Singapore Examinations and Assessment Board

Cambridge Assessment International Education

Singapore–Cambridge General Certificate of Education Normal (Academic) Level (2025)

Science

(Syllabus 5105 Science: Physics, Chemistry)
(Syllabus 5106 Science: Physics, Biology)
(Syllabus 5107 Science: Chemistry, Biology)

CONTENTS

AIMS

The syllabus aims to:

1. provide a worthwhile educational experience for all students, whether or not they go on to study science beyond this level.

2. develop in students the understanding, and skills relevant to the practices of science, and enable them to

   2.1 appreciate practical applications of science in the real world

   2.2 deepen their interest in science for future learning and work

   2.3 become scientifically literate citizens who can innovate and seize opportunities in the 21st century

   2.4 develop a way of thinking and use the disciplinary ideas to approach, analyse and solve problems in biological, chemical and physical systems.

3. develop in students the values, ethics and attitudes relevant to science such as

   3.1 curiosity – desiring to explore the environment and question what is found

   3.2 creativity – seeking innovative and relevant ways to solve problems

   3.3 integrity – handling and communicating data and information with complete honesty

   3.4 objectivity – seeking data and information to validate observations and explanations without bias

   3.5 open-mindedness – accepting all knowledge as tentative and suspending judgement, tolerance for ambiguity, willingness to change views if the evidence is convincing

   3.6 resilience – not giving up on the pursuit of answers/solutions, willingness to take risks and embrace failure as part of the learning process

   3.7 responsibility – showing care and concern for living things and awareness of our responsibility for the quality of the environment

   3.8 healthy scepticism – questioning the observations, methods, processes and data, as well as trying to review one’s own ideas.

PRACTICES OF SCIENCE

The *Practices of Science* represents the set of established procedures and practices associated with scientific inquiry, what scientific knowledge is and how it is generated and established, and how Science is applied in society respectively. It consists of three components:

1. Demonstrating Ways of Thinking and Doing in Science (WoTD)

1.1 Posing questions and defining problems

1.2 Designing investigations

1.3 Conducting experiments and testing solutions

1.4 Analysing and interpreting data

1.5 Communicating, evaluating and defending ideas with evidence

1.6 Making informed decisions and taking responsible actions

1.7 Using and developing models

1.8 Constructing explanations and designing solutions

2. Understanding the Nature of Scientific Knowledge (NOS)

2.1 Science is an evidence-based, model-building enterprise concerned with understanding the natural world

2.2 Science assumes there are natural causes for physical phenomena and an order and consistency in natural systems

2.3 Scientific knowledge is generated using a set of established procedures and practices, and through a process of critical debate within the scientific community

2.4 Scientific knowledge is reliable and durable, yet open to change in the light of new evidence

3. Relating Science, Technology, Society and Environment (STSE)

3.1 There are risks and benefits associated with the applications of science in society. Science and its applications have the potential to bring about both benefits and harm to society

3.2 Applications of science often have ethical, social, economic and environmental implications

3.3 Applications of new scientific discoveries often inspire technological advancements while advances in technology motivate scientists to ask new questions and/or empower scientists in their inquiry (e.g. collecting more precise data or carrying out more complex data analysis)

The *Practices of Science* serve to highlight that the discipline of Science is more than the acquisition of a *body of knowledge* (e.g. scientific facts, concepts, laws, and theories); it is also a way of *thinking and doing*. In particular, it is important to appreciate that the cognitive, epistemic and social aspects of the *Practices of Science* are intricately related. For example, observation of events can lead to the generation of scientific knowledge which is, simultaneously, shaped by the beliefs of scientific knowledge. In addition, scientists develop models to construct theories, based on the assumption that there is order and consistency in natural systems. The practice of theory-making, in turn, reinforces the explanatory power of scientific knowledge. The scientific endeavour is embedded in the wider ethical, social, economic and environmental contexts.

ASSESSMENT OBJECTIVES

The *Assessment Objectives* listed below reflect those parts of the *Aims* and *Practices of Science* that will be assessed.

A Knowledge with Understanding

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

1. scientific phenomena, facts, laws, definitions, concepts and theories
2. scientific vocabulary, terminology and conventions (including symbols, quantities and units contained in '*Signs, Symbols and Systematics: The ASE Companion to 16–19 Science* (2000)' and the recommendations on terms, units and symbols in '*Biological Nomenclature 4th Edition* (2009)' published by the Institute of Biology, in conjunction with the Association for Science Education)
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 subject content defines the factual knowledge that candidates may be required to recall and explain. Questions testing these objectives will often begin with one of the following words: *define, state, name, describe, explain* or *outline.* (See the *Glossary of Terms*)

B Handling Information and Solving Problems

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

1. locate, select, organise and present information from a variety of sources
2. translate information from one form to another
3. manipulate numerical and other data
4. use information to identify patterns, report trends and draw inferences
5. present reasoned explanations for phenomena, patterns and relationships
6. make predictions and propose hypotheses
7. solve problems.

These *Assessment Objectives* cannot be precisely specified in the syllabus content because questions testing such skills may be 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 syllabus and apply them in a logical, reasoned or deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *predict, deduce, suggest, calculate* or *determine*. (see the *Glossary of Terms*)

C Experimental Skills and Investigations

Candidates should be able to:

1. select and use techniques, apparatus and materials
2. take readings and record observations
3. interpret and evaluate experimental data and observations
4. evaluate methods and suggest possible improvements.

Scientific subjects are by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to facilitate the learning of this subject and to meet objectives C1–C4 above.

Weighting of Assessment Objectives

Theory Papers (Papers 1, 2, 3, 4, 5 and 6)

A Knowledge with Understanding, approximately 45% of the marks with approximately 20% allocated to recall.

B Handling Information and Solving Problems, approximately 45% of the marks.

C Experimental Skills and Investigations, approximately 10% of the marks.

Questions on experimental skills and investigations will normally be set within the bounds of the syllabus. If questions are based on apparatus or topics beyond the syllabus, candidates will not be assessed on knowledge of the apparatus or topics. They will be assessed on knowledge or general skills (e.g. reading of scales, data handling), which are required by the syllabus. Questions may be set requiring the candidates to:

(a) select appropriate experimental techniques
(b) select and use apparatus and materials
(c) draw, complete or label diagrams of apparatus
(d) record readings from diagrams of apparatus
(e) read, complete or draw tables of data
(f) take readings from or plot graphs
(g) determine a gradient, intercept or intersection on a graph
(h) interpret or draw conclusions from observations and experimental data
(i) suggest a needed modification to a step in an experiment
(j) recognise or comment on possible sources of error from experimental data
(k) comment on the safety or suggest safety procedures when using apparatus, materials and techniques.

SCHEME OF ASSESSMENT

There will be six papers of which candidates will take four as described below.

5105 Science (Physics, Chemistry) Papers 1, 2, 3, 4
5106 Science (Physics, Biology) Papers 1, 2, 5, 6
5107 Science (Chemistry, Biology) Papers 3, 4, 5, 6

The pair of Papers 1 and 2, 3 and 4, 5 and 6 will be taken in one session of 1 hour 15 minutes. Candidates will be advised not to spend more than 30 minutes on each of Papers 1, 3 and 5.

Paper	Type of Paper	Duration	Marks	Weighting
1	Multiple Choice (Physics)	1 hour 15 minutes	20	20%
2	Structured (Physics)		30	30%
3	Multiple Choice (Chemistry)	1 hour 15 minutes	20	20%
4	Structured (Chemistry)		30	30%
5	Multiple Choice (Biology)	1 hour 15 minutes	20	20%
6	Structured (Biology)		30	30%

Theory papers

Paper 1, 3, 5 (20 marks)

Each of these papers consists of 20 compulsory multiple choice questions.

A copy of The Periodic Table of Elements will be printed as part of Paper 3 for syllabuses 5105 and 5107.

Paper 2, 4, 6 (30 marks)

Each of these papers consists of *two* sections.

Section A will carry 22 marks and will contain a number of compulsory structured questions. The last question will carry 8 marks.

