



**Republic of Namibia**

**MINISTRY OF EDUCATION, ARTS AND CULTURE**

**NAMIBIA SENIOR SECONDARY CERTIFICATE (NSSC)**

**CHEMISTRY SYLLABUS  
ADVANCED SUBSIDIARY LEVEL  
SYLLABUS CODE: 8224  
GRADE 12**

**FOR IMPLEMENTATION IN 2021  
FOR FIRST EXAMINATION IN 2021**

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*Chemistry Syllabus Advanced Subsidiary Level Grade 12*

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## 1. INTRODUCTION

The Namibia Senior Secondary Certificate Advance Subsidiary (NSSCAS) level syllabus is designed as a one-year course leading to examination after completion of the Namibia Senior Secondary Certificate Ordinary (NSSCO) level. The syllabus is designed to meet the requirements of the *National Curriculum for Basic Education (NCBE)* and has been approved by the National Examination, Assessment and Certification Board (NEACB).

The Namibia National Curriculum Guidelines, applicable at the stage of senior secondary education (Grade 10-12) and at equivalent stages of non-formal education, as a part of life-long learning, recognise the uniqueness of the learner and adhere to the philosophy of learner-centred education.

The Namibia National Curriculum Guidelines:

- recognise that learning involves developing values and attitudes as well as knowledge and skills
- promote self-awareness and an understanding of the attitudes, values and beliefs of others in a multilingual and multicultural society
- encourage respect for human rights and freedom of speech
- provide insight and understanding of crucial “global” issues in a rapidly changing world which affects quality of life: the AIDS pandemic, global warming, environmental degradation, distribution of wealth, expanding and increasing conflicts, the technological explosion and increased connectivity
- recognise that as information in its various forms becomes more accessible, learners need to develop higher cognitive skills of analysis, interpretation and evaluation to use information effectively
- seek to challenge and to motivate learners to reach their full potential and to contribute positively to the environment, economy and society

Thus the Namibia National Curriculum Guidelines should provide opportunities for developing essential skills across the various fields of study. Such skills cannot be developed in isolation and they may differ from context to context according to a field of study. The skills marked with an \* are relevant to this syllabus.

The skills are:

- communication skills\*
- numeracy skills\*
- information skills\*
- problem-solving skills\*
- self-management and competitive skills\*
- social and cooperative skills\*
- physical skills\*
- work and study skills\*
- critical and creative thinking\*

## 2. RATIONALE

This syllabus describes the intended learning and assessment for Chemistry in the NSSCAS phase. As a subject, Chemistry is within the natural science area/areas of learning in the curriculum, but has thematic links to other subjects across the curriculum.

The subject Chemistry places strong emphasis on the learners' understanding of the physical and biological world around them at the local, regional and international levels. It thus includes how societies use natural resources to satisfy their needs, and how the environment may be changed in ecologically sustainable ways. At this phase and subject area, the application of scientific knowledge and attitudes to health is of special relevance for the individual, the family, and society as a whole as well as the environment around us including the sustainability of our natural resources. Critical thinking, investigating phenomena, interpreting data, and applying knowledge to practical (experimental and investigative) skills and abilities are essential to understanding the value and limitations of natural scientific knowledge and methods, and their application to daily life. This requires advanced technology through the efficient and effective usage of equipment, materials and processes. Modern technology is required in order to assist our learners and society to solve problems through planning, design, realisation, and evaluation of activities and goals.

## 3. AIMS

The aims of the syllabus are the same for all learners. These are set out below and describe the educational purposes of a course in Chemistry for the NSSCAS examination. They are not listed in order of priority.

Chemistry promotes the following aims in the curriculum:

1. Provide, through well designed studies of theoretical and practical science, a worthwhile educational experience for all learners, whether or not they go on to study science beyond this level and in particular, enables learners to acquire sufficient understanding and knowledge to:
  - become confident citizens in a technological world, able to take or develop an informed interest in scientific matters;
  - recognise the usefulness and limitations of scientific method and to appreciate its applicability in other disciplines and in everyday life;
  - be suitable prepared for employment and/or further studies beyond the NSSCAS in Chemistry.
2. Develop abilities and skills that:
  - are relevant to the study and practice of Chemistry
  - are useful in everyday life
  - encourage efficient and safe practice
  - encourage effective communication
3. Develop attitudes relevant to Chemistry such as: concern for accuracy and precision; objectivity, integrity, enquiry, initiative and inventiveness.
4. Stimulate interest in, and care for, the environment.
5. To develop self-motivation and ability to study in a sustained fashion.
6. To develop social, cooperative and physical skills.

7. Promote an awareness that:

- scientific theories and methods have developed, and continue to do so, as a result of the co-operative activities of groups and individuals
- the study and practice of science is subject to social, economic, technological, ethical and cultural influences and limitations
- the applications of science may be both beneficial and detrimental to the individual, the community and the environment
- science transcends national boundaries and that the language of science, correctly and rigorously applied, is universal

## **4. ADDITIONAL INFORMATION**

### **4.1 Guided learning hours**

The NSSCAS level syllabuses are designed on the assumption that learners have about 180 guided learning hours per subject over the duration of one year, but this is for guidance only. The number of hours required to gain the qualification may vary according to local conditions and the learners' prior experience of the subject. *The National Curriculum for Basic Education (NCBE)* indicates that this subject will be taught for 9 periods of 40 minutes each per 7-day cycle over one year.

### **4.2 Prior learning**

It is recommended that learners who are beginning this course should have previously studied Chemistry at Namibia Senior Secondary Certificate Ordinary (NSSCO) level.

### **4.3 Progression**

NSSCAS level Chemistry provides a suitable foundation for the study of chemistry or related courses in higher education. It is also suitable for candidates intending to pursue careers or further study in science, or as part of a course of general education.

### **4.4 Grading and reporting**

NSSCAS results are shown by one of the grades a, b, c, d or e indicating the standard achieved, grade a being the highest and grade e the lowest. 'Ungraded' indicates that the candidate has failed to reach the minimum standard required for a pass at NSSCAS level.

### **4.5 Support materials and approved textbooks**

NSSCAS syllabuses, recent specimen material, question papers and examiners reports are sent to all schools. Assessment manuals in subjects, where applicable are sent to schools. Approved learning support materials are available on the Senior Secondary Textbook Catalogue for Schools. The Senior Secondary Textbook Catalogue is available on the institution's (NIED) website (<http://www.nied.edu.na>).

## 5. LEARNING CONTENT

The content is divided into themes and topics as follow:

### Mathematical requirements

#### Theme 1: The particulate nature of matter and stoichiometry

- 1.1 Atoms, molecules and stoichiometry
- 1.2 Atomic structure
- 1.3 Chemical bonding
- 1.4 The ideal gas and real gases and  $pV = nRT$

#### Theme 2: Physical chemistry

- 2.1 Chemical energetics
- 2.2 Electrochemistry
- 2.3 Equilibria
- 2.4 Reaction kinetics

#### Theme 3: Inorganic chemistry

- 3.1 The periodic table and chemical periodicity
- 3.2 Group 2
- 3.3 Transition elements
- 3.4 Group 17
- 3.5 Nitrogen and Sulfur

#### Theme 4: Organic chemistry and analysis

- 4.1 Foundations of organic chemistry
- 4.2 Hydrocarbons
- 4.3 Halogen derivatives
- 4.4 Hydroxyl compounds
- 4.5 Isomerism: structural and stereoisomerism
- 4.6 Carbonyl compounds
- 4.7 Carboxylic acids and derivatives

## Mathematical requirements

It is assumed that candidates will be competent in the techniques described below:

- perform calculations involving addition, subtraction, multiplication and division of quantities
- make appropriate evaluations of numerical expressions
- express small fractions as percentages, and *vice versa*
- calculate an arithmetic mean
- convert numbers in decimal notation to standard form notation (scientific notation)
- use tables or calculators to evaluate logarithms (for pH calculations), squares, square roots, and reciprocals
- change the subject of a formula (most such equations involve only the simpler operations but may include positive and negative indices and square roots)
- substitute physical quantities into an equation using consistent units so as to calculate one quantity and check the dimensional consistency of such calculations, e.g. the units of a rate constant  $k$
- solve simple algebraic equations
- understand and use the symbols/notations  $<$ ,  $>$ ,  $\approx$ ,  $/$ ,  $\Delta$ ,  $\equiv$ ,  $\bar{x}$  (or  $\langle x \rangle$ )
- test tabulated pairs of values for direct proportionality by a graphical method or by constancy of ratio
- select appropriate variables and scales for plotting a graph, especially to obtain a linear graph of the form  $y = mx + c$
- determine and interpret the gradient (slope) and intercept of a linear graph
- choose by inspection a straight line or curve that will serve as the 'line of best fit' linear model for a set of data presented graphically
- understand:
  - the gradient of a tangent to a curve as a measure of rate of change
  - the 'area' below a curve where the area has physical significance, e.g. Boltzmann distribution curves
- understand how to perform calculations so that significant figures are neither lost unnecessarily nor used beyond what is justified
- estimate orders of magnitude
- set up simple algebraic equations as mathematical models, e.g. construct a rate equation, and identify limitations of such models.

## Calculators

If calculators are to be used, it is suggested that they should have the following functions:

$+$ ,  $-$ ,  $\times$ ,  $\div$ ,  $\sqrt{x}$ ,  $x^2$ ,  $x^y$ ,  $\lg x$

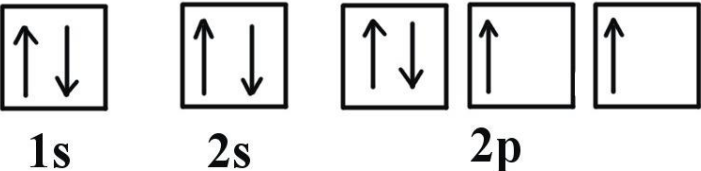
A memory function may be useful but is not essential.



