CHEMISTRY
SYLLABUS
Pre-University
Higher 3
Syllabus 9813

Implementation starting with
2018 Pre-University One Cohort

Ministry of Education
SINGAPORE

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1. INTRODUCTION

1.1 Background

The MOE-H3 Chemistry (9813) syllabus has been designed to build on and extend the knowledge, understanding and skills acquired from the H2 Chemistry (9729) syllabus. It caters to students of strong ability and keen interest in chemistry, and is designed with a strong emphasis on independent and self-directed learning. Students should simultaneously offer H2 Chemistry. The H3 Chemistry syllabus is meant to nurture students' passion for the subject and provide greater depth and rigour in the subject for those pursuing further studies in chemistry-related fields.

1.2 Aims

The aims of a course based on this syllabus should be to:

1. provide students an experience that deepens their knowledge and skills, and fosters attitudes necessary for further studies in related fields;

2. develop in students the appreciation of the practice, value and rigour of chemistry as a discipline; and

3. develop in students the skills to analyse chemical issues, and to apply relevant concepts and techniques to solve problems.

1.3 Practices of Science (POS)

Science as a discipline is more than the acquisition of a body of knowledge (e.g. scientific facts, concepts, laws, and theories); it is a way of knowing and doing. It includes an understanding of the nature of scientific knowledge and how this knowledge is generated, established and communicated. Scientists rely on a set of established procedures and practices associated with scientific inquiry to gather evidence and test their ideas on how the natural world works. However, there is no single method and the real process of science is often complex and iterative, following many different paths. While science is powerful, generating knowledge that forms the basis for many technological feats and innovations, it has limitations.

Teaching students the nature of science helps them develop an accurate understanding of what science is and how it is practised and applied in society. Students should be encouraged to consider relevant ethical issues, how scientific knowledge is developed, and the strengths and limitations of science. Teaching the nature of science also enhances the students' understanding of science content, increases their interest in science and helps show its human side. Science teaching should emphasise *how* we know as well as *what* we know.

Understanding the nature of scientific knowledge, demonstrating science inquiry skills and relating science and society are the three components that form our Practices of Science. Students' understanding of the nature and limitations of science and scientific inquiry are developed effectively when the practices are taught in the context of relevant science content. Attitudes relevant to science such as inquisitiveness, concern for accuracy and precision, objectivity, integrity and perseverance are emphasised.

The curriculum provides opportunities for students to reflect how the Practices of Science contribute to the accumulation of scientific knowledge. Students are encouraged to think about the 'whys' when planning and conducting investigations, developing models[1] or engaging in scientific arguments. Through such reflection, they can come to understand the importance of each practice and develop a nuanced appreciation of the nature of science.

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[1] A model is a representation of an idea, an object, a process or a system that is used to describe and explain phenomena that cannot be experienced directly. Models exist in different forms from the concrete, such as physical scale models, to abstract representations, such as diagrams or mathematical expressions. The use of models involves the understanding that all models contain approximations and assumptions limiting their validity and predictive power.

Developing 21st Century Competencies Through the Learning of Science

To prepare our students for the future, a Framework for 21st Century Competencies (21CC) and Student Outcomes was developed by MOE (see Figure 1.1). This 21CC framework is meant to equip students with the key competencies and mindsets to be successful in the 21st century, even as we maintain our strong fundamentals in teaching and learning.

