Living

Chemistry

TEACHER'S GUIDE

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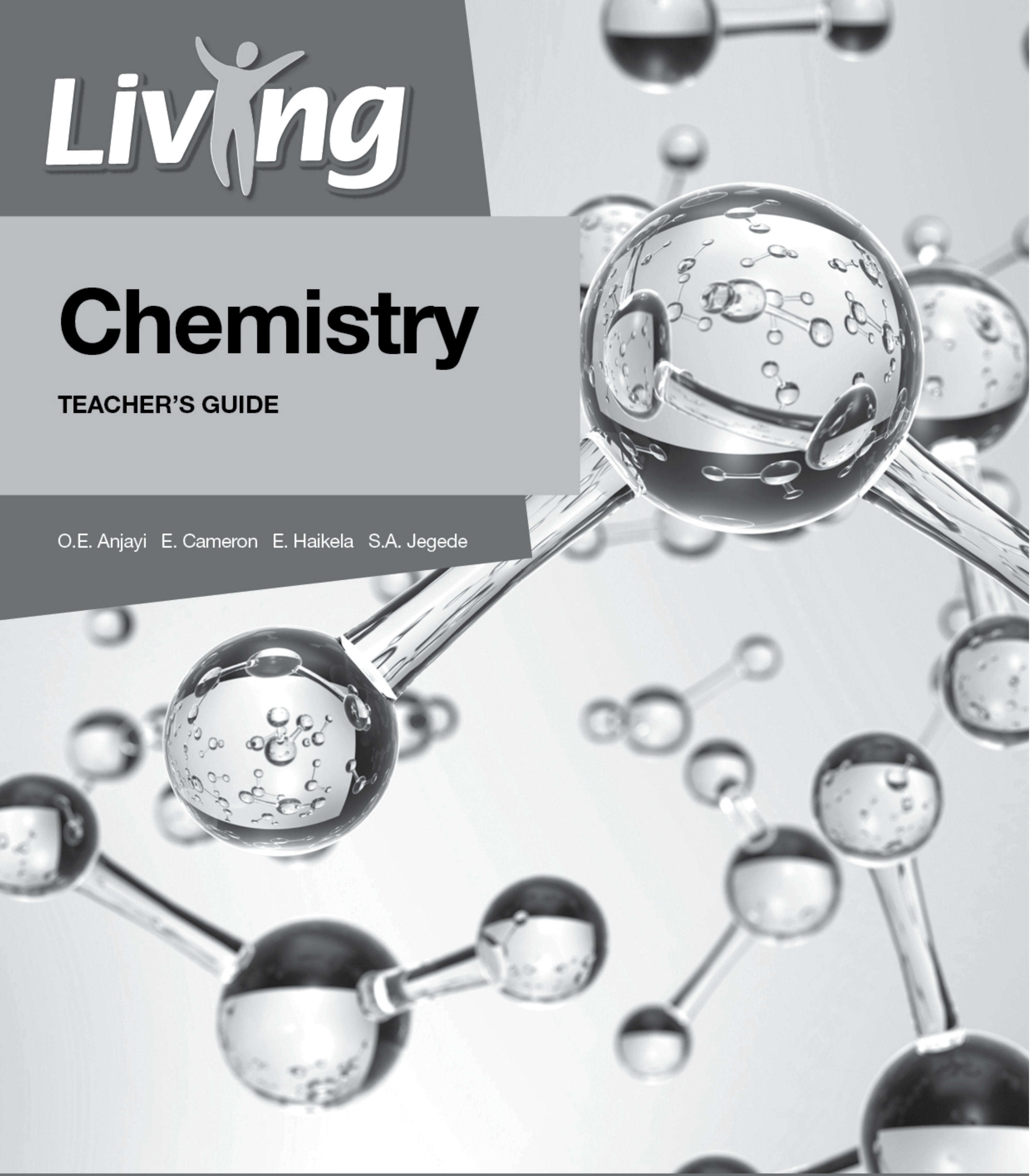

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Contents

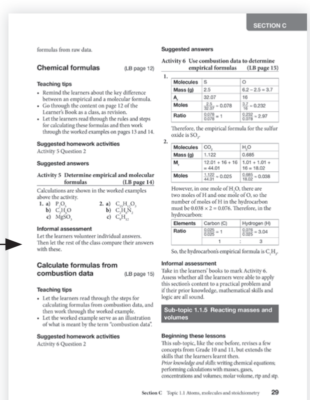
How to use this Teacher's Guide

Use this Teacher's Guide with the *Living Chemistry Grade 12 Learner's Book*. These components follow the Namibia Senior Secondary Certificate Advanced Subsidiary (NSSCAS) Chemistry syllabus. This means they are up-to-date and relevant to current classroom environments and educational needs.

