CHEMISTRY CURRICULUM AND ASSESSMENT GUIDE (SECONDARY 4 – 6)
(FIRST IMPLEMENTED IN THE 2018/19 SCHOOL YEAR FOR SECONDARY 4 STUDENTS)

NOTES FOR TEACHERS

INTRODUCTION

The Curriculum Development Council (CDC), the Education Bureau (EDB) and the Hong Kong Examinations and Assessment Authority (HKEAA) have jointly reviewed the Chemistry curriculum and assessment, after the first cycle of implementation of the revised Chemistry Curriculum commenced in the 2013/14 school year. Recommendations have been put forward based on the views and suggestions collected from frontline teachers and other stakeholders.

This document consists of two parts. Part I aims to illustrate the recommendations for the curriculum contents with the changes on the overviews, learning objectives (students should learn), learning outcomes (students should be able to), suggested learning and teaching activities, values and attitudes, and science-technology-society-environment connections of the curriculum topics. These recommendations are to be implemented in the 2018/19 school year for Secondary 4 students who will sit the 2021 HKDSE Examination. Teachers should also make reference to the captioned Guide (or the Guide) published in 2007 (with updates in 2018) by the CDC and the HKEAA when planning the curriculum. The revised curriculum in Part I of this document refers to sections 2.3.1 and 2.3.2 of the Guide.

Part II aims to highlight some key aspects of the Guide, and to interpret the depth and breadth of some topics of the Curriculum for the reference of teachers. The explanatory notes listed in this part are by no means exhaustive nor intended to dictate the scope of learning and teaching at the classrooms. Instead, the notes serve as a reference for teachers to plan how to implement the curriculum in consideration of their students' interests and abilities, and availability of teaching time and resources.

PART I – UPDATES FOR THE CHEMISTRY CURRICULUM
(FIRST IMPLEMENTED IN THE 2018/19 SCHOOL YEAR FOR SECONDARY 4 STUDENTS)

Compulsory Part

Topic I Planet Earth

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

Students should learn	**Students should be able to**
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
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

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

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

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

Students should be able to

- 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

Students should learn

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

Students should be able to

- 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.
- writing balanced chemical equations with the aid of computer simulations.
- 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.
- interpreting the observations from a chemical demonstration of the displacement reaction between zinc and copper(II) oxide solid.
- writing ionic equations.
- performing an experiment~~s~~ to determine the empirical formula of ~~magnesium oxide or~~ copper(II) oxide.
- performing calculations related to moles and reacting masses.
- performing an experiment to study the thermal decomposition of baking soda / sodium hydrogencarbonate and solving the related stoichiometric problems.
- 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

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 solutions
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 concentration 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.
- performing an experiment for distinguishing a strong acid and a weak acid having the same pH value.
- 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

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 like free radicals.

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	**Students should be able to**
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	• 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~~ suitable diagrams or equations • 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 • structures, 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

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~~ bonds and their partial charges. With reference to polarity of bonds and molecular shape, students should be able to explain the polarity of a molecule. The knowledge of ~~bond~~ polarity of molecules will in turn assist students in understanding the different natures of intermolecular forces. Students should also be able to understand the origin, nature and strength 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~~ its structure~~s~~. 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 how the ~~unequal~~ sharing of electrons in covalent bonds leads to non-polar and polar bonds • ~~identify~~ explain the ~~partial charges of~~ polar nature of molecules (such as HF, H_2O, NH_3 and $CHCl_3$) and the non-polar nature of molecules (such as CH_4 and BF_3) with reference to electronegativity, polarity of bonds and molecular shape • ~~explain the non-polar nature of CH_4 and BF_3~~

Students should learn	Students should be able to
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
c. Structures and properties of ~~molecular crystals~~ ice	• describe the structures of ice ~~and C_{60}~~ • state and explain the properties of ice ~~and C_{60}~~ in terms of ~~their~~ its 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.
- investigating the shapes of some selected molecules with the aid of computer simulations.

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~~ one atom thick two-dimensional crystal graphene.

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.
- Graphenes are being studied for use in high-performance applications such as gas-free water filtration system, graphene-enhanced sports equipment and graphene super capacitors.