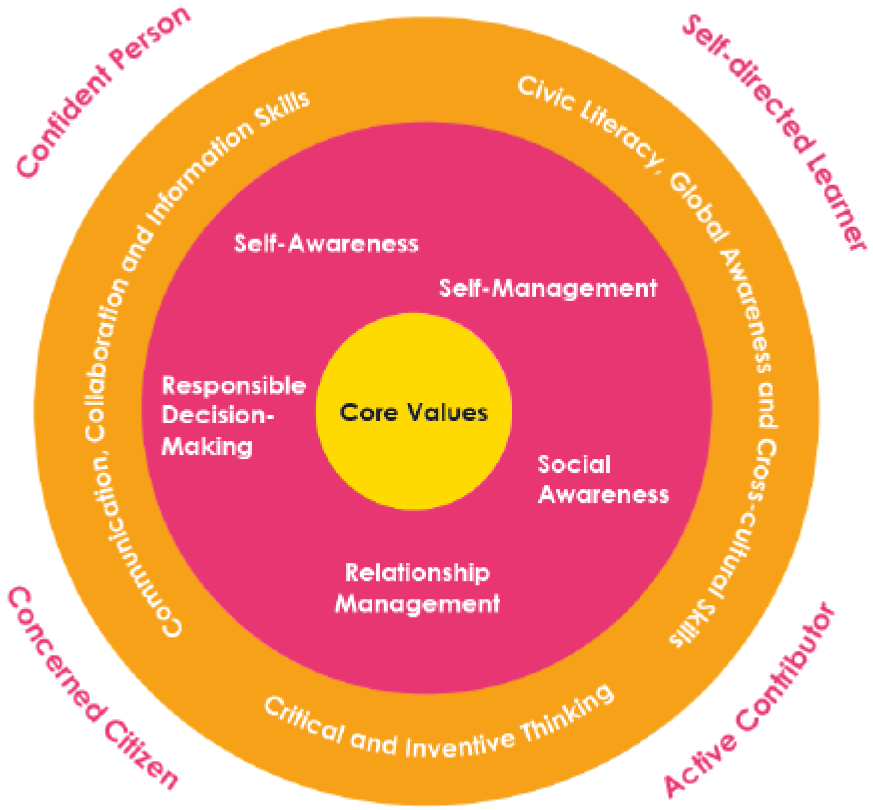

Figure 1.1: Framework for 21st Century Competencies and Student Outcomes

The features and intent of the Practices of Science are consistent with the emphasis on developing 21CC in our students.

The development of 21CC should not be seen as separate from the learning of science. The features of scientific inquiry, such as the processes of scientific investigation, reasoning, modelling and problem solving support a student's development of 21CC. The nature and limitations of science and scientific inquiry are developed effectively when scientific practices are learnt in the context of relevant science content. Deep disciplinary learning in science develops 21CC and promotes the process of learning for transfer to other areas of life.

1.4 H3 Chemistry Curriculum Framework

The H3 Chemistry framework (see Figure 1.2) is built on H2 Chemistry, anchored by the three Core Ideas – (1) Matter, (2) Structure and Properties, and (3) Transformation. Throughout the study of H3 Chemistry, explicit links will be made to the Core Ideas, deepening students' understanding of their knowledge in these Core Ideas and the Practices of Science. Learning Experiences also feature prominently in H3 Chemistry to enhance students' learning.

