Singapore Examinations and Assessment Board

Cambridge Assessment International Education

Singapore–Cambridge General Certificate of Education Ordinary Level (2022)

Science
Syllabus codes

5076 Science: Physics, Chemistry
5077 Science: Physics, Biology
5078 Science: Chemistry, Biology

CONTENTS

AIMS

These are not listed in order of priority.

The aims are to:

1. provide, through well-designed studies of experimental and practical science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge to

   1.1 become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific importance

   1.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life

   1.3 be suitably prepared for studies beyond Ordinary Level in related pure sciences, in applied sciences or in science-related courses.

2. develop abilities and skills that

   2.1 are relevant to the study and practice of science

   2.2 are useful in everyday life

   2.3 encourage efficient and safe practice

   2.4 encourage effective communication.

3. develop attitudes relevant to science such as

   3.1 accuracy and precision

   3.2 objectivity

   3.3 integrity

   3.4 inquiry

   3.5 initiative

   3.6 inventiveness.

4. stimulate interest in and care for the local and global environment.

5. promote an awareness that

   5.1 the study and practice of science are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations

   5.2 the applications of science may be both beneficial and detrimental to the individual, the community and the environment

   5.3 science transcends national boundaries and that the language of science, correctly and rigorously applied, is universal

   5.4 the use of information technology is important for communications, as an aid to experiments and as a tool for interpretation of experimental and theoretical results.

ASSESSMENT OBJECTIVES

A Knowledge with Understanding

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

1. scientific phenomena, facts, laws, definitions, concepts, theories

2. scientific vocabulary, terminology, conventions (including symbols, quantities and units contained in '*Signs, Symbols and Systematics 16–19',* Association for Science Education, 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, describe, explain* or *outline.* (See the *Glossary of Terms*.)

B Handling Information and Solving Problems

Students should be able – in words or by using other written, 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 hypotheses

7. solve problems.

These assessment objectives cannot be precisely specified in the subject 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, deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *predict, suggest, calculate,* or *determine.* (See the *Glossary of Terms*.)

C Experimental Skills and Investigations

Students should be able to:

1. follow a sequence of instructions

2. select and use techniques, apparatus and materials

3. make and record observations, measurements and estimates

4. interpret and evaluate observations and experimental results

5. plan investigations, select techniques, apparatus and materials

6. evaluate methods and suggest possible improvements.

Weighting of Assessment Objectives

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

A Knowledge with Understanding, approximately 50% of the marks with approximately 20% allocated to recall.

B Handling Information and Solving Problems, approximately 50% of the marks.

Practical Assessment (Paper 5)

Paper 5 is designed to test appropriate skills in **C**, Experimental Skills and Investigations.

In one or more of the questions in Paper 5, candidates will be expected to suggest a modification or an extension, which does not need to be executed. Depending on the context in which the modification / extension element is set, the number of marks associated with this element will be in the range of 10% to 20% of the total marks available for the practical test.

SCHEME OF ASSESSMENT

Candidates are required to enter for Paper 1, Paper 5 and two of Papers 2, 3 and 4.

Paper	Type of Paper	Duration	Marks	Weighting
1	Multiple Choice	1 h	40	20.0%
2	Structured and Free Response (Physics)	1 h 15 min	65	32.5%
3	Structured and Free Response (Chemistry)	1 h 15 min	65	32.5%
4	Structured and Free Response (Biology)	1 h 15 min	65	32.5%
5	Practical Test	1 h 30 min	30	15.0%

Science (Physics, Chemistry), Syllabus 5076
Paper 1 will be based on the Physics and Chemistry sections of the syllabus.
Paper 2 will be based on the Physics section of the syllabus.
Paper 3 will be based on the Chemistry section of the syllabus.
Paper 5 will be based on the Physics and Chemistry sections of the syllabus.

Science (Physics, Biology), Syllabus 5077
Paper 1 will be based on the Physics and Biology sections of the syllabus.
Paper 2 will be based on the Physics section of the syllabus.
Paper 4 will be based on the Biology section of the syllabus.
Paper 5 will be based on the Physics and Biology sections of the syllabus.

Science (Chemistry, Biology), Syllabus 5078
Paper 1 will be based on the Chemistry and Biology sections of the syllabus.
Paper 3 will be based on the Chemistry section of the syllabus.
Paper 4 will be based on the Biology section of the syllabus.
Paper 5 will be based on the Chemistry and Biology sections of the syllabus.

Theory papers

Paper 1 (1 h, 40 marks)	This paper consists of 40 compulsory multiple choice questions of the direct choice type providing approximately equal coverage of the two appropriate sections of the syllabus. This paper will be set at the same time for all *three* syllabuses, 5076, 5077, 5078. A copy of the *Data Sheet* 'Colours of Some Common Metal Hydroxides' and 'The Periodic Table of Elements' will be printed as part of Paper 1 for syllabus 5076 and 5078.
Paper 2 (1 h 15 min, 65 marks)	This paper consists of *two* sections. *Section A* will carry 45 marks and will contain a number of compulsory structured questions of variable mark value. *Section B* will carry 20 marks and will contain *three* questions, each of 10 marks. Candidates are required to answer any *two* questions. The questions will be based on the Physics section of the syllabus.
Paper 3 (1 h 15 min, 65 marks)	This paper consists of *two* sections. *Section A* will carry 45 marks and will contain a number of compulsory structured questions of variable mark value. *Section B* will carry 20 marks and will contain *three* questions, each of 10 marks. Candidates are required to answer any *two* questions. The questions will be based on the Chemistry section of the syllabus. A copy of the *Data Sheet* 'Colours of Some Common Metal Hydroxides' and 'The Periodic Table of Elements' will be printed as part of this Paper.
Paper 4 (1 h 15 min, 65 marks)	This paper consists of *two* sections. *Section A* will carry 45 marks and will contain a number of compulsory structured questions of variable mark value. *Section B* will carry 20 marks and will contain *three* questions, each of 10 marks. Candidates are required to answer any *two* questions. The questions will be based on the Biology section of the syllabus.

Practical assessment

Paper 5 (1 h 30 min, 30 marks) consisting of *one* or *two* compulsory questions on each of the two Sciences. The Physics question(s) will be identical in Papers 5076 and 5077. The Chemistry and the Biology question(s) will, likewise, be common to the respective papers.

