions, including calculating cell potentials under standard conditions, using the mole concept to calculate moles, mass, volume and concentrations from volumetric analysis data, determining the yield of incomplete reactions, and calculating the pH of solutions of strong acids and bases (ACSCH080)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH081)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSCH082)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSCH083)

The acceptance of scientific knowledge can be influenced by the social, economic, and cultural context in which it is considered (ACSCH084)

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People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSCH085)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSCH086)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSCH087)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH088)

Science Understanding

Chemical equilibrium systems

Chemical systems may be open or closed and include physical changes and chemical reactions which can result in observable changes to the system (ACSCH089)

All physical changes are reversible, whereas only some chemical reactions are reversible (ACSCH090)

Over time, physical changes and reversible chemical reactions reach a state of dynamic equilibrium in a closed system, with the relative concentrations of products and reactants defining the position of equilibrium (ACSCH091)

The reversibility of chemical reactions can be explained by considering the activation energies of the forward and reverse reactions (ACSCH092)

The effect of changes of temperature on chemical systems at equilibrium can be explained by considering the enthalpy changes for the forward and reverse reactions (ACSCH093)

The effect of changes of concentration and pressure on chemical systems at equilibrium can be explained and predicted by applying collision theory to the forward and reverse reactions (ACSCH094)

The effects of changes of temperature, concentration of chemicals and pressure on equilibrium systems can be predicted using Le Chatelier’s Principle (ACSCH095)

Equilibrium position can be predicted qualitatively using equilibrium constants (ACSCH096)

Acids are substances that can act as proton (hydrogen ion) donors and can be classified as monoprotic or polyprotic depending on the number of protons donated by each molecule of the acid (ACSCH097)

The strength of acids is explained by the degree of ionisation at equilibrium in aqueous solution, which can be represented with chemical equations and equilibrium constants (Ka) (ACSCH098)

The relationship between acids and bases in equilibrium systems can be explained using the Brønsted-Lowry model and represented using chemical equations that illustrate the transfer of hydrogen ions (ACSCH099)

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The pH scale is a logarithmic scale and the pH of a solution can be calculated from the concentration of hydrogen ions; K_w can be used to calculate the concentration of hydrogen ions from the concentration of hydroxide ions in a solution (ACSCH100)

Acid-base indicators are weak acids or bases where the acidic form is of a different colour to the basic form (ACSCH101)

Volumetric analysis methods involving acid-base reactions rely on the identification of an equivalence point by measuring the associated change in pH, using chemical indicators or pH meters, to reveal an observable end point (ACSCH102)

Oxidation and reduction

A range of reactions, including displacement reactions of metals, combustion, corrosion, and electrochemical processes, can be modelled as redox reactions involving oxidation of one substance and reduction of another substance (ACSCH103)

Oxidation can be modelled as the loss of electrons from a chemical species, and reduction can be modelled as the gain of electrons by a chemical species; these processes can be represented using half-equations (ACSCH104)

The ability of an atom to gain or lose electrons can be explained with reference to valence electrons, consideration of energy, and the overall stability of the atom, and can be predicted from the atom's position in the periodic table (ACSCH105)

The relative strength of oxidising and reducing agents can be determined by comparing standard electrode potentials (ACSCH106)

Electrochemical cells, including galvanic and electrolytic cells, consist of oxidation and reduction half-reactions connected via an external circuit that allows electrons to move from the anode (oxidation reaction) to the cathode (reduction reaction) (ACSCH107)

Galvanic cells, including fuel cells, generate an electrical potential difference from a spontaneous redox reaction; they can be represented as cell diagrams including anode and cathode half-equations (ACSCH108)

Fuel cells can use metal nanoparticles as catalysts to improve the efficiency of energy production (ACSCH109)

Cell potentials at standard conditions can be calculated from standard electrode potentials; these values can be used to compare cells constructed from different materials (ACSCH110)

