Science Education
Key Learning Area

Chemistry
Curriculum and Assessment Guide (Secondary 4 - 6)

Jointly prepared by the Curriculum Development Council and
The Hong Kong Examinations and Assessment Authority

Recommended for use in schools by the Education Bureau
HKSARG
2007 (with updates in November 2015)

Contents

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Preamble

The Education and Manpower Bureau (EMB, now renamed Education Bureau (EDB)) stated in its report[1] in 2005 that the implementation of a three-year senior secondary academic structure would commence at secondary 4 in September 2009. The senior secondary academic structure is supported by a flexible, coherent and diversified senior secondary curriculum aimed at catering for students' varied interests, needs and abilities. This Curriculum and Assessment (C&A) Guide is one of the series of documents prepared for the senior secondary curriculum. It is based on the goals of senior secondary education and on other official documents related to the curriculum and assessment reform since 2000 including the *Basic Education Curriculum Guide* (2002) and the *Senior Secondary Curriculum Guide* (2009). To gain a full understanding of the connection between education at the senior secondary level and other key stages, and how effective learning, teaching and assessment can be achieved, it is strongly recommended that reference should be made to all related documents.

This C&A Guide is designed to provide the rationale and aims of the subject curriculum, followed by chapters on the curriculum framework, curriculum planning, pedagogy, assessment and use of learning and teaching resources. One key concept underlying the senior secondary curriculum is that curriculum, pedagogy and assessment should be well aligned. While learning and teaching strategies form an integral part of the curriculum and are conducive to promoting learning to learn and whole-person development, assessment should also be recognised not only as a means to gauge performance but also to improve learning. To understand the interplay between these three key components, all chapters in the C&A Guide should be read in a holistic manner.

The C&A Guide was jointly prepared by the Curriculum Development Council (CDC) and the Hong Kong Examinations and Assessment Authority (HKEAA) in 2007. The first updating was made in January 2014 to align with the short-term recommendations made on the senior secondary curriculum and assessment resulting from the New Academic Structure (NAS) review so that students and teachers could benefit at the earliest possible instance. This updating is made to align with the medium-term recommendations of the NAS review made on curriculum and assessment. The CDC is an advisory body that gives recommendations to the HKSAR Government on all matters relating to curriculum development for the school system from kindergarten to senior secondary level. Its membership includes heads of schools, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields/bodies, representatives from the

[1] The report is "*The New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong*".

HKEAA and the Vocational Training Council (VTC), as well as officers from the EDB. The HKEAA is an independent statutory body responsible for the conduct of public assessment, including the assessment for the Hong Kong Diploma of Secondary Education (HKDSE). Its governing council includes members drawn from the school sector, tertiary institutions and government bodies, as well as professionals and members of the business community.

The C&A Guide is recommended by the EDB for use in secondary schools. The subject curriculum forms the basis of the assessment designed and administered by the HKEAA. In this connection, the HKEAA issues a handbook to provide information on the rules and regulations of the HKDSE Examination as well as the structure and format of public assessment for each subject.

The CDC and HKEAA will keep the subject curriculum under constant review and evaluation in the light of classroom experiences, students' performance in the public assessment, and the changing needs of students and society. All comments and suggestions on this C&A Guide may be sent to:

Chief Curriculum Development Officer (Science Education)
Curriculum Development Institute
Education Bureau
Room E232, 2/F, East Block
Education Bureau Kowloon Tong Education Services Centre
19 Suffolk Road
Kowloon Tong, Hong Kong

Fax: 2194 0670
E-mail: science@edb.gov.hk

Acronyms

AL	Advanced Level
ApL	Applied Learning
ASL	Advanced Supplementary Level
C&A	Curriculum and Assessment
CDC	Curriculum Development Council
CE	Certificate of Education
EC	Education Commission
EDB	Education Bureau
EMB	Education and Manpower Bureau
HKALE	Hong Kong Advanced Level Examination
HKCAA	Hong Kong Council for Academic Accreditation
HKCEE	Hong Kong Certificate of Education Examination
HKDSE	Hong Kong Diploma of Secondary Education
HKEAA	Hong Kong Examinations and Assessment Authority
HKEdCity	Hong Kong Education City
HKSAR	Hong Kong Special Administrative Region
IT	Information Technology
KLA	Key Learning Area
KS1/2/3/4	Key Stage 1/2/3/4
LOF	Learning Outcomes Framework
MOI	Medium of Instruction
NOS	Nature of Science
NGO	Non-governmental Organisation
OLE	Other Learning Experiences
P1/2/3/4/5/6	Primary 1/2/3/4/5/6
PDP	Professional Development Programmes

QF	Qualifications Framework
RASIH	Review of the Academic Structure for Senior Secondary Education and Interface with Higher Education
S1/2/3/4/5/6	Secondary 1/2/3/4/5/6
SBA	School-based Assessment
SEN	Special Educational Needs
SLP	Student Learning Profile
SRR	Standards-referenced Reporting
STSE	Science, Technology, Society and Environment
TPPG	Teacher Professional Preparation Grant
VTC	Vocational Training Council

Chapter 1 Introduction

This chapter provides the background, rationale and aims of Chemistry as an elective subject in the three-year senior secondary curriculum, and highlights how it articulates with the junior secondary curriculum, post-secondary education, and future career pathways.

1.1 Background

The Education Commission's education blueprint for the 21st Century, *Learning for Life, Learning through Life – Reform Proposals for the Education System in Hong Kong* (EC, 2000), highlighted the vital need for a broad knowledge base to enable our students to function effectively in a global and technological society such as Hong Kong, and all subsequent consultation reports have echoed this. The *334 Report* advocated the development of a broad and balanced curriculum emphasising whole-person development and preparation for lifelong learning. Besides the four core subjects, Chinese Language, English Language, Mathematics and Liberal Studies, students are encouraged to select two or three elective subjects from different Key Learning Areas (KLAs) according to their interests and abilities, and also to engage in a variety of other learning experiences such as aesthetic activities, physical activities, career-related experiences, community service, and moral and civic education. This replaces the traditional practice of streaming students into science, arts and technical/commercial subjects.

Study of the three different areas of biology, chemistry and physics often complement and supplement each other. In order to provide a balanced learning experience for students studying sciences, the following elective subjects are offered under the Science Education KLA:

- **Biology**, **Chemistry** and **Physics**
  These subjects are designed to provide a concrete foundation in the respective disciplines for further studies or careers.

- **Science**
  This subject operates in two modes. Mode I, entitled Integrated Science, adopts an interdisciplinary approach to the study of science, while Mode II, entitled Combined Science, adopts a combined approach. The two modes are developed in such a way as to provide space for students to take up elective subjects from other KLAs after taking one or more elective subject(s) from the Science Education KLA.

- Mode I: Integrated Science

  This is designed for students wishing to take up one elective subject in the Science Education KLA. It serves to develop in students the scientific literacy essential for participating in a dynamically changing society, and to support other aspects of learning across the school curriculum. Students taking this subject will be provided with a comprehensive and balanced learning experience in the different disciplines of science.

- Mode II: Combined Science →
  - Combined Science (Physics, Chemistry)
  - Combined Science (Chemistry, Biology)
  - Combined Science (Biology, Physics)

  Students wishing to take two elective subjects in the Science Education KLA are recommended to take one specialised science subject, and Combined Science with the content selected from the other two science subjects. Students are, therefore, offered three possible combinations:

  - Combined Science (Physics, Chemistry) + Biology
  - Combined Science (Chemistry, Biology) + Physics
  - Combined Science (Biology, Physics) + Chemistry

1.2 Implementation of Science Subjects in Schools

The five separate Curriculum and Assessment Guides for the subjects of Biology, Chemistry, Physics, Integrated Science and Combined Science are prepared for the reference of school managers and teachers, who are involved in planning school-based curriculum, designing learning and teaching activities, assessing students, allocating resources and providing administrative support to deliver the curricula in schools. Arrangements for time-tabling and deployment of teachers are given in the Appendix 1.

This C&A Guide sets out guidelines and suggestions for the Chemistry Curriculum. The delivery of the Chemistry part of Combined Science contributing towards the qualifications of Combined Science (Physics, Chemistry) and Combined Science (Chemistry, Biology) in the Hong Kong Diploma of Secondary Education will be discussed in the *Combined Science C&A Guide* (CDC & HKEAA, 2007).

1.3 Rationale

The emergence of a highly competitive and integrated economy, rapid scientific and technological innovations, and a growing knowledge base will continue to have a profound impact on our lives. In order to meet the challenges posed by these developments, Chemistry, like other science electives, will provide a platform for developing scientific literacy and for building essential scientific knowledge and skills for lifelong learning in science and technology.

Chemistry deals with the composition, structures and properties of matter, the interactions between different types of matter, and the relationship between matter and energy. Through the learning of chemistry, it is possible to acquire relevant conceptual and procedural knowledge. A study of chemistry also helps to develop understanding and appreciation of developments in engineering, medicine and other related scientific and technological fields. Furthermore, learning about the contributions, issues and problems related to innovations in chemistry will help students develop an understanding of the relationship between science, technology, society and the environment.

The curriculum attempts to make the study of chemistry exciting and relevant. It is suggested that the learning of chemistry be situated in real-life contexts. The adoption of a range of such contexts together with a range of learning and teaching strategies and assessment practices is intended to appeal to students of all abilities and aspirations, and to stimulate interest and motivation for learning. Students are expected to be able to apply their knowledge of chemistry, to appreciate the relationship between chemistry and other disciplines, to be aware of the science-technology-society-environment (STSE) connections within contemporary issues, and to become responsible citizens.

1.4 Curriculum Aims

The overarching aim of the Chemistry Curriculum is to provide chemistry-related learning experiences for students to develop scientific literacy, so that they can participate actively in our rapidly changing knowledge-based society, prepare for further studies or careers in fields related to chemistry, and become lifelong learners in science and technology.

The broad aims of the Chemistry Curriculum are to enable students to:

- develop interest and maintain a sense of wonder and curiosity about chemistry;
- construct and apply knowledge of chemistry, and appreciate the relationship between chemistry and other disciplines;

- appreciate and understand the evolutionary nature of science;
- develop skills for making scientific inquiries;
- develop the ability to think scientifically, critically and creatively, and solve problems individually and collaboratively in chemistry-related contexts;
- discuss science-related issues using the language of chemistry;
- make informed decisions and judgements on chemistry-related issues;
- develop open-mindedness, objectivity and pro-activeness;
- show appropriate awareness of working safely;
- understand and evaluate the social, ethical, economic, environmental and technological implications of chemistry, and develop an attitude of responsible citizenship.

1.5 Interface with the Junior Secondary Curriculum and Post-secondary Pathways

The Chemistry Curriculum builds on the CDC Syllabus for Science (S1-3) published in 1998 and extends the study of the three strands in science education KLA: “The Material World”, “Scientific Investigation” and “STSE”. Figure 1.1 depicts how the strands in the science education KLA are interrelated.

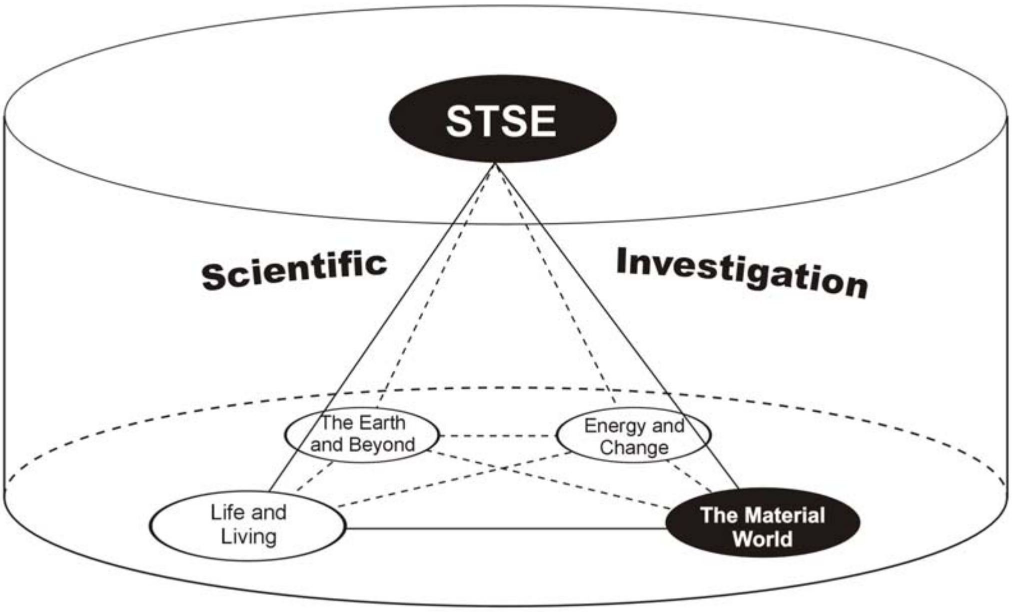

Figure 1.1 Diagrammatic Representation of the Strands in Science Education

Please refer to Chapter 3 of this Guide for details about the interface between the junior secondary science curriculum and the Chemistry Curriculum.

The senior secondary academic structure provides multiple pathways to post-secondary education and the workplace so that every student has an opportunity to succeed in life. Figure 1.2 shows the continuum of study and career pathways open to students studying Chemistry.

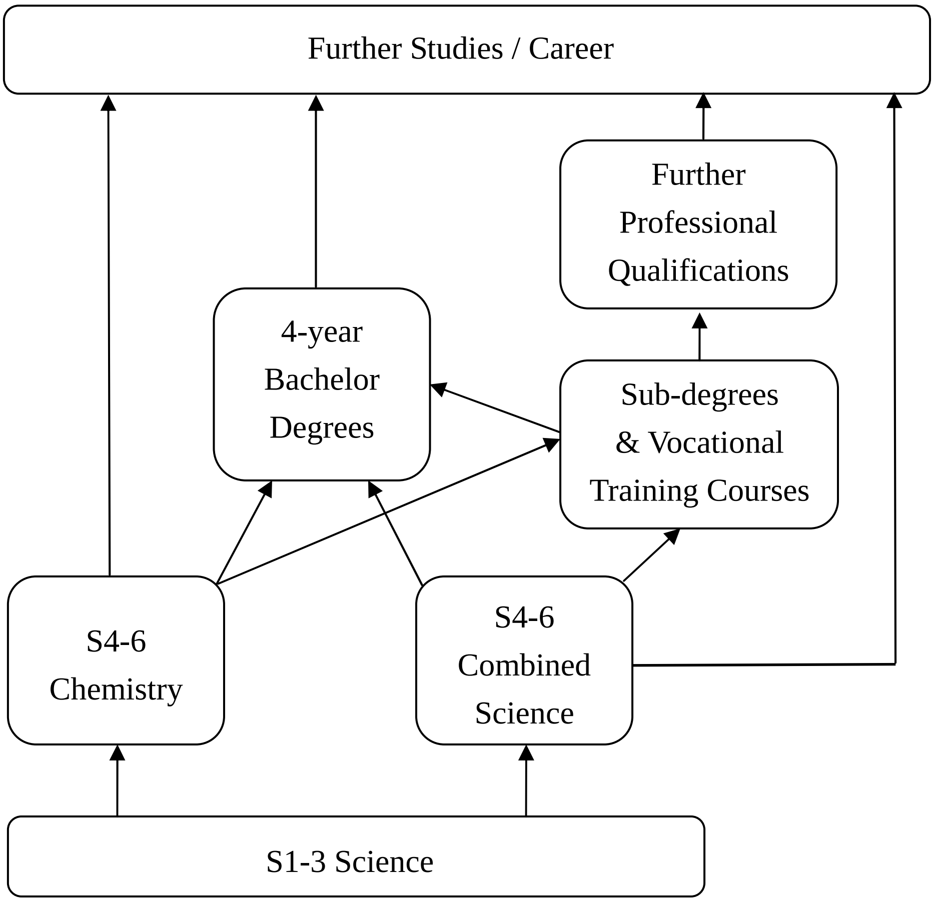

Figure 1.2 Multiple Pathways to Higher Education and the Workplace

For some students, the study of this curriculum facilitates their pursuit of degree courses in science-related or other disciplines. Some students may find the study of this curriculum suitable for their further study in sub-degree course. Knowledge of daily-life applications of chemistry and the practical skills acquired through this curriculum will also enable students to study effectively in various vocational training courses. Furthermore, the logical thinking and the problem-solving skills acquired from the study of this curriculum will make the students more competitive in the workplace.

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Chapter 2 Curriculum Framework

The curriculum framework for Chemistry embodies the key knowledge, skills, values and attitudes that students are to develop at senior secondary level. It forms the basis on which schools and teachers plan their school-based curriculum and design appropriate learning, teaching and assessment activities.

2.1 Design Principles

The Chemistry Curriculum is one of the constituents of the senior secondary curriculum. In this connection, the recommendations in Chapter 3 of the report *New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong* (EMB, 2005a) and in Booklet 1 of the *Senior Secondary Curriculum Guide* (CDC, 2009) have been adopted. The following principles are used in the design of the Chemistry Curriculum framework.

(1) Prior knowledge

This curriculum is developed upon the knowledge, skills, values and attitudes, and learning experiences acquired by students in the Science Curriculum (S1-3). There is a close connection between the topics in the Science Curriculum (S1-3) and the Chemistry Curriculum. Please refer to Chapter 3 for details.

(2) Balance between breadth and depth

The Chemistry Curriculum serves as one of the elective subjects. On the one hand, a broad coverage of topics is provided, while on the other hand there will be in-depth study on a certain number of topics to prepare students for further study in a particular field of science and technology.

(3) Balance between theoretical and applied learning

Learning of the conceptual knowledge described in this curriculum should enable students to develop a solid foundation in chemistry. In addition, students are expected to apply the knowledge, concepts and skills to real-life contexts, to develop an understanding of how science, technology, society and environment are interrelated, and to analyse authentic problems they may encounter.

(4) Balance between essential learning and a flexible and diversified curriculum

The compulsory part of the curriculum provides students with essential knowledge and concepts, whilst the choices in the elective part provide flexibility to cater for students with different interests, aspirations and abilities.

(5) Learning how to learn and inquiry-based learning

In this curriculum, a wide range of learning activities is suggested to help develop students' capacities for self-directed and lifelong learning. In addition, teachers are recommended to adopt a range of learning and teaching strategies, e.g. application-first approach, scientific investigations and problem-based learning, to enhance students' understanding of contemporary issues.

(6) Progression

Students may explore their interests through the study of selected topics within the compulsory part in S4. This will also ensure effective progression to S5 and S6 and their chosen studies. Please refer to Chapter 3 for details.

(7) Smoother articulation to a range of progression pathways

The curriculum enables students to pursue a wide range of post-secondary education and vocational/professional training. It also equips students with knowledge and skills to enter the workplace.

(8) Greater coherence

There are cross-curricular elements in the curriculum to strengthen connections with other subjects.

(9) Catering for diversity

Students vary in their aspirations, abilities, interests and needs. This curriculum provides an opportunity for students to choose topics in the elective part according to their interests and needs. Furthermore, the curriculum is designed to enable students to achieve the learning targets at their own pace.

(10) Relevance to students' life

Motivation and interest are key student characteristics in active and effective learning. This curriculum includes learning content and activities that are relevant to students' real life, especially the events and substances they commonly encounter daily.

2.2 Learning Targets

The learning targets of the curriculum are categorised into three domains: knowledge and understanding, skills and processes, and values and attitudes.

2.2.1 Knowledge and Understanding

Students are expected to:

- understand phenomena, facts and patterns, principles, concepts, laws and theories in chemistry;
- learn chemical vocabulary, terminology and conventions;
- appreciate applications of chemistry in everyday life;
- understand methods used in scientific investigations.

2.2.2 Skills and Processes

(1) Scientific thinking

Students are expected to:

- identify patterns and changes in the natural world, and predict trends from them;
- appreciate the fundamental role of models in exploring phenomena, and that models are modified as new or conflicting evidences are found;
- examine evidence and apply logical reasoning to draw valid conclusions;
- examine theories and concepts using logical reasoning and experimentation;
- integrate new concepts into their existing knowledge framework, and apply them to new situations.

(2) Scientific method, scientific investigations and problem solving

Students are expected to:

- identify scientific, social, technological and environmental problems and ask relevant questions;
- identify assumptions, concepts and theories related to a problem posed;
- propose hypotheses and devise methods to test them;
- identify dependent and independent variables;
- devise plans and procedures to carry out investigations;
- select appropriate apparatus to carry out investigations;
- observe and record experimental observations accurately and honestly;
- analyse data gathered from experiments or other sources;
- draw conclusions and make predictions;

- use appropriate techniques to present findings and to convey concepts;
- evaluate suggested solutions to a problem from different perspectives;
- evaluate the validity and reliability of findings and identify factors affecting their validity and reliability;
- propose plans for further investigations, if appropriate;
- apply knowledge and understanding to solve problems in unfamiliar situations;
- recognise the usefulness and limitations of scientific methods.

(3) Decision making

Students are expected to:

- make decisions based on evidence and arguments;
- support judgements using appropriate scientific principles;
- put forward suitable reasoning to choose between alternatives.

(4) Practical work

Students are expected to:

- select appropriate apparatus and materials for an experiment;
- handle chemicals safely and apparatus in a proper way;
- carry out instructions for experiments and record observations accurately;
- interpret observations and experimental data;
- devise and plan experiments;
- evaluate experimental methods and suggest possible improvements;
- build models to aid comprehension.

(5) Information handling

Students are expected to:

- search, retrieve, reorganise, analyse and interpret scientific information from a variety of sources;
- use information technology to manage and present information;
- be wary of the accuracy and credibility of information from secondary sources;
- distinguish among fact, opinion and value judgement in processing scientific information.

(6) Communication

Students are expected to:

- use symbols, formulae, equations and conventions appropriately;
- interpret scientific information from text and data presented in verbal, diagrammatic, numerical, tabular and graphical forms;
- organise and present ideas and arguments in a clear and logical form;
- communicate scientific ideas and values in a meaningful and creative way.

(7) Collaboration

Students are expected to:

- participate actively, share ideas and offer suggestions in group discussions;
- liaise, negotiate and compromise with others in group work;
- identify collective goals, define and agree on roles and responsibilities of members in group work;
- make use of strategies to work effectively as a group member.

(8) Learning and self-directed learning

Students are expected to:

- develop study and self-directed learning skills to improve the effectiveness and efficiency of learning;
- develop basic learning habits, abilities and attitudes that are essential to lifelong learning.

2.2.3 Values and Attitudes

Students are expected to:

- develop curiosity and interest in making scientific investigation;
- develop personal integrity through objective observation and honest recording of experimental data;
- be willing to communicate and make decisions on issues related to chemistry and demonstrate an open-minded attitude towards the views of others;
- be aware that chemistry is a developing science and that it has its limitations;
- appreciate the interrelationship of chemistry with other disciplines in providing social and cultural values;
- be committed to working safely in a laboratory;
- be aware of the impact of chemistry in social, economic, industrial, environmental and technological contexts;
- appreciate the importance of lifelong learning in our rapidly changing knowledge-based society.

Figure 2.1 summarises some important learning targets of the curriculum.

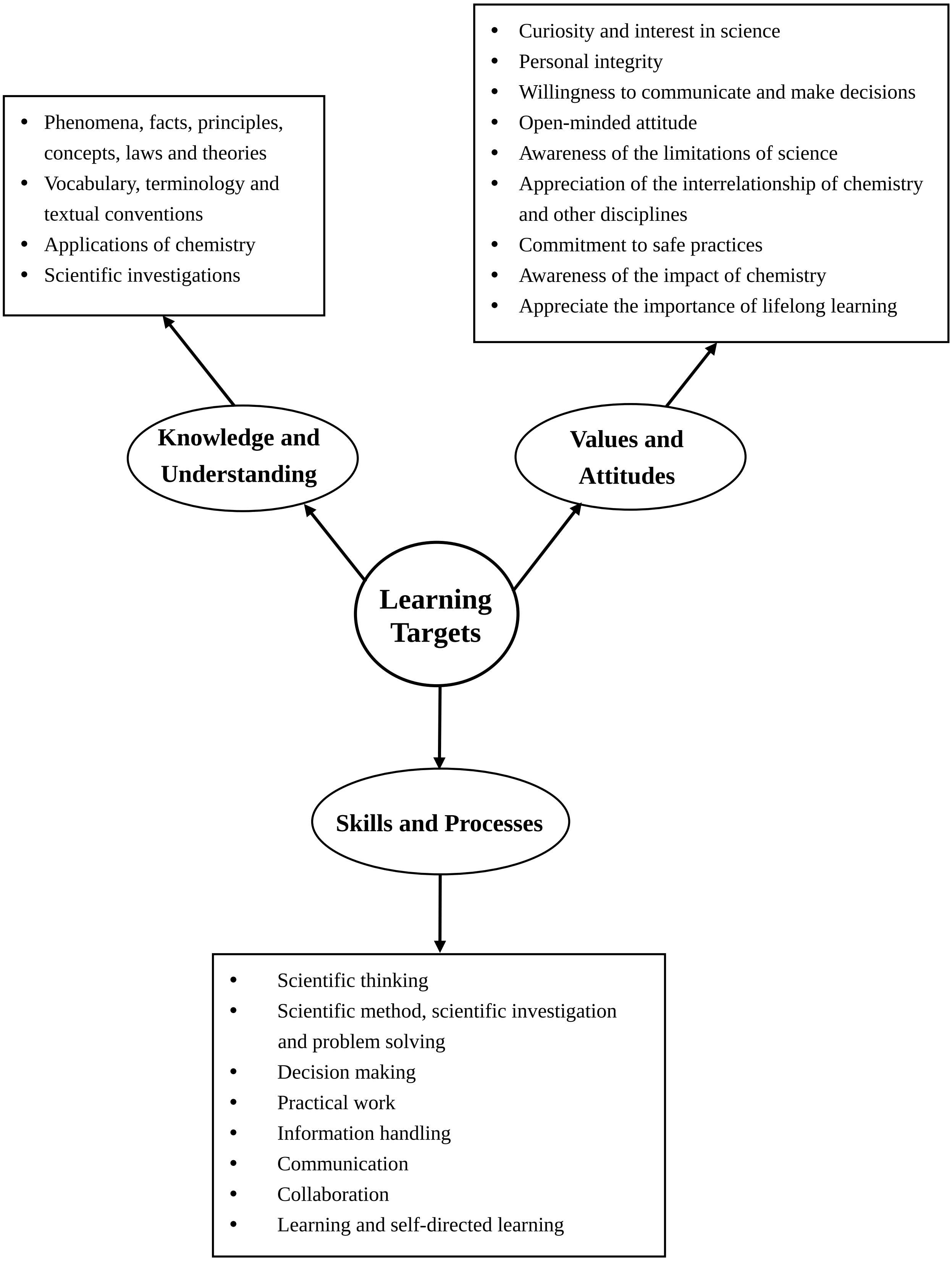

Figure 2.1 Learning Targets of the Chemistry Curriculum.

2.3 Curriculum Structure and Organisation

The curriculum consists of compulsory and elective parts. The compulsory part covers a range of content that enables students to develop an understanding of fundamental chemistry principles and concepts, and scientific process skills. Topics such as “atomic structure”, “bonding, structures and properties”, “metals and non-metals”, “periodicity”, “mole and stoichiometry”, “acids and bases”, “electrochemistry”, “chemistry of carbon compounds”, “chemical energetics”, “chemical kinetics” and “chemical equilibrium” are included. Please refer to topics I to XII for details.

To cater for the diverse interests, abilities and needs of students, an elective part is included in the curriculum. The elective part aims to provide an in-depth treatment of some of the compulsory topics, or an extension of certain areas of study. The elective part consists of three topics: “Industrial Chemistry”, “Materials Chemistry” and “Analytical Chemistry”. In addition, “green chemistry” is introduced in this part. Please refer to topics XIII to XV for details.