This Paper will be set at the same time for all *three* syllabuses, 5076, 5077, and 5078.

The use of reference material, other than the Chemistry Practical Notes is not permitted.

In one or both questions, candidates will be expected to suggest a modification or extension, which does not need to be executed.

Physics section

INTRODUCTION

The Ordinary 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.

CONTENT STRUCTURE

Section		Topics
I.	**MEASUREMENT**	1. Physical Quantities, Units and Measurement
II.	**NEWTONIAN MECHANICS**	2. Kinematics 3. Dynamics 4. Mass, Weight and Density 5. Turning Effect of Forces 6. Pressure 7. Energy, Work and Power
III.	**THERMAL PHYSICS**	8. Kinetic Model of Matter 9. Transfer of Thermal Energy 10. Thermal Properties of Matter
IV.	**WAVES**	11. General Wave Properties 12. Light 13. Electromagnetic Spectrum 14. Sound
V.	**ELECTRICITY AND MAGNETISM**	15. Static Electricity 16. Current of Electricity 17. D.C. Circuits 18. Practical Electricity 19. Magnetism and Electromagnetism

SUBJECT CONTENT

SECTION I: MEASUREMENT

Overview

In order to gain a better understanding of the physical world, scientists use a process of investigation that follows a general cycle of observation, hypothesis, deduction, test and revision, sometimes referred to as the scientific method. Galileo Galilei, one of the earliest architects of this method, believed that the study of science had a strong logical basis that involved precise definitions of terms and physical quantities, and a mathematical structure to express relationships between these physical quantities.

In this section, we examine how a set of base physical quantities and units is used to describe all other physical quantities. These precisely defined quantities and units, with accompanying order-of-ten prefixes (e.g. milli, centi and kilo) can then be used to describe the interactions between objects in systems that range from celestial objects in space to sub-atomic particles.

1. Physical Quantities, Units and Measurement

Content

- Physical quantities
- SI units
- Prefixes
- Scalars and vectors
- Measurement of length and time

Learning Outcomes:

Candidates should be able to:

(a) show understanding that all physical quantities 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)

(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)

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

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

(f) add two vectors to determine a resultant by a graphical method

(g) describe how to measure a variety of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier scale as necessary

(h) describe how to measure a short interval of time including the period of a simple pendulum with appropriate accuracy using stopwatches or appropriate instruments

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 2000 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.

In this section, we begin by examining kinematics, which is a study of motion without regard for the cause. After which, we study the conditions required for an object to be accelerated and introduce the concept of forces through Newton's Laws. Subsequently, concepts of moments and pressure are introduced as consequences of a force. Finally, this section rounds up by leading the discussion from force to work and energy, and the use of the principle of conservation of energy to explain interactions between bodies.

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 using *distance travelled* / *time taken*

(c) state what is meant by uniform acceleration and calculate the value of an 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

(f) deduce from the shape of a distance-time graph when a body 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 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 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. Dynamics

Content

- Balanced and unbalanced forces
- Free-body diagram
- Friction

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
    (stating of Newton's laws is not required)

(b) identify forces acting on an object and draw free-body diagram(s) representing the forces acting on the object (for cases involving forces acting in at most 2 dimensions)

(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

4. Mass, Weight and Density

Content

- Mass and weight
- Gravitational field and field strength
- Density

Learning Outcomes:

Candidates should be able to:

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

(b) state that mass of a body resists a change in the state of rest or motion of the body (inertia)

(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*

(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

5. Turning Effect of Forces

Content

- Moments
- Centre of gravity
- Stability

Learning Outcomes:

Candidates should be able to:

(a) describe the moment of a force in terms of its turning effect and relate this to everyday examples

(b) recall and apply the relationship *moment of a force* (or *torque*) = *force × perpendicular distance from the pivot* to new situations or to solve related problems

(c) state the principle of moments for a body in equilibrium

(d) apply the principle of moments to new situations or to solve related problems

(e) show understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity

(f) describe qualitatively the effect of the position of the centre of gravity on the stability of objects

6. Pressure

Content

- Pressure

Learning Outcomes:

Candidates should be able to:

(a) define the term pressure in terms of force and area

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

7. Energy, Work and Power

Content

- Energy conversion and conservation
- Work
- Power

Learning Outcomes:

Candidates should be able to:

(a) show understanding that kinetic energy, potential energy (chemical, gravitational, elastic), light energy, thermal energy, electrical energy and nuclear energy are examples of different forms of energy

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

(c) state that kinetic energy $E_k = \frac{1}{2} mv^2$ and gravitational potential energy $E_p = mgh$ (for potential energy changes near the Earth's surface)

(d) apply the relationships for kinetic energy and potential energy to new situations or to solve related problems

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

(f) recall and apply the relationship *power* = *work done* / *time taken* to new situations or to solve related problems

SECTION III: THERMAL PHYSICS

Overview

Among the early scientists, heat was thought of as some kind of invisible, massless fluid called 'caloric'. Certain objects that released heat upon combustion were thought to be able to 'store' the fluid. However, this explanation failed to explain why friction was able to produce heat. In the 1840s, James Prescott Joule used a falling weight to drive an electrical generator that heated a wire immersed in water. This experiment demonstrated that work done by a falling object could be converted to heat.

In the previous section, we studied energy and its conversion. Many energy conversion processes which involve friction will have heat as a product. This section begins with the introduction of the kinetic model of matter. This model is then used to explain and predict the physical properties and changes of matter at the molecular level in relation to heat or thermal energy transfer.

8. Kinetic Model of Matter

Content

- States of matter
- Kinetic model

Learning Outcomes:

Candidates should be able to:

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

(b) describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules

(c) describe the relationship between the motion of molecules and temperature

9. Transfer of Thermal Energy

Content

- Conduction
- Convection
- Radiation

Learning Outcomes:

Candidates should be able to:

(a) show understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature

(b) describe, in molecular terms, how energy transfer occurs in solids

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

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

(e) apply the concept of thermal energy transfer to everyday applications

10. Thermal Properties of Matter

Content

- Internal energy
- Melting, boiling and evaporation

Learning Outcomes:

Candidates should be able to:

(a) describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)

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

(c) explain the difference between boiling and evaporation

SECTION IV: WAVES

Overview

Waves are inherent in our everyday lives. Much of our understanding of wave phenomena has been accumulated over the centuries through the study of light (optics) and sound (acoustics). The nature of oscillations in light was only understood when James Clerk Maxwell, in his unification of electricity, magnetism and electromagnetic waves, stated that all electromagnetic fields spread in the form of waves. Using a mathematical model (Maxwell's equations), he calculated the speed of electromagnetic waves and found it to be close to the speed of light, leading him to make a bold but correct inference that light consists of propagating electromagnetic disturbances. This gave the very nature of electromagnetic waves, and hence its name.