Section B will carry 8 marks and will contain *two* structured questions. Candidates must answer only one out of these two questions.

A copy of The Periodic Table of Elements will be printed as part of Paper 4 for syllabuses 5105 and 5107.

Physics section

INTRODUCTION

The N-Level Science (Physics) Syllabus provides students with a coherent understanding of energy, matter, and their interrelationships. It focuses on investigating natural phenomena and then applying patterns, models (including mathematical ones), principles, theories and laws to explain the physical behaviour of the universe. The theories and concepts presented in this syllabus belong to a branch of physics commonly referred to as classical physics. Modern physics, developed to explain the quantum properties at the atomic and sub-atomic level, is built on knowledge of these classical theories and concepts.

Students should think of physics in terms of scales. Whereas the classical theories such as Newton's laws of motion apply to common physical systems that are larger than the size of atoms, a more comprehensive theory, quantum theory, is needed to describe systems that are very small, at the atomic and sub-atomic scales. It is at this atomic and sub-atomic scale that physicists are currently making new discoveries and inventing new applications.

It is envisaged that teaching and learning programmes based on this syllabus would feature a wide variety of learning experiences designed to promote acquisition of scientific expertise and understanding, and to develop values and attitudes relevant to science. Teachers are encouraged to use a combination of appropriate strategies to effectively engage and challenge their students. It is expected that students will apply investigative and problem-solving skills, effectively communicate the theoretical concepts covered in this course and appreciate the contribution physics makes to our understanding of the physical world.

DISCIPLINARY IDEAS OF PHYSICS

The disciplinary ideas of Physics represent the overarching ideas essential for the understanding of Physics. An understanding of these ideas helps students see the interconnectedness of ideas within and across the sub-disciplines of Physics. Equipping students with a coherent view and conceptual framework facilitates the application and transfer of learning. These disciplinary ideas can be revisited and deepened at higher levels of learning and beyond the schooling years.

Disciplinary ideas are introduced at the upper secondary levels when students begin to specialise in the sub-disciplines of science.

1. Matter and energy make up the Universe
2. Matter interacts through forces and fields
3. Forces help us understand motion
4. Waves can transfer energy without transferring matter
5. Conservation laws constrain the changes in systems
6. Microscopic models can explain macroscopic phenomena

CONTENT STRUCTURE

SECTION	Topics
I. Measurement	1. Physical Quantities, Units and Measurement
II. Newtonian Mechanics	2. Kinematics 3. Force and Pressure 4. Dynamics 5. Energy
III. Thermal Physics	6. Kinetic Particle Model of Matter 7. Thermal Processes
IV. Waves	8. General Wave Properties 9. Electromagnetic Spectrum
V. Electricity and Magnetism	10. Electric Charge and Current of Electricity 11. D.C. Circuits 12. Practical Electricity
VI. Radioactivity	13. Radioactivity

SUBJECT CONTENT

SECTION I: MEASUREMENT

Overview

Physics is an experimental science and precise measurements enable the collection of useful experimental data which can be tested against hypothesis for the development of physical theories. With the development of better measurement tools and techniques, the data available is improved and scientific knowledge continue to evolve in light of new information.

There is a variety of instruments available and our choice of instrument should take into consideration the precision, and feasibility of the choice of instrument when making measurements. We need to be cognisant of the limitations associated with the measurement process which can arise from the precision of the instrument chosen, the mechanics of the measuring instrument and the design of the experiment.

Apart from the need of accurate measurements, interactions between objects in systems should also be described with precisely defined quantities and units and as these interactions could range from celestial objects to sub-atomic particles, prefixes in order-of-ten are necessary to depict such diversity in range of magnitude.

1. Physical Quantities, Units and Measurement

Content

- Physical quantities and SI units
- Measurement
- Scalars and vectors

Learning Outcomes

Candidates should be able to:

(a) show an understanding that physical quantities typically consist of a numerical magnitude and a unit

(b) recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol)

(c) use the following prefixes and their symbols to indicate decimal sub-multiples and multiples of the SI units: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)

(d) show an understanding of the orders of magnitude of the sizes of common objects ranging from a typical atom to the Earth

(e) select and explain the use of appropriate measuring instruments to measure or determine physical quantities listed in ‘Summary of key quantities, symbols and units’ taking into consideration the range and precision of the instrument

(f) state what is meant by *scalar* and *vector* quantities and give common examples of each

SECTION II: NEWTONIAN MECHANICS

Overview

Mechanics is the branch of physics that deals with the study of motion and its causes. Through a careful process of observation and experimentation, Galileo Galilei used experiments to overturn Aristotle's ideas of the motion of objects, for example the flawed idea that heavy objects fall faster than lighter ones, which dominated physics for about 2,000 years.

The greatest contribution to the development of mechanics is by one of the greatest physicists of all time, Isaac Newton. By extending Galileo's methods and understanding of motion and gravitation, Newton developed the three laws of motion and his law of universal gravitation, and successfully applied them to both terrestrial and celestial systems to predict and explain phenomena. He showed that nature is governed by a few special rules or laws that can be expressed in mathematical formulae. Newton's combination of logical experimentation and mathematical analysis shaped the way science has been done ever since.

2. Kinematics

Content

- Speed, velocity and acceleration
- Graphical analysis of motion
- Free-fall

Learning Outcomes

Candidates should be able to:

(a) state what is meant by speed and velocity

(b) calculate *average speed = distance travelled / time taken*

(c) state what is meant by *uniform acceleration* and calculate the value of acceleration using *change in velocity / time taken*

(d) interpret given examples of non-uniform acceleration

(e) plot and interpret a distance-time graph and a speed-time graph for motion in one direction.

(f) deduce from the shape of a distance-time graph when a body travelling in one direction is:
  (i) at rest
  (ii) moving with uniform speed
  (iii) moving with non-uniform speed

(g) deduce from the shape of a speed-time graph when a body travelling in one direction is:
  (i) at rest
  (ii) moving with uniform speed
  (iii) moving with uniform acceleration
  (iv) moving with non-uniform acceleration

(h) calculate the area under a speed-time graph to determine the distance travelled for motion in one direction with uniform speed or uniform acceleration

(i) state that the acceleration of free fall for a body near to the Earth is constant and is approximately 10 m/s^2

3. Force and Pressure

Content

- Types of forces
- Mass, weight and gravitational field
- Density
- Pressure

Learning Outcomes

Candidates should be able to:

(a) identify and distinguish between contact forces (e.g. friction, air resistance, tension and normal force) and non-contact forces (e.g. gravitational, electrostatic and magnetic forces)

(b) state that mass is a measure of the amount of matter in a body

(c) state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction

(d) define gravitational field strength, g, as *gravitational force per unit mass placed at that point*

(e) recall and apply the relationship *weight = mass* × *gravitational field strength* to new situations or to solve related problems

(f) distinguish between mass and weight

(g) recall and apply the relationship *density = mass / volume* to new situations or to solve related problems

(h) define pressure in terms of force and area

(i) recall and apply the relationship *pressure = force / area* to new situations or to solve related problems

4. Dynamics

Content

- Newton's laws of motion
- Effects of resistive forces on motion

Learning Outcomes

Candidates should be able to:

(a) apply Newton's Laws to:
   (i) describe the effect of balanced and unbalanced forces on a body
   (ii) describe the ways in which a force may change the motion of a body
   (iii) identify action-reaction pairs acting on two interacting bodies
   (stating of Newton's Laws is not required)

(b) identify forces acting on a body and draw free body diagram(s) representing the forces acting on the body (for cases involving forces acting in one dimension)

(c) recall and apply the relationship *resultant force = mass × acceleration* to new situations or to solve related problems

(d) explain the effects of friction on the motion of a body

5. Energy

Content

- Energy stores and transfers
- Work
- Power

Learning Outcomes

Candidates should be able to:

(a) show an understanding that there are energy stores, e.g. kinetic, potential (gravitational, chemical, elastic), nuclear and internal, and that energy that can be transferred from one store to another:
  (i) Mechanically (by a force acting over a distance)
  (ii) Electrically (by an electric current)
  (iii) By heating (due to a temperature difference)
  (iv) By propagation of waves (both electromagnetic and mechanical)

(b) recall and apply the relationships for kinetic energy ($E_k = \frac{1}{2} m v^2$) and gravitational potential energy near the Earth's surface ($E_p = mgh$) to new situations or to solve related problems

(c) state the principle of the conservation of energy and apply the principle to new situations or to solve related problems

(d) recall and apply the relationship *work done = force × distance moved in the direction of the force* to new situations or to solve related problems

(e) recall and apply the relationship *power = energy transfer / time taken* to new situations or to solve related problems

SECTION III: THERMAL PHYSICS

Overview

When asked what was the most valuable scientific information in a single sentence, Richard Feynman response was, ‘All things are made of atoms – little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. In that one sentence ... there is an enormous amount of information about the world.’ (Six Easy Pieces, p.4)

Understanding thermal physics requires us to approach the concepts from both the macroscopic and microscopic lenses. The *Kinetic Model of Matter* is a cornerstone theory that is used extensively to explain how different types of matter exhibit certain physical properties by relating them to behaviour of atoms and molecules.