## THEME 1: THE PARTICULATE NATURE OF MATTER AND STOICHIOMETRY

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>1.1 Atoms, molecules and stoichiometry</b> <i>This topic shows how quantitative relationships can be established when different substances react. (The term relative formula mass [Mr] will be used for all compounds including ionic).</i>		
1.1.1 Relative masses of atoms and molecules	<ul style="list-style-type: none"> <li>know relative atomic, isotopic, molecular and formula masses</li> </ul>	<ul style="list-style-type: none"> <li>define and use the terms <i>relative atomic, isotopic, molecular</i> and <i>formula masses</i>, based on the <math>^{12}\text{C}</math> scale</li> </ul>
1.1.2 The mole and the Avogadro constant	<ul style="list-style-type: none"> <li>know the mole and Avogadro constant</li> </ul>	<ul style="list-style-type: none"> <li>define and use the term <i>mole</i> in terms of the <i>Avogadro constant</i></li> </ul>
1.1.3 The determination of the relative atomic masses, ( $A_r$ )	<ul style="list-style-type: none"> <li>understand mass spectra and calculate relative atomic mass</li> </ul>	<ul style="list-style-type: none"> <li>analyse mass spectra in terms of isotopic abundances (knowledge of the working of the mass spectrometer is not required)</li> <li>calculate the relative atomic mass of an element given the relative abundances of its isotopes, or its mass spectrum</li> <li>calculate the percentage by mass of an element in a compound</li> </ul>
1.1.4 The calculation of empirical and molecular formulae	<ul style="list-style-type: none"> <li>know and calculate empirical and molecular formulae</li> </ul>	<ul style="list-style-type: none"> <li>define and use the terms <i>empirical</i> and <i>molecular</i> formula</li> <li>calculate empirical and molecular formulae, using combustion data or composition by mass</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
1.1.5 Reacting masses and volumes (of solutions and gases)	<ul style="list-style-type: none"> <li>know how to construct balanced equations and apply these in stoichiometric calculations</li> </ul>	<ul style="list-style-type: none"> <li>write and construct balanced equations, including state symbols</li> <li>perform calculations, including use of the mole concept, involving:               <ul style="list-style-type: none"> <li>reacting masses (from formulae and equations)</li> <li>volumes of gases at r.t.p and s.t.p (e.g. in the burning of hydrocarbons)</li> <li>volumes and concentrations of solutions</li> </ul> </li> </ul> <p><b>NOTE:</b></p> <ul style="list-style-type: none"> <li>Answers to calculations should reflect the number of significant figures given or asked for in the question. Significant figures should neither be lost unnecessarily nor used beyond what is justified (see also Practical Assessment, Paper 3, Display of calculation and reasoning, in Annexe A2)</li> <li><math>V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}</math> at s.t.p</li> <li><math>V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}</math> at r.t.p (where s.t.p is expressed as 101 kPa, approximately, and 273K (0 °C), and r.t.p is expressed as 101 kPa and 298K (25°C))</li> </ul>
<p><b>1.2 Atomic structure</b> <i>This topic describes the type, number and distribution of the fundamental particles which make up an atom and the impact of this on some atomic properties.</i></p>		
1.2.1 Particles in the atom	<ul style="list-style-type: none"> <li>know protons, neutrons and electrons, their distribution in the atom and their behaviour in electric fields</li> </ul>	<ul style="list-style-type: none"> <li>identify and describe protons, neutrons and electrons in terms of their relative charges and relative masses</li> <li>describe the distribution of mass and charge within an atom</li> <li>deduce the numbers of protons, neutrons and electrons present in both atoms and ions given proton (atomic) and nucleon (mass) numbers and charge</li> </ul>
1.2.2 The nucleus of the atom	<ul style="list-style-type: none"> <li>understand nucleon number and relate it to isotopes</li> </ul>	<ul style="list-style-type: none"> <li>describe the contribution of protons and neutrons to atomic nuclei in terms of proton (atomic) number and nucleon (mass) number</li> <li>distinguish between isotopes on the basis of different numbers of neutrons present</li> <li>recognise and use the symbolism <math>{}^A_ZX</math> for isotopes, where <sup>A</sup> is the nucleon (mass) number and <sub>z</sub> is the proton (atomic) number</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
1.2.3 Electrons: energy levels, atomic orbitals	<ul style="list-style-type: none"> <li>know and apply the s, p and d orbitals for principal quantum numbers 1, 2, 3 and 4</li> </ul>	<ul style="list-style-type: none"> <li>describe the number and relative energies of the s, p and d orbitals for the principal quantum numbers (shells) 1, 2 and 3 and also the 4s and 4p orbitals</li> <li>describe and sketch the shapes of s and p orbitals</li> <li>recall that each orbital can hold up to 2 electrons</li> <li>recall the number of orbitals making up s-, p- and d- sub-shells, and the number of electrons that can fill s-,p- and d-sub-shells</li> <li>describe the increase in energy between quantum numbers (shells) 1, 2 and 3 and between the s, p and d subshells in each shell</li> <li>describe how electrons fill orbitals: <ul style="list-style-type: none"> <li>up to subshell 4d, including the filling of 4s before 3d (example in Fe, Fe<sup>2+</sup>, etc)</li> <li>for orbitals with the same energy, electrons occupy each orbital singly before pairing</li> </ul> </li> <li>state the electronic configuration of atoms and ions given the proton (atomic) number and charge, using the convention 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup>, etc, and electrons in boxes representation, for example: <p>oxygen</p>  </li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>1.3 Chemical bonding</b> <i>This topic introduces the different ways by which chemical bonding occurs and the effect this can have on physical properties.</i>		
1.3.1 Ionic bonding	<ul style="list-style-type: none"> <li>understand ionic bonding</li> </ul>	<ul style="list-style-type: none"> <li>describe ionic bonding, as in sodium chloride, magnesium oxide and calcium fluoride, including the use of 'dot-and-cross' diagrams</li> <li>describe the electrostatic forces in ionic compounds as being attraction between oppositely charged ions</li> <li>describe, interpret and predict the effect of ionic bonding on physical properties (including physical state, melting point, boiling point, solubility)</li> <li>explain the electrical conductivity of ionic compounds when solid, molten or in solution</li> </ul>
1.3.2 Covalent bonding and co-ordinate (dative covalent) including shapes of simple molecules	<ul style="list-style-type: none"> <li>understand covalent bonding and co-ordinate (dative-covalent) bonding</li> <li>understand shapes of simple molecules including bond angles and the principle of electron-pair repulsion</li> <li>understand the reactions involving ligands and complexes</li> </ul>	<ul style="list-style-type: none"> <li>describe, including the use of 'dot-and-cross' diagrams: <ul style="list-style-type: none"> <li>covalent bonding, including molecules such as hydrogen, chlorine, oxygen, nitrogen, hydrogen chloride, carbon dioxide, methane, ethene</li> <li>dative covalent (co-ordinate) bonding, including in the formation of the ammonium ion and in the <math>\text{Al}_2\text{Cl}_6</math> molecule, <math>\text{CO}</math>, <math>\text{NH}_4^+</math>, <math>\text{H}_3\text{O}^+</math></li> </ul> </li> <li>explain the shapes of, and bond angles in, molecules by using the <ul style="list-style-type: none"> <li>qualitative model of electron-pair repulsion (including lone pairs), using as simple examples: <math>\text{BF}_3</math> (trigonal planar), <math>\text{CO}_2</math> (linear), <math>\text{CH}_4</math> (tetrahedral), <math>\text{NH}_3</math> (pyramidal), <math>\text{H}_2\text{O}</math> (non-linear/v-shaped), <math>\text{SF}_6</math> (octahedral), <math>\text{PF}_5</math> (trigonal bipyramidal)</li> </ul> </li> <li>use the electron-pair repulsion theory to predict the shapes of, and bond angles in other molecules analogous to those specified in bullet 2 above (see section 4.1.2)</li> <li>describe, interpret and predict the effect of covalent bonding on physical properties (including physical state, melting point, boiling point, solubility)</li> </ul>
1.3.3 Electronegativity	<ul style="list-style-type: none"> <li>understand the concept electronegativity</li> </ul>	<ul style="list-style-type: none"> <li>explain the concept of <i>electronegativity</i></li> <li>explain, in terms of electronegativity, the properties of molecules such as bond polarity the dipole moments of molecules and the behaviour of oxides with water</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
1.3.4 Intermolecular forces, electronegativity and bond properties	<ul style="list-style-type: none"> <li>• understand hydrogen bonding</li> <li>• understand electronegativity and its applications</li> <li>• understand intermolecular forces and their applications in bond properties</li> </ul>	<ul style="list-style-type: none"> <li>• describe the differences between bonding (intramolecular) and intermolecular forces in covalent molecules</li> <li>• describe that the electrostatic forces in ionic compounds are much stronger than intermolecular forces in covalent molecules</li> <li>• describe that the bonding (intramolecular) forces are much stronger than intermolecular forces in covalent bonding</li> <li>• describe the difference in volatility, solubility, melting/boiling points and electrical conductivity between ionic and covalent compounds in terms of forces of attraction (knowledge of hybridisation is not required)</li> <li>• describe intermolecular forces in covalent compounds and noble gases: induced dipole (van der Waals) forces, permanent dipole forces and hydrogen bonding</li> <li>• explain differences in physical properties in terms of intermolecular forces, including: <ul style="list-style-type: none"> <li>- noble gases, Br<sub>2</sub>(l),</li> <li>- HCl(g), CHCl<sub>3</sub>(l),</li> <li>- ammonia and water as simple examples of molecules containing N–H and O–H groups</li> </ul> </li> <li>• state that when giant covalent substances melt, covalent bonds break and when simple molecular substances melt or boil, forces between molecules weaken</li> <li>• describe hydrogen bonds as the strongest intermolecular force yet still weak compared with covalent bonding</li> <li>• explain the effect of hydrogen bonding on the physical properties of substances, including ice, water, methane, ammonia, hydrogen fluoride and methanol (for example, boiling and melting points, viscosity and surface tension)</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
1.3.5 Metallic bonding	<ul style="list-style-type: none"> <li>understand metallic bonding</li> </ul>	<ul style="list-style-type: none"> <li>describe metallic bonding in terms of a lattice of positive ions surrounded by delocalised electrons</li> <li>describe and explain the electrical conductivity, melting point and malleability/ductility of metals in terms of their structure and bonding</li> </ul>
1.3.6 Bonding, structure and physical properties	<ul style="list-style-type: none"> <li>relate different types of bonding to physical properties of substances</li> <li>show understanding of lattice structures</li> <li>relate hydrogen bonding to physical properties of substances</li> </ul>	<ul style="list-style-type: none"> <li>describe, in simple terms, the lattice structure of a crystalline solid which is: <ul style="list-style-type: none"> <li>ionic, including sodium chloride, magnesium oxide</li> <li>simple molecular, including iodine and the fullerene allotropes of carbon (C<sub>60</sub> and nanotubes only)</li> <li>giant molecular, including silicon(IV) oxide and the graphite, diamond and graphene allotropes of carbon</li> <li>hydrogen-bonded, including ice</li> <li>metallic, including copper</li> </ul> </li> <li>explain the relative energy and temperature required for changes of state in terms of the relative energy needed to break bonds (with reference to ionic, giant covalent and metallic substances) and to weaken intermolecular forces (with reference to simple covalent structures)</li> <li>describe, interpret and predict the effect of different types of structure and bonding ionic bonding, covalent bonding (giant and simple structures), hydrogen bonding, other intermolecular interactions, metallic bonding on the physical properties of substances, including electrical conductivity</li> <li>deduce the type of bonding and structure present from given information</li> </ul>
1.4 The ideal gas and real gases and $pV = nRT$	<ul style="list-style-type: none"> <li>show understanding of ideal and real gas and associated conditions</li> <li>appreciate <math>pV = nRT</math></li> </ul>	<ul style="list-style-type: none"> <li>state the basic assumptions of the kinetic theory as applied to an ideal gas</li> <li>explain qualitatively in terms of intermolecular forces and molecular size: <ul style="list-style-type: none"> <li>the conditions necessary for a gas to approach ideal behaviour</li> <li>the limitations of ideality at very high pressures and very low temperatures</li> </ul> </li> <li>recall and use the general gas equation <math>pV = nRT</math> in calculations, including the determination of <math>M_r</math> (NOTE: <math>R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}</math>)</li> </ul>

## THEME 2: PHYSICAL CHEMISTRY

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>2.1 Chemical energetics</b> <i>This topic deals with enthalpy and entropy changes which accompany chemical reactions. It also demonstrates why some reactions and processes occur spontaneously and others do not.</i>		
2.1.1 Enthalpy change ( $\Delta H$ )	<ul style="list-style-type: none"> <li>• understand enthalpy change and <math>\Delta H</math> and appreciate their applications in chemical reactions</li> <li>• understand and interpret reaction pathway diagrams</li> </ul>	<ul style="list-style-type: none"> <li>• explain that chemical reactions are accompanied by energy changes, principally in the form of heat energy; the energy changes can be exothermic (<math>\Delta H</math> is negative) or endothermic (<math>\Delta H</math> is positive)</li> <li>• explain and use the terms:               <ul style="list-style-type: none"> <li>– <i>enthalpy change of reaction</i> and <i>standard conditions</i>, with particular reference to: formation, combustion, hydration, solution, neutralisation, atomisation</li> <li>– <i>bond energy</i> (<math>\Delta H</math> positive, i.e. bond breaking)</li> </ul> </li> <li>• calculate enthalpy changes from appropriate experimental results, including the use of the relationship enthalpy change, <math>\Delta H = -mc\Delta T</math></li> <li>• outline chemical reactions in terms of energy transfers associated with the breaking and making of chemical bonds</li> <li>• calculate energy changes for simple reactions using bond energies</li> <li>• explain why <math>\Delta H</math> values from calculated bond energies differ from those obtained from data booklet and experimentally determined values</li> </ul>
2.1.2 Hess' law	<ul style="list-style-type: none"> <li>• know Hess' law and apply it in calculations</li> </ul>	<ul style="list-style-type: none"> <li>• apply Hess' law to construct simple energy cycles, and carry out calculations involving such cycles and relevant energy terms</li> <li>• apply Hess' law to determine enthalpy changes that cannot be found by direct experiment, e.g. an enthalpy change of formation from enthalpy changes of combustion</li> <li>• construct and interpret a reaction pathway diagram, in terms of the enthalpy change of the reaction and of the activation energy</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>2.2 Electrochemistry</b> <i>This topic demonstrates the relationship between electricity and chemical changes and how chemical reactions can be investigated by looking at electrode potentials.</i>		
2.2.1 Redox processes: electron transfer and changes in oxidation number (oxidation state)	<ul style="list-style-type: none"> <li>• know redox processes and apply them in calculation of oxidation numbers and in balancing chemical equations</li> </ul>	<ul style="list-style-type: none"> <li>• calculate oxidation numbers of elements in compounds and ions</li> <li>• describe and explain redox processes in terms of electron transfer and changes in oxidation number</li> <li>• use changes in oxidation numbers to help balance chemical equations</li> <li>• describe the use of aqueous potassium iodide in testing for oxidising agents and acidified potassium manganate(VII) in testing for reducing agents from the resulting colour changes</li> <li>• use oxidation numbers to name oxyanions, including nitrate(III) <math>\text{NO}_2^-</math>, nitrate(V) <math>\text{NO}_3^-</math>, chlorate(I) <math>\text{ClO}^-</math>, chlorate(V) <math>\text{ClO}_3^-</math></li> </ul>
2.2.2 Electrolysis	<ul style="list-style-type: none"> <li>• understand electrolysis and its application</li> </ul>	<ul style="list-style-type: none"> <li>• describe electrolysis as the conduction of electricity by an ionic compound (an electrolyte), when molten or dissolved in water, leading to the decomposition of the electrolyte</li> <li>• use the concept of selective discharge to identify the electrode products of aqueous solutions to include:               <ul style="list-style-type: none"> <li>– hydrogen ions and metal cations: silver, copper, (hydrogen), iron, zinc, sodium</li> <li>– non-metal anions hydroxide and chloride in dilute and concentrated solutions</li> </ul> </li> <li>• describe in outline the use of electrolysis in the extraction of metals from acidic leached solutions, for example copper and manganese</li> <li>• construct ionic half-equations for reactions at the cathode and anode</li> <li>• describe the transfer of charge during electrolysis to include:               <ul style="list-style-type: none"> <li>– the movement of electrons in the metallic conductor</li> <li>– the removal or addition of electrons from the external circuit at the electrodes</li> <li>– the movement of ions in the electrolyte</li> </ul> </li> </ul>



TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>2.3 Equilibria</b> <i>This topic illustrates that many chemical reactions are reversible and involve an equilibrium process. The consideration of the many factors that can affect equilibrium is an important aspect of Physical Chemistry.</i>		
2.3.1 Chemical equilibria: reversible reactions, dynamic equilibrium	<ul style="list-style-type: none"> <li>• understand reversible reactions, dynamic equilibrium and Le Chatelier's principle</li> <li>• understand equilibrium constants and apply them in calculations</li> <li>• understand the application of chemical equilibria in the Haber and Contact processes</li> </ul>	<ul style="list-style-type: none"> <li>• explain, in terms of rates of the forward and reverse reactions, what is meant by a <i>reversible reaction</i> and <i>dynamic equilibrium</i></li> <li>• state Le Chatelier's principle and apply it to deduce qualitatively (from appropriate information) the effects of changes in temperature, concentration or pressure on a system at equilibrium</li> <li>• state whether changes in temperature, concentration or pressure or the presence of a catalyst affect the value of the equilibrium constant for a reaction</li> <li>• deduce expressions for equilibrium constants in terms of concentrations, <math>K_c</math>, and partial pressures, <math>K_p</math> (treatment of the relationship between <math>K_p</math> and <math>K_c</math> is not required)</li> <li>• calculate the values of equilibrium constants in terms of concentrations or partial pressures from appropriate data</li> <li>• calculate the quantities present at equilibrium, given appropriate data (such calculations will not require the solving of quadratic equations)</li> <li>• explain the importance of choice of conditions (temperature, pressure, use of a catalyst) for processes used in the chemical industry including the Haber process and the Contact process, in terms of equilibrium (yield) and rate</li> <li>• interpret data about the conditions used in industrial processes in terms of equilibrium (yield) and rate</li> </ul>
2.3.2 Ionic equilibria	<ul style="list-style-type: none"> <li>• understand ionic equilibria in acids and bases</li> </ul>	<ul style="list-style-type: none"> <li>• explain, and use, the Brønsted-Lowry theory of acids and bases, including the use of the acid-I base-I, acid-II base-II concept</li> <li>• explain qualitatively the differences in behaviour between strong and weak acids and bases and the pH values of their aqueous solutions in terms of the extent of dissociation</li> <li>• calculate <math>[H^+(aq)]</math> and pH values for strong acids</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>2.4 Reaction kinetics</b> <i>The investigation of the factors that affect the rate of a chemical reaction is important in the study of physical chemistry. The temperature and the addition of a catalyst can both affect the progression of a chemical reaction.</i>		
2.4.1 Rate of reactions	<ul style="list-style-type: none"> <li>• know rates of reactions and how concentration affects rate of reaction</li> </ul>	<ul style="list-style-type: none"> <li>• explain and use the term <i>rate of reaction</i></li> <li>• explain qualitatively, in terms of collisions, the effect of concentration changes on the rate of a reaction</li> </ul>
2.4.2 Effect of temperature on reaction rates and the concept of activation energy	<ul style="list-style-type: none"> <li>• understand how temperature affects rates of reactions</li> </ul>	<ul style="list-style-type: none"> <li>• explain and use the term <i>activation energy</i>, including reference to the Boltzmann distribution</li> <li>• explain qualitatively, in terms both of the Boltzmann distribution and of collision frequency, the effect of temperature change on the rate of a reaction</li> </ul>
2.4.3 Homogenous and heterogeneous catalysts including enzymes	<ul style="list-style-type: none"> <li>• understand homogenous and heterogeneous catalysts including enzymes and their applications</li> </ul>	<ul style="list-style-type: none"> <li>• explain and use the term <i>catalysis</i></li> <li>• explain that catalysts can be homogenous or heterogeneous</li> <li>• explain that, in the presence of a catalyst, a reaction has a different mechanism, i.e. one of lower activation energy and interpret this catalytic effect in terms of the Boltzmann distribution</li> <li>• describe enzymes as biological catalysts which may have specificity</li> <li>• explain that reactions which use enzymes only work under specific conditions (pH and temperature)</li> </ul>