In this section, we examine the nature of waves in terms of the coordinated movement of particles. The discussion moves on to wave propagation and its uses by studying the properties of light, electromagnetic waves and sound, as well as their applications in wireless communication, home appliances, medicine and industry.

11. General Wave Properties

Content

- Describing wave motion
- Wave terms
- 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

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

(c) define *speed*, *frequency*, *wavelength*, *period* and *amplitude*

(d) state what is meant by the term *wavefront*

(e) recall and apply the relationship *velocity* = *frequency* × *wavelength* to new situations or to solve related problems

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

12. Light

Content

- Reflection of light
- Refraction of light
- Thin converging lenses

Learning Outcomes:

Candidates should be able to:

(a) recall and use the terms for reflection, including *normal*, *angle of incidence* and *angle of reflection*

(b) state that, for reflection, the angle of incidence is equal to the angle of reflection and use this principle in constructions, measurements and calculations

(c) recall and use the terms for refraction, including *normal*, *angle of incidence* and *angle of refraction*

(d) recall and apply the relationship sin i / sin r = *constant* to new situations or to solve related problems

(e) define *refractive index* of a medium in terms of the ratio of speed of light in vacuum and in the medium

(f) explain the terms *critical angle* and *total internal reflection*

(g) describe the action of a thin converging lens on a beam of light

(h) define the term *focal length* for a converging lens

(i) draw ray diagrams to illustrate the formation of real and virtual images of an object by a thin converging lens

13. Electromagnetic Spectrum

Content

- Properties of electromagnetic waves
- Applications of electromagnetic waves

Learning Outcomes:

Candidates should be able to:

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

(b) describe the main components of the electromagnetic spectrum

(c) state examples of the use of the following components:
(i) radiowaves (e.g. radio and television communication)
(ii) microwaves (e.g. microwave oven and satellite television)
(iii) infra-red (e.g. infra-red remote controllers and intruder alarms)
(iv) light (e.g. optical fibres for medical uses and telecommunications)
(v) ultra-violet (e.g. sunbeds and sterilisation)
(vi) X-rays (e.g. radiological and engineering applications)
(vii) gamma rays (e.g. medical treatment)

14. Sound

Content

- Sound waves
- Speed of sound
- Echo

Learning Outcomes:

Candidates should be able to:

(a) describe the production of sound by vibrating sources

(b) describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction

(c) explain that a medium is required in order to transmit sound waves and the speed of sound differs in air, liquids and solids

(d) relate loudness of a sound wave to its amplitude and pitch to its frequency

(e) describe how the reflection of sound may produce an echo, and how this may be used for measuring distances

SECTION V: ELECTRICITY AND MAGNETISM

Overview

For a long time, electricity and magnetism were seen as independent phenomena. Hans Christian Oersted, in 1802, discovered that a current carrying conductor deflected a compass needle. This discovery was overlooked by the scientific community until 18 years later. It may be a chance discovery, but it takes an observant scientist to notice. The exact relationship between an electric current and the magnetic field it produced was deduced mainly through the work of Andre Marie Ampere. However, the major discoveries in electromagnetism were made by two of the greatest names in physics, Michael Faraday and James Clerk Maxwell.

The section begins with a discussion of electric charges that are static, i.e. not moving. Next, we study the phenomena associated with moving charges and the concepts of current, voltage and resistance. We also study how these concepts are applied to simple circuits and household electricity. Thereafter, we study the interaction of magnetic fields to pave the way for the study of the interrelationship between electricity and magnetism. The phenomenon in which a current interacts with a magnetic field is studied in electromagnetism.

15. Static Electricity

Content

- Principles of electrostatics
- Electric field

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) describe an electric field as a region in which an electric charge experiences a force

(d) draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge

(e) draw the electric field pattern between two isolated point charges

16. Current of Electricity

Content

- Conventional current and electron flow
- Electromotive force
- Potential difference
- Resistance

Learning Outcomes:

Candidates should be able to:

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

(b) distinguish between conventional current and electron flow

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

(d) define electromotive force (e.m.f.) as the work done by a source in driving a unit charge around a complete circuit

(e) state that the e.m.f. of a source and the potential difference (p.d.) across a circuit component is measured in volts

(f) define the p.d. across a component in a circuit as the work done to drive a unit charge through the component

(g) state the definition that *resistance* = *p.d.* / *current*

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

(i) describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations

(j) 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

(k) 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

17. D.C. Circuits

Content

- Current and potential difference in circuits
- Series and parallel circuits

Learning Outcomes:

Candidates should be able to:

(a) draw circuit diagrams with power sources (cell or battery), switches, lamps, 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 current from the source is the sum of the currents in the separate branches of a parallel circuit 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 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

18. Practical Electricity

Content

- Electric 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 cases 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 wired into the live conductor

19. Magnetism and Electromagnetism

Content

- Laws of magnetism
- Magnetic properties of matter
- Magnetic field
- Magnetic effect of a current
- Application of the magnetic effect of a current
- Force on a current-carrying conductor

Learning Outcomes:

Candidates should be able to:

(a) state the properties of magnets

(b) describe induced magnetism

(c) describe electrical methods of magnetisation and demagnetisation

(d) distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)

(e) draw the magnetic field pattern around a bar magnet and between the poles of two bar magnets

(f) describe the plotting of magnetic field lines with a compass

(g) draw the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and / or direction of the current

(h) describe the application of the magnetic effect of a current in a circuit breaker

(i) describe experiments to show the force on a current-carrying conductor in a magnetic field, including the effect of reversing
   (i) the current
   (ii) the direction of the field

(j) deduce the relative directions of force, field and current when any two of these quantities are at right angles to each other using Fleming's left-hand rule

(k) explain how a current-carrying coil in a magnetic field experiences a turning effect (recall of structure of an electric motor is not required)

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

Students should be able to state the symbols for the following physical quantities and, where indicated, state the units in which they are measured. Students 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*	Pa*, N / m^2
temperature	θ, *T*	°C, K
frequency*	*f*	Hz
wavelength*	λ	m, cm
focal length	*f*	m, cm
angle of incidence	*i*	degree (°)
angles of reflection, refraction	*r*	degree (°)
critical angle	*c*	degree (°)
potential difference* / voltage	*V*	V*, mV
current*	*I*	A, mA
charge	*q, Q*	C, A s
e.m.f.*	*E*	V
resistance	*R*	Ω

Chemistry section

INTRODUCTION

The Ordinary Level Science (Chemistry) Syllabus is designed to place less emphasis on factual materials and greater emphasis on the understanding and application of scientific concepts and principles. This approach has been adapted in recognition of the need for students to develop skills that will be of long-term value in an increasing technological world rather than focusing on large quantities of factual materials, which may have only short-term relevance.

