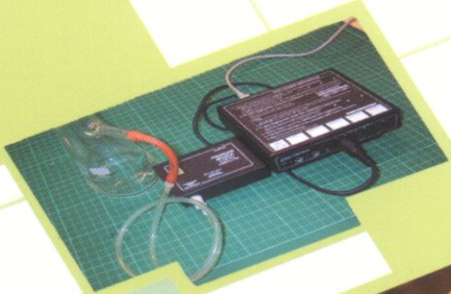
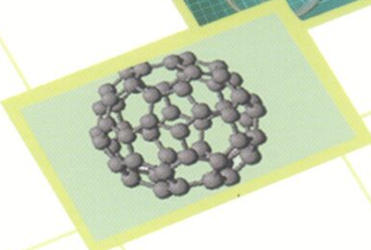
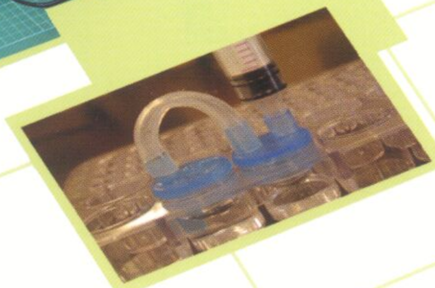
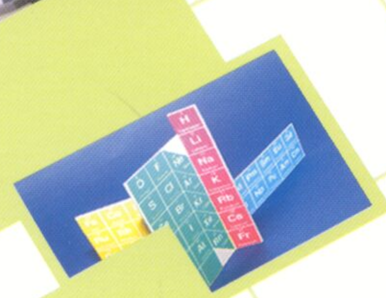






Science Education Key Learning Area

Chemistry Curriculum Guide (Secondary 4-5)



Prepared by
The Curriculum Development Council

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The Education Department
HKSAR
(2002)

CONTENTS

Membership of the Joint CDC and HKEA Working Party on the Revision of S4-5 Chemistry Syllabus

(From October 1998 to August 1999)

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PREAMBLE

This Curriculum Guide is one of the series prepared by the Hong Kong Curriculum Development Council for use in secondary schools.

The Curriculum Development Council is an advisory body giving recommendations to the Hong Kong Special Administrative Region Government on all matters relating to curriculum development for the school system from kindergarten to sixth form. Its membership includes heads of schools, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields or related bodies, representatives from the Hong Kong Examinations Authority and the Vocational Training Council, as well as officers from the Education Department.

This Curriculum Guide is recommended by the Education Department for use in secondary schools. The curriculum developed for the senior secondary levels normally leads to appropriate examinations provided by the Hong Kong Examinations Authority.

The Curriculum Development Council will review the curriculum from time to time in the light of classroom experiences. All comments and suggestions on the Curriculum Guide may be sent to:

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I. AIMS AND OBJECTIVES

Aims

The overarching aim of science education is to provide learning experiences for students to engage in processes for scientific understanding and the application of science, and to recognise the impacts of scientific and technological developments. These learning experiences will lay the foundation for students to communicate and make informed judgements based on scientific evidence, develop further in science and technology, and become life-long learners in science and technology.

The broad aims of this curriculum are that students should:

1. develop curiosity and interest in chemistry;
2. acquire an appropriate body of knowledge and understanding in chemistry;
3. acquire an ability to think rationally and critically, and to apply the knowledge of chemistry in making judgements and solving problems;
4. develop skills in scientific investigations;
5. recognise the evolutionary and sometimes transitory nature of chemical knowledge;
6. be acquainted with the language of chemistry and be equipped with the skills in communicating ideas in chemistry related contexts;
7. develop an appreciation of chemistry and its applications in daily life;
8. become aware of the social, economic, environmental and technological implications of chemistry, and show concern for the environment and society; and
9. develop open-mindedness, objectivity and proactiveness.

The chemistry curriculum is set to prepare students for the formulation of values and attitudes related to social, ethical, political, economic, and environmental aspects of chemistry, so that they may grow up to become responsible citizens.

Objectives

Based on the broad aims, it is possible to identify the learning objectives for the curriculum as follows:

A. Knowledge and Understanding

Students should learn

1. some phenomena, facts, principles, concepts, laws and theories in chemistry;
2. chemical vocabulary, terminology and conventions; and
3. some applications of chemistry in society and in everyday life.

B. Skills and Thinking Processes

1. Scientific method and problem solving skills

Students should be able to

1.1 identify scientific, social and technological problems and ask relevant questions;

1.2 identify assumptions, concepts and theories related to a problem posted;

1.3 propose hypotheses and devise methods to test them;

1.4 analyse data from experimental results or from other sources;

1.5 draw conclusions and make predictions;

1.6 evaluate suggested solutions to a problem from different perspectives, including scientific, social, ethical, political and economic aspects where appropriate;

1.7 apply knowledge and understanding to solve problems in unfamiliar situations; and

1.8 recognise the usefulness and limitations of scientific methods.

2. Practical skills

Students should be able to

2.1 select appropriate apparatus and materials for an experiment;

2.2 handle chemicals and apparatus safely and properly;

2.3 carry out instructions for experiments and record observations accurately;

2.4 interpret observations and experimental data;

2.5 devise and plan experiments;

2.6 evaluate experimental methods and suggest possible improvements; and

2.7 build models to aid comprehension.

3. Communication skills

Students should be able to

3.1 use symbols, formulae, equations and conventions appropriately;

3.2 extract useful information from a variety of sources;

3.3 interpret scientific information from text and data presented in diagrammatic, numerical, tabular and graphical forms;

3.4 organise and present ideas and arguments in a clear and logical form; and

3.5 communicate scientific ideas and values in a meaningful and creative way.

4. Decision making skills

Students should be able to

4.1 make decisions based on the examination of evidences and arguments;

4.2 support judgements using appropriate scientific principles; and

4.3 put forward suitable reasoning to choose between alternatives.

5. Learning and self-learning

Students should be able to

5.1 develop study skills to improve the effectiveness and efficiency of learning; and

5.2 develop abilities, habits and attitudes that are essential to life-long learning.

6. Collaboration

Students should be able to

6.1 participate actively, share ideas and offer suggestions in group discussions;

6.2 liaise, negotiate and compromise with others in group work;

6.3 identify collective goals, define and agree on roles and responsibilities of members in group work; and

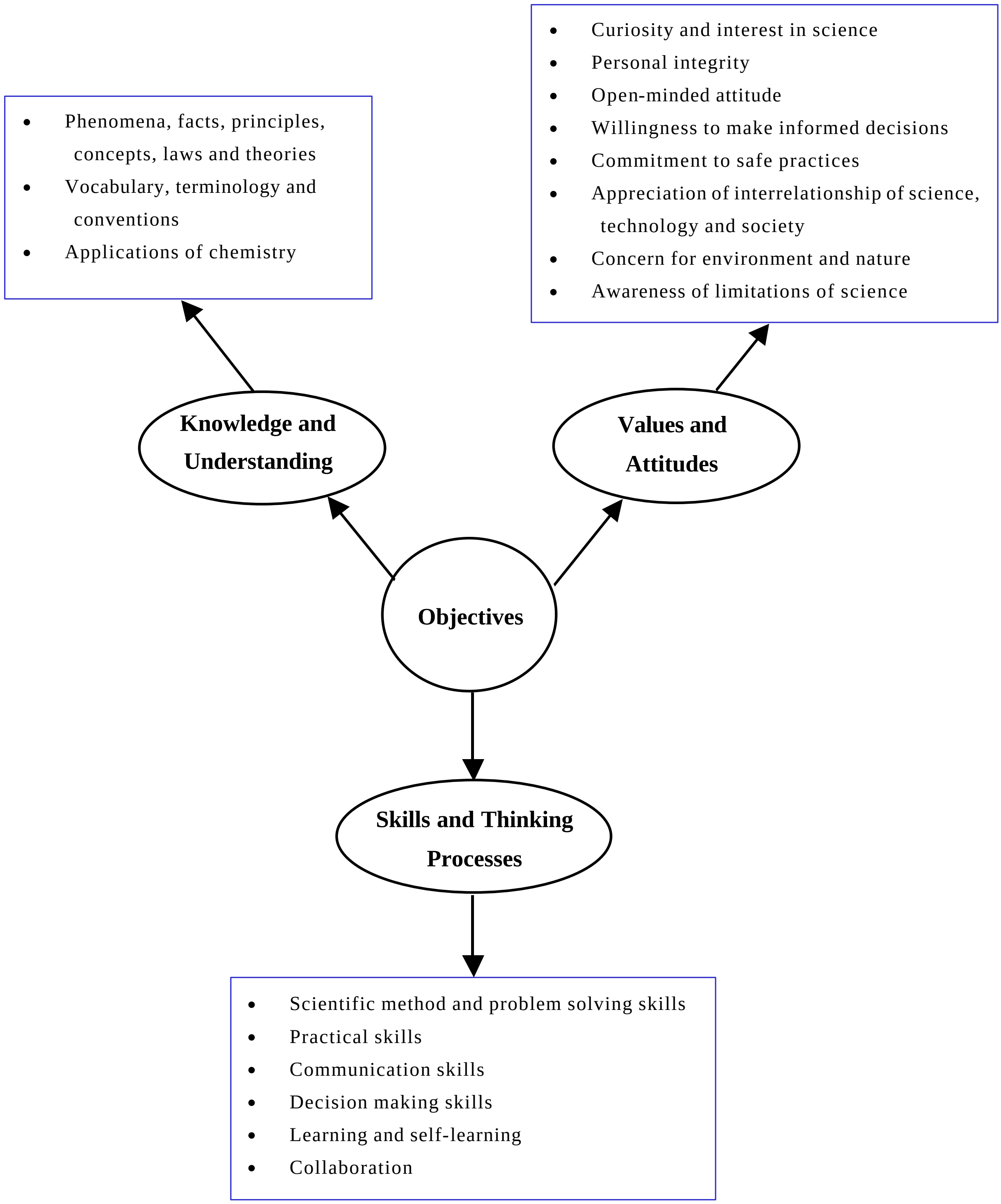
6.4 implement strategies to work effectively as a group member.