### THEME 3: INORGANIC CHEMISTRY

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>3.1 The Periodic Table and chemical periodicity</b> <i>This topic illustrates the regular patterns in chemical and physical properties of the elements in the Periodic Table.</i>		
3.1.1 Periodicity of physical properties of elements in Period 3	<ul style="list-style-type: none"><li>understand the periodicity of physical properties of elements in Period 3</li><li>understand ionisation energy</li></ul>	<ul style="list-style-type: none"><li>explain and use the term <i>ionisation energy</i></li><li>explain the factors influencing the ionisation energies of elements</li><li>describe qualitatively and explain the variations in atomic radius, ionic radius and electronegativity across Period 3 in terms of attraction, number of electrons and nuclear charge</li><li>describe qualitatively and explain the general trend in first ionisation energy across Period 3 in terms of attraction, nuclear charge and atomic radius (effect of paired electrons in orbitals of sub-shells is not expected) (see section 1.2.3)</li><li>describe qualitatively and explain the variations in melting point and electrical conductivity across Period 3 in terms of the simple molecular, giant molecular or metallic bonding in the elements</li></ul>
3.1.2 Trends in physical properties of elements down a group	<ul style="list-style-type: none"><li>understand the trends in physical properties of elements down Group 2 and Group 17</li></ul>	<ul style="list-style-type: none"><li>describe qualitatively and explain the trends in atomic radius, ionic radius and electronegativity down Group 2 and Group 17 in terms of attraction, number of electrons, nuclear charge and degree of shielding</li><li>describe qualitatively and explain the general trend in first ionisation energy down Group 2 and Group 17 in terms of attraction, nuclear charge, atomic radius and degree of shielding (effect of paired electrons in orbitals of sub-shells is not expected) (see section 1.2.3)</li></ul>

<b>TOPIC</b>	<b>GENERAL OBJECTIVES</b> <i>Learners will:</i>	<b>SPECIFIC OBJECTIVES</b> <i>Learners should be able to:</i>
3.1.3 Periodicity of chemical properties of the elements in Period 3	<ul style="list-style-type: none"> <li>understand the periodicity of chemical properties of elements in the third period</li> </ul>	<ul style="list-style-type: none"> <li>describe the reactions of Period 3 elements with oxygen (to give <math>\text{Na}_2\text{O}</math>, <math>\text{MgO}</math>, <math>\text{Al}_2\text{O}_3</math>, <math>\text{P}_4\text{O}_{10}</math>, <math>\text{SO}_2</math>, <math>\text{SO}_3</math>), chlorine (to give <math>\text{NaCl}</math>, <math>\text{MgCl}_2</math>, <math>\text{Al}_2\text{Cl}_6</math>, <math>\text{SiCl}_4</math>, <math>\text{PCl}_5</math>) and water (Na and Mg only)</li> <li>state and explain the variation in oxidation number of the oxides (sodium to sulfur only) and chlorides (sodium to phosphorus only) in terms of their valence shell electrons</li> <li>describe the reactions of the oxides with water</li> <li>describe and explain the acid/base behaviour of oxides and hydroxides including, where relevant, amphoteric behaviour in reaction with acids and bases (sodium hydroxide only)</li> <li>describe and explain the reactions of the chlorides with water</li> <li>interpret the variations and trends of the above in terms of bonding and electronegativity</li> <li>suggest the types of chemical bonding present in chlorides and oxides from observations of their chemical and physical properties</li> </ul>
3.1.4 Chemical periodicity of other elements	<ul style="list-style-type: none"> <li>appreciate chemical periodicity of other elements given appropriate information</li> </ul>	<ul style="list-style-type: none"> <li>predict the characteristic properties of an element in a given group by using knowledge of chemical periodicity</li> <li>deduce the nature, possible position in the Periodic Table and identity of unknown elements from given information about physical and chemical properties</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>3.2 Group 2</b> <i>The physical and chemical properties of the elements of Group 2 (the alkaline Earth metals) are introduced in this topic.</i>		
3.2.1 Similarities and trends in the properties of the Group 2 metals	<ul style="list-style-type: none"> <li>• understand the trends in properties of the Group 2 elements, magnesium to barium and their compounds</li> </ul>	<ul style="list-style-type: none"> <li>• describe the trends in physical properties down Group 2 including melting points</li> <li>• describe the reactions of the elements with oxygen, water and dilute acids</li> <li>• describe the behaviour of the oxides, hydroxides and carbonates with water and dilute acids</li> <li>• describe the thermal decomposition of the nitrates and carbonates</li> <li>• interpret, and make predictions from, the trends in physical and chemical properties of the elements and their compounds</li> <li>• describe the variation in the solubilities of the hydroxides and sulfates</li> </ul>
3.2.2 Some uses of Group 2 compounds	<ul style="list-style-type: none"> <li>• appreciate the uses of calcium hydroxide and calcium carbonate in agriculture</li> </ul>	<ul style="list-style-type: none"> <li>• describe the addition of water to calcium oxide (lime) to form calcium hydroxide (slaked lime)</li> <li>• describe and explain the use of calcium hydroxide and calcium carbonate (powdered limestone) in agriculture and manufacture of building materials (cement)</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>3.3 Transition elements</b> <i>This topic introduces the chemistry of the transition elements.</i>		
3.3.1 Characteristics of typical transition elements	<ul style="list-style-type: none"> <li>• know the characteristics of the first series transition elements</li> </ul>	<ul style="list-style-type: none"> <li>• explain what is meant by a transition element in terms of d-block elements forming one or more ions with incomplete d orbitals</li> <li>• represent the electronic configuration of transition elements using s, p, d and electrons in boxes notations (see section 1.2.3)</li> <li>• recognise that transition elements have variable oxidation states, act as catalysts and form coloured compounds and that these properties are linked to their incomplete d orbitals</li> <li>• contrast qualitatively the melting points and densities of the transition elements with those of calcium as a typical s-block element</li> </ul>
3.3.2 Extraction of transition elements from their ores	<ul style="list-style-type: none"> <li>• understand the extraction of transition elements from their ores</li> </ul>	<ul style="list-style-type: none"> <li>• recognise that copper, manganese and uranium are produced from ores in Namibia</li> <li>• describe the reduction by carbon of metals from their ores</li> <li>• describe the use of carbon as a reducer, including in the production of (impure) copper from copper oxide and (impure) ferromanganese from a mixture of iron oxide and manganese oxide in Namibia</li> <li>• describe the use of sulfuric acid as a leaching agent for example in the production of copper, manganese and uranium</li> <li>• describe the extraction of pure metals, including electrolysis of leached solutions and the reduction of uranium ions using magnesium</li> <li>• recognize that it is important to monitor and control waste from metal extraction including: <ul style="list-style-type: none"> <li>– sulfur dioxide as a pollutant product from the roasting of metal ores</li> <li>– waste acids from leaching processes</li> <li>– toxic metal waste in water and as atmospheric particles</li> </ul> </li> <li>• discuss the finite nature of metal ores and the benefits and problems of recycling metals</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>3.4 Group 17</b> <i>This topic introduces the chemistry of halogens.</i>		
3.4.1 Physical properties of the group 17 elements	<ul style="list-style-type: none"> <li>• know the physical properties of group 17 elements</li> </ul>	<ul style="list-style-type: none"> <li>• describe the colours of chlorine, bromine and iodine:               <ul style="list-style-type: none"> <li>– as vapours</li> <li>– at room temperature and pressure</li> <li>– in solution</li> </ul> </li> <li>• describe the trend in state of chlorine, bromine and iodine at room temperature and pressure</li> <li>• interpret the volatility of the elements in terms of intermolecular forces</li> </ul>
3.4.2 The chemical properties of the elements and their hydrides	<ul style="list-style-type: none"> <li>• know the chemical properties of group 17 elements and their hydrides</li> </ul>	<ul style="list-style-type: none"> <li>• describe the relative reactivity of the elements as oxidising agents</li> <li>• describe and explain the reactions of the elements with hydrogen</li> <li>• describe and explain the relative thermal stabilities of the hydrides</li> <li>• interpret these relative stabilities in terms of bond energies</li> </ul>
3.4.3 Some reactions of the halide ions	<ul style="list-style-type: none"> <li>• know some reactions of halide ions</li> </ul>	<ul style="list-style-type: none"> <li>• describe and explain the reactions of halide ions with:               <ul style="list-style-type: none"> <li>– aqueous silver ions followed by aqueous ammonia</li> <li>– concentrated sulfuric acid</li> </ul> </li> </ul>
3.4.4 The reactions of chlorine with aqueous sodium hydroxide	<ul style="list-style-type: none"> <li>• understand the reactions of chlorine with aqueous sodium hydroxide</li> </ul>	<ul style="list-style-type: none"> <li>• describe, in terms of changes of oxidation number, the disproportionation reaction of chlorine with cold and with hot aqueous sodium hydroxide</li> <li>• describe the effects on equilibrium of changes in pH to the reactions of chlorine with sodium hydroxide</li> </ul>
3.4.5 Some important uses of halogens and of halogen compounds	<ul style="list-style-type: none"> <li>• appreciate some industrial applications of halogens</li> </ul>	<ul style="list-style-type: none"> <li>• explain the use of chlorine in water treatment</li> <li>• state the industrial importance and environmental significance of the halogens and their compounds (e.g. for bleaches, PVC, halogenated hydrocarbons as solvents, refrigerants and in aerosols, see section 4.3.2)</li> <li>• relate the importance of these reactions to the use of chlorine as a bleach and the treatment of water in Namibia</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>3.5 Nitrogen and Sulfur</b> <i>This topic introduces some of the chemistry associated with nitrogen and sulfur.</i>		
3.5.1 Nitrogen	<ul style="list-style-type: none"> <li>show understanding of the chemistry of nitrogen and its application in industry</li> </ul>	<ul style="list-style-type: none"> <li>describe and explain:               <ul style="list-style-type: none"> <li>the basicity of ammonia (see section 2.3.2)</li> <li>the structure of the ammonium ion and its formation by an acid-base reaction</li> <li>the displacement of ammonia from its salts</li> </ul> </li> <li>comment on the depletion of nitrogen, phosphorus and potassium from soils by leaching and farming</li> <li>explain the lack of reactivity of nitrogen and relate this to the need for the industrial manufacture of ammonia and its salts for use as fertilisers</li> <li>describe the changes in the oxidation number of nitrogen in the nitrogen cycle in terms of the ions and molecules involved, i.e. <math>\text{NH}_3</math> (-3), <math>\text{N}_2</math> (0), <math>\text{N}_2\text{O}</math> (+1), <math>\text{NO}_3^-</math> (+5)</li> <li>state the industrial importance of ammonia and ammonium salts for use as fertilisers</li> <li>explain the environmental consequences of using soluble, synthetic nitrate fertilisers, including their rapid leaching, eutrophication and possible contamination of drinking water, including from bore holes</li> <li>suggest the benefits of the use of organic fertilisers in terms of their lower solubility</li> </ul>
3.5.2 Sulfur	<ul style="list-style-type: none"> <li>show understanding of the chemistry of sulfur and its environmental implications</li> </ul>	<ul style="list-style-type: none"> <li>recall that sulfur dioxide is an atmospheric pollutant formed from burning fossil fuels and from the processing of metal sulfide ores</li> <li>recall that sulfur dioxide causes breathing difficulties and forms acid rain</li> <li>recall the importance of the use of low sulfur fuels to keep sulfur dioxide emissions from vehicles and power stations within the World Health Organisation (WHO) limits (e.g. the van Eck coal-fired power station at Windhoek)</li> </ul>