It is important that, throughout the course, attention should be drawn to:

(i) the finite life of the world's resources and hence the need for recycling and conservation

(ii) economic considerations in the chemical industry, such as the availability and cost of raw materials and energy

(iii) the social, environmental, health and safety issues relating to the chemical industry

(iv) the importance of chemicals in industry and in everyday life.

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 expertise and understanding. Teachers are encouraged to use a combination of appropriate strategies including developing appropriate practical works for their students to facilitate a greater understanding of the subject.

CONTENT STRUCTURE

	SECTION	Topics
I.	**EXPERIMENTAL CHEMISTRY**	1. Experimental Chemistry
II.	**ATOMIC STRUCTURE AND STOICHIOMETRY**	2. The Particulate Nature of Matter 3. Formulae, Stoichiometry and the Mole Concept
III.	**CHEMISTRY OF REACTIONS**	4. Energy Changes 5. Chemical Reactions 6. Acids, Bases and Salts
IV.	**PERIODICITY**	7. The Periodic Table 8. Metals
V.	**ATMOSPHERE**	9. Air
VI.	**ORGANIC CHEMISTRY**	10. Organic Chemistry

SUBJECT CONTENT

SECTION I: EXPERIMENTAL CHEMISTRY

Overview

Chemistry is typically an experimental science and relies primarily on practical work. It is important for students to learn the techniques of handling laboratory apparatus and to pay special attention to safety while working in the laboratory. Accidents happened even to German chemist, Robert Bunsen, while working in the laboratory. Robert Bunsen spent most of his time doing experiments in the laboratory and at the age of 25, he lost an eye in a laboratory explosion due to the lack of proper eye protection.

In this section, students examine the appropriate use of simple apparatus and chemicals, and the experimental techniques. Students need to be aware of the importance of purity in the electronic, pharmaceutical, food and beverage industries, and be allowed to try out different methods of purification and analysis in school science laboratories. Students should be able to appreciate the need for precision and accuracy in making readings and also value the need for safe handling and disposing of chemicals.

1. Experimental Chemistry

Content

1.1 Experimental design

1.2 Methods of purification and analysis

1.3 Identification of ions and gases

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 and measurement of rates of reaction

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 **10.1**(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 (the use of R_f values is **not** required)

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

1.3 Identification of ions and gases

(a) describe the use of aqueous sodium hydroxide and aqueous ammonia to identify the following aqueous cations: ammonium, calcium, copper(II), iron(II), iron(III), lead(II) and zinc (formulae of complex ions are **not** required)

(b) describe tests to identify the following anions: carbonate (by the addition of dilute acid and subsequent use of limewater), chloride (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate), nitrate (by reduction with aluminium and aqueous sodium hydroxide to ammonia and subsequent use of litmus paper) and sulfate (by reaction of an aqueous solution with nitric acid and aqueous barium nitrate)

(c) describe tests to identify the following gases: ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using a burning splint), oxygen (using a glowing splint) and sulfur dioxide (using acidified potassium manganate(VII))

SECTION II: ATOMIC STRUCTURE AND STOICHIOMETRY

Overview

For over 2000 years, people have wondered about the fundamental building blocks of matter. As far back as 440 BC, the Greek Leucippus and his pupil Democritus coined the term atomos to describe the smallest particle of matter. It translates to mean something that is indivisible. In the eighteenth century, chemist, John Dalton, revived the term when he suggested that each element was made up of unique atoms and the atoms of an element are all the same. At that time, there were about 35 known elements. This simple model could explain the millions of different materials around us.

Differences between atoms give elements their different chemical properties. Atoms of one or more substances (reactants) undergo some “rearrangements” during a chemical change (reaction). These rearrangements form new and different substances (products). After the chemical reaction, all the atoms of the reactants are still present in the products. Balanced chemical equations can be written because of the law of conservation of mass. These equations make it possible to predict the masses of reactants and products involved in chemical reactions.

In this section, the idea of atoms and chemical bonding being the most important fundamental concept in chemistry is introduced. The knowledge of atomic structure opens the door for students to understand the world of chemical reactions. Students are also introduced to the use of models and theories in the study of the structures of atoms, molecules and ions, and the bonding in elements and compounds. Calculations for chemical reactions involving chemical formulae, reacting masses and volumes, and concentrations introduce students to the fundamentals of stoichiometry.

2. The Particulate Nature of Matter

Content

2.1 Kinetic particle theory

2.2 Atomic structure

2.3 Structure and properties of materials

2.4 Ionic bonding

2.5 Covalent bonding

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 containing 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 number* (*atomic number*) and *nucleon number* (*mass number*)

(d) interpret and use symbols 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

2.3 Structure and properties of materials

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

2.4 Ionic bonding

(a) describe the formation of ions by electron loss / gain in order to obtain the electronic configuration of a noble gas

(b) describe 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

2.5 Covalent bonding

(a) describe the formation of a covalent bond by the sharing of a pair of electrons in order to gain 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 and 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. Formulae, Stoichiometry and the Mole Concept

Learning Outcomes:

Candidates should be able to:

(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

(f) define relative *atomic mass*, A_r

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

(h) calculate stoichiometric reacting masses and volumes of gases (one mole of gas occupies 24 dm^3 at room temperature and pressure); calculations involving the idea of limiting reactants may be set

(knowledge of the gas laws and the calculations of gaseous volumes at different temperatures and pressures are **not** required)

(i) apply the concept of solution concentration (in mol / dm^3 or g / dm^3) to process the results of volumetric experiments and to solve simple problems

(appropriate guidance will be provided where unfamiliar reactions such as redox are involved. Calculations on % yield and % purity are **not** required)

SECTION III: CHEMISTRY OF REACTIONS

Overview

Chemists like Svante Arrhenius played an important role in providing a comprehensive understanding of what happens in chemical reactions. In 1887, the Swedish chemist, Svante Arrhenius proposed the theory that acids, bases, and salts in water are composed of ions. He also proposed a simple yet beautiful model of neutralisation – the combination of hydrogen and hydroxyl ions to form water.

