CHEMISTRY

SYLLABUS
for the
SENIOR
EXTERNAL
EXAMINATION

1998
(Amended 2006)

QUEENSLAND
Board of Senior Secondary School Studies

This syllabus is effective for, and as from, the 1999 Senior external examination.

National Library of Australia Cataloguing-in-Publication data

Chemistry: syllabus for the Senior external examination

Bibliography

ISBN 0 7242 7624 6.

1. Chemistry—Study and teaching (Secondary)—Queensland. 2. Chemistry—Outlines, syllabi, etc. I. Queensland. Board of Senior Secondary School Studies.

540.712943

Queensland Board of Senior Secondary School Studies(Queensland Studies Authority)
Level 7, 154 Melbourne Street, South Brisbane
PO Box 307, Spring Hill, Qld 4004

Telephone: (07) 3864 0299
Facsimile: (07) 3221 2553
email: office@qsa.qld.edu.au

CM795

PREFACE

This external senior syllabus in Chemistry involves a number of significant changes from the 1987 external syllabus in Chemistry

The general objectives are listed under the five headings:

- attitudes and values
- knowledge of subject matter
- scientific processes
- complex reasoning processes
- manipulative skills.

The number of topics has been reduced from twelve to eight. The recommended minimum times to be spent on each topic are provided in section 6.

The difficulties experienced by many candidates studying this subject externally are appreciated. It is realised that there is little opportunity to engage in subject matter other than that listed in the stated objectives.

Candidates will be assessed by means of two examinations, and details of the papers are provided in section 8. While direct assessment of the suggested experiments and manipulative skills stated in the syllabus is not possible, they will be assessed indirectly in the examination papers. Consequently, there may be questions assessing candidates' knowledge of, and ability to relate the practical work, safety considerations and the use of relevant equipment to both familiar and unfamiliar situations.

The change that will have the greatest impact on the course and its assessment will be the new general objectives with their increased emphasis on scientific processes and complex reasoning processes.

CONTENTS

1 A VIEW OF SCIENCE

Science is a cultural endeavour. It incorporates a way of thinking as well as a body of knowledge. Characteristically, it adopts an empirical approach to the search for natural explanations of phenomena observed in the universe. Although the study of science in the senior school is divided into a number of disciplines, at the core of each lies continuous questioning of results and methods. Education in and through science is an avenue by which citizens may participate in its endeavours and influence the extent and direction of its use and application. As part of their general education, candidates should access, participate in, and evaluate scientific pursuits. They need also to be able to act on their findings.

Scientific disciplines are more than collections of facts, sets of theories, or mental processes and manipulative skills. The sciences are evolving ways of understanding natural phenomena and bodies of knowledge. They are the product of imaginative human endeavour. Behind every scientific idea lies a trail of effort, study and modification. This human side of science is interesting and revealing. It can show how science 'works'. Use of societal and historical references can foster better understanding of the nature of science.

Science has profound worldwide impacts—economic, environmental, ethical, political, social and technological. An understanding of scientific perspectives can enhance participation by citizens in deciding on, and responding to, the directions of science and technology. Social awareness within the scientific community and scientific literacy in the general community, are essential for human survival and economic development.

2 RATIONALE

Chemistry is the study of matter and its interactions. Because humans live in this material universe, chemistry is central to understanding the phenomena of the reactions of matter. It therefore provides a link with other branches of natural science. Candidates should come to understand that no real distinction can be made between 'chemicals' and matter.

Chemistry possesses a theoretical framework that allows new knowledge to be organised and related to other aspects of the discipline. The modern chemical approach seeks an understanding of natural phenomena—in the test tube, in the crust of the earth and in living organisms, and in terms of the events at the atomic and molecular level. The course should enable candidates to appreciate the power of this way of thinking and investigating. Chemistry remains a growing discipline, with exciting and unexpected developments on its frontiers. It is a discipline in which candidates may experience beauty at many levels, whether in comprehending the ordered structure of matter, or in what they see in their own experiments.

A knowledge of chemistry can assist candidates in understanding and interpreting many experiences in their everyday surroundings, thus enriching their daily lives. Chemistry is intimately involved in extractive, refining and manufacturing industries, which provide our food, clothing and many of the articles we use daily These industries are important to our economy. Candidates should come to appreciate the impact of chemical knowledge and technology on their society

The impact of human activities on our environment has not always been benign. Responsible decisions on possible future activities can be made, among other things, in the light of the fullest understanding of the chemical consequences of those activities. Problems have sometimes arisen in the past because of the limitations of our chemical understanding. The solutions to these problems will usually require the application of chemical knowledge. An understanding of chemistry will assist candidates to participate as informed and responsible citizens in making decisions in which economic benefit and the quality of the environment are considered. The Senior Chemistry course will provide a foundation for candidates who will proceed to tertiary level courses in science, engineering or health sciences.

3 GLOBAL AIMS

Candidates come from varied geographical, socioeconomic and sociocultural backgrounds and language backgrounds other than English. Candidates’backgrounds legitimately and significantly influence the nature of their learning.

A study of a senior science should provide an opportunity for and assistance in the further development of candidates’ abilities to access, process and communicate information so that they might be culturally and scientifically informed and awareTo achieve these global aims, Senior Chemistry should provide learning experiences that will assist candidates to develop:

- the ability to recall specific knowledge and apply this in simple situations
- scientific processes, complex reasoning processes and appropriate attitudes and values
- proficiency and safety in the use of field and laboratory equipment and other resources
- English language and Chemistry-specific language skills through explicit teaching of, and immersion in, the language of Chemistry

4 GENERAL OBJECTIVES

The **general objectives** of this chemistry syllabus are derived from the interaction of the **global aims**, the **rationale** and **a view of science**. These general objectives are described in terms of what a candidate should gain from undertaking this course of study. He/she should:

- develop attitudes and values
- have knowledge of subject matter
- be able to use scientific processes
- be able to use complex reasoning processes
- develop manipulative skills.

Whilst candidates will not be assessed on attitudes and values nor directly on manipulative skills, the other three general objectives form the broad categories under which the candidates will be assessed.

In order to elaborate on the meaning of the **general objectives** for candidates, more specific **objectives** have been identified. These more specific objectives are further elaborated upon through dot-pointed **outcomes** which contain examples.

Whilst the general objectives, specific objectives and dot-pointed outcomes are descriptions of mandatory processes in this course of study, the examples are provided to further explain the outcomes and thus assist the candidate to develop an understanding of how the outcomes may be dealt with. It is not envisaged that the candidate will necessarily engage with every example but primarily with those most appropriate to their own learning context.

Specific applications of the objectives and outcomes are provided in the core topics.

As a result of undertaking a course of study based upon this syllabus, a candidate should:

- **develop attitudes and values**

Note: These attitudes and values are not assessable.

Objective	Outcomes
To develop attitudes and values	• concerning the impact and limitations of science (be concerned for wise application of science and its ethical use) • arising from the practice of science (be open-minded, critically respectful of data, be sceptical, willing to shift in the face of evidence, systematic, persistent in the practice of science) • concerning personal behaviour (be honest, concerned, tolerant and aware of individual differences and cultural diversity within the learning environment, be cooperative when participating in group tasks) • …

- **have a knowledge of subject matter**

Note: This general objective refers to the development and assessment of content and its simple application.