C. Values and Attitudes

Students should

1. develop curiosity and interest in making scientific investigations;
2. be committed to safe practices of handling chemicals in the laboratory and in daily life, and act responsibly;
3. develop personal integrity through objective observation and honest recording of experimental data;
4. appreciate the interrelationship of chemistry with other disciplines in providing societal and cultural values;
5. be aware that science has its limitations and cannot always provide clear-cut answers in certain areas;
6. be willing to relate chemistry to its social, economic, environmental and technological implications;
7. be willing to communicate and make decisions on issues related to chemistry and demonstrate an open-minded attitude towards the views of others;
8. appreciate that chemistry is a developing science and the role of scientific method in the development of new ideas; and
9. show concern for the care of the environment, and be committed to the wise use of natural resources.

The chart below summarises some important objectives of the curriculum.



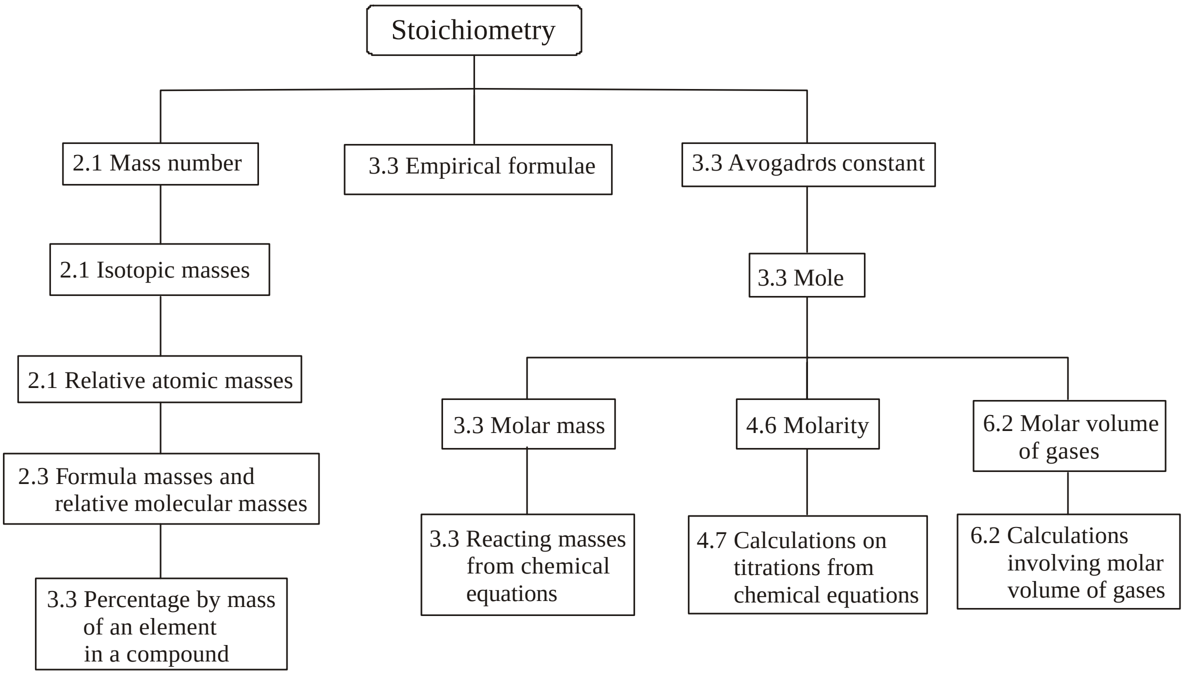
II. CURRICULUM FRAMEWORK

A. Organisation

The two-year course builds on the foundation of the CDC Syllabus for Science (Secondary 1-3) published in 1998. It starts with the section "Planet Earth" which helps students acquire some basic knowledge of chemistry and develop fundamental practical skills and positive attitudes towards chemistry. Through a study of the subsequent sections, students should develop a progressing complexity of knowledge and skills in chemistry. Major concepts on scientific investigations are reinforced and expanded. The section "Products from Important Processes" is arranged right after the section "Chemical Cells and Electrolysis". This arrangement allows students to reinforce the concept "Redox" through the study of chemical processes. The last section "Detection and Analysis" serves two purposes, namely, to provide an opportunity for students to apply the knowledge and skills learnt to solve problems in a way chemists do, and to have a better insight of the world of chemistry.

Concepts related to chemical equations like word equations, state symbols, ionic equations, half equations and balanced chemical equations are introduced in different parts of the course in a progressive order, and so are the calculations related to mole, formula mass, empirical formula, molar mass, molarity and molar volume. These arrangements help students master concepts without being loading them with a great deal of abstract and unfamiliar information. Teachers should help students link these concepts in a systematic way.

The figure below illustrates how the concepts related to mole and formulae are organised in this curriculum.



Core and Extension

The content of the curriculum consists of two components, Core and Extension. The Core is the basic component of senior secondary level chemistry for all students whereas the Extension component is generally more demanding and more suitable for students aiming to pursue further study in the subject. For some students, it will be less stressful and more effective to just concentrate on the Core so that more time is available to master the basic concepts and principles; for others, the challenges provided by the Extension component may provide a better sense of achievement. A good school-based chemistry course should have an in-built flexibility to cater for the interest and abilities of students so that a balance between the quantity and quality of learning is achieved.

Promoting Higher Order Thinking

Various learning activities such as experiments, discussions, building models, searching and presenting information, debates, decision making exercises and project work can help students develop an ability to use skills and thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making. The thinking processes often begin with an unresolved problem or issue, or an unanswered question. The problem, issue or question is usually defined and hypotheses formulated before information gathering can begin. At certain points in the process, the information needs to be organised and analysed. Additional ideas may be generated – for example, by prediction or inference – and these new ideas, when incorporated into previous learning, can create a new knowledge structure. Eventually, an outcome, such as a solution, an answer or a decision is reached. Finally, criteria are established to judge ideas and information in order to assess both the problem solving process and its outcomes. The skills developed through these learning processes include problem solving, communication, decision making, collaboration as well as practical skills.

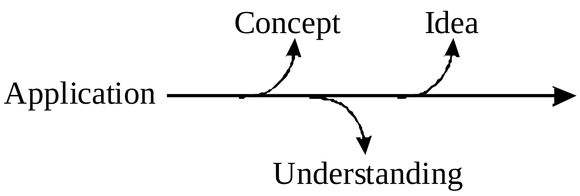
In keeping with the exploratory spirit of science, teachers should encourage students to actively engage in the learning processes and should avoid giving away the expected results of experiments/activities. Teachers should exercise their professional judgements in choosing appropriate learning and teaching activities to cater for the needs of their students. Teachers are encouraged to design or develop any experiments/activities that might facilitate the learning and teaching of the subject.

Science, Technology and Society

The chemistry curriculum advocates the Science, Technology and Society (STS) approach introduced in the "CDC Chemistry Syllabus" published in 1991. The STS approach attempts to help students realise that science is useful in their everyday lives. Students should be given opportunities to learn more than recalling knowledge and concepts, and performing certain skills. Rather, the approach enhances students' curiosity about the objects, events and issues around them and develop their understanding of the interactions between science, technology and society.

Topic 7.4 "Consequences of using fossil fuels" entails that students work on the environmental problems associated with the burning of fossil fuels. Teachers help students study environmental issues like air pollution and measures to reduce air pollutants. On completion of the topic, students are expected to have a better understanding of how science, technology and society interact. Further, students should appreciate that the applications of science and technology have brought us benefits and convenience, alongside environmental problems. Other topics with STS elements include corrosion of metals, chemical cells, chemical plants, plastics, detergents, etc.

In the learning and teaching of chemistry, "daily-life application first" approach can be used where appropriate. A topic can be started with a question or an issue. Students then attempt to resolve it by proposing explanations, finding resources, seeking advice, experimenting, reaching consensus, dealing with different opinions and unexpected observations, using information to support one's explanation, and making informed judgements. Through the aforesaid approach, chemistry knowledge, concepts and skills related to the questions or issues are evolved and consolidated. Furthermore, the interactions between science, technology and society are well addressed.



B. Time Allocation

The curriculum is compiled on the assumption that schools will devote at least four 40-minute periods per week to the teaching of Chemistry in Secondary 4 to 5. A total of 192 periods should be enough to cover the whole curriculum.