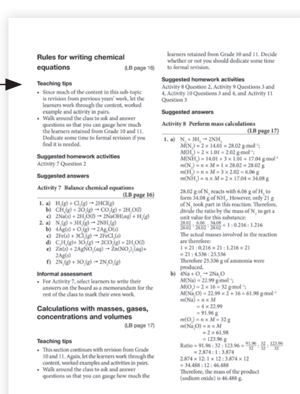
The Teacher's Guide is divided into four sections.

- **Section A** tells you what you need to know about the new syllabus and how the Learner's Book and Teacher's Guide will help you meet the objectives laid out in the syllabus.
- **Section B** contains a lesson plan template, a suggested year plan for teaching and guidelines about assessment.
- **Section C** contains teaching guidelines that correspond to each topic and sub-topic of the Learner's Book. These teaching guidelines serve as one possible way of guiding your learners through the content.
- **Section D** contains additional resources you might find useful. You may photocopy these resources to use in your classroom.

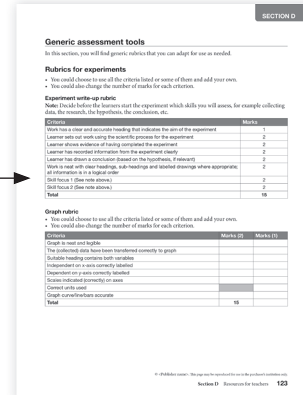
Guidelines for assessment



Teaching tips for you, the teacher



Assessment templates for you to photocopy



Bloom's taxonomy

The self-assessment questions at the end of each topic in the Learner's Book have been graded to reflect the types of questions outlined by Bloom's taxonomy. Although not shown in the Learner's Book, the answers given in the Teacher's Guide reflect the Bloom's level in brackets after the mark allocation. The symbols that you will see here correspond to the following Bloom's levels:

Symbol	Bloom's level
K	Knowledge
C	Comprehension
Ap	Application
An	Analysis
S	Synthesis
E	Evaluation

The teaching guidelines

The teaching guidelines for each topic starts with a table that gives you suggested time allocations and cross-curricular links.

The overview tables are followed by teaching guidelines, which correspond to the Learner's Book pages. In these notes you will find:

- answers to activities and experiments
- suggestions on when individual, pair or group work is appropriate
- applications for suggested resources
- suggestions for continuous assessment, remedial and extension activities.

Section A Teaching Chemistry

Teaching Chemistry at the Advanced Subsidiary Level

Each classroom is unique in the composition of its learners, the social and physical environment of your school and the types of resources you have. As a teacher, you are trained to find the most readily available resources as you teach the content covered in these books.

Where possible, this guide will help you with ideas on how you can overcome obstacles to deliver the best possible lessons to your learners.

The main aim of the Chemistry syllabus is to provide the necessary scientific background for our learners with the hope of producing the much-needed chemists for the country. The Namibian society needs to be scientifically literate if they are to cope with the challenges of appropriate global technology requirements.

The Namibia National Curriculum Guidelines outline the cornerstones of learner-centred education. These are:

- recognising that learning involves developing values and attitudes as well as knowledge and skills
- promoting self-awareness and an understanding of the attitudes, values and beliefs of others in a multilingual and multicultural society
- encouraging respect for human rights and freedom of speech
- providing 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
- recognising 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
- seeking to challenge and to motivate learners to reach their full potential and to contribute positively to the environment, economy and society.

(NSSC AS Level Chemistry Syllabus, National Institute for Educational Development / NIED 2019 p. 1)

Methods suited to teaching Chemistry

Chemistry is one learning area where teachers must encourage, guide and nurture the curiosity of young minds. The practical activities, tasks and investigations form an integral part of the Chemistry curriculum.

Encourage the learners by providing an atmosphere in which they can ask and answer questions on a practical level.

Try to allocate as much time as possible to practical investigations and tasks. When learners put their knowledge into practice by doing practical activities, real learning has taken place. Not only will learners remember the theory with greater ease, but they will enjoy Chemistry.