To facilitate the integration of knowledge and skills, students are required to conduct an investigative study relevant to the curriculum. A proportion of the total lesson time is allocated to this study. Please refer to Topic XVI “Investigative Study in Chemistry” for details.

The content of the curriculum is divided into 15 topics and an investigative study. However, the concepts and principles of chemistry are interrelated and should not be confined by any artificial boundaries between topics. The order of presentation of the topics in this chapter can be regarded as a possible teaching sequence, but teachers should adopt sequences that best suit their chosen teaching approaches. For instance, one topic can be integrated with a later one; some parts of a certain topic may be covered in advance if they fit well in a chosen context. Please refer to Suggested Learning and Teaching Sequences depicted in Chapter 3 for details.

There are five major parts in each of the topics I to XV:

Overview – outlines the main theme of the topic. The major concepts and important chemistry principles to be acquired will be highlighted. The foci of each topic will be briefly described. The interconnections between subtopics will also be outlined.

What students should learn and should be able to – lists learning objectives (students should learn) and learning outcomes (students should be able to) to be achieved by students in the curriculum. It provides a broad framework upon which learning and teaching activities can be developed. For general principles and examples of learning and teaching strategies, please refer to Chapter 4 of this Guide.

Suggested Learning and Teaching Activities – lists some possible activities that may enable students to acquire some of the skills associated with the topic. The list includes a wide range of activities, such as discussion, debate, practical work, investigations and information searching. It should be seen as a guide for teachers rather than as an exhaustive or mandatory list. Teachers should use their professional judgement to arrange learning activities that will develop the knowledge and skills listed in the "What students should learn and should be able to" part of the Curriculum Framework. More discussion on learning and teaching strategies will be provided in Chapter 4 of this Guide.

Values and Attitudes – suggests some desirable values and attitudes that can be related to particular topics. Students are expected to develop such intrinsically worthwhile values and positive attitudes in the course of the study of Chemistry. Through discussion and debate, students are encouraged to develop value judgements and good habits for the benefit of themselves and society.

STSE Connections – suggests interconnections between science, technology, society and the environment. Through discussion, debate, role play, information search and investigative study on the STSE issues, students can develop communication skills, information handling skills, critical thinking and the making of informed judgements. Teachers are free to select other current topics and issues as a basis for meaningful learning activities.

The table shows the topics and time allocations for the Chemistry Curriculum.[2]

Compulsory Part (Total 182 hours)

I. Planet earth* (6 hours)
II. Microscopic world I* (21 hours)
III. Metals* (22 hours)
IV. Acids and bases* (25 hours)
V. Fossil fuels and carbon compounds* (18 hours)
VI. Microscopic world II (8 hours)
VII. Redox reactions, chemical cells and electrolysis* (23 hours)
VIII. Chemical reactions and energy* (7 hours)
IX. Rate of reaction (9 hours)
X. Chemical equilibrium (10 hours)
XI. Chemistry of carbon compounds (25 hours)
XII. Patterns in the chemical world (8 hours)

Elective Part (Total 48 hours, select any 2 out of 3)

XIII. Industrial chemistry (24 hours)
XIV. Materials chemistry (24 hours)
XV. Analytical chemistry (24 hours)

Investigative Study (20 hours)

XVI. Investigative study in chemistry

** These topics are included in the chemistry part of Combined Science Curriculum.*

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[2] The lesson time for Liberal Studies and each elective subject is 250 hours (or 10% of the total allocation time) for planning purpose, and schools have the flexibility to allocate lesson time at their discretion in order to enhance learning and teaching effectiveness and cater for students' needs.

"250 hours" is the planning parameter for each elective subject to meet local curriculum needs as well as requirements of international benchmarking. In view of the need to cater for schools with students of various abilities and interests, particularly the lower achievers, "270 hours" was recommended to facilitate schools' planning at the initial stage and to provide more time for teachers to attempt various teaching methods for the NSS curriculum. Based on the calculation of each elective subject taking up 10% of the total allocation time, 2500 hours is the basis for planning the 3-year senior secondary curriculum. This concurs with the reality check and feedback collected from schools in the short-term review, and a flexible range of 2400±200 hours is recommended to further cater for school and learner diversity.

As always, the amount of time spent in learning and teaching is governed by a variety of factors, including whole-school curriculum planning, learners' abilities and needs, students' prior knowledge, teaching and assessment strategies, teaching styles and the number of subjects offered. Schools should exercise professional judgement and flexibility over time allocation to achieve specific curriculum aims and objectives as well as to suit students' specific needs and the school context.

2.3.1 Compulsory Part (Total 182 hours)

Topic I Planet Earth (6 hours)

Overview

The natural world is made up of chemicals which can be obtained from the earth's crust, the sea and the atmosphere. The purpose of this topic is to provide opportunities for students to appreciate that we are living in a world of chemicals and that chemistry is a highly relevant and important area of learning. Another purpose of this topic is to enable students to recognise that the study of chemistry includes the investigation of possible methods to isolate useful materials in our environment and to analyse them. Students who have completed this topic are expected to have a better understanding of scientific investigation and chemistry concepts learned 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, to suggest appropriate methods for the separation of mixtures, and to undertake tests for chemical species.

Students should learn	Students should be able to
a. The atmosphere	
• composition of air • separation of oxygen and nitrogen from liquid air by fractional distillation • test for oxygen	• describe the processes involved in fractional distillation of liquid air, and understand the concepts and procedures involved • demonstrate how to carry out a test for oxygen
b. 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	• describe various kinds of minerals in the sea • demonstrate how to extract common salt and isolate pure water from sea water • describe the processes involved in evaporation, distillation, crystallisation and filtration as different kinds of physical separation methods and understand the concepts and procedures involved • evaluate the appropriateness of using evaporation, distillation, crystallisation and filtration for different physical separation situations • demonstrate how to carry out the flame test, test for chloride and test for water

Students should learn	Students should be able to
c. Rocks and minerals • rocks as a source of minerals • isolation of useful materials from minerals as exemplified by the 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	• describe the methods for the extraction of metals from their ores, such as the physical method, heating alone and heating with carbon • describe different forms of calcium carbonate in nature • understand that chemicals may change through the action of heat, water and acids • use word equations to describe chemical changes • demonstrate how to carry out tests for carbon dioxide and calcium

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for information on issues related to the atmosphere, such as air pollution and the applications of the products obtained from fractional distillation of liquid air.
- using an appropriate method to test for oxygen and carbon dioxide.
- performing experiments and evaluating methods of 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.
- doing problem-solving exercises on separating mixtures (e.g. a mixture of salt, sugar and sand, and a mixture of sand, water and oil).
- extracting silver from silver oxide.
- investigating the actions of heat, water and acids on calcium carbonate.
- designing and performing chemical tests for calcium carbonate.
- participating in decision-making exercises or discussions on issues related to conservation of natural resources.
- describing chemical changes using word equations.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the need for the safe handling and disposal 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 chemistry and curiosity about it.
- to appreciate the contribution of chemists to the separation and identification of chemical species.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Oxygen extracted from air can be used for medicinal purposes.
- Methods involving chemical reactions are used to purify drinking water for travellers to districts without a clean and safe water supply.
- Desalination is an alternative means of providing fresh water to the Hong Kong people rather than importing water from the Guangdong province.
- Mining and extraction of chemicals from the earth should be regulated to conserve the environment.
- Products obtained by the electrolysis of sea water are beneficial to our society.

Topic II Microscopic World I (21 hours)

Overview

The study of chemistry involves the linkage between phenomena in the macroscopic world and the interaction of atoms, molecules and ions in the microscopic world. Through studying the structures of atoms, molecules and ions, and the bonding in elements and compounds, students will acquire knowledge of some basic chemical principles. These can serve to further illustrate the macroscopic level of chemistry, such as patterns of change, observations in various chemical reactions, the rates of reactions and chemical equilibria. In addition, students should be able to perform calculations related to chemical formulae, which are the basis of mole calculations to be studied in later topics.

Students should also be able to appreciate the interrelation between bonding, structures and properties of substances by learning the properties of metals, giant ionic substances, simple molecular substances and giant covalent substances. With the knowledge of various structures, students should be able to differentiate the properties of substances with different structures, and to appreciate that knowing the structure of a substance can help us decide its applications. While materials chemistry is becoming more important in applied chemistry, this topic provides the basic knowledge for further study of the development of new materials in modern society.

Through activities such as gathering and analysing information about atomic structure and the Periodic Table, students should appreciate the impact of the discoveries of atomic structure and the development of the Periodic Table on modern chemistry. Students should also be able to appreciate that symbols and chemical formulae constitute part of the common language used by scientists to communicate chemical concepts.

Students should learn	Students should be able to
a. Atomic structure • elements, atoms and symbols • classification of elements into metals, non-metals and metalloids • electrons, neutrons and protons 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	• state the relationship between element and atom • use symbols to represent elements • classify elements as metals or non-metals on the basis of their properties • be aware that some elements possess characteristics of both metals and non-metals • state and compare the relative charges and the relative masses of a proton, a neutron and an electron • describe the structure of an atom in terms of protons, neutrons and electrons • interpret and use symbols such as $^{23}_{11}Na$ • deduce the numbers of protons, neutrons and electrons in atoms and ions with given atomic numbers and mass numbers • identify isotopes among elements with relevant information • perform calculations related to isotopic masses and relative atomic masses • understand and deduce the electronic arrangements of atoms • represent the electronic arrangements of atoms using electron diagrams • relate the stability of noble gases to the octet rule
b. The Periodic Table • the position of the elements in the Periodic Table related to their electronic arrangements • similarities in chemical properties among elements in Groups I, II, VII and 0	• understand that elements in the Periodic Table are arranged in order of ascending atomic number • appreciate the Periodic Table as a systematic way to arrange elements • define the group number and period number of an element in the Periodic Table • relate the position of an element in the Periodic Table to its electronic structure and vice versa • relate the electronic arrangements to the chemical properties of the Group I, II, VII and 0 elements • describe differences in reactivity of Group I, II and VII elements • predict chemical properties of unfamiliar elements in a group of the Periodic Table

Students should learn	Students should be able to
c. Metallic bonding	• describe the simple model of metallic bond
d. Structures and properties of metals	• describe the general properties of metals • relate the properties of metals to their giant metallic structures
e. Ionic and covalent bond • transfer of electrons in the formation of ionic bond • cations and anions • electron 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 • electron diagrams of simple covalent molecules • names and formulae of covalent compounds • formula masses and relative molecular masses	• describe, using electron diagrams, the formation of ions and ionic bonds • draw the electron diagrams of cations and anions • predict the ions formed by atoms of metals and non-metals by using information in the Periodic Table • identify polyatomic ions • name some common cations and anions according to the chemical formulae of ions • name ionic compounds based on the component ions • describe the colours of some common ions in aqueous solutions • interpret chemical formulae of ionic compounds in terms of the ions present and their ratios • construct formulae of ionic compounds based on their names or component ions • describe the structure of an ionic crystal • describe the formation of a covalent bond • describe, using electron diagrams, the formation of single, double and triple bonds • describe the formation of the dative covalent bond by means of electron diagram using H_3O^+ and NH_4^+ as examples • interpret chemical formulae of covalent compounds in terms of the elements present and the ratios of their atoms • write the names and formulae of covalent compounds based on their component atoms • communicate scientific ideas with appropriate use of chemical symbols and formulae • define and distinguish the terms: formula mass and relative molecular mass • perform calculations related to formula masses and relative molecular masses of compounds

Students should learn	Students should be able to
f. Structures and properties of giant ionic substances	• describe giant ionic structures of substances such as sodium chloride and caesium chloride • state and explain the properties of ionic compounds in terms of their structures and bonding
g. Structures and properties of simple molecular substances	• describe simple molecular structures of substances such as carbon dioxide and iodine • recognise that van der Waals' forces exist between molecules • state and explain the properties of simple molecular substances in terms of their structures and bonding
h. Structures and properties of giant covalent substances	• describe giant covalent structures of substances such as diamond, graphite and quartz • state and explain the properties of giant covalent substances in terms of their structures and bonding
i. Comparison of structures and properties of important types of substances	• compare the structures and properties of substances with giant ionic, giant covalent, simple molecular and giant metallic structures • deduce the properties of substances from their structures and bonding, and vice versa • explain applications of substances according to their structures

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for and presenting information on the discoveries related to the structure of an atom.
- searching for 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 electron diagrams to represent atoms, ions and molecules.

- investigating chemical similarities of elements in the same group of the Periodic Table (e.g. reactions of group I elements with water, group II elements with dilute hydrochloric acid, and group VII elements with sodium sulphite solution).
- predicting chemical properties of unfamiliar elements in a group of the Periodic Table.
- writing chemical formulae for ionic and covalent compounds.
- naming ionic and covalent compounds.
- exploring relationship of colour and composition of some gem stones.
- predicting colours of ions from a group of aqueous solutions (e.g. predicting colour of $K^+(aq)$, $Cr_2O_7^{2-}(aq)$ and $Cl^-(aq)$ from aqueous solutions of potassium chloride and potassium dichromate).
- investigating the migration of ions of aqueous solutions, e.g. copper(II) dichromate and potassium permanganate, towards oppositely charged electrodes.
- building models of three-dimensional ionic crystals and covalent molecules.
- using computer programs to study three-dimensional images of ionic crystals, simple molecular substances and giant covalent substances.
- building models of diamond, graphite, quartz and iodine.
- predicting the structures of substances from their properties, and vice versa.
- justifying some particular applications of substances in terms of their structures.
- reading articles or writing essays on the applications of materials such as graphite and aluminium in relation to their structures.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- 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 perseverance of scientists in developing 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.
- to appreciate the usefulness of the concepts of bonding and structures in understanding phenomena in the macroscopic world, such as the physical properties of substances.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Using the universal conventions of chemical symbols and formulae facilitates communication among people in different parts of the world.
- Common names of substances can be related to their systematic names (e.g. table salt and sodium chloride; baking soda and sodium hydrogencarbonate).
- Some specialised new materials have been created on the basis of the findings of research on the structure, chemical bonding, and other properties of matter (e.g. bullet-proof fabric, superconductors and superglue).

Topic III Metals (22 hours)

Overview

Metals have a wide range of uses in daily life. Therefore, the extraction of metals from their ores has been an important activity of human beings since prehistoric times. This topic provides opportunities 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 a reactivity series of metals 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 of methods to prevent metals from corroding is a valuable problem-solving exercise and can help students develop a positive attitude towards the use of resources on our planet.

A chemical equation is a concise and universally adopted way to represent a chemical reaction. 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 perform calculations involving the mole and chemical equations. The mole concepts acquired from this topic prepare students for performing further calculations involving concentration of solutions, molar volume of gases and equilibrium constant of reaction in other topics of the curriculum.

Students should learn	**Students should be able to**
a. 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 reserves of metals and their conservations	• state the sources of metals and their occurrence in nature • explain why extraction of metals is needed • understand that the extraction of metals involves reduction of their ores • describe and explain the major methods of extraction of metals from their ores • relate the ease of obtaining metals from their ores to the reactivity of the metals • deduce the order of discovery of some metals from their relative ease of extraction • write word equations for the extraction of metals

Students should learn	Students should be able to
	• describe metal ores as a finite resource and hence the need to recycle metals • evaluate the recycling of metals from social, economic and environmental perspectives
b. Reactivity of metals • reactions of some common metals (sodium, calcium, magnesium, zinc, iron, lead, copper, etc.) with oxygen/air, water, dilute hydrochloric acid and dilute sulphuric acid • metal reactivity series and the tendency of metals to form positive ions • displacement reactions and their interpretations based on the reactivity series • prediction of the occurrence of reactions involving metals using the reactivity series • relation between the extraction method of a metal and its position in the metal reactivity series	• describe and compare the reactions of some common metals with oxygen/air, water and dilute acids • write the word equations for the reactions of metals with oxygen/air, water and dilute acids • construct a metal reactivity series with reference to their reactions, if any, with oxygen/air, water and dilute acids • write balanced chemical equations to describe various reactions • use the state symbols (*s*), (*l*), (*g*) and (*aq*) to write chemical equations • relate the reactivity of metals to the tendency of metals to form positive ions • describe and explain the displacement reactions involving various metals and metal compounds in aqueous solutions • deduce the order of reactivity of metals from given information • write balanced ionic equations • predict the feasibility of metal reactions based on the metal reactivity series • relate the extraction method of a metal to its position in the metal reactivity series

Students should learn	**Students should be able to**
c. Reacting masses	
• quantitative relationship of the reactants and the products in a reaction as revealed by a chemical equation • the mole, Avogadro's constant and molar mass • percentage by mass of an element in a compound • empirical formulae and molecular formulae derived from experimental data • reacting masses from chemical equations	• understand and use the quantitative information provided by a balanced chemical equation • perform calculations related to moles, Avogadro's constant and molar masses • calculate the percentage by mass of an element in a compound using appropriate information • determine empirical formulae and molecular formulae from compositions by mass and molar masses • calculate masses of reactants and products in a reaction from the relevant equation and state the interrelationship between them • solve problems involving limiting reagents
d. Corrosion of metals and their protection	
• factors that influence the rusting of iron • methods used to prevent rusting of iron • socioeconomic implications of rusting of iron • corrosion resistance of aluminium • anodisation as a method to enhance corrosion resistance of aluminium	• describe the nature of iron rust • describe the essential conditions for the rusting of iron • describe and explain factors that influence the speed of rusting of iron • describe the observations when a rust indicator (a mixture of potassium hexacyanoferrate(III) and phenolphthalein) is used in an experiment that investigates rusting of iron • describe and explain the methods of rusting prevention as exemplified by i. coating with paint, oil or plastic ii. galvanising iii. tin-plating iv. electroplating v. cathodic protection vi. sacrificial protection vii. alloying • be aware of the socio-economic impact of rusting • understand why aluminium is less reactive and more corrosion-resistant than expected • describe how the corrosion resistance of aluminium can be enhanced by anodisation

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for and presenting information about the occurrence of metals and their uses in daily life.
- analysing information to relate the reactivity of metals to the chronology of the Bronze Age, the Iron Age and the modern era.
- designing and performing experiments to extract metals from metal oxides (e.g. silver oxide, copper(II) oxide, lead(II) oxide, iron(III) oxide).
- deciding on appropriate methods for the 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 the displacement reactions of metals with aqueous metal ions.
- writing ionic equations.
- performing experiments to determine the empirical formula of magnesium oxide or copper(II) oxide.
- 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.
- deciding on appropriate methods to prevent metal corrosion based on social, economic and technological considerations.
- searching for and presenting information about the metal-recycling industry of Hong Kong and the measures for conserving metal resources in the world.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- 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 and violent reactions.
- 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.
- to appreciate the contribution of chemistry in developing methods of rust prevention and hence its socio-economic benefit.

STSE Connections

Students are encouraged to appreciate and to comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Although the steel industry has been one of the major profit-making industries in mainland China, there are many constraints on its growth, e.g. the shortage of raw materials in China.
- New technologies are being implemented to increase the efficiency of the metal extraction process and at the same time to limit its impact on the environment.
- Conservation of metal resources should be promoted to arouse concern for environmental protection.
- The development of new alloys to replace pure metals is needed in order to enhance the performance of some products, such as vehicles, aircrafts, window frames and spectacles frames.

Topic IV Acids and Bases (25 hours)

Overview

Acids and bases/alkalis are involved in numerous chemical processes that occur around us, from industrial processes to biological ones, and from reactions in the laboratory to those in our environment. Students have encountered acids and alkalis in their junior science courses. In this topic, 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 will learn to use an instrumental method of pH measurement, to prepare salts by different methods, and to perform volumetric analysis involving acids and alkalis. Through these experimental practices students should be able to demonstrate essential experimental techniques, to analyse data and to interpret experimental results. On completion of this topic, students are expected to have acquired skills that are essential for conducting the investigative study required in the curriculum, as well as some basic knowledge for further study in Analytical Chemistry and carrying out more complicated quantitative analysis in chemistry.

Students should learn	**Students should be able to**
a. Introduction to acids and alkalis • common acids and alkalis 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 properties of acid • basicity of acid • 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 acids and concentrated alkalis	• recognise that some household substances are acidic • state the common acids found in laboratory • describe the characteristics of acids and their typical reactions • write chemical and ionic equations for the reactions of acids • relate acidic properties to the presence of hydrogen ions ($H^+(aq)$) • describe the role of water for acids to exhibit their properties • state the basicity of different acids such as HCl, H_2SO_4, H_3PO_4, CH_3COOH • define bases and alkalis in terms of their reactions with acids • recognise that some household substances are alkaline • state the common alkalis found in the laboratory • describe the characteristics of alkalis and their typical reactions • write chemical and ionic equations for the reactions of alkalis • relate alkaline properties to the presence of hydroxide ions ($OH^-(aq)$) • describe the corrosive nature of acids and alkalis and the safety precautions in handling them
b. Indicators and pH • acid-base indicators as exemplified by litmus, methyl orange and phenolphthalein • pH scale as a measure of acidity and alkalinity $pH = -\log[H^+(aq)]$ • use of universal indicator and an appropriate instrument to measure the pH of solutions	• state the colours produced by litmus, methyl orange and phenolphthalein in acidic solutions and alkaline solutions • describe how to test for acidity and alkalinity using suitable indicators • relate the pH scale to the acidity or alkalinity of substances • perform calculations related to the concentration of $H^+(aq)$ and the pH value of a strong acid solution • suggest and demonstrate appropriate ways to determine pH values of substances

Students should learn	Students should be able to
c. 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 in aqueous solutions • methods to compare the strength of acids/alkalis	• describe the dissociation of acids and alkalis • relate the strength of acids and alkalis to their extent of dissociation • describe acids and alkalis with the appropriate terms: strong and weak, concentrated and dilute • suggest and perform experiments to compare the strength of acids or alkalis
d. Salts and neutralisation	
• 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 • naming of common salts • applications of neutralisation	• write chemical and ionic equations for neutralisation • state the general rules of solubility for common salts in water • describe the techniques used in the preparation, separation and purification of soluble and insoluble salts • suggest a method for preparing a particular salt • name the common salts formed from the reaction of acids and alkalis • explain some applications of neutralisation
e. Concentration of solutions	
• concentration of solutions in mol dm^{-3} (molarity)	• convert the molar concentration of solutions to g dm^{-3} • perform calculations related to the concentration of solution
f. Volumetric analysis involving acids and alkalis	
• standard solutions • acid-alkali titrations	• describe and demonstrate how to prepare solutions of a required concentration by dissolving a solid or diluting a concentrated solution • calculate the concentrations of the solutions prepared • describe and demonstrate the techniques of performing acid-alkali titration • apply the concepts of concentration of solution and use the results of acid-alkali titrations to solve stoichiometric problems • communicate the procedures and results of a volumetric analysis experiment by writing a laboratory report

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for examples of naturally occurring acids and bases, and their chemical composition.
- 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 properties of acids.
- 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.
- searching for information about the nature of common acid-base indicators.
- performing experiments to find out the pH values of some domestic substances.
- measuring pH values of substances by using data-logger or pH meter.
- designing and performing experiments to compare the strengths of acids/alkalis.
- investigating the temperature change in a neutralisation process.
- preparing and isolating soluble and insoluble salts.
- searching for and presenting information on applications of neutralisation.
- preparing a standard solution for volumetric analysis.
- performing calculations involving molarity.
- performing acid-alkali titrations using suitable indicators/pH meter/data-logger.
- using a titration experiment to determine the concentration of acetic acid in vinegar or the concentration of sodium hydroxide in drain cleaner.
- performing calculations on titrations.
- writing a detailed report for an experiment involving volumetric analysis.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to develop a positive attitude towards the safe handling, storage and disposal of chemicals, and hence adopt safe practices.
- to appreciate the importance of proper laboratory techniques and precise calculations for obtaining accurate results.
- to appreciate that volumetric analysis is a vital technique in analytical chemistry.
- to appreciate the importance of controlling experimental variables in making comparisons.
- to appreciate the use of instruments in enhancing the efficiency and accuracy of scientific investigation.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Measures involving neutralisation have been implemented to control the emission of nitrogen oxides and sulphur dioxide from vehicles, factories and power stations.
- Caustic soda is manufactured by the chloroalkali industry which is a traditional chemical raw materials industry.
- Volumetric analysis, as an essential technique in analytical chemistry, is applied in testing laboratories and forensic science.
- Antacid is a common drug which contains base(s) for neutralising stomach acid and therefore relieving stomach ache.

Topic V Fossil Fuels and Carbon Compounds (18 hours)

Overview

Carbon compounds play an important role in industry and in daily life. Coal and petroleum are two major sources of carbon compounds. In this topic, 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, such as providing us with domestic fuels and raw materials for making synthetic polymers like plastics and synthetic fibers, alongside environmental problems such as air pollution, acid rain, and the global warming. Eventually, they should realise that human activities can have a significant impact on our environment.

This topic also introduces some basic concepts of organic chemistry such as 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 carbon chains not more than eight carbon atoms. In addition, they are expected to learn the chemical reactions of alkanes and alkenes. By illustrating the formation of monosubstituted halomethane with electron diagrams, students should realise that chemical reactions often take place in more than one step and involve reactive species.

Polymers can be synthesised by reacting small organic molecules (monomer) together in a chemical reaction. This process is called polymerisation. Students should understand the formation of addition polymers. Also, they should realise that the uses of some common addition polymers can be related to their physical properties which are, in turn, related to their structures. The formation of condensation polymers and a more in-depth treatment of the properties of polymers are included in Topic XI “Chemistry of Carbon Compounds” and Topic XIV “Materials Chemistry” respectively.