An estimate of the number of periods for each section is shown below:

		No. of Periods
Section 1	**Planet Earth**	8
	1.1 The atmosphere	
	1.2 The ocean	
	1.3 Rocks and minerals	
Section 2	**The Microscopic World**	28
	2.1 Atomic structure	
	2.2 Periodic Table	
	2.3 Ionic and covalent bonding	
	2.4 Metallic bonding	
	2.5 Structures and properties	
Section 3	**Metals**	22
	3.1 Occurrence and extraction of metals	
	3.2 Reactivity of metals	
	3.3 Reacting masses	
	3.4 Corrosion of metals and their protection	
Section 4	**Acids and Alkalis**	28
	4.1 Acids	
	4.2 Alkalis	
	4.3 Indicators and pH	
	4.4 Strength of acids and alkalis	
	4.5 Neutralisation and salts	
	4.6 Concentration of solutions	
	4.7 Simple volumetric work involving acids and alkalis	
	4.8 Rate of reaction	

		No. of Periods
Section 5	**Chemical Cells and Electrolysis**	24
	5.1 Chemical cells in daily life	
	5.2 Simple chemical cells	
	5.3 Redox reactions	
	5.4 Reactions in chemical cells	
	5.5 Electrolysis	
Section 6	**Products from Important Processes**	24
	6.1 Chlorine and hypochlorite	
	6.2 Sulphuric acid and sulphur dioxide	
	6.3 Chemical plants	
Section 7	**Fossil Fuels and Carbon Compounds**	30
	7.1 Fossil fuels	
	7.2 Homologous series, structural formulae and naming of carbon compounds	
	7.3 Alkanes and alkenes	
	7.4 Consequences of using fossil fuels	
	7.5 Alcohols	
Section 8	**Plastics and Detergents**	22
	8.1 Plastics	
	8.2 Detergents	
Section 9	**Detection and Analysis**	6
	9.1 Separation of mixtures	
	9.2 Detection of substances	
	Total:	**192**
		(Equivalent to 128 hours)

C. Content

Section 1 Planet Earth (8 periods)

The natural world is made up of chemicals. The earth's crust, the sea and the atmosphere are major sources of chemicals. The study of chemistry includes the investigation of possible methods to isolate useful materials from these sources and the analysis of these materials using various tests. Students who have completed this section should have a better understanding of scientific investigation and chemistry concepts learnt in the junior science curriculum.

Students should know the terms "element", "compound" and "mixture", "physical change" and "chemical change", "physical property" and "chemical property", "solvent", "solute" and "saturated solution". They should also be able to use word equations to represent chemical changes, and to suggest appropriate methods for the separation of mixtures and tests for some chemical species.

I. Knowledge and Understanding

Students should learn

1.1 The atmosphere	• Composition of air. • Separation of oxygen and nitrogen from liquid air by fractional distillation. • Test for oxygen.
1.2 The ocean	• Composition of sea water. • Extraction of common salt and isolation of pure water from sea water. • Tests to show the presence of sodium and chloride in a sample of common salt. • Test for the presence of water in a sample. • Electrolysis of sea water and uses of the products.

1.3	Rocks and minerals	• Rocks as a source of minerals. • Isolation of useful materials from minerals as exemplified by extraction of metals from their ores. • Limestone, chalk and marble as different forms of calcium carbonate. • Erosion processes as exemplified by the action of heat, water and acids on calcium carbonate. • Thermal decomposition of calcium carbonate and test for carbon dioxide. • Tests to show the presence of calcium and carbonate in a sample of limestone/chalk/marble.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- searching for information on issues related to the atmosphere.
- using an appropriate method to test for oxygen.
- performing experiments and evaluating methods on physical separation including evaporation, distillation, crystallisation and filtration.
- using appropriate apparatus and techniques to carry out the flame test and test for chloride.
- performing a test to show the presence of water in a given sample.
- investigating the actions of heat, water and acids on calcium carbonate.
- designing and performing chemical tests for calcium carbonate.
- describing chemical changes using word equations.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to value the need for the safe handling and disposing of chemicals.
- to appreciate that the earth is the source of a variety of materials useful to human beings.
- to show concern over the limited reserve of natural resources.
- to show an interest in and curiosity about chemistry.

Section 2 The Microscopic World (28 periods)

The study of chemistry involves the linking up of phenomena in the macroscopic world to the behaviour of atoms, molecules and ions in the microscopic world. Through a study of the structures of atoms, molecules and ions, and the bonding in elements and compounds, students will acquire knowledge of some basic chemical principles which facilitates learning of the latter sections. By performing activities such as gathering and analysing information from appropriate sources, students should appreciate that the Periodic Table demonstrates some remarkable patterns in the physical and chemical properties of the elements. They should also be able to relate properties of substances to their structures.

Students should appreciate that symbols and chemical formulae constitute part of the language used by scientists. Further, students should be able to perform calculations related to chemical formulae.

I. Knowledge and Understanding

Students should learn

2.1 Atomic structure	• Elements, atoms and symbols. • Classification of elements into metals, non-metals and metalloids. • Electron, neutron and proton as subatomic particles. • Simple model of atom. • Atomic number (Z) and mass number (A). • Isotopes. • Isotopic masses and relative atomic masses based on ^{12}C=12.00. • Electronic arrangement of atoms (up to Z=20). • Stability of noble gases related to their electronic arrangements.
2.2 Periodic Table	• The position of the elements in the Periodic Table related to their electronic arrangements. • Similarities in chemical properties among elements in Group I, II, VII and 0.

2.3	Ionic and covalent bonding	• Transfer of electrons in the formation of ionic bond. • Cations and anions. • Electronic diagrams of simple ionic compounds. • Names and formulae of ionic compounds. • Ionic structure as illustrated by sodium chloride. • Sharing of electrons in the formation of covalent bond. • Single, double and triple bonds. • Electronic diagrams of simple covalent molecules. • Names and formulae of covalent substances. • van der Waals' forces as weak intermolecular forces. • Simple molecular structure. • Giant covalent structures as illustrated by diamond and quartz. • Formula masses and relative molecular masses.
2.4	Metallic bonding	• Simple model of metallic bond.
2.5	Structures and properties	• Relationship between structures and properties of ionic, giant covalent, simple molecular and metallic substances.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- searching and presenting information on elements and the development of the Periodic Table.
- performing calculations related to relative atomic masses, formula masses and relative molecular masses.
- drawing electronic diagrams to represent atoms, ions and molecules.
- investigating chemical similarities of elements in the same group of the Periodic Table.
- predicting chemical properties of unfamiliar elements in a group of the Periodic Table.
- writing chemical formulae for ionic and covalent substances.
- building models of ionic and covalent substances.

- predicting the formation of ionic and covalent substances.
- <u>predicting structures and properties of substances</u>.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to appreciate that scientific evidence is the foundation for generalisations and explanations about matter.
- to appreciate the usefulness of models and theories in helping to explain the structures and behaviours of matter.
- to appreciate the development of the Periodic Table and hence to envisage that scientific knowledge changes and accumulates over time.
- to appreciate the restrictive nature of evidence when interpreting observed phenomena.

(Note: The underlined text represents the extension part of the curriculum.)

Section 3 Metals (22 periods)

Metals find a wide range of uses in our daily life, and as such the extraction of metals from their ores has been an important activity of human beings since prehistoric times. This section provides opportunity for students to develop an understanding of how metals are extracted from their ores and how they react with other substances. Students are expected to establish scientific principle based on experimental evidence.

The corrosion of metals poses a socioeconomic problem to human beings. It is therefore necessary to develop methods to preserve the limited reserve of metals. An investigation of factors leading to corrosion and methods to prevent metals from corrosion is a valuable problem solving exercise and can help students develop a positive attitude towards the use of resources in our planet earth.

A chemical equation is a concise and universally adopted way to represent a chemical change. Students should be able to transcribe word equations into chemical equations and appreciate that a chemical equation shows a quantitative relationship between reactants and products in a reaction. Students should also be able to do calculations involving mole and chemical equations.

I. Knowledge and Understanding

Students should learn

3.1	Occurrence and extraction of metals	• Occurrence of metals in nature in free state and in combined forms. • Obtaining metals by heating metal oxides or by heating metal oxides with carbon. • Extraction of metals by electrolysis. • Relation of the discovery of metals with the ease of extraction of metals and the availability of raw materials. • Limited reserve of metals and their conservations.

3.2	Reactivity of metals	• Reactions of some metals (sodium, magnesium, calcium, zinc, iron, lead, copper, etc.) with (a) oxygen/air, (b) water, (c) dilute hydrochloric acid and dilute sulphuric acid. • Metal reactivity series and the tendency of metal to form positive ion. • Displacement reactions and their interpretations based on reactivity series. • Prediction of metal reactions using the reactivity series. • Relation between the extraction method for a metal and its position in the metal reactivity series.
3.3	Reacting masses	• Quantitative relationship of the reactants and the products in a reaction as revealed from a chemical equation. • Mole, Avogadro' s constant and molar mass. • Percentage by mass of an element in a compound. • <u>Empirical formulae derived from experimental data.</u> • Reacting masses from chemical equations.
3.4	Corrosion of metals and their protection.	• Factors that influence the rusting of iron. • Methods used to prevent rusting (e.g. painting, oiling, galvanizing, tin-plating, electroplating, sacrificial protection and alloying). • Socioeconomic implications of rusting. • <u>Corrosion resistance of aluminium</u>. • <u>Anodisation as a method to enhance corrosion resistance of aluminium.</u>

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- searching and presenting information about the occurrence of metals and their uses in daily life.
- performing experiments to extract metals from metal oxides.
- deciding appropriate methods for extraction of metals from their ores.
- transcribing word equations into chemical equations.
- performing experiments to investigate reactions of metals with oxygen / air, water and dilute acids.
- constructing a metal reactivity series based on experimental evidence.
- performing experiments to investigate displacement reactions of metals with aqueous metal ions.
- writing ionic equations.
- <u>performing experiments to determine empirical formulae.</u>
- performing calculations related to moles and reacting masses.
- designing and performing experiments to investigate factors that influence rusting.
- performing experiments to study methods that can be used to prevent rusting.
- <u>deciding appropriate methods to prevent metal corrosion based on social, economic and technological considerations</u>.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to appreciate the contribution of science and technology in providing us with useful materials.
- to appreciate the importance of making fair comparisons in scientific investigations.
- to value the need for adopting safety measures when performing experiments involving potentially dangerous chemicals.
- to show concern for the limited reserve of metals and realise the need for conserving and using these resources wisely.
- to appreciate the importance of the mole concept in the study of quantitative chemistry.