It is essential that learners are able to connect the world with Chemistry classroom experiences. This will stimulate further inquiry and curiosity as learning becomes fun and enjoyable when learners see how chemical processes and skills apply to everyday life. It also promotes creative problem solving.

Not only will this benefit them in attaining good marks, but it may be the spark for a future career! It is essential that learners respect and appreciate the natural world and the realm of science.

When teaching science, it is very important to pitch your communication at the level of the learners. It is unfortunate if they are discouraged by language that is not suitable for their cognitive level. Science teachers should also be curious about scientific phenomena and lead by example.

Young, budding scientists should reflect positive attitudes towards themselves and society.

By creating opportunities for sharing ideas with peers, learners gain valuable communication and listening skills. It is important to remember that the science classroom is part of the learners' bigger world. By integrating other subjects such as Language, Physics and Mathematics into Chemistry education, learning is consolidated. This means that learners are actively busy, interacting with the content and each other, and using opportunities to apply their skills in the safety of the classroom.

Teaching time

- The NSSC AS Level Chemistry syllabus is designed to be taught over 180 guided learning hours over the duration of one year. However, this is only a guideline number of hours, and the course may be taught in more or fewer hours, depending on the abilities of the learners.
- 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. (NSSCAS Chemistry Syllabus, NIED 2019 p. 3)

Links to other subjects and cross-curricular issues

The cross-curricular issues (also sometimes called "cross-cutting issues") include Environmental Learning, HIV and AIDS, Population Education, Education for Human Rights and Democracy (EHRD), Information and Communication Technology (ICT), Road Safety and, last, Special Needs Education.

The links to cross-curricular issues are listed in the tables at the beginning of each topic in this Teacher's Guide, and further discussed within the starter activity notes. This course uses a character to champion each cross-curricular issue in the Learner's Book. These characters and their issues appear on page viii of the Learner's Book.

The links to other subjects appear in the Learner's Book as notes in the margin entitled ***Subject integration***. Where relevant, we have indicated where the content relates to other AS Level subjects, such as Biology, Mathematics, Geography and History.

The National Curriculum

The National Curriculum is based on the democratic principles of an equal opportunity being offered to all. Namibia has a diverse population made up of people of all cultures and languages. They should all receive the same opportunities to learn, develop and prosper in life. The diversity in your class will mean that learners have different learning styles and paces of learning. You may also find that your learners come from very different backgrounds. These factors will affect your planning and lessons. Your teaching challenges lie in your ability to become familiar with:

- issues in learner-centred education
- issues of inclusion in a diverse community
- issues of barriers to learning – their challenges and possible solutions managing large classes
- continuous assessment as a positive part of the learning process
- providing or developing resources that meet the requirements of the curriculum.

A guide to the Chemistry syllabus

- The objectives the learners must achieve are described in the Year plan on pages 11–25 of Section B of this Teacher's Guide.
- As the skills and requisite knowledge are given in the syllabus as well as in this guide, you can easily check that you are covering the requirements of the subject.

Inclusive education

Chemistry, in particular, lends itself towards the extensive promotion of inclusion. You can use these opportunities to instil in all learners a sense of inclusivity and caring towards others, as well as building the self-esteem of learners with special needs.

Your learners are all different. Learner-centred education meets the challenge of learning by respecting the individual learning needs and learning styles of every learner. For this model to work, create a positive learning environment that guides learners towards their own achievement and success, both in the classroom and in life. To ensure a match between your teaching style and the needs of the learners, focus your attention on the learners' experiences, backgrounds, interests, talents, capabilities and needs. These will determine the way in which you will present and explore content, and will have a direct impact on the likelihood of success.

Using previous knowledge and experiences

"A learner brings to the school a wealth of knowledge and social experience gained continually from the family, the community, and through interaction with the environment."

Your role is to create opportunities for successful learning by affirming what learners know, giving them opportunities to express themselves and to use their talents and strengths to direct and inform learning. More powerful learning is possible when learners can make connections to what they already know and when it builds on their interests. In this way, you can adapt and modify the curriculum to suit the needs of the learners rather than the learners adapting to the demands of the curriculum.

"Learning in school should thus involve, build on, extend and challenge the learner's prior knowledge and experiences."

Interactive learning

Not all learners learn in the same way. Experienced teachers know instinctively that chalk-and-talk teaching benefits only a small number of learners. By using a variety of teaching methods and presentation modes, science teaching will remain fresh and exciting for both you and your learners. It will also accommodate different learning styles. Engage the learners in the learning process by allowing them to carry out investigations and practical tasks. This gives them confidence with elementary scientific equipment and valuable skills for tertiary education.