By nature, energy exchange takes place between bodies of different temperatures until thermal equilibrium is reached. Energy may be transferred between bodies by heating through processes like conduction, convection and radiation. These processes could cause changes in the molecular structure of matter and result in macroscopic observations, e.g. monsoon winds and ocean currents observed are convectional currents produced in the process of regulating differences in temperature.

6. Kinetic Particle Model of Matter

Content

- States of matter
- Kinetic Particle Model
- Internal energy

Learning Outcomes

Candidates should be able to:

(a) compare the physical properties of solids, liquids and gases

(b) use the kinetic particle model to describe the different states of matter (solids, liquids and gases), relating their physical properties to the arrangement and motion of the particles (e.g. molecules, atoms) and the forces and distances between particles

(c) relate the rise in temperature of a body to the increase in average kinetic energy of all the particles in the body

(d) describe internal energy as an energy store that is made up of the total kinetic energy associated with the random motion of the particles and the total potential energy between the particles in the system

(e) describe melting/solidification and boiling/condensation as processes of energy transfer without a change in temperature

7. Thermal Processes

Content

- Thermal equilibrium
- Conduction
- Convection
- Radiation

Learning Outcomes

Candidates should be able to:

(a) show an understanding that energy is transferred (by *heating*) from a region of higher temperature to a region of lower temperature until thermal equilibrium is achieved between the two regions

(b) describe, in microscopic terms, how conduction occurs in solids (via vibration of atoms/molecules and movement of electrons)

(c) describe, in terms of density changes, how convection occurs in fluids

(d) explain that energy transfer by electromagnetic radiation does not require a material medium and that this rate of energy transfer to/from a body is affected by its:
(i) surface colour and texture
(ii) surface temperature
(iii) surface area

(e) apply the concepts of conduction, convection and radiation in everyday examples.

SECTION IV: WAVES

Overview

All waves have properties in common and a wave model can be used to explain many phenomena, both natural (like water waves and sound) and artificial (like many forms of electromagnetic waves). The ability of waves to transfer energy at great speed provides valuable propositions.

Much of our current understanding of wave motion has come from the study of acoustics, which is the science of sound. Many of the ancient Greek philosophers were interested in music. They had hypothesized that there was a connection between waves and sound, and that vibrations must be responsible for sounds. Pythagoras observed in 550 BC that vibrating strings produced sound and worked to determine the mathematical relationships between the lengths of strings that made harmonious tones.

Scientific theories of wave propagation became more prominent in the 17th Century, when Galileo Galilei published a clear statement that connected vibrating bodies to the sounds they produce. In 1640 Robert Boyle's classic experiment on the sound produced by a ticking watch in a partially evacuated glass vessel provided evidence that air is necessary, either for the production or transmission of sound.

The mathematical theory of sound propagation began with Isaac Newton, whose *Principia* (1686) included a mechanical interpretation of sound as being 'pressure' pulses transmitted through neighbouring fluid particles. In the 18th Century, French mathematician and scientist Jean Le Rond d'Alembert derived the wave equation, a thorough and general mathematical description of waves, which laid the foundation for generations of scientists to study and describe wave phenomena.

8. General Properties of Waves

Content

- Describing wave motion
- Wave properties
- Longitudinal and transverse waves

Learning Outcomes

Candidates should be able to:

(a) describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by waves in a ripple tank (including use of the term wavefront)

(b) show an understanding that waves transfer energy without transferring matter

(c) define and use the terms *speed, frequency, wavelength, period* and *amplitude* including graphical representation

(d) recall and apply the relationship *speed of wave* = *frequency* × *wavelength* to new situations or to solve related problems

(e) compare transverse and longitudinal waves and give suitable examples of each

9. Electromagnetic Spectrum

Content

- Properties of electromagnetic waves
- Applications of electromagnetic waves
- Effects of electromagnetic waves on cells and tissues

Learning Outcomes

Candidates should be able to:

(a) state that all electromagnetic waves are transverse waves that travel with the same speed in vacuum

(b) describe the main regions of the electromagnetic spectrum in order of wavelength and frequency

(c) state examples of typical uses of the following regions of the electromagnetic spectrum:
- (i) radio waves (e.g. radio and television communication, astronomy and RFID tags)
- (ii) microwaves (e.g. mobile (cell) phones, microwave oven and satellite television)
- (iii) infrared (e.g. infrared remote controllers, intruder alarms and thermal imaging)
- (iv) visible light (e.g. photography, optical fibres in medicine and telecommunications)
- (v) ultraviolet (e.g. sunbeds, bank note authentication and disinfecting water)
- (vi) X-rays (e.g. medical radiology, security screening and industrial defect detection)
- (vii) gamma (γ) rays (e.g. sterilising food, detection of cancer and its treatment)

(d) describe how over-exposure to electromagnetic waves can have hazardous effects (e.g. heating and ionising effects of radiation) on living cells and tissue

SECTION V: ELECTRICITY AND MAGNETISM

Overview

Electricity and magnetism were seen as separate and independent phenomena in the past. It only was when Danish physicist Hans Christian Ørsted discovered, accidentally, in 1820 that a magnetic needle is deflected when the current in a nearby wire varies - a phenomenon establishing a relationship between electricity and magnetism.

Inspired by Ørsted's discovery, André-Marie Ampère conducted a series of experiments in the same year designed to elucidate the exact nature of the relationship between electric current-flow and magnetism. Further works by Michael Faraday reinforced the magnetic effect of a current and introduced the idea of a 'field' of action to explain why electricity and magnetism had an 'area of activity'.

However, it was the work of James Clerk Maxwell, a mathematical physicist, who provided mathematical tools and equations to describe Faraday's ideas of the field. His works went on to prove that electromagnetic fields have wave-like properties which was a very important discovery in physics.

10. Electric Charge and Current of Electricity

Content

- Electric charge
- Conventional current and electron flow
- Electromotive force and potential difference
- Resistance

Learning Outcomes

Candidates should be able to:

(a) state that there are positive and negative charges and that charge is measured in coulombs

(b) state that unlike charges attract and like charges repel

(c) state that current is the rate of flow of charge and that it is measured in amperes

(d) distinguish between conventional current and electron flow

(e) recall and apply the relationship *charge* = *current* × *time* to new situations or to solve related problems

(f) state that the electromotive force (e.m.f.) of an electrical source of energy is measured in volts

(g) state that the potential difference (p.d.) across a component in a circuit is the work done per unit charge in driving charges through the component and that it is measured in volts

(h) state that *resistance = p.d./current*

(i) apply the relationship $R = V / I$ to new situations or to solve related problems

(j) recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems

11. D.C. Circuits

Content

- Circuit diagrams
- Series and parallel circuits

Learning Outcomes

Candidates should be able to:

(a) draw circuit diagrams with power sources (cell or battery), switches, lamps, light-emitting diodes (LEDs), resistors (fixed and variable), fuses, ammeters and voltmeters

(b) state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems

(c) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems

(d) state that the sum of the currents in the separate branches of a parallel circuit is equal to the current from the source and apply the principle to new situations or to solve related problems

(e) state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems

(f) recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems

(g) recall and apply the relevant relationships, including $R = V/I$ and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit.