Topic VII Redox Reactions, Chemical Cells and Electrolysis

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	• distinguish between primary and secondary cells
• uses of chemical cells in relation to their characteristics such as size, voltage, capacity, rechargeability and price	• 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

Students should learn	**Students should be able to**
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
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

Students should learn	**Students should be able to**
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
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: in electroplating 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 study electrolysis of tin(II) chloride solution or dilute sodium chloride solution using microscale apparatus.
- 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

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~~ recognise 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

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)
- performing an experiment to follow the progress of a catalysed decomposition of H_2O_2(aq) through measuring the change in height of foam in the presence of a surfactant / dish detergent.
- 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

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

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 *cis-trans* 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-ene.
- 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.
- performing an experiment to study the reduction of vanillin to vanillyl alcohol using sodium borohydride as reducing agent.
- 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 esters from different alkanoic acids and alcohols using microscale apparatus.
- preparing benzoic acid by alkaline hydrolysis of ethyl benzoate.
- 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

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.

Elective Part (Select any 2 out of 3)

Topic XIII Industrial Chemistry

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: $\log k = \text{constant} - \frac{E_a}{2.3RT}$	• 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:

- performing an experiment to determine the order of reaction for the decolourisation of phenolphthalein in a highly alkaline medium.
- 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

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.
- performing an experiment to synthesise silver nanoparticles from silver nitrate solution and sodium borohydride solution.
- 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 uses.
- 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

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 method 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 an experiment for the iodometric titration of ascorbic acid in a sample of vitamin C tablets or fruit juices.
- 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.
- performing experiments to separate and identify the major components of the selected over-the-counter analgesics by thin layer chromatography.
- planning and performing an experiment to determine the concentration of an unknown solution using a colorimeter.
- performing experiments to determine the amount of food dye present in soft drinks by using custom-made LED 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.

PART II – EXPLANATORY NOTES FOR THE CHEMISTRY CURRICULUM (FIRST IMPLEMENTED IN THE 2018/19 SCHOOL YEAR FOR SECONDARY 4 STUDENTS)

Introduction

This part aims to highlight some key aspects of the Guide, and to interpret the depth and breadth of some topics of the Curriculum for the reference of teachers.[1]

The Curriculum is neither intended to be a one-size-fit-all one, nor a prescription for all. With this in mind, teachers have to make professional judgement according to their own school contexts, student aspirations, etc. in planning their own curricula.

An annex (Page II-10) has been included in this part to further elaborate the details of the typical reactions in Topic XI of the Curriculum.

A. General Notes

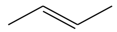
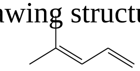
- **Breadth and depth of the curriculum**
  - **"Overview", "What students should learn" and "What students should be able to"** – The three parts in each of the topics of the Guide are intended to describe the breadth and depth of the curriculum, and should be taken as the key focuses of learning, teaching and assessment for all.
  - **Suggested Learning and Teaching Activities** – This part in each of the topics of the Guide lists possible activities that may enable students to acquire some of the skills associated with the topic. The list is a guide for teachers rather than a mandatory list. Some activities are challenging for students of average abilities and can be a starting point of an investigative study in chemistry. Teachers are encouraged to select and adopt some of these activities according to the learning targets and other school specific factors. Teachers are encouraged to read section 2.3 of the Guide for details.
- **Curriculum Planning** – This chapter of the Guide provides suggestions for teachers on how to integrate different topics for better learning, strategies for catering for learner diversities, etc. Teachers are encouraged to read Chapter 3 of the Guide for details.
- **Application of Knowledge and Concepts** – One of the scientific thinking skills expected in this Curriculum is that students should be able to integrate new concepts into their existing knowledge framework, and apply them to new situations. With this in mind and if deemed appropriate, teachers are encouraged to provide opportunities for students to

[1] This explanatory notes for the Chemistry curriculum is only applicable to the 2021 HKDSE examination and thereafter. For students who will sit the 2019 or 2020 HKDSE examinations, teachers should refer to the explanatory notes disseminated earlier. The notes can be downloaded at http://www.edb.gov.hk/attachment/en/curriculum-development/kla/science-edu/ref-and-resources/Supplementary_note_for_Chem_30Oct2015_e.pdf.

apply chemical knowledge to explain observations and solve problems which may involve unfamiliar situations. In such a case, students should be provided with sufficient information or required scaffolds. Please read sections 2.2 and 5.3 of the Guide for more information.