## THEME 4: ORGANIC CHEMISTRY AND ANALYSIS

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>4.1 Foundations of organic chemistry</b> <i>Organic chemistry involves the study of a large class of chemical compounds containing carbon. This topic introduces organic reaction terminology and structures of organic molecules.</i>		
4.1.1 Organic chemistry terminology	<ul style="list-style-type: none"> <li>show understanding of terminology used in organic chemistry</li> </ul>	<ul style="list-style-type: none"> <li>interpret and use the following terminology associated with organic reactions:               <ul style="list-style-type: none"> <li><i>functional group</i></li> <li><i>homolytic fission</i> and <i>heterolytic fission</i></li> <li><i>free radical, initiation, propagation, termination</i></li> <li><i>nucleophile, electrophile</i></li> <li><i>addition, substitution, elimination, hydrolysis, condensation</i></li> <li><i>oxidation and reduction</i></li> </ul> </li> <li>recall and use systematic nomenclature to name alkanes, alkenes, halogenoalkanes, alcohols, aldehydes, ketones, carboxylic acids, esters and amines, with chain length up to six carbon atoms, including:               <ul style="list-style-type: none"> <li>numbering the carbon atoms in a direction to give the lowest prefix possible e.g. 1-chlorobutane (not 4-chlorobutane)</li> <li>the use of the prefixes mono-, di-, tri-, tetra-, penta-, hexa-.</li> </ul>               (in equations for organic redox reactions, the symbols [O] and [H] are acceptable for oxidising and reducing agents)             </li> </ul>
4.1.2 Shapes of organic molecules	<ul style="list-style-type: none"> <li>understand shapes of, and bond angles in, molecules</li> </ul>	<ul style="list-style-type: none"> <li>describe and explain the shape of, and bond angles in, the ethane and ethene molecules in terms of electron pair repulsion theory (including relative length of bonds between carbon atoms) (see section 1.3.2)</li> <li>predict the shapes of, and bond angles in other related molecules</li> </ul>
4.1.3 Infra-red spectroscopy	<ul style="list-style-type: none"> <li>understand infra-red spectroscopy and its applications</li> </ul>	<ul style="list-style-type: none"> <li>analyse an infra-red spectrum of a simple molecule to identify functional groups (see <i>Data Booklet</i> for the functional groups required)</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>4.2 Hydrocarbons</b> <i>This topic introduces the study of compounds containing only carbon and hydrogen, called hydrocarbons. Alkanes and alkenes are examples of hydrocarbons. One important use of hydrocarbons is as fuels.</i>		
4.2.1 Alkanes	<ul style="list-style-type: none"> <li>• understand the chemistry of alkanes</li> </ul>	<ul style="list-style-type: none"> <li>• interpret and use the general, structural, displayed and skeletal formulae of the alkanes</li> <li>• recall and use systematic nomenclature to name alkanes, with chain length up to six carbon atoms, e.g. 2,2-dimethyl hexane</li> <li>• deduce the molecular formula of alkanes, given its structural, displayed or skeletal formula</li> <li>• explain the general unreactivity of alkanes, including towards polar reagents</li> <li>• describe the chemistry of alkanes as exemplified by the following reactions of ethane:               <ul style="list-style-type: none"> <li>– combustion</li> <li>– substitution by chlorine and by bromine</li> </ul> </li> <li>• describe the mechanism of free-radical reactions with particular reference to the initiation (<i>homolytic fission</i>), propagation and termination reactions, including the substitution of methyl groups by halogens</li> <li>• explain the use of crude oil as a source of both aliphatic and aromatic hydrocarbons</li> <li>• explain that cracking can be used to obtain more useful alkanes and alkenes of lower <math>M_r</math> from larger hydrocarbon molecules</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
4.2.2 Alkenes	<ul style="list-style-type: none"> <li>• understand the chemistry of alkenes</li> </ul>	<ul style="list-style-type: none"> <li>• interpret and use the general, structural, displayed and skeletal formulae of the alkenes</li> <li>• recall and use systematic nomenclature to name, alkenes, with chain length up to six carbon atoms, , e.g. but-1-ene, but-2-ene</li> <li>• deduce the molecular formula of alkenes, given its structural, displayed or skeletal formula</li> <li>• describe the chemistry of alkenes as exemplified, where relevant, by the following reactions of ethene and propene (including the Markovnikov addition of asymmetric electrophiles to alkenes using propene as an example): <ul style="list-style-type: none"> <li>– addition of hydrogen, steam, hydrogen halides and halogens</li> <li>– oxidation by cold, dilute, acidified manganate(VII) ions to form the diol</li> <li>– oxidation by hot, concentrated, acidified manganate(VII) ions leading to the rupture of the carbon–carbon double bond in order to determine the position of alkene linkages in larger molecules</li> <li>– polymerisation</li> </ul> </li> <li>• describe the concept <i>heterolytic fission</i></li> <li>• describe the mechanism of electrophilic addition in alkenes, using bromine/ethene and hydrogen bromide/propene as examples</li> <li>• describe and explain the inductive effects of alkyl groups on the stability of cations formed during electrophilic addition</li> <li>• describe the characteristics of addition polymerisation as exemplified by poly(ethene) and PVC</li> <li>• deduce the repeat unit of an addition polymer obtained from a given monomer</li> <li>• identify the monomer(s) present in a given section of an addition polymer molecule</li> <li>• recognise the difficulty of the disposal of poly(alkene)s, i.e. non-biodegradability</li> <li>• describe ways/ discuss approaches to dealing with waste polymers including manufacturing of biodegradable polymers</li> <li>• recognise that new polymers are being developed, including biodegradable and water soluble polymers</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
4.2.3 Hydrocarbons as fuels	<ul style="list-style-type: none"> <li>know the uses of hydrocarbon as fuels and appreciate the environmental implications thereof</li> </ul>	<ul style="list-style-type: none"> <li>describe and explain how the combustion reactions of alkanes led to their use as fuels in industry, in the home and in transport</li> <li>recognise the environmental consequences of:               <ul style="list-style-type: none"> <li>carbon monoxide, oxides of nitrogen and unburnt hydrocarbons arising from the internal combustion engine and of their catalytic removal</li> <li>gases that contribute to the enhanced greenhouse effect</li> </ul> </li> <li>outline the use of infra-red spectroscopy in monitoring air pollution</li> </ul>
<b>4.3 Halogen derivatives</b> <i>The inclusion of a halogen atom within an organic molecule affects its reactivity. The reactions of halogenoalkanes are very important in organic chemistry.</i>		
4.3.1 Halogenoalkanes	<ul style="list-style-type: none"> <li>know the chemistry of halogenoalkanes including the mechanisms of nucleophilic substitution</li> </ul>	<ul style="list-style-type: none"> <li>interpret and use the general, structural (condensed / semi-structural and displayed) and skeletal formulae of the halogenoalkanes</li> <li>recall and use systematic nomenclature to name halogenoalkanes, with chain length up to six carbon atoms, including: naming halogeno groups in alphabetical order, e.g. 1,2-dibromo, 1-chlorobutane</li> <li>deduce the molecular formula of halogenoalkanes, given its structural or skeletal formula</li> <li>describe the chemistry of halogenoalkanes as exemplified by:               <ul style="list-style-type: none"> <li>the following nucleophilic substitution reactions of bromoethane: hydrolysis, formation of nitriles, formation of primary amines by reaction with ammonia</li> <li>the elimination of hydrogen bromide from 2-bromopropane</li> </ul> </li> </ul>
4.3.2 Relative strength of the C-Hal bond	<ul style="list-style-type: none"> <li>understand the chemistry of halogenoalkanes and appreciate their concerns about the effects on the ozone layer</li> </ul>	<ul style="list-style-type: none"> <li>interpret the different reactivities of halogenoalkanes (with particular reference to hydrolysis and to the relative strengths of the C-Hal bonds)</li> <li>explain the uses of fluoroalkanes and fluorohalogenoalkanes in terms of their relative chemical inertness</li> <li>recall that the use of chlorofluoroalkanes leads to depletion of the ozone layer</li> <li>recall the development of replacement compounds to prevent further depletion and allows the ozone layer to repair</li> <li>explain the terms <i>bond energy</i>, <i>bond length</i> and <i>bond polarity</i> and use them to compare the reactivities of covalent bonds</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>4.4 Hydroxyl compounds</b> <i>This topic introduces the chemistry of a versatile class of organic compounds, hydroxyl compounds, which contain a –OH group. This topic introduces the chemistry of alcohols.</i>		
4.4.1 Alcohols	<ul style="list-style-type: none"> <li>• understand the chemistry of alcohols</li> </ul>	<ul style="list-style-type: none"> <li>• interpret and use the general, structural (condensed / semi-structural and displayed) and skeletal formulae of the alcohols (primary, secondary and tertiary)</li> <li>• recall and use systematic nomenclature of alcohols, with chain length up to six carbon atoms, e.g propan-1-ol</li> <li>• deduce the molecular formula of alcohols (including primary, secondary and tertiary), given its structural or skeletal formula</li> <li>• recall the chemistry of alcohols, exemplified by ethanol, in the following reactions: <ul style="list-style-type: none"> <li>– combustion</li> <li>– substitution to give halogenoalkanes</li> <li>– reaction with sodium</li> <li>– oxidation to carbonyl compounds and carboxylic acids</li> <li>– dehydration to alkenes</li> <li>– formation of esters by esterification with carboxylic acids</li> </ul> </li> <li>• classify hydroxy compounds into primary, secondary and tertiary alcohols</li> <li>• suggest characteristic distinguishing reactions, e.g. mild oxidation</li> <li>• deduce the presence of a <math>\text{CH}_3\text{CH}(\text{OH})-</math> group in an alcohol from its reaction with alkaline aqueous iodine to form tri-iodomethane</li> <li>• explain why alcohols are used as solvents, including their use in cosmetics and to remove sulfur compounds from coal</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
4.5 <b>Isomerism: structural and stereoisomerism</b>	<ul style="list-style-type: none"> <li>• understand structural and stereoisomerism</li> </ul>	<ul style="list-style-type: none"> <li>• deduce (draw and name) the possible isomers for an organic molecule of known molecular formula</li> <li>• describe structural isomerism and its division into chain, positional and functional group isomerism</li> <li>• describe stereoisomerism and its division into geometrical (cis-trans) and optical isomerism (use of E, Z nomenclature is acceptable but is not required)</li> <li>• describe geometrical (cis-trans) isomerism in alkenes, and explain its origin in terms of restricted rotation due to the presence of double bonds</li> <li>• explain what is meant by a chiral centre and that such a centre normally gives rise to optical isomerism (<b>NB:</b> Learners should appreciate that compounds can contain more than one chiral centre, but knowledge of meso compounds, or nomenclature such as <i>diastereoisomers</i> is <i>not</i> required)</li> <li>• identify chiral centres and geometrical (cis-trans) isomerism in a molecule of given structural formula</li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
<b>4.6 Carbonyl compounds</b> <i>This topic introduces the chemistry of the carbonyl compounds, aldehydes and ketones.</i>		
4.6.1 Aldehydes and ketones	<ul style="list-style-type: none"> <li>• understand the chemistry of aldehydes and ketones</li> </ul>	<ul style="list-style-type: none"> <li>• interpret and use the general, structural (condensed / semi-structural and displayed) and skeletal formulae of the aldehydes and ketones</li> <li>• recall and use systematic nomenclature of aldehydes and ketones with chain length up to six carbon atoms, e.g. pentan-2-one</li> <li>• deduce the molecular formula of aldehydes and ketones, given their structural or skeletal formula</li> <li>• describe the formation of aldehydes and ketones from primary and secondary alcohols respectively using <math>\text{Cr}_2\text{O}_7^{2-}/\text{H}^+</math></li> </ul>
<b>4.7 Carboxylic acids and derivatives</b> <i>This topic introduces the chemistry of carboxylic acids and their derivatives.</i>		
4.7.1 Carboxylic acids	<ul style="list-style-type: none"> <li>• understand the chemistry of carboxylic acids</li> </ul>	<ul style="list-style-type: none"> <li>• interpret and use the general, structural (condensed / semi-structural and displayed) and skeletal formulae of the carboxylic acids</li> <li>• recall and use systematic nomenclature of carboxylic acids chain length up to six carbon atoms, e.g. butanoic acid</li> <li>• deduce the molecular formula of carboxylic acids, given its structural or skeletal formula</li> <li>• describe the formation of carboxylic acids from alcohols and aldehydes</li> <li>• describe the reactions of carboxylic acids in the formation of: <ul style="list-style-type: none"> <li>- salts, by the use of reactive metals, alkalis or carbonates</li> <li>- alkyl esters</li> </ul> </li> </ul>

TOPIC	GENERAL OBJECTIVES <i>Learners will:</i>	SPECIFIC OBJECTIVES <i>Learners should be able to:</i>
4.7.2 Esters and amines	<ul style="list-style-type: none"> <li>• understand the chemistry of esters and amines</li> </ul>	<ul style="list-style-type: none"> <li>• interpret and use the general, structural (condensed / semi-structural and displayed) and skeletal formulae of the amines (primary only) and esters</li> <li>• recall and use systematic nomenclature of esters and amines, with chain length up to six carbon atoms, including:               <ul style="list-style-type: none"> <li>- using the parent alcohol and carboxylic acid to name esters e.g. methyl ethanoate.</li> <li>- naming amines, e.g. 2-aminobutane</li> </ul> </li> <li>• deduce the molecular formulae of esters and amines (primary only) given their structural or skeletal formula</li> <li>• describe the acid and base hydrolysis of esters and draw the structure of the hydrolysis of the products of any ester given</li> <li>• explain why esters are used as solvents, perfumes, flavourings</li> </ul>



## 6. ASSESSMENT OBJECTIVES

The assessment will include, wherever appropriate, personal, social, environmental, economic and technological applications of Chemistry in modern society. Learners are required to demonstrate the Assessment Objectives in the context of the content and skills prescribed. Within each of the Assessment Objectives the assessment must take account of the learners' ability to communicate clearly and logically and apply conventions where appropriate.

The three Assessment Objectives in Chemistry are:

- A Knowledge with understanding**
- B Handling information, application and solving problems**
- C Practical (experimental and investigative) skills and abilities**

Following is a description of each Assessment Objective:

### A Knowledge with understanding

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

- A1 scientific phenomena, facts, laws, definitions, concepts and theories
- A2 scientific vocabulary, terminology and conventions, (including symbols, quantities, units)
- A3 scientific instruments and apparatus, including techniques of operation and aspects of safety
- A4 scientific quantities and their determination
- A5 scientific and technological applications with their social, economic and environmental implications
- A6 reasoned explanations of phenomena, patterns and relationships

The Learning Content defines what learners may be required to recall and explain. Questions testing assessment objectives will often begin with one of the following words: *define, name, list, indicate, give examples, state, describe, compare, explain, distinguish, outline and give reasons.* (see glossary of terms).