In the learner-centred classroom, you create the opportunities for learner–teacher and learner–learner interactive learning. In this type of classroom, the different approaches to learning become apparent and guide you to identify what learners need to know, the pace at which they can learn and the support each learner requires.

Different types of learning

Give opportunities for different types of learning. For example, learners construct knowledge through the sense of hearing, i.e. talking through a problem to find a solution or different solutions.

Allow the descriptions given in the syllabus to guide you when choosing your method.

Be flexible enough to encourage learners to construct their own meaning and create their own learning. However, always remain the guide, using your year plan and lesson plans as maps with clear objectives, but various ways of achieving them. Have a planned route which you navigate sensitively so that the learners reach their destinations successfully in their own ways. Constantly make decisions about where to stop and what to experience (content/knowledge), visualise possibilities (methodology and lesson delivery), avoid or deal with misconceptions and make decisions to achieve your goal.

Participation, contribution and production

Participation, contribution and production are key words in the learning process. When they are applied, learning becomes possible. These principles enable each learner to satisfy her or his needs based on prior experience, knowledge and skills as well as set their pace for learning.

Inclusive education is the right of every learner to participate in and have access to all the educational programmes of mainstream schools. Inclusive education supports diversity amongst all learners, where diversity is regarded as a strength rather than a setback. This means that we have to remove all barriers to learning. In any class, and especially in larger ones, you will deal with many different learners who come from a wide range of backgrounds and abilities. Understanding these learners and their needs enables you to include their needs in their education in a beneficial way.

Namibia is a democratic society. "Democratic" means that decisions are made taking into account each member's contribution. For learners to become well-functioning adults, they should be accepted for who and what they are at this stage of their lives. Their potential should be recognised and developed to the best of their abilities.

Democracy also implies that people are individuals with their own strengths and weaknesses, which may be different to other people's strengths and weaknesses.

Classroom organisation

As learners will work alone, in pairs, in groups and as a class, it is useful to have a flexible approach to classroom organisation. Make sure you can move tables and chairs easily and quickly in order to accommodate various teaching and learning strategies. Plan where to stand, sit and move. Your use of classroom space is part of your teaching strategy. For some lessons, you might be upfront and clearly visible while, for other lessons, learners might take leadership and you will play a facilitative role in the background. When learners present or give feedback to the class, make sure they face the whole class and can be seen and heard by all.

Group and pair the learners quickly and efficiently. While it is sometimes useful to allow learners to choose their own groups, at other times it is best to place them in groups to ensure inclusivity so they learn to work in a range of groups and no learners feel rejected.

Managing your class to support inclusive education

This means putting learner-centred education into practice.

Small group work

The advantage of working with a small group of learners is that you can identify learners with similar prior knowledge or skills who will benefit from this way of teaching. Separate them from the rest of the class for about 15 minutes at a time.

Organise the rest of the class in a structured way so they are positively occupied while you are busy with the group needing your attention. For example, learners could do something they have done before, but can now add new information that they have recently learnt. Make sure your instructions are clear and easy to follow, giving you the time and opportunity to work closely with the small group.

Rotating group work

- Rotate the types of group work so that learners are not labelled in any way. The group that knows more about a topic and can move forward quickly should be able to do so. This gives you the opportunity to attend to the group needing extra input.
- Create groups with different abilities and needs. Mix the learners from the previous groups so there is no stigma attached to working in groups. This technique requires you to know each learner's prior knowledge and skills for whatever they are learning. Continuous assessment gives you this knowledge.

Learners guiding learners

Most of the teaching focus is on you as the source of knowledge and skills. Sometimes learners can be the source of knowledge and skills. A learner who has a family member or close friend who has a skill that relates to the content, has a great deal to share with classmates. This builds the learner's confidence and self-esteem, vocabulary, and speaking skills. Learners usually enjoy learning from their peers.

Handling barriers to learning

Include learners who have barriers to learning or other individual needs in mainstream schools. The education system addresses the needs of learners with barriers to learning by using different teaching methods and materials where needed.

Learning support units, resource units and resource schools provide for learners who are so severely impaired that they cannot benefit from attending inclusive schools. Once they are ready, they can join inclusive schools.