Objectives	Outcomes
To recall **To apply in simple situations**	• list, define, state, describe, select, identify, recognise, translate, reconstruct, calculate, deduce, explain, solve, exemplify spell correctly: – facts and formulae – procedures – terminology – theories and principles – sequences and events – shapes, patterns and diagrams – …

- **be able to use scientific processes**

Note: This general objective refers to the development and assessment of scientific processes at a simple level only.

Objectives	Outcomes
To collect and organise data	• use primary data resources: – observe accurately, being aware of the need to repeat and check observations – select appropriate measuring devices – use scales and units accurately, being aware of limitations and errors – describe properties and changes – …
	• use secondary data sources: – locate and comprehend relevant information from books, audiovisual and multimedia, databases and other resources – record references – …
	• record and organise data: – collect both qualitative and quantitative data and use standard units paying attention to accuracy and precision – record observations – tabulate – graph – sketch, draw, photograph – …
To make simple judgments	• reflect on the validity of qualitative and/or quantitative data: – distinguish fact from opinion – distinguish relevant from irrelevant information – distinguish observations from inferences – identify errors in measurement – …

continued next page

Objectives	Outcomes
To process and generate information	• infer and predict: – explain observations and forecast future observations based on past observations or theory – …
	• interpret: – identify trends or anomalies – interpolate and extrapolate – analyse – generate analogies – follow procedures – draw conclusions – …
	• generalise: – relate cause and effect – describe relationships (qualitatively and/or quantitatively) – …
To communicate information in various contexts	• present information in a variety of forms: – write reports of laboratory or field work – present results of library research – deliver oral reports on research or experiments – contribute to discussions and debates – produce pictorial and audiovisual presentations – construct physical representations – use correct spelling, grammar and punctuation – …
To devise and design simple and/or single-step investigations	• use scientific methodology: – identify and articulate investigation question(s) – identify and control variables – develop experimental procedures – establish a conceptual framework – hypothesise – identify safety issues – …

- **be able to use complex reasoning processes**

Note: This general objective refers to the development and assessment of higher order cognitive processes which provide challenge to candidates.

Objectives	Outcomes
To use complex reasoning in challenging situations	• solve challenging problems: – assemble several pieces of learned information and procedures and integrate them to complete a task – combine several of the scientific processes into a coherent strategy for a given task – respond to challenging novel tasks – …
	• make logical decisions: – select relevant knowledge and/or data and a procedure to reach a conclusion or support an argument – analyse alternative information to compare and contrast or make judgments – make inferences or predictions consistent with a set of assumptions – justify an outcome based on given or generated information – …
	• use creative and/or critical thinking: – identify assumptions on which claims are based – locate logical fallacies in arguments – recognise invalid conclusions – evaluate the worth of ideas and the authority on which claims are based – critically examine the adequacy of data – demonstrate originality in design, production, performance … – propose alternative theories for given evidence – propose evidence that would be required to confirm or refute a particular theory or belief – …
In addition to the outcomes identified above, other **complex reasoning processes** outcomes may involve an advanced level challenge from the **knowledge of subject matter** or **scientific processes** general objectives listing.	

- **develop manipulative skills**

Objectives	Outcomes
To operate safely and proficiently	• in laboratory, and/or field settings: – assemble, construct, manipulate, handle, calibrate, measure, sketch … – …

5 LEARNING EXPERIENCES

The range of learning experiences provided for candidates should promote the attainment of all of the global aims and objectives of the course of study

For a course of study in Chemistry to contribute to a general education in science, it should provide learning experiences which will contribute to the development of individuals who:

- can recognise issues and pose questions which are science or technology related
- are able to associate these with appropriate scientific concepts and principles
- can identify sources of relevant information and/or data
- are aware of, and are skilled in using, appropriate scientific methods for extracting and/or collecting information or data
- can manipulate data and information in ways appropriate to the task
- make decisions based upon the best available information
- through their actions, communicate their competence in and understanding of the issues listed above.

The effective use of language (written, spoken and symbolic) is integral to all of these functions. Science uses a rich spectrum of metaphors and similes to describe and communicate models that seek to explain natural phenomena. There is a general language of science, and each of the historical disciplines has its own arcane language and mental/verbal metaphors. Learning experiences should develop awareness and understanding of this language. This allows development of the successful use of appropriate scientific language and imagery.

The language characteristics of individuals and groups, varieties of English used, ways in which candidates communicate and their preferred learning styles all impact on the nature of learning Chemistry.

The following list of teaching/learning modes is neither prescriptive nor exhaustive. It is a broad list from which choices may be made:

- collaborative learning
- laboratory activities and experiments
- model construction
- simulation games
- teacher exposition and questioning
- film, video and slide audiovisual observation
- computer software simulation or tutorial use
- computer interfacing
- Internet/web sites
- …

These should require candidates to use language effectively (see page 7—*to communicate information*) for several purposes in different contexts and for a variety of audiences. Candidates should prepare and present communications in accordance with externally examinable scientific processes objectives.

Candidates should be engaged in learning experiences that involve them in:

Drawing upon sources of information, such as:	**Using language for the purposes of:**	**Presenting information in forms such as:**
existing knowledge	restating information	laboratory/field notes
observations	reporting results	formal reports
demonstrations	giving instructions	letters
experiments	formulating a hypothesis	abstracts
textbooks	designing an experiment	précis
handbooks of data	explaining a relationship	reviews
manuals of procedures	arguing a proposition	oral presentations
product brochures	proposing action	seminars
specification sheets	defending a position	discussions
computer files	justifying a stand	demonstrations
journal articles	evaluating an argument	charts
magazines	developing an idea	graphs
newspapers	interpreting a theory	sketches
broadcast media	persuading	models
advertisements	making conclusions	photographs
videos or films	following instructions	electronic media
lectures	predicting the results of an experiment	numerical, algebraic forms
interviews	evaluating scientific arguments	…
discussions	…	
web pages		
…		

The selection of resource material to support a course in Chemistry will be governed by local factors. While candidates will rely heavily on a textbook of Chemistry they must realise that any one text will not fully support the realisation of the process objectives (scientific processes and complex reasoning processes). General community resources such as libraries may need to be accessed. Other sources of information such as museums, science centres, popular science periodicals, electronic media materials, Internet and particularly television chemistry programs may need to be consulted.

Practical work is considered to be an integral part of the course and will be examined in knowledge and process objectives. Practical experiences should be selected and conducted with safety in mind. Suggested experimental work is given in section 6.2. Practical work should not be attempted without competent supervision.

6 COURSE REQUIREMENTS

6.1 Topics

There are eight topics with suggested time allocations given below Suggested total minimum time allocation necessary to gain a basic understanding of the topics is**100 hours**. In order to consolidate these understandings candidates will need to spend a significant amount of additional time on processing and interpreting information relevant to the topics.

Topics	Suggested minimum time (hours)
1. Materials—properties, bonding and structure	15
2. Reacting quantities and chemical analysis	15
3. Oxidation and reduction	11
4. Organic chemistry	11
5. Chemical periodicity	8
6. Gases and the atmosphere	8
7. Energy and rates of chemical reactions	12
8. Chemical equilibrium	20
Total	100

Each topic has an introduction and overview of subject matter. These describe the context for the scientific, historical, social, and practical applications of each topic. Broad connections with other topics, as well as other scientific disciplines, are suggested.

By their very nature, topic titles are arbitrary. However, they are a necessary structural element for any syllabus and corresponding course of study. These topics have been chosen to reflect broad groupings of 'traditional' topic headings. They will allow maximum flexibility for candidates to choose their own sequence while maintaining comparability of the basic elements of all chemistry courses throughout the State.