### B Handling information, application and solving problems

Learners should be able, in word or using other written forms of presentation (i.e. symbolic, graphical and numerical) to:

- B1 locate, select, organise and present information from a variety of sources
- B2 handle information, distinguishing the relevant from the extraneous
- B3 manipulate numerical and other data and translate information from one form to another
- B4 analyse and evaluate information so as to identify patterns, report trends and draw inferences
- B5 construct arguments to support hypotheses or to justify a course of action
- B6 evaluate information and hypotheses
- B7 apply knowledge, including principles, to new situations

These skills cannot be precisely specified in the Learning Content, because questions testing such skills are often based on information that is unfamiliar to the learner. In answering such questions, learners 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: discuss, deduce, compare and discuss, find, estimate, interpret, evaluate, sketch, predict, identify, relate, suggest, calculate and determine.* (see glossary of terms).

## C Practical (experimental and investigative) skills and abilities

Learners should be able to:

- C1 plan experiments and investigations
- C2 collect, record and present observations, measurements and estimates
- C3 analyse and interpret data to reach conclusions
- C4 evaluate methods and quality of data to reach conclusions

## 7. SCHEME OF ASSESSMENT

All learners should be entered for **Papers 1, 2 and 3** which are compulsory papers.

Paper	Description of paper and types of questions	Duration of paper	Marks
<b>Paper 1:</b> Theory: Multiple choice questions	This paper consists of forty multiple-choice items of the four-choice type. The questions are based on the content described as specific objectives and will test abilities in assessment objectives A and B.	1 hour	40
<b>Paper 2:</b> Theory: Structured questions	This paper consists of compulsory short-answer, structured and free-response questions. The questions will test skills and abilities in Assessment Objectives A and B. Learners will answer all questions on the question paper.	1 hour 15 minutes	60
<b>Paper 3:</b> Advanced practical skills	This paper requires learners to carry out practical work in timed conditions. Learners will be expected to collect, record and analyse data so that they can answer questions related to the activity. The paper will consist of two or three experiments drawn from different areas of Chemistry. Learners will answer all questions. Learners will answer on the question paper.  The notes for use in qualitative analysis ( <i>annexe D</i> ) will be supplied with paper 3.	2 hours	40
<b>TOTAL</b>			<b>140</b>

### Weighting of papers

All learners will be entered for Papers 1, 2 and 3 specified below.

Learners will be graded from a - e depending on their abilities and achievements. **Paper 1 and 2 will constitute 77% of the final assessment while Paper 3 will constitute 23%.**

Papers	Weighting of papers
Paper 1	31%
Paper 2	46%
Paper 3	23%

## 8. SPECIFICATION GRID

The specification grid gives a general idea of how marks are allocated to assessment objectives in the different components. However, the balance on each paper may vary slightly.

The approximate weightings allocated to each of the Assessment Objectives across the papers are summarised in the table:

Assessment Objective	Weighting across all components	Paper 1 (marks)	Paper 2 (marks)	Paper 3 (marks)
<b>A</b> Knowledge with understanding	40% (not more than 20% recall)	20	30	0
<b>B</b> Handling information, application and solving problems	40%	20	30	0
<b>C</b> Practical (experimental and investigative) skills and abilities	20%	0	0	40
		<b>40 marks</b>	<b>60 marks</b>	<b>40 marks</b>

Teachers should note that there is a greater weighting of 60 per cent for skills (including handling information, solving problems, experimental skills and investigations) compared to 40 per cent for knowledge with understanding. Teachers should make sure that their **schemes of work** and the **sequence of learning activities** reflect this balance so that the aims of the syllabus are met and the candidates are suitably prepared for the assessment.

## 9. GRADE DESCRIPTIONS

The scheme of assessment is intended to encourage positive achievement by all learners. Grade descriptions are therefore provided for judgmental Grades a, c and e to give a general indication of the standards of achievement likely to have been shown by learners awarded particular grades. The description must be interpreted in relation to the content specified by the Chemistry syllabus but are not designed to define that content. The grade awarded will depend in practice upon the extent to which the learner has met the assessment objective overall. Shortcomings in some aspects of the assessment may be balanced by better performance in others. Grade descriptions for Science Subjects will range from a to e.

*At **Grade a** - the learner is expected to:*

- show mastery of curriculum content;
- demonstrate the ability to interpret relatively complex data with precision;
- demonstrate the ability to discuss chemistry topics with depth and breadth of understanding, bringing together ideas from various areas of the curriculum and from the learner's own experience;
- communicate with clarity, by means of words, diagrams and other forms of presentation;
- be able to link his or her theoretical and practical studies in Chemistry with applications relating to society and to the environment;
- show a clear understanding of scientific method, and be able to design, carry out and evaluate experiments with confidence and competence.

*At **Grade c** - the learner is expected to:*

- show reasonable competence of curriculum content;
- demonstrate the ability to interpret relatively simple data with precision;
- demonstrate the ability to discuss Chemistry topics, with some success at bringing together ideas from different areas of the curriculum and the learners' experience;
- communicate effectively, by words, diagrams and other forms of presentation;
- show some ability to link his or her Chemistry studies with applications relating to society and the environment;
- show a reasonable understanding of scientific method and be able to design, carry out and evaluate experiments with reasonable confidence and competence.

*At **Grade e** - the learner is expected to:*

- show a limited range of competence of curriculum content;
- demonstrate the ability to interpret simple data with reasonable precision;
- demonstrate some ability to discuss Chemistry topics;
- communicate effectively, by words, diagrams and other forms of presentation;
- show some ability to link his or her Chemistry studies with applications relating to society and the environment;
- show a reasonable understanding of scientific method, and be able to design, carry out and evaluate simple experiments with some confidence and competence.

## 10. GLOSSARY OF COMMAND WORDS

This glossary of terms is intended to serve as a guide to learners, although it is not exhaustive and it has deliberately been kept brief. Learners should understand that the meaning of a term must depend in part on its context. The number of marks allocated for any part of a question is a guide to the depth required for the answer.

<b>Define (the term(s)...).</b>	is intended literally. Only a formal statement or equivalent paraphrase is required
<b>What do you understand by/What is meant by (the term(s)...)</b>	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 the light of the indicated mark value.
<b>State</b>	implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.
<b>List</b>	requires a number of points with no elaboration. If a specific number of points is requested, this number should not be exceeded.
<b>Explain</b>	may imply reasoning or some reference to theory, depending on the context.
<b>Describe</b>	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.  For particular phenomena, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. In other contexts, <b>describe and give an account of</b> 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. <b>Describe and explain</b> may be coupled in a similar way to <b>state and explain</b> .
<b>Discuss</b>	requires candidates to give a critical account of the points involved in the topic.
<b>Outline</b>	implies brevity, i.e. restricting the answer to giving essentials.
<b>Deduce/predict</b>	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 in an earlier part of the question.
<b>Comment</b>	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.
<b>Suggest</b>	is used in two main contexts. It may imply either that there is no unique answer (e.g. in chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or that candidates are expected to apply their general knowledge to a new situation (one that may not formally be in the syllabus).
<b>Find</b>	is a general term that may variously be interpreted as calculate, measure, determine, etc.

<b>Calculate</b>	is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.
<b>Measure</b>	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.
<b>Determine</b>	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, e.g. relative molecular mass.
<b>Estimate</b>	implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make any necessary simplifying assumptions about points of principle and about the values of quantities not otherwise included in the question.
<b>Sketch</b>	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 an intercept, asymptote or discontinuity at a particular value. In diagrams, sketch implies that a simple, freehand drawing is acceptable though care should be taken over proportions and the clear exposition of important details.
<b>Construct</b>	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.
<b>Compare</b>	requires candidates to provide both the similarities and differences between things or concepts.
<b>Classify</b>	requires candidates to group things based on common characteristics.

In all questions, the number of marks is shown on the examination paper and candidates should use this as a guide to how much detail to give. When describing a process, the candidate should use the number of marks to decide how many steps to include. When explaining why something happens, the candidate should use the number of marks to decide how many reasons to give, or how much detail to give for each reason

### **ANNEXE A: Assessment criteria for Paper 3 (Advanced practical skills)**

Scientific subjects are, by their nature, experimental. It is, accordingly, important that an assessment of a learner's knowledge and understanding of Chemistry should contain a component relating to practical work and experimental skills (as identified by assessment objective C). Teachers should ensure that learners practise experimental skills throughout the whole period of their course of study. As a guide, learners should expect to spend at least 20% of their time doing practical work individually or in small groups. This 20% does not include the time spent observing teacher demonstrations of experiments.

Paper 3 will be a timetabled, laboratory-based practical paper focusing on the following experimental skills:

- manipulation, measurement and observation (MMO)
- presentation of data and observations (PDO)
- analysis, conclusions and evaluation (ACE)

The paper will consist of *two* or *three* questions, totalling 40 marks.

One question will be an observational problem in which the candidate will be asked to investigate an unknown substance or substances by specified experiments. Candidates will be expected to record their observations, analyse their results and draw appropriate conclusions. The substances may be elements, compounds or mixtures.

The other question or questions will be quantitative: measurement of a quantity e.g. volumes of solutions or of gases, temperature changes during reactions, mass changes during reactions, times for reactions to occur. Candidates may be expected to draw suitable tables, graphs and other appropriate means of presenting the data. They will analyse the data, perform calculations and draw appropriate conclusions from it.

One or more of the questions may require candidates to comment on the accuracy of the procedure or identify sources of error and make suggestions for change. The apparatus requirements for Paper 3 will vary from paper to paper. A complete list of apparatus and materials required will be issued in the Confidential Instructions. The Confidential Instructions should be followed very carefully. If there is any doubt about how the practical examination should be set up, it is vital that Centres contact DNEA as soon as possible.

### A1: Mark scheme for Paper 3

Paper 3 will be marked using the generic mark scheme below. The expectations for each mark category are listed in the sections that follow.

<b>Skill</b>	<b>Minimum mark allocation*</b>	<b>Breakdown of skills</b>	<b>Minimum mark allocation *</b>
Manipulation, measurement and observation (MMO)	12 marks	Successful collection of data and observations	8 marks
		Quality of measurement or observation	2 marks
		Decision relating to observation or measurement	2 marks
Presentation of data and observations (PDO)	6 marks	Recording data and observations	2 marks
		Display of calculation and reasoning	2 marks
		Data layout	2 marks
Analysis, conclusions and evaluation (ACE)	10 marks	Interpretation of data or observations and identifying sources of error	4 marks
		Drawing conclusions	5 marks
		Suggesting improvements	1 mark

\*The remaining 12 marks will be allocated across the skills in this grid and their allocation may vary from paper to paper.



## A2: Expectations for each mark category (Paper 3)

This topic provides learners with the necessary skills they need to carry out experimental and investigative work. This is aimed at reinforcing their learning of the theoretical subject content of the syllabus and instills an understanding of the interplay of experimental and theory in scientific method. Scientific skills will be tested mainly in Paper 3. **(NB: Notes for Use in Qualitative Analysis, will be provided in the question paper)**

### Manipulation, measurement and observation

#### *Successful collection of data and observations*

Candidates should be able to:

- set up apparatus
- follow instructions given in the form of written instructions or diagrams
- use their apparatus to collect an appropriate quantity of data or observations, including subtle differences in colour, solubility or quantity of materials
- make measurements using pipettes, burettes, measuring cylinders, thermometers, timing devices (or stop clocks/watches) and other common laboratory apparatus

Systematic qualitative analysis and knowledge of traditional methods of separation will not be required.

It will be assumed that candidates will be familiar with the following qualitative analysis reactions

(i) the reactions of the following cations:  $\text{NH}_4^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Ba}^{2+}$

(ii) the reactions of the following anions:  $\text{CO}_3^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{SO}_3^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$

(iii) tests for the following gases:  $\text{NH}_3$ ,  $\text{CO}_2$ ,  $\text{Cl}_2$ ,  $\text{H}_2$ ,  $\text{O}_2$ .

Qualitative analysis notes are printed at the end of the question paper and are reproduced in *Annexe D* of this syllabus.

The substances to be investigated may contain ions not included in the above list. In such cases candidates will not be expected to identify the ions but only to draw conclusions of a general nature.

Candidates should not attempt tests on substances other than those specified, except when it is appropriate to test for a gas.

Exercises requiring a knowledge of simple organic reactions, e.g. test-tube reactions indicating the presence of groups given in the AS Level syllabus, may also be set. This would be for the testing of observational skills and drawing general conclusions only.

A knowledge of volumetric determinations using the materials listed in *Annexe A4* will be expected. This list is not exhaustive, and simple titrations involving other reagents may also be set. Sufficient working details will be given if appropriate.

Candidates should normally record burette readings to the nearest  $0.05 \text{ cm}^3$ . When using a thermometer calibrated at  $1^\circ\text{C}$  intervals, temperature readings should be recorded to the nearest  $0.5^\circ\text{C}$ .

### *Quality of measurements or observations*

Candidates should be able to:

- make accurate and consistent measurements and observations

In qualitative experiments, precise descriptions and comparisons of colour or other observations are expected. In a titration with a good end-point, candidates are expected to record two titres within 0.10 cm<sup>3</sup>. Marks will be awarded for consistency and accuracy of readings. In some cases, the candidate's data or observations may be compared with information supplied by the Supervisor or known to the Examiners; in other cases, the award of the mark may be based on the scatter of points on a graph. Candidates are expected to work to the precision of the apparatus and materials provided. Allowances will be made where the quality of data is limited by the experimental method required or by the apparatus and materials used.

### *Decisions relating to measurements or observations*

Candidates should be able to:

- decide how many tests or observations to perform
- make measurements that span a range and have a distribution appropriate to the experiment
- decide how long to leave experiments running before taking readings
- identify where repeated readings or observations are appropriate
- replicate readings or observations as necessary
- identify where confirmatory tests are appropriate and the nature of such tests
- select reagents to distinguish between given ions

Candidates may need to choose how many tests, measurements and observations can be made in the time available. Candidates will be expected to be able to identify the most appropriate range and distribution of values. In some experiments a regularly-spaced set of measurements will be appropriate. Repeated readings of particular quantities are often necessary in chemistry in order to obtain accurate values and minimise experimental error. Individual readings or observations should be repeated where they appear to be anomalous. In qualitative analysis experiments, candidates may be expected to identify appropriate confirmatory tests.