You might find barriers to learning that you cannot deal with in your class. It is important that you assess learners with barriers carefully, understanding their levels of capabilities and whether you can help them. If the learners need special education in smaller groups, you should recommend that. Remedial education specialists and psychologists will recommend the best approach to their education.

If learners with lesser barriers to their learning remain in your class, it is better to extend their learning at a different pace so they can reach the same outcomes as the other learners. Their sense of achievement encourages them to reach for further achievements. You might have different groups of learners in your class working at different paces and with different learning methods: this makes your approach and positive attitude important.

General tips to assist learners with learning barriers

- Learners who have difficulty organising themselves can be paired with learners who are more organised. These learners can support them with writing down homework and completing work on time.
- Help learners plan their tasks by developing short mind maps that will guide the process and help them feel less overwhelmed. Break down tasks into small sections that will help learners accomplish the task.
- Place learners who battle to concentrate in the front of the class. If you see their minds wandering, touch their arms gently as you walk around the class, or involve them in the class by asking them questions.
- It helps learners with learning barriers to have a daily structure that they trust and are familiar with. Always be organised and consistent.
- Remember to give instructions clearly and simply. As far as possible, involve the learners in doing practical, hands-on activities during science.

Achievements and the real world

Remember that school education should equip learners for life as adults. It must develop knowledge, skills and attitudes to help them succeed in the increasingly complex and rapidly changing world of information and communication technology. Use your learners' experience and prior knowledge to build new knowledge and skills.

Appreciation

We give you applause and accolades for teaching Chemistry at this level, and ensuring that your learners can reach their potential, ready for all possibilities and success! Your work is contributing to the development of our learners, our nation and our beautiful Namibia. Thank you for teaching Chemistry. We hope you and your learners enjoy the lessons.

Section B Planning and assessment

The year plan at the end of this section is based on 180 hours of learning. In practical terms, this corresponds to:

- approximately 11 weeks of teaching time and two weeks for revision and formal assessment for the first two terms
- approximately three weeks of teaching time and 10 weeks for revision and formal assessment for Term 3.

However, the year plan divides the teaching time into the approximate number of lessons per topic, assuming 9 lessons of 40 minutes each per 7-day cycle.

How to use a lesson plan

This Teacher's Guide provides lesson plans suggesting one possible way of teaching the content covered in the Learner's Book. The plans are developed to meet the requirements set out in the Namibia Senior Secondary Certificate Advanced Subsidiary Level syllabus for Chemistry.

Here is a template you can use for planning your lessons, with notes on how to complete each part.

A blank template is provided in the resources section at the end of this Teacher's Guide, which you may photocopy. You may use this template to make your own notes for lessons that suit your own classroom environment.

To guide you in planning your lessons, each lesson plan includes a guideline for the amount of time that a lesson should take. These times serve only as guidelines and may vary depending on the strength of your class and your available resources.

It is best that you consult the lesson plan well in advance of the lesson. This will help you prepare for lessons as you may need time to obtain additional resources that will enrich the learning experience. The lesson plans provide ideas on how to teach a given topic, providing you with insights that will assist your approach to a lesson, specifically in terms of how the work is covered in the Learner's Book.

Lesson plan guidelines

Subject: Chemistry	
Links to cross-curricular issues:	This shows the integration of Environmental Education; HIV and AIDS; Population Education; Education for Human Rights and Democracy (EHRD), Information and Communication Technology (ICT), Road Safety or Special Needs Education, where appropriate.
Topic and sub-topic:	This is the topic and sub-topic within the given syllabus that is being covered
Time for lesson:	How many periods or minutes are needed
Basic competencies:	These come from the syllabus and set out the new skills and concepts covered in a topic and that learners must master. Check their prior knowledge and ensure that your learners can accomplish these competencies before moving on to the next body of work. Revisit these when you have completed a lesson and ensure learners understand the concepts and skills that were covered.
Preparation:	• Preparation involves reading through the lesson plan provided in the Teacher's Guide. • Different lessons may call for different types of preparation, such as field trips or grouping learners for activities.
Resources:	• The Learner's Book will be your primary resource and the relevant pages should be listed here for easy reference. • If any other resources or knowledgeable persons are needed for the lesson, mention these here.

Beginning these lessons

- **Prior knowledge:** Explains what learners need to know so that they can understand what they will be learning about.
- **New concept/skill:** This refers to the new information that learners will encounter and is linked to their prior knowledge.