Topic-specific objectives are presented in three columns under the performance dimension headings of:

- knowledge objectives
- scientific processes
- complex reasoning processes.

Candidates *must* study *all* knowledge, scientific processes and complex reasoning processes objectives listed in the syllabus. These specific objectives all contribute to the general objectives outlined in section 4.

6.2 Practical work

This criterion deals with the ability of a candidate to operate scientific and experimental equipment proficiently and safely in practical work. *Performance in practical work will not be directly assessed* but questions on practical work may be included in the written examination.

The specific manipulative skills listed should be addressed in a course of study

6.2.1 Manipulative skills and laboratory safety

A. Candidates should be able to perform the following manipulative skills:

1. Using a graduated cylinder
2. Measuring mass of dry powders
3. Measuring mass of glassware and other laboratory equipment
4. Using Bunsen burners, electrical heaters, and water baths (where appropriate) for heating:
   - solids
   - non-flammable liquids
   - flammable liquids
5. Decanting
6. Filtering
7. Transferring solids from one container to another
8. Transferring liquids from one container to another
9. Preparing and assembling glassware and glass tubing
10. Using a pipette
11. Using a burette
12. Collection of a gas
13. Using a thermometer.

B. Candidates should also have knowledge of the safe operation of all laboratory equipment used and the operation of laboratory safety equipment, including:

1. fire extinguisher(s)
2. fire blanket
3. electrical isolation
4. gas isolation
5. eye-bath
6. safety shower.

Satisfactory knowledge need not necessarily require candidates to handle these items of safety equipment.

Additionally, candidates should be able to read and recognise the importance of widely used labelling, warning and information systems including the colour/alpha-numeric code used to designate the nature of substances stored or transported, the nationally used labelling icons for properties of substances (e.g. corrosive, toxic, flammable, ionising radiation) and material safety data sheets.

6.2.2 Experiments

Following is a list of experiments which should be completed during the course of study.

These experiments will assist the candidate in developing understanding of the concepts involved as well as providing an opportunity to engage with many of the general manipulative skills.

The topic numbers in brackets refer to the topics of the syllabus shown in 6.1.

1. Perform experiments illustrating the differences between ionic, covalent and metallic substances. (Topics 1, 5)
2. Perform volumetric analysis (at least HCl/NaOH). (Topics 2, 8)
3. Perform simple redox reactions of elements and their ions, including halogens (Cl_2, Br_2, I_2), iron, copper, zinc, silver. (Topics 3, 5)
4. Investigate the properties of at least the following: cyclohexene, benzoic acid, esters, alcohols. (Topics 1, 3, 4)
5. Apply a simple qualitative analysis scheme to identify ions (at least Cl^-, SO_4^{2-}, CO_3^{2-}, Ag^+, Ba^{2+} Cu^{2+}). (Topics 1, 5, 6, 8)
6. Generate small quantities, collect and test the properties of at least the following gases—H_2, O_2, CO_2. (Topics 1, 6, 8)
7. Use a simple calorimeter to determine the enthalpy of a chemical change. (Topics 2, 7)
8. Perform simple experiments to investigate the properties of acids and bases. (Topic 8)

Candidates should write a report on the experiments performed.

7 TOPICS

Topic 1 Materials—properties, bonding and structure

Introduction

All that physically exists is composed of matter including stars, planets, and all living organisms. People throughout history, and in different cultures, have classified the materials that they have encountered in their daily existence. These classifications have been based on the observed properties, as well as the practical use of these materials. Materials suitable for food, clothing, shelter, weapons and tools, production of fire, medicine, pigments, and decorative and aesthetic purposes were identified and categorised. Knowledge about their properties and application was constructed and passed from generation to generation. Widespread applications of certain materials have been identified as milestones of various human cultures. The use of fire and the various 'ages', including the Stone Age and the Bronze Age, are such examples. Application of the latest developments in the technology of materials have led to the naming of the 20th century as the 'Space Age'.

Chemistry, as a current scientific discipline, has grown from older technologies of materials and their applications. European alchemists sought to convert base metals to gold. The extraction, naming and describing of the properties of certain elements, acids, and inorganic salts are due to the efforts of early Arabian, European and Oriental philosophers and scientists. The medical properties of plant, animal and mineral substances have been described by, amongst others, Egyptian priests, community midwives of the Middle Ages, and aboriginal medicine men and women throughout the world.

The history of the development of current atomic models of structure and bonding is one of human endeavour from the earliest times. Aristotle encouraged experimental and inductive explorations. Dalton propounded the existence of atoms. Robert Millikan and Ernest Rutherford provided early experimental evidence indicating the nature of atomic structure. Dorothy Crowfoot-Hodgkin pioneered the use of X-ray crystallography in studying penicillin, allowing the synthesis of penicillin and new antibiotics on a large scale, as well as describing the structure of insulin and vitamin B-12. Chien-Shiung Wu is noted for her work in particle physics, X-rays, and beta decay.

Notions of energy related to the numbers and relative position of electrons seek to predict and explain whether and under what conditions a chemical reaction will occur. Such predictions are possible because of the direct link between an underlying structure and the nature of the bonds holding atoms and molecules together

Chemistry is the study of the interaction of different materials. Observation of recurring properties and types of interactions enable predictions to be made about the nature and quantities of products of reactions. A knowledge of the properties of a general category of matter allows the designing of new substances with specific purposes; for example, new metal alloys, plastics, medicines and drugs, and construction materials. Substances previously unknown, or whose effects were not understood or appreciated, are continually being identified and described by chemists. Recognition of the importance of the ozone layer and the high altitude chemistry of CFCs occurred because of chemical research. A study of organic substances, including proteins and their synthesis and application in living organisms, adds to the knowledge of life itself.

Subject matter

Candidates should become familiar with the main categories of matter. A knowledge of the full range of categories of matter and their general properties will also be developed in other topics, e.g. Organic Chemistry. Candidates should be able to recognise and describe examples of bonding and be able to relate the principles of atomic structure and bonding to substances or reactions that have relevance or interest to them.

Table 1

Knowledge objectives	Scientific processes	Complex reasoning processes
Candidates should be able to: 1.1 explain how elements, mixtures and compounds can be differentiated experimentally 1.2 recall the names, symbols and formulae of common elements, ions and compounds 1.3 explain the physical properties of metals, ionic compounds, covalent molecular substances and covalent network substances in terms of their respective bonding models 1.4 describe the structure of the atom in terms of its component elementary particles—protons, neutrons, electrons 1.5 explain the terms *atomic number, mass number, isotope, electron shell and electron configuration* 1.6 deduce the particle components and electron configuration of atoms given atomic number and mass number (up to element 21) 1.7 describe the nature of the major chemical bonds—covalent (single, double, triple), ionic and metallic 1.8 draw electron dot diagrams and Lewis valence structures for simple molecules—the hydrides of C, N, O and Cl 1.9 draw the shapes of simple covalent molecules with examples of linear, bent triatomic, planar trigonal, tetrahedral, pyramidal 1.10 compare and contrast the properties (solubility, boiling point, melting point) of polar and non-polar compounds and use models of intermolecular bonding (dispersion, dipole–dipole, hydrogen bonding) to explain these properties 1.11 compare the structures, properties and uses of allotropes of carbon (graphite, diamond and fullerenes).	Candidates should be able to: 1.1 process experimental data and classify materials in appropriate bonding categories 1.2 design experiments to separate different types of mixtures using physical properties 1.3 design experimental tests to determine the bonding classification of a substance 1.4 use properties of different materials to predict their possible uses in everyday life 1.5 translate a multistep extraction/separation process from text to diagram and vice versa 1.6 graph data of physical properties of elements and compounds and be able to use these results to predict properties of other elements and compounds. 1.7 Interpret data from material safety data sheet.	Candidates should be able to: 1.1 use the relationship between properties and core structure to interpret trends in experimental data and to explain anomalies 1.2 suggest materials that are suitable for given applications and justify their selection 1.3 apply at an advanced level the knowledge and scientific processes objectives.