In this section, students examine the chemical characteristic properties of acids, bases and salts, and also their reactions with substances, the factors affecting the rate of reaction and also the energy changes during a reaction. Students should be able to appreciate the importance of proper laboratory techniques and precise calculations for accurate results, and the importance of controlling variables in making comparisons. They should also value the knowledge of the hazardous nature of acids / alkalis and the safe handling, storing and disposing of chemicals.

4. Energy Changes

Learning Outcomes:

Candidates should be able to:

(a) describe the term *exothermic* as a process or chemical reaction which transfers energy, often in the form of heat, to the surroundings and may be detected by an increase in temperature, e.g. the reaction between sodium hydroxide and hydrochloric acid

(b) describe the term *endothermic* as a process or chemical reaction which takes in energy, often in the form of heat, from the surroundings and may be detected by a decrease in temperature, e.g. the dissolving of ammonium nitrate in water

5. Chemical Reactions

Content

5.1 Speed of reaction

5.2 Redox

Learning Outcomes:

Candidates should be able to:

5.1 Speed of reaction

(a) describe the effect of concentration, pressure, particle size and temperature on the speeds of reactions and explain these effects in terms of collisions between reacting particles

(b) interpret data obtained from experiments concerned with speed of reaction

5.2 Redox

(a) define *oxidation* and *reduction* (redox) in terms of oxygen / hydrogen gain / loss

(b) define *redox* in terms of electron transfer and changes in oxidation state

(c) describe the use of aqueous potassium iodide and acidified potassium manganate(VII) in testing for oxidising and reducing agents from the resulting colour changes

6. Acids, Bases and Salts

Content

6.1 Acids and bases

6.2 Salts

Learning Outcomes:

Candidates should be able to:

6.1 Acids and bases

(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 how to test hydrogen ion concentration and hence relative acidity using Universal Indicator and the pH scale

(c) describe the characteristic properties of acids as in reactions with metals, bases and carbonates

(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 as in reactions with acids and with ammonium salts

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

6.2 Salts

(a) describe the techniques used in the preparation, separation and purification of salts as examples of some of the techniques specified in chemistry Section **1.2**(a)

(methods for preparation should include precipitation and titration, together with reactions of acids with metals, insoluble bases and insoluble carbonates)

(b) suggest a method of preparing a given salt from suitable starting materials, given appropriate information

SECTION IV: PERIODICITY

Overview

The development of the Periodic Table started in the 1800s as chemists began to recognise similarities in the properties of various elements and place them in families. The most famous and successful classification, widely accepted by chemists, was published in 1869 by Dmitri Mendeleev, a Russian chemist. His periodic table arranged the elements known at that time, in order of increasing atomic masses.

The International Union of Pure and Applied Chemistry (IUPAC) is the gatekeeper of elements and it oversees the Periodic Table of elements. Until 2007, the Periodic Table consisted of 111 officially named elements. However, in 2009 it was reported that element 112, with an atomic number of 112 and about 227 times heavier than hydrogen, was discovered by Sigurd Hoffmann and his team of 21 scientists from Germany, Finland, Russia and Slovakia.

In this section, students examine the periodic trends and group properties of elements, occurrence of metals, their properties, reactivity and uses. Students should be able to appreciate the development of the Periodic Table and hence to envisage that scientific knowledge changes and accumulates over time, and also the need for conserving some of the finite resources.

7. The Periodic Table

Content

7.1 Periodic trends

7.2 Group properties

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 structure

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

(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 group number, number of valency electrons and metallic / non-metallic character

(f) predict the properties of elements in Group I and Group VII using the Periodic Table

7.2 Group properties

(a) describe lithium, sodium and potassium in Group I (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 VII (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 0 (the noble gases) in terms of their electronic structures

8. Metals

Content

8.1 Properties of metals

8.2 Reactivity series

8.3 Extraction of metals

8.4 Recycling of metals

8.5 Iron

Learning Outcomes:

Candidates should be able to:

8.1 Properties of metals

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

(b) describe *alloys* as a mixture of a metal with another element, e.g. brass; stainless steel

(c) identify representations of metals and alloys from diagrams of structures

8.2 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

8.3 Extraction of metals

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

8.4 Recycling of metals

(a) describe metal ores as a finite resource and hence the need to recycle metals, e.g. the recycling of iron

(b) discuss the social, economic and environmental issues of recycling metals

8.5 Iron

(a) describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace

(b) 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 V: ATMOSPHERE

Overview

Our atmosphere has been taken for granted in the past. In the last few decades, scientists and the general public began to realise the adverse effects of pollutants on the air we breathe. It is now recognised that pollutants such as sulfur dioxide, oxides of nitrogen, carbon monoxide and particulates released into the atmosphere as a result of energy generation and increased use of motor vehicles, have serious health and environmental consequences.

In this section, the sources of air pollutants and their effects are examined. Students should be able to value the knowledge of the hazardous nature of pollutants and the environmental issues related to air pollution.

9. Air

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 poisonous 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

SECTION VI: ORGANIC CHEMISTRY

Overview

In the nineteenth century, chemists believed that organic chemicals originated in tissues of living organisms. Friedrich Wohler, in 1828, changed this belief and synthesised the organic compound, urea, a compound found in urine, under laboratory conditions. His work led other chemists to attempt synthesis of other organic compounds.

In this section, students examine the sources of fuels, some basic concepts of organic chemistry like homologous series, functional group, general formula and structural formula, and polymers. Students should be able to identify and name unbranched alkanes, alkenes, alcohols and carboxylic acids. They should recognise that materials such as plastics, detergents and medicines, and even the food that we eat are examples of organic compounds. Students should be able to value the need for assessing the impacts of the use of synthetic materials and the environmental issues related to the use of plastics.