Students should learn

a. Hydrocarbons from fossil fuels

- coal, petroleum and natural gas as sources of fossil fuels and carbon compounds
- composition of petroleum and its separation
- gradation in properties of the various fractions of petroleum
- heat change during combustion of hydrocarbons
- major uses of distilled fractions of petroleum
- consequences of using fossil fuels

Students should be able to

- describe the origin of fossil fuels
- describe petroleum as a mixture of hydrocarbons and its industrial separation into useful fractions by fractional distillation
- recognise the economic importance of petroleum as a source of aliphatic and aromatic hydrocarbons (e.g. benzene)
- relate 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
- explain the demand for the various distilled fractions of petroleum
- recognise combustion of hydrocarbons as an exothermic chemical reaction
- recognise the pollution from the combustion of fossil fuels
- evaluate the impact of using fossil fuels on our quality of life and the environment
- suggest measures for reducing the emission of air pollutants from combustion of fossil fuels

b. Homologous series, structural formulae and naming of carbon compounds

- unique nature of carbon
- homologous series as illustrated by alkanes, alkenes, alkanols and alkanoic acids
- structural formulae and systematic naming of alkanes, alkenes, alkanols and alkanoic acids

- explain the large number and diversity of carbon compounds with reference to carbon’s unique combination power and ability to form different bonds
- explain the meaning of a homologous series
- understand that members of a homologous series show a gradation in physical properties and similarity in chemical properties
- write structural formulae of alkanes
- give systematic names of alkanes
- extend the knowledge of naming carbon compounds and writing structural formulae to alkenes, alkanols and alkanoic acids

Students should learn	Students should be able to
c. Alkanes and alkenes • petroleum as a source of alkanes • alkanes • cracking and its industrial importance • alkenes	• distinguish saturated and unsaturated hydrocarbons from the structural formulae • describe the following reactions of alkanes: i. combustion ii. substitution reactions with chlorine and bromine, as exemplified by the reaction of methane and chlorine (or bromine) • describe the steps involved in the monosubstitution of methane with chlorine using electron diagrams • recognise that cracking is a means to obtain smaller molecules including alkanes and alkenes • describe how to carry out laboratory cracking of a petroleum fraction • explain the importance of cracking in the petroleum industry • describe the reactions of alkenes with the following reagents: i. bromine ii. potassium permanganate solution • demonstrate how to carry out chemical tests for unsaturated hydrocarbons
d. Addition polymers • monomers, polymers and repeating units • addition polymerisation • structure, properties and uses of addition polymers as illustrated by polyethene, polypropene, polyvinyl chloride, polystyrene and Perspex	• recognise that synthetic polymers are built up from small molecules called monomers • recognise that alkenes, unsaturated compounds obtainable from cracking of petroleum fractions, can undergo addition reactions • understand that alkenes and unsaturated compounds can undergo addition polymerisation • describe addition polymerisation using chemical equations • deduce the repeating unit of an addition polymer obtained from a given monomer • deduce the monomer from a given section of a formula of an addition polymer

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for and presenting information about the locations of deposits of coal, petroleum and natural gases in China and other countries.
- investigating colour, viscosity, volatility and burning characteristics of petroleum fractions.
- searching for and presenting information about petroleum fractions regarding their major uses and the relation between their uses and properties.
- discussing the relationship between global warming and the use of fossil fuels.
- drawing structural formulae and writing systematic names for alkanes, alkenes, alkanols and alkanoic acids.
- building molecular models of simple alkanes, alkenes, alkanols and alkanoic acids.
- performing experiments to investigate the typical reactions of alkanes and alkenes.
- studying the nature of the substitution reaction of methane and halogen with the aid of relevant video or computer animation.
- performing an experiment on cracking of a petroleum fraction and testing the products.
- searching for information and presenting arguments on the risks and benefits of using fossil fuels to the society and the environment.
- discussing the pros and cons of using alternative sources of energy in Hong Kong.
- searching for information or reading articles about the discovery of polyethene and the development of addition polymers.
- investigating properties such as the strength and the ease of softening upon heating of different addition polymers.
- writing chemical equations for the formation of addition polymers based on given information.
- building physical or computer models of addition polymers.
- performing an experiment to prepare an addition polymer, e.g. polystyrene, Perspex.
- deducing the monomer from the structure of a given addition polymer.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate the importance of organising scientific information in a systematic way.
- to recognise the benefits and impacts of the application of science and technology.
- to value the need for the conservation of the Earth's resources.
- to appreciate the need for alternative sources of energy for sustainable development of our society.

- to value the need for the safe use and storage of fuels.
- to appreciate the versatility of synthetic materials and the limitations of their use.
- to show concern for the environment and develop a sense of shared responsibility for sustainable development of our society.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- The petroleum industry provides us with many useful products that have improved our standard of living. However, there are risks associated with the production, transportation, storage and usage of fossil fuels.
- Emissions produced from the burning of fossil fuels are polluting the environment and are contributing to long-term and perhaps irreversible changes in the climate.
- There are many examples of damages uncovered after using the applications of science and technology for a long period, e.g. the pollution problem arising from using leaded petrol and diesel; and the disposal problem for plastics. Therefore, it is essential to carefully assess the risks and benefits to society and the environment before actually using applications of science and technology in daily life.

Topic VI Microscopic World II (8 hours)

Overview

This topic builds on Topic II and aims at broadening students' knowledge and concepts of bonding and structures of substances. By learning the concept of electronegativity difference between atoms in covalent bonds, students should be able to identify the polar molecules and their partial charges. The knowledge of bond polarity will in turn assist students in understanding the different natures of intermolecular forces. Students should also be able to understand the origins, natures and strengths of hydrogen bonding, and differentiate van der Waals' forces in non-polar and polar covalent substances. With the knowledge of various intermolecular forces, they will be able to explain the properties of some molecular crystals such as ice and C_{60} in terms of their structures. In addition, students will learn more about molecular substances such as the shapes and the non-octet structures of some covalent molecules.

Students should learn	Students should be able to
a. Polarity of bond and molecule	• define the electronegativity of an atom • describe the general trends in the electronegativities of the main group elements down a group and across a period in the Periodic Table • explain the unequal sharing of electrons in covalent bonds • identify the partial charges of polar molecules such as HF, H_2O, NH_3 and $CHCl_3$ • explain the non-polar nature of CH_4 and BF_3
b. Intermolecular forces • van der Waals' forces • hydrogen bonding	• explain the existence of van der Waals' forces in non-polar and polar covalent substances • state the factors affecting the strength of van der Waals' forces between molecules • compare the strength of van der Waals' forces with that of covalent bonds • describe the formation of hydrogen bonding as exemplified by HF, H_2O and NH_3 • compare the strength of van der Waals' forces with that of hydrogen bonding • understand the effect of hydrogen bonding on properties of substances such as water and ethanol

Students should learn	Students should be able to
c. Structures and properties of molecular crystals	• describe the structures of ice and C_{60} • state and explain the properties of ice and C_{60} in terms of their structures and bonding
d. Simple molecular substances with non-octet structures	• recognise the existence of covalent molecules with non-octet structures • draw the electron diagrams of some non-octet molecules such as BF_3, PCl_5 and SF_6
e. Shapes of simple molecules	• Predict and draw three-dimensional diagrams to represent shapes of (i) molecules with central atoms obeying octet rule; and (ii) molecules with central atoms not obeying octet rule and with no lone pair of electrons (such as BF_3, PCl_5 and SF_6)

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- investigating the effect of a non-uniform electrostatic field on a jet of polar and non-polar liquid.
- investigating the effect of hydrogen bonding on liquid flow (e.g. comparing the viscosity of alcohols possessing different numbers of hydroxyl groups).
- determining the strength of the hydrogen bonding formed between ethanol molecules.
- comparing the boiling points of propane, methoxymethane and ethanol in terms of van der Waals' forces and hydrogen bonding.
- investigating the evaporation rates of substances with different intermolecular forces.
- investigating the surface tension and viscosity of water.
- searching for and presenting information on the important role of hydrogen bonding in macromolecules such as DNA and proteins.
- building models of ice and C_{60}.
- manipulating three-dimensional images of crystal structures using a computer programme.
- investigating the properties of graphite and C_{60}.
- reading articles on how Valence Shell Electron Pair Repulsion (VSEPR) theory can be used to predict the shapes of molecules and its limitations.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate the contribution of science and technology in providing us with useful materials.
- to appreciate the usefulness of models in helping us to visualise the structure of substances.
- to show curiosity about the latest development of chemical applications and their contributions to our society and technological advancement.
- to appreciate that knowledge about bonding may advance and have to be revised as new evidence arises, e.g. the discovery of the structure of Buckminsterfullerenes.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Carbon nanotube composites (a member of fullerene structural family) are being developed for use in aerospace and other high-performance applications such as body armour, sports equipment, and in the auto industry.
- Mass production of fullerenes has to be made commercially viable before implementing it in the fields of electronic devices, semiconductors and pharmaceuticals.

Topic VII Redox Reactions, Chemical Cells and Electrolysis (23 hours)

Overview

Chemical reactions involve the release or absorption of energy, which often appear in the form of heat, light or electrical energy. In a chemical cell, chemical energy is converted to electrical energy. The flow of electrons in an external circuit indicates the occurrence of reduction and oxidation (redox) at the electrodes. To help students understand the chemistry involved in a chemical cell, the concept of redox reactions is introduced in this topic. Students will carry out investigations involving common oxidising and reducing agents. They will also learn how to write chemical equations for redox reactions.

With the concepts related to redox reactions, students should be able to understand the reactions occurring in more complicated chemical cells and the processes involved in electrolysis. Students should also appreciate that the feasibility of a redox reaction can be predicted by comparing the different positions of the species in the electrochemical series. In addition, students should be able to predict products in electrolysis according to the different factors affecting the preferential discharge of ions.

The concepts of redox reactions have a number of applications in industrial chemistry and daily life. Students should appreciate the contribution of electrochemistry to technological innovations, which in turn improve our quality of life. Students should also be able to assess the environmental impact and safety issues associated with these technologies.

Students should learn	Students should be able to
a. Chemical cells in daily life	
• primary cells and secondary cells • uses of chemical cells in relation to their characteristics such as size, voltage, capacity, rechargeability and price	• distinguish between primary and secondary cells • describe the characteristics of common primary and secondary cells: i. zinc-carbon cell ii. alkaline manganese cell iii. silver oxide cell iv. lithium ion cell v. nickel metal hydride (NiMH) cell vi. lead-acid accumulator • justify uses of different chemical cells for particular purposes • understand the environmental impact of using dry cells
b. Reactions in simple chemical cells	
• chemical cells consisting of: i. two metal electrodes and an electrolyte ii. metal-metal ion half cells and salt bridge/porous device • changes occurring at the electrodes and electron flow in the external circuit • half equations and overall cell equations	• describe and demonstrate how to build simple chemical cells using metal electrodes and electrolytes • measure the voltage produced by a chemical cell • explain the problems associated with a simple chemical cell consisting of two metal electrodes and an electrolyte • explain the functions of a salt bridge/porous device • describe and demonstrate how to build simple chemical cells using metal-metal ion half cells and salt bridges/porous devices • explain the differences in voltages produced in chemical cells when different metal couples are used as electrodes • write a half equation representing the reaction at each half cell of a simple chemical cell • write overall equations for simple chemical cells • predict the electron flow in the external circuit and the chemical changes in the simple chemical cells

Students should learn	**Students should be able to**
c. Redox reactions	
• oxidation and reduction • oxidation numbers • common oxidising agents (e.g. $MnO_4^-(aq)/H^+(aq)$, $Cr_2O_7^{2-}(aq)/H^+(aq)$, $Fe^{3+}(aq)$, $Cl_2(aq)$, $HNO_3(aq)$ of different concentrations and conc. $H_2SO_4(l)$) • common reducing agents (e.g. $SO_3^{2-}(aq)$, $I^-(aq)$, $Fe^{2+}(aq)$, $Zn(s)$) • balancing equations for redox reactions	• identify redox reactions, oxidising agents and reducing agents on the basis of i. gain or loss of oxygen/hydrogen atom(s) ii. gain or loss of electron(s) iii. changes in oxidation numbers • assign oxidation numbers to the atoms of elements and compounds • construct a general trend of the reducing power of metals and the oxidising power of metal ions • describe the chemical changes of some common oxidising agents and reducing agents • relate the trends of the reducing power and oxidising power of chemical species to their positions in a given electrochemical series • balance half equations of reduction and oxidation • balance redox equations by using half equations or changes in oxidation numbers
d. Redox reactions in chemical cells	
• zinc-carbon cell • chemical cells with inert electrodes • fuel cell	• describe the structure of a zinc-carbon dry cell • write the half equation for reaction occurring at each electrode and the overall equation for reaction in a zinc-carbon dry cell • describe and construct chemical cells with inert electrodes • predict the chemical changes at each half cell of the chemical cells with inert electrodes • write a half equation for reaction occurring at each half cell and the overall ionic equation for reaction in the chemical cells with inert electrodes • understand the principles of hydrogen-oxygen fuel cell • write the half equation for reaction occurring at each electrode and the overall equation for reaction in a hydrogen-oxygen fuel cell • state the pros and cons of a hydrogen-oxygen fuel cell

Students should learn	Students should be able to
e. Electrolysis • electrolysis as the decomposition of substances by electricity as exemplified by electrolysis of i. dilute sulphuric acid ii. sodium chloride solutions of different concentrations iii. 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: i. electroplating ii. purification of copper	• describe the materials needed to construct an electrolytic cell • predict products at each electrode of an electrolytic cell with reference to the factors affecting the preferential discharge of ions • describe the anodic and cathodic reactions, overall reaction and observable changes of the electrolyte in electrolytic cells • understand the principles of electroplating and the purification of copper • describe the anodic and cathodic reactions, overall reaction and observable changes of electrolyte in electroplating and the purification of copper • understand the environmental impact of the electroplating industry

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- making decisions 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 with common oxidising and reducing agents.
- determining oxidation numbers of atoms in elements and compounds.
- balancing redox equations by using ionic half equations or by using oxidation numbers.
- investigating redox reactions of concentrated sulphuric acid with metals.
- investigating redox reactions of nitric acid of different concentrations with metals.
- searching for and presenting information about the applications of fuel cells.
- investigating the working principles of a fuel cell car.
- performing experiments to investigate the working principles of a lead-acid accumulator.
- predicting changes in chemical cells based on given information.
- viewing or constructing computer simulations illustrating the reactions in chemical cells.
- performing experiments to investigate changes in electrolysis.
- performing experiments to investigate factors affecting preferential discharge of ions

during electrolysis.

- searching for and presenting information about the possible adverse impact of the electroplating industry on the environment.
- designing and performing electroplating experiments.
- reading articles about the industrial processes involved in the extraction of aluminium from aluminium ore.
- discussing the pros and cons of using hydrogen-oxygen fuel cells in vehicles.
- investigating the chemistry involved in oxygen absorbers of packaged food.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the contribution of technological innovations to the quality of life.
- to appreciate the usefulness of the concept of oxidation number in the study of redox reactions.
- to develop a positive attitude towards the safe handling, storage and disposal of chemicals, and hence adopt safe practices.
- to value the need for assessing the impact of technology on our environment.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Various breath-testing technologies, such as passive alcohol sensors, preliminary breath tests, and evidentiary breath tests (e.g. the intoximeter EC/IR) all utilise fuel cell technology to detect alcohol.
- Hydrogen-oxygen fuel cells are being used for some areas like space missions and vehicles, but not widely for commercial or domestic purposes.
- Lithium cell chemistry variants, such as lithium-ion battery, lithium-ion polymer battery, lithium cobalt battery, lithium manganese battery and lithium nickel battery, have been developed to cope with the need for a wide range of consumer products.
- Many electrolytic processes are involved in industrial processes, e.g. refining of metals, the chloroalkali industry and the aluminium production from ore (bauxite).
- The development of electrolysis in extracting reactive metals is closely related to human history.

Topic VIII Chemical Reactions and Energy (7 hours)

Overview

Chemical reactions are accompanied by energy changes, which often appear in the form of heat. In fact, energy absorbed or released by a chemical system may take different forms. Basic concepts of chemical energetics and enthalpy terms are introduced in this topic. Practical work on the simple calorimetric method and quantitative treatment of Hess's law can help students to better understand the concepts of energetics. However, the use of equipment such as the bomb calorimeter is not expected at this level of study.

Students should learn	**Students should be able to**
a. Energy changes in chemical reactions	
• conservation of energy • endothermic and exothermic reactions and their relationship to the breaking and forming of bonds	• explain energy changes in chemical reactions in terms of the concept of conservation of energy • describe enthalpy change, ΔH, as heat change at constant pressure • explain diagrammatically the nature of exothermic and endothermic reactions in terms of enthalpy change • explain the nature of exothermic and endothermic reactions in terms of the breaking and forming of chemical bonds
b. Standard enthalpy changes of reactions	• explain and use the terms: enthalpy change of reaction and standard conditions, with particular reference to neutralisation, formation and combustion • carry out experimental determination of enthalpy changes using simple calorimetric method • calculate enthalpy changes from experimental results
c. Hess's law	
• use of Hess's law to determine enthalpy changes which cannot be easily determined by experiment directly • calculations involving enthalpy changes of reactions	• apply Hess's law to construct simple enthalpy change cycles • perform calculations involving such cycles and relevant energy terms, with particular reference to determining enthalpy change that cannot be found directly by experiment

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- using appropriate methods and techniques to design and carry out the determination of standard enthalpy change of (a) acid-base neutralisation and (b) combustion of alcohols.
- constructing enthalpy change cycles to quantitatively relate, according to Hess's law, reaction enthalpy changes and other standard enthalpy changes.
- discussing the limitations of simple calorimetric methods as opposed to other more sophisticated techniques.
- performing calculations on standard enthalpy change of reactions involving (a) standard enthalpy change of formation, (b) standard enthalpy change of combustion and (c) other standard enthalpy terms.
- performing experiments to determine the enthalpy change of formation of metal oxides or metal carbonates.
- finding out different approaches to solving problems of standard enthalpy changes in chemical reactions.
- investigating the chemistry involved in hand-warmers or cold-packs.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the need to understand heat changes in chemical reactions in a systematic way.
- to appreciate the importance of interdisciplinary relevance, e.g. knowledge of quantitative treatment in thermal physics is involved in enthalpy change calculations.
- to accept quantitative experimental results within tolerance limits.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Humans have been making efforts to discover more efficient release of thermal energy from chemical reactions, e.g. combustion of fuels.
- The ever-increasing use of thermal energy from chemical reactions has impacts on technology and the environment, e.g. energy crisis and global warming.
- Energy changes in chemical reactions have been utilised in many daily life products, e.g. hand-warmers, physiotherapy heat-packs, cold-packs, self-heating coffee and lunchboxes.
- Harnessing solar energy and storing it chemically are the challenges in using alternative energy sources.

Topic IX Rate of Reaction (9 hours)

Overview

Rate of reaction is a fundamental concept in the study of chemistry and in daily life. Students have had a lot of experience of different rates of changes in their previous learning. For example, students should know that rusting is a slow process but the reaction of hydrogen and oxygen can be extremely rapid. Furthermore, there is always a strong need for ways to control the rates of changes. In short, this topic attempts to help students to build up concepts related to rate of reaction.

Students will learn different methods that can be used to follow the progress of a reaction and the factors that affect the rate of reaction. Equipment and apparatus in the school laboratory should be able to provide students with such experience. With the use of more sophisticated instruments such as suitable sensors and data-logging system, investigations or practical work can be performed in a more accurate and efficient manner.

Catalysis plays an important role in both research and chemical industries. Students should be aware of the fact that practically all chemical reactions in large-scale chemical plants involve the use of catalysts and that reactions occurring in living systems are catalysed by enzymes. Students can find a further study of catalysis in Topic XIII "Industrial Chemistry".

The molar volume of gases at room temperature and pressure is included in this topic for a complete stoichiometric treatment of chemical equations at this level of study.

Students should learn	**Students should be able to**
a. Rate of chemical reaction	
• methods of following the progress of a chemical reaction • instantaneous and average rate	• select and justify the following techniques to follow the progress of a reaction: i. titrimetric analysis ii. measurement of the changes in: volume / pressure of gases, mass of a mixture and colour intensity of a mixture • interpret a graph showing the progress of a reaction • determine instantaneous and average rate from a suitable graph • recognise that initial rate equals to instantaneous rate at time t = 0
b. Factors affecting rate of reaction	
• concentration • temperature • surface area • catalyst	• design and perform experiments to study the effects of i. concentration, ii. temperature, iii. surface area, and iv. catalyst on rate of reaction • interpret results (e.g. graphs) collected through first-hand investigations on factors affecting rate of reaction: changes in volume / pressure of gases, mass of a mixture, colour intensity of a mixture and turbidity of a mixture • explain qualitatively the effect of changes in concentration, surface area and temperature on the rate of reaction • appreciate the importance of catalyst in chemical industries and biological systems
c. Molar volume of gases at room temperature and pressure (r.t.p.)	
• calculations involving molar volume of gases	• deduce the molar volume of gases at r.t.p. as 24 dm^3 using a given data set • perform stoichiometric calculations involving molar volume of gases at r.t.p.

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for information on accidents caused by the failure to control reaction rate.
- selecting and explaining the appropriateness of using different techniques to follow the progress of the chemical reactions such as:
  - (a) base hydrolysis of esters
  - (b) reaction of $CaCO_3$(s) or Mg(s) with dilute acids
  - (c) oxidation of $C_2O_4^{2-}$(aq) ion by acidified $KMnO_4$(aq)
- discussing the nature of rate studies with respect to methods of "quenching" and "on-going".
- using appropriate methods, skills and techniques, such as the micro-scale chemistry technique and data-loggers, to study the progress of a reaction.
- investigating the effect of changes in concentration of reactant, temperature, surface area, or the use of catalyst on reaction rate.
- performing calculations involving the constant molar volume of gases at room temperature and pressure viz. 24 dm^3.
- performing experiments to determine the molar volume of a gas.
- searching for information or reading articles on airbags of vehicles.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the need to control reaction rates for human advancement.
- to value the need to identify crucial variables in various situations.
- to appreciate that a problem can be solved by diverse approaches.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Control of metal corrosion has socio-economic importance and environmental relevance.
- The use of catalysts has been very important to industry and in the medical field.
- Research into reaction rates has made a positive contribution to society, e.g. airbags in vehicles.
- Research into reaction rates is closely linked with the development of lethal weapons.

Topic X Chemical Equilibrium (10 hours)

Overview

In general, chemical reactions are either reversible or irreversible. The concept of a state of equilibrium for the majority of reversible reactions is fundamental in chemistry. Students should appreciate the dynamic nature of chemical equilibrium, in particular the shifting of equilibrium position when a system at equilibrium is subjected to a change. It is therefore important to control variables such as pressure, concentration and temperature in an industrial process so as to establish the optimal reaction conditions. A more in-depth treatment of the above concepts is included in Topic XIII "Industrial Chemistry".

The equilibrium law provides a quantitative relationship between the concentrations of the reactants and products in systems which are existing in a state of equilibrium. Students should understand the equilibrium constant K_c and its mathematical treatment in relation to the stoichiometry of reactions. Students should also be able to predict the effect of changes in either concentration or temperature on the position of chemical equilibrium in a homogeneous reaction. But the effect on the position of equilibrium of introducing species not involved in the chemical reaction is not required. Detailed treatment of equilibrium systems involving redox and acid-base reactions are not expected at this level of study.

The concept of chemical equilibrium has a number of applications in daily life. Information search and reading on related topics can help students to build up their understanding of the concepts involved as well as the relationship between different types of equilibria.

Students should learn	**Students should be able to**
a. Dynamic equilibrium	
• characteristics of dynamic equilibrium	• describe reversible and irreversible reactions by using suitable examples • describe characteristics of a system existing in dynamic equilibrium
b. Equilibrium constant	
• equilibrium constant expressed in terms of concentrations (K_c)	• express the mathematical relationship between concentrations of reactants and products at equilibrium and K_c

Students should learn	**Students should be able to**
c. The effect of changes in concentration and temperature on chemical equilibria	
• a change in temperature results in possible changes in K_c of the system • changes in concentration result in the adjustment of the system without changing the value of K_c	• recognise that the value of K_c for an equilibrium system is a constant at constant temperature irrespective of changes in concentration of reactants and products • perform calculations involving K_c • perform practical work on the determination of K_c • derive inductively the relation of temperature and the value of K_c from given data sets • predict qualitatively the effect of temperature on the position of equilibrium from the sign of ΔH for the forward reaction • deduce the effect of change in concentration on the position of chemical equilibrium

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for information on issues related to chemical equilibrium.
- investigating examples of reversible and irreversible reactions.
- investigating the dynamic nature of chemical equilibrium.
- designing and performing experiments to investigate the qualitative effects of pH on chemical equilibrium systems such as
  $Br_2(aq) + H_2O(l) \rightleftharpoons HOBr(aq) + H^+(aq) + Br^-(aq)$
  $Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$
- investigating the effect of changes in concentration or temperature on chemical equilibria using a computer simulation.
- performing calculations related to equation stoichiometry and the equilibrium constant K_c by either finding K_c from equilibrium concentrations or vice versa.
- designing and performing an experiment to determine K_c of a chemical equilibrium system such as esterification of alkanol and alkanoic acid.
- investigating the equilibrium of
  $SCN^-(aq) + Fe^{3+}(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$ or
  $Co^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq)$
  to study the shift of equilibrium positions upon changing concentration or temperature.
- investigating the relationship of temperature and the value of K_c from given data sets.
- predicting the shift in equilibrium position using the reaction quotient.

- exploring how Le Chatelier's Principle can be used for predicting the shift in equilibrium position and recognising its limitations.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the need for quantitative treatment of chemical equilibrium systems for a better control of product formation.
- to recognise the fact that the majority of reactions employed in chemical industries are reversible.
- to appreciate the advantages of qualitative treatment and quantitative treatment in solving different problems.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Applications of chemical equilibrium play an important role in industries.
- Chemical equilibrium has been applied in a wider context in various scientific and technological areas.

Topic XI Chemistry of Carbon Compounds (25 hours)

Overview

Organic chemistry is a very important branch of chemistry as judged by the uniqueness of carbon and ubiquitousness of carbon compounds. Together with the basic concepts and knowledge acquired in the junior secondary course, and Topics V and VI in this curriculum, students build up concepts related to the structural characteristics of some common carbon compounds. Students are also expected to be able to use the systematic and common trivial names of carbon compounds to communicate knowledge and understanding in study and in daily life.

In this topic, basic concepts of isomerism including structural isomerism, *cis-trans* isomerism and enantiomerism are introduced. Students will also learn about the chemistry of a number of functional groups. They should be able to give systematic names of alkanes, alkenes, haloalkanes, alcohols, aldehydes and ketones, carboxylic acids, esters, unsubstituted amides and primary amines, with not more than eight carbon atoms in their carbon chains. Through studying the reactions of the functional groups (including the reagents, reaction conditions, products and observations), students will be able to make use of some chemical methods to distinguish different functional groups and to identify unknown carbon compounds. They should also be able to predict major products of reactions between alkenes and hydrogen halides using Markovnikov's rule. However, the use of reaction mechanisms to explain how carbon compounds react is not expected at this level of study.

Students should also recognise the relationship between different functional groups and be aware of the most important application of organic chemistry, i.e. the synthesis of useful carbon compounds through inter-conversions between different functional groups. To further their understanding of the reactions included in this topic, students should carry out experiments on synthesising simple organic substances. Important organic substances such as aspirin, detergents, nylon and polyesters are discussed in this topic, and students should be able to recognise the structures of these substances. In particular, they should appreciate that the hydrophobic and hydrophilic parts of detergents render the emulsifying and wetting properties of detergents. They should also understand the relation between the cleansing action of soaps and soapless detergents and their structures. In addition, students should recognise that nylon and polyesters are condensation polymers, and write the chemical equations for their formation.