(Note: The underlined text represents the extension part of the curriculum.)

Section 4 Acids and Alkalis (28 periods)

Acids and bases/alkalis are involved in numerous chemical processes that occur around us, from industrial processes to biological ones, from reactions in the laboratory to those in our environment. Students have encountered acids and alkalis in their junior science courses. In this section, they will further study the properties and reactions of acids and bases/alkalis, and the concept of molarity. Students should also be able to develop an awareness of the potential hazards associated with the handling of acids and alkalis.

Students studying the whole syllabus should have knowledge of strong and weak acids/alkalis, methods of salt preparation, and volumetric analysis involving acids and alkalis. They should have experience in investigating factors affecting the rate of reaction, but an interpretation at the molecular level and calculations are not required.

I. Knowledge and Understanding

Students should learn

4.1 Acids	• Common acids in daily life and in the laboratory. • Characteristics and chemical reactions of acids as illustrated by dilute hydrochloric acid and dilute sulphuric acid. • Acidic properties and hydrogen ions ($H^+(aq)$). • Role of water in exhibiting characteristic properties of acid. • Basicity of acid. • Corrosive nature of concentrated acids.
4.2 Alkalis	• Common alkalis in daily life and in the laboratory. • Characteristics and chemical reactions of alkalis as illustrated by sodium hydroxide and aqueous ammonia. • Alkaline properties and hydroxide ions ($OH^-(aq)$). • Corrosive nature of concentrated alkalis.

4.3	Indicators and pH	• Acid-base indicators as exemplified by litmus, methyl orange and phenolphthalein. • pH scale as a measure of acidity and alkalinity. • Use of universal indicator and an appropriate instrument to measure the pH of solutions.
4.4	Strength of acids and alkalis	• Meaning of strong and weak acids as well as strong and weak alkalis in terms of their extent of dissociation. • Methods to compare the strength of acids/alkalis.
4.5	Neutralisation and salts	• Bases as chemical opposites of acids. • Neutralisation as the reaction between acid and base/alkali to form water and salt only. • Exothermic nature of neutralisation. • Preparation of soluble and insoluble salts based on neutralisation. • Naming of common salts. • Applications of neutralisation.
4.6	Concentration of solutions	• Concentration of solutions in g dm^{-3} and in mol dm^{-3} (molarity).
4.7	Simple volumetric work involving acids and alkalis	• Standard solutions. • Acid-alkali titrations.
4.8	Rate of reaction	• Effects of concentration, surface area and temperature on the rate of reaction.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- investigating the actions of dilute acids on metals, carbonates, hydrogencarbonates, metal oxides and metal hydroxides.
- designing and performing experiments to study the role of water in exhibiting characteristic properties of acid.
- searching for information about the hazardous nature of acids/alkalis.
- investigating the action of dilute alkalis on aqueous metal ions to form metal hydroxide precipitates.

- investigating the action of dilute alkalis on ammonium compounds to give ammonia gas.
- performing experiments to investigate the corrosive nature of concentrated acids/alkalis.
- performing experiments to find out the pH values of some domestic substances.
- designing and performing experiments to compare the strengths of acids/alkalis.
- investigating the temperature change in a neutralisation process.
- preparing and isolating salts from acid-alkali or acid-base reactions.
- searching and presenting information on applications of neutralisation.
- performing calculations involving molarity.
- preparing solutions of known concentrations.
- performing acid-alkali titrations using suitable indicators.
- performing calculations on titrations.
- designing and performing experiments to study the effects of concentration, surface area and temperature on the rate of reaction.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to value the need for the safe handling, storing and disposing of chemicals.
- to appreciate the importance of proper laboratory techniques and precise calculations for obtaining accurate results.
- to appreciate the importance of controlling variables in making comparisons.

(Note: The underlined text represents the extension part of the curriculum.)

Section 5 Chemical Cells and Electrolysis (24 periods)

Chemical reactions are associated with the release or absorption of energy. In a chemical cell, chemical energy is converted to electrical energy. The flow of electrons in an external circuit indicates the occurrence of oxidation and reduction at the electrodes. To understand the chemistry involved in a cell, the concept of redox is introduced. Students should have experience in carrying out experiments with commonly used oxidising and reducing agents, and be able to write chemical equations for redox reactions.

Students studying the whole syllabus should know the reactions occurring in more complicated chemical cells, and have a better understanding of the processes involved in electrolysis.

I. Knowledge and Understanding

Students should learn

5.1	Chemical cells in daily life	• Uses of chemical cells in relation to factors such as size, price and life-expectancy.
5.2	Simple chemical cells	• Simple chemical cells: (a) consisting of two metal electrodes and an electrolyte, (b) consisting of metal-metal ion half-cells and salt bridge/porous device. • Changes occurring at the electrodes and electron flow in the external circuit. • Ionic half equations and overall cell equations.
5.3	Redox reactions	• Oxidation and reduction. • Oxidising agents (e.g. $MnO_4^-(aq)/H^+(aq)$, $Cr_2O_7^{2-}(aq)/H^+(aq)$, $Fe^{3+}(aq)$, $Cl_2(aq)$). • Reducing agents (e.g. $SO_3^{2-}(aq)$, $I^-(aq)$, $Fe^{2+}(aq)$, $Zn(s)$). • Oxidation numbers. • Balancing redox equations by using ionic half equations or by oxidation numbers. • Nitric acid of different concentrations as oxidising agent to give NO and NO_2.

5.4	Reactions in chemical cells	• Reactions in chemical cells consisting of half cell(s) other than metal-metal ion systems. • Reactions in a zinc-carbon cell.
5.5	Electrolysis	• Electrolysis as the decomposition of substances by electricity as exemplified by electrolysis of (a) dilute sulphuric acid, (b) sodium chloride solutions of different concentrations, (c) copper(II) sulphate solution. • Anodic and cathodic reactions. • Preferential discharge of ions in relation to the electrochemical series, concentration of ions and nature of electrodes. • Industrial applications of electrolysis: (a) electroplating, (b) electrolysis of brine.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- making decision on the choice of chemical cells in daily life based on available information.
- making simple chemical cells and measuring their voltages.
- writing ionic half equations.
- performing experiments to investigate redox reactions.
- determining oxidation numbers of elements in chemical species.
- balancing redox equations by using ionic half equations or by oxidation numbers.
- investigating redox reactions of nitric acid of different concentrations with metals.
- predicting changes in chemical cells based on given information.
- performing experiments to investigate changes in electrolysis.
- designing and performing electroplating experiments.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to value the contribution of technological innovations to the quality of living.
- to appreciate the usefulness of the concept of oxidation number in the study of chemical changes.

(Note: The underlined text represents the extension part of the curriculum.)

Section 6 Products from Important Processes (24 periods)

Chlorine and sulphuric acid are important chemicals as they are produced and consumed annually in a million tonne scale. Chlorine is commonly used as bleach and as disinfectant. Sulphuric acid finds a wide range of uses both in industry and in our daily life. This section helps students reinforce the concept of redox and develop a better awareness of the necessity in handling chemicals safely in the laboratory. Through a study of the Contact Process, students will embark on a wider horizon by looking into the industrial aspects of chemistry. Students should know the meaning of reversible reaction although the concept of equilibrium and technical details of the industrial processes are not required.

Students studying the whole syllabus are expected to have knowledge of the manufacture of chlorine, molar volume of gases and the factors that need to be considered when setting up a chemical plant.

I. Knowledge and Understanding

Students should learn

6.1 Chlorine and hypochlorite	• Uses of chlorine and hypochlorite. • <u>Manufacture of chlorine by electrolysis of brine</u>. • Properties and reactions of chlorine: (a) bleaching action of aqueous chlorine, (b) reactions with aqueous halides, (c) reaction with dilute sodium hydroxide solution. • Sodium hypochlorite as the active ingredient in chlorine bleach. • Properties and reactions of sodium hypochlorite: (a) bleaching action, (b) reaction with dilute acids. • Potential hazards associated with the use of chlorine bleach.

6.2	Sulphuric acid and sulphur dioxide	• Uses of sulphuric acid and sulphur dioxide. • Manufacture of sulphuric acid by the Contact Process. • Molar volume of gases at room temperature and pressure. • Properties and reactions of concentrated sulphuric acid: (a) dehydrating property, (b) oxidising property. • Properties and reactions of sulphur dioxide/sulphite: (a) bleaching action, (b) action of acids on sulphite.
6.3	Chemical plants	• Location of chemical plants in relation to the availability of resources, transport and environmental impact.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- searching for information on uses of chlorine and sulphuric acid.
- performing experiments to investigate the properties and reactions of chlorine and hypochlorite.
- designing and performing experiments to make chlorine bleach.
- performing experiments to investigate the dehydrating and oxidising properties of concentrated sulphuric acid.
- diluting concentrated sulphuric acid.
- designing and performing experiments to prepare sulphur dioxide.
- performing experiments to study the properties and reactions of sulphur dioxide.
- performing calculations involving molar volume of gases at room temperature and pressure.
- presenting arguments on the desirability of setting up chemical plants for the production of chlorine/sulphuric acid.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to appreciate that the application of scientific knowledge can be beneficial to human beings.
- to value the need for assessing the impacts of technology on our environment.
- to value the need for analysing an issue from multiple perspectives.
- to develop a positive attitude towards the safe handling, storing and disposing of chemicals, and hence adopt safe practices.

(Note: The underlined text represents the extension part of the curriculum.)

