higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE FOR ADULTS

NQF LEVEL 4

DRAFT SUBJECT STATEMENT

NATURAL SCIENCES

NASCA CURRICULUM
NATURAL SCIENCES

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Introduction

The field of Natural Sciences investigates physical, chemical and biological phenomena. This is done through scientific enquiry, and application of scientific models, theories, laws and principles in order to explain and predict events in the natural environment. The Natural Sciences field includes the subjects Physics, Chemistry and Biology. Physics focuses on the physical properties of matter and energy and the interactions and relationships between these, and attempts to develop mathematical and other models to explain physical phenomena. Chemistry focuses on the properties and reactions of materials, including identifying, classifying and changing matter from one form into another. Biology is the scientific study of living organisms from the molecular level to their interactions with one another and their environments.

This collection of subjects also deals with society's need to understand how the natural environment works in order to benefit from it and responsibly care for it. Scientific knowledge changes over time as scientists improve their knowledge and understanding. However, science is based on thorough investigation, debate and argument until a new idea is accepted by the scientific community.

In this course we recommend that Physics, Chemistry and Biology be studied in parallel, to ensure progressive development within each of these sections.

Aims

1. Provide a worthwhile educational experience for all adult students to enable them to acquire sufficient understanding and knowledge to:
    1.1. become confident citizens of South Africa, able to take or develop an informed interest in matters of scientific importance;
    1.2. recognise the usefulness, and limitations, of the scientific method, and to appreciate its applicability in other disciplines and in everyday life;
    1.3. be suitably prepared for further study in related scientific fields.

2. Develop thinking and process skills that:
    2.1. are relevant to the study of science;
    2.2. encourage curiosity about the natural world;
    2.3. develop accurate and precise observation;
    2.4. are useful in everyday life;
    2.5. promote logical and critical thinking and self-reflection;
    2.6. promote effective communication.

3. Develop attitudes relevant to science such as:
    3.1. objectivity;
    3.2. integrity;
    3.3. creativity;
    3.4. perseverence.

4. Stimulate interest in and care for the South African and global environment.

5. Promote an awareness that:

    5.1. the study and practice of science are cooperative activities, which are subject to socio-economic and political influences;
    5.2. the applications of science may benefit or harm the individual, the community and/or the environment;
    5.3. if used responsibly, science can enhance meaningful social, political and economic participation.

Exit-Level Outcomes

By the end of this course candidates should be able to:

1. understand and use subject-specific knowledge with regard to:
    1.1. scientific phenomena, facts, concepts, definitions, principles, theories and laws;
    1.2. scientific vocabulary, terminology and discourse (language of science);
    1.3. the process and application of scientific investigations and techniques;
    1.4. scientific and technological applications with their social, economic and environmental implications.

2. know and apply subject specific skills, namely:
    2.1. find, organise, synthesise and communicate information from a variety of sources;
    2.2. translate information from one form to another, e.g. table to graph, graph to text, text to diagram;
    2.3. manipulate numerical and other data;
    2.4. use data to identify patterns, trends and draw inferences;
    2.5. draw conclusions based on reasoning;
    2.6. hypothesise and predict;
    2.7. solve problems in familiar and novel contexts;
    2.8. evaluate information or investigative procedure.

3. understand, adopt and apply the values related to the subject, namely:
    3.1. use scientific knowledge effectively and critically, showing responsibility towards the environment and the health of others;
    3.2. make responsible decisions using critical and creative thinking;
    3.3. understand, adopt and display the values of ethical methodology and reporting of science.

Taxonomy and Weighting of Exit Level Outcomes

These exit level outcomes are reflected in the following taxonomy.

Taxonomy of Cognitive Demands for Natural Sciences				
	Remembering	**Understanding**	**Applying and Analysing**	**Evaluating and Creating**
Approximate weighting	20%	30%	35%	15%
Descriptors	Name, label, list, define, state, describe, explain (descriptive)	Explain underlying scientific process, compare, give an example of, rearrange, infer, classify	Calculate, apply, demonstrate, solve, illustrate, construct, sequence, interpret, draw, analyse, distinguish, compare and contrast, debate	Evaluate, criticise, justify, generalise, validate, predict, invent, formulate, plan, design, evaluate and solve complex problems in novel contexts
Related exit level outcomes	1. Understand and use subject-specific knowledge		2. Know and apply subject specific skills	
	3. Understand, adopt and apply the values related to the subject			

Scheme of Assessment

The Natural Sciences course will be examined in three separate papers. This is done in order to avoid confusion between the disciplines of Physics, Chemistry and Biology, and to prevent a student from having to cover a vast breadth of content for any examination.

Paper	Type of Paper	Marks	Duration	Weighting
1	Physics	100	2 hours	33,3%
2	Chemistry	100	2 hours	33,3%
3	Biology	100	2 hours	33,3%

Structure of the Examination Papers

Paper 1 – Physics (2 hours, 100 marks)
Section A (Short Structured Questions) 30 marks
Section B (Long Questions) 70 marks

Paper 2 – Chemistry (2 hours, 100 marks)
Section A (Short Structured Questions) 30 marks
Section B (Long Questions) 70 marks

Paper 3 – Biology (2 hours, 100 marks)
Section A (Short Structured Questions) 30 marks
Section B (Short Free-Response Questions) 50 marks
Section C (Essay Question) 20 marks

Paper 1 and Paper 2 will contain data sheets with the necessary formulae, tables and other information.

Candidates are required to answer ALL questions in all papers.

Section A of each paper will cover all categories of cognitive demand, and could include short structured questions such as:

- multiple choice questions
- supply labels for diagrams
- supply scientific terms for definitions

Section B of each paper could include questions requiring:

- answers that vary from one word to a paragraph
- calculations
- drawing, analysis and interpretation of graphs, tables and other data representations

Section C of Paper 3 consists of an essay question (requiring 2-3 pages of writing). This will be assessed on the presentation of correct information and the structure of the essay.

Suggested Study Hours

Natural Sciences is a 30 credit course, which relates to 300 notional study hours.

It is envisaged that a typical one-year offering of the course will cover 30 weeks, excluding revision and examination time. Candidates should therefore spend 10 hours per week on Natural Sciences. This should consist of 6 hours of face-to-face instruction and 4 hours of self-study.

A suggested time allocation for the course is shown in the table below:

Component	**Face-to-face Teaching Time**	**Self-study Time**
Physics	2 hours per week x 30 weeks	4 hours per week x 30 weeks
Chemistry	2 hours per week x 30 weeks	
Biology	2 hours per week x 30 weeks	
Total Course Hours	**300 hours**	

Guidelines for Teachers and Materials Developers

The candidates envisaged in the NASCA curriculum are a varied group of adult and out-of-school students, and come from a wide range of backgrounds and socio-economic contexts. In addition, the modes of delivery are envisaged to be varied, ranging from face-to-face teaching in community colleges to distance learning in remote areas. The curriculum is therefore not prescriptive about learning activities or teaching methods, but allows for a range of teaching and learning styles. The sequence is not prescribed, although there is a logic behind the order in which topics are presented in each section.

The teaching and learning that takes place in Natural Sciences should include a wide variety of learning experiences that promote the development of scientific skills and understanding, and that encourage values and attitudes that will enable candidates to be constructive citizens of South Africa. Teachers and materials developers are encouraged to use a combination of strategies to allow for active participation and critical thinking. These strategies should include investigative and problem-solving skills, effective communication and reflection on the learning process.