Students should learn	Students should be able to
a. Introduction to selected homologous series	
• homologous series • structural formulae and systematic naming	• give systematic names, general formulae, condensed formulae and structural formulae for: alkanes, alkenes, haloalkanes, alcohols, aldehydes and ketones, carboxylic acids, esters, unsubstituted amides and primary amines • draw the structures of the compounds based on their systematic names • understand the effects of functional groups and the length of carbon chains on physical properties of carbon compounds • identify common trivial names of some carbon compounds (e.g. formaldehyde, chloroform, acetone, isopropyl alcohol, acetic acid)
b. Isomerism	
• structural isomerism • *cis*-*trans* isomerism as exemplified by acyclic carbon compounds containing one C=C bond • enantiomerism as exemplified by compounds containing one chiral carbon	• understand that isomerism occurs when two or more compounds have the same molecular formula but different structures • recognise and predict the existence of structural isomerism which includes isomers containing the same functional group and isomers containing different functional groups • recognise the existence of *cis*-*trans* isomerism in acyclic carbon compounds resulting from restricted rotation about a C=C bond • show an understanding of structural and geometrical isomerism by predicting structures of the isomers of some given carbon compounds • recognise the existence of enantiomerism in compounds with only one chiral carbon • use structural formulae and molecular models to demonstrate the arrangement of atoms in isomers of carbon compounds

c. Typical reactions of various functional groups

- alkanes
- alkenes
- haloalkanes
- alcohols
- aldehydes
- ketones
- carboxylic acids
- esters
- amides

- describe the following reactions, in terms of reagents, reaction conditions and observations, and write the relevant chemical equations:
  i. alkanes: substitution with halogens
  ii. alkenes: addition of hydrogen, halogens and hydrogen halides
  iii. haloalkanes: substitution with OH (aq)
  iv. alcohols: substitution with halides using hydrogen halides or phosphorus trihalides; dehydration to alkenes; oxidation of primary alcohols to aldehydes and carboxylic acids; oxidation of secondary alcohols to ketones
  v. aldehydes and ketones: oxidation using $Cr_2O_7^{2-}$(aq); reduction using $LiAlH_4$ or $NaBH_4$
  vi. carboxylic acids: esterification and amide formation; reduction using $LiAlH_4$
  vii. esters: hydrolysis
  viii. amides: hydrolysis
- predict and name the products of the above reactions

d. Inter-conversions of carbon compounds

- inter-conversions between the functional groups
- laboratory preparations of simple carbon compounds

- suggest routes to convert one functional group into another by using the reactions described in (c)
- state the reagents and conditions to accomplish conversions of carbon compounds using the reactions described in (c)
- predict the major organic products of reactions, with given starting materials, reagents and reaction conditions
- describe how to carry out laboratory preparations and purification of simple carbon compounds such as ethanoic acid and ester
- calculate the percentage yield of a product obtained from a reaction

e. Important organic substances

• structure and medical applications of acetylsalicylic acid (aspirin) • structures and properties of soaps and soapless detergents • structures, properties and uses of nylon and polyesters	• identify the functional groups of the acetylsalicylic acid molecule • recognise that aspirin is used as a drug to relieve pain, reduce inflammation and fever, and the risk of heart attack • describe the structures of soaps and soapless detergents • recognise that detergents can be made from chemicals derived from petroleum • explain the wetting and emulsifying properties of detergents in relation to their structures • relate the cleansing action of soaps and soapless detergents to their structures • recognise that nylon and polyester are condensation polymers • describe the structures and properties of nylon and polyesters • write equations for the formation of nylon and polyesters • state the uses of nylon and polyesters

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- building molecular models of compounds with different functional groups.
- comparing physical properties of the following compounds: propane, butane, pentane, ethanol, propan-1-ol and butan-1-ol.
- searching for common trivial names of common carbon compounds.
- predicting the structures of the isomers of given carbon compounds.
- building molecular models of but-2-enes.
- building molecular models of butan-2-ol or 2-hydroxypropanoic acid (lactic acid).
- searching for and presenting information on the principles and applications of the alcohol breathalyser.
- inspecting reaction schemes and important synthetic routes in organic chemistry.
- inspecting or writing reaction schemes that summarise all the reactions described in this topic.

- planning synthetic routes of simple carbon compounds from precursors that are readily available by analysing the structures of the target molecules.
- searching for and presenting information about the synthetic routes of some important organic substances commonly found in daily life.
- preparing ethanoic acid or ethyl ethanoate.
- preparing soap from a fat or an oil, and testing its properties.
- searching for and presenting information on cationic surfactants and neutral surfactants.
- performing an experiment to prepare 2-chloro-2-methylpropane from 2-methylpropan-2-ol.
- searching for and presenting information on the discovery of aspirin and its applications.
- performing an experiment to analyse commercial aspirin tablets using back titration.
- searching for and presenting information on the historical development of detergents.
- performing experiments to investigate the wetting ability and emulsifying action of detergents.
- designing and carrying out experiments to compare the cleansing abilities of soaps and soapless detergents.
- searching for and presenting information on environmental issues related to the use of detergents.
- performing an experiment to prepare nylon.
- searching for and presenting information on the structures and uses of important organic substances such as aspirin, paracetamol, ibuprofen, saccharin, aspartame, sucrose, cellulose, starch, triglyceride, cholesterol, insulin and casein.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- 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 be aware of the hazards associated with the use and disposal of carbon compounds in the laboratory (e.g. their combustibility and toxicity) and the precautions to be taken.
- to show concern for the conservation of our environment and develop a sense of shared responsibility for sustainable development of our society.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Often more than one synthetic route may be available to prepare a particular carbon compound. However, some synthetic routes may have undesirable effects on our health and our environment. The best synthetic route may not be the one with the fewest steps or the lowest cost. It is, therefore, essential to apply our knowledge of organic chemistry so that useful organic products are developed and manufactured by safe, economic and environmentally acceptable routes.
- The search for new carbon compounds often requires the synthesis of hundreds of compounds which are variations of their basic structures. Some compounds which have been synthesised may have certain useful aspects, but also dangerous side-effects which prohibit their general use. It is often necessary to look for other compounds with similar structures but without the side-effects.

Topic XII Patterns in the Chemical World (8 hours)

Overview

Through the study of this topic, students can develop an understanding of the importance of the Periodic Table in chemistry. In this topic, students are required to acquire the knowledge and concepts about the periodic trends of physical properties of some elements and the periodic relationship between acid-base properties of selected oxides.

Students can also develop knowledge and concepts of the properties of selected transition metals and their compounds. The importance of the use of transition metals in industries and other applications will be discussed.

Students should learn	Students should be able to
a. Periodic variation in physical properties of the elements from Li to Ar • variation in the nature of bonding • variations in melting point and electrical conductivity	• describe the nature of bonding and structures of elements of Group I through Group 0 of the Periodic Table • describe the periodic variations of melting point and electrical conductivity of the elements • interpret the variations in melting point and in electrical conductivity in terms of the bonding and structures of the elements, viz. the presence of metallic structures, covalent structures and molecular structures
b. Bonding, stoichiometric composition and acid-base properties of the oxides of elements from Na to Cl	• describe the nature of bonding and stoichiometric composition of the oxides of elements from Na to Cl • describe the variation in behaviour of the following oxides in water: Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10}, SO_2 and Cl_2O • recognise the variations of acid-base properties of the oxides of elements from Na to Cl as exemplified by Na_2O, Al_2O_3 and SO_2

Students should learn	**Students should be able to**
c. General properties of transition metals • coloured ions • variable oxidation states • catalytic properties	• identify positions of the transition metals in the Periodic Table • recognise that most aqueous ions of transition metals are coloured • describe the colours of some transition metal ions such as $Fe^{3+}(aq)$, $Cr^{3+}(aq)$, $Cu^{2+}(aq)$ • describe that transition metals can exist in more than one oxidation states in their compounds, e.g. Fe^{2+} and Fe^{3+}; Mn^{2+}, MnO_2 and MnO_4^- • describe that transition metals and their compounds can be used as catalysts • describe the importance of transition metals

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for information on developments of the Periodic Table.
- searching for information and interpreting the trends of physical properties of elements, e.g. density and solubility in water, in Periods 2, 3, and 4.
- investigating the trends of the melting point and the electrical conductivity of elements across a period.
- investigating the behaviour of oxides of the elements Na to Cl in water and their corresponding acid-base properties.
- searching for information on the importance of transition metals and their compounds.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate the pattern-wise variations that occur in nature.
- to appreciate the human endeavour in searching for means to increase the efficiency of industrial processes.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Transition metals are used as catalysts in the fields of technology, medical research and industry.
- Transition metal ions have been playing an important role in maintaining our health.
- Myoglobin and haemoglobin are physiologically important in terms of their ability to bind molecular oxygen. The ability to bind oxygen is related to the deep red iron-containing prosthetic group in the molecule.

2.3.2 Elective Part (Total 48 hours, select any 2 out of 3)

Topic XIII Industrial Chemistry (24 hours)

Overview

This topic aims to provide students with opportunities to advance their knowledge and understanding of some fundamental chemistry principles, and to develop an understanding of industrial chemistry. A study of some important industrial processes such as the Haber process, chloroalkali industry and the methanol manufacturing process is required. Students are expected to have a more in-depth understanding of chemical kinetics including activation energy and catalysis. The content of this topic can be linked to the relevant topics in the Compulsory Part.

Through the learning of Industrial Chemistry, students can experience how chemists apply chemistry principles and scientific methods to solve authentic problems in industry, and to optimise the chemical processes. In addition, students should be able to appreciate how chemists make use of computer modelling to simulate and control a chemical plant. Students should also be able to evaluate the role of chemistry in society from different perspectives, and to develop concepts and understanding of green chemistry for the management and control of the impact of industrial processes on our environment. Students are also expected to develop skills related to quantitative chemistry by constructing and interpreting graphs, and performing calculations.

Students should learn	**Students should be able to**
a. Importance of industrial processes	
• development of synthetic products for modern ways of living	• discuss the advantages and disadvantages of using industrial processes such as petrochemistry for manufacturing products from social, economic and environmental perspectives • understand the recent progress in industrial processes such as the production of vitamin C to solve problems of inadequate or shrinking supply of natural products
b. Rate equation	
• rate equation determined from experimental results	• understand the interrelationship between reaction rate, rate constant, concentration of reactants and order of reaction • determine the rate equation of a chemical reaction by method of initial rate

Students should learn	**Students should be able to**
c. Activation energy	
• energy profile	• draw an energy profile of a reaction
• explanation of the effect of temperature change on reaction rate in terms of activation energy	• explain the relationship between temperature and reaction rate using Maxwell-Boltzmann distribution curve
• Arrhenius equation: $\ell og\ k = constant - \frac{E_a}{2.3RT}$	• determine the activation energy of a chemical reaction i. by gathering first-hand experimental data ii. with a given set of data
d. Catalysis and industrial processes	
• meaning and characteristics of catalyst	• describe the characteristics of catalysts using suitable examples
• relation between activation energy and catalysis	• understand that catalysts work by providing an alternative reaction route • describe the effect of catalyst on reversible reactions • describe the applications of catalysis in industrial processes with examples such as iron in the Haber process and enzymes in the production of alcoholic drinks

Students should learn	Students should be able to
e. Industrial processes • conversion of raw materials to consumer products as illustrated by the production of fertilisers • applications of principles of electrochemistry in industry as exemplified by the processes in the chloroalkali industry • advancement of industrial processes as exemplified by the conversion of methane to methanol • social, economic and environmental considerations of industrial processes	• describe feedstock, principles, reaction conditions, procedures and products for processes involved in the production of ammonia • describe the process of the conversion of ammonia to fertilisers • explain the physicochemical principles involved in the production of ammonia • explain how industrial processes such as the Haber process often involve a compromise between rate, yield and economic considerations • describe the importance of fertilisers to our world • describe the importance of the chloroalkali industry • explain the underlying chemical principles involved in flowing mercury cell process and membrane cell process of the chloroalkali industry • describe the importance of methanol • recognise the significance of the conversion of methane to methanol • describe feedstock, reaction conditions, procedures and products for processes involved in the manufacturing of methanol via syngas • discuss the advancement of the methanol production technology • discuss social, economic and environmental considerations of industrial processes as illustrated by the Haber process, the chloroalkali industry or the manufacturing of methanol via syngas
f. Green chemistry • principles of green chemistry • green chemistry practices	• describe the relation between sustainable development and green chemistry • calculate the atom economy of a chemical reaction • relate principles of green chemistry and practices adopted in the industrial processes as exemplified by the manufacture of acetic acid (ethanoic acid) • evaluate industrial processes using principles of green chemistry

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- using initial rate method to determine the rate equation of the reaction between sodium thiosulphate and dilute hydrochloric acid.
- performing experiments to determine the activation energy of a chemical reaction.
- designing and performing experiments to investigate ways to change the rate of a reaction with a suitable catalyst.
- performing calculations related to activation energy, percentage yield and atom economy.
- reading articles on the importance of nitrogen fixation.
- reading articles on the latest development of the methanol manufacturing process.
- using computer modelling to study an industrial process and to control the production of a chemical plant.
- analysing an industrial process from scientific, social, economic and environmental perspectives.
- discussing the feasibility of using the principles of green chemistry for daily-life applications of chemistry.
- searching for and presenting information about the greening of acetic acid manufacture.
- reviewing industrial processes using green chemistry principles.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate the significance of knowledge and understanding of fundamental chemical principles for the production of synthetic materials.
- to value the need for safe transport and storage of hazardous substances such as ammonia, acetic acid, hydrogen, chlorine and sodium hydroxide.
- to show concern for the limited supply of natural products and appreciate the contribution of industrial chemistry to our society.
- to recognise the importance of catalysts in chemical industry.
- to show willingness to adopt green chemistry practices.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Consumers have a great demand for products such as optical brighteners, but at the same time, the manufacturing process produces effluent, particularly volatile organic compounds (VOCs), and this is not environmentally friendly.
- Chemists developed the process for the mass production of fertilisers to relieve problems related to inadequate supply of food.
- Green chemistry involves the employment of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products. In order to encourage business leaders to choose responsibly between traditional options and green solutions, more environmentally benign alternatives to current materials and technologies must be developed and promoted.
- The fundamental challenge for the chemical industry is to maintain the benefits to the society without overburdening or causing damage to the environment, and this must be done at an acceptable cost.
- Environmental damages were caused by careless disposal or leakage of chemicals in manufacturing processes (e.g. Bhopal Disaster and Minamata mercury poisoning incident) or widespread use of toxic chemicals (e.g. arsenic, cadmium, chromium, lead, phthalates, PAHs, PBDEs and tributyl tin).

Topic XIV Materials Chemistry (24 hours)

Overview

This topic aims to provide students with opportunities to broaden their knowledge and understanding of materials chemistry. Studies of some important materials such as polymers, alloys, liquid crystals and nanomaterials are required. Students are expected to have a more thorough understanding of synthetic polymers including thermoplastics, thermosetting plastics, polymeric biomaterials and biodegradable plastics. The content of this topic can be linked to the relevant topics in the Compulsory Part.

Through the learning of Materials Chemistry, students can appreciate the contributions of chemists in the development of new materials to replace those that have been deemed to be no longer satisfactory in terms of meeting our needs in modern life. Students are also expected to appreciate that through application of concepts of green chemistry in the production processes of synthetic materials, the harm to our health or to the environment can be reduced or even eliminated.

Students should learn	Students should be able to
a. Naturally occurring polymers • structures and properties of cellulose and chitin	• explain the properties of cellulose and chitin in terms of their structures • compare structural features of cellulose and chitin

Students should learn	Students should be able to
b. Synthetic polymers and plastics • addition polymerisation • formation and uses of addition polymers such as polytetrafluoroethene (PTFE), polymethyl methacrylate (PMMA) and cyanoacrylate (superglue) • condensation polymerisation • formation and uses of condensation polymers such as polyesters and polyamides • polymeric biomaterials such as polylactide (PLA) • effect of structure on properties such as density, hardness, rigidity, elasticity and biodegradability as exemplified by i. high density polyethene and low density polyethene ii. nylon and Kevlar iii. vulcanisation of polymers iv. biodegradable plastics • plastics fabrication processes – injection moulding, blow moulding, extrusion moulding, vacuum forming and compression moulding	• explain the terms “thermoplastics” and “thermosetting plastics” • describe the characteristics of addition polymers using examples like PTFE, PMMA and cyanoacrylate • describe the characteristics of condensation polymers: poly(ethylene terephthalate) (PET), nylon, Kevlar and urea-methanal • deduce the type of polymerisation reaction for a given monomer or a pair of monomers • deduce the repeating unit of a polymer obtained from a given monomer or a pair of monomers • write equations for the formation of addition and condensation polymers • state the similarities and differences between addition polymerisation and condensation polymerisation • explain the properties of polymers in terms of their structures • recognise the applications of polymeric biomaterials • describe the process of making biodegradable plastics using PLA as an example • relate the choice of fabrication processes to the properties of plastics and the uses of their products • discuss the importance and problems of recycling plastics
c. Metals and alloys • metallic crystal structures: i. close-packed structures as illustrated by hexagonal and cubic close-packed structures ii. open structure as illustrated by body-centered cubic structure • unit cells and coordination numbers of metallic structures • differences in properties between metals and alloys	• describe the close-packed and open structures of metals • identify the unit cell and determine the coordination number of a given metallic structure • recognise that alloys are formed by the introduction of other elements into metals • explain the differences in properties (e.g. hardness and conductivity) between metals and alloys • relate the uses of alloys (e.g. steel and brass) to their properties as compared with the pure metals from given information

Students should learn	Students should be able to
d. Synthetic materials in modern life	
• liquid crystals • nanomaterials	• describe the chemical structures and different phases of organic liquid crystals • identify the structural features of substances that exhibit liquid-crystalline behaviour • relate the uses of liquid crystals to their properties • describe nanomaterials as organic or inorganic materials that have particle sizes up to 100 nm • state the uses of nanomaterials
e. Green chemistry	
• principles of green chemistry • green chemistry practices	• describe the relation between sustainable development and green chemistry • understand the green chemistry practices in the production of synthetic materials including the use of less hazardous chemical synthesis and safer solvents and auxiliaries • evaluate processes for the production of synthetic materials using the principles of green chemistry

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- writing chemical equations for the formation of polymers.
- deducing the monomer(s) from the structure of a given polymer.
- performing an experiment to prepare an addition polymer, e.g. polystyrene, Perspex.
- performing an experiment to prepare a condensation polymer, e.g. nylon, urea-methanal.
- searching for information or reading articles on the use of Kevlar in making bullet-proof vests.
- searching for information or reading articles on the advantages and disadvantages of using a biopolymer such as Biopol (polyhydroxybutyrate).
- searching for and presenting information related to structures and properties of polymeric materials that are used as adhesives, semiconductors and drug-carriers.
- searching for information or reading articles on the structural features, properties and uses of Gore-Tex™.
- building models or viewing computer simulations of metallic crystals.
- comparing the appearance, hardness, melting point and corrosion resistance of (a) brass and copper, (b) steel and iron, (c) solder and tin, (d) coinage metal and nickel, and (e) gold of different carats and pure gold.

- discussing the impact of the development of materials such as polymers or alloys on our society.
- doing a decision-making exercise on selecting the best materials for making items like daily commodities, statues and bridges.
- searching for and presenting information about the properties and structures of memory metals.
- searching for information about the discovery and applications of liquid crystals or nanomaterials.
- building models or viewing computer simulations of nanomaterials.
- preparing hexanedioic acid by catalytic oxidation of cyclohexene in the presence of a phase-transfer catalyst (Aliquat 336).
- discussing the advantages and disadvantages of using supercritical carbon dioxide and water as solvents in place of organic solvents in production processes.
- searching for and presenting information related to Ziegler-Natta catalysis on the production of polyethene.
- reading articles or writing essays on the impact of the development of modern materials, such as iron, semiconductors and nanotubes, on daily life.
- searching for uses of nanomaterials, such as in drug delivery, photodynamic therapy, high-definition phosphors, and catalysts.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- 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 appreciate the importance of recycling processes and that material resources are finite.
- to appreciate the need for alternative sources of the compounds presently obtained from the petroleum industry.
- to appreciate the need for considering various properties of a material when it is selected for a particular application.
- to appreciate that close collaboration between chemists, physicists and materials scientists is required for advances in materials chemistry.
- to show concern for the environment and develop a sense of shared responsibility for the sustainable development of our society.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Synthetic materials can raise our standard of living, but many production processes can have undesirable effects on our health and environment.
- Meeting the requirement of using "green" electronic materials, such as lead-free solder, set by the European Commission posts a challenge to scientists and engineers.
- The safety and toxicity of new materials, such as nanomaterials, should be considered when they are developed and used.

Topic XV Analytical Chemistry (24 hours)

Overview

At the beginning of this topic, students are expected to apply their knowledge and skills they have acquired in previous topics of the Compulsory Part to plan and carry out appropriate tests for the detection of some common chemical species. Other than the common separation methods learned in earlier topics, students should know that liquid-liquid extraction and chromatographic methods can be used to separate a mixture of substances. Students are also expected to understand that the determination of melting point and boiling point is an important way to indicate the purity of a substance.

In addition, this topic stresses quantitative methods of analysis. Students should be provided with the opportunity to solve problems related to estimating quantities of substances, if possible, in authentic situations. In this connection, investigations using different types of volumetric method, which may involve acid-base reactions and redox reactions, are conducted. On completion of this topic, students are expected to acquire skills related to quantitative chemistry, such as performing calculations and describing ways to minimise possible sources of error.

Modern instruments play a key role in chemical analysis nowadays. Students are expected to acquire a basic understanding of instrumental methods such as colorimetry for determining the quantity of coloured substances, infrared (IR) spectroscopy for identifying functional groups and mass spectrometry for determining molecular structures. 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. However, in-depth understanding of the principles and detailed operation procedure of the instruments are not expected at this level of study.

Instead of learning a number of tests and analytical methods, students can select the most appropriate means to solve problems in different situations, and justify their choices. Together with the hands-on experience of investigating the nature and the quantity of chemicals, students are expected to understand the important role of analytical chemistry in daily life.

Students should learn	**Students should be able to**
a. Detecting the presence of chemical species	
• detecting the presence of calcium, copper, potassium and sodium in substances by the flame test • application of appropriate tests for detecting the presence of i. molecules: hydrogen, oxygen, chlorine, carbon dioxide, water, ammonia, sulphur dioxide and hydrogen chloride ii. cations: aluminium, ammonium, calcium, magnesium, copper(II), iron(II), iron(III) and zinc iii. anions: chloride, bromide, iodide, carbonate, hypochlorite and sulphite iv. various functional groups in carbon compounds: C=C, –OH, –CHO, >C=O and –COOH	• select appropriate tools and apparatus for chemical tests • gather empirical information using chemical tests • record observations accurately and systematically • decide on and carry out an appropriate chemical test to detect the presence of a chemical species • justify the conclusion of the presence of a chemical species either orally or in written form • assess possible risks associated with chemical tests • state the reaction conditions and observations of the tests for the presence of carbonyl compounds using 2,4-dinitrophenylhydrazine and Tollens' reagent • devise a scheme to separate a mixture of known substances
b. Separation and purification methods	
• crystallisation • distillation / fractional distillation • liquid-liquid extraction • paper, column or thin layer chromatography	• describe various separation and purification methods • separate and purify substances by the following methods: i. crystallisation ii. distillation / fractional distillation iii. liquid-liquid extraction iv. chromatographic methods • determine the R_f values of substances in a chromatogram • determine the melting point or boiling point of a substance • examine the purity of a substance by measuring its melting or boiling point • justify the choice of an appropriate method used for the separation of substances in a mixture

Students should learn	Students should be able to
c. Quantitative methods of analysis • volumetric analysis	• gather data with appropriate instruments and apparatus in quantitative analysis • record observations and data accurately and systematically • be aware of and take necessary steps to minimise possible sources of error • perform calculations on data obtained to draw evidence-based conclusions • present observations, data, results, conclusions and sources of error either orally or in written form • justify the choice of an appropriate quantitative method for the determination of the quantity of a substance • assess possible risks associated with quantitative analysis
d. Instrumental analytical methods • basic principles and applications of colorimetry • identification of functional groups of carbon compounds using IR spectroscopy • basic principles and applications of mass spectrometry, including simple fragmentation pattern	• understand the basic principles deployed in the instrumental analytical methods, viz. colorimetry, IR spectroscopy and mass spectrometry • construct a calibration curve by measuring absorbance of standard solutions • determine the concentration of a solution using a calibration curve • identify the following groups from an IR spectrum and a given correlation table: C–H, O–H, N–H, C=C, C≡C, C=O and C≡N • identify the following groups from a mass spectrum: R^+, RCO^+ and $C_6H_5CH_2^+$ • analyse data from primary sources and draw evidence-based conclusions • analyse data from secondary sources, including textual and graphical information, and draw evidence-based conclusions • communicate information, and justify and defend evidence-based conclusions in both written and oral forms

Students should learn	Students should be able to
e. Contribution of analytical chemistry to our society	
• analysis of food and drugs • environmental protection • chemistry aspects of forensic science • clinical diagnoses	• recognise the use of modern instrumentation for analysis in daily life • discuss the role of analytical chemistry in modern ways of living such as gauging levels of atmospheric pollutants like CO and dioxin, and indoor air pollutants like formaldehyde • describe the role of forensic chemistry in providing legal evidence • discuss the role of analytical chemistry in the diagnosis, treatment and prevention of diseases

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- devising a scheme to separate a mixture of known substances.
- performing experiments to detect the presence of certain chemical species in a sample.
- designing and performing an investigation to deduce the chemical nature of a sample.
- performing an experiment for the titrimetric analysis of chloride using silver nitrate with chromate indicator (Mohr's method).
- performing an experiment for the titrimetric analysis of the amount of hypochlorite in a sample of bleach.
- investigating the iron content in some commercial 'iron tablets'.
- analysing the quality of water by determining its permanganate index.
- performing experiments to detect the presence of functional groups by simple chemical tests.
- performing an experiment to analyse a mixture by paper chromatography, column chromatography or thin layer chromatography.
- planning and performing an experiment to determine the concentration of an unknown solution using a colorimeter.
- analysing data provided in graphical forms like spectra, drawing evidence-based conclusions, and presenting them orally or in written form.
- reviewing laboratory reports and presenting critical comments orally or in written form.
- discussing the importance of integrity in recording and reporting data.
- designing and making a portable alcohol breathalyser and testing its accuracy.
- searching for and presenting information on the principle and application of instrumental analysis such as gas chromatography for blood alcohol content.

- identifying fingerprints by iodine sublimation.
- searching for and presenting information related to the use of chemical methods in forensic science.
- viewing video on the use of modern chemical techniques in chemical analysis.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:
- to be committed to the impartial and objective gathering, analysing and reporting of information.
- to respect the views of others and evidence-based conclusions.
- to appreciate the importance of knowledge and understanding in analytical chemistry and of the practices used to our society.
- to show a continuing interest in and curiosity about the advancement of science.
- to appreciate the importance of following standard methods and chemical analysis, and of validating measurements.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:
- Separation and purification techniques are used both in the laboratory and in daily life. The supply of clean water to people in metropolitan districts involves a number of techniques such as filtration, precipitation and distillation. For travellers to rural districts, 'safe' drinking water can be made from water obtained from natural sources by adding iodine tincture followed by ascorbic acid.
- Consumers often read reports of food containing carcinogens, heavy metals, pesticides, herbicides, or insecticides. Analytical chemists, with the aid of suitable tools and instruments, can provide information to assist in the understanding of the incidents.
- Chemicals of different natures can cause different threats or hazards to our environment. Analytical chemistry can provide qualitative and quantitative evidence in such cases.
- Forensic science is important in terms of its role in some legal proceedings. More specifically, chemistry plays a significant role in the process of gathering evidence and providing logical and valid conclusions.

2.3.3 Investigative Study

Topic XVI Investigative Study in Chemistry (20 hours)

Overview

This topic aims to provide students with opportunities to design and conduct an investigation with a view to solving an authentic problem. A portion of curriculum time is set aside for this purpose. Students are expected to make use of their knowledge and understanding of chemistry, together with generic skills – including, but not limited to, creativity, critical thinking, communication and problem-solving – to engage in a group-based experimental investigative study. Through the learning process in this study, students can enhance their practical skills and develop an awareness of the need to work safely in the laboratory.

Learning Outcomes

Students should be able to

- justify the appropriateness of an investigation plan;
- carry out a risk assessment for a scientific investigation;
- put forward suggestions for ways of improving the validity and reliability of a scientific investigation;
- use accurate terminology and appropriate reporting styles to communicate the findings and conclusions of a scientific investigation;
- evaluate the validity of conclusions with reference to the process of investigation and the data and information gathered;
- demonstrate mastery of manipulative skills and observation skills as well as good general bench performance;
- show appropriate awareness of the importance of working safely in the laboratory and elsewhere.

Implementation

In general, the investigative study involves the following processes: identifying relevant information; defining questions for study; planning an investigation; choosing equipment and resources; performing an investigation; organising and analysing information; and drawing conclusions based on available evidence.

The following is a rough estimate of the time required for the different parts of the study.

- Searching for and defining questions for investigation – 3 hours
- Developing an investigation plan – 4 hours
- Conducting the investigation – 6 hours
- Organising and analysing data for a justified conclusion – 4 hours
- Presenting findings in written reports, posters and by other means – 3 hours

Students should have some experience and be provided with guidelines on the following aspects before conducting an investigative study:

- How to work together in a group to develop an investigation plan and solve a problem
- How to select an appropriate question for the study, e.g. brainstorming techniques
- How to search for relevant information from various sources
- How to write an investigation plan
- How to write a laboratory report or make a poster for presentation

The investigative study aims to provide students with learning experiences which promote a sense of ownership of their learning and problem-solving in a group. Students should not be overloaded with an excessive number of tasks. The investigation can be conducted in groups of three to five students.