Electrolytic cells use an external electrical potential difference to provide the energy to allow a non-spontaneous redox reaction to occur, and can be used in small-scale and industrial situations (ACSCH111)

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Unit 4: Structure, synthesis and design

Unit Description

Current and future applications of chemistry include the development of specialised techniques to create, or synthesise, new substances to meet the specific needs of society, including pharmaceuticals, fuels, polymers and nanomaterials. In this unit, students focus on the principles and application of chemical synthesis, particularly in organic chemistry. This involves considering where and how functional groups can be incorporated into already existing carbon compounds in order to generate new substances with properties that enable them to be used in a range of contexts.

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

Students use science inquiry skills to investigate the principles and application of chemical structure, synthesis and design. They select and use data from instrumental analysis to determine the identity and structure of a range of organic materials. They make predictions based on knowledge of types of chemical reactions, and investigate chemical reactions qualitatively and quantitatively.

Learning Outcomes

By the end of this unit, students:

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

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Content Descriptions

Science Inquiry Skills (Chemistry Unit 4)

Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH112)

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 (ACSCH113)

Conduct investigations, including using organic synthesis methods and collating data from chemical analyses, safely, competently and methodically for the collection of valid and reliable data (ACSCH114)

Represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and analyse data to identify patterns and relationships; identify and distinguish between random and systematic errors, and estimate their effect on measured results; discuss how the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence from a range of sources to make and justify conclusions (ACSCH115)

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 (ACSCH116)

Select, construct and use appropriate representations, including physical, virtual and graphical models of primary, secondary and tertiary structures, structural formulas, chemical equations, systematic nomenclature (using IUPAC conventions) and spectra, to communicate conceptual understanding, solve problems and make predictions (ACSCH117)

Select and use appropriate mathematical representations to solve problems and make predictions, including using the mole concept to calculate quantities in chemical reactions, including multi-step reactions, and the percentage yield of synthesis reactions (ACSCH118)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH119)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSCH120)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSCH121)

The acceptance of scientific knowledge can be influenced by the social, economic and cultural context in which it is considered (ACSCH122)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSCH123)

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Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSCH124)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSCH125)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH126)

Science Understanding

Properties and structure of organic materials

Organic molecules have a hydrocarbon skeleton and can contain functional groups, including alcohols, carboxylic acids, esters, amines and amides (ACSCH127)

Each class of organic compounds displays characteristic chemical properties and undergoes specific reactions based on the functional groups present; these reactions, including acid-base and oxidation reactions, can be used to identify the class of the organic compound (ACSCH128)

Organic materials including proteins, carbohydrates and synthetic polymers display properties including strength, density and biodegradability that can be explained by considering the primary, secondary or tertiary structures of the material (ACSCH129)

Data from analytical techniques, including mass spectrometry, x-ray crystallography and infrared spectroscopy, can be used to determine the structure of organic molecules, often using evidence from more than one technique (ACSCH130)

Chemical synthesis and design

Chemical synthesis involves the selection of particular reagents to form a product with specific properties (for example, pharmaceuticals, fuels, cosmetics, cleaning products) (ACSCH131)

Designing chemical synthesis processes involves constructing reaction pathways that may include more than one chemical reaction (ACSCH132)

Designing chemical synthesis processes includes identifying reagents and reaction conditions in order to maximise yield and purity of product (ACSCH133)

The yield of a chemical synthesis reaction can be calculated by comparing stoichiometric quantities with actual quantities (ACSCH134)

Green chemistry principles include the design of chemical synthesis processes that use renewable raw materials, limit the use of potentially harmful solvents and minimise the amount of unwanted products (ACSCH135)

Organic molecules, including polymers, can be synthesised using addition and condensation reactions (ACSCH136)

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Fuels (for example, biodiesel, ethanol, hydrogen) can be synthesised from organic or inorganic sources using a range of chemical reactions including addition, oxidation and esterification (ACSCH137)