Topic 1 Materials—properties, bonding and structure

Topic 2 Reacting quantities and chemical analysis

Introduction

Lowering the salt or sugar content in a favourite biscuit recipe, or substituting margarine for butter, may all have no discernible effect and so go unnoticed. An extra 'glug' of nitro in the glycerine, lowering the methyl benzene content of petrol, or substituting hydrogen for helium, will have discernible effects and will certainly be noticed! The amounts, as well as the nature of all reacting species present in a reaction, are paramount in influencing if a reaction will occur, the nature of the products, and their amounts. Knowledge of the atomic model, principles of mass conservation, and stoichiometry have developed because of the empirical methods used in measuring masses and volumes of reactants and products. Observations that the quantities as well as kinds of reactants influenced chemical reactions led to the development of notions of Avogadro's Law, moles, and molarity. It was observed that concentration affected reactions, as did the presence of energy in the form of heat or light.

A language and a system of notation has been developed to represent chemical reactions. Formulae and equations using letters and numbers represent the kinds and numbers of particles present in a reaction. Other symbols represent the nature of the substances present; for example, whether they are precipitates, gases or species in aqueous solution. Precision and accuracy in measurements of mass and volume allow control of product yields. Part of the mystique and intrigue of Chemistry comes from this arcane symbolism. It can fire the passion and motivation of some candidates. It can also be alienating and frightening to others. Not only are candidates being exposed to new concepts about unseen (and unseeable) activities of atoms and molecules, but the mode of presentation is effectively in a second language (and this will be even more problematical for candidates whose first language is not English).

The exact nature of unknown substances can be determined by performing a sequence of reactions. Such analyses are based on knowledge about which chemical species reacts with others, and knowing if a precipitate, or a gas, or a change in solution colour will occur. There is an exciting atmosphere of challenge and discovery with this kind of chemical detective work. Much of the public's image of science is that of the analytical investigation of substance X! This image can be a powerful and motivating one for candidates interested in science in general, and Chemistry in particular. If candidates experience the excitement and passion (and success!) of chemical analyses, within the discipline of ordered, empirical quantitative chemistry then they can more readily construct links between this and the other core topics. To that extent, this topic provides a language and notational platform as well as an experiential base for Energy and Rates of Chemical Reactions, Chemical Equilibrium, and Oxidation and Reduction. With this comes the development of, and appreciation for, the rigour of chemistry.

Subject matter

Candidates should become familiar with the concepts, units of measurement and use of concentration information in calculations involving quantities of reactants and products. They should be able to write correct formulae and balanced equations. Candidates will study the mole concept and should be able to describe the evidence that has led to its construction. This topic is likely to allow significant experience to be gained through practical investigations leading to the development of a range of manipulative skills that should include volumetric and mass measurements. Other manipulative skills that could be developed include filtering, decanting, crystallising, and distilling. Concomitant with practical activities in the laboratory will be the development of observational skills, data collection and the accepted format, language and conventions of report writing. It is desirable that appropriate safety practices be developed through the laboratory experiences of this topic.

Table 2

Knowledge objectives	**Scientific processes**	**Complex reasoning processes** *(suggestions only)*
Candidates should be able to: 2.1 explain the terms *relative atomic mass*, *relative molecular mass* and *relative formula mass*, *mole*, *molar mass*, *molar volume*, *Avogadro's Number*, *molarity*, *empirical* and *molecular formulae* 2.2 solve simple stoichiometric problems involving relationships between moles, mass, volume, number of particles and molarity of solution 2.3 balance simple chemical equations 2.4 explain the information contained in a chemical equation 2.5 use the molar relationships in a balanced chemical equation to calculate unknown amounts or concentrations of the components involved 2.6 describe the correct techniques and procedures for volumetric and gravimetric analyses 2.7 explain basic mass spectrometry (parent ion, isotopes).	Candidates should be able to: 2.1 interpret and process data from a volumetric analysis 2.2 identify sources of error in simple analytical procedures.	Candidates should be able to: 2.1 perform multistep analytical procedures and calculations 2.2 solve challenging problems involving percentage yield in synthetic reaction processes 2.3 identify the formula of an unknown compound from complex analytical data 2.4 apply at an advanced level the knowledge and scientific processes objectives.

Topic 2 Reacting quantities and chemical analysis

Topic 3 Oxidation and reduction

Introduction

Chemical reactions that involve the transfer of electrons are oxidation-reduction reactions. Oxidising agents are atoms or ions that take up electrons during such reactions, while reducing agents are those that supply the electrons for such reactions. The oxidation state of a reacting species is indicated by an oxidation number Oxidation numbers can be used to balance equations that are not obvious by inspection. Some oxidation-reduction reactions occur spontaneously and can be used as a source of electrical energy. Electrochemical cells, commonly referred to as batteries, are responsible for the powering of transistor radios, walkmans and discmans, camera flash units, portable toys, electrical and electronic devices. There are varieties of electrochemical cells ranging from the ‘wet’ cells of the lead-acid car battery, through to the ‘dry’ cell using zinc and carbon electrodes and the ‘alkaline’ battery. Improved technologies have allowed the development of smaller cells for use in pocket calculators, hearing aids and other medical and miniaturised electronic devices. Oxidation-reduction reactions that are not spontaneous can be forced to react by an electric current. These electrolytic processes are important in many industrial applications including chrome and silver plating. A common laboratory demonstration is the electrolysis of water into its constituents of hydrogen and oxygen. Similar industrial applications of electrolysis include the production of aluminium and chlorine. Everyday occurrences of oxidation-reduction reactions include rusting of iron or other metals becoming coated in an oxide, bleaching, or the reaction of lead sinkers and salt water on the floor of an aluminium boat. Research continues into understanding the production and transmission of nervous impulses in animals and many biochemical reactions are redox in nature.

Subject matter

Candidates should gain an understanding of oxidation-reduction reactions and develop skills in balancing the equations that represent them. Candidates should be familiar with the definitions of oxidation and reduction and their basis of electron transfer. Through balancing redox reactions, candidates should develop concepts of conservation of mass, electrons and charge. Accumulation of experimental data from electrolytical experiments (for example, the quantitative application of Faraday’s Law) should be the basis of candidates’ understanding why the use of these arbitrary techniques can be justified. In this way candidates will not come to believe that the oxidation number represents an actual charge. Candidates should be able to use tables of half-reactions and be able to determine if reactions occur spontaneously and what the resultant potential will be. They should be able to rank substances as being stronger or weaker oxidising (or reducing) agents.