Because specialised laboratory equipment might not be readily available to many candidates, the activities should involve everyday found objects, but should illustrate the principles and processes of science.

Assumptions about prior knowledge and skills

This course relies on candidates having a certain baseline of numerical and general knowledge and skills. Candidates who enrol for this course should be able to:

- apply rules of basic algebra in order to solve an equation with one unknown, and to change the subject of a formula
- plot data points on a Cartesian plane
- draw a straight-line graph
- find the gradient and intercepts of a straight-line graph
- manipulate fractions and ratios
- interpret the meaning of direct and inverse proportions
- know how to use a scientific calculator
- work with arithmetic powers (including reciprocals and square roots)
- solve linear simultaneous equations
- comprehend and use the symbols $<$, $>$, $\approx$, $/$, $\propto$, Σ, Δx, $\sqrt{}$
- calculate areas of right-angled and isosceles triangles
- use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle
- apply basic trigonometric ratios to a right-angled triangle, (i.e. sin, cos and tan)

PHYSICS

Introduction

Physics focuses on the physical properties of matter and energy and the interactions and relationships between these, and attempts to develop mathematical models to explain physical phenomena. Physics concepts are usually organised under the themes Mechanics, Waves, Electricity and Magnetism, Heat and Modern Physics.

Rationale for Content Selection

The intention of this course is for candidates to engage with a narrow selection of content as deeply as possible. Therefore, to avoid the temptation to include too great a breadth of content for the time available for the Physics component, the content that has been included has been carefully selected to cover concepts and skills that are core to the Physics discipline. Mastery of this content will give candidates a solid foundation for further study in the discipline. The main topic headings selected for this curriculum are:

- Mechanics
- Waves
- Electricity and Magnetism

Physics Content Structure

Topic Heading	Topic (with approximate instructional time)
1 Basic scientific skills (5% weighting)	1.1 Physical quantities, units and measurement (1 hour) 1.2 Problem solving techniques (1 hour) 1.3 Graph drawing, analysis and interpretation (2 hours)
2 Mechanics (50% weighting)	2.1 Vectors (4 hours) 2.2 Motion in 1-dimension (13 hours) 2.3 Force, Newton's Laws (10 hours) 2.4 Momentum and impulse (3 hours) 2.5 Work, power and energy (3 hours)
3 Waves (10% weighting)	3.1 Transverse and longitudinal waves (3 hours) 3.2 Geometrical optics (2 hours)
4 Electricity and Magnetism (35% weighting)	4.1 Electrostatics (5 hours) 4.2 Electric circuits (8 hours) 4.3 Magnetism (1 hour) 4.4 Electromagnetism (4 hours)

The guidelines for instructional time given in the table above do not include self-study time, which should be included in the learning program.

Details of Content Coverage for Physics

SECTION 1. BASIC SCIENTIFIC SKILLS

Overview

The basic scientific skills described in this section will be applied in all the other sections of the Physics component of this curriculum. This section should be thoroughly covered at the start of the course, to make sure that all candidates are confident in the basic skills required to be able to tackle the remainder of the course.

1.1 Physical quantities, units and measurement

Content:

- Physical quantities
- SI units and conversions
- Scientific notation

Learning Outcomes:

Candidates should be able to:

1.1.1 write physical quantities as a numerical magnitude and a unit;

1.1.2 recall the following base quantities and their SI units: mass (kg), length (m), time (s), current (A), temperature (K);

1.1.3 convert between various scales of measurement: temperature (Celsius and Kelvin), length (km, m, cm, mm), mass (kg, g), pressure (kPa, atm);

1.1.4 display numerical values in scientific notation;

1.1.5 use the following prefixes and their symbols: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G);

1.1.6 relate the different orders of magnitude to the sizes and masses of common objects, ranging from an atom to the Earth.

1.2 Problem solving techniques

Content:

- Problem solving strategies and procedures

Learning Outcomes:

Candidates should be able to:

1.2.1 use diagrams as problem solving tools;

1.2.2 apply steps in problem solving procedures to solve single- and multi-step problems;

1.2.3 reflect on and interpret answers to calculations.

1.3 Graph drawing, analysis and interpretation

Content:

- Constructing a graph from given data
- Analysing and extracting information from a graph

Learning Outcomes:

Candidates should be able to:

1.3.1 select appropriate variables and scales for graph plotting;

1.3.2 accurately construct a straight-line graph from given data;

1.3.3 analyse a graph to extract meaningful information, namely:

- value and physical meaning of the gradient of a straight-line graph;
- value and physical meaning of the intercepts of a straight-line graph;
- physical interpretation of the shape of a non-linear graph.

SECTION 2. MECHANICS

Overview

> Mechanics is the study of motion and its causes. The greatest contribution to the development of mechanics was by Isaac Newton, who developed the three laws of motion and his law of universal gravitation to predict and explain phenomena. He showed that the physical world can be explained by a few special laws that can be expressed using mathematical formulae.

2.1 Vectors

Content:

- Introduction to vectors and scalars
- Vectors in 2-dimensions

Learning Outcomes:

Candidates should be able to:

2.1.1 state what is meant by scalar and vector quantities, and give examples of each;

2.1.2 add vectors that are co-linear (in 1-dimension) using a graphical method (head-to-tail) as well as by calculation;

2.1.3 add two vectors that are at right angles to determine the resultant using a graphical method (head-to-tail or tail-to-tail) as well as by calculation;

2.1.4 determine the x- and y-components of a vector on the Cartesian plane.

2.2 Motion in 1-dimension

Content:

- Position, displacement, distance
- Speed, velocity, acceleration
- Graphs of motion
- Equations of motion
- Projectile motion

Learning Outcomes:

Candidates should be able to:

2.2.1 define position, displacement and distance;

2.2.2 define position relative to a frame of reference;

2.2.3 determine displacement and distance for 1-dimensional motion;

2.2.4 define speed, instantaneous velocity and average velocity

2.2.5 determine speed, instantaneous velocity and average velocity for 1-dimensional motion;

2.2.6 define acceleration;

2.2.7 determine acceleration for 1-dimensional motion with uniform acceleration;

2.2.8 plot graphs of position vs time, velocity vs time and acceleration vs time;

2.2.9 interpret and determine information from graphs of position vs time, velocity vs time and acceleration vs time for 1-dimensional motion with uniform acceleration;

2.2.10 use the kinematics equations of motion to solve problems for 1-dimensional motion;

2.2.11 explain that objects in free-fall (projectiles) accelerate towards the earth with a constant acceleration of 9,8 $m{\cdot}s^{-2}$;

2.2.12 apply graphs and kinematics equations of motion to objects in free-fall.

2.3 Newton's laws of motion

Content:

- Mass and weight
- Types of forces
- Free body diagrams
- Balanced and unbalanced forces
- Newton's laws of motion

Learning Outcomes:

Candidates should be able to:

2.3.1 differentiate between mass and weight ;

2.3.2 calculate the weight of an object on earth;

2.3.3 identify all of the forces acting on an object, including weight, normal force, applied force, frictional force and tension force;

2.3.4 draw free body diagram(s) to represent the forces acting on an object;

2.3.5 state Newton's first, second and third laws of motion;

2.3.6 apply Newton's laws of motion to various scenarios involving forces in equilibrium and non-equilibrium (exclude objects on an inclined plane).