Molecular manufacturing processes, including protein synthesis, involve the positioning of molecules to facilitate a specific chemical reaction; such methods have the potential to synthesise specialised products (for example, carbon nanotubes, nanorobots, chemical sensors used in medicine) (ACSCH138)

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Units 3 and 4 Achievement Standards

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Chemistry concepts, models and applications

A	B	C	D	E
For the chemical systems studied, the student:	*For the chemical systems studied, the student:*	*For the chemical systems studied, the*	*For the chemical systems studied, the*	*For the chemical systems studied,*

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Chemistry concepts, models and applications

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Chemistry concepts, models and applications

• analyses how a range of interrelated factors affect atomic and molecular interactions and change the structure, properties and dynamics of chemical systems • analyses how interactions between matter and energy in complex chemical systems can be designed, monitored and controlled to produce desired outcomes • explains the theories and model/s used to explain the system, the supporting evidence, and their limitations and assumptions • applies theories and models of systems and processes to explain phenomena, critically analyse complex problems, and make reasoned, plausible predictions in unfamiliar contexts *For the chemical science contexts studied, the student:*	• explains how a range of interrelated factors change the structure, properties and dynamics of chemical systems • explains how interactions between matter and energy in chemical systems can be designed, monitored and controlled to produce desired outcomes • describes the theories and model/s used to explain the system, some supporting evidence, and their limitations • applies theories and models of systems and processes to explain phenomena, analyse problems, and make plausible predictions in	• explains how a range of factors change the structure, properties and dynamics of chemical systems • describes how chemical systems are controlled and monitored to produce desired outcomes • describes key aspects of a theory or model used to explain system processes, and the phenomena to which those processes can be applied • applies theories or models of systems and processes to explain phenomena, interpret problems, and make plausible predictions in	• describes how some factors affect the properties of chemical systems • describes how chemical systems are manipulated to produce desired outcomes • describes key aspects of a theory or model used to explain a system process • describes phenomena, interprets simple problems, and makes predictions in familiar contexts *For the chemical science contexts studied, the student:* • describes the roles of	• describes changes to chemical systems • describes how chemical systems are used to produce desired outcomes • identifies aspects of a theory or model related to a system process • describes phenomena and makes simple predictions in familiar contexts *For the chemical science contexts studied, the student:* • identifies that chemical science

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Chemistry concepts, models and applications

• analyses the roles of collaboration, debate and review, and technologies, in the development of chemical science theories and models • evaluates how chemical science has been used in concert with other sciences to meet diverse needs and inform decision making, and how these applications are influenced by interacting social, economic and ethical factors	predictions in unfamiliar contexts *For the chemical science contexts studied, the student:* • explains the roles of collaboration, debate and review, and technologies, in the development of chemical science theories and models • explains how chemical science has been used to meet diverse needs and inform decision making, and how these applications are influenced by social, economic and ethical factors	predictions in some unfamiliar contexts *For the chemical science contexts studied, the student:* • describes the roles of collaboration and review, and technologies, in the development of chemical science theories or models • discusses how chemical science has been used to meet needs and inform decision making, and some social, economic or ethical implications of these applications	communication and new evidence in developing chemical science knowledge • describes ways in which chemical science has been used in society to meet needs, and identifies some implications of these applications	knowledge has changed over time • identifies ways in which chemical science has been used in society to meet needs

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Chemistry inquiry skills

A	B	C	D	E
For the chemical science contexts studied, the student:	*For the chemical science contexts studied, the*	*For the chemical science contexts*	*For the chemical science contexts*	*For the chemical science contexts*

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Chemistry inquiry skills

	student:	studied, the student:	studied, the student:	studied, the student:
• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data, and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories, and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies, and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories, and provides evidence for conclusions • evaluates processes and claims, provides a critique with reference to evidence, and identifies possible improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies, and sources of error • selects data to demonstrate relationships linked to chemical science knowledge, and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects , constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends, and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

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Chemistry Glossary

Algebraic representation

A set of symbols linked by mathematical operations; the set of symbols summarise relationships between variables.