The investigation can be undertaken on completion of a relevant topic of the curriculum. For instance, an investigative study on the topic “Chemical cell” can be carried out towards the end of S5 and completed at the beginning of S6. In other words, students can develop their investigation plan from March to May of S5, the investigation can be conducted at the end of S5, and the presentation can be done at the beginning of S6. Alternatively, it is possible to conduct an investigation in conjunction with the learning of a topic. It is therefore possible to conduct and complete the investigation mentioned above in S5.

The study should focus on authentic problems, events or issues which involve key elements such as "finding out" and "gathering first-hand information". Also, to maximise the benefit of learning from the investigation within the time allocated, teachers and students should work together closely to discuss and decide on an appropriate and feasible topic. The scope and depth of the study should be given adequate consideration.

Listed below are some possible topics for investigation.

- Variation in the amount of active ingredient in a bleach solution upon storage.
- Analysis of the vitamin C content in citrus fruits or vegetables.
- Extraction of naturally occurring chemicals and testing their uses, e.g. natural pest repellent from citrus fruit peelings.
- Synthesis of a photodegradable soapy detergent and investigating its characteristics.
- Construction and testing of a chemical cell.
- Construction and testing of a home-made alcohol breathalyser.

Assessment

To facilitate learning, teachers and students can discuss and agree on the following assessment criteria with due consideration given to factors that may facilitate or hinder the implementation of the study in a particular school environment.

- Feasibility of the investigation plan (i.e. is the topic being studied researchable?)
- Understanding of relevant chemistry concepts and concerns about safety
- Manipulative skills and general bench performance
- Proper data collection procedures and ways of handling possible sources of error
- Ability to analyse and interpret data obtained from first-hand investigation
- Ability to evaluate the validity and reliability of the investigation process and the findings
- Ability to communicate and defend the findings in front of the teacher and peers
- Appropriateness of references to back up the methods and findings
- Attitudes towards the investigation

A number of assessment methods, such as observation, questioning, oral presentations, poster presentation sessions and the scrutiny of written products (investigation plans, reports, posters, etc.) can be used where appropriate.

Chapter 3 Curriculum Planning

This chapter provides guidelines to help schools and teachers to develop a flexible and balanced curriculum that suits the needs, interests and abilities of their students, and the contexts of their school, in accordance with the central framework provided in Chapter 2.

3.1 Guiding Principles

As a senior secondary science subject in Science Education KLA, Chemistry builds on the junior secondary Science Curriculum. This chapter describes the links between the two levels of study in terms of knowledge, concepts, process skills and generic skills. Teachers can consider the details described below as a reference for planning their Chemistry curricula for their students. Furthermore, this chapter discusses "progression of studies" in an attempt to help students with different aptitudes and abilities to explore their interests in different senior secondary subjects.

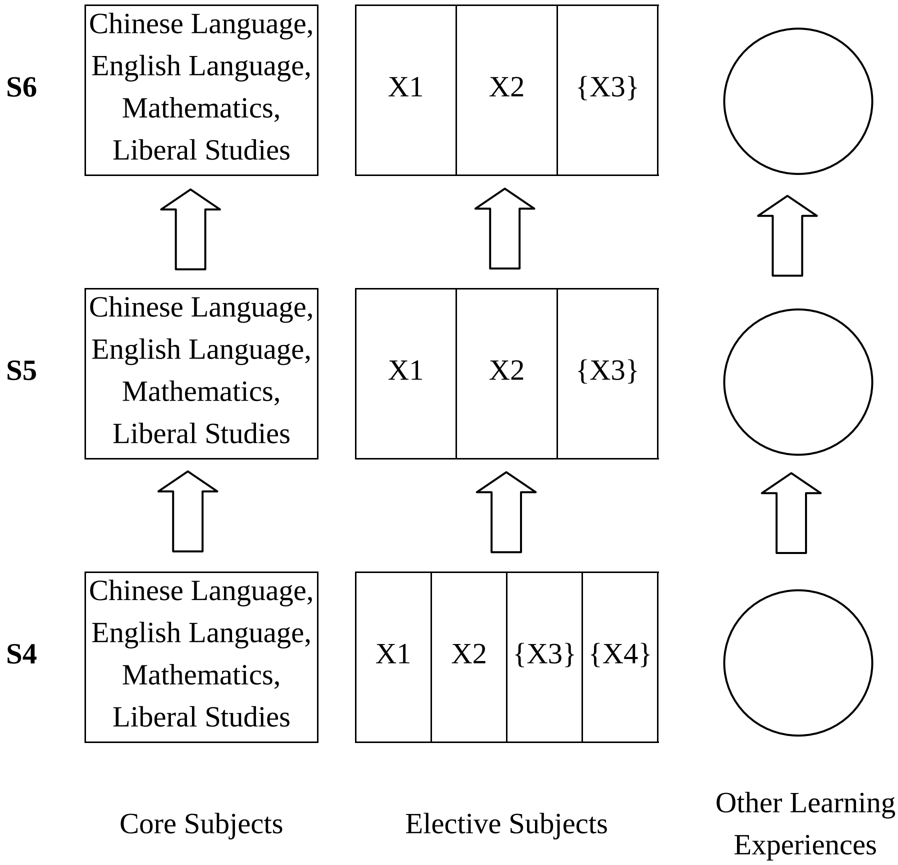
This Guide sets out what is expected in terms of knowledge, skills, values and attitudes for the majority of students in different schools in the territory. The expectations may not be appropriate for all students. Teachers must exercise their professional judgement in the planning and delivery of a broad and balanced curriculum suitable for all their students. In addition, teachers are encouraged to organise the curriculum in different ways to ensure "fitness for purpose". This chapter attempts to suggest some curriculum planning strategies and ideas for teachers to consider.

In planning school-based Chemistry curriculum, schools and teachers are encouraged to:

- design the school-based Chemistry curriculum with reference to the curriculum aims, learning targets and students' abilities so as to bring about pleasurable, meaningful and productive learning experiences;
- facilitate continuity with the junior secondary Science Curriculum through a comprehensive coverage of the learning targets to promote integrative use of skills and a balanced development of learning experiences;
- plan and devise appropriate and purposeful learning and teaching activities to develop students' knowledge and understanding, skills and processes, values and attitudes, problem-solving skills, critical thinking skills, creativity, and strategies for learning to learn;
- make flexible use of lesson time to facilitate learning;
- review and plan the curriculum flexibly and make appropriate re-adjustments when necessary, taking into account the SBA implementation arrangements for the subject as specified in Chapter 5 – Assessment.

3.2 Progression of Studies

To help students with different aptitudes and abilities to explore their interests in different senior secondary subjects, the report *New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong* (EMB, 2005a) recommends the idea "progression of studies". The following figure illustrates the idea.



X represents an elective subject and { } indicates optional

Figure 3.1 Progression of Studies at Senior Secondary Levels

In short, schools can offer their students a total of 4 elective subjects at S4 level, 3 at S5 level and 3 at S6 level respectively.

A number of topics have been identified from this curriculum for students intending to explore their interests in science subjects at S4 level. The topics identified should help to lay the foundations for learning chemistry. A possible arrangement of the topics is described in the scheme below. Schools can determine for themselves whether or not this scheme will enable effective progression in senior secondary Chemistry.

The following topics may be included in S4 in the school-based curriculum plan.

Topic		Remarks
I.	Planet earth	All subtopics are included.
II.	Microscopic world I	
III.	Metals	
IV.	Acids and bases a. Introduction to acids and alkalis b. Indicators and pH c. Strength of acids and alkalis d. Salts and neutralisation	Subtopics (e) and (f) can be studied at a later stage as an introduction to volumetric analysis or as a preparation for topic XV "Analytical chemistry".
V.	Fossil fuels and carbon compounds a. Hydrocarbon from fossil fuels b. Homologous series and structural formulae c. Alkanes and alkenes	A detailed study of naming of organic compounds, and subtopic (d) can be studied later together with topic XI "Chemistry of carbon compounds"

Subtopics (e) and (f) of topic IV "Acids and bases" can be introduced at an early stage in S5. After that, all topics can be organised in the sequence suggested in Chapter 2. However, it is necessary to include a detailed study of naming of organic compounds, and subtopic (d) of topic V "Fossil fuels and carbon compounds" into topic XI "Chemistry of carbon compounds".

Considering the rapid advancements in the world of science and technology, many contemporary issues and scientific problems are best tackled by studying the three science disciplines – chemistry, biology and physics.

To cater for students who show an interest in learning science and intend to take two or three subjects in science education, schools might offer a balanced science curriculum for students in S4 covering selected parts from chemistry, biology and physics. Students would then understand the different nature of the three science disciplines and be more able to choose their specialised study in higher forms.

Figure 3.2 is an example on how schools can organise the progression of studies for students who wish to devote time to the study of science.

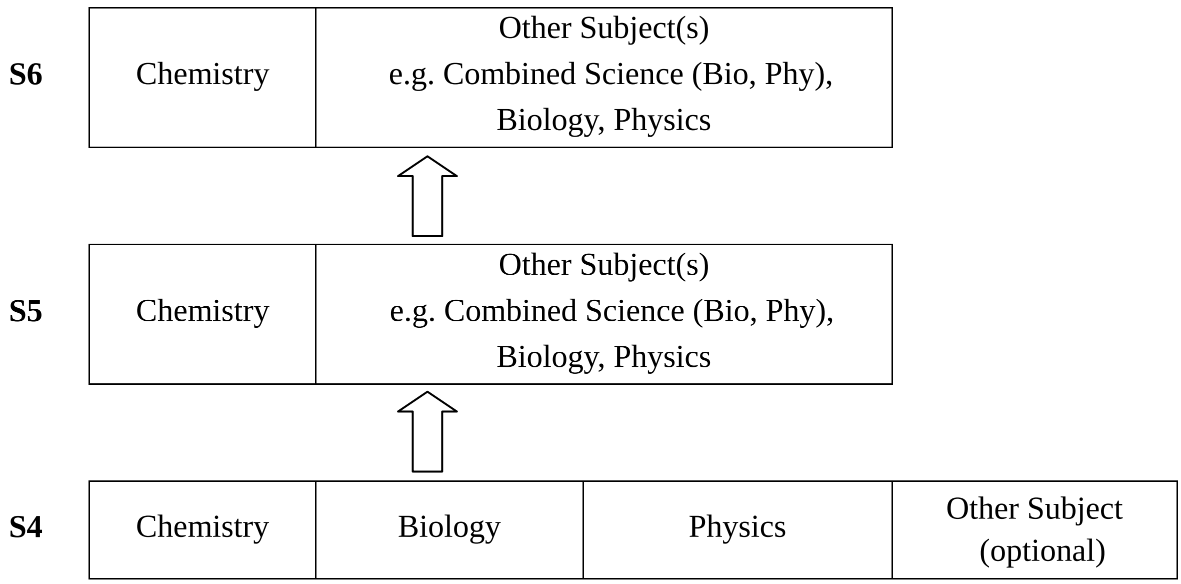


Figure 3.2 Progression to Senior Secondary Science Subjects

Under the Senior Secondary Academic Structure, there will be flexibility to allow students to take up the study of Chemistry in S5. For these students, a similar sequence of learning applies. Schools may consider allocating more learning time and providing other supporting measures (e.g. bridging programmes) for these students so that they can develop the foundation knowledge and skills as soon as possible.

3.3 Curriculum Planning Strategies

3.3.1 Interface with the Junior Secondary Science Curriculum

This curriculum starts with the topic "Planet Earth" which helps students appreciate that the world is made up of chemicals, develop some basic knowledge of chemistry, acquire some fundamental practical skills and develop positive attitudes towards chemistry. Furthermore, through the study of the topic, students can consolidate their knowledge, understanding and skills of scientific investigation acquired in their junior secondary science courses. Unit 1 "Introducing Science" and the experience of undertaking scientific investigations in Science (S1-3) are relevant.

Knowledge and understanding of chemistry developed through the three-year junior secondary science courses are "stepping stones" towards senior secondary Chemistry. Figure 3.3 shows how relevant chemistry topics in the CDC Syllabus for Science (S1-3) are related to different topics in this curriculum.

Science (S1-3)		Chemistry	
Unit		**Topic**	
4.3	Fuels	V.	Fossil fuels and carbon compounds
5.1	Water purification	I.	Planet earth
5.2	Further treatment of water		
5.5	Dissolving		
5.6	Growing crystals		
6.1	State of matter	II. VI.	Microscopic world I Microscopic world II
6.3	Particle model for the three states of matter		
7.2	Burning	V.	Fossil fuels and carbon compounds
7.6	Balance of carbon dioxide and oxygen in nature	I.	Planet earth
10.1	Common acids and alkalis	IV. III.	Acids and bases Metals
10.2	Indicators for testing acids and alkalis		
10.3	Acid and corrosion		
10.5	Neutralisation		
10.6	Every day uses of acids, alkalis and neutralisation		
13.2	How to obtain metals	III.	Metals
13.3	Properties and uses of metals		
13.4	Making metals more useful		
14.1	Making plastics from crude oil	V. XI. XIV.	Fossil fuels and carbon compounds Chemistry of carbon compounds Materials chemistry
14.2	Environmental problems associated with the disposal of plastics		

Figure 3.3 Relationship between Syllabus for Science (S1-3) and the Chemistry Curriculum

3.3.2 Suggested Learning and Teaching Sequences

The topics in compulsory and elective parts of the curriculum are listed in a possible sequence suitable for the majority of students (figure 3.4, sequence I). This sequence is organised in such a way that learning starts with topics with more concrete content, and then progresses onto topics that are more abstract. For instance, students are expected to start the curriculum with the topic “Planet Earth” which is designed to be a bridge between students’ junior secondary science courses and the Chemistry Curriculum. Then, students are expected to start learning the chemistry of matters like metals, acids and bases, and fossil fuels with which they are familiar in daily life. After that, students have to face the challenge of learning more abstract concepts in topics like “Redox reactions, chemical cells and electrolysis”, “Chemical equilibrium”, etc.

The learning sequence mentioned above is not intended to be the only one suitable for all schools. Alternative sequences with due regard to the interests, needs, prior knowledge and readiness of students can be adopted where appropriate. Some alternative learning and teaching sequences (sequences II and III) for the compulsory part are suggested in figure 3.4.

Year	Sequence I	Sequence II	Sequence III
S4	Planet earth	Planet earth	Planet earth
	⇩	⇩	⇩
	Microscopic world I	Microscopic world I	Microscopic world I
	⇩	⇩	⇩
	Metals	Metals	Microscopic world II
	⇩	⇩	⇩
	Acids and bases	Acids and bases	Metals
	⇩	⇩	⇩
	Fossil fuels and carbon compounds	Chemical reactions and energy	Acids and bases
	⇩	⇩	⇩
S5	Microscopic world II	Rate of reaction	Redox reactions, chemical cells and electrolysis
	⇩	⇩	⇩
	Redox reactions, chemical cells and electrolysis	Redox reactions, chemical cells and electrolysis	Fossil fuels and carbon compounds
	⇩	⇩	⇩
	Chemical reactions and energy	Microscopic world II	Chemistry of carbon compounds
	⇩	⇩	⇩
	Rate of reaction	Fossil fuels and carbon compounds	Chemical reactions and energy
	⇩	⇩	⇩
	Chemical equilibrium	Chemistry of carbon compounds	Rate of reaction
	⇩	⇩	⇩
	Chemistry of carbon compounds	Chemical equilibrium	Chemical equilibrium
	⇩	⇩	⇩
	Patterns in the chemical world	Patterns in the chemical world	Patterns in the chemical world

Figure 3.4 Suggested Learning and Teaching Sequences for the Chemistry Curriculum

Besides the suggestions mentioned above, teachers can also consider the following ideas.

(1) Curriculum organisation of knowledge and skills of "stoichiometry and mole"

Stoichiometry deals with the quantitative aspects of chemistry and is an emphasis within senior secondary Chemistry. Concepts related to stoichiometry and calculations related to mole, formula mass, empirical formula, molecular formula, molar mass, molarity and molar volume are introduced at different parts of this curriculum, and are organised in a progressive hierarchy. These practices help students to master concepts and acquire the skills to perform calculations without being loaded with a great deal of abstract and unfamiliar information. Teachers should provide opportunities that enable students to link these concepts and master the skills in a systematic way.

Figure 3.5 illustrates how the concepts related to stoichiometry and calculations related to mole are organised in this curriculum.

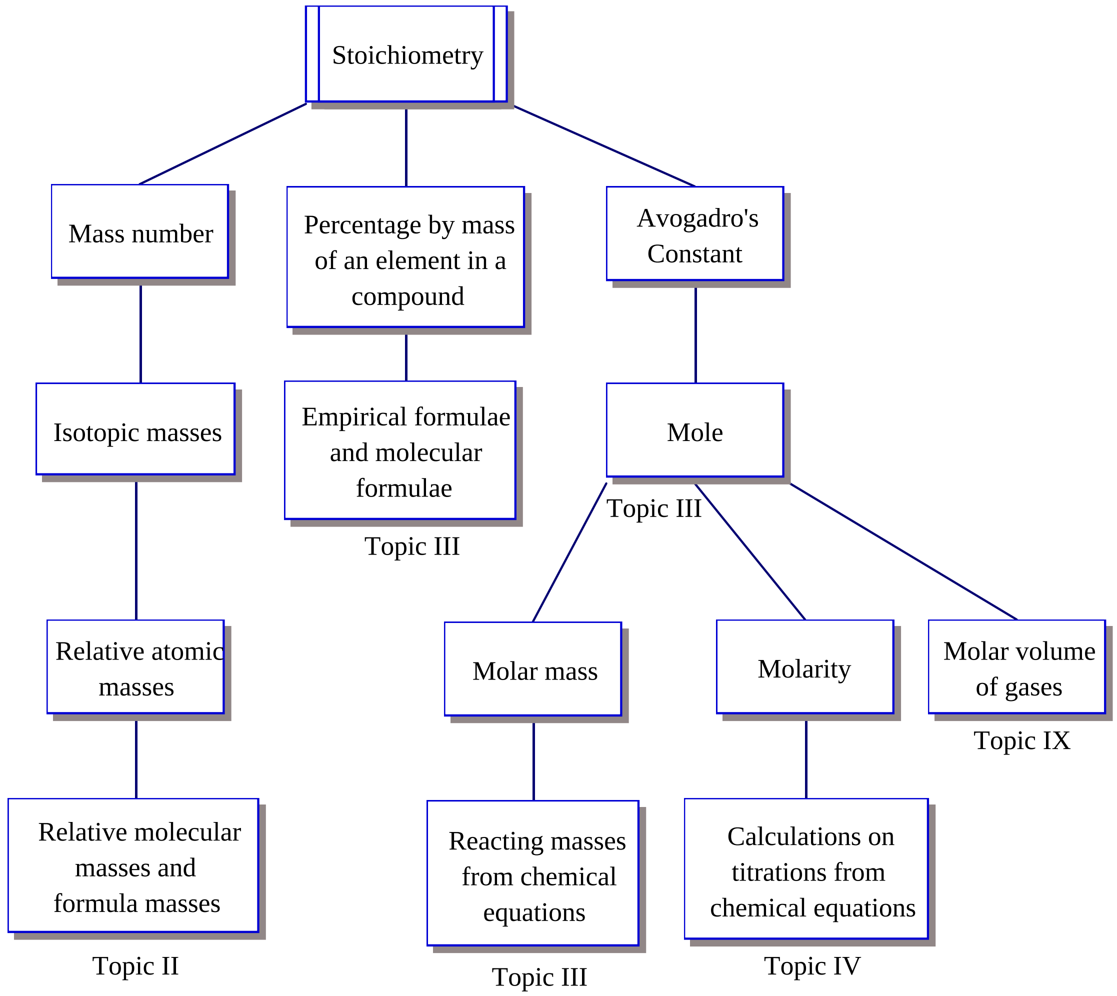


Figure 3.5 Organisation of Stoichiometry and Calculations Related to Mole

Alternatively, it is known that some teachers prefer to complete the study of calculations related to mole in a relatively short period of time, say before the end of S4. Such teachers can organise the subtopic "molar volume of gases" after topic IV in their teaching. This arrangement can be beneficial to some students as they can then concentrate their efforts on mastering concepts related to mole. However, it is unlikely that this arrangement would suit all students.

(2) Integration of Microscopic World I and II

The curriculum puts forward the idea of organising the learning and teaching of concepts related to the microscopic world into two separate topics (i.e. Microscopic world I and II) at different years of study. The purpose of this organisation is to avoid loading students with a large number of abstract concepts in a short period of time, particularly at the early stages of senior secondary learning. The organisation suggested provides an opportunity for students to revisit their learning in the previous year of study. However, some teachers may prefer to introduce the concepts related to structures and properties in one go, and believe that their students can benefit from this organisation. Such teachers can organise their own curriculum so that the topics "Microscopic world I and II" can be studied together. This kind of integration can be extended to topics like: "Fossil fuels and carbon compounds" and "Chemistry of carbon compounds"; and "Metals" and "Redox reactions, chemical cells and electrolysis".

(3) Integration of the investigative study with elective topics

If students have a strong interest in chemical analysis and intend to carry out investigative study with more emphasis on analytical chemistry, teachers can organise the learning of the elective topic "Analytical chemistry" in parallel with the Investigative Study. This organisation helps students to apply the concepts of analytical chemistry to solve problems, and at the same time to develop various skills expected (please refer to "Investigative study in chemistry" in Chapter 2 for details). Furthermore, teachers can also adopt a problem-based approach by posing challenging problems to students. By solving the problems through gathering information, reading critically, learning new knowledge on their own, discussion, experimentation, etc., students can master the knowledge and understanding required in the topic "Analytical chemistry", and acquire relevant skills expected in the "Investigative study in chemistry". This kind of integration can be extended to other elective topics including "Industrial chemistry" and "Materials chemistry".

(4) Organisation within a topic

Further to the suggested integration of major topics listed above, teachers can also arrange different sequences for learning and teaching within a topic for their students. For instance, in "Microscopic world I", the teacher can start with the more concrete ideas related to properties of substances and then move on to the more abstract concepts of chemical bonding. Two possible sequences are outlined in figure 3.6.

Sequence A	Sequence B
a. Atomic structure	a. Atomic structure
⇩	⇩
b. The Periodic Table	b. The Periodic Table
⇩	⇩
d. Structures and properties of metals	e. Ionic and covalent bonding
⇩	⇩
c. Metallic bonding	c. Metallic bonding
⇩	⇩
f. Structures and properties of giant ionic substances	f. Structures and properties of giant ionic substances
⇩	⇩
e. Ionic bonding	d. Structures and properties of metals
⇩	⇩
g. Structures and properties of simple molecular substances	g. Structures and properties of simple molecular substances
⇩	⇩
e. Covalent bonding	h. Structures and properties of giant covalent substances
⇩	⇩
h. Structures and properties of giant covalent substances	i. Comparison of structures and properties of important types of substances
⇩	
i. Comparison of the structures and properties of important types of substances	

Figure 3.6 Possible Learning and Teaching Sequence for Topic II

It is possible to attain the learning targets associated with the subtopic "Industrial Processes" in Topic XIII, for example, in two different ways. The first approach is to provide all the foundation knowledge and concepts required prior to an in-depth treatment of the prescribed industrial processes. The second approach, the application-first approach, is to study the industrial processes as the central theme, while knowledge, understanding and ideas emerge and are learnt along the way. The two possible approaches are depicted below.

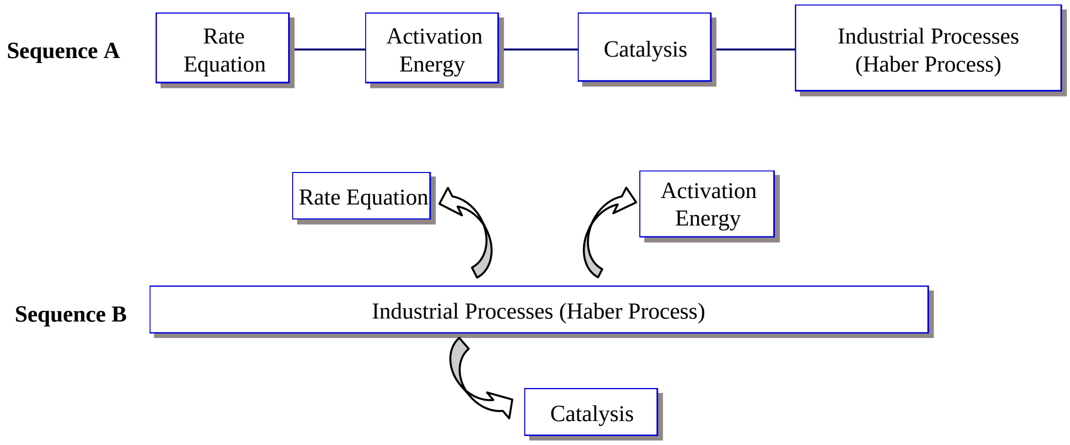


Figure 3.7 Possible Learning and Teaching Approach for Topic XIII

3.3.3 Curriculum Adaptations for Learner Diversity

Teachers must design and deliver a curriculum in line with the different interests and abilities of their students. Teachers may need to design and implement a curriculum for students who can only master part of the concepts and skills described in this Guide, while teachers of more able students may have to devise more complex learning and activities that challenge them at greater depth. This curriculum has been designed flexibly with this in mind, and is intended to serve as a reference rather than a prescription.

This curriculum can be adapted in a number of ways such as focusing learning only on the topics in the compulsory part and putting less emphasis on topics in the elective part. Teachers can reflect on the following suggestions when planning how to design a school-based curriculum for students with different needs.

(1) If students have difficulty in mastering the whole curriculum, teachers and students can work out the appropriate level of study for the topics in the compulsory part. Listed below are some topics of the compulsory part with subtopics which are considered to be cognitively more demanding, i.e. students may need extra support to master the knowledge and understanding in these topics:

- Microscopic world II
- Chemical reactions and energy
- Chemical equilibrium
- Chemistry of carbon compounds
- Patterns in the chemical world

(2) Where students have difficulty in coping with the whole curriculum, teachers and students can discuss and agree on alternative arrangements like putting only a minimum of effort into study of the topics of the elective part, or skipping the study of the elective part altogether.

In brief, teachers are encouraged to design their curriculum to cater for diversity among their students and to evaluate it against the design principles described in Chapter 2.

3.3.4 Flexible Use of Learning Time

As mentioned in Chapter 2, a total of 250 hours or 10% of total senior secondary lesson time should be allocated to cover this curriculum. Teachers are encouraged to use this time flexibly to help students attain all the learning targets of the curriculum. More or less time may be allocated to particular topics in line with student interests and abilities. Schools may allocate more learning time for the study of the compulsory part to ensure students are equipped with sound fundamental knowledge and skills before starting the elective part. Concerning the 20 hours allocated to the Investigative Study, teachers can allocate the time available flexibly to promote students' learning and to develop the full range of abilities. Lastly, schools are also encouraged to include half-day or whole-day activity sessions in the time-table, to allow continuous stretches of time for visits, scientific investigations outside the school, or other life-wide learning activities that can enhance the effectiveness of learning in chemistry.

3.4 Curriculum Management

3.4.1 Effective Curriculum Management

In order to develop and manage the curriculum effectively, curriculum leaders in a school have to work collaboratively and to take the following aspects into consideration.

(1) Understanding the curriculum and student needs

The Chemistry Curriculum Framework describes the rationale, curriculum aims, learning targets, curriculum structure and organisation, curriculum planning, learning and teaching as well as assessment. A good understanding of the Chemistry Curriculum, the needs and interests of students, and the strength and culture of the school would facilitate effective school-based curriculum development and the alignment of learning and teaching with the school vision and mission as well as the central framework.