12. Practical Electricity

Content

- Electrical working, power and energy
- Dangers of electricity
- Safe use of electricity in the home

Learning Outcomes

Candidates should be able to:

(a) describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters

(b) recall and apply the relationships $P = VI$ and $E = VIt$ to new situations or to solve related problems

(c) calculate the cost of using electrical appliances where the energy unit is the kW h

(d) state the hazards of using electricity in the following situations:
(i) damaged insulation
(ii) overheating of cables
(iii) damp conditions

(e) explain the use of fuses and circuit breakers in electrical circuits and of fuse ratings

(f) explain the need for earthing metal casings and for double insulation

(g) state the meaning of the terms *live, neutral* and *earth*

(h) describe the wiring in a mains plug

(i) explain why switches, fuses, and circuit breakers are fitted to the live wire.

SECTION VI: RADIOACTIVITY

Overview

Radioactivity was first discovered through the handling of radioactive uranium by physicists Pierre and Marie Curie during which they suffered radioactive burns due to inadequate handling of the substance. *Radioactivity* is the study of the nature of the radiation emitted by radioactive materials. It was later understood that there are three types of emissions: the alpha particles (helium atoms with no electrons), beta particles (fast moving electrons) and the gamma rays (electromagnetic radiation similar to X-rays). These emissions are the result of the decay or disintegration of an unstable atomic nucleus.

Radioactivity has important medical uses, which include the killing of cancer cells. However excessive exposure to radioactivity can cause cancer if the dose is too high. Many early scientists working with radioactive materials died early from the harmful effects of high radiation before proper safety guidelines were drawn. 'Radiometric dating' makes use of a radioactive element's half-life to help determine the age of rocks or carbon.

Large amounts of energy are also involved in radioactive emissions and physicists quickly recognised the power of this. Many scientists working on this from 1930 to 1940 in Europe were forced to leave their home countries, fleeing to the United States due to the development of the war. This led to a 'brain drain' which benefited the United States and allowed them to develop the two atomic bombs which ended the war. This highlights the impact of science on society and human interactions. Since the development of the atomic bomb, much has been learnt about how to control the release of energy and nuclear power can generate electricity with only a fraction of the greenhouse gases released by burning coal and other fossil fuels.

Because radiation cannot be easily seen, it is commonly feared and shunned. Coupled with news about the dangers of nuclear radiation and the potential detriments to health, the general public is apprehensive about the use and application of any form of radiation. This topic aims to provide an objective evaluation of the risks and benefits of the use of radiation through the development of a good understanding of the many practical uses of radioactive materials.

13. Radioactivity

Content

- The composition of the atom
- Radioactive decay
- Dangers and uses of radioactivity

Learning Outcomes

Candidates should be able to:

(a) describe the composition of an atom in terms of a positively charged nucleus (with protons and neutrons) and negatively charged electrons

(b) use the terms proton (atomic) number Z, nucleon (mass) number A and isotope

(c) use and interpret the term nuclide and use the nuclide notation ${}^{A}_{Z}X$

(d) show an understanding that nuclear decay is a random and spontaneous process whereby an unstable nucleus loses energy by emitting radiation

(e) show an understanding of the nature of alpha (α), beta (β), and gamma (γ) radiation (including ionising effect and penetrating power) [β-particles are assumed to be β^- particles only]

(f) show an understanding of background radiation

(g) use the term half-life in simple calculations, which might involve information in tables or decay curves

(h) state the applications (e.g. medical and industrial uses) and hazards of radioactivity.

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

Candidates should be able to state the symbols for the following physical quantities and, where indicated, state the units in which they are measured. Candidates should be able to define those items indicated by an asterisk (*).

Quantity	***Symbol***	***Unit***
length	*l*, *h* . . .	km, m, cm, mm
area	*A*	m^2, cm^2
volume	*V*	m^3, cm^3
weight*	*W*	N
mass	*m*, *M*	kg, g, mg
time	*t*	h, min, s, ms
period*	*T*	s
density*	ρ	g/cm^3, kg/m^3
speed*	*u*, *v*	km/h, m/s, cm/s
acceleration*	*a*	m/s^2
acceleration of free fall	*g*	m/s^2, N/kg
force*	*F*, *f*	N
moment of force*		N m
work done*	*W*, *E*	J
energy	*E*	J, kW h
power*	*P*	W
pressure*	*p*, *P*	N / m^2, Pa
temperature	θ, *T*	°C, K
frequency*	*f*	Hz
wavelength*	λ	m, cm
potential difference*/voltage	*V*	V, mV
current*	*I*	A, mA
charge	*q*, Q	C, A s
e.m.f.*	*E*	V
resistance	*R*	Ω
proton number	*Z*	
nucleon number	*A*	
half-life	$t_{1/2}$	s
activity of a radioactive source	*A*	Bq

PRACTICAL GUIDELINES

Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to support and facilitate the learning of this subject. A list of practical work is provided below. Candidates are expected to show familiarity with laboratory practical procedures and to have carried out at least four practical tasks from this list.

1. Measurements of:

   (i) length by using tapes, rules, digital calipers and digital micrometers
   (ii) time interval (including period of a simple pendulum) by using digital stopwatches
   (iii) volume of solids/liquids by using measuring cylinders
   (iv) mass and weight by using electronic balances and spring balances
   (v) temperature by using laboratory thermometers
   (vi) current and voltage by using ammeters and voltmeters

2. Determination of the density of a liquid, or of a regularly or irregularly shaped solid that sinks in water

3. Determination of the value of the acceleration of free fall

4. Investigation of the effects of balanced and unbalanced forces

5. Investigation of the factors affecting transfer of energy by thermal processes

6. Determination of the resistance of a circuit component

This is not intended to be an exhaustive list. Reference may be made to the techniques used in these experiments in the theory papers but no detailed description of the experimental procedures will be required. Candidates may be asked about other practical work and appropriate guidance will be provided where unfamiliar experiments are involved.

Chemistry section

INTRODUCTION

The Normal (Academic) Level (Chemistry) Syllabus is designed to place less emphasis on factual materials while having a 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 complex and globalised world, rather than focusing on large quantities of factual materials, which may have only short-term relevance.

It is envisaged that teaching and learning programmes based on this syllabus will feature a wide variety of learning experiences designed to promote acquisition of scientific expertise and understanding, and to develop values and attitudes relevant to science. Teachers are encouraged to use a combination of appropriate strategies including developing practical works for their students to facilitate a greater understanding of the subject. It is expected that students will apply investigative and problem-solving skills and effectively communicate the theoretical concepts covered in this course.

DISCIPLINARY IDEAS OF CHEMISTRY

The disciplinary ideas of Chemistry described below represent the overarching ideas which can be applied to explain, analyse and solve a variety of problems that seek to address the broader questions of what matter is and how particles interact with one another. Equipping students with a coherent view and conceptual framework facilitates the application and transfer of learning. These disciplinary ideas can be revisited and deepened at higher levels of learning and beyond the schooling years.

1. Matter is made up of a variety of chemical elements, each with characteristic properties, and the smallest particle that characterises a chemical element is an atom.
2. The structure of matter and its chemical and physical properties are determined by the arrangement of particles and electrostatic interactions between them.
3. Energy changes across and within systems usually occur during physical and chemical changes, when there is rearrangement of particles.
4. Energy plays a key role in influencing the rate and extent of physical and chemical changes.
5. Matter and energy are conserved in all physical and chemical changes.