10. Organic Chemistry

Content

10.1 Fuels and crude oil

10.2 Alkanes

10.3 Alkenes

10.4 Alcohols

10.5 Carboxylic acids

Learning Outcomes:

Candidates should be able to:

10.1 Fuels and crude oil

(a) name natural gas, mainly methane, and petroleum as sources of energy

(b) describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation (see also **1.2** (a))

(c) name the following fractions and state their uses:
(i) petrol (gasoline) as a fuel in cars
(ii) naphtha as the feedstock for the petrochemical industry
(iii) paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines
(iv) diesel as a fuel for diesel engines
(v) lubricating oils as lubricants and as a source of polishes and waxes
(vi) bitumen for making road surfaces

10.2 Alkanes

(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; flammability

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

10.3 Alkenes

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

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

(c) 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

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

(e) describe the properties of alkenes (exemplified by ethene) in terms of combustion and the addition reactions with bromine and hydrogen

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

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

(h) describe the formation of *poly(ethene)* as an example of addition polymerisation of ethene as the monomer

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

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

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

10.4 Alcohols

(a) describe the alcohols as a homologous series containing the –OH group

(b) draw the structures of unbranched alcohols, C_1 to C_3 and name the unbranched alcohols, methanol to propanol

(c) describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids

(d) describe the formation of ethanol by fermentation of glucose

10.5 Carboxylic acids

(a) describe the carboxylic acids as organic acids containing the $–CO_2H$ group

(b) describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium manganate(VII)

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, 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
bond energy	-	kJ / mol
concentration	c	mol / dm^3, g / dm^3
pH	pH	–

NOTES FOR QUALITATIVE ANALYSIS

Test for anions

anion	test	test result
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt.

Test for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
ammonium (NH_4^+)	ammonia produced on warming	–
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt.
copper(II) (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
lead(II) (Pb^{2+})	white ppt., soluble in excess giving a colourless solution	white ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess giving a colourless solution	white ppt., soluble in excess giving a colourless solution

Test for gases

gas	test and test result
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	gives white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	“pops” with a lighted splint
oxygen (O_2)	relights a glowing splint
sulfur dioxide (SO_2)	turns aqueous acidified potassium manganate(VII) from purple to colourless

Colours of Some Common Metal Hydroxides

calcium hydroxide	white
copper(II) hydroxide	light blue
iron(II) hydroxide	green
iron(III) hydroxide	red-brown
lead(II) hydroxide	white
zinc hydroxide	white

The Periodic Table of Elements

Group																	
I	II											III	IV	V	VI	VII	0
				Key			1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9			proton (atomic) number atomic symbol name relative atomic mass								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 –		114 Fl flerovium –		116 Lv livermorium –		

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.)

Biology section

INTRODUCTION

The Ordinary 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 technological 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 inquiry. 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.

CONTENT STRUCTURE

SECTION	Topics
I. PRINCIPLES OF BIOLOGY	1. Cell Structure and Organisation 2. Movement of Substances 3. Biological Molecules
II. MAINTENANCE AND REGULATION OF LIFE PROCESSES	4. Nutrition in Humans 5. Nutrition in Plants 6. Transport in Flowering Plants 7. Transport in Humans 8. Respiration in Humans 9. Co-ordination and Response in Humans
III. CONTINUITY OF LIFE	10. Reproduction 11. Molecular Genetics 12. Inheritance
IV. MAN AND HIS ENVIRONMENT	13. Organisms and their Environment

SUBJECT CONTENT

SECTION I: PRINCIPLES OF BIOLOGY

Overview

A basic characteristic of life is the hierarchy of structural order within the organism. Robert Hooke (1635–1703), one of the first scientists to use a microscope to examine pond water, cork and other things, was the first to refer to the cavities he saw in cork as “cells”, Latin for chambers. Subsequent scientists developed Hooke’s discovery of the cell into the Cell Theory upon which modern biology is built. The Cell Theory states that all organisms are composed of one or more cells, and that those cells have arisen from pre-existing cells.

In this section, we study two key principles of biology. The first principle is the correlation of structure to function. This is illustrated by how each part of the cell is suited for its intended function.

The second principle is that specialisation results in the division of labour which enables the cell to effectively carry out a number of vital life processes. A strong foundation in the principles of biology will pave the way for students to master the content in the subsequent topics.

1. Cell Structure and Organisation

Content

- Plant and animal cells
- Specialised cells, tissues and organs

Learning Outcomes:

Candidates should be able to:

(a) identify cell structures (including organelles) of typical plant and animal cells from diagrams, photomicrographs and as seen under the light microscope using prepared slides and fresh material treated with an appropriate temporary staining technique:
- (i) chloroplasts
- (ii) cell membrane
- (iii) cell wall
- (iv) cytoplasm
- (v) cell vacuoles (large, sap-filled in plant cells, small, temporary in animal cells)
- (vi) nucleus

(b) identify the following organelles from diagrams and electronmicrographs:
- (i) mitochondria
- (ii) ribosomes

(c) state the functions of the organelles identified above

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

(e) state, in simple terms, the relationship between cell function and cell structure for the following:
- (i) absorption – root hair cells
- (ii) conduction and support – xylem vessels
- (iii) transport of oxygen – red blood cells

(f) differentiate cell, tissue, organ and organ system

Use the knowledge gained in this section in new situations or to solve related problems.

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* and describe the effects of osmosis on plant and animal tissues

Use the knowledge gained in this section in new situations or to solve related problems.

3. Biological Molecules

Content

- Water and living organisms
- Carbohydrates, fats and proteins
- Enzymes

Learning Outcomes:

Candidates should be able to:

(a) state the roles of water in living organisms

(b) describe and carry out tests for
 (i) starch (iodine in potassium iodide solution)
 (ii) reducing sugars (Benedict's solution)
 (iii) protein (biuret test)
 (iv) fats (ethanol emulsion)

(c) state that large molecules are synthesised from smaller basic units
 (i) glycogen from glucose
 (ii) polypeptides and proteins from amino acids
 (iii) lipids such as fats from glycerol and fatty acids

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

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

Use the knowledge gained in this section in new situations or to solve related problems.