2.4 Momentum and impulse

Content:

- Linear momentum
- Impulse
- Momentum in collisions

Learning Outcomes:

Candidates should be able to:

2.4.1 define linear momentum and impulse;

2.4.2 calculate the momentum of a moving object;

2.4.3 calculate the change in momentum of an accelerating object;

2.4.4 define force as the rate of change of momentum;

2.4.5 state the principle of conservation of momentum;

2.4.6 apply the principle of conservation of momentum to solve problems involving collisions between two bodies in 1-dimension.

2.5 Work, power and energy

Content:

- Energy conversion and conservation
- Work
- Power

Learning Outcomes:

Candidates should be able to:

2.5.1 list examples of different forms of energy, including kinetic energy, potential energy (gravitational, chemical, elastic), electrical energy, light energy, thermal energy and nuclear energy;

2.5.2 define kinetic energy and gravitational potential energy in words and using mathematical expressions: $E_k = ½ mv^2$ and $E_p = mgh$;

2.5.3 define mechanical energy;

2.5.4 state the principle of the conservation of mechanical energy;

2.5.5 apply the principle of conservation of mechanical energy to various contexts, including objects that are dropped or thrown vertically upwards, and the motion of a swing or pendulum;

2.5.6 define work done as the force multiplied by the distance moved in the direction of the force $W = F_x \Delta x$;

2.5.7 apply the relationship for work done to various related problems;

2.5.8 define power as the work done divided by the time taken to do the work;

2.5.9 apply the relationship for power to various related problems.

SECTION 3. WAVES

Overview

We experience waves all the time in the world around us, whenever we see or hear anything. We can represent waves using simple diagrams that show their structure and characteristics. By understanding waves we can predict their behaviour in different conditions, and we can put them to use in many helpful ways.

3.1 Transverse and longitudinal waves

Content:

- Properties of waves
- Transverse and longitudinal waves

Learning Outcomes:

Candidates should be able to:

3.1.1 describe wave motion as a vibration in a medium, resulting in the transfer of energy without matter being transferred;

3.1.2 differentiate between transverse and longitudinal waves, and give examples of each;

3.1.3 define frequency, wavelength, period and amplitude;

3.1.4 draw a diagram of a transverse wave and indicate the wavelength, amplitude, particle movement and direction of propagation of the wave;

3.1.5 define the wave speed as the product of the frequency and wavelength of a wave $v = f\lambda$ (the wave equation);

3.1.6 apply the wave equation to solve problems involving transverse and longitudinal waves.

3.2 Geometrical optics

Content:

- Reflection of light
- Refraction of light
- Total internal reflection

Learning Outcomes:

Candidates should be able to:

3.2.1 describe reflection of light;

3.2.2 define normal, angle of incidence and angle of reflection;

3.2.3 state that, for reflection, the angle of incidence is equal to the angle of reflection;

3.2.4 define refraction as a change of wave speed in different media, while the frequency remains constant;

3.2.5 define angle of refraction, refractive index and optical density;

3.2.6 draw ray diagrams to show the path of light as it travels between mediums with different optical densities;

3.2.7 explain critical angle and total internal reflection.

SECTION 4. ELECTRICITY AND MAGNETISM

Overview

Electricity and magnetism are very important aspects of Physics, because they underlie many of the daily tools and instruments that we rely on. The ability to understand and harness electricity has resulted in the development of lighting and other electrical devices. An understanding of the relationship between electricity and magnetism has led to the development of motorcars and other machines.

4.1 Electrostatics

Content:

- Forces between charges
- Coulomb's law
- Electric field

Learning Outcomes:

Candidates should be able to:

4.1.1 describe charge as either positive or negative, and measured in coulombs;

4.1.2 state that unlike charges attract and like charges repel;

4.1.3 explain the attraction between a charged object and a neutral object (polarization);

4.1.4 state Coulomb's Law in words and mathematically: $F = \frac{kQ_1Q_2}{r^2}$;

4.1.5 solve problems using Coulomb's Law to calculate the force exerted on a charge by one or more charges in 1-dimension;

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

4.1.7 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;

4.1.8 draw the electric field pattern between two isolated point charges

4.1.9 define the magnitude of the electric field at a point as the force per unit charge, $E = F/q$;

4.1.10 calculate the electric field at a point due to a number of point charges in 1-dimension, using the equation $E = \frac{kQ}{r^2}$.

4.2 Electric circuits

Content:

- Conventional current
- Potential difference
- Resistance
- Energy transfer in electrical circuits

Learning Outcomes:

Candidates should be able to:

4.2.1 state that current (I) is a rate of flow of charge, measured in amperes;

4.2.2 apply the equation $I = Q/\Delta t$;

4.2.3 explain conventional current;

4.2.4 define electromotive force (*emf*) as the work done in moving a unit charge around a complete circuit, measured in volts;

4.2.5 define the potential difference (V) across an element in a circuit as the work done to move a unit charge through the element, measured in volts;

4.2.6 draw diagrams to show how to connect an ammeter to measure current through a circuit element, and a voltmeter to measure voltage across a circuit element;

4.2.7 define resistance;

4.2.8 apply the formulae for the equivalent resistance of a number of resistors in series and in parallel;

4.2.9 state that the current is constant through each element in a series circuit;

4.2.10 state that the total potential difference is equal to the sum of the potential differences across the individual elements in a series circuit;

4.2.11 calculate the equivalent resistance of resistors connected in series: $R_s = R_1 + R_2 + ...$;

4.2.12 state that the potential difference is constant across circuit elements that are connected in parallel;

4.2.13 state that the current from the source is the sum of the currents in the separate branches of a parallel circuit;

4.2.14 calculate the equivalent resistance of resistors connected in parallel: $1/R_p = 1/R_1 + 1/R_2 + ...$;

4.2.15 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;

4.2.16 state Ohm's Law in words and mathematically: $R = V/I$;

4.2.17 solve problems for circuits involving resistors connected in series and parallel;

4.2.18 define power as the rate at which electrical energy is converted in an electric circuit, measured in watts;

4.2.19 state that electrical power dissipated in a device is equal to the product of the potential difference across the device and current flowing through it: $P = IV$;

4.2.20 apply the concepts of electrical energy and power to solve related problems.

4.3 Magnetism

Content:

- Magnets
- Magnetic field

Learning Outcomes:

Candidates should be able to:

4.3.1 describe a permanent magnet as having a north pole and a south pole;

4.3.2 state that like poles repel and unlike poles attract;

4.3.3 define the magnetic field;

4.3.4 describe the magnetic field around a bar magnet and a pair of bar magnets placed close together;

4.3.5 explain how a compass indicates the direction of a magnetic field;

4.3.6 describe the Earth's magnetic field.

4.4 Electromagnetism

Content:

- Magnetic effect of a current
- Force on a current-carrying conductor

Learning Outcomes:

Candidates should be able to:

4.4.1 draw the direction of the magnetic field near a current-carrying wire and a current-carrying loop;

4.4.2 state the effect on the magnetic field of changing the magnitude and / or direction of the current;

4.4.3 explain how an electromagnet works;

4.4.4 determine the direction of the force on a current-carrying conductor in a magnetic field.