- **Role of Textbooks for Learning and Teaching** – Among all the resource materials designed for the Curriculum, textbooks are perhaps the most important one. Textbooks do provide a good support to students and teachers. However, textbooks should not be regarded as the manifested breadth and depth of the curriculum. Teaching with the textbooks from cover to cover is not necessarily the best means to help students master the curriculum. Rather, textbooks can be used in different ways: e.g. selected parts of the textbooks are used as pre- and post-lesson reading materials, as scaffold for interactive learning during lessons, and as resources for consolidation of learning after schools or at home. Teachers are encouraged to read section 6.3.1 of the Guide and make professional judgement such that the intended curriculum can be implemented, with the support of textbooks, appropriately in their classrooms for their own groups of students.

B. Topic Specific Notes

Topic	Students should learn	Students should be able to	Notes
IV (f)	Volumetric analysis involving acids and alkalis • standard solutions • acid-alkali titrations	• apply the concepts of concentration of solution and use the results of acid-alkali titrations to solve stoichiometric problems	• With sufficient information given, students should be able to solve problems involving back titration. (Please read the note for back titration involving aspirin on page II-7.)
V (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	• 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	• The use of different notations in drawing structural formulae of organic compounds (e.g.  ) is expected. • Students should be able to give systematic names of alkanes, alkenes, alkanols and alkanoic acids with carbon chains not more than eight carbon atoms (mentioned in the overview of the topic in the Guide). • Students should be able to give systematic names for organic compounds with multiple functional groups of the same type, e.g. propane-1,2,3-triol. For other compounds with multiple functional groups, the use of order of priority of principal functional groups is not expected.[2] • Students should be able to give systematic names for organic compounds with unsaturated carbon-carbon bonds and/or halogen substituents, e.g. 3,3-dichloropropene and 2-bromopent-3-en-1-ol.
V (c)	Alkanes and alkenes	• Describe the steps involved in the monosubstitution of methane with chlorine using suitable diagrams or equations	• The use of suitable diagrams or chemical equations in describing the reaction steps (e.g. $CH_4 + Cl\cdot \rightarrow CH_3\cdot + HCl$) is acceptable.

[2] Reference: http://www.acdlabs.com/iupac/nomenclature/93/r93_326.htm

Topic	Students should learn	Students should be able to	Notes
V (d)	Addition polymers	• understand that alkenes and unsaturated compounds can undergo addition polymerisation	• Students should be reminded that the carbon-carbon double bonds in benzene and phenyl group of the aromatic compounds will not undergo addition polymerisation. • Students are not expected to explain the stability of benzene and aromatic compounds.
VI (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 how the sharing of electrons in covalent bonds leads to non-polar and polar bonds • explain the polar nature of molecules (such as HF, H_2O, NH_3 and $CHCl_3$) and the non-polar nature of molecules (such as CH_4 and BF_3) with reference to electronegativity, polarity of bonds and molecular shape	• Dipole moment (i.e. the magnitude of the separated charge x the distance between the charges) is not expected. • Students are not expected to memorise the electronegativity scales. But they should be able to describe the general trend in electronegativity of elements in the Periodic Table so that they can identify the partial charges in polar molecules.
VI (b)	Intermolecular forces • van der Waals' forces	• 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	• Classifying van der Waals' forces into "dipole-dipole forces", "dispersion forces", "permanent dipole-permanent dipole attractions", "permanent dipole-induced dipole attractions", "instantaneous dipole-induced dipole attractions" etc. is not expected.[3] However, students should be able to state the factors affecting the strength of van der Waals' forces between molecules and differentiate van der Waals' forces in non-polar and polar covalent substances.
VI (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)	• Students are not expected to explain shapes of molecules and predict the shapes of polyatomic ions or molecules with more than one central atom. • Stating bond angles for the molecules is not expected.