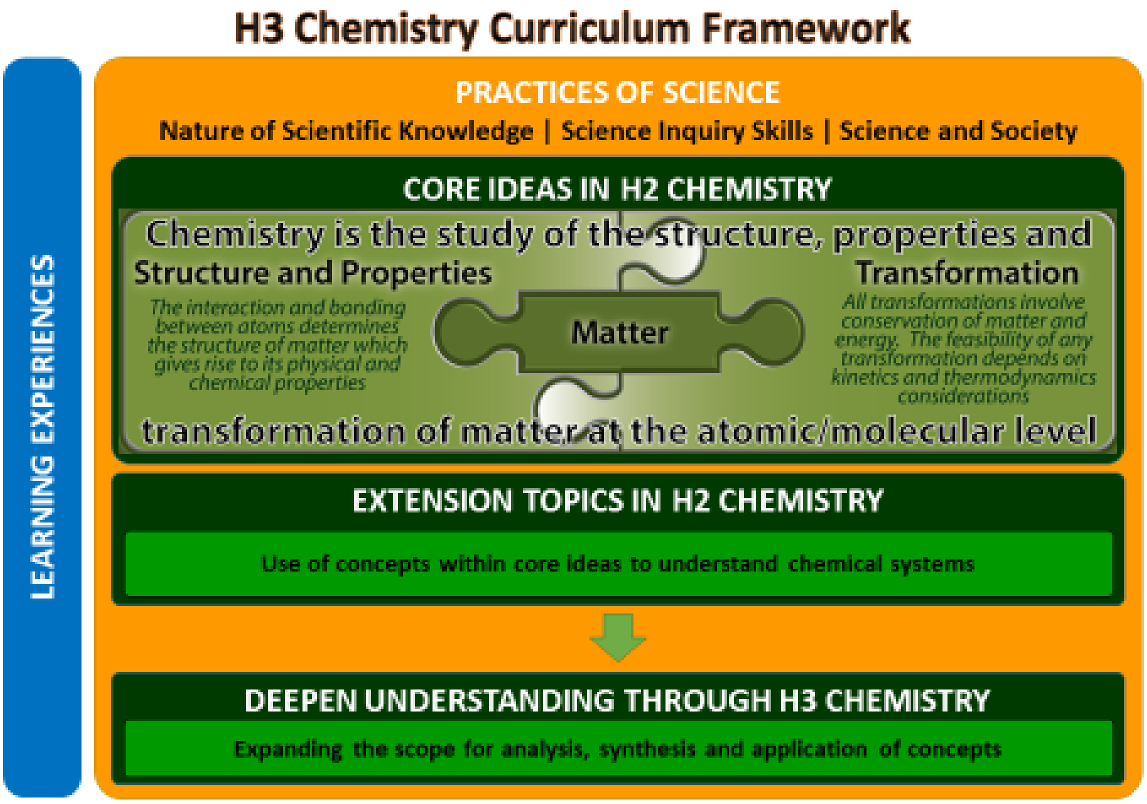

Figure 1.2: H3 Chemistry Curriculum Framework

Core Ideas and Extension Topics

The topics in H3 Chemistry are organised into three levels underpinned by the Practices of Science:

- <u>Core Ideas</u>: The three Core Ideas of Chemistry are **Matter**, **Structure and Properties**, and **Transformation**. The concepts in these Core Ideas are inter-related and form the basis for which further learning and understanding of chemical phenomena and reactions is built upon.

- <u>Extension Topics</u>: Concepts in the Core Ideas extend into the learning of different chemical systems such as the chemistry of organic compounds and transition elements. As an example, an understanding of the concepts of Chemical Bonding and

The Periodic Table is extended to the study of the chemistry of transition metals where students learn to appreciate the similarities and differences when comparing with main group metals.

- Additional Content: Spectroscopic Techniques and Further Organic Mechanisms have been chosen to complement the H2 curriculum with a stronger focus on applications. The additional content draws strong links to the core ideas and extension topics in H2 and meaningfully expands the content scope, providing the opportunity for students to apply relevant concepts and skills from H2 to tackle a more diverse range of problems. Students will engage in analysis, synthesis and integration of concepts for a wider and deeper appreciation and understanding of the discipline of chemistry.

2. CONTENT

Students who offer H3 Chemistry should have a strong foundation in H2 Chemistry. The syllabus for H3 Chemistry builds on that for H2 Chemistry, and includes the whole of the H2 Chemistry (9729) syllabus. Only content that is not already part of the H2 Chemistry syllabus is specifically set out here.

Students who offer H3 Chemistry are also expected to tackle more sophisticated problems than other students who only offer H2 Chemistry, especially because of the expanded scope.

2.1 Additional Content 1: Spectroscopic Techniques

How spectroscopy is linked to H2

Spectroscopy involves the study of the interaction between matter and electromagnetic radiation. While we are unable to "see" matter at the atomic level, spectroscopy provides a method for the structural identification of organic and inorganic compounds. There are various spectroscopic techniques involving electromagnetic radiation of different frequencies. Spectroscopy is widely used in modern research and its applications span across all fields of science and society.