General Information for Physics

TABLE OF CONSTANTS

Name	Symbol	Value
Gravitational acceleration	g	$9{,}8\ m\cdot s^{-2}$
Speed of light in a vacuum	c	$3{,}0 \times 10^{8}\ m\cdot s^{-1}$
Coulomb's constant	k	$9{,}0 \times 10^{9}\ N\cdot m^{2}\cdot C^{-2}$
Charge on electron	e	$-1{,}6 \times 10^{-19}\ C$
Electron mass	m_e	$9{,}11 \times 10^{-31}\ kg$

TABLE OF FORMULAE

Mechanics	$v_f = v_i + a\Delta t$ OR $v = u + a\Delta t$	$v_f^2 = v_i^2 + 2a\Delta x$ OR $v^2 = u^2 + 2a\Delta x$
	$\Delta x = v_i\Delta t + ½\, a\Delta t^2$ OR $\Delta x = u\Delta t + ½\, a\Delta t^2$	$\Delta x = ½\, (v_f+v_i)/\Delta t$ OR $\Delta x = ½\, (v+u)/\Delta t$
	$F_g = mg$	$F_{net} = ma$
	$p = mv$	$F_{net}\, \Delta t = \Delta p$
	$W = F_x\, \Delta x$	$P = W/\Delta t$
	$E_k = ½mv^2$	$E_p = mgh$
Waves	$v = f\lambda$	$T = 1/f$
Electricity and Magnetism	$F = \frac{kQ_1Q_2}{r^2}$	$E = \frac{kQ}{r^2}$
	$E = F/q$	$I = Q/\Delta t$
	$V = W/Q$	$R = V/I$
	$R_s = R_1 + R_2 + \ldots$	$1/R_p = 1/R_1 + 1/R_2 + \ldots$
	$emf = IR_{external} + Ir_{internal}$	$P = IV$

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

Quantity	Symbol	Unit symbol
mass	m	kg
position	x	m
displacement	Δx	m
velocity	v	$m \cdot s^{-1}$
initial velocity	v_i or u	$m \cdot s^{-1}$
final velocity	v_f or v	$m \cdot s^{-1}$
acceleration	a	$m \cdot s^{-2}$
gravitational acceleration	g	$m \cdot s^{-2}$
time (instant)	t	s
time interval	Δt	s
energy	E	J
kinetic energy	E_k	J
potential energy	E_p	J
work	W	J
power	P	W
momentum	p	$kg \cdot m \cdot s^{-1}$
force	F	N
weight	F_g or w	N
normal force	F_N	N
tension	F_T	N
friction force	F_f	N
wavelength	λ	m
frequency	f	Hz or s^{-1}
period	T	s
speed of light	c	$m \cdot s^{-1}$
charge	Q, q	C
electric field	E	$N \cdot C^{-1}$ or $V \cdot m^{-1}$
potential difference	V	V
emf	emf	V
current	I, i	A
resistance	R	Ω
internal resistance	r	Ω

GLOSSARY OF TERMS USED IN PHYSICS PAPERS

1. *Calculate* is used when a numerical answer is required. All working should be clearly shown, and the answer should be given with the correct units.
2. *Define* means to give the definition, e.g. define the term work.
3. *Describe* means to give a detailed account of a phenomenon or process, e.g. describe the movement of particles in a transverse wave.
4. *Explain* means to give a detailed account of the reasoning behind a phenomenon or process, e.g. explain why motion remains constant when all forces are balanced.
5. *Determine* means to arrive at an answer through either calculation or reasoning or a combination of both, e.g. use the given information to determine the resultant force.
6. *Discuss* means to give a critical account of the points involved in the topic.
7. *Find* is a general term that could include calculation, reasoning, interpretation etc.
8. *List* means to provide a number of points with no discussion.
9. *Predict* or *deduce* means to show a logical connection between pieces of information.
10. *Sketch*, when applied to graph work, means to show just the shape and / or position of the curve. In diagrams, *sketch* means that a simple, freehand but neat drawing is acceptable, e.g. sketch a velocity-time graph to represent the motion.
11. *State* means to give a short, clear answer with little or no supporting argument, e.g. state the principle of conservation of linear momentum.

BIOLOGY

Introduction

Biology is the scientific study of living organisms from the molecular level to their interactions with one another and their environment. Biology at foundational level is selected from a range of topics, which include molecules and cells, genetics and heredity, evolution and diversity, structure and function of animals and plants, and ecology. This curriculum focuses on the topics Evolution and diversity, linking them with genetics and heredity.

Rationale for Content Selection

The intention of this course is to develop ways of thinking that are important in Biology. Because limited time is available for Biology, a decision was made to focus on content that gives opportunities to develop higher order thinking skills, and that provides the core foundation for further study in Biology. Evolution is the core principle in Biology that explains the diversity we see around us. Genetics and heredity help us to understand the mechanisms of evolution. Since these are the core principles in Biology, they will provide a strong foundation for further study in Biology.

Biology Content Structure

Topic Heading	Topic
1. The nature of science (10%)	1.1 How scientific understanding grows (6 hours)
2. Biodiversity (15%)	2.1 Principles of classification (7 hours) 2.2 The history of life (2 hours)
3. Evolution (25%)	3.1 The theory of evolution by natural selection (5 hours) 3.2 Evidence supporting evolution (10 hours)
4. Genetics and Heredity (50%)	4.1 Patterns of inheritance (15 hours) 4.2 DNA structure and function (15 hours)

The guidelines for instructional time given in the table above do not include self-study time, which should be included in the learning program.

Details of Content Coverage for Biology

SECTION 1. THE NATURE OF SCIENCE

Overview

Scientific inquiry begins with curiosity about something to do with living organisms, based on our observations of that phenomenon. The scientist then proposes a hypothesis that might explain the phenomenon. If the hypothesis is correct, he predicts what the outcome might be if he manipulates the situation through an experiment.

The scientist sets up a research programme with other researchers to carry out the experiments. He collects data in a careful and rigorous manner. Once he has sufficient data, he writes a scientific paper that is sent to a number of other scientists for review. Once they are satisfied, the paper is published in a journal or presented at a conference.

If the hypothesis is supported by other scientists' research, it achieves the status of a theory. A scientific theory is supported by a great deal of evidence, and is consistent with all known facts. While the so-called "hard sciences" (Physics and Chemistry) arrive at Laws that explain physical phenomena, Biology has a few Laws, but many Principles, which are generally true, but it has exceptions.

1.1 The nature of science

Content

- Importance of rigour in science
- Difference between hypothesis and theory
- Inductive and deductive reasoning

Learning outcomes

Candidates should be able to:

1.1.1 explain the importance of precision, accuracy and integrity in building scientific evidence;

1.1.2 differentiate between hypothesis and theory;

1.1.3 describe the importance of inductive reasoning and deductive reasoning in the growth of biological knowledge, e.g. inductive reasoning and the development of cell theory; deductive reasoning and hypothesis-testing;

1.1.4 Design and conduct a hypothesis-testing investigation into ONE condition required for growth of bean or mealie seedlings, e.g. water, warmth, light, or compost.