[3] Reference: http://goldbook.iupac.org/V06597.html

Topic	Students should learn	Students should be able to	Notes
VII (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	• 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	• Describing structures and working principles of zinc-carbon cell, alkaline manganese cell, silver oxide cell, lithium ion cell, nickel metal hydride (NiMH) cell and lead-acid accumulator are not expected.
VII (d)	Redox reactions in chemical cells • chemical cells with inert electrodes • fuel cell		• With sufficient information given, students should be able to apply the concepts of electrochemistry to solve problems involving more complicated chemical cells.
VIII (a)	Energy changes in chemical reactions	• recognise enthalpy change, ΔH, as heat change at constant pressure	• Deriving the relation between enthalpy change and heat change at constant pressure is not expected.
VIII (b)	Standard enthalpy changes of reactions	• carry out experimental determination of enthalpy changes using simple calorimetric method	• Principle and operation procedure of a bomb calorimeter are not expected (mentioned in the overview of the topic in the Guide).
IX (a)	Rate of chemical reaction • methods of following the progress of a chemical reaction	• 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	• Calculation and instrumentation details of different techniques to follow reaction progress are not expected. • Calibration curve and related details of colorimetry are covered in “Analytical Chemistry”.
IX (b)	Factors affecting rate of reaction • concentration • temperature • surface area • catalyst	• 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	• Maxwell-Boltzmann distribution curve in explaining the effect of changes in temperature on the rate of reaction is covered in “Industrial Chemistry”. • Students are expected to be aware of the importance of catalyst, but not to describe specific industrial processes and biological systems (mentioned in the overview of the topic in the Guide).

Topic	Students should learn	Students should be able to	Notes
X (c)	The effect of changes in concentration and temperature on chemical equilibria	• 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	• Only a single homogenous reaction will be referred to when predicting changes in concentration and temperature on chemical equilibria (mentioned in the overview of the topic in the Guide). • $\ell n\,K = \text{constant} - \frac{\Delta H}{RT}$ or $\log K = \text{constant} - \frac{\Delta H}{2.3RT}$ is not expected. • Details of the contact process are not expected. • Students should be able to use the reaction quotient to deduce the effect of change in concentration on the position of chemical equilibrium.
XI (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	• Students should be able to give systematic names of alkanes, alkenes, haloalkanes, alcohols, aldehydes and ketones, carboxylic acids, esters, unsubstituted amides and primary amines with carbon chains not more than eight carbon atoms (mentioned in the overview of the topic in the Guide). • Students should be able to give systematic names for organic compounds with multiple functional groups of the same type, e.g. propane-1,2,3-triol. For other compounds with multiple functional groups, the use of order of priority of principal functional groups is not expected.[4] • Students should be able to give systematic names for organic compounds with unsaturated carbon-carbon bonds and/or halogen substituents, e.g. 3,3-dichloropropene and 2-bromopent-3-en-1-ol.

[4] Reference: http://www.acdlabs.com/iupac/nomenclature/93/r93_326.htm

Topic	Students should learn	Students should be able to	Notes
XI (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	• recognise the existence of *cis-trans* isomerism in acyclic carbon compounds resulting from restricted rotation about a C=C bond • recognise the existence of enantiomerism in compounds with only one chiral carbon	• Describing and explaining properties of specific examples of *cis-trans* isomers such as butenedioic acid are not expected. However, students are expected to apply their knowledge acquired in Topic VI to relate structures of *cis-trans* isomers to their properties. • Students should be able to recognise that enantiomers of a chiral compound can rotate the plane of plane-polarised light by the same extent, but in opposite directions. However, details of polarimetry and concepts related to racemic mixture are not expected.
XI (c)	Typical reactions of various functional groups (Annex)	• 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	• Reactions included are summarised in Annex. • Reactivity of haloalkanes in their substitution with hydroxide ions is not expected. • Amide formation from carboxylic acids is confined to unsubstituted amide. • For describing the substitution reactions of alcohols with halides, the use of the notations HX and PX_3 as the reagents is acceptable at this level of study (X = Cl, Br or I). However, experimental details of how to produce HX and PX_3 for the reactions are not expected.
XI (e)	Important organic substances • structure and medical applications of acetylsalicylic acid (aspirin)	• 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	• Analysing aspirin tablets by back titration is not expected. (Please read the note for back titration on page II-3.)