## **Presentation of data and observations**

### *Recording data and observations*

Candidates should be able to:

- present numerical data, values or observations in a single table of results
- draw an appropriate table in advance of taking readings/making observations, so that they do not have to copy their results
- include in the table of results, if necessary, columns for raw data, for calculated values and for analyses or conclusions
- use column headings that include both the quantity and the unit and that conform to accepted scientific conventions
- record raw readings of a quantity to the same degree of precision, and observations to the same level of detail [e.g. if one measurement of mass in a column is given as 0.06g, then all masses in that column should be given to the nearest 0.01g]

As an example of accepted practice in column headings, if the quantity being measured is volume in cm<sup>3</sup>, then 'volume/cm<sup>3</sup>' would be the usual way to write the column heading, but 'volume in cm<sup>3</sup>' or

'volume (cm<sup>3</sup>)' would be allowed. Headings such as 'volume cm<sup>3</sup>' or just 'cm<sup>3</sup>' are not acceptable. The quantity or the unit or both may be written in words, or appropriate symbols may be used provided that their meaning is clear and unambiguous in the context (e.g. avoid t, since it may be used for time and for temperature). Conventional symbols or abbreviations, such as  $\Delta H$  for enthalpy change or ppt. for precipitate, may be used without explanation. In recording data and observations, if one measurement of mass in a column of raw data is given as 0.06 g, then all the masses in that column should be given to the nearest 0.01 g. The degree of precision recorded should be compatible with the measuring instrument used, e.g. a measuring cylinder calibrated at 1.0 cm<sup>3</sup> should normally be read to the nearest 0.5 cm<sup>3</sup>. Observations of qualitative variables such as colour should be recorded in simple language such as 'blue' or 'yellow'. Where fine discrimination is required, terms such as 'pale' or 'dark' should be used, and comparisons made such as 'darker brown than at 3 minutes' or 'paler green than with 0.2 mol dm<sup>-3</sup>'.

#### *Display of calculation and reasoning*

Candidates should be able to:

- show their working in calculations, and the key steps in their reasoning
- use the correct number of significant figures for calculated quantities

Where calculations are carried out, all the key stages in the calculation should be recorded by candidates, so that credit can be given for correctly displaying working. Similarly, where observations form the basis for logical deduction (e.g. the concentration of a solution or the identity of an unknown substance), the steps in making the deduction should be shown. Where specific observations are used to build a general prediction or to support a general theory, the candidates should show the sequence of steps used in the inductive process. Calculated quantities should be given to the same number of significant figures as (or one more than) the measured quantity of least accuracy. For example, if titre volume is measured to four significant figures, e.g. 23.45 cm<sup>3</sup>, then the corresponding molar concentrations should be given to four significant figures, e.g. 1.305 mol dm<sup>-3</sup> or 0.9876 mol dm<sup>-3</sup>. However, if the concentration of one of the reactants is given to three significant figures, then the calculated concentration could be given to three or four significant figures. For example, if the concentration of alkali in an acid-base titration is given as 0.100 mol dm<sup>-3</sup>, then the concentration of the acid may be shown as 0.1305 mol dm<sup>-3</sup> or 0.131 mol dm<sup>-3</sup>.

#### *Data layout*

Candidates should be able to:

- choose a suitable and clear method of presenting the data, e.g. tabulations, graphs or a mixture of methods of presentation
- use the appropriate presentation medium to produce a clear presentation of the data
- plot appropriate variables on appropriate, clearly labelled x- and y-axes
- choose suitable scales for graph axes
- plot all points or bars to an appropriate accuracy
- draw straight lines of best fit or curves to show the trend of a graph.
- select appropriate variables and scales for plotting a graph, especially to obtain a linear graph of the form  $y = mx + c$ .
- determine and interpret the slope and intercept of a linear graph.
- choose by inspection a straight line that will serve as the 'least bad' linear model for a set of data presented graphically.
- understand
  - the slope of a tangent to a curve as a measure of the rate of change, the 'area' below a curve where the area has physical significance, e.g. Boltzmann distribution curves.

Generally, candidates are expected to present data in the form in which the key points of the data can be most easily visualised. For qualitative data this is likely to be a table. For quantitative data this may be a graph or a table. Candidates should choose scales for the graph axes that allow the graph to be read easily, such as 1, 2 or 5 units to a 20 mm square. Candidates should normally make the best use of the space available for making their presentation: they should use over half of the length of a grid in both x and y- directions so that the data points occupy at least half of the graph grid in both directions. Tables of qualitative observations should be large enough for all the entries to fit comfortably in the available space. Lines for tables and graphs should be drawn in pencil. The accepted scientific conventions for labelling the axes of a graph are the same as for the column headings in a table of results with both the quantity and the unit shown (where appropriate). Points should be finely drawn with a sharp pencil, but must still be visible. A fine cross or an encircled dot is suitable; a thick pencil blob is not. Often it is obvious that the data fall on a straight line or smooth curve, and a line of best fit (straight or curved) should be drawn. In some cases candidates may be expected to draw more than one line of best fit and find the intersection. Any line of best fit should show an even distribution of points on either side of the line along its whole length. Any points deemed to be anomalous by the candidate should be ringed or labelled as such to indicate their exclusion when determining such lines of best fit. Lines should be finely drawn and should not contain kinks or breaks. Candidates will be expected to extrapolate lines to read intercepts with axes or other lines or predict values outside the range of the experiment.

### **Analysis, conclusions and evaluation**

#### *Interpretation of data or observations and identifying sources of error*

Candidates should be able to:

- describe the patterns and trends shown by data in tables and graphs
- describe and summarise the key points of a set of observations
- find an unknown value by using co-ordinates or intercepts on a graph
- calculate other quantities from data, or calculate the mean from repeated values, or make other appropriate calculations
- determine the gradient of a straight-line graph or tangent to a curve
- evaluate the effectiveness of control variables
- identify the most significant sources of error in an experiment
- estimate, quantitatively, the uncertainty in a quantitative measurement and express such uncertainty in a measurement as an actual or percentage error
- show an understanding of the distinction between systematic errors and random errors

Descriptions should be precise, giving quotations of figures to support the description and calculated values where these are appropriate. Unknown values may include a change in temperature found graphically, or a change in mass for example. Calculations may involve mean, percentage, percentage gain or loss, rate of reaction, concentration, molar mass and volume of gases or other appropriate calculations. When a gradient of a graph is to be determined, the points on the line chosen for the calculation should be separated by at least half of the length of the line drawn. Candidates should have experience of looking at experiments and assessing the relative importance of errors in measurement or in making observations so that they can judge which sources of error are most important. They should be familiar with simple means of estimating error, such as the errors intrinsic in measuring devices or in experiments where limitations of the method introduce errors (e.g. heat loss when trying to assess enthalpy change). A statement of 'human errors' is not acceptable; though there are occasionally errors arising in the observer's ability to observe (e.g. in the

disappearing cross experiment) which would be a random error. They should be able to express these errors in standard forms such as length =  $73 \pm 1$  mm, or temperature increase =  $14 \pm 4$  °C. Candidates should be able to suggest which of the sources of error described are likely to be systematic errors, such as those resulting from thermometers that consistently read 1 °C above actual temperature, or reading volumes to the wrong part of the meniscus, as well as those which are likely to be random errors due to variability of materials, or random variations in room temperature.

#### *Drawing conclusions*

Candidates should be able to:

- draw conclusions from an experiment, giving an outline description of the main features of the data, considering whether experimental data supports a given hypothesis, and making further predictions
- draw conclusions from interpretations of observations, data and calculated values
- make scientific explanations of the data, observations and conclusions that they have described

Hypotheses that are being tested will be given to the candidates, although hypothesis formulation is in Assessment objective 2, and so may be tested in the theory components. Candidates may be required to prove or disprove hypotheses, using deductions from the data, observations or calculated values. Simple scientific explanations form a part of such conclusions and therefore form a part of this practical assessment: candidates will be expected to refer to knowledge and understanding gained in the theory part of the course in order to provide explanations of their practical conclusions.

#### *Suggesting improvements*

Candidates should be able to:

- suggest modifications to an experimental arrangement that will improve the accuracy of the experiment or the observations that can be made
- suggest ways in which to extend the investigation to answer a new question
- describe such modifications clearly in words or diagrams

Candidate's suggestions should be realistic, so that in principle they are achievable in practice, although they may include the use of apparatus that is not available to the candidate (e.g. a calorimeter). The suggestions may relate to the apparatus used, to the experimental procedure followed, to the nature of the observations or to the means used to make them. Candidates may include improvements that they have actually made while carrying out the experiment, such as repeating readings. The suggested modifications may relate to sources of error identified by the candidate or to other sources of error. Extensions of the investigation should only be proposed in order to permit the answering of a specified new question.

### A3: Administration of Paper 3

Detailed regulations on the administration of Namibia practical examinations are contained in the *DNEA handbook* for centres. Details of the specific requirements for apparatus and materials for a particular examination are given in the Confidential Instructions which are sent to Centres several weeks prior to the examination. Centres should contact DNEA if they believe the Confidential Instructions have not been received.

#### **Access to the question paper itself is not permitted in advance of the examination.**

It is essential that absolute confidentiality be maintained in advance of the examination date: the contents of the Confidential Instructions must not be revealed either directly or indirectly to candidates.

The Confidential Instructions describe information required by the Examiners. This will include a set of numerical results for the experiments, which the Supervisor should obtain out of sight of the candidates. A Supervisor's Report Form is included in the Confidential Instructions. Centres must complete this form and enclose a copy in each envelope of scripts. The marking process may be delayed and candidates may be disadvantaged if the Supervisor's Report Form or sample results are missing or do not contain the information required.

If there is any doubt about the interpretation of the Confidential Instructions document or the suitability of the apparatus available, enquiries should be sent to the education officer for Chemistry at DNEA. Detailed guidance on preparing the standard bench reagents and indicators will **not** be given in the Confidential Instructions. The Confidential Instructions will refer Supervisors to the following guidance notes in this syllabus document.

The following hazard codes are used where relevant.

<b>[C]</b> = corrosive <b>[HH]</b> = health hazard <b>[F]</b> = flammable <b>[N]</b> = hazardous to the aquatic environment	<b>[MH]</b> = moderate hazard <b>[T]</b> = toxic substance <b>[O]</b> = oxidising substance
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**The attention of Centres is drawn to any local regulations relating to safety, first-aid and disposal of chemicals.** 'Hazard Data Sheets' should be available from your chemical supplier.

**Guidance for the preparation of standard bench reagents for qualitative analysis and of indicators**

Hazard	Label	Identity	Instructions
	<b>dilute hydrochloric acid</b>	2.0 mol dm <sup>-3</sup> HCl	Dilute 170 cm <sup>3</sup> of concentrated (35–37%; approximately 11 mol dm <sup>-3</sup> ) hydrochloric acid <b>[C]</b> to 1 dm <sup>3</sup> .
<b>[C]</b>	<b>dilute nitric acid</b>	2.0 mol dm <sup>-3</sup> HNO <sub>3</sub>	Dilute 128 cm <sup>3</sup> of concentrated (70% w/v) nitric acid <b>[C]</b> <b>[O]</b> to 1 dm <sup>3</sup> .
<b>[MH]</b>	<b>dilute sulfuric acid</b>	1.0 mol dm <sup>-3</sup> H <sub>2</sub> SO <sub>4</sub>	Cautiously pour 55 cm <sup>3</sup> of concentrated (98%) sulfuric acid <b>[C]</b> into 500 cm <sup>3</sup> of distilled water with continuous stirring. Make the solution up to 1 dm <sup>3</sup> with distilled water. <b>Care: concentrated H<sub>2</sub>SO<sub>4</sub> is very corrosive.</b>
<b>[C]</b> <b>[MH]</b> <b>[N]</b>	<b>aqueous ammonia</b>	2.0 mol dm <sup>-3</sup> NH <sub>3</sub>	Dilute 112 cm <sup>3</sup> of concentrated (35%) ammonia <b>[C]</b> <b>[N]</b> to 1 dm <sup>3</sup> .
<b>[C]</b>	<b>aqueous sodium hydroxide</b>	2.0 mol dm <sup>-3</sup> NaOH	Dissolve 80.0 g of NaOH <b>[C]</b> in each dm <sup>3</sup> of solution. <b>Care: the process of solution is exothermic and any concentrated solution is very corrosive.</b>
	<b>0.1 mol dm<sup>-3</sup> barium chloride</b> or <b>0.1 mol dm<sup>-3</sup> barium nitrate</b>	0.1 mol dm <sup>-3</sup> barium chloride or 0.1 mol dm <sup>-3</sup> barium nitrate	Dissolve 24.4 g of BaCl <sub>2</sub> ·2H <sub>2</sub> O <b>[T]</b> in each dm <sup>3</sup> of solution, or dissolve 26.1 g of Ba(NO <sub>3</sub> ) <sub>2</sub> <b>[H]</b> <b>[O]</b> in each dm <sup>3</sup> of solution.
<b>[N]</b>	<b>0.05 mol dm<sup>-3</sup> silver nitrate</b>	0.05 mol dm <sup>-3</sup> silver nitrate	Dissolve 8.5 g of AgNO <sub>3</sub> <b>[C]</b> <b>[N]</b> in each dm <sup>3</sup> of solution.
<b>[MH]</b>	<b>limewater</b>	saturated aqueous calcium hydroxide, Ca(OH) <sub>2</sub>	Prepare fresh limewater by leaving distilled water to stand over solid calcium hydroxide <b>[H]</b> for several days, shaking occasionally. Decant or filter the solution.
	<b>0.1 mol dm<sup>-3</sup> potassium iodide</b>	0.1 mol dm <sup>-3</sup> KI	Dissolve 16.6 g of KI <b>[H]</b> in each dm <sup>3</sup> of solution.
	<b>0.02 mol dm<sup>-3</sup> potassium manganate(VII)</b>	0.02 mol dm <sup>-3</sup> KMnO <sub>4</sub>	Dissolve 3.16 g of KMnO <sub>4</sub> <b>[N]</b> <b>[O]</b> <b>[H]</b> in each dm <sup>3</sup> of solution.
	<b>starch indicator</b>	freshly prepared aqueous starch indicator (approx 2% solution w/v)	Mix 2 g of <b>soluble</b> starch with a little cold water until a smooth paste is obtained. Add 100 cm <sup>3</sup> boiling water and stir. Boil until a clear solution is obtained (about 5 minutes).
<b>[F]</b> <b>[HH]</b> <b>[MH]</b>	<b>methyl orange indicator</b>	methyl orange indicator (pH range 2.9 to 4.6)	Use commercially produced solution or dissolve 0.4 g of solid indicator <b>[H]</b> in 200 cm <sup>3</sup> of ethanol (IMS) <b>[F]</b> and make up to 1 dm <sup>3</sup> with distilled water.
<b>[F]</b> <b>[HH]</b> <b>[MH]</b>	<b>bromophenol blue indicator</b>	bromophenol blue indicator (pH range 3.0 to 4.5)	Dissolve 0.4 g of the solid indicator <b>[H]</b> in 200 cm <sup>3</sup> of ethanol (IMS) <b>[F]</b> and make up to 1 dm <sup>3</sup> with distilled water.