CONTENT STRUCTURE

SECTION	Topics
I. Matter – Structures and Properties	1. Experimental Chemistry 2. The Particulate Nature of Matter 3. Chemical Bonding and Structure
II. Chemical Reactions	4. Chemical Calculations 5. Acid-Base Chemistry 6. Qualitative Analysis 7. Patterns in the Periodic Table
III. Chemistry in a Sustainable World	8. Organic Chemistry 9. Maintaining Air Quality

SUBJECT CONTENT

SECTION I: MATTER – STRUCTURES AND PROPERTIES

Overview

Matter is understood in terms of particles, the way particles are arranged and the forces that hold them together. Evidence of the particulate nature of matter come from daily observable phenomena such as diffusion and crystal growth. The simplest particle is known as an atom, which consists of sub-atomic particles like protons, neutrons and electrons. A myriad of molecules with different properties are formed from the atoms of hundreds of elements discovered to date. The physical properties of a substance are determined by how its particles are arranged (i.e. structure) and the strength of the electrostatic forces between them.

Chemistry is typically an experimental science and relies primarily on practical work. This section also examines the appropriate use of simple apparatus and chemicals, and experimental techniques.

1. Experimental Chemistry

Content

1.1 Experimental Design

1.2 Methods of Purification and Analysis

Learning Outcomes

Candidates should be able to:

1.1 Experimental Design

(a) name appropriate apparatus for the measurement of time, temperature, mass and volume; including burettes, pipettes, measuring cylinders and gas syringes

(b) suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases.

1.2 Methods of Purification and Analysis

(a) describe methods of separation and purification for the components of mixtures, to include:
  (i) use of a suitable solvent, filtration and crystallisation or evaporation
  (ii) distillation and fractional distillation (see also **8.1**(b))
  (iii) paper chromatography

(b) suggest suitable separation and purification methods, given information about the substances involved in the following types of mixtures:
  (i) solid-solid
  (ii) solid-liquid
  (iii) liquid-liquid (miscible)

(c) interpret paper chromatograms including comparison with 'known' samples (the use of R_f values is **not** required)

(d) deduce from given melting point and boiling point data the identities of substances and their purity.

2. The Particulate Nature of Matter

Content

2.1 Kinetic Particle Theory

2.2 Atomic Structure

Learning Outcomes

Candidates should be able to:

2.1 Kinetic Particle Theory

(a) describe the solid, liquid and gaseous states of matter and explain their interconversion in terms of the kinetic particle theory and of the energy changes involved.

2.2 Atomic Structure

(a) state the relative charges and approximate relative masses of a proton, a neutron and an electron

(b) describe, with the aid of diagrams, the structure of an atom as consisting of protons and neutrons (nucleons) in the nucleus and electrons arranged in shells (energy levels)

(knowledge of s, p, d and f classification is **not** required; a copy of the Periodic Table will be available in the examination)

(c) define *proton (atomic) number* and *nucleon (mass) number*

(d) interpret and use nuclide notations such as $^{12}_{6}C$

(e) define the term *isotopes*

(f) deduce the numbers of protons, neutrons and electrons in atoms and ions given proton and nucleon numbers.

3. Chemical Bonding and Structure

Content

3.1 Ionic Bonding

3.2 Covalent Bonding

3.3 Structure and Properties of Materials

Learning Outcomes

Candidates should be able to:

3.1 Ionic Bonding

(a) describe the formation of ions by electron loss/gain and that these ions usually have the electronic configuration of a noble gas

(b) describe, including the use of 'dot-and-cross' diagrams, the formation of ionic bonds between metals and non-metals, e.g. $NaCl$; $MgCl_2$

(c) relate the physical properties (including electrical property) of ionic compounds to their lattice structure.

3.2 Covalent Bonding

(a) describe the formation of a covalent bond by the sharing of a pair of electrons and that the atoms in the molecules usually have the electronic configuration of a noble gas

(b) describe, using 'dot-and-cross' diagrams, the formation of covalent bonds between non-metallic elements, e.g. H_2; O_2; H_2O; CH_4; CO_2

(c) deduce the arrangement of electrons in other covalent molecules

(d) relate the physical properties (including electrical property) of covalent substances to their structure and bonding.

3.3 Structure and Properties of Materials

(a) describe the differences between elements, compounds and mixtures

(b) describe the general physical properties of metals as solids having high melting and boiling points, malleable and good conductors of heat and electricity

(c) describe an alloy as a mixture of a metal with another element, e.g. brass; stainless steel

(d) identify representations of metals and alloys from diagrams of structures.

SECTION II: CHEMICAL REACTIONS

Overview

This section provides an understanding of the changes at the sub-microscopic level during chemical reactions. Different types of chemical reactions are delved into and lay the foundation for understanding what happens during a chemical change. The study of reactions also reveals patterns in the chemical properties of substances, leading to the organisation of elements in the Periodic Table.

In all chemical reactions, matter is conserved and this is illustrated by balanced chemical equations. Chemists use symbols and formulae to construct these chemical equations, from which the molar ratios are used to quantify the amount of reactants and products in a reaction.

4. Chemical Calculations

Content

4.1 Formulae and Equation Writing

4.2 The Mole Concept

Learning Outcomes

Candidates should be able to:

4.1 Formulae and Equation Writing

(a) state the symbols of the elements and formulae of the compounds mentioned in the syllabus

(b) deduce the formulae of simple compounds from the relative numbers of atoms present and vice versa

(c) deduce the formulae of ionic compounds from the charges on the ions present and vice versa

(d) interpret chemical equations with state symbols

(e) construct chemical equations, with state symbols, including ionic equations.

4.2 The Mole Concept

(a) define relative atomic mass, A_r

(b) define relative molecular mass, M_r, and calculate relative molecular mass (and relative formula mass) as the sum of relative atomic masses

(c) perform calculations involving the relationship between the amount of substances in moles, mass and molar mass

(calculations of stoichiometric reacting masses and volumes of gases are **not** required).

5. Acid-Base Chemistry

Learning Outcomes

Candidates should be able to:

(a) describe the meanings of the terms acid and alkali in terms of the ions they produce in aqueous solution and their effects on Universal Indicator

(b) describe neutrality and relative acidity and alkalinity, in terms of
   (i) relative H^+ and OH^- ion concentrations,
   (ii) colour in Universal Indicator, and
   (iii) the pH scale
   (calculation of pH from hydrogen ion concentration is **not** required)

(c) describe the characteristic properties of acids as in reactions with metals, bases and carbonates to form salts
(description of the preparation of pure salts is **not** required)

(d) describe the reaction between hydrogen ions and hydroxide ions to produce water,
$H^+ + OH^- \rightarrow H_2O$, as neutralisation

(e) describe the importance of controlling the pH in soils and how excess acidity can be treated using calcium hydroxide

(f) describe the characteristic properties of bases in reactions with acids and with ammonium salts

(g) classify oxides as acidic, basic, amphoteric or neutral based on metallic/non-metallic character.

6. Qualitative Analysis

Learning Outcomes

Candidates should be able to:

(a) describe tests to identify the following gases: carbon dioxide (using limewater); hydrogen (using a burning splint); oxygen (using a glowing splint).

7. Patterns in the Periodic Table

Content

7.1 Periodic Trends

7.2 Group Properties

7.3 Reactivity Series

Learning Outcomes

Candidates should be able to:

7.1 Periodic Trends

(a) describe the Periodic Table as an arrangement of the elements in the order of increasing proton (atomic) number

(b) describe how the position of an element in the Periodic Table is related to proton number and electronic configuration

(c) explain the similarities between the elements in the same group of the Periodic Table in terms of their electronic configuration

(d) describe the change from metallic to non-metallic character from left to right across a period of the Periodic Table

(e) describe the relationship between number of outer (valence) electrons and metallic/non-metallic character

(f) predict the properties of elements in Group 1 and Group 17 using the Periodic Table.

7.2 Group Properties

(a) describe lithium, sodium and potassium in Group 1 (the alkali metals) as a collection of relatively soft, low density metals showing a trend in melting point and in their reaction with water

(b) describe chlorine, bromine and iodine in Group 17 (the halogens) as a collection of diatomic non-metals showing a trend in colour, state and their displacement reactions with solutions of other halide ions

(c) describe the lack of reactivity of the elements in Group 18 (the noble gases) in terms of their electronic configurations.