Table 3

Knowledge objective	Scientific processes	Complex reasoning processes
Candidates should be able to: 3.1 explain the meaning of the terms *oxidation number*, *oxidation*, *reduction*, *electron transfer*, *oxidising agent (oxidant)*, *reducing agent (reductant)*, *electrochemical*, *galvanic*, *electrolytic*, *cell*, *anode*, *cathode*, *electrode*, *salt bridge* 3.2 recall the rules for assigning oxidation numbers and apply them to calculate the oxidation numbers of elements in molecules and ions 3.3 write balanced half and net equations for redox reactions including reactions of MnO_4^- and $Cr_2O_7^{2-}$ aqueous solution 3.4 determine the possibility of simple electrochemical reactions occurring using a reactivity series 3.5 draw fully labelled diagrams of simple galvanic and electrolytic cells demonstrating their principles of operation, e.g. Zn/Cu, electroplating 3.6 solve simple problems using Faraday's law of electrolysis 3.7 describe the chemical processes involved in the extraction and purification of copper	Candidates should be able to: 3.1 construct a reactivity series from information about the relative reactivity of a series of elements and ions 3.2 design simple galvanic and electrolytic cells from information given 3.3 relate redox processes to commonly used cells.	Candidates should be able to: 3.1 interpret complex redox systems 3.2 design redox experiments to separate metals from solutions containing their ions 3.3 write and balance complex equations using oxidation numbers and/or half-cell equations 3.4 perform challenging calculations involving Faraday's law 3.5 apply at an advanced level the knowledge and scientific processes objectives.

Topic 3 Oxidation and reduction

Topic 4 Organic chemistry

Introduction

Organic chemistry is the study of the chemistry of carbon. Because of its bonding properties, chains of carbon atoms can be linked together in an almost infinite array of different configurations. Bonding with hydrogen, oxygen, nitrogen, the halogens, the hydroxyl and other radicals produces a vast array of the chemicals of life. Proteins, carbohydrates, and fats and oils are all classes of organic substances. DNA, the coded blueprint for all living things, has its properties because of a unique double-helix arrangement of two long spiral strands joined by energy-binding bonds. Fossil fuels are rich and complex mixtures of organic chemicals. These are a source of energy, as well as being the building blocks of today's world of synthetic materials. Flavours and odours are due to properties of groups of organic chemicals including esters. Pheromones are chemical messengers used by a wide variety of animals. Sexual attraction of many species—humans included—involves these substances. Solvents, pharmaceuticals, paints, dyes, building materials, synthetic fabrics, plastics and a host of other human-designed everyday substances are possible because of the application of organic chemistry.

While there is a bewildering array of organic compounds, a systematic classification of them based on their properties, which is in turn based on their structure, is possible. An international convention of nomenclature enables consistent naming and representation of structural and empirical formulae. A range of analytical procedures from chromatography to absorption spectroscopy allows investigation of molecular structure and bonds. A systematic application of knowledge of bonds and reactive properties allows the design and synthesis of new substances with the specific properties required for a particular application (e.g. an industrial adhesive). Other applications of this include the identification of natural insecticides and anti-mould agents. Many careers are possible in the field of organic chemistry. These can include the food industries that are searching for the identity of tastes and flavours so that they can be duplicated. Some Queensland researchers are leaders in extracting and identifying the 'flavours' of tropical fruits. New careers are opening in the plastics industry—from building materials to medical technology including prosthetic devices and reconstruction technologies.

Subject matter

Candidates should become familiar with the IUPAC conventions for naming organic substances and representing their molecular structure. They should have experience of the general properties of the main organic groups and series. They should be able to describe the reactivities and energies associated with multiple bonds. Isomerism will be introduced. Literature research into the applications of organic chemistry to today's life-style could enable candidates to investigate issues of interest and relevance to them. These could range from epoxy chemistry, food chemistry, analysis technology, biochemistry, medical applications, through to the problems of using plasticers in cling wrap, PET container recycling technology, or debating the use of paper cups versus styrofoam ones. It is likely that through this topic links with the biological and environmental sciences, fuel technologies of physics, explorative and extractive technologies used by geologists and refining technologies of the fossil fuels industries can be established. Many lifestyle-related issues such as designer drugs or the labelling of food additives could be studied. Marketplace or consumer chemistry could be used as an organisational theme.

Table 4

Knowledge objectives	Scientific processes	Complex reasoning processes
Candidates should be able to: 4.1 write the general formulae for alkanes, alkenes, alkynes, alcohols, carboxylic acids, esters, amines, aldehydes, ketones and amides, and give simple examples of each 4.2 use IUPAC rules to name alkanes, alkenes, alkynes and simple alcohols, carboxylic acids, esters, amines, aldehydes, ketones and amides 4.3 explain the terms *structural isomerism, geometrical isomerism, functional group, homologous series (up to C10), saturated and unsaturated, substitution, addition, elimination, monomer, polymer, polymerisation, repeat unit* 4.4 recall simple physical properties (melting point, boiling point, solubility) of alkanes, alkenes, alcohols, acids, addition and condensation polymers and relate these properties to structure 4.5 recall simple chemical properties of halogens, alkanes, alkenes, alcohols, acids and esters, combustion, substitution of alkanes, addition to alkenes, oxidation of alcohols, esterification, hydrolysis of esters (**not** including preparation) 4.6 draw structures of compounds in 4.1 and 4.5 4.7 identify the structural features of some biochemical molecules—amino acids, proteins, fats, carbohydrates 4.8 describe the properties, preparation and use of ethanol and its significance to society.	Candidates should be able to: 4.1 identify functional groups from simple unfamiliar chemical tests 4.2 process and identify trends from data in tabular or graphical form 4.3 relate the properties of organic substances to their use and structure 4.4 devise simple tests to identify unknown organic compounds.	Candidates should be able to: 4.1 predict the products of multistep processes 4.2 identify molecular and structural formulae of unknown compounds from quantitative and qualitative data 4.3 apply at an advanced level the knowledge and scientific processes objectives.

Topic 5 Chemical periodicity

Introduction

Early in the 19th century, chemists, observing that some elements had similar properties, sought to place them in groups based on these similarities. The German chemist, Dobereiner, recognised triads like calcium–strontium–barium and chlorine–bromine–iodine. The English scientist, Newlands, arranged elements in order of increasing atomic mass and noticed a similarity of every eighth element. The Russian chemist, Mendeleev, recognised the trend of increasing atomic mass, as had Newlands. He also recognised that similar properties occurred after periods (horizontal rows) of varying length, rather than according to the constant law of octaves proposed by Newlands. His construction of a periodic table which had the first two rows of seven elements each, followed by seventeen in the next two, has provided the basis for modern periodic tables. These are based on the electronic configuration of atoms. A horizontal row of elements is called a period and a vertical column of elements is called a group or family. Such families include the halogens, the alkali metals, and the noble gases. Elements in the same family tend to have similar properties. This is because they have similar arrangements of the outer-shell electrons. Elements with one, two, or three electrons in the outer level tend to be metals, while representative elements with five, six, seven, or eight outer electrons tend to be non-metals. The periodic table, together with the octet rule, can be used to predict oxidation numbers. Trends in atomic size and ionisation energies (the energy required to remove an electron) are observed through periods. The concepts of ionisation energy and electron affinity can be useful in understanding how compounds are formed and can be used to predict which elements will react to produce compounds.