The study of spectroscopy will broaden students' perspective on analytical chemistry – the branch of chemistry that looks into methods for determining the structure, chemical composition, or purity of matter. Analytical methods can range from qualitative (obtaining information about the identity of the atomic or molecular species, or the functional groups in the sample) to quantitative (obtaining numerical information as to the relative amount of one or more of the components in the sample).

Spectroscopy is a natural extension of H2 Chemistry, providing complementary methods of qualitative and quantitative analysis to the classical wet-lab methods that students encounter in H2 Chemistry. The introduction of spectroscopy builds on students' knowledge across the core ideas (matter, structure and properties, transformation) and extension topics (organic chemistry, transition elements).

How spectroscopy is relevant to students

In modern day chemistry, advancements in technology have led to new instrumental methods that allow for greater precision, sensitivity, selectivity, and speed of analysis. Chemical analysis could also be performed with a smaller sample size and some methods are also nondestructive. This is useful when there are limited samples (e.g. from a crime scene[2]) or if the sample is rare (e.g. an art piece[3]). Generally, there should be sufficient analyte concentration present to produce an analytical signal that can reliably be distinguished from "analytical noise," the signal produced in the absence of analyte.[4] Classical methods are useful when the analyte concentration is high, but instrumental techniques will be more appropriate for lower analyte concentration.

Students should appreciate that while these new instrumental techniques are convenient and accurate; the role of the scientist has not been relegated to a "machine operator". A single spectrum usually does not provide sufficient information, and a combination of analytical methods is often employed for structural elucidation. The scientist has to play a critical role in terms of selecting the appropriate analytical methods based on the context. Following that, the data has to be analysed and interpreted, and various bits of information have to be fitted together to obtain a conclusion about the nature of the substance.

The inclusion of this topic aims to give students insight into the physical background of spectroscopic techniques, and the skills to interpret various spectra. Students will be expected to justify their conclusions based on the spectra and other provided information through reasoning and logical argument.

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[2] Find out more about forensic science and medicine from the Health Sciences Authority website (as of 12 Sept 2018):http://www.hsa.gov.sg/content/hsa/en/Applied_Sciences/Forensic_Science/Overview_Forensic_Science.html.html

[3] Read about how science can help in art and conservation research at the Netherlands Institute for Conservation, Art and Science (as of 12 Sept 2018): http://www.nicas-research.nl/

[4] D. A. A. and T.Pry (2008). Limit of Blank, Limit of Detection and Limit of Quantitation. Clin Biochem Rev., Aug; 29 (Suppl 1): S49–S52. Retrieved from : http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2556583/ (Date of retrieval: 12 Sept 2018)

1.1. Basic Principles of Spectroscopy

Learning Outcomes Students should be able to:
(a) understand basic Molecular Orbital (MO) theory, involving (i) atomic and molecular orbitals (ii) bonding, anti-bonding and non-bonding orbitals (iii) molecular orbitals with σ and π symmetry (b) understand that molecular orbitals represent discrete electronic energy levels in molecules [see also e(ii)] (c) apply Linear Combination of Atomic Orbitals (LCAO) principles to obtain the shape and relative energies of molecular orbitals in the following: (i) simple homonuclear diatomic molecules such as H_2, O_2, F_2 (ii) benzene and linear polyenes (molecular orbitals of π symmetry only) [quantitative treatment of LCAO is **not** required] (d) construct and interpret molecular orbital diagrams, and identify the Highest Occupied Molecular Orbital (HOMO) and Lowest Unoccupied Molecular Orbital (LUMO) for the following: (i) simple homonuclear diatomic molecules such as H_2, O_2, F_2 (ii) benzene and linear polyenes (molecular orbitals of π symmetry only) [knowledge of orbital mixing between orbitals of the same symmetry is **not** required] (e) understand the following in relation to the fundamental principles of spectroscopy: (i) properties of electromagnetic radiation – the electromagnetic spectrum (with range of wavelengths for different types of radiation used in spectroscopy) – the photon as a discrete packet (quantum) of electromagnetic energy – the relationship between wavelength, frequency and speed of light, including the use of the equation, $E = hf$ (ii) the quantisation of energy in relation to – electronic, vibrational and rotational energy levels – nuclear energy levels in applied magnetic field (iii) energy level transitions associated with the absorption and emission of photons with energy matching the energy gap