(2) Teamwork

Different curriculum leaders including heads of Science Education KLA, Chemistry panel chairpersons and chemistry teachers have to work collaboratively as a team and play different roles in managing school-based curriculum development. In addition to overseeing and co-ordinating the implementation of the curriculum, heads of Science Education KLA and panel chairpersons have to develop plans for enhancing teamwork and the professional capacity of teachers.

(3) Curriculum planning

Schools have to develop a holistic plan for school-based curriculum development in Science Education to ensure vertical and lateral coherence among different science subjects and with other subjects. It is important to plan for the interface with the junior secondary Science Curriculum and provide a balanced foundation in science education for students. For details of curriculum planning strategies, please refer to section 3.3 of this chapter.

(4) Capacity building and professional development

Team building is enhanced through regular exchange of ideas, experiences and reflections, and by collaborative lesson preparation, peer coaching and lesson observation. These practices promote a collaborative and sharing culture among teachers and facilitate their professional development. Schools should create space for teachers to participate in various professional development programmes and deploy teachers according to their strengths.

(5) Development of resources

The Education Bureau will continue to develop resources that facilitate learning and teaching with a view to supporting the implementation of the curriculum. Schools are encouraged to adapt these resources or to develop their own learning and teaching materials to meet the needs of their students. Materials can be shared among teachers through the development of a school-based learning and teaching resources bank or a sharing platform in the school's intranet. For effective use of learning and teaching resources, please refer to Chapter 6 for details.

(6) Managing change

In view of the dynamic nature of chemistry knowledge and ongoing social change, the school-based curriculum must remain flexible to accommodate such change. The scope and direction of curriculum development may be clear, but implementation needs to be flexible enough to accommodate change and learning derived from experience. Strategies for managing change include promoting participation and communication, and undertaking periodic reviews to monitor progress and collect evidence for making informed changes in implementing the curriculum.

3.4.2 Roles of Different Stakeholders in Schools

In schools, curriculum leaders take up different roles in managing curriculum change. The roles they assume may vary depending on the school context.

(1) Chemistry teachers

Chemistry teachers contribute to the development of the school-based Chemistry curriculum by working in line with school policy and contributing to the work of the Chemistry panel. Furthermore, chemistry teachers can work in collaboration with laboratory supporting staff to design interesting activities and a safe environment conducive to learning. They can also take the role of curriculum leader by initiating innovative curricular changes.

When implementing the school-based Chemistry curriculum, teachers could:

- explain clearly to students the overall plan and purpose of the school-based Chemistry curriculum;
- provide adequate guidance and support to students to achieve learning targets set out in the school-based Chemistry curriculum;
- foster a motivating learning environment among students, and promote self-directed and self-regulated learning;
- take initiatives in trying out innovative learning and teaching strategies;
- initiate the sharing of ideas, knowledge and experience to foster peer support and improvement in teaching and learning;
- keep abreast of the latest curriculum developments and changes through reading and sharing with fellow teachers;

- participate actively in professional development courses, workshops, seminars, etc. to enhance professionalism;
- ensure students take adequate safety measures for the proper conduct of practical and investigative activities;
- review or evaluate the school-based Chemistry curriculum from time to time with a view to improving it.

(2) Co-ordinators of the Science Education KLA / Chemistry panel chairpersons

Co-ordinators of the Science Education KLA and Chemistry panel chairpersons play a significant role in developing and managing the school-based science curriculum as well as facilitating its implementation. They act as the bridge between the school administrative personnel and other science panel members.

Co-ordinators of the Science Education KLA serve as the links among different science panels. To facilitate coordination and collaboration among different panels and to monitor the implementation of the curriculum, the co-ordinators of the Science Education KLA should:

- develop a holistic plan for a balanced science education by making use of the guidelines set out in the Science Education KLA Curriculum Guide and related Curriculum and Assessment Guides;
- work closely with different science panels to ensure coherence in planning and collaboration among teachers in the junior and senior secondary levels;
- hold regular meetings with different science panels to discuss matters such as curriculum and assessment policies, and to further explore implementation strategies to enhance the quality of learning and teaching;
- promote regular exchange of ideas, experiences and reflections by various means such as peer coaching, lesson observation, collaborative lesson preparation, etc.;
- facilitate professional development by encouraging panel members to participate in professional development courses, workshops, seminars and projects;
- develop and nourish students' thirst for learning science by organising interclass science project competitions, or encouraging them to participate in interschool science activities;
- ensure safety by taking precautionary measures for practical works and scientific investigations.

Chemistry panel chairpersons help to develop and manage the school-based Chemistry curriculum, and monitor its implementation. They should:

- keep abreast of the developments and innovations of the Chemistry Curriculum;
- set clear learning targets for the school-based Chemistry curriculum;
- plan and provide an appropriate school-based Chemistry programme by making reference to this Guide;

- decide what topics in the Elective Part to offer, taking into account students' needs, interests and abilities as well as teachers' strength and the school context;
- hold regular meetings with teachers to discuss matters such as curriculum planning, assessment policies, use of learning and teaching materials and strategies, learning progress, etc. and to further explore curriculum implementation strategies to enhance the quality of learning and teaching;
- promote regular exchange of learning and teaching ideas, experiences and reflections by various means such as peer coaching, lesson observation and collaborative lesson preparation;
- take the lead to try out and work on innovative learning and teaching strategies;
- facilitate professional development by encouraging panel members to participate in professional development courses, workshops, seminars and projects;
- ensure the availability and effective use of sufficient resources to support the implementation of the Chemistry Curriculum in school, e.g. laboratory facilities, laboratory supporting staff, IT equipment, etc.;
- ensure that panel members take adequate safety measures for the proper conduction of practical and investigative activities;
- monitor, review or evaluate the implementation of the school-based Chemistry Curriculum from time to time;
- provide comments and suggestions on the curriculum framework to relevant bodies.

(3) School Heads

School heads take the leading role in directing, planning and supporting school-based curriculum development. They need to understand the central curriculum framework and be well aware of contextual factors such as the needs of the students, the strengths of the Chemistry Panel and other panels in the Science Education KLA as well as the organisational culture of the school. School heads are encouraged to work closely with their Deputy Heads or Academic Masters / Mistresses to:

- understand the big picture and define the scope of curriculum development for the Science Education KLA so that it aligns with the vision and mission of the school and accords with the direction taken in the whole school curriculum development;
- clarify the roles and responsibilities of the co-ordinators and panel chairpersons of the Science Education KLA;
- adopt flexible time-tabling to facilitate the implementation of Combined Science to complement the learning of Chemistry in order to provide a balanced foundation in science for students;
- deploy school resources appropriately (e.g. laboratory supporting staff and equipment) to facilitate effective learning and teaching;
- promote a collaborative and sharing culture among teachers by encouraging collaborative lesson preparation and peer lesson observation;

- create space for teachers to participate in professional development programmes;
- appreciate and commend progress made, treasure quality rather than quantity, and sustain appropriate curriculum initiatives;
- help parents and students to understand the school’s beliefs, rationale and practices in the implementation of the curriculum, and their roles in facilitating learning;
- network with other schools on a face-to-face and electronic basis to facilitate the professional exchange of information and sharing of good practices.

For details about the roles of teachers, KLA co-ordinators, panel chairpersons and school heads as the key change agents, please refer to Booklet 9 of the *Senior Secondary Curriculum Guide* (CDC, 2009).

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Chapter 4 Learning and Teaching

This chapter provides guidelines for effective learning and teaching of the Chemistry Curriculum. It is to be read in conjunction with Booklet 3 in the *Senior Secondary Curriculum Guide* (CDC, 2009), which provides the basis for the suggestions set out below.

4.1 Knowledge and Learning

As discussed in Chapter 1 of this Guide, students have to adapt to a highly competitive and integrated economy, scientific and technological innovations, and a rapidly growing knowledge base. Chemistry is a discipline with established knowledge. For instance, experts can be almost certain as to how metals react with acids at the macroscopic level. However, there is also much knowledge in chemistry that is contextualised, and this changes dynamically. For example, knowledge about the nature of an atom, and how atoms interact in different cases, has varying degrees of uncertainty, and it is expected that a more accurate "truth" may be discovered in the future.

Learning takes place in different ways. Some knowledge can be acquired by listening, reading and modelling. For example, topics such as how to make use of symbolic representations in chemistry or how to carry out an experimental procedure are normally learned through direct instruction. However, some knowledge and skills can be constructed through personal reflection or engaging in investigative learning. For instance, an investigative study in chemistry can be used to help students develop the knowledge needed for conducting a scientific study. Also, some knowledge can be co-constructed through working with others. For example, a problem such as how to dispose of plastic waste can be approached by organising students in groups to gather the required information, synthesise knowledge and concepts, and debate the ideas and practices.

Students and teachers play different roles in learning and teaching activities based on different pedagogical approaches. For instance, a direct instruction approach requires students to be active listeners, with the teacher as an information provider. In contrast, in an inquiry-based experiment students have to work in groups and take a more active role as independent problem-solvers, as well as information seekers; and the teacher plays a variety of roles – as a resource person, facilitator and consultant.

4.2 Guiding Principles

Some key guidelines for the learning and teaching of the Chemistry Curriculum are listed below, which take into account the recommendations in Booklet 3 of the *Senior Secondary Curriculum Guide* (CDC, 2009).

(1) Building on strengths

The strengths of both teachers and students in Hong Kong should be acknowledged and treasured. In learning science, most Hong Kong students are strong in memorising content knowledge, analysing numerical data and understanding scientific concepts.

(2) Understanding learning targets

Each learning activity should be designed with learning targets which are clear to both the teacher and the students.

(3) Teaching for understanding

The activities used should enable students to act and think flexibly with what they know.

(4) Prior knowledge and experience

The learning activities should be planned with students' prior knowledge and experience in mind.

(5) A wide range of learning and teaching activities

A variety of learning and teaching activities which involve different pedagogies should be deployed so that different learning targets can be attained effectively.

(6) Quality interaction

Teachers are encouraged to use activities which promote quality interaction – such as scaffolding students' learning, using challenging open-ended questions, providing suggestions on how to improve, and organising group activities to facilitate peer learning.

(7) Promoting independent learning

Learning and teaching activities within the curriculum that aim at nurturing generic skills and thinking skills can enhance students' capacity for independent learning. Students should be provided with opportunities to take responsibility for their own learning.

(8) Roles of teachers and students

The roles of teachers and students in learning and teaching activities should be clearly delineated.

(9) Feedback and assessment

Providing immediate and useful feedback should be an integral part of teaching. In addition, strategies for "assessment for learning" and "assessment of learning" should be used where appropriate.

(10) Resources

A variety of resources can be employed as tools for learning. Suggestions on resources which can be used to enhance the quality of learning are given in Chapter 6 of this Guide.

(11) Motivation

Students learn best when they are motivated. To inspire motivation, learning activities should build on students' successful experiences and meet their needs and interests.

(12) Engagement

Activities that engage the students' minds should be used.

(13) Catering for learner diversity

Students have different characteristics. Appropriate learning and teaching strategies should be employed to cater for learner diversity.

4.3 Approaches and Strategies

4.3.1 Approaches to Learning and Teaching

Broadly speaking, there are three common and intertwined pedagogical approaches to learning and teaching Chemistry:

(1) "Teaching as direct instruction" is perhaps the best-known approach. It has a teacher-centred orientation and requires the teacher to transmit knowledge or skills to the learner. In this approach, teachers assess students' understanding through questioning, provide opportunities for practice or application, and give assignments for consolidation. A brief lecture can help students to develop their understanding of topics such as the nomenclature of compounds, writing chemical equations or describing the safety aspects of a laboratory experiment. Moreover, a vivid presentation or a good video may convey the key points in a topic effectively in a short period of time. But still, good interaction between teacher and students is generally important to the success of this method.

(2) "Teaching as inquiry" is advocated by many educators who view personal effort in the construction of knowledge as of prime importance. This is a more student-centred approach

in which learners take responsibility for their own learning. It advocates the use of learning activities such as problem-solving tasks which require various cognitive abilities, and inquiry-based experiments which involve testing hypothesis, designing working procedures, gathering data, performing calculations and drawing conclusions. The Investigative Study in Chemistry discussed in Chapter 2 is an example of how "teaching as inquiry" can be implemented in class.

(3) "Teaching as co-construction" is another important pedagogical approach which involves students and teachers constructing knowledge together. It stresses the value of students sharing their knowledge and generating new knowledge through group work, with teachers providing support as a partner in learning. Students can also work together with other experts to co-construct knowledge. For instance, students might work together on the choice of a site for establishing a chemical plant, and through this develop knowledge and understanding of the issues involved.

These three learning and teaching approaches can be represented as a continuum along which the role of the teacher varies, but is not diminished. For example, a teacher is more of a resource person than an information provider in a co-construction learning process.

Overall, it is important for teachers to adopt a wide variety of learning and teaching strategies and activities to help students attain the various learning targets. Teachers should note that more than one learning target can often be achieved by engaging students in a single learning activity. Learning and teaching activities appropriate for Chemistry are listed in figure 4.1.

Direct instruction	Interactive teaching	Individualisation	Inquiry	Co-construction
• Explanation • Demonstration • Video shows	• Teacher questioning • Whole-class or group discussion • Visits • The use of IT and multimedia packages	• Constructing concept maps • Reading to learn • Information searching • Writing learning journals / note-taking	• Problem-solving • Practical work • Scientific investigations • Simulation and modelling	• Group discussion • Role play • Debates • Project work

Figure 4.1 Learning and Teaching Activities in Chemistry

As mentioned above, the specific learning targets outlined in Chapter 2 of this Guide can be attained through a variety of approaches to suit the different learning styles of students. The three approaches above are not listed in any order of preference but should be adopted where appropriate.

4.3.2 Variety and Flexibility in Learning and Teaching Activities

This curriculum has an in-built flexibility to cater for the varied interests, abilities and needs of students. Teachers should provide ample opportunities for students to engage in a variety of learning activities to attain the learning targets, with different activities being used to match students' learning styles.

The learning and teaching activities employed should aim to promote deep learning for understanding, not surface learning of unconnected facts. Deep learning is more likely to be achieved when students are active rather than passive, when ideas are discussed and negotiated with others rather than learned by oneself, and when the content is learned as an integrated whole rather than in small separate parts. In short, activities that encourage meaningful, integrated learning should be used as far as possible.

4.3.3 From Curriculum to Pedagogy: How to Start

Teachers have to make informed decisions on the approaches and activities which are most appropriate for achieving specific learning targets. In the learning of chemistry, activities should be made relevant to daily life wherever possible, so that students experience chemistry as interesting, relevant and important to them.

For example, the following factors should be considered when judging the appropriateness of an inquiry-based experiment in learning and teaching.

- Does the activity address something worth learning?
- Is the topic socially relevant, interesting and motivating?
- Is the cognitive demand appropriate?
- Do students have the required prior knowledge and adequate skills?
- Are resources such as journal articles, reference books, chemicals and apparatus available?
- Is the time available sufficient for the activity?
- Can laboratory supporting staffs help in its implementation?

Listed below are some learning and teaching strategies which can be useful in Chemistry. They are by no means the only strategies that can be used. It should be noted that learning targets can be achieved using different strategies, depending on students' strengths and learning styles, teachers' preferred teaching approaches, and the classroom context.

(1) Constructing concept maps

Concept maps are visual aids to thinking and discussion, and help students to visualise and describe the links between important concepts. They can be used as tools to generate ideas, communicate complex ideas, aid learning by explicitly integrating new and old knowledge and assess understanding or diagnose misconceptions. Students should be encouraged to construct concept maps to review their understanding of a topic, and subsequently refine them in the light of teachers' comments, peer review and self-evaluation in the course of learning. To familiarise students with this way of representing information, they may first be asked to add the links between concepts or label the links on a partially-prepared concept map. Apart from drawing them by hand, a wide range of software packages for concept mapping is available to enable users to create and revise concept maps easily.

(2) Searching for and presenting information

Searching for and presenting information are important skills in the information era. Students can gather information from various sources such as books, magazines, scientific publications, newspapers, CD-ROMs and the Internet. Students should not just collect information randomly, but should be required to select, categorise, and analyse it critically, and to present their findings.

(3) Reading to learn

Reading to learn promotes independent learning. In particular, it enables students to understand various aspects of the past, present and possible future developments of chemistry. Students should be given opportunities to read science articles of appropriate breadth and depth independently. This will develop their ability to read, interpret, analyse and communicate new scientific concepts and ideas.

Meaningful discussions on good science articles among students and with their teachers may be used to co-construct knowledge and to strengthen students' general communication skills. The development of the capacity for self-directed learning is invaluable in preparing students to become active lifelong learners.

Articles which emphasise the interconnections between science, technology, society and the environment can enliven the curriculum by bringing in current developments and issues, and so arouse students' interest in learning. Teachers should select articles suited to the interests and abilities of their students; and students should be encouraged to search for articles themselves from newspapers, science magazines, the Internet and library books.

The main purpose of reading scientific articles is to extend student learning about chemistry. A wide variety of after-reading activities can be arranged including, for example, simple or open-ended questions to help students relate what they have read to their chemical knowledge. Students may be asked to write a summary, critique or report on an article, prepare a poster or write a story to demonstrate their understanding. They should also be encouraged to share what they have read with their classmates, either in class or using web-based technologies, in order to cultivate the habit of reading chemistry articles.

Example In topic XIV "Materials Chemistry", it is suggested that students should read articles or write essays on the impact of the development of modern materials, such as semiconductors and nanotubes, on daily life. This activity not only helps students to understand the latest developments in chemistry, but also to appreciate that knowledge about bonding is changing dynamically and is revised when new evidence arises, e.g. the discovery of the structure of Buckminsterfullerene. This activity also helps teachers to assess what their students have learned.

(4) Discussion

Questioning and discussion in the classroom promote students' understanding, and help them to develop higher-order thinking skills as well as an active approach to learning. Presenting arguments enables them to develop the following skills: extracting useful information from a variety of sources; organising and presenting ideas in a clear and logical way; thinking critically; and making judgments based on valid arguments.

Teachers must avoid discouraging discussion in the classroom by insisting too much and too soon on the use of objective and formal scientific language. It is vital to accept relevant discussion in the students' own language during the early stages of chemistry learning, and then move progressively towards more formal and objective scientific language.

Student-centred strategies can be adopted in addressing issues related to science, technology, society and the environment. For example, in topic V, which considers environmental issues related to the use of plastics, teachers can start by raising the issues of domestic waste classification, and plastic waste collection in schools and housing estates. In the discussion, students should be free to express their opinions, and then pool their ideas on why plastic waste should be collected, and the difficulties of putting this into practice. Lastly, students can present their views to the whole class for their classmates and the teacher to comment on.

(5) Practical work

As chemistry is a practical subject, it is essential for students to gain personal experience of science through practical activity and investigation. In the curriculum, the design and performance of experiments are given due emphasis. The experimental techniques for this curriculum are listed in Appendix 2 for reference.

When students have sufficient knowledge and skills related to practical work, teachers are encouraged to progressively introduce manuals or worksheets for experiments with fewer procedural guidelines and ready-made data tables, so as to provide opportunities for students to learn and appreciate the process of science by themselves. In such inquiry-based experiments, students have to design all or part of the experimental procedure, decide on what data to record, and analyse and interpret the data. Because they are in charge of their own learning, students will show more curiosity and a greater sense of responsibility in their work, leading to significant gains in their basic science process skills.

It is better to design experiments to "find out" rather than to "verify". Teachers should avoid telling students the results before they engage in practical work, and students should try to draw their own conclusions from the experimental results. This helps to consolidate the learning of scientific principles.

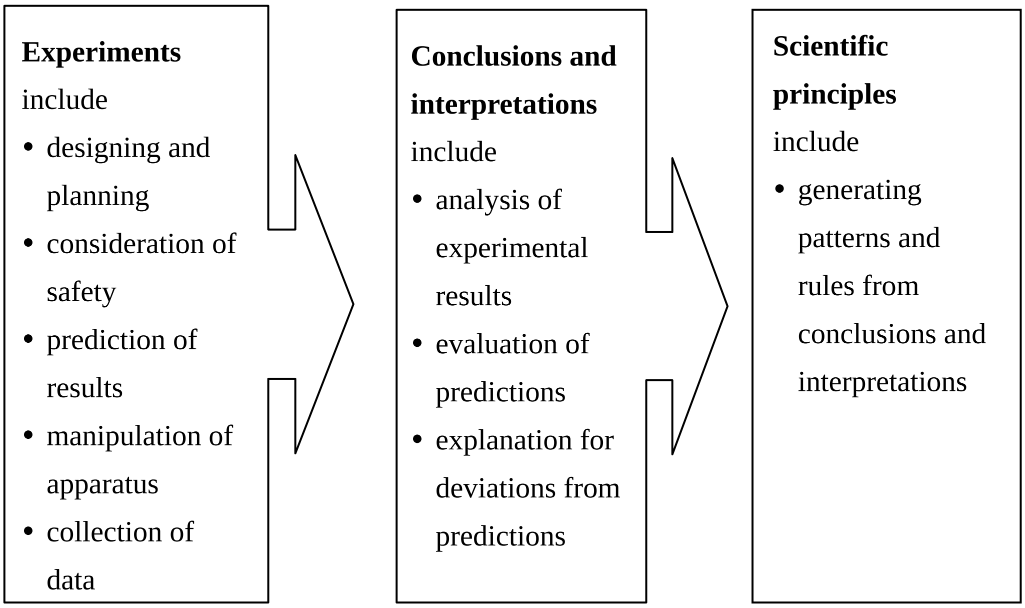

Figure 4.2 The Development of Understanding of Scientific Principles through Practical Work

Other than using 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 demonstrations can be converted to student experiments in microscale practice.

> *Example*
>
> After some practice in volumetric analysis involving acids and alkalis in topic IV, students can be asked to design and carry out an experiment to determine which of the two brands of vinegar is the "best-buy". The experiment can be carried out using either conventional titration apparatus or microscale chemistry apparatus.

(6) Investigative studies

Investigative studies, which are a powerful strategy for promoting self-directed and self-regulated learning and reflection, enable students to connect knowledge, skills, values and attitudes, and to construct knowledge collaboratively through a variety of learning experiences. In the Investigative Study in this curriculum, students work in small groups to plan, collect information and make decisions over a period of time. As figure 4.3 illustrates, this approach serves to develop a variety of skills including science process skills.

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

* *The skills correspond to the learning targets listed in Chapter 2.*

Figure 4.3 Science Process Skills in Investigative Studies

Short and simple investigations can be arranged, preferably from an early stage in the curriculum, to develop the skills required for a complete investigative study. As there are many ways to collect scientific evidence, it is desirable to expose students to different types of chemistry investigation, such as identification of the unknown, quantitative analysis, preparation of substances, making things or developing systems. Through these, students will progress from "cook-book" type experiments to more open-ended investigations which involve finding the answers to questions they have formulated themselves. An Investigative Study in Chemistry can be pitched somewhere between the two extremes of the teacher-directed and student-centred continuum.

Example

A short investigation on the extraction of copper from its ore can be organised after covering the topics "Metals", "Acids and Bases" and "Redox Reactions, Chemical Cells and Electrolysis". Students can complete the task either by carbon reduction, or by dissolving the ore in dilute acid and then extracting copper by metal displacement / electrolysis.

A more in-depth version of this investigation may require students to determine the percentage purity of copper and the amount of iron impurity in the copper obtained.

(7) Problem-based learning

Problem-based learning (PBL) is an instructional method driven by a problem. PBL is most commonly used in professional courses where students are given real-world problems of the kind they will face at work, but it is being adopted increasingly in many disciplines. The problems are open-ended, often based on real-life situations and ill-defined with no quick and easy solutions. In the process, students may acquire new knowledge and integrate it with what they have learned previously to solve the problem. Students are required to work in groups to: understand and define the problem; discover what they need to know to tackle it; generate alternatives; develop and test solutions; and justify their suggested solutions. Teachers assume the role of facilitators, resource persons and observers. Students are motivated by being actively engaged in the learning process and taking responsibility for their own learning.

Apart from motivating students to develop a deeper subject understanding, PBL also encourages them to think scientifically, critically and creatively, and to solve problems collaboratively in chemistry-related contexts. Many topics in the curriculum offer rich opportunities for using PBL. Also, problems with different levels of complexity can be given to students, with hints or thought-provoking questions to guide them in their analysis, if necessary.

Example

You are a chemist working for a coffee company. Your company plans to launch the world's first self-heating can of coffee. You are asked to design the can which can heat the coffee contained in a standard size aluminium can to $60^{o}C$ within three minutes and maintain the temperature for 30 minutes. The can should be convenient to carry and easy to use, and the coffee is to be served straight out of the can.

The following questions can be raised to help students analyse the problem:

- What is the volume of the coffee the can holds?
- How much heat energy is required to heat up the coffee to the required temperature?
- Which chemicals react to produce a steady supply of heat?
- How much of each chemical should be used?
- Is your product safe for use by customers?

Students can test their proposed solutions to the problem in many ways, such as in a real laboratory or in a virtual environment (e.g. ChemCollective Virtual Laboratory at http://www.chemcollective.org).

(8) Information technology (IT) for interactive learning

IT often provides an interactive environment for learners to take control of the organisation and content of their own learning. With the appropriate use of IT-mediated resources, teachers can enhance students' understanding of chemistry concepts and processes, and develop their IT skills which are useful for lifelong learning.

There are numerous and growing opportunities to use IT in learning chemistry. If appropriately used, it can enrich the learning experience. The following are some examples for illustration:

Examples

- Three-dimensional computer images can be used to illustrate the shapes of molecules, the concept of chirality and the chemical structures of crystals, polymers, etc. These computer images can be manipulated as if one was examining a real model.
- Animations can help students to visualise abstract chemistry concepts and processes, especially in the microscopic world, e.g. reactions in chemical cells.
- Digitised videos are particularly useful to stimulate the interest of students and give them some experiences of the world outside school – for example, industrial processes in the extraction of metals and refining of crude oil, and the use of modern chemical techniques in chemical analysis. In addition, digitised videos can be used to show experiments which are difficult or dangerous to conduct in school laboratories. They also allow students to review observations and laboratory techniques of chemistry experiments without actually repeating them.
- Computer simulations can be used to model a reversible reaction at equilibrium, the factors affecting rate of reaction and the processes of a chemical plant. Students can carry out a number of virtual experiments safely and quickly to discover the relationship between different variables of a chemical system. They can learn from their mistakes without paying the price of real errors.
- Spreadsheets can be used in analysing and plotting experimental data, and also for the modelling of chemical systems, thus allowing students to explore "what-if" situations. This helps to move students' understanding beyond repetitive calculations and the plotting of numerical results.
- Data-loggers and sensors are particularly useful for experiments which involve very rapidly changing data, are very lengthy or have to capture multiple sets of data simultaneously. For instance, they can be used to study the rate of reaction. The software accompanying a data-logger can generate graphical representations of the data immediately so that students have more time to analyse, discuss and evaluate experimental results right after the runs.

- The Internet allows students to go beyond textbooks and find current and authentic information to help them understand concepts, construct knowledge, and observe and explore the world outside school.
- Communication tools (synchronous and asynchronous) and web-based collaborative knowledge-building platforms can facilitate interaction and dialogue among students, which promotes knowledge sharing and construction. More knowledgeable participants can act as teachers as well as learners.
- Online assessment tools can provide instant feedback to teachers and students. The functions for tracking the answers of individual students can give teachers information on students' understanding of concepts which may help them to identify students' misconceptions and learning difficulties.
- Interactive computer-aided learning resources can enhance the active participation of students in the learning process. Since Internet access is widespread, students can easily get access to web-based learning resources anywhere and at any time.