Subject matter

Modern periodic tables are human-constructed organisers that reflect observed properties and presumed models of atomic structure and orbital theories. Candidates should become familiar with the major features of periodicity and the general trends observed through families and periods. Candidates should be able to locate those elements that are gases, liquids and solids, and those that are metals and non-metals. While it is necessary that many aspects of periodicity will be best introduced within a specific learning unit, frequent reference will be made to the periodic table in other core topics. Candidates will refer to the periodic table for information on atomic mass, atomic weight, atomic number, and elemental symbols when learning about formulae, molarity, molecular weight, and isotopes, for example. Their understanding of underlying atomic structure and the principles of reactivity and the energy of bonds will be reinforced by the information systematically conveyed through the periodic table. The topic, Chemical Periodicity, reinforces these other topics, as well as it being reinforced by them. In this way, candidates should gain an appreciation of the interrelated nature of all aspects of the full course.

Chemical Periodicity could be used as the platform for commencing other core topics, or it could be used as a unifier after other core topics have been introduced. It is possible that a spirally arranged sequence of learning experiences would continue to revisit this, and other core topics, to continue to develop increasing conceptual understandings. There are many video programs that would support Chemical Periodicity. Those interested in presenting a history of science might use this topic as a particular focus, since the elemental symbols and names, as well as the sequence of the discovery of new elements and the study of their properties, represent a history of human endeavour and scientific enlightenment. Such a study could also help candidates understand the international and multicultural nature of science. The importance of communicating discoveries in scientific reports and journals, and debating theories at meetings of professional societies, symposia and conferences could be discussed. An appreciation of internationally recognised and observed conventions and protocols related to formula and equation writing and report format could also be developed through such studies.

Table 5

Knowledge objectives	Scientific processes	Complex reasoning processes
Candidates should be able to: 5.1 describe the general organisation of the periodic table in terms of electron arrangement 5.2 identify the s, p, d and f block groups of elements on the periodic table 5.3 recall the characteristics of the main groups 1, 2, 16, 17, 18 (in IUPAC nomenclature) of the periodic table 5.4 recall the trends across a period or down a group in the periodic table for properties—melting or boiling point, reactivity, ionisation energy, atomic radius, metallic character, nature of oxides (acidic, basic, amphoteric) 5.5 explain the relationship between the number of valence electrons for an element, its position in the periodic table, and its chemical properties.	Candidates should be able to: 5.1 identify trends and anomalies in experimental data for groups and periods in the periodic table 5.2 present data in graphical or tabular form.	Candidates should be able to: 5.1 identify the group classification of an unknown element or ion on the basis of its physical and chemical properties 5.2 interpret trends in previously unseen properties of compounds of a group or period of the periodic table 5.3 apply at an advanced level the knowledge and scientific processes objectives.

Topic 5 Chemical periodicity

Topic 6 Gases and the atmosphere

Introduction

Gas is one of the four phases of matter. Current models of the creation of the universe describe chemical and physical processes involving gases. Life on earth is dependent on the mantle of gases that constitute the earth's atmosphere. Many powerful and subtle properties and reactions of these gases are involved in life's ultimate chemistry—that of photosynthesis and respiration. Weather, and its influence on the nature and distribution of life-forms, occurs because of complex physical and chemical processes of atmospheric gases. A host of land-clearing, agricultural, industrial and Western lifestyle practices influence the composition of the atmosphere, and therefore have changed, and continue to change, the nature of the atmosphere's chemistry and physics. Understanding the impacts of phenomena such as the greenhouse effect, ozone layer depletion and acid rain requires both a broad, as well as intimate, knowledge of a wide range of chemical, physical and biological processes.

Gases have featured in the history of science in general, and of Chemistry in particular. Through studying the properties of gases, current concepts of the particle nature of matter, the mole, temperature, heat and kinetic theory, and equilibria amongst others have been constructed. Significant industrial processes involving gases are responsible for the manufacture of a host of substances. Specific gases are used in medicine, space and underwater exploration, computer chip assembly, agricultural processes of ripening, food processing, manufacturing construction materials, welding and the plastics industry The chemistry of fuel gases is exploited for the engines of industry and the motor car.

Subject matter

Candidates should become familiar with the general physical properties of gases and the relationship between gases and the other three phases of matter. They should be able to locate the gaseous elements on a periodic table as studied in the topic, Chemical Periodicity and to relate the properties of these gases to their atomic properties, including atomic mass and electronic configuration as studied in the topic, Materials-Properties, Bonding and Structure.

Table 6

Knowledge objectives	Scientific processes	Complex reasoning processes
Candidate should be able to: 6.1 describe the physical properties common to gases—compressibility, diffusion, pressure, temperature, solubility 6.2 explain the kinetic theory of gases and the relationship between absolute temperature and kinetic energy 6.3 recall the ideal gas law and use it to solve simple problems 6.4 describe the conditions under which real gases approach ideal gas behaviour 6.5 recall Dalton's Law of Partial Pressures and use it to solve simple problems 6.6 explain the concept of vapour pressure and the factors on which it depends 6.7 list the major gases (O_2, CO_2, N_2, H_2O) in the earth's atmosphere and describe how the presence of each affects human welfare 6.8 explain why the concentration of ozone in the upper atmosphere is important to humans and describe the factors which affect that concentration.	Candidates should be able to: 6.1 process information to explore the ideal gas law 6.2 analyse quantitatively and qualitatively the concept of partial pressure to make simple judgments.	Candidate should be able to: 6.1 use the kinetic theory to critically examine common gas properties 6.2 solve multistep problems involving the ideal gas law and partial pressure 6.3 apply at an advanced level the knowledge and scientific processes objectives.

Topic 6 Gases and the atmosphere

Topic 7 Energy and rates of chemical reactions

Introduction

Photosynthetic plants and bacteria take ‘free’ environmental energy in the form of light and convert it into the energy of bonds of organic molecules. Chemosynthetic bacteria use the energy released during certain chemical reactions in a similar way. All living things rely on the energy in the bonds of a wide range of organic compounds for the processes of life. Energy in the bonds of fuels, including wood, coal, kerosene and petrol are released during combustion to provide energy for heating, lighting, electricity generation, and to drive the engines and motors of cars, ships, aeroplanes, and the host of machinery used to produce all the products that contribute to our lifestyle.

Energy holds the particles of every atom together. The energies of electrons relate to their motion, position and reactivity. The energies of atoms and molecules relate to their motion and closeness to each other, and hence such properties as their state of matter and temperature. To understand energy and its relationships in chemical reactions is to start to understand the nature of the universe itself. Einstein’s formula $E=mc^2$ shows the link between matter and energy. Energy is the weave that holds the material fabric of the universe together.

Chemical reactions involve energy transfer. First-hand laboratory experiences, as well as observation of everyday chemical reactions, will reveal that some reactions proceed more quickly than others. Observation and measurement of time, temperature and concentrations of reactants provide data that enable the construction of models to explain these different rates of reactions. The construction of understandings of the concepts of the kinetic theory, molecular architecture and reaction kinetics is based on the real-world experiences of chemical reactions experienced by candidates. A significant core of first-hand experience of a wide variety of chemical reactions and the factors affecting their rates will enable candidates to make the connections between the unseen and unseeable world of atoms and molecules and the concepts relating to their size, mass, architecture and reactive properties.

Subject matter

Familiarity with the kinetic model of matter and collision theory should enable candidates to relate the states of matter to the energies of atoms and molecules. Concepts of enthalpy and entropy will be introduced. Candidates should be able to describe concepts related to endothermic and exothermic reactions, activation energy and reaction kinetics. The properties of everyday substances and their reaction rates could be used to demonstrate the ‘real-world’ applicability of knowledge of this topic. Epoxy resins, glues, adhesives and other binding and filling products, cooking and other food reactions (or their absence, as in preserving technologies), dyeing, bleaching, detergents and other cleaning agents are possible chemicals and reactions that might have relevance for candidates. Many of these are redox in nature and candidates could study the links between energy transformations of electrochemical reactions.