SECTION 2: BIODIVERSITY

Overview

There are estimated to be between 5 and 20 million species of living organisms on Earth at present, representing only 10% of all the life that has ever existed. Scientists organise living organisms according to a hierarchical classification scheme, according to similarities and differences between the organisms.

The highest level of organisation in the classification scheme is the Kingdom. Here, we encounter the distinguishing characteristics of the five kingdoms: Bacteria, Protista, Fungi, Plantae and Animalia. The history of the major groups of living organisms is illustrated.

2.1 Principles of classification

Content

- Extent of biodiversity
- Taxonomic levels
- Characteristics of the five kingdoms

Learning outcomes

Candidates should be able to:

2.1.1 demonstrate awareness of the extent of biodiversity in South Africa;

2.1.2 represent biodiversity of the most abundant groups of plants and animals in the form of graphs and charts;

2.1.3 distinguish between natural and artificial classification schemes;

2.1.4 define a species using the biological species concept;

2.1.5 apply the species concept to biodiversity with particular emphasis on the binomial system of naming species;

2.1.6 apply the nested hierarchical classification system used to classify species according to genus, family, order, class, phylum (animals) or division (plants), kingdom;

2.1.7 identify the distinguishing characteristics of the five kingdoms:

- Bacteria: prokaryotic, unicellular, autotrophic, heterotrophic or saprotrophic;
- Protista: eukaryotic, unicellular or simple multicellular, autotrophic or heterotrophic;
- Fungi: eukaryotic, having chitin in the cell walls, unicellular or simple multicellular, saprotrophic;
- Plantae: eukaryotic, having cellulose in the cell walls, multicellular, most having differentiated tissues, autotrophic;
- Animalia: eukaryotic, with no cell walls, multicellular, most having differentiated tissues, heterotrophic;

2.1.8 construct a timeline showing key events in the history of life on earth, including the earliest bacteria, the first eukaryotes, first land plants, first fish, first amphibians, first reptiles, first flowering plants, first mammals, first birds, first pre-humans.

SECTION 3. EVOLUTION

Overview

This section studies the most important principle in Biology, which is evolution by natural selection. Life evolves from previously-existing life-forms by the process of natural selection. Supporting evidence comes from study of artificial selection, the fossil record, comparative anatomy, and biogeography.

3.1 The theory of evolution by natural selection

Content

- Development of the theory of evolution by natural selection
- The theory of evolution by natural selection
- Natural selection in action, e.g. antibiotic resistance
- Mechanisms of speciation and reproductive isolation

Learning outcomes

Candidates should be able to:

3.1.1 describe the contributions of Charles Darwin and Alfred Wallace to the development of the theory of evolution by natural selection, specifically:

- Darwin's observations during the Voyage of the Beagle;
- Darwin's reluctance to publish;
- Wallace's paper on evolution by natural selection;
- the joint presentation of the theory of evolution by natural selection;

3.1.2 describe the theory of evolution by natural selection in terms of over-production of offspring in every generation, resulting in a struggle to survive, heritable variation between individuals, differential reproductive success between individuals, resulting in gradual shift of the population in the direction of favourable adaptations;

3.1.3 use evolution of antibiotic resistance in bacteria as an example of natural selection;

3.1.4 describe how geographical isolation gives rise to speciation, with reference to Galapagos finches;

3.1.5 describe mechanisms of reproductive isolation including temporal isolation, ecological isolation, behavioural isolation, gamete incompatibility, hybrid sterility.

3.2 Evidence supporting evolution

Content

- Artificial selection
- Fossil record
- Comparative anatomy
- Biogeography

Learning outcomes

Candidates should be able to:

3.2.1 explain how artificial selection imitates and supports the theory of natural selection, with reference to:

- *Brassica* giving rise to cabbages, broccoli, cauliflower and brussel sprouts;
- Origin of cattle breeds for different purposes;

3.2.2 describe how the fossil record supports evolution, including:

- how fossils form in sedimentary rock;
- relative and radiometric dating of fossils;

- patterns of succession seen in the fossil record, such as mammal-like reptiles to mammals in southern Africa;
- similarities and differences between fossils and modern species, e.g. *Australopithecus* and modern humans;

3.2.3 illustrate diagrammatically the evolutionary relationships among the kingdoms;

3.2.4 describe how comparative anatomy supports evolution with reference to the vertebrate forelimb;

3.2.5 describe how the configuration of the earth's surface has changed over long periods of time, e.g. the existence and subsequent separation of Gondwana;

3.2.6 describe how biogeography supports evolution, e.g. the distribution of large flightless birds on different landmasses.

SECTION 4. GENETICS AND HEREDITY

Overview

Evolution by natural selection depends on heritable variation in organisms, that is, variation that is passed on from one generation to another. The science of genetics provides strong evidence that characteristics do pass from one generation to another, and it provides some Principles that explain the patterns of inheritance. Gregor Mendel founded the science of genetics, and his work had an enormous impact on understanding of the mechanisms of evolution by natural selection.

The chemical nature of hereditary material was discovered in the mid-20th century. Deoxyribonucleic acid (DNA) encodes the information that controls the structure and functioning of every organism, and is passed on from one generation to the next. It controls the synthesis of proteins at particular stages in an organism's development. Studying and manipulating the structure and functioning of DNA is cutting-edge research in Biology at present.

4.1 Patterns of inheritance

Content

- Mendel and the science of genetics
- Cell division
- The nature of genes and alleles and their role in determining the phenotype
- Solving genetics problems
- Variation

Learning outcomes

Candidates should be able to:

4.1.1 define inheritance and describe the contribution of Mendel's work to understanding inheritance;

4.1.2 identify the following structures in a cell: nucleus, nuclear membrane, chromosomes, centromere, chromatin, homologous pairs;

4.1.3 describe the role of chromosomes in passing information accurately from one generation to the next;

4.1.4 identify, with the aid of diagrams, prophase, metaphase, anaphase and telophase of mitosis;

4.1.5 identify, with the aid of diagrams, prophase, metaphase, anaphase and telophase of meiosis I and meiosis II (Names of the subdivisions of prophase are not required);

4.1.6 define the terms haploid and diploid, and explain the need for a reduction division prior to fertilisation;

4.1.7 define a gene as a unit of inheritance and distinguish clearly between the terms gene and allele;

4.1.8 explain the terms dominant, recessive, codominant, homozygous, heterozygous, genotype, phenotype, sex-linked inheritance, F_1 generation and F_2 generation;

4.1.9 solve genetics problems involving monohybrid and dihybrid crosses;

4.1.10 solve genetics problems involving codominance and multiple alleles with reference to inheritance of the ABO blood group phenotypes – A, AB, O, gene alleles I^A, I^B and I^O;

4.1.11 describe the determination of sex in humans – XX and XY chromosomes;

4.1.12 describe mutation as a change in the structure of a gene and nondisjunction as failure of homologous pairs to separate properly during meiosis;

4.1.13 describe the effects of gene mutations, such as in sickle cell anaemia, and chromosomal nondisjunction, such as in Downs' syndrome;

4.1.14 explain the role of meiosis, fertilisation and mutations in producing genotypic and phenotypic variation;

4.1.15 differentiate between continuous and discontinuous variation, such as height of people of the same age (continuous variation) and human blood type (discontinuous variation);

4.1.16 explain that natural selection acts on variation in phenotypes, which are determined by genotypes;

4.1.17 explain that natural selection influences the survival of alleles in a population by operating on phenotypes that have a heritable, genetic basis;

4.1.18 define the terms gene pool, allele frequency, microevolution.