1.2. Ultraviolet/visible Spectroscopy

Learning Outcomes Students should be able to:	
(a)	explain that ultraviolet/visible absorption in organic molecules requires electronic transitions ($\sigma \rightarrow \sigma^*$, $n \rightarrow \sigma^*$, $\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$ transitions; forbidden and allowed transitions) between energy levels in chromophores which contain a double or triple bond, a delocalised system, or a lone pair of electrons [detailed knowledge of instrumentation is **not** required]
(b)	predict whether a given organic molecule will absorb in the ultraviolet/visible region by identifying the chromophore
(c)	explain qualitatively how increasing conjugation in an organic molecule decreases the gap between energy levels and hence shifts the absorption towards longer wavelength
(d)	use Beer-Lambert's Law, absorbance = $\lg(I_o/I) = \varepsilon cl$, where ε is taken merely as a constant characteristic of the substance concerned, to calculate the concentration of a given species (either organic or inorganic) in solution
(e)	apply ultraviolet/visible spectroscopy to quantitative analysis of a given species (either organic or inorganic) in solution

1.3. Infra-red (IR) Spectroscopy

Learning Outcomes Students should be able to:
(a) explain the origin of IR spectroscopy in simple molecules in terms of (i) stretching vibrations (ii) bending vibrations [detailed knowledge of instrumentation is **not** required] (b) predict the number of IR absorptions for a given simple molecule (e.g. CO_2 or SO_2), and identify the molecular vibrations which give rise to them (c) identify characteristic IR absorptions in the IR spectrum of a compound which may contain different functional groups [Absorptions of common functional groups will be provided in the *Data Booklet*.] (d) suggest structures for a compound from its IR spectrum (e) predict the characteristic IR absorptions that will be present in the IR spectrum of a compound, given its structure

1.4. Nuclear Magnetic Resonance (NMR) Spectroscopy

Learning Outcomes Students should be able to:
(a) outline the basic principles of NMR with reference to (i) nuclear spin (ii) the process of absorption of energy [quantitative calculations of transitional energy are **not** required; detailed knowledge of instrumentation is **not** required] (b) understand the following features and use them in the interpretation and prediction of ^{1}H NMR spectra: (i) chemical shift (ii) deuterated solvents in the identification of labile protons (iii) the number of ^{1}H NMR signals: equivalent and non-equivalent protons (iv) peak area (integration) and proton counting (v) spin-spin splitting: first order spin-spin coupling; multiplicity (c) explain the use of the δ scale with tetramethylsilane (TMS) as the reference (d) explain the factors affecting chemical shift (i) electronegativity: inductive effect of substituents, including shielding and deshielding effects (ii) anisotropic effects (iii) hydrogen bonding

1.5 Mass Spectrometry

Learning Outcomes Students should be able to:
(a) outline the basic principles of mass spectrometry, with reference to (i) ionisation and fragmentation (ii) mass/charge ratio, *m/z* [detailed knowledge of instrumentation is **not** required] (b) understand the following features and use them in the interpretation and prediction of mass spectra: (i) molecular ion peak (ii) isotopic abundances including the use of (M+1) peak caused by ^{13}C and (M+2) and (M+4) peaks for the identification of halogen compounds (iii) major fragment ions [fragment ions obtained from rearrangements are **not** included]

2.2 Additional Content 2: Further Organic Mechanisms

How Further Organic Mechanisms is linked to H2

Further organic mechanisms involve studying the relationships between structure, bonding and reactivity in organic systems, leading to the quantitative, molecular level understanding of their properties.

Students will analyse organic structures, intermediates and mechanisms from a broader perspective that takes into consideration more factors and does not necessarily result in clear-cut conclusions. For example, in an elimination reaction, a change in temperature results in different (kinetic and thermodynamic) products. A change in solvent or base also results in a completely different reaction pathway (e.g. from elimination to substitution).