As in the topic, Reacting Quantities and Chemical Analysis, candidates should have a significant number of laboratory experiences that develop early skills of following experimental instructions, recording observations and quantitative data and writing experimental results in an accepted report mode. Once mastered, these skills will provide a platform for the development of the higher cognitive scientific processes and complex reasoning related to rates of chemical reactions. Candidates will study how concentration, temperature and catalysts affect rates of reaction. Candidates can then start to appreciate the subtleties of ‘elegant’ models of atoms and molecules, and of the rigour of scientific method.

Table 7

Knowledge objectives	Scientific processes	Complex reasoning processes
Candidates should be able to: 7.1 state the Law of Conservation of Energy 7.2 define the terms *exothermic, endothermic, combustion, enthalpy, entropy, reaction rate, reaction coordinate, activated complex, activation energy, catalyst* and *reaction mechanism* 7.3 define ΔH, ΔH^0 and ΔH^0_f and identify whether a reaction is exothermic or endothermic given ΔH values 7.4 describe energies involved in phase changes 7.5 explain how potential energy-reaction coordinate diagrams change if a catalyst is present in a reaction 7.6 define bond energy and relate it to enthalpy changes in a reaction 7.7 list the factors that influence the rate of reaction 7.8 recall the basic postulates of collision theory 7.9 use collision theory to explain how the nature of reactants, the concentration or pressure of the reactants, the surface area of the reactants, the temperature of the system and the action of catalysts and inhibitors influence the rate of reaction 7.10 describe the difference between a stoichiometric equation and a reaction mechanism 7.11 perform simple calculations involving Hess' law.	Candidates should be able to: 7.1 interpret information on energy sources 7.2 interpret temperature changes during chemical reactions 7.3 determine ΔH values from calorimetric experimental data for chemical reactions only 7.4 process experimental rate data graphically and/or numerically.	Candidates should be able to: 7.1 solve multistep problems involving ΔH 7.2 make decisions regarding the energy efficiency and energy supply capacity of some fossil fuels and alternative energy sources 7.3 design an experimental investigation to follow the course of a reaction and/or determine the influence of variables on reaction rates 7.4 justify the choice of conditions for an unseen industrial or technological process not previously encountered by the candidates 7.5 apply at an advanced level the knowledge and scientific processes objectives.

Topic 7 Energy and rates of chemical reactions

Topic 8 Chemical equilibrium

Introduction

Many reactions and processes are reversible. Equilibrium is a dynamic state in which two opposing processes take place at the same time and at the same rate. In 1888, the French chemist Henri Louis Le Chatelier published this principle: *If a system at equilibrium is subjected to stress, the equilibrium will be displaced in such direction as to relieve the stress*. Equilibrium between a solid and a solution is the state attained in which the opposing processes of dissolving and crystallising of a solute occur at equal rates. Significant numbers of chemical reactions occur when the reacting species are in solution. Life as we know it on Earth would not be possible without water. More substances dissolve in water than any other solvent, thus allowing the maximum number of substances to react with each other. This leads to the diversity of chemical reactions that constitute the totality of the biochemical processes of each individual cell, and ultimately each living organism. Many natural environmental processes are reversible, and the chemistry of soil, water and the atmosphere involves the dynamic equilibria of substances going into and out of solution. Human activities have caused changes to watertables and water catchments and changes to the soil by extraction of substances and deliberate and unintentional additions of soluble and insoluble substances. The chemistry of soils and water catchments has therefore been altered. Answers to many current environmental problems caused by these changes will be found when these reactions and their dynamics have been better identified and quantified.

Electrolytes are substances that in solution conduct an electric current because they have dissociated into ions. Historically, they have been classified into three classes—acids, bases, and salts. Nearly all fruits contain acids, as do many other foods. Mineral acids such as hydrochloric acid, sulphuric acid, phosphoric acid and nitric acid are very important in the chemical production industries. Common bases include household ammonia and sodium hydroxide. Milk of magnesia is a suspension of magnesium hydroxide and is used as an antacid and a laxative. Different acids and bases dissociate differently in water. Dissociation is a reversible process and Le Chatelier's Principle applies. Specific reaction constants, K_a and K_b, can be determined.

Subject matter

Candidates will encounter solvents, solutes, solutions, dissolving, solubility and insolubility, solubility constant and precipitation.They should be able to describe Le Chatelier's Principle and apply it quantitatively to solubility equilibria and acid-base equilibria. Candidates should be able to explain the effects of temperature and the presence of other ions on solubility. Candidates will study acids and bases and should be able to describe the properties of weak and strong acids and bases and the difference between strength and concentration.

Significant laboratory experience will enable candidates to be familiar with methods of making solutions of different concentrations and the different ways of indicating those concentrations (for example, p.p.m. and molarity). They should be able to select appropriate indicators for the determination of pH of solutions and apply appropriate titration techniques. Through laboratory activities, candidates should develop skills in accuracy and precision in quantitative measurements of mass and volume. Where available candidates may gain additional laboratory skills with pH meters and probes. Candidates should be able to write balanced equations showing solubility and acid-base equilibria and be able to apply the equilibrium law to these reactions.

Table 8

Knowledge objectives	Scientific processes	Complex reasoning processes
Candidates should be able to: 8.1 describe reversibility of a chemical reaction 8.2 identify the characteristics of an equilibrium state 8.3 compare and contrast the concepts of steady state and dynamic equilibrium 8.4 write the appropriate balanced equations for equilibrium systems including phase changes, gas phase reactions, redox, acid-base, solubility processes and reactions in aqueous solution—precipitation 8.5 apply the concept of dynamic equilibrium to the changes listed in 8.4 8.6 describe the meaning of the terms *saturated, unsaturated, dilute, concentrated, strong electrolyte, weak electrolyte, non-electrolyte, strong and weak acids* as applied to solutions and give examples 8.7 recall the solubility of a range of common salts (nitrates, alkali metal salts, AgCl, $BaSO_4$) 8.8 state the Equilibrium Law and apply it to the equilibria listed in 8.4 8.9 estimate the relative extent of reactions given equilibrium constants 8.10 perform simple equilibrium calculations on gases in homogeneous equilibria relating equilibrium constants to equilibrium concentrations only 8.11 state Le Chatelier's Principle and use it to explain and/or predict the effect of an imposed change on an equilibrium system 8.12 apply equilibrium principles to explain the Haber Process 8.13 describe the physical properties and simple chemical reactions of acids and bases 8.14 define acids and bases using the Lowry-Bronsted theory 8.15 define pH and K_w 8.16 perform simple calculations relating pH to $[H_3O^+]$ and $[OH^-]$.	Candidates should be able to: 8.1 interpret the effect of factors such as concentration, pressure, temperature and presence of catalysts on the position of a given system equilibrium 8.2 predict the pH of solutions (acids, bases, salts) from data given 8.3 process experimental data to evaluate whether an electrolyte is strong or weak or is a non-electrolyte 8.4 predict qualitatively the formation of insoluble salts in solution, given suitable data.	Candidates should be able to: 8.1 use qualitative analysis schemes to determine the identity of unknown solutions 8.2 predict and/or explain the effects of imposed changes (concentration, pressure, temperature, competing equilibria) on complex or novel equilibrium systems 8.3 perform multistep or more difficult calculations 8.4 apply at an advanced level the knowledge and scientific processes objectives.