7.3 Reactivity Series

(a) place in order of reactivity calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to the reactions, if any, of the metals with water, steam and dilute hydrochloric acid

(b) deduce the order of reactivity from a given set of experimental results

(c) describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series

(d) describe the essential conditions for the corrosion (rusting) of iron as the presence of oxygen and water; prevention of rusting can be achieved by placing a barrier around the metal, e.g. painting; greasing; plastic coating.

SECTION III: CHEMISTRY IN A SUSTAINABLE WORLD

Overview

Ubiquitous in modern life, organic compounds range from the fuels we burn, the materials we use such as plastics to the food we eat. Urbanisation, industrialisation, increasing population and economic development especially in developing countries also create a huge demand for consumption of material goods and energy, accelerating the rate of waste output and emissions of pollutants. The excessive use of crude oil and its products results in detrimental effects on the environment and sustainability. Chemists have made significant contributions towards reducing these effects and improving sustainability through innovative use of chemical knowledge.

In this section, knowledge and concepts from other topics within the syllabus are applied to assess the impacts of the consumption of organic compounds like fuels and plastics, the environmental issues related to their use and the solutions afforded by chemistry.

8. Organic Chemistry

Content

8.1 Fuels and Crude Oil

8.2 Hydrocarbons

8.3 Polymers

In describing reactions, candidates will be expected to quote the reagents, e.g. aqueous bromine, and the essential conditions, e.g. high temperature and pressure. Detailed conditions involving specific temperature and pressure values are not required.

Learning Outcomes

Candidates should be able to:

8.1 Fuels and Crude Oil

(a) name natural gas, mainly methane, and crude oil as non-renewable sources of energy

(b) describe crude oil as a mixture of hydrocarbons and its separation by fractional distillation to yield fractions which have competing uses as fuels and as a source of chemicals (see also **1.2**(a))

(c) describe biofuel (exemplified by bioethanol from sugarcane) as a renewable alternative to natural gas and crude oil

(d) describe how biofuel, when compared to fossil fuels, is more environmentally sustainable in terms of the offset in carbon dioxide emission during burning by that taken in during plant growth (see also **9**(e)).

8.2 Hydrocarbons

(a) describe a homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, e.g. melting and boiling points; viscosity

(b) describe the alkanes as a homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}

(c) draw the structures of unbranched alkanes, C_1 to C_3, and name the unbranched alkanes methane to propane

(d) describe alkanes (exemplified by methane) as being generally unreactive except in terms of combustion and substitution by chlorine

(e) describe the alkenes as a homologous series of unsaturated hydrocarbons with the general formula C_nH_{2n}

(f) draw the structures of unbranched alkenes, C_2 and C_3, and name the unbranched alkenes ethene and propene

(g) describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process

(h) describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine

(i) describe the reactions of alkenes (exemplified by ethene) in terms of combustion, polymerisation (see also **8.3**(b)) and the addition with bromine and hydrogen

(j) state the meaning of *polyunsaturated* when applied to food products

(k) describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product.

8.3 Polymers

(a) describe polymers as large molecules built up from small units (monomers), different polymers having different units

(b) describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer (see also **8.2**(i))

(c) state some uses of poly(ethene) as a typical plastic, e.g. plastic bags; clingfilm

(d) deduce the structure of the addition polymer product from a given monomer and vice versa

(e) describe the pollution problems caused by the disposal of non-biodegradable plastics

(f) describe two methods of recycling plastics as
   (i) physical method (exemplified by melting small pieces of poly(ethene) waste into pellets)
   (ii) chemical method (exemplified by cracking of plastic waste into fuel)

(g) discuss the social, economic and environmental issues of recycling plastics.

9. Maintaining Air Quality

Learning Outcomes

Candidates should be able to:

(a) describe the volume composition of gases present in dry air as being approximately 78% nitrogen, 21% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide

(b) name some common atmospheric pollutants, e.g. carbon monoxide; methane; nitrogen oxides (NO and NO_2); ozone; sulfur dioxide; unburned hydrocarbons

(c) state the sources of these pollutants as
  (i) carbon monoxide from incomplete combustion of carbon-containing substances
  (ii) nitrogen oxides from lightning activity and internal combustion engines
  (iii) sulfur dioxide from volcanoes and combustion of fossil fuels

(d) discuss some of the effects of these pollutants on health and on the environment
  (i) the toxic nature of carbon monoxide
  (ii) the role of nitrogen dioxide and sulfur dioxide in the formation of 'acid rain' and its effects on respiration and buildings

(e) describe the carbon cycle in simple terms, to include
  (i) the processes of combustion, respiration and photosynthesis
  (ii) how the carbon cycle regulates the amount of carbon dioxide in the atmosphere
  (see also **8.1**(d))

(f) state that carbon dioxide and methane are greenhouse gases and may contribute to global warming; give the sources of these gases and describe the potential effects of increased levels of these greenhouse gases, including more extreme weather events and melting of polar ice.

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The list below is intended as a guide to the more important quantities which might be encountered in teaching and used in question papers. The list is not exhaustive.

Quantity	Symbol	Unit
Base quantities		
mass	m	g, kg, tonne
length	l	cm, m
time	t	s, min
amount of substance	n	mol
Other quantities		
temperature	θ, t	°C
volume	V	cm^3, m^3, dm^3
density	ρ	g/cm^3, kg/m^3
atomic mass	m_a	g
relative { atomic / isotopic } mass	A_r	–
molecular mass	m	g
relative molecular mass	M_r	–
molar mass	M	g / mol
nucleon number	A	–
proton number	Z	–
neutron number	N	–
enthalpy change of reaction	ΔH	J, kJ, J / mol, kJ / mol
bond energy	-	kJ / mol
concentration	c	mol/dm^3, g/dm^3
pH	pH	–

PRACTICAL GUIDELINES

Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to facilitate the learning of this subject. A list of practicals is provided. Candidates are expected to show familiarity with laboratory practical procedures and to have carried out at least four practical tasks from this list.

1. Separation techniques including crystallisation (of salts), filtration, paper chromatography and distillation
2. Measurements of temperature based on thermometers with 1° C graduation
3. Determination of melting point and boiling point
4. Acid/alkali titration involving the use of a pipette, burette and a suitable given indicator
5. Identification of gases as specified in the syllabus
6. Experiments involving displacement reactions
7. Experiments involving reactivity of metals

This is not intended to be an exhaustive list. Reference may be made to the techniques used in these experiments in the theory papers but no detailed description of the experimental procedures will be required. Candidates may be asked about other practical work and appropriate guidance will be provided where unfamiliar experiments are involved.

Responsibility for safety matters rests with Centres.

NOTES FOR QUALITATIVE ANALYSIS

Test for gases

gas	***test and test result***
carbon dioxide (CO_2)	gives white ppt. with limewater (ppt. dissolves with excess CO_2)
hydrogen (H_2)	‘pops’ with a lighted splint
oxygen (O_2)	relights a glowing splint

The Periodic Table of Elements

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57 – 71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89 – 103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).
The Avogadro constant, $L = 6.02 \times 10^{23}\ mol^{-1}$.

Biology section

INTRODUCTION

The Normal (Academic) Level Science (Biology) syllabus is designed to have less emphasis on factual materials, but a much 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 complex and globalised world, rather than focusing on large quantities of factual material, which may have only short-term relevance.

It is envisaged that teaching and learning programmes based on this syllabus will feature a wide variety of learning experiences designed to promote acquisition of scientific expertise and understanding, and to develop values and attitudes relevant to science. Teachers are encouraged to use a combination of appropriate strategies in teaching topics in this syllabus. The assessment will be specifically intended to test skills, comprehension and insight in familiar and unfamiliar contexts.