Further organic mechanisms serve as a meaningful link between the concepts of energetics and kinetics from the core idea of 'Transformation', and chemical bonding from the core idea of 'Structure and Properties'. It also enhances the bridging of the traditional 'physical chemistry' and 'organic chemistry' divide.

How Further Organic Mechanisms is relevant to students

Students should appreciate the complexities of real-world systems, where many factors can affect the reaction pathways and yields, and be able to evaluate these factors and make careful decisions to optimise the synthesis process. This mirrors what scientists do in the real world when trying to optimise a synthesis pathway to obtain high yield and high regioselectivity at a reasonable cost e.g. for drug development.

As such, students can reflect on the practices of science and better appreciate the rigour of scientific research, which contributes to the accumulation of scientific knowledge today. The fundamental linkage between structure and reactivity also has clear links to other applications in bioorganic chemistry, organometallic chemistry and material science, and is relevant to modern research approaches such as developing electronic organic materials and optimising enzymatic reactions.

2.1. Molecular Stereochemistry

Learning Outcomes Students should be able to:
(a) (i) use stereochemical projections, including Newman projection, to represent molecules (ii) interpret stereochemical projections of molecules [knowledge of Fischer projection is **not** required] (b) apply their understanding of the following types of isomerism to explain the stereochemistry of molecules, including saturated ring systems: (i) conformational isomerism, including energy barriers to rotation and interconversion (ii) *cis-trans* isomerism, including *E, Z* nomenclature (iii) enantiomerism and diastereomerism – *R*,*S* configuration – optical activity – optical purity as the excess of one enantiomer, including calculation of optical purity by the equation: optical purity = $\dfrac{[\alpha]_{\text{obs}}}{[\alpha]_{\text{pure material}}} \times 100\%$

2.2. Basic Physical Organic Chemistry

Learning Outcomes Students should be able to:
(a) understand and apply the following concepts involving kinetic control and thermodynamic control to the study of reaction mechanisms: (i) the Hammond Postulate: relationship between the transition state and the nearest stable species (ii) the Bell–Evans–Polanyi Principle – relationship between activation energy and enthalpy change of reaction – quantitative calculations based on $E_a = A + B\Delta H_r$

2.3. Nucleophilic Substitution

Learning Outcomes Students should be able to:
(a) explain how the relative rate of nucleophilic substitution is affected by the nature of the (i) nucleophile (ii) leaving group (iii) substituents (b) describe and compare the mechanisms and kinetics of S_N1 and S_N2 reactions, in terms of (i) the energy profile and rate law, including steady state approximation in S_N1 [mathematical treatment of steady state is **not** required] (ii) stereochemistry, including ion pair interactions in S_N1 (iii) substituent effects (c) explain the factors affecting competition between S_N1 and S_N2 mechanisms [solvent effects are **not** required]

2.4. Elimination

Learning Outcomes Students should be able to:
(a) understand and apply the following concepts to the study of elimination reactions: (i) *syn*- and *anti*-elimination; and its effect on stereoselectivity (ii) regioselectivity: Zaitsev (thermodynamic) and Hofmann (kinetic) product(s) (b) describe and compare the mechanisms and kinetics of E1 and E2 reactions, in terms of (i) the energy profile and rate law (ii) regioselectivity (c) explain the E2/S_N2 competition, in terms of (i) substrate effects (ii) base effects

3. PEDAGOGY

To achieve the aims of the H3 Chemistry syllabus, the learning experiences of the students should be one where they are given opportunities to:

- work independently and discuss collaboratively in solving a range of non-routine problems that require them to apply the different concepts, techniques and skills;
- explore concepts through investigations and discussions
- participate and learn through a variety of channels such as face-to-face or online talks, seminars, discussion forums, symposia and learning journeys related to Chemistry, but in which the content may not directly correspond to those within the syllabus, to allow students to explore more contemporary or inter-disciplinary topics.