8 ASSESSMENT

8.1 The examination

The examination will consist of two papers:

- Paper One, of up to 2.5 hours
- Paper Two, of up to 2 hours

Each paper will have 10 minutes perusal time.

Assessment of the general objectives will be made in three dimensions (criteria):

- **knowledge of subject matter**
- **ability to use scientific processes**
- **ability to use complex reasoning processes**

Paper One will contain questions assessing candidates' knowledge of subject matter and scientific processes. The paper will contain questions across the knowledge objectives (approximately 70%) and the scientific processes objectives (approximately 30%). Questions with respect to experimental procedures and laboratory safety may be included in this paper. The paper will consist of multiple choice and short answer questions. The short answer questions may consist of several parts. Paper one will be a closed book examination and data tables will be supplied.

Paper Two will contain questions designed to assess the candidate's ability to use complex reasoning processes. As a consequence of the nature of these complex reasoning processes the paper will consist of a small number of extended answer questions. Paper two will be an open book examination. In this examination students will be permitted to bring to the examination room any relevant paper-based written or printed material. Data tables will be supplied.

Both papers will provide a coverage of syllabus topics although a wider coverage will be possible in the first paper.

8.2 Exit Levels of Achievement

On completion of the examinations, each candidate will be awarded one of the following Levels of Achievement:

- Very High Achievement
- High Achievement
- Sound Achievement
- Limited Achievement
- Very Limited Achievement

To be awarded a particular Level of Achievement candidates must perform to the standard specified in each dimension, that is: knowledge, scientific processes and complex reasoning processes. When a candidate's performance is uneven, resulting in different standards in each dimension (criterion), slight trade-offs are possible (see section 8.3).

The Levels of Achievement are thus defined in terms of a candidate's performance across each dimension (criterion) as shown in the following table.

Table 9. Minimum standards associated with exit criteria

	Very High Achievement	**High Achievement**	**Sound Achievement**	**Limited Achievement**	**Very Limited Achievement**
Knowledge of subject matter	A very high ability to recall and apply knowledge of Chemistry in simple situations.	A high ability to recall and apply knowledge of Chemistry in simple situations.	A satisfactory ability to recall and apply knowledge of Chemistry in simple situations.	Limited ability to recall and apply knowledge of Chemistry in simple situations.	Very limited ability to recall and apply knowledge of Chemistry in simple situations.
Scientific processes	A very high ability to succeed in simple scientific process tasks—collecting and organising data, processing information, making simple judgments, communicating information in various contexts, devising and designing simple and/or single-step investigations.	A high ability to succeed in simple scientific process tasks—collecting and organising data, processing information, making simple judgments, communicating information in various contexts, devising and designing simple and/or single-step investigations.	A satisfactory ability to succeed in simple scientific process tasks—collecting and organising data, processing information, making simple judgments, communicating information in various contexts, devising and designing simple and/or single-step investigations.	Limited ability to succeed in simple scientific process tasks.	Very limited ability to succeed in simple scientific process tasks.
Complex reasoning processes	A high ability to use complex reasoning in challenging situations involving the candidate's understanding of subject matter, and a high ability to use scientific processes at an advanced level.	Competence in using complex reasoning in challenging situations involving the candidate's understanding of subject matter, and competence in using scientific processes at an advanced level.	Some success in using complex reasoning in challenging situations involving the candidate's understanding of subject matter, and some success in using scientific processes at an advanced level.		

8.3 Trade-offs

When data in a candidate's profile of achievement are uneven resulting in different standards for some of the exit criteria, a trade-off must be considered if a single criterion deficiency for a particular Level of Achievement is '**slight**' (i.e. less than one-third of the relevant Level of Achievement range).

Only one trade-off is permissible.

Under these conditions:

- A slight deficiency in **knowledge of subject matter** may be offset by a comparable excess in **scientific processes** or vice versa

OR

- A slight deficiency in **knowledge of subject matter OR scientific processes** may be offset by a comparable excess in **complex reasoning processes**.

No other trade-offs, other than those listed above, are permissible for **knowledge of subject matter, scientific processes** or **complex reasoning processes**.

9 RESOURCES

Following is a list of texts commonly used in Queensland secondary schools which offer Chemistry. This list is current at the time of publication.

If candidates require additional information it is recommended that they contact a Queensland teaching institution which offers Chemistry. A list of institutions may be found in the *External Examinations Handbook*. Candidates should also refer to section 5 for other suggested types of resources.

Ash, M. et al. 1995, *Q Chemistry*, Jacaranda Wiley, Brisbane.

Bucat, R. B. (ed), 1983, *Elements of Chemistry: Earth, Air, Fire and Water Vols. I & II*, Australian Academy of Science, Canberra.

Commons, C. 1991, *Chemistry*, *Two: Chemistry and the Marketplace, Energy and Matter*, Heinemann Educational, Melbourne.

Elvins, C. 1990, *Chemistry One: Materials, Chemistry in Everyday Life*, Heinemann Educational, Melbourne.

Garnett P. J. et al. 1996, *Foundations of Chemistry*, 2nd edn, Addison Wesley Longman, Australia, South Melbourne.

Smith, A. and Dryer, C. 1992, *Key Chemistry: Investigating Chemistry in the Contemporary World: Book I: Materials and Everyday Life*, Melbourne University Press, Melbourne.

Smith, A. and Dryer, C. 1992, *Key Chemistry: Investigating Chemistry in the Contemporary World: Book II: Energy, Matter and the Marketplace*, Melbourne University Press, Melbourne.

Smith, R. 1994, *Conquering Chemistry*, 2nd edn, McGraw-Hill Australia, Roseville, NSW.

Smith, R. 1995, *Exploring Chemistry*, McGraw-Hill Australia, Roseville, NSW. ISBN 0074702491

Wilbraham, A. C. et al. 1996, *Addison Wesley Chemistry*, 4th edn, Addison Wesley Longman, USA.

10 GLOSSARY

Complex reasoning processes. Complex reasoning processes are those higher order or more involved problem-solving processes that provide challenge to candidates and hence would discriminate across the range of candidate abilities. They are likely to include responding to novel tasks, making logical decisions involving the selection of relevant knowledge and/or data, and using creative and/or critical thinking—which could include the identification of assumptions, fallacies, valid or invalid conclusions, adequacy of data, and the proposing of alternative theories. Complex reasoning processes might also involve advanced level challenges derived from the knowledge of subject matter or scientific processes. The candidate who is a novice to the context and/or material necessary to demonstrate use of complex reasoning is likely to perceive difficulty in such challenging situations.

Criteria. Criteria are those aspects, dimensions or characteristics on which candidate performance is judged.

Exit Criteria. These are the broad performance dimensions that are used to determine exit Levels of Achievement. They are derived from the general objectives of the syllabus. In this syllabus they have been identified as:

- knowledge of subject matter
- scientific processes
- complex reasoning processes.

Knowledge. Knowledge is the recall of learned material and its simple application (see section 4).

Manipulative skills. Manipulative Skills include the operation of scientific and experimental equipment and materials proficiently and safely (see section 6.2.1).

Scientific processes. Scientific Processes are those processes that involve collection and organisation of data, processing of information, making simple judgments, communicating information in various contexts, devising and designing simple and/or single-step investigations at a simple level.

Trade-off. The process of trade-off is used to assist in determining a candidate's exit Level of Achievement when the candidate has attained different standards for the various exit criteria.