Section 7 Fossil Fuels and Carbon Compounds (30 periods)

Carbon compounds play an important role in industry and in our daily life. Coal and petroleum are two major sources of carbon compounds. In this section, the main focus is placed on the use of petroleum fractions as fuel and as a source of hydrocarbons. Students should appreciate that the use of fossil fuels has brought us benefits and convenience, alongside environmental problems like air pollution, acid rain, global greenhouse effect, etc. Eventually, they should realise that human activities can have impacts on our environment.

This section also introduces some basic concepts of organic chemistry like homologous series, functional group, general formula and structural formula. Students should be able to give systematic names of alkanes, alkenes, alkanols and alkanoic acids with not more than four carbon atoms. Further, students are expected to know the terms "exothermic reaction" and "endothermic reaction".

I. Knowledge and Understanding

Students should learn

7.1 Fossil fuels	• Coal, petroleum and natural gas as fossil fuels. • Petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation. • Relation of the gradation in properties (e.g. colour, viscosity, volatility and burning characteristics) with the number of carbon atoms in the molecules of the various fractions. • Major uses of distilled fractions of petroleum.
7.2 Homologous series, structural formulae and naming of carbon compounds	• Homologous series as illustrated by alkanes, alkenes, alkanols and alkanoic acids. • Structural formulae and systematic naming of alkanes, alkenes, alkanols and alkanoic acids.

7.3	Alkanes and alkenes	• Petroleum as a source of alkanes. • Reactions of alkanes: (a) combustion, (b) substitution reactions with chlorine and bromine. • Cracking and its industrial importance. • Reactions of alkenes with: (a) bromine, (b) acidified potassium permanganate solution.
7.4	Consequences of using fossil fuels	• Fossil fuels as an important source of energy. • Complete and incomplete combustion of hydrocarbons. • Hazards associated with the use of household fuels: (a) toxicity, (b) flammability. • Safety precautions in using household fuels. • Major air pollutants from cars, factories, incinerators and power stations: unconsumed hydrocarbons, particulates, carbon monoxide, sulphur dioxide and oxides of nitrogen. • Environmental problems associated with the burning of fossil fuels. • Measures to reduce air pollutants from the burning of fossil fuels. • Alternative sources of energy.
7.5	Alcohols	• Uses of alcohols in drinks, as solvents and fuels. • Reactions of alkanols with (a) acidified potassium dichromate to produce alkanoic acids, (b) alkanoic acids to produce esters. • Uses of esters as fragrances, flavourings and solvents.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- investigating colour, viscosity, volatility and burning characteristics of petroleum fractions.
- searching and presenting information about oil fractions regarding their major uses and the relation between uses and properties.
- building models of simple alkanes, alkenes, alkanols and alkanoic acids.
- drawing structural formulae and writing systematic names for alkanes, alkenes, alkanols and alkanoic acids.
- performing experiments to investigate reactions of alkanes and alkenes.
- performing an experiment on cracking of a petroleum fraction and testing the products.
- selecting and carrying out suitable chemical tests for unsaturated hydrocarbons.
- searching for information and presenting arguments on the pros and cons of using fossil fuels.
- searching for information on alternative sources of energy.
- making informed decisions on the safe practice of using household fuels.
- searching and presenting information on problems associated with drinking alcohol.
- performing experiments to investigate reactions of alkanols with acidified potassium dichromate and with alkanoic acids.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to appreciate the importance of organising scientific information in a systematic way.
- to appreciate the usefulness of models in helping to visualise the structure of molecules.
- to value the need for the safe use and storage of fuels.
- to recognise the benefits and impacts of the application of science and technology.
- to appreciate the need for alternative sources of energy for a sustainable development of our society.

Section 8 Plastics and Detergents (22 periods)

Plastics are remarkably useful materials. Many objects used in our daily life are made of plastics. Students should know that plastics is a collective term which embraces a large number of polymers, and that the uses of different plastics are related to their thermal properties which are in turn related to their structures. Students should appreciate that one great advantage of using plastics over other materials, their durability, is also a drawback, as most plastics do not readily degrade in a natural environment. It is therefore necessary to explore appropriate ways for the disposal of plastic wastes.

In this section, the term "detergent" denotes two classes of substances which assist cleaning: soaps and soapless detergents. Students should appreciate that the structure of detergents consists of both hydrophobic and hydrophilic parts. These structural characteristics of detergents render the emulsifying properties of detergents.

Students studying the whole syllabus should know what condensation polymers are, the differences in the cleaning abilities of soaps and soapless detergents, and the environmental problems associated with the use of detergents.

I. Knowledge and Understanding

Students should learn	
8.1 Plastics	• Plastics as important materials in the modern world. • Thermoplastics and thermosetting plastics: (a) uses and moulding methods in relation to their thermal properties, (b) differences in thermal properties explained in terms of their structures. • Monomers, polymers and repeating units. • Addition polymerisation. • <u>Condensation polymerisation as exemplified by the formation of nylon and polyester.</u> • Environmental issues related to the use of plastics.

8.2	Detergents	• Detergent as a substance which helps to remove dirt by (a) its ability to act as a wetting agent, (b) its emulsifying action. • Structures of soaps and soapless detergents. • Emulsifying properties of detergents in relation to their structures. • Production of soaps by reacting a fat or an oil with an alkali. • Cleaning abilities of soaps and soapless detergents in hard water. • Environmental problems associated with the use of detergents.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- investigating properties such as the strength and ease of softening upon heating of different plastics.
- writing chemical equations for the formation of polymers based on given information.
- deducing the monomer from the structure of a given addition polymer.
- searching and presenting information on environmental issues related to the use of plastics.
- searching and presenting information on the historical development of detergents.
- performing experiments to investigate the wetting ability and emulsifying action of detergents.
- preparing soap from a fat or an oil, and testing its properties.
- designing and carrying out experiments to compare the cleaning abilities of soaps and soapless detergents.
- searching and presenting information on environmental issues related to the use of detergents.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to appreciate that science and technology provide us with useful products.
- to appreciate the versatility of synthetic materials and the limitations of their use.
- to value the need for assessing the impacts of the use of synthetic materials.
- to show concern for the environment and develop a sense of shared responsibility for a sustainable development of our society.

(Note: The underlined text represents the extension part of the curriculum.)

Section 9 Detection and Analysis (6 periods)

In this section, students are expected to apply their knowledge and skills acquired in previous sections to suggest tests for some common chemicals. Other than the common separation methods learnt in previous sections, students should also know that chromatography can be used to separate a mixture of substances. By investigating the nature of chemicals encountered in daily life, students should appreciate that these methods and tests play an important role in everyday life.

Students should be aware of the limitations inherent in the use of conventional chemical tests in the detection of chemical species and hence appreciate the application of modern instruments in chemical analysis.

I. Knowledge and Understanding

Students should learn

9.1 Separation of mixtures	• Paper chromatography. • Crystallisation, filtration and evaporation. • Distillation and fractional distillation.
9.2 Detection of substances	• Detecting the presence of calcium, copper, potassium and sodium in substances by the flame test. • Application of appropriate tests to detect the presence of (a) hydrogen, oxygen, chlorine, carbon dioxide, water, ammonia and sulphur dioxide. (b) ions: aluminium, calcium, copper(II), iron(II), iron(III), zinc, chloride, bromide, iodide, carbonate, hypochlorite, ammonium and sulphite. • Awareness of the uses of modern chemical instruments.

II. Skills and Thinking Processes

Students should develop the *skills and thinking processes* associated with the practice of science by

- performing experiments to separate colour mixtures by chromatography.
- devising a scheme to separate a mixture of known substances.
- performing experiments to detect the presence of certain chemical species in a sample.
- <u>designing and performing an investigation to deduce the chemical nature of a sample</u>.
- searching for information on the uses of modern chemical techniques.

III. Values and Attitudes

Students are expected to develop in particular, *values and attitudes* as follows:

- to value the need for a systematic method of solving problems.
- to appreciate the importance of evidence in drawing conclusions.
- to appreciate the use of modern techniques in chemical analysis.
- to show a continuing interest in and curiosity about the advancement of science.

(Note: The underlined text represents the extension part of the curriculum.)

III. LEARNING AND TEACHING

Learning effectiveness depends on the motivation of students and their prior knowledge, the learning contexts, teaching methods and strategies, and assessment practices. To learn effectively, students should take an active role in science learning processes. Appropriate teaching strategies and assessment practices should be employed with this view in mind.

A. Teacher's role

Teachers should be well acquainted with the aims and objectives of the curriculum and arrange meaningful learning activities for their fulfillment. They should timely and appropriately employ different learning and teaching approaches, and play the roles of a resource person, facilitator and assessor. Teachers are encouraged to use different strategies such as discussion, practical work and project learning to facilitate students' learning. The learning process can be enhanced by stimulating students to think, encouraging students to explore and inquire, and giving appropriate guidance and encouragement to students according to individual needs. The followings are some suggestions made in accordance with these observations.

Designing teaching sequence

The topics in the curriculum are listed in a possible teaching sequence. However, different teaching sequences can be adopted to enhance learning. Teachers are encouraged to design teaching sequences for their particular groups of students.

Example:
In Section 2 "The Microscopic World", some abstract ideas are introduced. A possible teaching approach is to start with the more concrete topic "Properties of substances" and then move on to the concepts of chemical bonding. Two possible teaching sequences are outlined below.

Sequence A

2.1 Atomic structure
⇩
2.2 Periodic Table
⇩
2.3 Ionic and covalent bonding
⇩
2.4 Metallic bonding
⇩
2.5 Structures and properties

Sequence B

2.1 Atomic structure
⇩
2.2 Periodic Table
⇩
2.5 Properties of substances
⇩
2.3 Ionic and covalent bonding
⇩
2.4 Metallic bonding
⇩
2.5 Structures of substances

Catering for students' abilities

In deciding teaching strategies, students' abilities should be given due consideration, and it is unrealistic to expect every student to achieve the same level of attainment. Teachers should have the flexibility to devise teaching schemes with appropriate breadth and depth according to the abilities of their own students and to make learning challenging but not too demanding. This can pave the way to enjoyable learning experiences. The core and extension approach adopted in this curriculum can facilitate teachers to design their teaching strategies so as to cater for their students' abilities.