DISCIPLINARY IDEAS OF BIOLOGY

The disciplinary ideas of Biology described below represent the overarching ideas which can be applied to explain, analyse and solve a variety of problems that seek to address the broader question of how living organisms work to sustain life. The purpose of equipping students with an understanding of these ideas is to develop in them a coherent view and conceptual framework of scientific knowledge to facilitate the application and transfer of learning. These ideas can be revisited throughout the syllabus, deepened at higher levels of learning and beyond the schooling years.

1. **The Cell** – Diverse life forms are similar in that their basic unit are cells.

2. **Structure and Function** – Structure and function of organisms from the molecular to the organ system levels are related to each other.

3. **Systems** – Biological systems interact among themselves and with the environment resulting in the flow of energy and nutrients.

4. **Energy** – To ensure survival, living organisms obtain, transform and utilise energy from the external world.

5. **Homeostasis, Co-ordination and Response** – Living organisms detect changes both from the surrounding environment and within themselves so that they are able to respond to these changes to maintain a constant internal environment needed for sustaining life.

6. **Evolution** – The diversity of living organisms is achieved through a process of evolution, driven by mechanisms such as natural selection.

CONTENT STRUCTURE

SECTION	Topics
I. Cells and the Chemistry of Life	1. Cell Structure and Organisation 2. Movement of Substances 3. Biological Molecules
II. The Human Body – Maintaining Life	4. Nutrition in Humans 5. Transport in Humans 6. Respiration in Humans 7. Infectious Diseases in Humans
III. Living Together – Plants and Animals	8. Nutrition and Transport in Flowering Plants

SUBJECT CONTENT

SECTION I: CELLS AND THE CHEMISTRY OF LIFE

Overview

Living things are different from non-living things in their ability to grow, reproduce, move, and respond to change. Understanding what makes these characteristics of life possible requires an appreciation of the hierarchical organisation of life (from cells → tissues → organs → systems → organism) and the processes needed to sustain life at each level.

In this section, we begin by exploring life at the smallest level. Amidst the great diversity of living organisms on earth, all living organisms are fundamentally similar at the smallest level; they are all made of cells and a common set of carbon-based molecules. Physiological processes in living organisms can be explained through activities happening at the cellular level. For instance, the transport of oxygen around the body is made possible by red blood cells that bind oxygen to haemoglobin.

In order to sustain life, all living things require three macromolecules – carbohydrates, proteins and fats. They make life possible by providing energy, building cellular structures, and for growth and repair.

The overarching ideas of this section are cells as the basic unit of life, correlation between structure and function and how living organisms obtain, transform and utilise energy from the external world at the cellular level to sustain life. Knowing how life works at the cellular and molecular level will provide students with a foundation to understand processes needed to sustain life at the tissue, organ and system levels, which are covered in subsequent sections of this syllabus.

1. Cell Structure and Organisation

Content

- Plant and Animal Cells
- Cell Specialisation

Learning Outcomes

Candidates should be able to:

(a) identify and state the functions of the following cell structures (including organelles) of typical plant and animal cells from diagrams, light micrographs and as seen under the light microscope using prepared slides and fresh material treated with an appropriate temporary staining technique:

- cell wall
- cell membrane
- cytoplasm
- nucleus
- cell vacuoles (large, sap-filled in plant cells, small, temporary in animal cells)
- chloroplasts

(b) identify and state the functions of the following organelles from diagrams and electron micrographs:

- mitochondria
- ribosomes

(c) compare the structure of typical animal and plant cells

(d) explain how the structures of specialised cells are adapted to their functions (e.g. muscle cell – many mitochondria to supply more energy, root hair cell – large surface area of cell membrane for greater absorption, red blood cell – lack of nucleus allowing it to transport more oxygen)

2. Movement of Substances

Content

- Diffusion
- Osmosis

Learning Outcomes

Candidates should be able to:

(a) define *diffusion* and describe its role in nutrient uptake and gaseous exchange in plants and humans

(b) define *osmosis*, investigate and describe the effects of osmosis on plant and animal tissues

3. Biological Molecules

Content

- Carbohydrates, Fats and Proteins
- Enzymes

Learning Outcomes

Candidates should be able to:

(a) state the main roles of carbohydrates, fats and proteins in living organisms:

- carbohydrates as an immediate source of energy
- fats for insulation and long-term storage of energy
- proteins for growth and repair of cells

(b) describe and carry out tests for:

- starch (using iodine in potassium iodide solution)
- reducing sugars (using Benedict's solution)
- protein (using biuret solution)
- fats (using ethanol)

(c) state that large molecules are synthesised from smaller basic units:

- cellulose, glycogen and starch from glucose
- polypeptides and proteins from amino acids
- lipids such as fats from glycerol and fatty acids

(d) explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex and enzyme specificity using the 'lock and key' hypothesis

(e) investigate and explain the effects of temperature and pH on the rate of enzyme catalysed reactions

SECTION II: THE HUMAN BODY – MAINTAINING LIFE

Overview

Life is sustained through the integrated organisation of the whole organism. In humans, the maintenance and regulation of life processes include nutrition, transport and respiration.

Living systems utilise energy and macromolecules to maintain life processes such as growth, reproduction and homeostasis. Interactions also exist between living systems within organisms, which are often accompanied by the transfer of energy between matter and transfer or exchange of matter. Each system has their component parts, characterised by the division of labour. This division of labour enables an organism to function efficiently and allows for the various systems to work together as a co-ordinated whole.

The threat of diseases disrupts the maintenance of important life processes and the functioning of human body systems. In ancient times, the concept of ‘catching’ a disease was unheard of, and diseases were even thought to be caused by the imbalance of ‘humours’ (internal fluids) within the body. However, with the invention of the microscope, we have found out that infectious diseases are often caused by pathogens, e.g. viruses and bacteria.

The overarching ideas in the study of this section are the co-ordination of the human body system as a whole and the correlation between structure and function.

4. Nutrition in Humans

Content

- Human Digestive System
- Physical and Chemical Digestion
- Absorption and Assimilation

Learning Outcomes

Candidates should be able to:

(a) describe the functions of the various parts of the digestive system: mouth, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, anus, in relation to ingestion, digestion, absorption, assimilation and egestion of food, as appropriate

(b) describe the functions of enzymes (e.g. amylase, maltase, protease, lipase) in digestion, listing the substrates and end-products

(c) state the function of the hepatic portal vein as the transport of blood rich in absorbed nutrients from the small intestine to the liver

(d) state the role of the liver in:

- conversion of glucose to glycogen and vice versa
- fat digestion
- metabolism of amino acids and formation of urea
- breakdown of alcohol
- breakdown of hormones

(e) define a *hormone* as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs

(f) outline how blood glucose concentration is regulated by insulin and glucagon

(g) describe type 2 *diabetes mellitus* in terms of a persistently higher than normal blood glucose concentration due to the body's resistance to insulin or insufficient production of insulin

(h) identify the risk factors of (e.g. unhealthy diet and sedentary lifestyle) and ways to manage type 2 *diabetes mellitus*

5. Transport in Humans

Content

- Parts and Functions of the Circulatory System
- Blood
- Coronary Heart Disease

Learning Outcomes

Candidates should be able to:

(a) identify the main blood vessels to and from the heart, lungs, liver and kidney

(b) relate the structures of arteries, veins and capillaries to their functions (specific names of muscle layers in arteries and veins are **not** required)

(c) state the components of blood and their roles in transport and defence:

- red blood cells – haemoglobin for oxygen transport
- plasma – transport of blood cells, ions, soluble food substances, hormones, carbon dioxide, urea, vitamins, plasma proteins
- white blood cells – phagocytosis, antibody formation and tissue rejection
- platelets – fibrinogen to fibrin, causing clotting

(d) describe the structure and function of the heart in terms of muscular contraction and the working of valves (histology of the heart muscle, names of nerves and transmitter substances are **not** required)

(e) describe coronary heart disease in terms of the occlusion of coronary arteries and list the possible causes, such as unhealthy diet, sedentary lifestyle, and smoking, stating the possible preventative measures

6. Respiration in Humans

Content

- Human Gas Exchange
- Cellular Respiration

Learning Outcomes

Candidates should be able to:

(a) identify the larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries and state their functions in human gaseous exchange

(b) explain how the structure of an alveolus is suited for its function of gaseous exchange

(c) state the major toxic components of tobacco smoke – nicotine, tar and carbon monoxide, and describe their effects on health

(d) define *aerobic respiration* in human cells as the release of energy by the breakdown of glucose in the presence of oxygen and state the word equation

(e) define *anaerobic respiration* in human cells as the release of energy by the breakdown of glucose in the absence of oxygen and state the word equation

(f) explain why cells respire anaerobically during vigorous exercise resulting in an oxygen debt that is removed by rapid, deep breathing after exercise

7. Infectious Diseases in Humans

Content

- Organisms affecting Human Health
- Influenza and Pneumococcal Disease
- Prevention and Treatment of Infectious Diseases

Learning Outcomes

Candidates should be able to:

(a) state that infectious diseases can be spread from person to person whereas non-infectious diseases cannot and identify examples of each

(b) explain that infectious diseases are caused by pathogens such as bacteria and viruses and can be spread from person to person through body fluids, food and water (knowledge of the structure of bacteria and viruses is **not** required)

(c) state the signs and symptoms of:

- influenza – caused by the influenza virus
- pneumococcal disease – caused by the bacteria, pneumococcus

(d) describe the transmission and methods to reduce the transmission of:

- influenza virus
- pneumococcus

(e) state that vaccines contain an agent that resembles a pathogen and prevent infectious diseases by stimulating white blood cells to quickly produce antibodies when the pathogen invades

(f) state that antibiotics kill bacteria and are ineffective against viruses

(g) explain that the misuse and overuse of antibiotics may accelerate the emergence of antibiotic-resistant bacteria

SECTION III: LIVING TOGETHER – PLANTS AND ANIMALS

Overview

The sun is the principal source of energy for almost all living organisms on earth, without which, life will not exist as it is today. Green plants are able to capture and convert light energy to useful chemical forms in the unique process of photosynthesis.

Plants are important to most living organisms that depend on the energy captured by plants through direct or indirect feeding relationships to sustain life. The process of photosynthesis helps to capture the carbon dioxide released through respiration and other human activities such as combustion. This ensures that the concentration of carbon dioxide in the atmosphere is maintained within healthy limits, beyond which will result in global warming.

The overarching idea of this section is the adaptation of plant structures that allow them to transform light energy into chemical energy efficiently to sustain life on earth.

8. Nutrition and Transport in Flowering Plants

Content

- Plant Structure
- Photosynthesis
- Transpiration
- Translocation

Learning Outcomes

Candidates should be able to:

(a) identify the cellular and tissue structure of a dicotyledonous leaf, as seen in transverse section using the light microscope and describe the significance of these features in terms of their functions, such as the:

- distribution of chloroplasts for photosynthesis
- stomata and mesophyll cells for gaseous exchange
- vascular bundles for transport

(b) identify the positions of and state the functions of xylem vessels and phloem in sections of a herbaceous dicotyledonous leaf and stem, under the light microscope

(c) explain how the structure of a root hair cell is suited for its function of water and ion uptake

(d) state that chlorophyll absorbs light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent uses

(e) briefly explain why most forms of life are completely dependent on photosynthesis

(f) state the word equation for photosynthesis (details of light-dependent and light-independent stages are **not** required)

(g) describe how carbon dioxide reaches mesophyll cells in a leaf

(h) investigate and describe the effects of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plant)

(i) state that *transpiration* is the loss of water vapour from the stomata

(j) briefly explain the movement of water through the stem in terms of transpiration pull

(k) investigate and explain:

- the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate
- how wilting occurs

(l) define the term *translocation* as the transport of food (mainly sucrose) in the phloem tissue

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The list below is intended as a guide to the more important quantities which might be encountered in teaching and learning. This list is not exhaustive.

Quantity	**Symbol**	**Unit**
length	l	mm, cm, m
area	A	cm^2, m^2
volume	V	cm^3, dm^3, m^3
mass	*m*	mg, g, kg
concentration	*c*	g/dm^3
time	*t*	ms, s, min
pH	pH	–
temperature	*T*	°C
energy	*E*	J

PRACTICAL GUIDELINES

Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to support and facilitate the learning of this subject. A list of practical work is provided below. Candidates are expected to show familiarity with laboratory practical procedures and to have carried out at least four practical tasks from this list.

1. Preparation and observation of specimens under a light microscope
2. Investigation of the effects of osmosis on plant cells
3. Identification of nutrients (carbohydrates, proteins and fats) in given samples
4. Investigation of the effects of temperature and pH on enzyme action
5. Test for the presence of carbon dioxide released during respiration
6. Investigation of the factors affecting photosynthesis
7. Investigation on the process of transpiration

This is not intended to be an exhaustive list. Reference may be made to the techniques used in these experiments in the theory papers but no detailed description of the experimental procedures will be required. Candidates may be asked about other practical work and appropriate guidance will be provided where unfamiliar experiments are involved.

GLOSSARY OF TERMS USED IN SCIENCE PAPERS

It is hoped that the glossary (which is relevant only to science papers) will prove helpful to candidates as a guide, i.e. it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

2. *Classify* requires candidates to group things based on common characteristics.

3. *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

4. *Compare* requires candidates to provide both similarities and differences between things or concepts.

5. *Construct* is often used in relation to chemical equations where a candidate is expected to write a balanced equation, not by factual recall but by analogy or by using information in the question.

6. *Define (the term(s)…)* is intended literally, only a formal statement or equivalent paraphrase being required.

7. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. In the latter instance the answer may often follow a standard pattern, e.g. Apparatus, Method, Measurement, Results and Precautions.

   In other contexts, *describe and give an account of* should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. *Describe and explain* may be coupled in a similar way to *state and explain.*

8. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula.

9. *Discuss* requires candidates to give a critical account of the points involved in the topic.

10. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about the points of principle and about values of quantities not otherwise included in the question.

11. *Explain* may imply reasoning or some reference to theory, depending on the context.

12. *Find* is a general term that may be variously interpreted as calculate, measure, determine, etc.

13. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should not be exceeded.

14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

15. *Outline* implies brevity, i.e. restricting the answer to giving essentials.

16. *Predict* or *deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted from an earlier part of the question.
    Predict also implies a concise answer with no supporting statement required.

17. *Sketch*, when applied to graph work, implies that the shape and / or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having the intercept, asymptote or discontinuity at a particular value.

    In diagrams, *sketch* implies that a simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

18. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained ‘by inspection’.

19. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer, or to imply that candidates are expected to apply their general knowledge to a ‘novel’ situation, one that may be formally ‘not in the syllabus’.

20. *What do you understand by/What is meant by (the term(s)...)* normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in light of the indicated mark value.

SPECIAL NOTE

Nomenclature

Students will be expected to be familiar with the nomenclature used in the syllabus. The proposals in '*Signs, Symbols and Systematics: The ASE Companion to 16–19 Science* (2000)' and the recommendations on terms, units and symbols in '*Biological Nomenclature 4th Edition* (2009)' published by the Institute of Biology, in conjunction with the ASE, will generally be adopted although the traditional names sulfate, sulfite, nitrate, nitrite, sulfurous and nitrous acids will be used in question papers. Sulfur (and all compounds of sulfur) will be spelt with f (not with ph) in question papers, however students can use either spelling in their answers.

It is intended that, in order to avoid difficulties arising out of the use of l as the symbol for litre, use of dm^3 in place of l or litre will be made.

In chemistry, full *structural formulae (displayed formulae)* in answers should show in detail both the relative placing of atoms and the number of bonds between atoms. Hence, $–CONH_2$ and $–CO_2H$ are not satisfactory as full structural formulae, although either of the usual symbols for the benzene ring is acceptable.

Units and significant figures

Candidates should be aware that misuse of units and / or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

Calculators

An approved calculator may be used in all papers.

Geometrical Instruments

Candidates should have geometrical instruments with them for Paper 1 and Paper 2 for syllabus 5105 and 5106.