The pedagogy and assessment should support this approach to learning. Formative assessment, in particular, should focus on the process of problem solving and reasoning, with feedback on the strategies used and how the presentation of solutions can be improved, beyond just a focus on the correctness of the solutions.

Learning science is more than acquiring the facts and the outcomes of scientific investigations as a body of knowledge. Science is also a way of knowing and doing. Through the Practices of Science, students should acquire an appreciation of the nature of scientific knowledge, the scientific enterprise as well as an understanding of the skills and processes in scientific inquiry:

- **Nature of scientific knowledge:** Students understand the nature of scientific knowledge implicitly through the process of 'doing science'. To complement this, an explicit approach may be used. This approach utilises elements from the history of science or the processes in science to improve students' views of the nature of scientific knowledge.

- **Science as an inquiry:** Broadly, scientific inquiry refers to the different approaches by which scientists study and develop an understanding of the natural and physical world around us. Inquiry-based instruction could be used to develop the different aspects of the Practices of Science together with the understanding of science concepts as well as the dispositions and attitudes associated with science. Strategies that could be used to support inquiry-based learning in science include questioning, demonstrations, use of technology, as well as models and modelling.

- **Relating science and society:** Students should appreciate how science and technology are used in daily life. Learning science in a real-life context accessible to students can increase their interest and enhance their awareness of the interconnections among science, technology, society and the environment.

Science practical work supports the teaching and learning of science through developing the Practices of Science, experimental techniques, practical manipulative skills and conceptual understanding. It also cultivates interest in science and in learning science. In addition, attitudes like objectivity and integrity, which are important in the learning of the discipline of science, are reinforced.

Through critical reading and scientific argumentation, scientific articles and journals could provide students with both up-to-date advances in science and authentic problems encountered by scientists. Peer discussion sessions could provide a platform for students to analyse the situation and share their thoughts. In particular, students are encouraged to read beyond the required learning outcomes, and be kept up-to-date through reading books and articles about cutting-edge science in fields such as semi-conductor chemistry, organometallic chemistry, nanochemistry, green chemistry, quantum chemistry, and so on.

Through partnership with Institutes of Higher Learning (IHLs), research institutes and industries, students are encouraged to participate in science fairs, learning journeys, workshops, seminars and dialogues with scientists. These varied experiences aim to give students an authentic taste of how science features in society, and would greatly enrich students' learning and inspire them to take up science as a career.

4. ASSESSMENT

Assessment is the process of gathering and analysing evidence about student learning. This information is used to make decisions about students, curricula and programmes. Assessment for Learning (AfL) is assessment conducted constantly during classroom instruction to support teaching and learning. With the feedback about the state of students' learning, teachers then adapt their teaching strategies and pace based on the students' needs. Assessment of Learning (AoL) aims to summarize how much or how well students have achieved at the end of a course of study over an extended period of time. The A-level examination is an example of AoL.

This syllabus is designed to place less emphasis on factual material and greater emphasis on the understanding and application of scientific concepts and principles. This approach has been adopted in recognition of the need for students to develop skills that will be of long term value in an increasingly technological world rather than focusing on large quantities of factual material which may have only short term relevance.

Experimental work is an important component and should underpin the teaching and learning of Chemistry.

4.1 ASSESSMENT OBJECTIVES

The assessment objectives listed below reflect those parts of the Aims and Practices of Science which will be assessed.

A Knowledge with understanding

Candidates should be able to demonstrate knowledge with understanding in relation to:

1. scientific phenomena, facts, laws, definitions, concepts and theories
2. scientific vocabulary, terminology, conventions (including symbols, quantities and units)
3. scientific instruments and apparatus, including techniques of operation and aspects of safety
4. scientific quantities and their determination
5. scientific and technological applications with their social, economic and environmental implications.

The syllabus content defines the factual materials that candidates need to recall and explain. Questions testing the objectives above will often begin with one of the following words: *define*, *state*, *name*, *describe*, *explain* or *outline*.