(9) Providing life-wide learning opportunities

As learning can take place anywhere in the community, not just in the classroom or school environment, it is essential to provide out-of-school learning experiences for students. Life-wide learning opportunities can increase students' exposure to the real scientific world. Examples of appropriate learning programmes include popular science lectures, debates and forums, field studies, visits, invention activities, science competitions, science projects and science exhibitions. These programmes can also offer challenging learning opportunities for students with outstanding ability or a strong interest in science. The STSE connections described in Chapter 2 of this Guide are a good reference for organising life-wide learning experiences.

4.4 Interaction

Interaction involves teachers and students communicating with each other to enhance learning and teaching, and is an important element in many learning and teaching strategies. In studying this curriculum, most students, irrespective of ability, will encounter some difficulties that cannot be easily resolved. Students and teachers can work together through discussion on these learning problems. Good interaction between teachers and students is fundamental to school learning.

4.4.1 Scaffolding Learning

To achieve the learning targets of the curriculum described in Chapter 2 of this Guide, students have to be provided with appropriate scaffolding of their learning from time to time. Scaffolding can take many forms, including:

- a collection of resource materials – for example, an article on Kevlar with detailed uncluttered description, schematic drawings of polymeric structures and photographs of bullet-proof vests made of Kevlar, to help students understand the relation between the structures of polymers and their properties;
- a learning task with clear procedural guidelines and reporting templates – for instance, a worksheet with guiding questions to help students in planning their own experiments;
- guidance, in a variety of formats, on the development of cognitive abilities, and social and investigative skills – for example, showing a video clip on how to conduct an acid-alkali titration to enhance the acquisition of the practical skills required for a titration;
- teacher debriefings – for instance, the presentation of a clear conceptual framework at the end of an activity to help students who have difficulty in conceptualising the essence of the activity, or encounter obstacles that significantly hinder their learning.

The use of scaffolds helps students to learn by making sense of concepts and building knowledge individually or collaboratively.

4.4.2 Questioning and Feedback

Good use of questioning, with feedback provided, improves learning. By asking questions, ranging from simple close-ended to demanding open-ended ones, and giving quality feedback on students’ responses, teachers can help them to stay on the right track and learn more effectively. For different learning targets, teachers can select questions with varying levels of demand, so as to provide appropriate feedback to students. This will help to build students’ confidence and intrinsic motivation to learn chemistry.

Formative assessment, when tightly integrated into learning and teaching processes, helps to develop students’ understanding. By putting into practice the concept of “assessment for learning”, teachers go beyond the simple provision of marks to provide, for example, oral or written comments on students’ strengths and weaknesses in learning, and suggestions on areas for improvement. Their peers and others, such as laboratory supporting staff, can also provide worthwhile feedback on students’ learning. From a student perspective, formative assessment tasks help to clarify the learning targets expected and enable them to adjust their learning progress.

There are a number of scenarios in learning and teaching in which teachers can make use of quality feedback to enhance students' learning. Some examples are listed below.

- An open-ended question such as "Explain the special properties of ice in terms of its structure and bonding" requires higher-order thinking and an understanding of various related concepts
- A problem on redox reactions involving some abstract and complex concepts
- A teacher-made standard-referenced formative assessment task on concepts and skills related to molarity

4.5 Learning Communities

A learning community is a group of people who learn together. Groups of students can work together to build knowledge, develop understanding of natural phenomena and relationship, find solutions to problems, or create products using their knowledge and skills. In some cases, students and their teachers learn together. In a learning community students participate actively in groups, while teachers help to steer the direction of learning, devise different ways to group students, and provide guidance and feedback where appropriate. Teachers who intend to use collaborative learning activities in their classrooms should anticipate and attempt to resolve the difficulties which may arise – for example because group members differ in their knowledge and skills and in their ability to work effectively with others. They also need to try to avoid the situation in which the achievement of quicker students in a group is limited by what the slower members can do.

In Chemistry, learning and teaching activities such as debates, discussions, problem-based learning, and investigative studies in chemistry provide good opportunities to build learning communities. Given the availability of a sophisticated information and communication network, web-based collaborative learning tools can be deployed to facilitate knowledge building in learning communities.

4.6 Catering for Learner Diversity

4.6.1 Understanding the Students

Students range widely in their academic readiness, needs, learning pace and aspirations. It is therefore unrealistic to expect every student to achieve the same level of attainment and to complete learning tasks at the same pace. However, it is necessary to provide opportunities for them all to develop their potential. Teachers can gather information about their students through reading formal documents, through personal contacts in and out of class and, more importantly, through ongoing formative assessment; and they should use this knowledge in deciding on the most appropriate learning and teaching activities. Also, teachers should relate the breadth and depth of their teaching schemes to their students' abilities – the schemes should be challenging, but within the students' reach. Moreover, they should create an understanding and accepting learning atmosphere in which students can build up their confidence and self-esteem, find learning enjoyable and be motivated to study chemistry.

Teachers need to identify the "building blocks" of learning and systematically make them available to students in manageable chunks that do not exceed their capacities, as this will enable them to learn more efficiently and enhance their overall capacity for self-directed learning. When most students have mastered the basics of the subject, the differences in learning outcomes among students will be narrowed.

4.6.2 Flexible Grouping

Student diversity can be viewed as an opportunity to get students to provide mutual support, particularly when they work collaboratively to complete learning tasks. Students of differing abilities can be grouped together so that the more and less able ones can share their knowledge. Alternatively, teachers can group students of similar ability together to work on tasks with an appropriate degree of challenge.

4.6.3 The Use of Diverse Learning and Teaching Approaches

Using a range of teaching and learning approaches and matching these to students' learning styles can improve learning significantly. For instance, topic V (c) "monosubstitution of methane with chlorine" can be delivered using either a direct instruction or an inquiry approach. In the former case, the teacher can explain to students that the substitution of methane consists of three steps, i.e. initiation, propagation and termination. Asking students to draw the electron diagrams for each step of the substitution reaction will help them to understand that the first step of the reaction involves the formation of reactive radicals, and the second and third steps involve the propagation and termination of free radicals respectively. Alternatively, students can be asked to watch a video of the substitution reaction of methane with chlorine, and then work in small groups to predict, discuss and deduce the possible sequence of steps involved in the reaction. Teachers can help students to articulate concepts and observations with a debriefing, which, together with group discussion and individual self-reflection, should enable them to build the relevant knowledge.

4.6.4 The Use of Differentiated Learning Tasks

When students of average or low ability are faced with highly demanding learning tasks, they become demotivated, and when very able students are asked to complete non-demanding learning tasks, they become bored; and in both cases, they lose interest in learning. When necessary, teachers have to devise different learning tasks for students within a class or in different classes. For example, as some students have difficulty in doing chemical calculations in topic VIII (c) "Hess's law" and topic X (b) "Equilibrium constant", tasks with varying degrees of demand can be allocated to students of different ability levels. Students may also be given flexibility in the ways they demonstrate their understanding, for instance in the format in which they present their work such as text, graphics, computer-mediated presentations or other media.

4.6.5 The Use of Information Technology

If used appropriately, information technology can be effective in catering for different learning styles and expanding students' learning beyond the classroom. For instance, some learners who are quiet in class may participate actively in manipulating text, and contribute useful ideas in an online discussion forum. Online assessment tools, with mechanisms to support learning, can be very helpful for motivating students. Also, the multimedia elements in information technology are particularly useful for students who prefer visual or auditory approaches to learning. Lastly, the non-linear nature of IT-based learning resources enables students to learn at their own pace and follow up their own interests.

4.6.6 Catering for Gifted Students

Schools should help students with a special talent in science to develop their full potential. One way of achieving this is through enrichment – that is, by involving such gifted learners in additional challenging or thought-provoking work, while keeping them with their peers in school. For example, they can be allocated more demanding problems and asked to define and then explore them, using a range of information sources and evaluating possible solutions with a view to solving them. Also, gifted students who can regulate their learning can be allowed to explore their personal interests by, for example, setting their own objectives for their investigative studies.

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Chapter 5 Assessment

This chapter discusses the roles of assessment in learning and teaching Chemistry, the principles that should guide assessment of the subject and the need for both formative and summative assessment. It also provides guidance on internal assessment and details of the public assessment of Chemistry. Finally, information is given on how standards are established and maintained and how results are reported with reference to these standards. General guidance on assessment can be found in the *Senior Secondary Curriculum Guide* (SSCG) (CDC, 2009).

5.1 The Roles of Assessment

Assessment is the practice of collecting evidence of student learning. It is a vital and integral part of classroom instruction, and serves several purposes and audiences.

First and foremost, it gives feedback to students, teachers, schools and parents on the effectiveness of teaching and on students' strengths and weaknesses in learning.

Second, it provides information to schools, school systems, government, tertiary institutions and employers to enable them to monitor standards and to facilitate selection decisions.

The most important role of assessment is in promoting learning and monitoring students' progress. However, in the senior secondary years, the more public roles of assessment for certification and selection come to the fore. Inevitably, these imply high-stakes uses of assessment since the results are typically employed to make critical decisions about individuals.

The Hong Kong Diploma of Secondary Education (HKDSE) provides a common end-of-school credential that gives access to university study, work, and further education and training. It summarises student performance in the four core subjects and in various elective subjects, including both discipline-oriented subjects such as Chemistry and the new Applied Learning courses. It needs to be interpreted in conjunction with other information about students as shown in the Student Learning Profile.

5.2 Formative and Summative Assessment

It is useful to distinguish between the two main purposes of assessment, namely "assessment *for* learning" and "assessment *of* learning".

"Assessment *for* learning" is concerned with obtaining feedback on learning and teaching, and utilising this to make learning more effective and to introduce any necessary changes to teaching strategies. We refer to this kind of assessment as "formative assessment" because it is all about forming or shaping learning and teaching. Formative assessment is something that should take place on a daily basis and typically involves close attention to small "chunks" of learning.

"Assessment *of* learning" is concerned with determining progress in learning, and is referred to as "summative" assessment because it is all about summarising how much learning has taken place. Summative assessment is normally undertaken at the conclusion of a significant period of instruction (e.g. at the end of the year, or of a key stage of schooling) and reviews much larger "chunks" of learning.

In practice, a sharp distinction cannot always be made between formative and summative assessment, because the same assessment can in some circumstances serve both formative and summative purposes. Teachers can refer to the SSCG for further discussion of formative and summative assessment.

Formative assessment should be distinguished from continuous assessment. The former refers to the provision of feedback to improve learning and teaching based on formal or informal assessment of student performance, while the latter refers to the assessment of students' on-going work and may involve no provision of feedback that helps to promote better learning and teaching. For example, accumulating results in class tests carried out on a weekly basis, without giving students constructive feedback, may neither be effective formative assessment nor meaningful summative assessment.

There are good educational reasons why formative assessment should be given more attention and accorded a higher status than summative assessment, on which schools tended to place a greater emphasis in the past. There is research evidence on the beneficial effects of formative assessment when used for refining decision-making in teaching and generating feedback to improve learning. For this reason, the CDC report *Learning to Learn – The Way Forward in Curriculum Development* (CDC, 2001) recommended that there should be a change in assessment practices, with schools placing due emphasis on formative assessment to make assessment *for* learning an integral part of classroom teaching.

It is recognised, however, that the primary purpose of public assessment, which includes both public examinations and moderated School-based Assessments, is to provide summative assessments of the learning of each student. While it is desirable that students are exposed to SBA tasks in a low-stakes context, and that they benefit from practice and experience with such tasks for formative assessment purposes without penalty, similar tasks will need to be administered subsequently as part of the public assessment to generate marks to summarise the learning of students (i.e. for summative assessment purposes).

Another distinction to be made is between internal assessment and public assessment. Internal assessment refers to the assessment practices that teachers and schools employ as part of the ongoing learning and teaching process during the three years of senior secondary studies. In contrast, public assessment refers to the assessment conducted as part of the assessment process in place for all schools. Within the context of the HKDSE, this means both the public examinations and the moderated School-based Assessment (SBA) conducted or supervised by the HKEAA. On balance, internal assessment should be more formative, whereas public assessment tends to be more summative. Nevertheless, this need not be seen as a simple dichotomy. The inclusion of SBA in public assessment is an attempt to enhance formative assessment or assessment *for* learning within the context of the HKDSE.

5.3 Assessment Objectives

The assessment objectives are closely aligned with the curriculum framework and the broad learning outcomes presented in earlier chapters.

The learning objectives to be assessed in Chemistry are listed below:

- recall and show understanding of chemical facts, patterns, principles, terminology and conventions;
- demonstrate understanding of the use of apparatus and materials in performing experiments;
- handle materials, manipulate apparatus, carry out experiments safely and make accurate observations;
- demonstrate understanding of the methods used in chemical investigations;
- analyse and interpret data from various sources, and draw relevant conclusions;
- manipulate and translate chemical data and perform calculations;
- apply chemical knowledge to explain observations and solve problems which may involve unfamiliar situations;
- select and organise scientific information from appropriate sources and communicate this information in an appropriate and logical manner;

- understand and evaluate the social, economic, environmental and technological implications of the applications of chemistry; and
- make decisions based on the examination of evidence and arguments.

5.4 Internal Assessment

This section presents the guiding principles that can be used as the basis for designing the internal assessment and some common assessment practices for Chemistry for use in schools. Some of these principles are common to both internal and public assessment.

5.4.1 Guiding Principles

Internal assessment practices should be aligned with curriculum planning, teaching progression, student abilities and local school contexts. The information collected will help to motivate, promote and monitor student learning, and will also help teachers to find ways of promoting more effective learning and teaching.

(1) Alignment with the learning objectives

A range of assessment practices should be used to assess the achievement of different learning objectives for whole-person development, which include: knowledge and understanding of chemical principles and concepts; scientific skills and processes; and positive values and attitudes. The weighting given to different areas in assessment should be discussed and agreed among teachers. The assessment purposes and assessment criteria should also be made known to students, so that they can have a full understanding of what is expected of them.

(2) Catering for the range of student ability

Assessment practices at different levels of difficulty and in diverse modes should be used to cater for students with different aptitudes and abilities. This helps to ensure that the more able students are challenged to develop their full potential and the less able ones are encouraged to sustain their interest and sense of success in learning.

(3) Tracking progress over time

As internal assessment should not be a one-off exercise, schools are encouraged to use practices that can track learning progress over time (e.g. portfolios). Assessment practices of this kind allow students to set their own incremental targets and manage their own pace of learning, which will have a positive impact on their commitment to learning.

(4) Timely and encouraging feedback

Teachers should provide timely and encouraging feedback through a variety of means, such as constructive verbal comments during classroom activities and written remarks on assignments. Such feedback, together with indications as to where improvements can be made, helps students to sustain their momentum in learning and to identify their strengths and weaknesses.

(5) Making reference to the school's context

As learning is more meaningful when the content or process is linked to a setting which is familiar to students, schools are encouraged to design assessment tasks that make reference to the school's own context (e.g. its location, relationship with the community, and mission).

(6) Making reference to current progress in student learning

Internal assessment tasks should be designed with reference to students' current progress, as this helps to overcome obstacles that may have a cumulative negative impact on learning. Teachers should be mindful in particular of concepts and skills which form the basis for further development in learning.

(7) Feedback from peers and from the students themselves

In addition to giving their own feedback, teachers should also provide opportunities for peer assessment and self-assessment in student learning. The former enables students to learn among themselves, and the latter promotes reflective thinking which is vital for students' lifelong learning.

(8) Appropriate use of assessment information to provide feedback

Continuous assessment provides a rich source of data for providing feedback on learning in a formative manner. The appropriate use of assessment results helps to provide evidence-based feedback.

5.4.2 Internal Assessment Practices

A range of assessment practices, such as assignments, practical work and scientific investigations, and oral questioning, suited to Chemistry should be used to promote the attainment of the various learning outcomes. However, teachers should note that these practices should be an integral part of learning and teaching, not "add-on" activities.

(1) Assignments

Assignments are a valuable and widely used assessment tool that reflects students' efforts, achievements, strengths and weaknesses over time. A variety of assignment tasks – such as exercises, essays, designing posters or leaflets and model construction – can be used to allow students to demonstrate their understanding and creative ideas. The assignment tasks should be aligned with the learning objectives, teaching strategies and learning activities. Teachers can ask students to select a topic of interest, search for information, summarise their findings and devise their own ways of presenting their work (e.g. role-play, essays, poster designs or PowerPoint slides). Teachers should pay close attention to students' organisation of the materials, the language they use, the breadth and depth of their treatment, and the clarity with which they explain concepts. The scores or grades for assignments can be used as part of the record of students' progress; and the comments on their work, with suggestions for improvement, provide valuable feedback to them. Assignments can also help in evaluating the effectiveness of teaching by providing feedback upon which teachers can set further operational targets for students and make reasonable adjustments in their teaching strategies.

(2) Practical work and scientific investigation

Practical work and scientific investigation are common activities in the learning and teaching of science subjects. They offer students "hands-on" experience of exploring, and opportunities to show their interest, ingenuity and perseverance. In scientific investigations, teachers can first pose a problem and ask students to devise a plan and suggest appropriate experimental procedures for solving it – and the design of the investigations can then be discussed and, if necessary, modified. During such sessions, teachers can observe students' practical skills and provide feedback on how the experiment/investigation can be improved. Marking students' laboratory reports can provide teachers with a good picture of students' understanding of the chemical concepts and principles involved, as well as their ability to handle and interpret data obtained in investigations.

(3) Oral questioning

Oral questioning can provide teachers with specific information on how students think in certain situations, as their responses often provide clues to their level of understanding, attitudes and abilities. Teachers can use a wide range of questions, from those which involve fact-finding, problem-posing, and reason-seeking to more demanding ones which promote higher levels of thinking and allow for a variety of acceptable responses. This can be a valuable supplement to conventional assessment methods.

5.5 Public Assessment

5.5.1 Guiding Principles

Some principles guiding public assessment are outlined below for teachers' reference.

(1) Alignment with the curriculum

The outcomes that are assessed and examined through the HKDSE should be aligned with the aims, objectives and intended learning outcomes of the new senior secondary curriculum. To enhance the validity of the public assessment, the assessment procedures should address the range of valued learning outcomes, not just those that are assessable through external written examinations.

The public assessment for Chemistry will place emphasis on testing candidates' ability to apply and integrate knowledge in authentic and novel situations. In addition, the SBA component extends the public assessment to include valuable scientific investigative skills and generic skills such as creativity, critical thinking, communication and problem-solving.

(2) Fairness, objectivity and reliability

Students should be assessed in ways that are fair and are not biased against particular groups of students. A characteristic of fair assessment is that it is objective and under the control of an independent examining authority that is impartial and open to public scrutiny. Fairness also implies that assessments provide a reliable measure of each student's performance in a given subject so that, if they were to be repeated, very similar results would be obtained.

(3) Inclusiveness

The assessments and examinations in the HKDSE need to accommodate the full spectrum of student aptitude and ability.

The public examination for Chemistry will contain questions which test candidates' knowledge of the foundations and selected areas in chemistry, and assess higher-order thinking skills. At the same time, the SBA component offers room for a wide range of activities to cater for the differing preferences and readiness of students and/or schools.

(4) Standards-referencing

The reporting system is "standards-referenced", i.e. student performance is matched against standards, which indicate what students have to know and be able to do to merit a certain level. Level descriptors have been developed for Chemistry to provide information about the typical performance of candidates at the different levels.

(5) Informativeness

The HKDSE qualification and the associated assessment and examinations system provide useful information to all parties. Firstly, it provides feedback to students on their performance and to teachers and schools on the quality of the teaching provided. Secondly, it communicates to parents, tertiary institutions, employers and the public at large what it is that students know and are able to do, in terms of how their performance matches the standards. Thirdly, it facilitates selection decisions that are fair and defensible.

5.5.2 Assessment Design

The table below shows the assessment design of the subject with effect from the 2016 HKDSE Examination. The assessment design is subject to continual refinement in the light of feedback from live examinations. Full details are provided in the Regulations and Assessment Frameworks for the year of the examination and other supplementary documents, which are available on the HKEAA website (www.hkeaa.edu.hk/en/hkdse/assessment/assessment_framework/).

Component		**Weighting**	**Duration**
Public Examination	Paper 1 Compulsory part of the curriculum	60%	2 hours 30 minutes
	Paper 2 Elective part of the curriculum	20%	1 hour
School-based Assessment (SBA)		20%	

5.5.3 Public Examinations

The overall aim of the public examination is to assess candidates' ability to demonstrate their knowledge and understanding in different areas of chemistry, and to apply this to familiar and unfamiliar situations.

Different types of items, including multiple-choice questions, short questions, structured questions and essays, are used to assess students' performance in a broad range of skills and abilities. Multiple-choice questions permit a more comprehensive coverage of the curriculum, while basic knowledge and concepts can be tested through short questions. Structured questions require candidates to analyse given information and apply their knowledge to different situations. Finally, essay questions allow candidates to discuss chemistry topics in depth and demonstrate their ability to organise and communicate ideas logically and coherently. Schools may refer to the live examination papers regarding the format of the examination and the standards at which the questions are pitched.

5.5.4 School-based Assessment (SBA)

In the context of public assessment, SBA refers to assessments administered in schools and marked by the students' own teachers. The primary rationale for SBA in Chemistry is to enhance the validity of the assessment by including the assessment of students' practical skills and generic skills.

There are, however, some additional reasons for SBA. For example, it reduces dependence on the results of public examinations, which may not always provide the most reliable indication of the actual abilities of candidates. Obtaining assessments based on student performance over an extended period of time and developed by those who know the students best – their subject teachers – provides a more reliable assessment of each student.

Another reason for including SBA is to promote a *positive impact or "backwash effect" on students, teachers and school staff*. Within Chemistry, SBA can serve to motivate students by requiring them to engage in meaningful activities; and for teachers, it can reinforce the curriculum aims and good teaching practice, and provide structure and significance to an activity they are in any case involved in on a daily basis, namely assessing their own students.

It should be noted that SBA is not an "add-on" element in the curriculum. The modes of SBA above are normal in-class and out-of-class activities suggested in the curriculum. The requirement to implement the SBA has taken into consideration the wide range of student ability, and efforts have been made to avoid unduly increasing the workload of both teachers and students. Detailed information on the requirements and implementation of the SBA and samples of assessment tasks are provided to teachers by the HKEAA.

5.5.5 Standards and Reporting of Results

Standards-referenced reporting is adopted for the HKDSE. What this means is that candidates' levels of performance are reported with reference to a set of standards as defined by cut scores on the mark scale for a given subject. Standards referencing relates to the way in which results are reported and does not involve any changes in how teachers or examiners mark student work. The set of standards for a given subject can be represented diagrammatically as shown in figure 5.1.

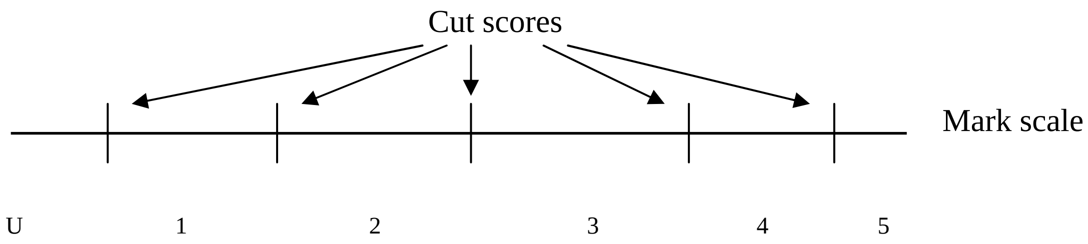

Figure 5.1 Defining Levels of Performance via Cut Scores on the Mark Scale for a Given Subject

Within the context of the HKDSE there are five cut scores, which are used to distinguish five levels of performance (1–5), with 5 being the highest. A performance below the cut score for Level 1 is labelled as "Unclassified" (U).

For each of the five levels, a set of written descriptors has been developed to describe what the typical candidate performing at this level is able to do. The principle behind these descriptors is that they describe what typical candidates *can* do, not what they *cannot* do. In other words, they will describe performance in positive rather than negative terms. These descriptors represent "on-average" statements and may not apply precisely to individuals, whose performance within a subject may be variable and span two or more levels. Samples of students' work at various levels of attainment are provided to illustrate the standards expected of them. These samples, when used together with the level descriptors, will clarify the standards expected at the various levels of attainment.

In setting standards for the HKDSE, Levels 4 and 5 are set with reference to the standards achieved by students awarded grades A–D in the HKALE. It needs to be stressed, however, that the intention is that the standards will remain constant over time – not the percentages awarded at different levels, as these are free to vary in line with variations in overall student performance. Referencing Levels 4 and 5 to the standards associated with the old grades A–D is important for ensuring a degree of continuity with past practice, for facilitating tertiary selection and for maintaining international recognition.

The overall level awarded to each candidate is made up of results in both the public examination and the SBA. SBA results for Chemistry are statistically moderated to adjust for differences among schools in marking standards, while preserving the rank ordering of students as determined by the school.

To provide finer discrimination for selection purposes, the Level 5 candidates with the best performance have their results annotated with the symbols ** and the next top group with the symbol *. The HKDSE certificate itself records the Level awarded to each candidate.

Chapter 6 Learning and Teaching Resources

This chapter discusses the importance of selecting and making effective use of learning and teaching resources, including textbooks, to enhance student learning. Schools need to select, adapt and, where appropriate, develop the relevant resources to support student learning.

6.1 Purpose and Function of Learning and Teaching Resources

There is a wide range of learning and teaching resources suitable for the Chemistry Curriculum, e.g. this curriculum and assessment guide and the supplementary notes, textbooks and experimental workbooks, reference books, journal articles, materials and audio-visual aids published by the Education Bureau, IT-based software packages produced by various organisations, the Internet and the media. In addition, some local organisations, various government departments and the public libraries offer additional resources, and experts in chemistry-related departments of tertiary institutions can provide useful support for learning and teaching this curriculum. Last but not least are the valuable contextualised learning and teaching resources developed in schools.

The purpose of using learning and teaching resources is to provide a basis for students' learning experiences. A wide variety of resources should be drawn upon to broaden students' learning experiences and meet their varied learning needs. If used effectively, they will help them to consolidate what they have learned, construct knowledge for themselves, develop the learning strategies, generic skills, values and attitudes they need, and thus lay a solid foundation for lifelong learning.

6.2 Guiding Principles

Learning and teaching resources should be selected to meet the curriculum aims and learning targets and the needs of students.

Learning and teaching resources for Chemistry should:

- arouse students' interest and engage them actively in learning;
- inform teachers and students of any prior knowledge and experience that will be required;
- be in line with the aims and targets of the curriculum, and contain essential elements of the curriculum;

- facilitate direct instruction, inquiry and co-construction learning and teaching approaches;
- promote independent learning by complementing and extending what students have learned in class;
- cater for learner diversity by providing learning activities at different levels of difficulty;
- use accurate language and representations;
- present information and concepts in a clear, precise and concise manner;
- provide easy access to information, as well as scaffolds, to help students progress in their learning.

6.3 Types of Resources

6.3.1 Textbooks

Well-written textbooks developed in accordance with the new curriculum framework have an important role to play in learning Chemistry. Teachers can use textbooks as the basic sources of learning and teaching activities, but not as the only one; a variety of other learning and teaching resources need to be used to complement them. The textbooks selected should cover all the essential elements in the curriculum and help students to develop critical and creative thinking, and other generic skills.

Teachers should use the material in textbooks selectively and adapt them to the different needs and abilities of the students, rather than working through them from cover to cover. They are advised to exercise their professional judgement in selecting tasks and exercises from the textbooks, and make use of other ready-made resources, or produce their own, to develop a wide range of learning activities for their students.

It is anticipated that good textbooks and supporting learning and teaching reference materials suited to this curriculum will be available in the market. A recommended textbook list will be compiled and updated to help schools to choose appropriate ones.