Teaching tips

- This will provide notes on how to approach the content, including the new skills and concepts, covered in the lesson.
- The approach will be modelled on how the lesson is covered in the Learner's Book and will follow the same order.

Suggested homework activities

This provides you with options for homework assignments, if needed.

Suggested answers

Answers to activities are provided here.

Informal (diagnostic) assessment

This explains how you can use different strategies to continually assess learners.

Extension activities

Extension activities go further into a concept and provide a challenge for faster learners to keep them engaged in the learning experience.

Remedial activities

These are support activities for learners who struggle. These activities help build learners' understanding in areas where they may have experienced difficulties and need extra support and practice.

Summary

Consolidation at the end of each topic helps the learners establish what the key points of the topic were, and where they may need to improve their skills or knowledge.

Self-assessment

Learners should reflect on what they have learnt and ensure they have met the basic competencies. You as the teacher should also reflect on your teaching of the lesson.

Assessment

Types and methods of assessment

Continuous and informal assessment

Continuous assessment is "process-and-product" assessment. You observe, listen carefully and make short notes on either the aspect you are assessing or on something worth noting.

The role of continuous assessment is to find what is positive about each learner, what they are achieving and what they have achieved. Affirm these aspects and give the learner clear instructions to assist him or her to take the next step.

The role of continuous assessment is also to discover shortcomings, a possible lack of essential knowledge or an inability to perform a skill. In this case, the learner needs your guidance. This does not mean that you do the work for the learner. Neither does it mean that you explain it so precisely that the learner does not give any input. Guidance means to give enough information to empower the learners to do the tasks by themselves.

There is a distinct difference between informal and formal assessment. Informal assessment is noting with criteria how each learner deals with learning or social issues, such as co-operation and negotiation, and then doing something about whatever you discover.

In this Teacher's Guide, you will find suggestions for informal (diagnostic) assessment at the end of each section in a topic.

In terms of learning issues, informal assessment becomes diagnostic, as it allows problems to be diagnosed, but also potential extensions to be discovered for those learners who excel.

You can observe every stage of the process as long as you know what you are looking for. During the process, there is time and opportunity for questions, answers and discussion. There is also the opportunity for the learners to self-assess or for you to encourage peer assessment. Informal (diagnostic) assessment also allows for the learner to become aware of problems or areas in which he or she excels. However, be alert when asking for peer assessment because learners must learn from you how to give feedback that is positive. You can assist the learner-assessors by asking them questions. This takes away the negative possibilities and focuses on positive feedback and assessment.

Informal (diagnostic) assessment helps improve the process. You should informally assess at every stage of the process, noting the learners' experimentation, their learning, their growing confidence and competence.

Ultimately, this form of assessment does not only diagnose problems or opportunities, but also provides guidance on the type of remedial or extension action that can be taken. In this Teacher's Guide, remedial and extension activities are suggested at the end of each topic.

Formal assessment

In Chemistry at the Advanced Subsidiary Level, the formal assessment tasks are as the three compulsory papers that the learners will be entered for at the end of the course:

Paper	Description of paper and types of questions	Duration of paper	Marks
Paper 1: Theory: Multiple choice questions	This paper will consist 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
Paper 2: 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 [booklet].	1 hour 15 minutes	60
Paper 3: 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 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 (Annexe D) will be supplied with paper 3.	2 hours	40
TOTAL			**140**

(NSSCAS Chemistry Syllabus, NIED 2019 p. 31)

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%.

Paper	Weighting
Paper 1	31%
Paper 2	46%
Paper 3 (Applied Practical Skills Paper)	23%

The approximate weightings allocated to each of the assessment objectives across the papers are summarised in the table below:

Assessment objective	Weighting across all components	Paper 1	Paper 2	Paper 3
A Knowledge with understanding	40% (not more than 20% recall)	20 marks	30 marks	0 marks
B Handling information, application and solving problems	40%	20 marks	30 marks	0 marks
C Practical (experimental and investigative) skills and abilities	20%	0 marks	0 marks	40 marks
		40 marks	60 marks	40 marks
Total for all three papers		**140 marks**		

(NSSCAS Chemistry Syllabus, NIED 2019 pp. 31–32)

Assessment objectives

The assessment for this course of Chemistry includes, wherever appropriate, personal, social, environmental, economic and technological applications of Chemistry in modern society. The learners are required to demonstrate the assessment objectives in the context of the content and skills prescribed. Within each of the assessment objectives (reflected in the table above), the assessment must take account of the learners' ability to communicate clearly and logically and apply conventions where appropriate.