SECTION II: MAINTENANCE AND REGULATION OF LIFE PROCESSES

Overview

Life is sustained through the integrated organisation of the whole organism. In humans, the maintenance and regulation of life processes include nutrition, transport, respiration, excretion, homeostasis and co-ordination and response. The key overarching theme in the study of the organ systems is the correlation between form and function.

4. Nutrition in Humans

Content

- Human alimentary canal
- Chemical digestion
- Absorption and assimilation

Learning Outcomes:

Candidates should be able to:

(a) describe the functions of main regions of the alimentary canal and the associated organs: 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 substrate 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:
(i) the metabolism of glucose
(ii) the metabolism of amino acids and the formation of urea
(iii) the breakdown of alcohol

Use the knowledge gained in this section in new situations or to solve related problems.

5. Nutrition in Plants

Content

- Leaf structure
- Photosynthesis

Learning Outcomes:

Candidates should be able to:

(a) identify the cellular and tissue structure of a dicotyledonous leaf, as seen in cross-section under the microscope and state their functions:
(i) distribution of chloroplasts – photosynthesis
(ii) stomata and mesophyll cells – gaseous exchange
(iii) vascular bundles – transport

(b) state the equation, in words only, for photosynthesis

(c) describe the intake of carbon dioxide and water by plants

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

(e) investigate and state the effect of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plants)

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

Use the knowledge gained in this section in new situations or to solve related problems.

6. Transport in Flowering Plants

Content

- Water and ion uptake
- Transpiration and translocation

Learning Outcomes:

Candidates should be able to:

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

(b) relate the structure and functions of root hairs to their surface area, and to water and ion uptake

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

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

(e) describe
  (i) the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate
  (ii) how wilting occurs

(f) define the term *translocation* as the transport of food in the phloem tissue

Use the knowledge gained in this section in new situations or to solve related problems.

7. Transport in Humans

Content

- Circulatory system

Learning Outcomes:

Candidates should be able to:

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

(b) state the functions of blood
  (i) red blood cells – haemoglobin and oxygen transport
  (ii) plasma – transport of blood cells, ions, soluble food substances, hormones, carbon dioxide, urea, vitamins, plasma proteins
  (iii) white blood cells – phagocytosis, antibody formation and tissue rejection
  (iv) platelets – fibrinogen to fibrin, causing clotting

(c) relate the structure of arteries, veins and capillaries to their functions

(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 diet, stress, smoking, and the possible preventative measures

Use the knowledge gained in this section in new situations or to solve related problems.

8. Respiration in Humans

Content

- Human gas exchange
- Aerobic respiration
- Anaerobic respiration

Learning Outcomes:

Candidates should be able to:

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

(b) state the characteristics of, and describe the role of, the exchange surface of the alveoli in gas exchange

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

(d) define and state the equation, in words only, for aerobic respiration in humans

(e) define and state the equation, in words only, for anaerobic respiration in humans

(f) describe the effect of lactic acid in muscles during exercise

Use the knowledge gained in this section in new situations or to solve related problems.

9. Co-ordination and Response in Humans

Content

- Receptors – eye
- Nervous system – neurones
- Effectors – endocrine glands

Learning Outcomes:

Candidates should be able to:

(a) state the relationship between receptors, the central nervous system and the effectors

(b) state the principal functions of component parts of the eye in producing a focused image of near and distant objects on the retina

(c) describe the pupil reflex in response to bright and dim light

(d) outline the functions of sensory neurones, relay neurones and motor neurones

(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 and is then destroyed by the liver

(f) state what is meant by an endocrine gland, with reference to the islets of Langerhans in the pancreas

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

Use the knowledge gained in this section in new situations or to solve related problems.

SECTION III: CONTINUITY OF LIFE

Overview

The many aspects of form and function that we have examined in this syllabus can be viewed in the widest context as various adaptations aimed at ensuring reproductive success. Reproduction is vital for the survival of species across generations. In 1953, James Watson and Francis Crick developed the model for deoxyribonucleic acid (DNA), a chemical that had then recently been deduced to be the physical carrier of inheritance. In this section, we examine how genes interact to produce hereditary characteristics in the offspring. This section focuses on understanding the processes involved in the continuity of life and how genetic information is passed from one generation to the next.

10. Reproduction

Content

- Asexual reproduction
- Sexual reproduction in plants
- Sexual reproduction in humans
- Sexually transmitted diseases

Learning Outcomes:

Candidates should be able to:

(a) define *asexual reproduction* as the process resulting in the production of genetically identical offspring from one parent

(b) define *sexual reproduction* as the process involving the fusion of nuclei to form a zygote and the production of genetically dissimilar offspring

(c) state the functions of the sepals, petals, anthers and carpels

(d) outline the process of pollination

(e) describe the growth of the pollen tube and its entry into the ovule followed by fertilisation (production of endosperm and details of development are **not** required)

(f) identify on diagrams of the male reproductive system and give the functions of: testes, scrotum, sperm ducts, prostate gland, urethra and penis

(g) identify on diagrams of the female reproductive system and give the functions of: ovaries, oviducts, uterus, cervix and vagina

(h) briefly describe the menstrual cycle with reference to the alternation of menstruation and ovulation, the natural variation in its length, and the fertile and infertile phases of the cycle, with reference to the roles of oestrogen and progesterone only

(i) briefly describe fertilisation and early development of the zygote simply in terms of the formation of a ball of cells which becomes implanted in the wall of the uterus

(j) discuss the spread of human immunodeficiency virus (HIV) and methods by which it may be controlled

Use the knowledge gained in this section in new situations or to solve related problems.

11. Molecular Genetics

Content

- The structure of DNA
- The role of DNA in protein synthesis

Learning Outcomes:

Candidates should be able to:

(a) outline the relationship between genes, chromosomes, and DNA

(b) state the structure of DNA in terms of the bases, sugar and phosphate groups found in each of the nucleotides

(c) state the rule of complementary base pairing

(d) state that DNA is used to carry the genetic code (details of translation and transcription are **not** required)

(e) state that each gene
  (i) is a sequence of nucleotides, as part of a DNA molecule
  (ii) controls the production of one polypeptide

Use the knowledge gained in this section in new situations or to solve related problems.