4.2 DNA structure and function

Content

- The Structure of DNA
- Replication of DNA
- The role of DNA in protein synthesis
- The effect of mutations on DNA structure and function

Learning outcomes

Candidates should be able to:

4.2.1 describe the relationship between chromosomes, genes and DNA;

4.2.2 identify the structure of a DNA molecule as a double helical-structure, consisting of two parallel strands of nucleotides;

4.2.3 describe the components of a nucleotide (ribose or deoxyribose sugar, phosphate and nitrogenous base, being adenine, guanine, cytosine and thymine or uracil);

4.2.4 describe the process of DNA replication, and relate it to mitosis and meiosis;

4.2.5 explain that DNA carries the genetic code, which is transcribed into sequences of amino acids to form proteins that are responsible for phenotypic characteristics;

4.2.6 explain the importance of exact replication of DNA for transmission of genetic material to other cells and the next generation;

4.2.7 describe the structure, types and location of messenger-RNA, transfer-RNA and ribosomal-RNA;

4.2.8 differentiate between the structure of DNA and RNA;

4.2.9 describe the transcription of a gene into m-RNA, including the role of the promoter, RNA polymerase, complementary base pairing, nucleotide joining and the stop signal;

4.2.10 describe the translation of m-RNA into a polypeptide chain, including initiation of protein synthesis on the ribosomes, the role of t-RNA, the start codon, elongation of the polypeptide chain, the role of the stop codon, and disassembly of the ribosome-polypeptide complex;

4.2.11 explain the concept of the triplet code, and translate a sequence of mRNA codons into t-RNA anticodons and an amino-acid sequence;

4.2.12 explain the effects of mutations on the triplet code, including base-pair substitutions, deletions and insertions;

4.2.13 apply the processes of mutations in DNA to genetic mutations and phenotypic variation, and thereby to natural selection.

General Information for Biology

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

Quantity	Symbol	Unit symbol
length	l	m, cm, mm, µm
Geological time		mya
temperature	T	°C

GLOSSARY OF TERMS USED IN BIOLOGY PAPERS

1. *State* means to give the facts about a topic, e.g. state the function of mRNA in protein synthesis.
2. *List* means to construct a list relevant to a topic, but without giving details, e.g. list four sources of evidence supporting evolution.
3. *Define* means to give the definition, e.g. define the term genotype.
4. *Describe* means to give a detailed account of a structure or process, e.g. describe the process of natural selection.
5. *Explain* means to give a detailed account, but also to give reasons for certain steps, e.g. explain how meiosis contributes to genetic variation.
6. *Compare* means to set two structures or processes in contrast to each other and to identify the similarities and differences, e.g. compare continuous and discontinuous variation.
7. *Differentiate* means to focus on the differences between two similar structures or concepts, e.g. differentiate between natural selection and artificial selection.
8. *Discuss* means to consider an issue from several different angles; consider the pros and cons of a solution to a problem, e.g. discuss the effects of the use of antibiotics for relatively minor illnesses.
9. *What is meant by* …. usually means that a definition should be given.
10. *Tabulate* means to give your answer in the form of a table, e.g. tabulate three differences between mitosis and meiosis.
11. *Find* is a general term that often requires you to calculate, measure or solve a problem, e.g. find the ratio of red flowers to white flowers in a genetic cross.

SPECIAL NOTE

The Biology section of this curriculum assumes that candidates have an understanding of the structure of the characteristics of life, and a basic understanding of cell structure. They may need to revise terms such as autotrophic, heterotrophic, prokaryotic and eukaryotic.

CHEMISTRY

Introduction

Chemistry spans the divide between the macroscopic and microscopic. It is one branch of Natural Sciences but itself consists of many branches, such as inorganic chemistry, organic chemistry, physical chemistry and biochemistry. Chemistry can be viewed as the study different types, components and properties of matter, and the chemical changes that different types of matter undergo.

Rationale for Content Selection

This chemistry curriculum aims to help students develop their understanding of several concepts that are commonly viewed as foundational to chemistry, and then to extend their understanding to some selected and more advanced topics. The curriculum thus begins with an introduction to matter before shifting focus to the chemical changes that matter undergoes. It is envisaged that this approach will scaffold candidates for more advanced chemistry studies and/or their study of other science subjects. The teaching and study of chemistry theory can be greatly enhanced through the use of practical activities that traditionally employ specialist resources but these are often difficult to access. Since chemistry occurs within us and all around us, suitable practical activities employing resources available in everyday life can successfully be incorporated into the learning experience of this curriculum to either introduce, illustrate or re-inforce chemistry theory.

Chemistry Content Structure

Topic Heading	Topic
1. Matter (50% weighting)	1.1 Particle theory of matter and the three states of matter (2 hours) 1.2 Classification and Separation of matter (2 hours) 1.3 Atomic structure (3 hours) 1.4 Periodic table and periodicity (4 hours) 1.5 Particles substances are made of (5 hours) 1.6 Types of Chemical Bonding (3 hours) 1.7 Chemical Formulae and Naming of Compounds (3 hours) 1.8 Molecular structure (5 hours) 1.9 Intermolecular forces (3 hours) 1.10 Types of Organic molecules (3 hours)
2. Chemical Change (50% weighting)	2.1 Representing Chemical Change (4 hours) 2.2 Stoichiometry (8 hours) 2.3 Energy changes during chemical reactions (4 hours) 2.4 Reaction rate (4 hours) 2.5 Chemical Equilibrium (6 hours) 2.6 Acids, Bases and Neutralisation reactions (8 hours)

The guidelines for instructional time given in the table above do not include self-study time, which should be included in the learning program.

Details of Content Coverage for Chemistry

SECTION 1. MATTER

Overview

Various experiments/demonstrations provide evidence that the solid, liquid and gaseous states of all types of matter consists of particles. Kinetic molecular theory describes the movement of particles making up the solid, liquid and gaseous state of a substance.

Matter consisting of a physical combination of more than one type of atom or chemical combination of atoms/ions are referred to as mixtures. The separation technique employed for a specific mixture depends on the properties of the substances it contains.

The smallest particle of matter is the atom and over time different scientists have described various models of the atom. One model of the atom describes it as containing three subatomic particles (neutrons, protons and electrons) with the neutral neutrons and positive protons bound in a nucleus at the center of the atom and negative electrons spinning in orbitals surrounding the nucleus. There are different types of atoms, each with its own number of protons. The different types of atoms are known as elements and are listed on the periodic table, arranged in such a way that illustrates the patterns in their chemical and physical properties, known as periodicity.

While some types of matter consists of individual atoms, other forms of matter consists of charged atoms called ions or of two or more atoms bonded together to form molecules. The shape of a molecule can be predicted using the valence shell electron pair repulsion theory. The intermolecular forces between molecules depends on the polarity of the bonds they contain and their molecular geometry.

Molecules containing the element carbon are usually described as organic, and there are several different types of organic molecules. Each type is names according to the IUPAC (International Union of Pure and Applied Chemistry) system depending on the functional groups of atoms contained by the molecule.