A set of guiding principles has been developed for writing, reviewing and selecting textbooks which support the curriculum framework and a learner-centred approach to learning and teaching. Teachers are encouraged to refer to these guidelines under textbook information at http://www.edb.gov.hk/textbook when selecting textbooks for their students.

6.3.2 The Internet and Technologies

The massive increase in the quantity of information available today, especially with the advance of the Internet, has led to new approaches to learning and teaching. Teachers can act as facilitators of learning by helping students to search for information and requesting them to work on it, in order to turn it into personal knowledge.

The Internet and technologies help learning and teaching in many different situations by:

- providing audio-visual aids for the understanding of difficult concepts;
- providing access to information from a wide variety of sources, handling large quantities of information, and facilitating the extraction of valid and useful information;
- allowing students to work at their own pace, including the use of specially designed software packages;
- promoting interaction among students, and between students and resources / teachers;
- enhancing collaboration among students, and between students and teachers;
- facilitating access to information for the development of critical thinking and the building of knowledge.

Teachers are encouraged to make use of various applications of information technology. For example, there are several computer software packages which are useful for the Chemistry Curriculum, e.g. *Chemistry Animations*, *Nomenclature of Organic Compounds*, *Visualising Chemistry I and II*, and *Modern Chemical Techniques*. Also of value are multi-media databases which provide interactive access to information presented in a variety of forms, e.g. *Reactions of Metals* and other commercially available ones such as *ChemSet 2000*. In addition, various websites are rich sources of relevant information – for example, the websites of the Chinese Chemical Society, the Royal Society of Chemistry, the American Chemical Society and *the WebElements periodic table*. Finally, data-logging system, a computer-based data acquisition technology, can make an important contribution to the learning and teaching of chemistry.

6.3.3 Resource Materials from the EDB

New resource materials on learning and teaching strategies as well as the investigative study in Chemistry will be developed by the EDB to provide ideas on designing appropriate learning and teaching activities for students.

Existing resource materials such as *Exemplars of Learning Materials for S4–5 Chemistry* (EMB, 2003c), *Exemplars of Learning and Teaching Activities for the Sixth Form Chemistry Curriculum* (EMB, 2005b) and *Nomenclature of Organic Compounds* (EMB, 2004) will be updated to meet the requirements of the Chemistry Curriculum. Resources such as

Inquiry-based Chemistry Experiments (ED, 2002), *Chemistry Animations* (EMB, 2003a), *Resource Book for Sixth-form Practical Chemistry* (CUHK, EMB & HKEAA, 2004) and *Visualising Chemistry I and II* (EMB, 2006) are also appropriate for use with the Chemistry Curriculum, but teachers may need to make adjustments when using them.

The handbook *Safety in Science Laboratories* (EDB, 2013) and Materials Safety Data Sheets (MSDS) are valuable resources that provide guidelines and information related to laboratory safety in routine laboratory experiments, and more importantly, in designing experiments for the Investigative Study in Chemistry.

Publications from various collaborative research and development projects such as *Informed Decisions in Science Education, Assessment for Learning in Science, Infusing Process and Thinking Skills and Collaborative Development of Assessment Tasks and Assessment Criteria to Enhance Learning and Teaching in Science Curriculum* are also good sources of information for teachers.

A list of resource materials published by the EDB is compiled for teachers' reference. In addition, to assist schools to manage curriculum change, the EDB has developed a curriculum resources directory service at http://www.edb.gov.hk/cr, which provides a central pool of ready-to-use learning and teaching resources and useful references developed by the EDB and other parties.

6.3.4 Community Resources

Resource materials relevant to the Chemistry Curriculum are readily available in the community. For instance, several tertiary institutions are playing an active role in developing science learning resource materials for secondary schools. Relevant projects include: *Case-based Learning of High School Science Subjects to Support Learning to Learn*; *Enhancing Senior Secondary Students' Understanding of Nature of Science and the Interconnection between Science*, *Technology and Society through Innovative Teaching and Learning Activities*; and *Inquiry-based Experiments and Collaborative Learning in Chemistry*.

Professional and non-government organisations are also good sources of support for the learning and teaching of chemistry, e.g. the Hong Kong Association for Mathematics and Science Education and the Hong Kong Chemical Society. They can provide opportunities for teacher development in the field, as well as other means of supporting students' learning.

Government departments such as the Environmental Protection Department, the Water Supplies Department, the Drainage Services Department and the Government Laboratory can also provide students with valuable, authentic life-wide learning experiences, and some departments offer guided educational tours for students.

Many aspects of the Chemistry Curriculum are directly related to the local environment. Visits to the Hong Kong Science Museum, the local universities and other research institutes can enhance students' interest in chemistry, and help them to understand the latest developments in the subject.

Publications from the organisers of some local science competitions such as "The Hong Kong Chemistry Olympiad for Secondary Schools" and "The Hong Kong Student Science Project Competition" provide valuable ideas on scientific investigations and inventions.

Fieldwork that involves studying the chemistry of water bodies and the quality of air samples allows students to understand key concepts for knowledge-building. Students who participate in such activities will be more motivated and have a better understanding of chemistry phenomena.

Parents can play an important part in complementing the work in school. For instance, they can support the curriculum by providing extended learning experiences outside school, e.g. by discussing the social, moral and ethical issues related to chemistry with their children; and they can instil in them an appreciation of the value of learning. Parents from different professions can also be invited to deliver speeches or lectures to the students which can help them to gain authentic knowledge from various disciplines.

6.3.5 Documentary Videos and Television Programmes

The use of audio-visual materials allows students to experience a world beyond the classroom and gives visual realisation to abstract ideas and concepts. Many videotaped science programmes are good learning and teaching materials for helping students to keep abreast of the latest scientific and technological developments.

Television series can make learning chemistry interesting and relevant. Television programmes and documentary videos produced by broadcasting organisations and professional bodies are often pitched at a level appropriate for students. Teachers are encouraged to draw students' attention to these programmes, and follow them up with discussions that help them to relate the programmes to the curriculum.

6.3.6 Journals and Newspaper Articles

Useful learning and teaching strategies, and information on the latest developments in science and technology, can be found in education and science research journals respectively. The articles in these journals usually go beyond simply reporting how to conduct learning and teaching activities – they frequently suggest how to integrate the activities into the curriculum and implement them in the classroom. A list of suitable journals is compiled for teachers' reference. School librarians may provide assistance to teachers and students in identifying and locating these journals.

Articles from local newspapers and other media also provide valuable reference materials for developing learning and teaching activities, especially on the interconnections of Science–Technology–Society–Environment. Students can collect articles on topics of interest such as the invention of LifeStraw™ and "How fireworks work". Critical examination of such articles can provide valuable learning experiences that extend classroom learning. Students are expected to have a better understanding of chemistry and to be able to develop an interest in the subject through reading interesting articles. In short, journals and newspaper articles are resources for supporting the use of "reading to learn".

6.4 Flexible Use of Learning and Teaching Resources

To assist schools in implementing the senior secondary curriculum, the EDB will continue to provide them with additional funding and allow flexibility in the use of resources. Schools are advised to refer to the relevant circulars issued by the EDB from time to time.

Teachers have to make professional judgments on how to use the resources outlined above flexibly to attain the aims and targets of the curriculum and to meet the needs of their students. As noted already, teachers should not feel obliged to use textbooks in their entirety. They can select and adapt some parts for particular learning purposes, and can modify the suggested sequences to suit their own contexts. Teachers also have to consider how to use other resources in conjunction with textbooks. For instance, viewing a short documentary video on the pros and cons of using fossil fuel can be a good introduction to the topic. This can extend students' knowledge of the chemistry of fossil fuels, and help them to evaluate the issues associated with their use. The information presented in textbooks can then be used to further enrich their understanding of the topic. In short, teachers should try to integrate various resources creatively to enhance student learning.

The following ideas can be considered when adapting learning and teaching resources to cater for student diversity:

- Make reference to the learning targets of the curriculum and identify the key building blocks in topics.
- Design differentiated learning activities that actively engage all students in the learning process.
- Tailor the learning and teaching resources for students with different abilities and learning styles by, for example, designing more challenging learning tasks or ill-defined problems for more able students, and more systematic and organised learning tasks or straightforward problems for the less able ones.

6.5 Resource Management

6.5.1 Acquisition of Resources

Students and teachers should share the responsibility for locating useful learning and teaching resources. For example, teachers can provide students with lists of recommended websites and reference books for particular topics in chemistry; and students can also search for useful resources from the Internet, libraries, government departments and other community organisations on their own, and make suggestions to enrich the teachers' lists.

6.5.2 Sharing Resources

A culture of sharing is the key to effective knowledge management. Schools should make arrangements for:

- teachers and students to share learning and teaching resources through the Intranet or other means within the school;
- teachers to form professional development groups for the exchange of experience through well-established web-based platforms such as the Hong Kong Education City website or face-to-face meetings.

6.5.3 Storing Resources

Schools should assign staff to keep up-to-date inventories of learning resources, using school Intranets or e-learning platforms to enable students and teachers to access suitable resources for specific topics easily.

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Appendix 1

Timetable arrangement and deployment of teachers to cater for the diverse needs of students

There are four subjects, Biology, Chemistry, Physics and Science (including Mode I and Mode II), offered in the Science Education KLA, leading to a number of different options for students to choose from. The provision of these options serves the needs of students pursuing different pathways. Possible ways of managing school time-tabling and deployment of teachers are discussed below.

Implementation of Mode I – Integrated Science Curriculum

If this subject is to be taken by a class of students as a single elective subject, the normal time-tabling for elective subjects can be adopted. It is a common practice in schools for teachers to be involved in teaching a course for three years. However, due to the multi-disciplinary nature of this subject, schools may consider assigning teachers with different expertise to teach this subject at different levels (S4, 5 and 6), or two teachers with different subject expertise to teach one class, so that teachers can focus more on modules with which they are familiar. This helps share out the effort required in preparing for the new curriculum.

We encourage schools to promote partnership in the preparation of lessons, team teaching and lesson observation, so that teachers can learn from each other. It is recommended that schools reserve time for collaborative lesson planning in the time-table so that teachers can work together.

In cases where a school is offering this subject to two or more classes, it is advisable to assign teachers with different subject expertise to the different classes. With special time-tabling, it is then possible to swap classes so that teachers can concentrate on the modules they are more familiar with. After a few years, the teachers will be able to cover the teaching of the whole curriculum and to monitor the progress of the students effectively.

The following illustrates the different arrangements that schools may adopt, according to their resources and the readiness of their teachers:

Option A:	One teacher teaches one class at all three levels. If the teacher is required to teach beyond his/her own expertise, more time should be allowed for his/her professional development in knowledge updating and lesson preparation.
Option B:	Teachers with different expertise share the teaching of one class. This allows them to concentrate on preparing the modules in the areas in which they are most knowledgeable.
Option C:	Two teachers with different expertise teach two classes, with each teaching one class. These teachers should share their knowledge and experience regularly and help each other in preparing resources.
Option D:	Two teachers with different expertise teach two classes, with a special time-tabling arrangement which allows them to swap their responsibilities at various times in the year.

Implementation of Mode II – Combined Science Curriculum with Biology, Chemistry and Physics

The Combined Science Curriculum is designed for students taking two elective subjects in the Science Education KLA; it comprises three parts with the content selected from the Biology, Chemistry and Physics curricula. Students will have to take the two parts that are complementary to the discipline in which they specialise. Special time-tabling and teacher deployment are needed for its smooth implementation in schools.

To help students build up a broad knowledge base, it is recommend that students should be offered more elective subjects in S4 and be guided to select two or three electives to focus on in S5 and S6. Students wishing to opt for two elective subjects in the Science Education KLA should start with all three science disciplines, using the lesson time for two elective subjects in S4, i.e. if it is planned that four periods per cycle are allocated for one elective subject, schools may arrange two to three periods per cycle for each science discipline in S4. Teachers should refer to the respective Curriculum and Assessment Guides for a selection of topics suitable for inclusion in the S4 curriculum to help students build up a broad foundation. Schools may consider the following two arrangements in S5 and S6:

A. Flexible grouping and split class arrangement

Students from two or three different classes are arranged into three groups – namely, a Biology group, a Chemistry group and a Physics group, depending on the specialised subject they opt for. As illustrated in the figure below, the students will have four periods per cycle for their specialised subject and two lessons per cycle for the other two complementary subjects.

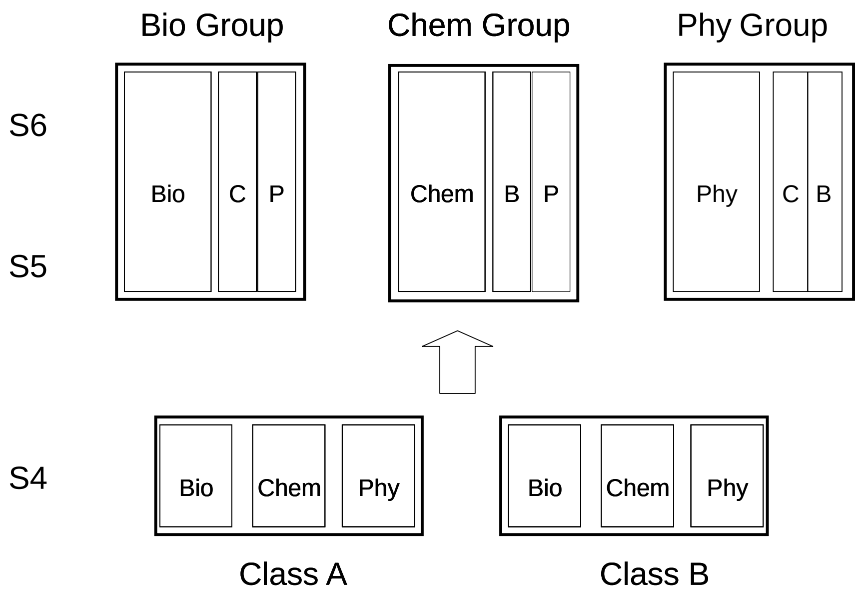

Figure A1: An Example of 2 Classes Taking Two Elective Subjects from the Science Education KLA

To implement the split-class arrangement, three common blocks in the time-table have to be arranged for the Biology, Chemistry and Physics teachers. That is, in the four periods allocated for the 1st Block, the respective subject teachers will be teaching the groups that chose to specialise in their areas. In the 2nd and 3rd Block, they will give two lessons each to the groups taking the other two specialised subjects.

	Biology Teacher	**Chemistry Teacher**	**Physics Teacher**
1st Block (4 periods)	Biology (Bio Group)	Chemistry (Chem Group)	Physics (Phy Group)
2nd Block (2 periods)	Biology part of Combined Science (Chem Group)	Chemistry part of Combined Science (Phy Group)	Physics part of Combined Science (Bio Group)
3rd Block (2 periods)	Biology part of Combined Science (Phy Group)	Chemistry part of Combined Science (Bio Group)	Physics part of Combined Science (Chem Group)

B. Block time-table arrangement

Schools may arrange three common blocks in the time-table for three classes. The three subjects in each block will share the same time slots in the time-table. In each block, students may take any one subject from the three subjects offered in the block.

<table>
<tr><th></th><th>Class A</th><th>Class B</th><th>Class C</th><th>Other Classes</th></tr>
<tr><td rowspan="4">Core Subjects</td><td>Chin Lang</td><td>Chin Lang</td><td>Chin Lang</td><td>Chin Lang</td></tr>
<tr><td>Eng Lang</td><td>Eng Lang</td><td>Eng Lang</td><td>Eng Lang</td></tr>
<tr><td>Math</td><td>Math</td><td>Math</td><td>Math</td></tr>
<tr><td>LS</td><td>LS</td><td>LS</td><td>LS</td></tr>
<tr><td>1st Block</td><td colspan="3">Biology / Combined Science (Chem, Bio) / X from other KLAs</td><td>Integrated Science</td></tr>
<tr><td>2nd Block</td><td colspan="3">Chemistry / Combined Science (Phy, Chem) / X from other KLAs</td><td>X from other KLAs</td></tr>
<tr><td>3rd Block</td><td colspan="3">Physics / Combined Science (Bio, Phy) / X from other KLAs</td><td>X from other KLAs</td></tr>
</table>

In the above arrangement, X is an elective subject from the other KLAs or an ApL course. Students in Classes A, B and C are offered the following possible choices:

- Biology + 2X
- Chemistry + 2X
- Physics + 2X
- Biology + Combined Science (Phy, Chem) + X
- Chemistry + Combined Science (Bio, Phy) + X
- Physics + Combined Science (Chem, Bio) + X
- Biology + Chemistry + X
- Chemistry + Physics + X
- Biology + Physics + X
- Biology + Chemistry + Physics
- 3X (from other KLAs / ApL course)

From the time-table, it is clear that two teachers of each science discipline are needed. For example, in the 2nd common block, one chemistry teacher is needed to teach four lessons of Chemistry, and another chemistry teacher is needed to teach the two lessons for the chemistry part of the Combined Science.

Appendix 2

Experimental techniques for the Chemistry Curriculum

Chemistry is a practical oriented discipline of science, and there are numerous relevant experimental techniques. In this curriculum, teachers are expected to make use of different learning and teaching activities to help students develop an understanding of various experimental techniques. To facilitate this, the following is a list of some experimental techniques and related suggested learning and teaching activities. Please note that the list is not exhaustive, and the experimental techniques listed here are not all mandatory in the curriculum.

Experimental technique	**Examples of relevant experiments**
Collection of gases	● Cracking of a petroleum fraction and testing the products (Topic V) ● Investigating changes in electrolysis (Topic VII) ● Studying the progress of a reaction (Topic IX)
Crystallisation	● Experiments of physical separation including evaporation, distillation, crystallisation and filtration (Topic I) ● Preparing and isolating soluble salts (Topic IV) ● Separating a mixture of known substances (Topic XV)
Determination of melting and boiling points	● Preparing ethanoic acid or ethyl ethanoate (Topic XI) ● Preparing 2-chloro-2-methylpropane from 2-methylpropan-2-ol (Topic XI)
Distillation and reflux	● Experiments of physical separation including evaporation, distillation, crystallisation and filtration (Topic I) ● Preparing ethanoic acid or ethyl ethanoate (Topic XI)
Filtration	● Doing problem-solving exercises on separating mixtures (Topic I) ● Preparing and isolating soluble and insoluble salts (Topic IV) ● Investigating the iron content in some commercial ‘iron tablets’ (Topic XV)

Experimental technique	Examples of relevant experiments
Handling of colorimeter, pH meter and datalogging system	● Measuring pH value of substances by using data-logger or pH meter (Topic IV) ● Investigating the effect of changes in concentration of reactant, temperature, surface area, or the use of catalyst on reaction rate (Topic IX) ● Determining the concentration of an unknown solution using a colorimeter (Topic XV)
Flame test	● Carrying out the flame test (Topic I) ● Detecting the presence of certain chemical species in a sample (Topic XV)
Handling of simple electrical devices	● Investigating the migration of ions towards oppositely charged electrodes (Topic II) ● Comparing strengths of acids/alkalis (Topic IV) ● Making simple chemical cells and measuring their voltages (Topic VII) ● Designing and performing electroplating experiments (Topic VII)
Liquid-liquid extraction	● Separating a mixture of known substances (Topic XV)
Simple chromatography	● Analysing a mixture by paper chromatography, column chromatography or thin layer chromatography (Topic XV)
Use of electronic balance	● Determining the empirical formula of magnesium oxide or copper(II) oxide (Topic III) ● Preparing a standard solution for volumetric analysis (Topic IV) ● Analysing commercial aspirin tablets (Topic XI)

Experimental technique	Examples of relevant experiments
Use of thermometers	● Determining the strength of the hydrogen bonding formed between ethanol molecules (Topic VI) ● Determining standard enthalpy change of acid-base neutralisation and combustion of alcohols (Topic VIII) ● Investigating the effect of change in temperature on reaction rate (Topic IX) ● Determining the activation energy of a chemical reaction (Topic XIII)
Use of timing devices	● Determining standard enthalpy change of acid-base neutralisation (Topic VIII) ● Studying the progress of a reaction (Topic IX) ● Investigating the effect of changes in concentration of reactant, temperature, surface area, or the use of catalyst on reaction rate (Topic IX) ● Investigating ways to change the rate of a reaction with a suitable catalyst (Topic XIII)
Use of volumetric apparatus	● Preparing and isolating soluble salts (Topic IV) ● Performing acid-alkali titrations using suitable indicators/data-logger (Topic IV) ● Determining K_c of a chemical equilibrium system (Topic X) ● Titrimetric analysis of chloride using silver nitrate with chromate indicator (Topic XV)

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Glossary

Term	Description
Applied Learning (ApL, formerly known as Career-oriented Studies)	Applied Learning (ApL, formerly known as Career-oriented Studies) is an essential component of the senior secondary (SS) curriculum. ApL uses broad professional and vocational fields as the learning platform, developing students' foundation skills, thinking skills, people skills, values and attitudes, and career-related competencies, to prepare them for further studies and / or for work as well as for lifelong learning. ApL courses complement 24 senior secondary subjects, diversifying the senior secondary curriculum.
Assessment objectives	The outcomes of the curriculum to be assessed in the pubic assessment.
Biliterate and trilingual	Capable of reading and writing effectively in Standard Written Chinese, English and to use Cantonese, Putonghua and spoken English. The language education policy of Hong Kong is to enable the Hong Kong students to become biliterate (in written Chinese and English) and trilingual (in Cantonese, Putonghua and spoken English).
Co-construction	Different from the direct instruction and construction approaches to learning and teaching, the co-construction approach emphasises the class as a community of learners who contribute collectively to the creation of knowledge and the building of criteria for judging such knowledge.
Core subjects	Subjects recommended for all students to take at senior secondary level: Chinese Language, English Language, Mathematics and Liberal Studies.
Curriculum and Assessment (C&A) Guide	A guide prepared by the CDC-HKEAA Committee. It embraces curriculum aims/objectives/contents and learning outcomes, and assessment guidelines.

Term	Description
Curriculum interface	Curriculum interface refers to the interface between the different key stages/educational stages of the school curriculum (including individual subjects), e.g. the interface between Kindergarten and Primary; Primary and Secondary; and Junior Secondary and Senior Secondary. The Hong Kong school curriculum, made up of eight key learning areas (under which specific subjects are categorised), provides a coherent learning framework to enhance students' capabilities for whole-person development through engaging them in the five essential learning experiences and helping them develop the nine generic skills as well as positive values and attitudes. Thus when students move on to senior secondary education, they will already have developed the basic knowledge and skills that the study of various subjects requires. When designing the learning and teaching content and strategies, teachers should build on the knowledge and learning experiences students have gained in the previous key stages.
Elective subjects	A total of 20 subjects in the proposed new system from which students may choose according to their interests, abilities and aptitudes.
Generic skills	Generic skills are skills, abilities and attributes which are fundamental in helping students to acquire, construct and apply knowledge. They are developed through the learning and teaching that take place in different subjects or key learning areas, and are transferable to different learning situations. Nine types of generic skills are identified in the Hong Kong school curriculum, i.e. collaboration skills, communication skills, creativity, critical thinking skills, information technology skills, numeracy skills, problem solving skills, self-management skills and study skills.
Hong Kong Diploma of Secondary Education (HKDSE)	The qualification to be awarded to students after completing the senior secondary curriculum and taking the public assessment.
Internal assessment	This refers to the assessment activities that are conducted regularly in school to assess students' performance in learning. Internal assessment is an inseparable part of the learning and teaching process, and it aims to make learning more effective. With the information that internal assessment provides, teachers will be able to understand students' progress in learning, provide them with appropriate feedback and make any adjustments to the learning objectives and teaching strategies they deem necessary.

Term	Description
Key learning areas (KLA)	Organisation of the school curriculum structured around fundamental concepts of major knowledge domains. It aims at providing a broad, balanced and coherent curriculum for all students in the essential learning experiences. The Hong Kong curriculum has eight KLAs, namely, Chinese Language Education, English Language Education, Mathematics Education, Personal, Social and Humanities Education, Science Education, Technology Education, Arts Education and Physical Education.
Knowledge construction	This refers to the process of learning in which learners are involved not only in acquiring new knowledge, but also in actively relating it to their prior knowledge and experience so as to create and form their own knowledge.
Learning community	A learning community refers to a group of people who have shared values and goals, and who work closely together to generate knowledge and create new ways of learning through active participation, collaboration and reflection. Such a learning community may involve not only students and teachers, but also parents and other parties in the community.
Learning differences	This refers to the gaps in learning that exist in the learning process. Catering for learning differences does not mean rigidly reducing the distance between the learners in terms of progress and development but making full use of their different talents as invaluable resources to facilitate learning and teaching. To cater to learners' varied needs and abilities, it is important that flexibility be built into the learning and teaching process to help them recognise their unique talents and to provide ample opportunities to encourage them to fulfil their potential and strive for achievement.
Learning outcomes	Learning outcomes refer to what learners should be able to do by the end of a particular stage of learning. Learning outcomes are developed based on the learning targets and objectives of the curriculum for the purpose of evaluating learning effectiveness. Learning outcomes also describe the levels of performance that learners should attain after completing a particular key stage of learning and serve as a tool for promoting learning and teaching.

Term	Description
Learning targets and learning objectives	● Learning targets set out broadly the knowledge/concepts, skills, values and attitudes that students need to learn and develop. ● Learning objectives define specifically what students should know, value and be able to do in each strand of the subject in accordance with the broad subject targets at each key stage of schooling. They are to be used by teachers as a source list for curriculum, lesson and activity planning.
Level descriptors	A set of written descriptions that describe what the typical candidates performing a certain level is able to do in public assessments.
Other learning experiences	For whole person development of students, 'Other Learning Experiences' (OLE) is one of the three components that complement the examination subjects and Applied Learning (formerly named as Career-oriented Studies) under the Senior Secondary Curriculum. It includes Moral and Civic Education, Aesthetics Development, Physical Development, Community Service and Career-related Experiences.
Public assessment	The associated assessment and examination system for the Hong Kong Diploma of Secondary Education.
SBA Moderation Mechanism	The mechanism adopted by HKEAA to adjust SBA marks submitted by schools to iron out possible differences across schools in marking standards and without affecting the rank order determined by the school.
School-based assessment (SBA)	Assessments administered in schools as part of the teaching and learning process, with students being assessed by their subject teachers. Marks awarded will count towards students' public assessment results.
School-based curriculum	Schools and teachers are encouraged to adapt the central curriculum to develop their school-based curriculum to help their students achieve the subject targets and overall aims of education. Measures may include readjusting the learning targets, varying the organisation of contents, adding optional studies and adapting learning, teaching and assessment strategies. A school-based curriculum, hence, is the outcome of a balance between official recommendations and the autonomy of the schools and teachers.

Term	Description
Standards-referenced Reporting	Candidates' performance in public assessment is reported in terms of levels of performance matched against a set of standards.
Student diversity	Students are individuals with varied family, social, economic and cultural backgrounds and learning experience. They have different talents, personalities, intelligence and interests. Their learning abilities, interests and styles are, therefore, diverse.
Student learning profile	It is to provide supplementary information on the secondary school leavers' participation and specialties during senior secondary years, in addition to their academic performance as reported in the Hong Kong Diploma of Secondary Education, including the assessment results for Applied Learning courses, thus giving a fuller picture of the student's whole person development.
Values & attitudes	Values constitute the foundation of the attitudes and beliefs that influence one's behaviour and way of life. They help form principles underlying human conduct and critical judgment, and are qualities that learners should develop. Some examples of values are rights and responsibilities, commitment, honesty and national identity. Closely associated with values are attitudes. The latter supports motivation and cognitive functioning, and affects one's way of reacting to events or situations. Since both values and attitudes significantly affect the way a student learns, they form an important part of the school curriculum.

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