Animal ethics

Animal ethics involves consideration of respectful, fair and just treatment of animals. The use of animals in science involves consideration of replacement (substitution of insentient materials for conscious living animals), reduction (using only the minimum number of animals to satisfy research statistical requirements) and refinement (decrease in the incidence or severity of 'inhumane' procedures applied to those animals that still have to be used).

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 tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement that can be supported or refuted by experiment.

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.

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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.

Reliability

The degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

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.

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.

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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.

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Glossary

Abstract
Abstract scenario: a scenario for which there is no concrete referent provided.

Account
Account for: provide reasons for (something).

Give an account of: report or describe an event or experience.

Taking into account: considering other information or aspects.

Analyse
Consider in detail for the purpose of finding meaning or relationships, and identifying patterns, similarities and differences.

Apply
Use, utilise or employ in a particular situation.

Assess
Determine the value, significance or extent of (something).

Coherent
Orderly, logical, and internally consistent relation of parts.

Communicates
Conveys knowledge and/or understandings to others.

Compare
Estimate, measure or note how things are similar or dissimilar.

Complex
Consisting of multiple interconnected parts or factors.

Considered
Formed after careful thought.

Critically analyse
Examine the component parts of an issue or information, for example the premise of an argument and its plausibility, illogical reasoning or faulty conclusions

Critically evaluate
Evaluation of an issue or information that includes considering important factors and available evidence in making critical judgement that can be justified.

Deduce
Arrive at a conclusion by reasoning.

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Demonstrate
Give a practical exhibition as an explanation.

Describe
Give an account of characteristics or features.

Design
Plan and evaluate the construction of a product or process.

Develop
In history: to construct, elaborate or expand.

In English: begin to build an opinion or idea.

Discuss
Talk or write about a topic, taking into account different issues and ideas.

Distinguish
Recognise point/s of difference.

Evaluate
Provide a detailed examination and substantiated judgement concerning the merit, significance or value of something.

In mathematics: calculate the value of a function at a particular value of its independent variables.

Explain
Provide additional information that demonstrates understanding of reasoning and/or application.

Familiar
Previously encountered in prior learning activities.

Identify
Establish or indicate who or what someone or something is.

Integrate
Combine elements.

Investigate
Plan, collect and interpret data/information and draw conclusions about.

Justify
Show how an argument or conclusion is right or reasonable.

Locate
Identify where something is found.

Manipulate
Adapt or change.

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Non-routine

Non-routine problems: Problems solved using procedures not previously encountered in prior learning activities.

Reasonableness

Reasonableness of conclusions or judgements: the extent to which a conclusion or judgement is sound and makes sense

Reasoned

Reasoned argument/conclusion: one that is sound, well-grounded, considered and thought out.

Recognise

Be aware of or acknowledge.

Relate

Tell or report about happenings, events or circumstances.

Represent

Use words, images, symbols or signs to convey meaning.

Reproduce

Copy or make close imitation.

Responding

In English: When students listen to, read or view texts they interact with those texts to make meaning. Responding involves students identifying, selecting, describing, comprehending, imagining, interpreting, analysing and evaluating.

Routine problems

Routine problems: Problems solved using procedures encountered in prior learning activities.

Select

Choose in preference to another or others.

Sequence

Arrange in order.

Solve

Work out a correct solution to a problem.

Structured

Arranged in a given organised sequence.

In Mathematics: When students provide a structured solution, the solution follows an organised sequence provided by a third party.

Substantiate

Establish proof using evidence.

Succinct

Written briefly and clearly expressed.

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Sustained

Consistency maintained throughout.

Synthesise

Combine elements (information/ideas/components) into a coherent whole.

Understand

Perceive what is meant, grasp an idea, and to be thoroughly familiar with.

Unfamiliar

Not previously encountered in prior learning activities.

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