To cater for students with a strong interest or outstanding abilities in chemistry, teachers can set more challenging learning objectives on top of those described in this document. Teachers should exercise their professional judgements to design and implement a broad and balanced chemistry curriculum for their students so that they would not be deprived of opportunities to develop their full potential.

Moreover, the time allocation for each section is suggested in Part B of Chapter II. Rough as they are, these estimates could nonetheless provide useful guidance to teachers as to the depth of treatment required and the weighting to be placed on each section.

Designing learning activities

Teachers should motivate students through a variety of ways such as letting them know the goals and expectations of learning, building on their successful experiences, meeting their interest and considering their emotional reactions. Learning activities are designed according to these considerations. Some examples of these activities are given below.

Discussion

Questioning and discussion in the classroom promote students' understanding, and help them develop higher order thinking skills as well as an active learning attitude. Presenting arguments help students develop skills related to extracting useful information from a variety of sources, organising and presenting ideas in a clear and logical form, and making judgements based on valid arguments.

Teachers must avoid discouraging discussion in the classroom by insisting too much and too soon on an impersonal and formal scientific language. It is vital to accept relevant discussions in students' own language during the early stages of concept learning, and to move towards precision and accuracy of scientific usage in a progressive manner.

One of the effective ways to motivate students is to make discussion and debate relevant to their everyday life. For example, in topic 7.4, the hazards and the safety precautions associated with the use of household fuels are interesting topics for discussion.

In addressing issues related to science, technology and society, more student-centred strategies can be adopted. For example, in topic 8.1, environmental issues related to the use of plastics will be discussed. Teachers can start the discussion with domestic wastes classification, and plastic wastes collection in schools and in housing estates. In the discussion, students are free to express their opinions, and then pool together the reasons of collecting plastic wastes and the difficulties of putting that into practice. Finally students can present their ideas to the whole class and receive comments from their classmates and teacher.

Practical work

Chemistry is a practical subject and thus practical work is essential for students to gain personal experience of science through doing and finding out. In the curriculum, designing and performing experiments are given due emphasis.

Teachers should avoid giving manuals or worksheets for experiments with ready-made data tables and detailed procedures, for this kind of instructional materials provide fewer opportunities for students to learn and appreciate the process of science. With an inquiry-based approach, students are required to design all or part of the experimental procedures, to decide what data to record, and to analyse and interpret the data. Students will show more curiosity and sense of responsibility for their own experiments leading to significant gains in their basic science process skills.

Moreover, experiments are better designed to "find out" rather than to "verify". Teachers should avoid giving away the results before the practical work, and students should try to draw their own conclusions from the experimental results. The learning of scientific principles will then be consolidated.

Experiments include

- designing and planning
- prediction of results
- manipulation of apparatus
- collection of data
- consideration of safety

→

Conclusions and interpretations include

- analysis of experimental results
- evaluation of predictions
- explanation for deviations from predictions

→

Scientific Principles include

- generation of patterns and rules from conclusions and interpretations

Other than ordinary apparatus and equipment, teachers may explore the use of microscale equipment to enhance the hands-on experience of students in practical work. With careful design, some teacher demonstration experiments can be converted to student experiments in microscale practice.

Project Learning

Learning through project work, a powerful strategy to promote self-directed, self-regulated and self-reflecting learning, enables students to connect knowledge, skills and values and attitudes, and to construct knowledge through a variety of learning experiences. It serves to develop a variety of skills such as scientific problem solving, critical thinking and communication. Project work involves students in planning, collecting information and making decisions over a period of time, and those involving experimental investigations can also help develop practical skills and more importantly science process skills. Project work carried out in small groups can enhance the development of collaboration skills.

Example:

A project work can be organised for the topic "Detection of substances" in Section 9. Students are expected to apply their knowledge and skills acquired in previous sections to design and perform tests for a variety of substances. During the investigation process, various skills outlined in the table below can be developed.

Stage \ *Skills	Scientific method and problem solving skills	Practical skills	Communication skills	Decision making skills	Learning and self-learning	Collaboration
Analysing the problem and searching for information	✓		✓		✓	
Devising the scheme of work	✓	✓	✓	✓		✓
Performing experiments		✓				✓
Analysing and evaluating results	✓	✓		✓		
Reporting the results			✓			✓

* The skills correspond to the "Skills and Thinking Processes" objectives listed in Chapter I.

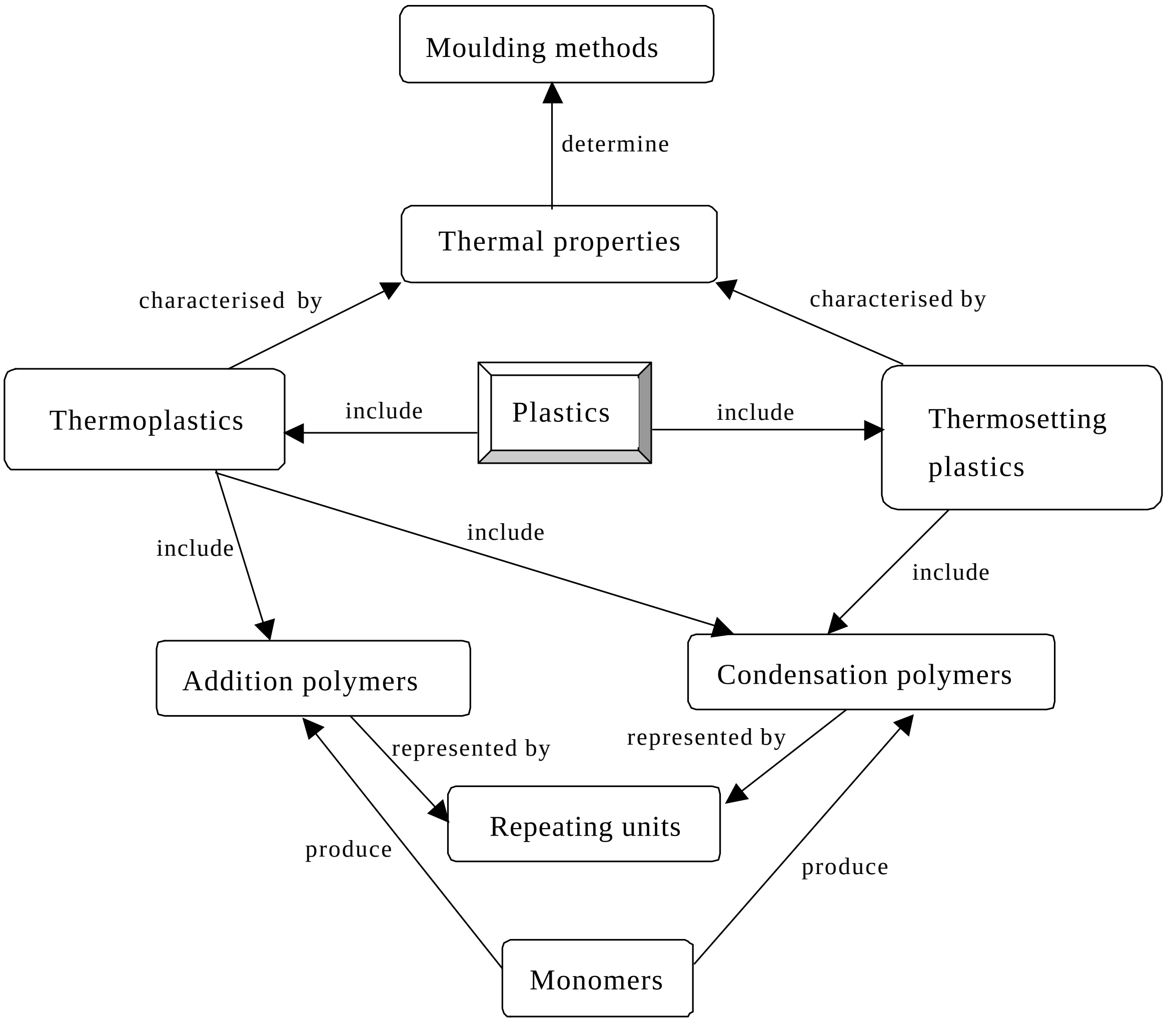
Searching and presenting information

Searching for information is an important skill to be developed in the information era. Students can gather information from various sources such as books, magazines, scientific publications, newspapers, CD-ROMs and the Internet. Searching for information can cater for knowledge acquisition and informed judgements by students. The activity should not just be limited to the collecting of information, but should also include selection and categorisation, and the presentation of findings.

Construction of concept maps

Concept maps are visual aids to thought and discussion, and help students describe the links between important concepts. Students should be encouraged to construct concept maps, subsequently refine their concept maps in the light of teachers' comments, peer review and self-evaluation in the course of learning.

Concept maps can be presented in different ways. The following is an example illustrating how the concepts related to plastics outlined in topic 8.1 can be linked.



Information technology (IT) for interactive learning

IT is a valuable tool for interactive learning, which complements the strategies of learning and teaching inside and outside the classroom. Teachers should select and use IT-based resources as appropriate to facilitate students' learning. However, an improper use of IT may distract student attention, have little or no educational value and may sometimes cause annoyance.

There are numerous and growing opportunities to use IT in science education. IT can help search, store, retrieve and present scientific information. Interactive computer-aided learning programmes can enhance active participation of students in the learning process. Computer-based laboratory devices allow students to collect and analyse data as scientists do. Simulation and modelling tools can be employed for exploratory learning.