<b>Hazard</b>	<b>Label</b>	<b>Identity</b>	<b>Instructions</b>
[F] [HH] [MH]	<b>thymol blue indicator</b>	thymol blue indicator (pH range 8.0 to 9.6)	Dissolve 0.4 g of the solid indicator [H] in 200 cm <sup>3</sup> of ethanol (IMS) [F] and make up to 1 dm <sup>3</sup> with distilled water.
[F] [HH] [MH]	<b>thymolphthalein indicator</b>	thymolphthalein indicator (pH range 9.3 to 10.5)	Dissolve 2.0 g of the solid indicator [H] in 1 dm <sup>3</sup> of ethanol (IMS) [F].
[MH]	<b>acidified aqueous potassium manganate(VII)</b>	0.01 mol dm <sup>-3</sup> KMnO <sub>4</sub> 0.5 mol dm <sup>-3</sup> sulfuric acid	Mix equal volumes of 0.02 mol dm <sup>-3</sup> KMnO <sub>4</sub> and 1.0 mol dm <sup>-3</sup> H <sub>2</sub> SO <sub>4</sub> [H].



#### A4: Apparatus and material list

The list given below gives guidance to schools concerning the apparatus and materials that are expected to be generally available for examination purposes (Paper 3 Advanced Practical Skills). The list is not intended to be exhaustive: in particular, items (such as Bunsen burners, tripods, glass tubing) that are commonly regarded as standard equipment in a chemical laboratory are not included. Unless otherwise stated, the rate of allocation is 'per candidate'. Centres **should keep these in stock** and candidates should be accustomed to using these. To provide some variation in the questions set, some additional items of equipment or materials may be required. Glassware should, where possible, conform to the quality specifications given, or Supervisors should otherwise satisfy themselves that the glassware used is of an appropriate accuracy.

- two burettes, 50 cm<sup>3</sup> (ISO385 or grade B)
- two pipettes, 25 cm<sup>3</sup> (ISO648 or grade B)
- one pipette, 10 cm<sup>3</sup> (ISO648 or grade B)
- teat/dropping pipettes
- one pipette filler
- conical flasks: two within range 150 cm<sup>3</sup> to 250 cm<sup>3</sup>
- one-mark graduated volumetric flask, 250 cm<sup>3</sup> (ISO1042 or grade B)
- measuring cylinders, 25 cm<sup>3</sup> and 50 cm<sup>3</sup> (ISO6706 or ISO4788 or grade B)
- measuring cylinder, 250 cm<sup>3</sup> (glass or plastic)
- side-arm conical flask or third conical flask with suitable bung and delivery tube
- tub suitable for acting as a trough (for collecting gas over water)
- wash bottle
- two filter funnels
- two porcelain crucibles, approximately 15 cm<sup>3</sup>, with lids
- one pipe-clay triangle
- one evaporating basin, at least 30 cm<sup>3</sup>
- beakers, squat form with lip: 100 cm<sup>3</sup>, 250 cm<sup>3</sup>
- one thermometer: -10 °C to +110 °C at 1 °C
- two foamed plastic (expanded polystyrene) cups approximately 150 cm<sup>3</sup>
- test-tubes (some of which should be Pyrex or hard-glass) approximately 125 mm × 16 mm
- boiling tubes, approximately 150 mm × 25 mm
- clocks to measure to an accuracy of 1 s (Where clocks are specified, candidates may use their own wrist watches if they prefer.)
- balance, single-pan, direct reading, **minimum** accuracy 0.1 g (1 per 8–12 candidates) weighing to 200 g
- stand and clamp suitable for a burette
- glass rod
- two spatula
- test tube rack
- crucible tongs

It is suggested that the following chemicals be used in the Centre as part of the practical course. These chemicals may be required for the practical examination. Practical examinations may also require chemicals that are not listed.

### **For quantitative analysis**

This list is not exhaustive. Other chemicals may be used in a practical examination.

#### **Acid/base titration**

common laboratory acids (hydrochloric acid, sulfuric acid, nitric acid)

a weak acid such as ethanoic or propanoic acid

sodium hydroxide

sodium carbonate

indicators such as methyl orange or screened methyl orange, bromophenol blue and thymol blue or thymolphthalein

#### **Manganate(VII) titration**

potassium manganate(VII)

hydrogen peroxide

iron(II) sulfate or ammonium iron(II) sulfate

sodium nitrite

ethanedioic acid or its soluble salts

#### **Gravimetric, thermometric, rates and gas collection**

copper(II) sulfate

Group 2 carbonates

iron, magnesium, zinc metals

potassium iodide

potassium peroxydisulfate

sodium thiosulfate

solid hydrated barium chloride and magnesium sulfate

### For qualitative analysis

This list is not exhaustive. Other chemicals may be used in a practical examination.

### Bench reagents and equipment

aqueous ammonia (approximately  $2.0 \text{ mol dm}^{-3}$ )  
aqueous sodium hydroxide (approximately  $2.0 \text{ mol dm}^{-3}$ )  
hydrochloric acid (approximately  $2.0 \text{ mol dm}^{-3}$ )  
nitric acid (approximately  $2.0 \text{ mol dm}^{-3}$ )  
sulfuric acid (approximately  $1.0 \text{ mol dm}^{-3}$ )  
aqueous barium nitrate or barium chloride (approximately  $0.1 \text{ mol dm}^{-3}$ )  
aqueous silver nitrate (approximately  $0.05 \text{ mol dm}^{-3}$ )  
aqueous potassium iodide (approximately  $0.1 \text{ mol dm}^{-3}$ )  
aqueous potassium manganate(VII) (approximately  $0.02 \text{ mol dm}^{-3}$ )  
limewater (a saturated solution of calcium hydroxide) and the equipment normally used by the Centre to test for carbon dioxide  
aqueous iodine (approximately  $0.01 \text{ mol dm}^{-3}$  in  $0.2 \text{ mol dm}^{-3}$  potassium iodide)  
sodium carbonate or sodium hydrogencarbonate  
starch indicator  
aluminium foil  
red and blue litmus paper

### For inorganic analysis

the carbonates (where they exist), sulfates, nitrates and chlorides of the cations listed in the Qualitative Analysis Notes

The sodium and potassium salts of the anions listed in the Qualitative Analysis Notes

### For organic analysis

alcohols (primary, secondary, tertiary)  
aldehydes and ketones  
(N.B. Tests for aldehydes may be performed by substituting glucose for the aldehyde.)  
carboxylic acids and esters  
halogenoalkanes

#### **A5: Safety in the laboratory**

Responsibility for safety matters rests with schools and other centres. It is further advised that, as it is the current practice in Namibia, schools and centres should consult local authorities for additional support services regarding safety. These are for example Town Council, Village Council, Municipality Service providers and other service providers who deal with waste management.

**A5: Model layout of a titration table**

	Trial	1	2	3	
Initial burette reading / cm <sup>3</sup>					
Final burette reading / cm <sup>3</sup>					
Titre / cm <sup>3</sup>					
Mean titre / cm <sup>3</sup>					

When recording burette readings, it is normal practice to record to 2 decimal places. The last decimal place should always be 0 or 5, for example 21.20 or 21.25. Titres should be repeated until there are two concordant values (within 0.10 cm<sup>3</sup>). The two titres with the closest values should be used to calculate the mean titre. The mean should be calculated using titres that are all within 0.2 cm<sup>3</sup> of each other. Values used to calculate the mean should be clearly indicated by ringing or ticking the chosen titres in the table or the mathematics of the calculation should be shown.

## ANNEXE B: 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	Usual symbol	Usual unit
<b>Base quantities</b>		
mass	$m$	g
length	$l$	m
time	$t$	s
electric current	$I$	A
thermodynamic temperature	$T$	K
amount of substance	$n$	mol

Quantity	Usual symbol	Usual unit
<b>Other quantities</b>		
atomic mass	$m_a$	g
avogadro constant	$L$	mol <sup>-1</sup>
bond energy	-	KJmol <sup>-1</sup>
concentration	$c$	mol dm <sup>-3</sup>
density	$\rho$	kgm <sup>-3</sup> , g dm <sup>-3</sup> , g cm <sup>-3</sup> .
molar gas constant	$R$	JK <sup>-1</sup> mol <sup>-1</sup>
molar mass	$M$	g mol <sup>-1</sup>
molecular mass	$m$	g
neutron number	$N$	-
nucleon number	$A$	-
number of molecules	$N$	-
number of molecules per unit volume	$n$	m <sup>-3</sup>
pH	pH	-
pressure	$p$	Pa
proton number	$Z$	-
relative atomic {isotopic} mass	$A_r$	-
relative molecular mass	$M_r$	-
temperature	$\theta, T$	°C
volume	$V, v$	m <sup>3</sup> , dm <sup>3</sup>

## ANNEXE C: Requirements for organic chemistry and analysis

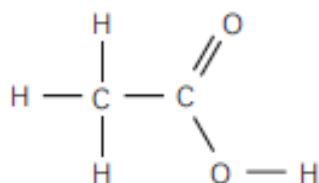
This section gives details of the terminology used when referring to organic structures, reactions and mechanisms.

### Structural condensed formulae

In candidates' answers, an acceptable response to a request for a structural condensed formula will be to give the minimal detail, using conventional groups, for an unambiguous structure, e.g.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$  for propan-1-ol, not  $\text{C}_3\text{H}_7\text{OH}$ , and  $\text{CH}_3\text{CH}=\text{CHCH}_3$  or  $\text{CH}_3\text{CHCHCH}_3$  for but-2-ene, not  $\text{C}_4\text{H}_8$ .

### Structural displayed formulae

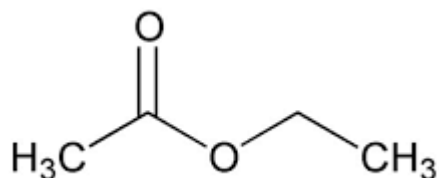
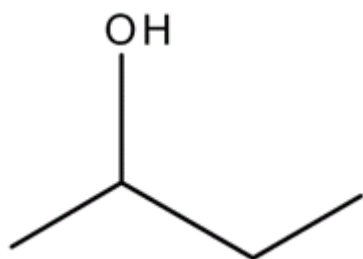
A structural displayed formula should show both the relative placing of atoms and the number of bonds between them, for example methyl ethanoate below.



### Skeletal formulae

A skeletal formulae is a simplified representation of an organic structure. It is derived from the structural displayed formula by removing hydrogen atoms (and their associated bonds) and carbon atoms from alkyl chains, leaving just the carbon-carbon bonds in the carbon skeleton and associated functional groups. Skeletal or partial-skeletal representations may be used in question papers and are acceptable in candidates' answers where they are unambiguous.

The skeletal formula for butan-2-ol and a partial-skeletal formula for methyl ethanoate are shown below.



## ANNEXE D: Notes for use in qualitative analysis

### Tests for anions

anion	test	test result
carbonate ( $\text{CO}_3^{2-}$ )	add dilute acid	effervescence, carbon dioxide produced
chloride ( $\text{Cl}^-$ ) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt. (soluble in dilute ammonia)
bromide ( $\text{Br}^-$ ) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	cream ppt. (partially soluble in dilute ammonia)
iodide ( $\text{I}^-$ ) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt (insoluble in dilute ammonia).
nitrate ( $\text{NO}_3^-$ ) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
nitrite ( $\text{NO}_2^-$ ) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced;
sulfate ( $\text{SO}_4^{2-}$ ) [in solution]	add aqueous barium nitrate then nitric acid	white ppt, insoluble in nitric acid
sulfite ( $\text{SO}_3^{2-}$ ) [in solution]	add aqueous barium nitrate then nitric acid	white ppt, soluble in nitric acid

### Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
aluminium ( $\text{Al}^{3+}$ )	white ppt. soluble in excess	white ppt., insoluble in excess
calcium ( $\text{Ca}^{2+}$ )	white ppt. with high aqueous $\text{Ca}^{2+}$	no ppt.
barium ( $\text{Ba}^{2+}$ )	faint white ppt. is nearly always observed (unless reagents are pure)	no ppt.
ammonium ( $\text{NH}_4^+$ )	no ppt. ammonia produced on warming	-
chromium (III), ( $\text{Cr}^{3+}$ )	grey-green ppt. soluble in excess giving a green solution	grey-green ppt. insoluble in excess
copper(II) ( $\text{Cu}^{2+}$ )	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess, giving a dark blue solution
iron(II) ( $\text{Fe}^{2+}$ )	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III) ( $\text{Fe}^{3+}$ )	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, ( $\text{Mg}^{2+}$ )	off-white ppt. insoluble in excess	white ppt. insoluble in excess
manganese (II), ( $\text{Mn}^{2+}$ )	off-white ppt. rapidly turning brown on contact with air, insoluble in excess	off-white ppt. rapidly turning brown on contact with air, insoluble in excess
zinc ( $\text{Zn}^{2+}$ )	white ppt. soluble in excess	white ppt. soluble in excess



### Tests for gases

gas	test and test result
ammonia (NH <sub>3</sub> )	turns damp red litmus paper blue
carbon dioxide (CO <sub>2</sub> )	turns limewater milky
chlorine (Cl <sub>2</sub> )	bleaches damp litmus paper
hydrogen (H <sub>2</sub> )	'pops' with a lighted splint
oxygen (O <sub>2</sub> )	relights a glowing splint

## **ANNEXE E: DATA BOOKLET**

The data booklet contains the information that will be made available to candidates for paper 1 and paper 2.