12. Inheritance

Content

- The passage of information from parent to offspring
- The nature of genes and alleles, and their role in determining the phenotype
- Monohybrid crosses
- Variation

Learning Outcomes:

Candidates should be able to:

(a) define a *gene* as a unit of inheritance and distinguish clearly between the terms *gene* and *allele*

(b) describe the difference between continuous and discontinuous variation and give examples of each

(c) explain the terms *dominant*, *recessive*, *homozygous*, *heterozygous*, *phenotype* and *genotype*

(d) predict the results of simple crosses with expected ratios of 3:1 and 1:1, using the terms *homozygous*, *heterozygous*, F_1 *generation* and F_2 *generation*

(e) state why observed ratios often differ from expected ratios, especially when there are small numbers of progeny

(f) describe the determination of sex in humans – XX and XY chromosomes

(g) describe mutation as a change in the structure of a gene such as in sickle cell anaemia, or in the chromosome number such as the 47 chromosomes in a condition known as Down's Syndrome

(h) name radiation and chemicals as factors which may increase the rate of mutation

Use the knowledge gained in this section in new situations or to solve related problems.

SECTION IV: MAN AND HIS ENVIRONMENT

Overview

All living organisms are part of a complex network of interactions called the web of life. This section focuses on the interrelationships between living things and the environment. These include two major processes. The first is the cycling of nutrients, as illustrated by the carbon cycle. The second major process is the flow of energy from sunlight to organisms further down the food chain.

Human activities can upset natural ecosystems, causing permanent damage not just to local environments but also the global environment. As a part of this environment, humans must show a sense of responsibility for its maintenance.

13. Organisms and their Environment

Content

- Energy flow
- Food chains and food webs
- Carbon cycle
- Effects of man on the ecosystem
- Environmental biotechnology
- Conservation

Learning Outcomes:

Candidates should be able to:

(a) briefly describe the non-cyclical nature of energy flow

(b) establish the relationship of the following in food webs: producer, consumer, herbivore, carnivore, decomposer, food chain, trophic level

(c) describe energy losses between trophic levels and infer the advantages of short food chains

(d) interpret pyramids of numbers and biomass

(e) explain the importance of the carbon cycle and outline the role of forests and oceans as carbon sinks

(f) evaluate the effects of
  (i) water pollution by sewage
  (ii) pollution due to insecticides including bioaccumulation up food chains and impact on top carnivores

(g) outline the roles of microorganisms in sewage treatment as an example of environmental biotechnology

(h) discuss reasons for conservation of species with reference to the maintenance of biodiversity and how this is done, e.g. management of fisheries and management of timber production

Use the knowledge gained in this section in new situations or to solve related problems.

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 ASSESSMENT

Scientific subjects are, by nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of science should include a component relating to practical work and experimental skills. This assessment is provided in Paper 5, as a formal practical test, and is outlined in the **Scheme of Assessment**.

Paper 5 Practical Test

Physics Practical Test

Candidates may be asked to carry out exercises based on:

(a) measurements of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier as necessary

(b) measurements of time intervals, including the period of a simple pendulum, by means of clocks and stopwatches

(c) measurements of temperature by using appropriate thermometers

(d) measurements of mass and weight by using appropriate balances

(e) measurements of the volume of a liquid or solid by using a measuring cylinder

(f) determination of the density of a liquid, of a regularly and irregularly shaped solid, which sinks in water

(g) the principle of moments

(h) determination of the position of the centre of gravity of a plane lamina

(i) the law of reflection

(j) determination of the position and characteristics of an optical image formed by a plane mirror or a thin converging lens

(k) the refraction of light through glass blocks

(l) measurements of current and voltage by using appropriate ammeters and voltmeters

(m) determination of the resistance of a metallic conductor using a voltmeter and an ammeter

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.

Chemistry Practical Test

Candidates may be asked to carry out exercises based on:

(a) quantitative experiments involving the use of a pipette, burette and an indicator such as methyl orange or screened methyl orange; if titrations other than acid / alkali are set, full instructions and other necessary information will be given

(b) speeds of reaction

(c) measurements of temperature based on thermometers with 1 °C graduations

(d) problems of an investigatory nature, possibly including suitable organic compounds

(e) simple paper chromatography

(f) filtration

(g) tests for oxidising and reducing agents as specified in the syllabus

(h) identification of ions and gases as specified in the syllabus.
Candidates would not be required to carry out tests involving Pb^{2+} ions or sulfur dioxide gas.

This question paper will contain *Notes For Qualitative Analysis* for the use of candidates in the examination.

Candidates may also be required to perform simple calculations.

Biology Practical Test

1. The practical examination is designed to test candidates' abilities to:

   (a) follow carefully a sequence of instructions within a set time allowance

   (b) use familiar and unfamiliar techniques to record their observations and make deductions from them

   (c) recognise and observe features of familiar and unfamiliar biological specimens, record their observations and make deductions about functions of whole specimens or their parts

   (d) make clear line drawings of the specimens provided, indicate magnification and to label familiar structures

   (e) interpret unfamiliar data and draw conclusions from their interpretations

   (f) design / plan an investigation to solve a problem

   (g) comment on a procedure used in an experiment and suggest an improvement

   (h) employ manipulative skills in assembling apparatus, in using chemical reagents and in using such instruments as mounted needles, scalpels and razor blades, forceps and scissors

   (i) observe reactions, read simple measuring instruments and perform simple arithmetical calculations

   (j) measure to an accuracy of 1 mm, using a ruler.

2. Candidates may be asked to carry out simple physiological experiments, involving tests for food substances (specifically reducing sugars with Benedict's solution, starch using iodine solution, protein using the biuret test and fats using the ethanol emulsion test), enzyme reactions, hydrogen carbonate indicator solution, cobalt(II) chloride paper etc. It is expected that glassware and instruments normally found in a laboratory (e.g. beakers, test-tube racks, funnels, thermometers, droppers and so on) should be available for these experiments.

3. Candidates may be asked to carry out simple physiological experiments, involving the use of the above mentioned instruments 1(h) on plant or animal materials. Accurate observations of these specimens will need a hand lens of not less than ×6 magnification for each candidate.

4. The material set will be closely related to the subject matter of the syllabus, but will not necessarily be limited to the particular types mentioned therein. In order to assist their own practical work, and to supply possible examination specimens, schools are asked to build up a reference collection of material.

5. When planning practical work, teachers should make sure that they do not contravene any school, education authority, or government regulations which restrict the sampling, in educational establishments, of urine, saliva, blood or other bodily secretions and tissues.

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 Association for Science Education 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, 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 5076 and 5077.