Example:
In topic 4.8, "Rate of reaction", the effect of concentration on the rate of reaction can be investigated by monitoring the pressure generated in the reaction of magnesium ribbons with hydrochloric acid of different concentrations. It is possible to make use of a data-logger with a pressure sensor interfaced with a computer for the investigation. The use of data-logger can help students capture sufficient experimental data in a short duration. The software accompanying a data-logger can generate graphical representations of the data immediately so that students can analyse and discuss the experimental results right after the runs.

Providing life-wide learning opportunities

A diversity of learning and teaching resources should be used appropriately to enhance the effectiveness of learning. Life-wide learning opportunities should be provided to widen the exposure of students to the scientific world. Examples of learning programmes serving this purpose include popular science lectures, debates and forums, field studies, museum visits, invention activities, science competitions, science projects and science exhibitions. Students with high abilities or a strong interest in science may need more challenging learning opportunities. These programmes can stretch students' science capabilities and allow them to develop their full potential.

B. Student's role

As active learners, students should initiate, organise, make decisions and take responsibility for their own learning, and participate in the learning activities with their hands-on and minds-on. To foster the ownership of learning, students need to be guided to and engaged in setting own goals, develop own criteria of assessment and evaluate own progress. The feeling of ownership generates enthusiasm.

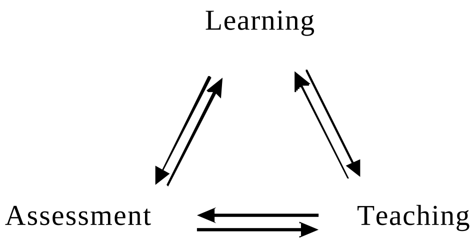
The following are activities that can enhance students' learning.

- Collecting specimens
- Performing practical work
- Proposing questions
- Designing experiments
- Completing project work
- Participating in discussions
- Taking part in role play
- Participating in debates
- Conducting surveys
- Brainstorming
- Demonstrating in front of a class
- Presenting ideas
- Sharing experiences
- Writing reports
- Reading books, newspapers, magazines, periodicals, etc.
- Searching for information from CD-ROMs, the Internet, etc.
- Following self-instructional materials
- Constructing concept maps and composing notes
- Evaluating their own performance
- Attending seminars and exhibitions

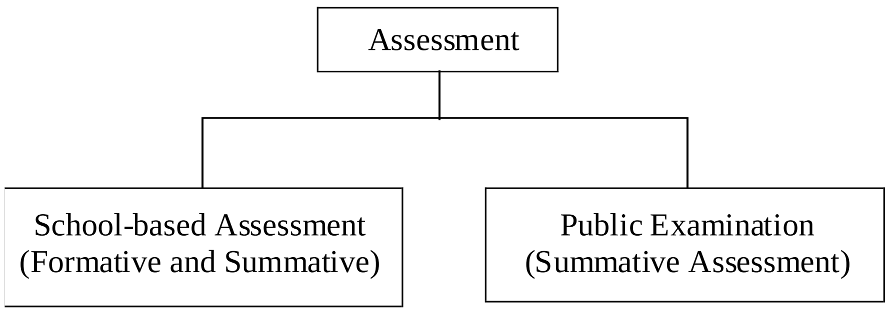
Students should learn to transfer skills and learning from one context to another. Transferability of the process of investigation and acquisition of new knowledge will help students continue to learn. When students start to believe in themselves, confidence will grow. This in turn breeds positive feelings and motivation resulting in effective learning. The skills and habits developed in active learning are essential for students to become life-long learners.

IV. ASSESSMENT

Assessment is the practice of collecting evidence of students' progress in learning. It is an integral part of the learning and teaching cycle. Assessment provides information needed for improving learning and teaching processes to both teachers and students.



In order to bring about improvements in learning and teaching, it is essential that any assessment be aligned to the processes of learning and teaching. Apart from the better known summative assessment which would normally be identified with tests, end-of-term examinations and public examinations, authentic formative assessment needs to be introduced to serve as a diagnostic tool to help improving students' learning. Further, school-based assessment, both formative and summative, should be given due consideration.



Formative assessment should be carried out on a continuous basis and through different ways such as oral questioning, observation of students' performance, assignments, project work, practical tests and written tests. It should be integrated with learning and teaching throughout the course with the purpose of promoting the quality and effectiveness of learning and teaching. It should provide feedback to teachers who could then make decisions about what should be done next to enhance students' learning; sometimes it may lead to the employment of a more appropriate teaching method. It should also provide feedback to students so that they understand how to improve their learning.

Quality criteria, which are descriptions of what students are able to do in relation to the set of aims and objectives, can serve as the foci that guide the learning and teaching processes. Students and teachers can share expected learning outcomes right at the beginning of a lesson or a small unit of the curriculum. Teachers can make judgements on students' progress and students can evaluate their own learning based on the established quality criteria. For example, in the domain of knowledge and understanding, the quality criterion "can give clear explanation to questions that involve individual chemistry concepts" is suitable for students of average ability while the quality criterion "can give appropriate, clear and logical explanation to questions by linking up concepts from two or more topics" is more suitable for students of higher ability.

Assessment Domains

Assessment provides information on students' achievement in relation to the set objectives. It is important that not only the objectives in the domain of knowledge and understanding are assessed, but those related to skills and processes, being essential to the study of chemistry, should also be assessed throughout the course.

Higher order skills such as problem solving and decision making can be tested by using questions based on information which is unfamiliar to students who are required to use the principles and concepts learnt and apply them in a logical manner to a novel situation. In answering open-ended questions which test abilities in analysis and evaluation, they are expected to consider as many relevant aspects as possible to form judgements. In questions testing communication skills, students are expected to give essay-type answers, presenting arguments clearly and logically.

For objectives related to values and attitudes, a certain degree of flexibility in assessment may be employed. Observations, interviews, essay-writing and students' self-assessment are some of the possible assessment strategies.

Assessment Strategies

In the learning and teaching of chemistry, a number of assessment strategies can be used. Teachers should have well-thought-out plans on how to assess students' achievements and should let students know how they will be assessed.

Paper and pencil tests

Paper and pencil tests have been widely employed as the major method of assessment in schools. However, the prolonged reliance on these types of assessment strategies would have a narrowing effect on learning, and probably teaching too. Teachers should refrain from the temptation of teaching knowledge and understanding that can only be assessed by paper and pencil tests. Teachers should also avoid testing only basic information recall and should try to construct test items that assess the understanding of concepts, problem solving abilities and higher order thinking skills. Incorporation of open-ended questions in tests and examinations could also help evaluating students' creativity and critical thinking skills.

Written assignments

Written assignment is widely used in learning and teaching processes. It is an assessment tool that continuously reflects students' efforts, achievements, strengths and weaknesses. The scores or grades for assignments can be used to form part of the record to show students' progress. Teachers are encouraged to make use of students' written assignments as a formative assessment tool. The use of appropriate assignments aligned with learning objectives can lessen the pressure of formal assessment. Comments on students' written work with concrete suggestions for improvement are valuable feedback to students. As a means of evaluation, assignments can also reflect the effectiveness of teaching, provide feedback upon which teachers can set further operational targets for students, and make reasonable adjustments in teaching.

Oral questioning

Oral questioning can provide teachers with specific information on how the students think in certain situations. Students' responses often provide clues to their strengths, weaknesses, misunderstandings, levels of understanding, interest, attitudes and abilities. Teachers are encouraged to use questions targeting a range of abilities, from those requiring only recall of facts to those demanding higher order thinking. In addition, a balance of both open-ended and closed-end questions should be maintained, and problems based on information which is unfamiliar to students could be set.

Observation

While students are working in groups or individually, teachers could take the opportunity to observe and note the different aspects of students' learning. When students are engaged in learning activities, teachers could observe the approaches students take to solve problems and their attitudes to work, such as perseverance, independence, cooperation, and willingness to address difficulties. In practical sessions, teachers could look for the choices students make in regard to the equipment they use, the safety measures they adopt, the activities they prefer, whom they work with, and the interaction with others. Teachers should keep brief records and use such information for making further judgements about students' learning.

Practical work and scientific investigations

Whether the practice of assessing practical skills and skills in scientific investigations by written tests and examinations is desirable or appropriate deserves further deliberation. It is generally agreed that more suitable strategies for assessing these skills are direct observations or practical tests, i.e. assessing in an authentic environment where learning and assessments are integrated, and a feedback can be given to students immediately. Students' laboratory or investigation reports can also be assessed so that a more complete picture about students' performance can be obtained.

Project work

Project work, a powerful learning and teaching as well as assessment strategy, allows students not only to exercise their practical skills and apply what they have learnt, but also to employ various skills and thinking processes such as identifying problems, formulating hypotheses, designing and implementing strategies and evaluation. Teachers can make use of a combination of assessment strategies to collect evidences of student learning in the knowledge and skill domains, and gauge their creativity, communication skills, collaboration skills and problem solving abilities. Teachers can also make use of appropriate criteria to assess students' values and attitudes demonstrated in the process of doing a project.

To conclude the discussion, it is needed to state that the assessment strategies suggested above are by no means exhaustive. A combination of assessment strategies can provide a more vivid picture of students' achievements, and teachers should explore appropriate assessment opportunities for their own students.

Public Examination

The Hong Kong Examinations Authority (HKEA) organises the Hong Kong Certificate of Education Examination (HKCEE) to assess students' attainment and publishes a chemistry examination syllabus annually. Teachers should note that the syllabus serves to provide information to teachers and students so that they have a clear understanding of the examination requirements. It should be read alongside this document.