1.1 Particle theory of matter and the three states of matter

Content:

- Particle nature of matter
- States of matter
- State changes
- Kinetic molecular theory

Learning Outcomes:

Candidates should be able to:

1.1.1 describe evidence for the particle nature of matter;

1.1.2 state the kinetic molecular theory;

1.1.3 describe the states of matter;

1.1.4 explain the state changes in terms of kinetic molecular theory.

1.2 Classification and separation of matter

Content:

- Mixtures and pure substances
- Heterogeneous and homogeneous mixtures
- Separation of mixtures

Learning Outcomes:

Candidates should be able to:

1.2.1 define and differentiate between mixtures and pure substances, heterogeneous mixtures and homogenous mixtures;

1.2.2 classify different examples of matter according to a classification scheme for matter involving homogenous mixtures (solid, liquid and gaseous solutions), heterogeneous mixtures, compounds (ionic and covalent) and elements (metals, metalloids and non-metals);

1.2.3 describe the separation of different types of mixtures (solid-solid, solid-liquid when soluble and insoluble, liquid-liquid when miscible and immiscible).

1.3 Atomic Structure

Content:

- Subatomic particles
- Atomic structure

Learning Outcomes:

Candidates should be able to:

1.3.1 list the subatomic particles (electrons, protons and neutrons), their charges and location within an atom;

1.3.2 draw simple atomic models (Bohr models) to represent atoms in terms of their subatomic particles.

1.4 Periodic table and periodicity

Content:

- Periodic table and periodicity
- Aufbau diagrams
- Spectroscopic electron configurations
- Lewis dot diagrams
- Mass Number and Atomic Number

Learning Outcomes:

Candidates should be able to:

1.4.1 state the chemical symbol when given the name, or the name when given the symbol, for the first 20 elements of the periodic table as well as iron, cobalt, nickel, copper, zinc, palladium, silver, platinum, gold and mercury;

1.4.2 explain the arrangement of elements on the periodic table in terms of metals, metalloids and non-metals; increasing atomic number and number of valence electrons from left to right across a period; increasing number of shells from top to bottom down a group;

1.4.3 state the names given to group 1 and 2 metals and groups 17 and 18 non-metals in the periodic table;

1.4.4 draw Aufbau diagrams (using Hund's rule and Pauli's exclusion principle) and Lewis dot diagrams for the first 20 elements of the periodic table;

1.4.5 identify the specific element(s) represented by a particular Aufbau diagram or Lewis dot diagram;

1.4.6 write spectroscopic electron configurations for the first 20 elements of the periodic table;

1.4.7 identify the specific element(s) represented by a particular spectroscopic electron configuration;

1.4.8 define mass number and atomic number;

1.4.9 calculate the number of neutrons in atoms of different elements, using the mass and atomic numbers of each element.

1.5 Particles substances are made of

Content:

- Atoms, ions and molecules
- Octet Rule
- Anion and cation formation
- Compound ions

Learning Outcomes:

Candidates should be able to:

1.5.1 differentiate between individual atoms, ions and molecules;

1.5.2 state the octet rule;

1.5.3 describe the formation of cations by metal atoms, and anions by non-metal atoms following the octet rule;

1.5.4 state the name of compound ions such as hydroxide, ammonium, nitrate, nitrite, sulfate, sulfite and carbonate.

1.6 Types of chemical bonding

Content:

- Elements and compounds
- Ionic, covalent and metallic bonding
- Electronegativity
- Bond polarity

Learning Outcomes:

Candidates should be able to:

1.6.1 differentiate between an element and a compound;

1.6.2 describe ionic bonding in words and using Lewis dot diagrams;

1.6.3 describe the formation of molecules of elements (the 7 diatomic gases) and molecules of compounds (covalent bonding) in words and using Lewis dot diagrams;

1.6.4 define electronegativity and explain the trend in electronegativity on the periodic table;

1.6.5 define polar and non-polar molecules;

1.6.6 identify whether simple diatomic molecules will be polar or non-polar based on the relative electronegativities of the atoms involved;

1.6.7 describe metallic bonding and explain the hardness/softness of metals, electrical and thermal conductivity in terms of metallic bonding.

1.7 Chemical formula and naming of compounds

Content:

- Scientific and common names of compounds
- Chemical formulae of compounds
- Mole concept
- Molar Mass

Learning Outcomes:

Candidates should be able to:

1.7.1 state the scientific name of compounds (such as salts) as well as the common names of compounds (such as common acids and bases);

1.7.2 write chemical formulae for compounds using the concept of valency or cation and anion tables;

1.7.3 describe one mole of a substance as containing Avogadro's number of particles;

1.7.4 define molar mass;

1.7.5 calculate the molar mass from the chemical formulae of chemical compounds, using the periodic table.

1.8 Molecular Structure

Content:

- Valence shell electron pair repulsion theory
- Polar and Non-Polar molecules

Learning Outcomes:

Candidates should be able to:

1.8.1 explain the valence shell electron pair repulsion theory;

1.8.2 use valence shell electron pair repulsion theory to predict molecular geometry for molecules when the central atom **has** lone pairs;

1.8.3 use valence shell electron pair repulsion theory to predict molecular geometry for molecules when the central atom and **does not have** lone pairs;

1.8.4 identify polar and non-polar molecules based on electronegativity of the atoms involved and whether the geometry is symmetrical or asymmetrical.

1.9 Intermolecular Forces

Content:

- Intramolecular vs. Intermolecular forces
- Types of intermolecular forces

Learning Outcomes:

Candidates should be able to:

1.9.1 define and differentiate between, intramolecular and intermolecular forces;

1.9.2 explain the following types of intermolecular forces: ion-dipole forces, ion-induced dipole forces, Van der Waals forces (dipole-dipole, dipole-induced dipole and induced dipole-induced dipole/London/dispersion forces);

1.9.3 identify the type of intermolecular force between specific types of particles (atoms, ions or molecules).

1.10 Types of organic molecules

Content:

- Hydrocarbons
- Functional groups and homologous series

- IUPAC naming

Learning Outcomes:

Candidates should be able to:

1.10.1 define the term 'organic' as used in chemistry;

1.10.2 define functional group, hydrocarbon and homologous series;

1.10.3 name organic molecules containing the following functional groups: alkanes, alkenes, alkyne, alkyl halides, alcohols, ketones, aldehydes, with up to 8 carbon atoms on the parent chain.

SECTION 2. CHEMICAL CHANGES

Overview

Chemical changes happen within living organisms and in non-living systems. The chemical change from reactants to products can be described using chemical equations involving words, models or chemical symbols. Due to the laws of constant composition and conservation of mass, chemical equations must be balanced. The coefficients of reactants and products in balanced chemical equations play a key role in chemical calculations of quantities such as molar concentrations, limiting reagents, percentage yield and equilibrium constants.

Chemical changes involve energy being absorbed (to break existing chemical bonds) and energy being released (when new chemical bonds are formed). Depending on the relative amounts of energy absorbed or energy released, a chemical reaction can be described as exothermic or endothermic. The changes in potential energy over the course of chemical reactions can be represented using potential energy profiles. It is important to develop an understanding of these energy changes that take place during chemical reactions.