Topic	Students should learn	Students should be able to	Notes
XIII (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	• Details of industrial processes of the production of vitamin C are not expected.
XIII (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	• Half-life of a reaction is not expected.
XIII (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	• Details of industrial processes of the manufacture of acetic acid are not expected.
XIV (d)	Synthetic materials in modern life • liquid crystals	• 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	• Recall of molecular formulae of substances that exhibit liquid-crystalline behaviour is not expected.

Topic	Students should learn	Students should be able to	Notes
XV (c)	Quantitative method 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	• Details of specific chemical processes involved in volumetric analysis, other than those included in the previous topics, are not expected.

ANNEX

Reactions in Topic XI (c)	Remarks
Alkane $\xrightarrow[\text{UV light, light or heat}]{X_2}$ Haloalkane	X_2 : Cl_2, Br_2
Alkene $\xrightarrow{X_2 \text{ (in organic solvent)}}$ Haloalkane	X_2: Cl_2, Br_2, I_2
Alkene $\xrightarrow[\text{Pt, Ni or Pd}]{H_2}$ Alkane	Suitable catalysts: platinum (Pt), nickel (Ni) or palladium (Pd)
Alkene $\xrightarrow{HX}$ Haloalkane	HX: HF, HBr, HCl, HI Prediction of major product by Markovnikov's Rule is required
Haloalkane $\xrightarrow{OH^- (aq)}$ Alcohol	Relative reactivity of different haloalkanes is not required
Alcohol $\xrightarrow{HX \text{ or } PX_3}$ Haloalkane	HX: HCl, HBr, HI PX_3: PCl_3, PBr_3, PI_3
Alcohol $\xrightarrow[\text{or conc. } H_2SO_4\text{, heat}]{Al_2O_3\text{, heat}}$ Alkene	
1° Alcohol $\xrightarrow[\text{heat}]{Cr_2O_7^{2-}(aq) / H^+(aq)}$ Aldehyde or Carboxylic acid	
2° Alcohol $\xrightarrow[\text{heat}]{Cr_2O_7^{2-}(aq) / H^+(aq)}$ Ketone	

Reactions in Topic XI (c)	Remarks
Ketone or Aldehyde $\xrightarrow[\text{2. } H^+(aq)]{\text{1. } LiAlH_4\text{, dry ether}}$ Alcohol Ketone or Aldehyde $\xrightarrow{NaBH_4(aq)}$ Alcohol	
Aldehyde $\xrightarrow[\text{heat}]{Cr_2O_7^{2-}(aq)\ /\ H^+(aq)}$ Carboxylic acid	
Carboxylic acid + Alcohol $\xrightleftharpoons{\text{conc. } H_2SO_4\text{, heat}}$ Ester + Water	
Carboxylic acid $\xrightarrow[\text{2. } H^+(aq)]{\text{1. } LiAlH_4\text{, dry ether}}$ Alcohol	
Carboxylic acid $\xrightarrow[\text{2. } NH_3]{\text{1. } PCl_3}$ Unsubstituted amide Carboxylic acid $\xrightarrow{NH_3\text{, heat}}$ Unsubstituted amide	
Ester $\xrightarrow{OH^-(aq)\text{, heat}}$ Carboxylate + Alcohol Carboxylate $\xrightarrow{H^+(aq)}$ Carboxylic acid Ester $\xrightleftharpoons{H^+(aq)\text{, heat}}$ Carboxylic acid + Alcohol	

Reactions in Topic XI (c)	Remarks
N-Substituted amide $\xrightarrow{OH^-(aq),\ heat}$ Carboxylate + Alkylamine $\xrightarrow{H^+(aq)}$ Carboxylic acid + Alkylammonium salt	
Unsubstituted amide $\xrightarrow{OH^-(aq),\ heat}$ Carboxylate + Ammonia $\xrightarrow{H^+(aq)}$ Carboxylic acid + Ammonium salt	
N-Substituted amide $\xrightarrow{H^+(aq),\ heat}$ Carboxylic acid + Alkylammonium salt	
Unsubstituted amide $\xrightarrow{H^+(aq),\ heat}$ Carboxylic acid + Ammonium salt	