Namibia  
Senior  
Secondary  
Certificate  
Advanced  
Subsidiary  
**NSSCAS**

# Data Booklet

Namibia Senior Secondary Certificate Advanced Subsidiary Level  
in Chemistry (8224)

For use from 2021 in Papers 1 and 2 examinations.

Contents: Tables of Chemical data

1 Important values, constants and standards

2 Ionisation energies (1st, 2nd, 3rd and 4th) of selected elements in  $\text{kJ mol}^{-1}$

3 Bond energies

4 Atomic and ionic radii

5 Characteristic infra-red absorption frequencies for some selected bonds

6 The Periodic Table of Elements

## 1. Important values, constants and standards

Molar gas constant	$R = 8.31 \text{ JK}^{-1}\text{mol}^{-1}$
the Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ under room conditions (where s.t.p is expressed as 101kPa, approximately, and 273 K (0 °C))
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$= 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ( $= 4.18 \text{ J g}^{-1} \text{ K}^{-1}$ )

**2. Ionisation energies (1st, 2nd, 3rd and 4th) of selected elements in kJ mol<sup>-1</sup>**

element	proton number	first	second	third	fourth
H	1	1310	-	-	-
He	2	2370	5250	-	-
Li	3	519	7300	11 800	-
Be	4	900	1760	14 800	21 000
B	5	799	2420	3660	25 000
C	6	1090	2350	4610	6220
N	7	1400	2860	4590	7480
O	8	1310	3390	5320	7450
F	9	1680	3370	6040	8410
Ne	10	2080	3950	6150	9290
Na	11	494	4560	6940	9540
Mg	12	736	1450	7740	10 500
Al	13	577	1820	2740	11 600
Si	14	786	1580	3230	4360
P	15	1060	1900	2920	4960
S	16	1000	2260	3390	4540
Cl	17	1260	2300	3850	5150
Ar	18	1520	2660	3950	5770
K	19	418	3070	4600	5860
Ca	20	590	1150	4950	6480
Sc	21	632	1240	2390	7110
Ti	22	661	1310	2720	4170
V	23	648	1370	2870	4600
Cr	24	653	1590	2990	4770
Mn	25	716	1510	3250	5190
Fe	26	762	1560	2960	5400
Co	27	757	1640	3230	5100
Ni	28	736	1750	3390	5400
Cu	29	745	1960	3350	5690
Zn	30	908	1730	3828	5980
Ga	31	577	1980	2960	6190
Br	35	1140	2080	3460	4850
Rb	37	403	2632	3900	5080
Sr	38	548	1060	4120	5440
Ag	47	731	2074	3361	-
I	53	1010	1840	2040	4030
Cs	55	376	2420	3300	-
Ba	56	502	966	3390	-

### 3. Bond energies

#### 3 (a) Bond energies in diatomic molecules (these are exact values)

##### *Homonuclear*

Bond	Energy (kJmol <sup>-1</sup> )
H-H	436
D-D	442
N≡N	944
O=O	496
P≡P	485
S=S	425
F-F	158
Cl-Cl	242
Br-Br	193
I-I	151

##### *Heteronuclear*

Bond	Energy (kJmol <sup>-1</sup> )
H-F	562
H-Cl	431
H-Br	366
H-I	299
C≡O	1077

### 3 (b) Bond energies in polyatomic molecules (these are average values)

#### *Homonuclear*

Bond	Energy (kJmol <sup>-1</sup> )
C-C	350
C=C	610
C≡C	840
benzene	520
N-N	160
N=N	410
O-O	150
Si-Si	222
P-P	200
S-S	264

#### *Heteronuclear*

Bond	Energy (kJmol <sup>-1</sup> )
C-H	410
C-Cl	340
C-Br	280
C-I	240
C-N	305
C=N	610
C≡N	890
C-O	360
C=O	740
C=O in CO <sub>2</sub>	805
N-H	390
N-Cl	310
O-H	460
Si-Cl	359
Si-H	320
Si-O in SiO <sub>2(s)</sub>	460
Si=O in SiO <sub>2(g)</sub>	640
P-H	320
P-Cl	330
P-O	340
P=O	540
S-H	347
S-Cl	250
S-O	360
S=O	500



#### 4. Atomic and ionic radii

<b>(a) Period 1</b>	<b>atomic/nm</b>	<b>ionic/nm</b>
single covalent	H 0.037	H <sup>+</sup> 0.208
van der Waals	He 0.140	
<b>(b) Period 2</b>		
metallic	Li 0.152	Li <sup>+</sup> 0.060
	Be 0.112	Be <sup>2+</sup> 0.031
single covalent	B 0.080	B <sup>3+</sup> 0.020
	C 0.077	C <sup>4+</sup> 0.015    C <sup>4-</sup> 0.260
	N 0.074	N <sup>3-</sup> 0.171
	O 0.073	O <sup>2-</sup> 0.140
	F 0.072	F <sup>-</sup> 0.136
van der Waals	Ne 0.160	
<b>(c) Period 3</b>		
metallic	Na 0.186	Na <sup>+</sup> 0.095
	Mg 0.160	Mg <sup>2+</sup> 0.065
	Al 0.143	Al <sup>3+</sup> 0.050
single covalent	Si 0.117	Si <sup>4+</sup> 0.041
	P 0.110	P <sup>3-</sup> 0.212
	S 0.104	S <sup>2-</sup> 0.184
	Cl 0.099	Cl <sup>-</sup> 0.181
van der Waals	Ar 0.190	
<b>(d) group 2</b>		
metallic	Be 0.112	Be <sup>2+</sup> 0.031
	Mg 0.160	Mg <sup>2+</sup> 0.065
	Ca 0.197	Ca <sup>2+</sup> 0.099
	Sr 0.215	Sr <sup>2+</sup> 0.113
	Ba 0.217	Ba <sup>2+</sup> 0.135
	Ra 0.220	Ra <sup>2+</sup> 0.140

<b>(d) group 14</b>		
single covalent	C 0.077	
	Si 0.117	Si <sup>4+</sup> 0.041
	Ge 0.122	Ge <sup>2+</sup> 0.093
metallic	Sn 0.162	Sn <sup>2+</sup> 0.112
	Pb 0.175	Pb <sup>2+</sup> 0.120
<b>(d) group 17</b>		
single covalent	F 0.072	F <sup>-</sup> 0.136
	Cl 0.099	Cl <sup>-</sup> 0.181
	Br 0.114	Br <sup>-</sup> 0.195
	I 0.133	I <sup>-</sup> 0.216
	At 0.140	
<b>(e) first row transition element</b>		
metallic	Sc 0.164	Sc <sup>3+</sup> 0.081
	Ti 0.146	Ti <sup>2+</sup> 0.090    Ti <sup>3+</sup> 0.067
	V 0.135	V <sup>2+</sup> 0.079    V <sup>3+</sup> 0.064
	Cr 0.129	Cr <sup>2+</sup> 0.073    Cr <sup>3+</sup> 0.062
	Mn 0.132	Mn <sup>2+</sup> 0.067    Mn <sup>3+</sup> 0.062
	Fe 0.126	Fe <sup>2+</sup> 0.061    Fe <sup>3+</sup> 0.055
	Co 0.125	Co <sup>2+</sup> 0.078    Co <sup>3+</sup> 0.053
	Ni 0.124	Ni <sup>2+</sup> 0.070    Ni <sup>3+</sup> 0.056
	Cu 0.128	Cu <sup>2+</sup> 0.073
	Zn 0.135	Zn <sup>2+</sup> 0.075

### 5. Characteristic infra-red absorption frequencies for some selected bonds

Bond	Functional groups containing the bond	Absorption range (in wavenumbers) / $cm^{-1}$	Appearance of peak (s = strong, w = weak)
C-O	alcohols, ethers, esters	1040 -1300	<b>s</b>
C=C	alkenes	1500 – 1680	<b>w</b> unless conjugated
C=O	amides	1640 – 1690	<b>s</b>
	ketones and aldehydes	1670 – 1740	<b>s</b>
	carboxylic acids	1680 – 1730	<b>s</b>
	esters	1710 – 1750	<b>s</b>
C-H	alkanes, CH <sub>2</sub> -H	2850 – 2950	<b>s</b>
	alkenes	3000 – 3100	<b>w</b>
N-H	amides, amines	3300 – 3500	<b>w</b>
O-H	carboxylic acids, RCO <sub>2</sub> -H	2500 – 3000	<b>s</b> and very broad
	H-bonded alcohol, RO-H	3200 – 3600	<b>s</b>
	free alcohol, RO-H	3580 – 3650	<b>s</b> and sharp

## 6. The Periodic Table of the Elements

Group																											
1	2											13	14	15	16	17	18										
<p style="text-align: center;"><b>Key</b></p> <p>A = relative atomic mass                      X = atomic symbol                      Name of element                      Z = proton (atomic) number</p>												1.0 <b>H</b> Hydrogen 1															4.0 <b>He</b> Helium 2
												6.9 <b>Li</b> Lithium 3	9.0 <b>Be</b> Beryllium 4											10.8 <b>B</b> Boron 5	12.0 <b>C</b> Carbon 6	14.0 <b>N</b> Nitrogen 7	16.0 <b>O</b> Oxygen 8
23.0 <b>Na</b> Sodium 11	24.3 <b>Mg</b> Magnesium 12	3	4	5	6	7	8	9	10	11	12	27.0 <b>Al</b> Aluminium 13	28.1 <b>Si</b> Silicon 14	31.0 <b>P</b> Phosphorus 15	32.1 <b>S</b> Sulfur 16	35.5 <b>Cl</b> Chlorine 17	39.9 <b>Ar</b> Argon 18										
39.1 <b>K</b> Potassium 19	40.1 <b>Ca</b> Calcium 20	45.0 <b>Sc</b> Scandium 21	47.9 <b>Ti</b> Titanium 22	50.9 <b>V</b> Vanadium 23	52.0 <b>Cr</b> Chromium 24	54.9 <b>Mn</b> Manganese 25	55.8 <b>Fe</b> Iron 26	58.9 <b>Co</b> Cobalt 27	58.7 <b>Ni</b> Nickel 28	63.5 <b>Cu</b> Copper 29	65.4 <b>Zn</b> Zinc 30	69.7 <b>Ga</b> Gallium 31	72.6 <b>Ge</b> Germanium 32	74.9 <b>As</b> Arsenic 33	79.0 <b>Se</b> Selenium 34	79.9 <b>Br</b> Bromine 35	83.8 <b>Kr</b> Krypton 36										
85.5 <b>Rb</b> Rubidium 37	87.6 <b>Sr</b> Strontium 38	88.9 <b>Y</b> Yttrium 39	91.2 <b>Zr</b> Zirconium 40	92.9 <b>Nb</b> Niobium 41	95.9 <b>Mo</b> Molybdenum 42	— <b>Tc</b> Technetium 43	101.1 <b>Ru</b> Ruthenium 44	102.9 <b>Rh</b> Rhodium 45	106.4 <b>Pd</b> Palladium 46	107.8 <b>Ag</b> Silver 47	112.4 <b>Cd</b> Cadmium 48	114.8 <b>In</b> Indium 49	118.7 <b>Sn</b> Tin 50	121.8 <b>Sb</b> Antimony 51	127.6 <b>Te</b> Tellurium 52	126.9 <b>I</b> Iodine 53	131.3 <b>Xe</b> Xenon 54										
132.9 <b>Cs</b> Caesium 55	137.3 <b>Ba</b> Barium 56	lanthanoids 57–71	178.5 <b>Hf</b> Hafnium 72	180.9 <b>Ta</b> Tantalum 73	183.8 <b>W</b> Tungsten 74	186.2 <b>Re</b> Rhenium 75	190.2 <b>Os</b> Osmium 76	192.2 <b>Ir</b> Iridium 77	195.1 <b>Pt</b> Platinum 78	197.0 <b>Au</b> Gold 79	200.6 <b>Hg</b> Mercury 80	204.4 <b>Tl</b> Thallium 81	207.2 <b>Pb</b> Lead 82	209.0 <b>Bi</b> Bismuth 83	— <b>Po</b> Polonium 84	— <b>At</b> Astatine 85	— <b>Rn</b> Radon 86										
— <b>Fr</b> Francium 87	— <b>Ra</b> Radium 88	actinoids 89–103	— <b>Rf</b> Rutherfordium 104	— <b>Db</b> Dubnium 105	— <b>Sg</b> Seaborgium 106	— <b>Bh</b> Bohrium 107	— <b>Hs</b> Hassium 108	— <b>Mt</b> Meitnerium 109	— <b>Ds</b> Darmstadtium 110	— <b>Rg</b> Roentgenium 111	— <b>Cn</b> Copernicium 112		— <b>Fl</b> Flerovium 114		— <b>Lv</b> Livermorium 116												

*	lanthanoids	138.9 <b>La</b> Lanthanum 57	140.1 <b>Ce</b> Cerium 58	140.9 <b>Pr</b> Praseodymium 59	144.4 <b>Nd</b> Neodymium 60	— <b>Pm</b> Promethium 61	150.4 <b>Sm</b> Samarium 62	152.0 <b>Eu</b> Europium 63	157.3 <b>Gd</b> Gadolinium 64	158.9 <b>Tb</b> Terbium 65	162.5 <b>Dy</b> Dysprosium 66	164.9 <b>Ho</b> Holmium 67	167.3 <b>Er</b> Erbium 68	168.9 <b>Tm</b> Thulium 69	173.1 <b>Yb</b> Ytterbium 70	175.0 <b>Lu</b> Lutetium 71
	actinoids	— <b>Ac</b> Actinium 89	232.0 <b>Th</b> Thorium 90	231.0 <b>Pa</b> Protactinium 91	238.0 <b>U</b> Uranium 92	— <b>Np</b> Neptunium 93	— <b>Pu</b> Plutonium 94	— <b>Am</b> Americium 95	— <b>Cm</b> Curium 96	— <b>Bk</b> Berkelium 97	— <b>Cf</b> Californium 98	— <b>Es</b> Einsteinium 99	— <b>Fm</b> Fermium 100	— <b>Md</b> Mendelevium 101	— <b>No</b> Nobelium 102	— <b>Lr</b> Lawrencium 103

The volume of one mole of any gas is 24 dm<sup>3</sup> at room temperature and pressure (r.t.p.).





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