B Handling, applying and evaluating information

Candidates should be able to (in words or by using symbolic, graphical and numerical forms of presentation) to:

1. locate, select, organise, interpret and present information from a variety of sources
2. handle information, distinguishing the relevant from the extraneous
3. manipulate numerical and other data and translate information from one form to another
4. present reasoned explanations for phenomena, patterns, trends and relationships
5. make comparisons that may include the identification of similarities and differences
6. analyse and evaluate information to identify patterns, report trends, draw inferences, report conclusions and construct arguments
7. justify decisions, make predictions and propose hypotheses
8. apply knowledge, including principles, to novel situations
9. use skills, knowledge and understanding from different areas of Chemistry to solve problems
10. organise and present information, ideas and arguments clearly and coherently, using appropriate language

These assessment objectives above cannot be precisely specified in the syllabus content because questions testing such skills are often based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the H2 syllabus and additional content and apply them in a logical, reasoned or deductive manner to a novel situation. Questions testing these objectives may begin with one of the following words: *discuss*, *predict*, *suggest*, *calculate* or *determine*.

4.2 Scheme of Assessment

There is one paper (2 h 30 min, 100 marks) for this subject. This paper will consist of two sections, as follows.

Section A (60 marks)

This section will consist of a variable number of compulsory free response questions including 1 or 2 stimulus-based questions. The stimulus-based question(s) constitute(s) 15–20 marks for this paper."

Section B (40 marks)

This section will consist of a choice of two from three 20-mark longer structured questions.

Weighting of Assessment Objectives

Assessment Objectives		Weighting (%)
A	**Knowledge with understanding**	25
B	**Handling, applying and evaluating information**	75

4.3 ADDITIONAL INFORMATION

Required Subject Combinations

Candidates should simultaneously offer H2 Chemistry.

For more information on assessment, please refer to the Singapore Examinations and Assessment Board http://www.seab.gov.sg/ .

5. RESOURCES AND REFERENCES

Students may find reference to the following books helpful.

- A Primer to Mechanism in Organic Chemistry by P. Sykes, published by Longman Scientific & Technical
- Advanced Organic Chemistry (5th Edition) by F.A. Carey & R.J. Sundberg, published by Springer
- Introduction to Spectroscopy (5th Edition) by D.L. Pavia, G.M. Lampman, G.S. Kriz & J.A. Vyvyan, published by Cengage Learning
- IR Spectroscopy: An Introduction by H. Günzler & H. Gremlich, published by Wiley-VCH
- March’s Advanced Organic Chemistry: Reactions, Mechanisms, and Structure (7th Edition) by M. Smith, published by Wiley
- Modern Physical Organic Chemistry by E.V. Anslyn & D.A. Dougherty, published by University Science
- NMR Spectroscopy: Basic Principles, Concepts and Applications in Chemistry (3rd Edition) by H. Günther, published by Wiley-VCH
- Organic Mechanisms: Reactions, Stereochemistry and Synthesis (English edition) by R. Bruckner, M. Harmata & K. Beifuss, published by Springer
- Organic Spectroscopy by L.D.S. Yadav, published by Kluwer
- Organic Synthesis: The Disconnection Approach (2nd Edition) by S. Warren & P. Wyatt, published by Wiley
- Oxford Chemistry Primers: Foundations of Organic Chemistry by M. Hornby & J. Peach, published by Oxford University Press
- Oxford Chemistry Primers: Structure and Reactivity in Organic Chemistry by H. Maskill, published by Oxford University Press
- Oxford Chemistry Primers: Mechanisms of Organic Chemistry by H. Maskill, published by Oxford University Press

- Perspectives on Structure and Mechanism in Organic Chemistry (2nd Edition) by F.A. Carroll, published by Wiley

- The Art of Writing Reasonable Organic Reaction Mechanisms (2nd Edition) by R.B. Grossman, published by Springer

- UV Spectroscopy: Techniques, Instrumentation, Data handling by B.J. Clark, T. Frost & M.A. Russell, published by Chapman & Hall