Some chemical reactions (such as those in a fireworks display) happen very quickly while others may take place very slowly (such as the rusting or iron). The rate of a chemical reaction is the change in reactant/product concentration per unit time and this can be measured in various ways depending on the characteristics of a particular reaction. In this section, the factors that influence the rate of a chemical reaction will be explored.

In a closed system, chemical reactions are reversible. Initially only the forward reaction takes places but as the product concentration increases the reverse reaction begins. Left undisturbed, a dynamic equilibrium will be reached in which the rate of forward and reverse reactions are equal. This section explores the effects of various stresses on this state of dynamic equilibrium.

Different types of chemical reactions are explored, such as neutralisation reactions, redox reactions and electrochemical reactions.

2.1 Representing chemical change

Content:

- Chemical change
- Chemical equations

Learning Outcomes:

Candidates should be able to:

2.1.1 represent chemical reactions using words, models and chemical symbols (including state symbols);

2.1.2 state the laws of constant composition and conservation of matter;

2.1.3 write balanced chemical equations.

2.2 Stoichiometry

Content:

- Limiting reagent
- Theoretical, actual and percentage yield
- Empirical and molecular formula

Learning Outcomes:

Candidates should be able to:

2.2.1 define limiting reagent, theoretical yield, actual yield and percentage yield;

2.2.2 calculate number of moles, volume, concentration, limiting reagent and percentage yield for chemical reactions;

2.2.3 determine the empirical and molecular formulae when given the percentage composition of a particular compound.

2.3 Energy changes during chemical reactions

Content:

- Potential energy profiles
- Exothermic and endothermic reactions
- Catalysis

Learning Outcomes:

Candidates should be able to:

2.3.1 define exothermic and endothermic;

2.3.2 label and interpret potential energy profiles for exothermic and endothermic reactions;

2.3.3 draw labelled potential energy profiles for exothermic and endothermic chemical reactions;

2.3.4 explain the effect of catalysis using potential energy profiles.

2.4 Reaction rate

Content:

- Measuring reaction rate
- Factors affecting reaction rate

Learning Outcomes:

Candidates should be able to:

2.4.1 describe experimental methods for measuring reaction rate depending on the particular chemical reaction;

2.4.2 list the factors affecting reaction rate and explain their effect using collision theory.

2.5 Chemical Equilibrium

Content:

- Reversible reactions
- Dynamic equilibrium
- Factors affecting equilibrium and Le Chatelier's principle
- Equilibrium constant

Learning Outcomes:

Candidates should be able to:

2.5.1 draw graphs of concentration against time and reaction rate against time to illustrate chemical equilibrium;

2.5.2 list the factors affecting equilibrium and explain their effect for particular chemical reactions using Le Chatelier's principle;

2.5.3 calculate and interpret K_c for particular chemical reactions.

2.6 Acids, Bases and Neutralisation reactions

Content:

- Arrhenius and Bronsted-Lowry models of acids and bases
- Neutralisation reactions
- Chemical indicators
- Chemical titrations
- pH and pOH

Learning Outcomes:

Candidates should be able to:

2.6.1 define acids and bases according to the Arrhenius model and Bronsted-Lowry model;

2.6.2 predict the products of reactions between specific acids and metal hydroxides, acids and metal oxides, acids and metal carbonates, and acids and metals;

2.6.3 differentiate between equivalence point and end point;

2.6.4 explain the difference between strong and concentrated acids/bases and between weak and dilute acids/bases;

2.6.5 calculate pH and pOH;

2.6.6 calculate quantities such as concentration of an acid or base using titration data.

General Information for Chemistry

TABLE OF CONSTANTS

Name	Symbol	Value
Avogadro's constant	N_A	$6{,}02 \times 10^{23}$ mol^{-1}
Molar Volume of gas at STP	V_M	22,4 dm^3·mol^{-1}
Standard temperature	T^θ	273 K
Standard pressure	P^θ	$1{,}013 \times 10^5$ Pa

TABLE OF FORMULAE

Stoichiometry	$n = m / M$	$n = N / N_A$
	$n = v / V_m$	$c = n / v$ OR $c = m / Mv$
	percentage yield = *actual yield / theoretical yield × 100%*	
Rate of reaction	*rate of reaction = Δ [reactant]/Δt* OR *rate of reaction = Δ [product]/Δt*	
Chemical Equilibrium	$K_c = [C]^c[D]^d / [A]^a[B]^b$	
Acids, Bases and Neutralisation Reactions	$pH = -\log[H^+]$	$pOH = -\log [OH^-]$
	$n_A / n_B = c_A \times v_A / c_B \times v_B$	

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

Quantity	Symbol	Unit symbol
concentration	c	$mol{\cdot}dm^{-3}$
concentration of acid	c_A	$mol{\cdot}dm^{-3}$
concentration of base	c_B	$mol{\cdot}dm^{-3}$
equilibrium constant	K_c	-
mass	m	g
molar mass	M_m	$g{\cdot}mol^{-1}$
molar volume	V_m	$dm^3{\cdot}mol^{-1}$
number of moles	n	mol
number of mols of acid	n_A	mol
number of mols of base	n_B	mol
number of particles	N	-
pressure	P	Pa
temperature	T	K
time (instantaneous)	t	s
volume	v	dm^3
volume of acid	v_A	dm^3
volume of base	v_B	dm^3

GLOSSARY OF TERMS USED IN CHEMISTRY PAPERS

1. *Calculate* is used when a numerical answer is required. All working should be clearly shown, and the answer should be given with the correct units.
2. *Classify* means to state the category to which something belongs, e.g. classify the following elements as metals, metalloids or non-metals.
3. *Define* means to give the definition, e.g. define the term 'mass number'.
4. *Describe* means to give a detailed account of a phenomenon or process, e.g. describe experimental methods for measuring reaction rate.
5. *Determine* means to arrive at an answer through either calculation or reasoning or a combination of both, e.g. determine the empirical and molecular formula for a compound with a particular composition.
6. *Differentiate* means to focus on the differences between two similar structures or concepts, e.g. differentiate between homogenous mixtures and heterogenous mixtures.
7. *Draw* means to illustrate (not necessarily to scale) using scientific conventions, e.g. draw an afbau diagram for the element chlorine.
8. *Explain* means to give a detailed account of the reasoning behind a phenomenon or process, e.g. explain catalysis.

9. *Discuss* means to give a critical account of the points involved in the topic.
10. *Identify* means to recognise instances, examples, types of something, e.g. identify the polar molecules in the list provided.
11. *Interpret* means to make meaning from information provided in some form, e.g. interpret the K_c value for a particular chemical equilibrium.
12. *Label* means to provide the names for parts or sections of something, e.g. label the following potential energy profile.
13. *List* means to provide a number of points with no discussion.
14. *Predict* or *deduce* means to show a logical connection between pieces of information.
15. *Represent* means to show/illustrate an object or phenomenon, e.g. represent the following chemical reaction using words, models and chemical symbols.
16. *Sketch*, when applied to graph work, means to show just the shape and / or position of the curve. In diagrams, sketch means that a simple, freehand but neat drawing is acceptable, e.g. sketch a graph of reactant concentration vs. time for the chemical reaction.
17. *State* means to give a short, clear answer with little or no supporting argument, e.g. state the law of constant composition.
18. *Write* means to use written words and/or symbols to represent something, e.g. write spectroscopic electron configurations for the first 20 elements of the periodic table.