Given the mode of assessment adopted in the HKCEE, it is neither possible nor desirable to translate all the learning objectives into assessment objectives. Teachers should note the assessment objectives of the HKEA syllabus are based on the learning objectives suggested in this Curriculum. However, teachers should not ignore the learning objectives not included in the assessment objectives.

Appendix: Reference Books

Title	*Author*	*Publisher*	*Year of Publication*
A Guide to IUPAC Nomenclature of Organic Compounds	Panico, R., Powell, W. H. & Richer, J.C.	Blackwell Science Ltd.	1993
Applied Chemistry (3rd Edition)	Stine	D. C. Heath and Company	1994
ChemCom: chemistry in the community (3rd Edition)	American Chemical Society	Kendall/Hunt Publishing Co.	1998
Chemical Demonstrations (A Handbook for Teachers of Chemistry) Volume 3	Shakhashiri, B.Z.	The University of Wisconsin Press	1989
Chemical Demonstrations (A Handbook for Teachers of Chemistry) Volume 4	Shakhashiri, B.Z.	The University of Wisconsin Press	1992
Chemistry – The Salters' Approach	Hill, Holman, Lazonby, Raffan, Waddington	Heinemann	1989
Chemistry & Society (5th Edition)	Jones, M.M., Johnston, D.O., Netterville, J.T., Wood, J.L. & Joesten, M.D.	Saunders College	1987
Chemistry and Our Changing World (3rd Edition)	Sherman, A., Sherman, S.J.	Prentice-Hall, Inc	1992
Chemistry and the Environment	Johnston, J., Reed. N. & Faust, B.	The Royal Society of Chemistry	1993
Chemistry Counts – Activities	Hill	Hodder & Stoughton	1988
Chemistry Experiments	Hunt, Sykes & Mason	Longman	1986
Chemistry for Every Kid, 101 Easy Experiments That Really Work	Sobel, D.	John Wiley & Sons, Inc.	1989
Chemistry for GCSE	Johnson	Heinemann	1987
Chemistry in the Marketplace (5th Edition)	Selinger, B.	Harcourt Brace	1998
Chemistry of the Environment	Ramsden, E.N.	Stanley Thornes (Publishers) Ltd	1996

Title	*Author*	*Publisher*	*Year of Publication*
Chemistry, Science Projects	Oxlade, C.	Wayland	1998
Classic Chemistry Experiments	Osborne, C. & Johnston, J.	The Royal Society of Chemistry	2000
Conservation 2000: The Acid Rain Effect	Neal, P.	Batsford	1992
Conservation 2000: The Greenhouse Effect	Neal, P.	Batsford	1992
Conservation 2000: The Ozone Layer	Neal, P.	Batsford	1993
Cool Chemistry, Great Experiments with Simple Stuff	Moje, S.W.	Sterling Publishing Co. Ltd.	1999
Core Chemistry	Mills, J. & Evans, P.	Cambridge	1999
Detection and Analysis	Ramsden, E.N.	Stanley Thornes (Publishers) Ltd	1996
Engaging Children’s Minds: The Project Approach	Katz, K.G. & Chard, S.C.	Ablex Publishing Corporation	1993
Environmental Chemistry	Winfield, A.	Cambridge	1995
Examining GCSE Chemistry	McDuell	Hutchinson	1989
Experiments and Investigations in Chemistry	Crowther, B. & Freemantle, M.	Oxford	1989
Extension Chemistry	Milner, B. & Mills, J.	Cambridge	1998
In Search of More Solutions	O’ Driscoll, C., Eccles, H. & Reed, N.	The Royal Society of Chemistry	1995
Industrial Chemistry Case Studies	Osborne, C. & Johnston, J.	The Royal Society of Chemistry	1998
Inquiry-based Experiments in Chemistry	Lechtanski, V.L.	Oxford	2000
Laboratory Manual for Principles of General Chemistry (5th Edition)	Beran, J. A.	John Wiley & Sons, Inc.	1994
Materials Science	Ramsden, E.N.	Stanley Thornes (Publishers) Ltd	1995

Title	***Author***	***Publisher***	***Year of Publication***
Methane Global Warming and Production by Animals	Moss, A.R.	Chalcombe	1993
Methods of Analysis and Detection	McCarthy, A.	Cambridge	1997
Microscale Chemistry – Experiments in miniature	Skinner, J.	The Royal Society of Chemistry	1997
Modern Chemical Techniques	Johnston, J. & Reed, N.	The Royal Society of Chemistry	1992
Nomenclature of Inorganic Chemistry	Leigh, G.J.	Blackwell Scientific	1990
Nuffield Co-ordinated Sciences – Chemistry	Hunt, A.	Longman	1988
Nuffield Co-ordinated Sciences – Teachers' Guide	Dillon, J., Dorling, G., Ellse, M., Hunt, A., Ingram, N.R., Monger, G. & Norris, R.	Longman	1992
Our World, Our Future	Educational Projects Resources Trust	ICI Environmental Education Service	
Pollution Prevention Problems and Solutions	Theodore, L., Dupont, R.R. & Reynolds, J.	Gordon and Breach Science	1994
Polymer Chemistry (Revised Edition)	Lipscomb, R.	National Science Teachers Association	1995
Principles of Chemical Nomenclature	Leigh, G. J., Favre, H.A. & Metanomski, W.V.	Blackwell Scientific	1998
Revised Nuffield Chemistry	Nuffield Foundation	Longman	1975-78
Science and Technology in Society (SATIS)	Holman (Editor)	Association for Science Education	1986
Science Puzzle Aid Key Stage 4, Chemistry Materials and Their Properties	Williams, M.H.	Foulsham	1993
Teaching Chemistry with Toys	Sarquis, J.L., Sarquis, M. & Williams, J.P.	Learning Triangle Press	1995
Teaching General Chemistry: A Materials Science Companion	Ellis, A.B., Geselbracht, M.J., Johnson, B.J., Lisensky, G.C. & Robinson, W.R.	American Chemical Society	1993

Title	***Author***	***Publisher***	***Year of Publication***
Teaching Science, Technology and Society	Solomon, J.	Open University Press	1993
The Age of the Molecule	Hall, N.	The Royal Society of Chemistry	1999
The Chemistry Classroom Formulas for Successful Teaching	Herron, J.D.	The American Chemical Society	1996
The Essential Chemical Industry	Hubbard, E., Stephenson, M. & Waddington, D.	Chemical Industry Education Centre	1999
The Salters' Chemistry Course	Science Education Group, University	Science Education Group, University of York	1988
Understanding Our Environment	Hester (Editor)	The Royal Society of Chemistry	1986
Visualizing Chemistry	Ealy, J.B. & Ealy, Jr., J.L.	The American Chemical Society	1995
World of Chemistry – Essentials	Joesten, M.D., Netterville, J.T. & Wood, J.L.	Saunders College	1993
中學化學教師備課資料手冊	**金德淵**	**上海教育出版社**	1994
中學化學實驗大全	**劉正賢**	**上海教育出版社**	1994
分析化學實驗	**劉宏毅**	**中國紡織出版社**	1997
化工百科全書	**陳冠榮**	**化學工業出版社**	1993
化學五千年	**王德勝、朱天娥**	**曉園出版社**	1992
化學元素周期系的發現和發展	**凌永樂**	**化學工業出版社**	1990
化學史圖冊	**吳守玉、高興華、李華隆、黎加厚**	**高等教育出版社**	1993
化學名詞	**王寶瑄**	**科學出版社**	1991
化學教育學	**楊先晶、廖可珍、施志毅**	**江西教育出版社**	1995

Title	*Author*	*Publisher*	*Year of Publication*
化學課程論與課程教材改革	王秀紅、周仕東	東北師範大學出版社	1999
世界的石油	錢今昔	江蘇教育出版社	1992
生活的化學	陳潤杰	香港教育圖書公司	1999
名師授課錄中學化學	劉知新、孫元清	上海教育出版社	1998
有機化學實驗	謝冬	中國紡織出版社	1997
奇妙的科學實驗室理化篇	珍妮絲、普拉特、范克莉芙	浙江科學技術出版社	1999
初中化學特級教師談學習策略	陸禾	北京師範大學出版社	1993
初中化學教學大綱及教材分析	趙寧	東北師範大學出版社	1999
初中化學演示實驗技能訓練	趙寧、陳杰、張正飆	東北師範大學出版社	1999
金屬電鍍工藝	林西音	香港萬里書店	1975
香港環境保護 2000	香港環境保護署		2000
高中化學教學大綱及教材分析	申再植	東北師範大學出版社	1999
高等院校選用教材系列微型有機化學實驗	周寧懷、王德琳	科學出版社	1999
常見有毒和危險化學品手冊	羅明泉、俞平	中國輕工業出版社	1992
無機化學實驗	陸寧寧、伍天榮	中國紡織出版社	1997
無機化學實驗	袁書玉	清華大學出版社	1996

Title	*Author*	*Publisher*	*Year of Publication*
微型化學實驗冊（初中全一冊）	**王興華、劉衛國、李秀雲**	**科學出版社**	1995
電池的科學	**郁仁貽**	**復文書局**	1990
電鍍原理與工藝	**上海輕工業專科學校**	**上海科學技術出版社**	1978
趣味化學 365	**于浩、方維海、錢楊義**	**北京廣播學院出版社**	1993
趣味化學辭典	**范杰**	**上海辭書出版社**	1994
應用科學最新電池	**鄭振東**	**建宏出版社**	1991
環境化學概論	**盧昭彰**	**曉園出版社**	1995
環境保護	**金鑒明、周富祥、李金晶、陳昌篤**	**北京科學出版社**	1983