The three assessment objectives in Advanced Subsidiary Chemistry are:

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

Here are the descriptions of each assessment objective (NSSCAS Chemistry Syllabus, NIED 2019 pp. 30–31).

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.*

B Handling information, application and solving problems

Learners should be able to, in words 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 and calculate or determine*

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.

Year plan

This is a summary of the learning content for Chemistry AS Level together with a suggested plan for the year.
Note about suggested lessons: Approximately two lessons per topic have been allocated to the introduction, the summary and the self-assessment.

Theme 1 The particulate nature of matter and stoichiometry

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 1.1: Atoms, molecules and stoichiometry	**11**	**2–21**	**26–32**
Sub-topic 1.1.1: Relative masses of atoms and molecules • Define and use the terms relative atomic, isotopic, molecular and formula masses, based on the ^{12}C scale	1.5	5–7	27
Sub-topic 1.1.2: The mole and the Avogadro constant • Define and use the term mole in terms of the Avogadro constant	1	8	27–28
Sub-topic 1.1.3: Relative atomic masses • Analyse mass spectrums in terms of isotopic abundances (knowledge of the working of the mass spectrometer is not required) • Calculate the relative atomic mass of an element given the relative abundances of its isotopes, or its mass spectrum • Calculate the percentage by mass of an element in a compound	1.5	9–11	28
Sub-topic 1.1.4: Empirical and molecular formulas • Define and use the terms empirical and molecular formula • Calculate empirical and molecular formulas using combustion data or composition by mass	2	12–15	28–29
Sub-topic 1.1.5: Reacting masses and volumes • Write and construct balanced equations, including state symbols • Perform calculations, including use of the mole concept, involving: » reacting masses (from formulas and equations) » volumes of gases at rtp and stp (e.g. in the burning of hydrocarbons) » volumes and concentrations of solutions	3	16–19	29–31
Topic 1.2: Atomic structure	**8**	**22–35**	**33–36**
Sub-topic 1.2.1: Particles in the atom • Identify and describe protons, neutrons and electrons in terms of their relative charges and relative masses • Describe the distribution of mass and charge within an atom • Deduce the numbers of protons, neutrons and electrons present in both atoms and ions, given proton (atomic) and nucleon (mass) numbers and charge	1.5	23–25	33–34
Sub-topic 1.2.2: The nucleus of the atom • Describe the contribution of protons and neutrons to atomic nuclei in terms of proton (atomic) number and nucleon (mass) number • Distinguish between isotopes on the basis of different numbers of neutrons present • Recognise and use the symbolism $^{A}_{Z}X$ for isotopes, where A is the nucleon (mass) number and Z is the proton (atomic) number	1.5	26–27	34

(Sub-topic 1.2.3 on the next page)

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Sub-topic 1.2.3: Electrons • 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 4*s*- and 4*p*-orbitals • Describe and sketch the shapes of *s*- and *p*-orbitals • Recall that each orbital can hold up to 2 electrons • Recall the number of orbitals making up *s*-, *p*- and *d*- subshells, and the number of electrons that can fill *s*-, *p*- and *d*-subshells • Describe the increase in energy between quantum numbers (shells) 1, 2 and 3 and between the *s*-, *p*- and *d*-subshells in each shell • Describe how electrons fill orbitals: » up to subshell 4*d*, including the filling of 4*s* before 3*d* (example in Fe, Fe^{2+}, and so on) » for orbitals with the same energy, electrons occupy each orbital singly before pairing • State the electronic configuration of atoms and ions given the proton (atomic) number and charge, using the convention $1s^2 2s^2 2p^6$, and so on, and electrons in box representation	3	28–33	34–36
Topic 1.3: Chemical bonding	**12**	**36–57**	**37–44**
Sub-topic 1.3.1: Ionic bonding • Describe ionic bonding, as in sodium chloride, magnesium oxide and calcium fluoride, including the use of dot-and-cross diagrams • Describe the electrostatic forces in ionic compounds as being attraction between oppositely charged ions • Describe, interpret and predict the effect of ionic bonding on physical properties (including physical state, melting point, boiling point, solubility) • Explain the electrical conductivity of ionic compounds when solid, molten or in solution	2	37–39	38–39
Sub-topic 1.3.2: Covalent and coordinate bonding • Describe, including the use of dot-and-cross diagrams: » covalent bonding, including molecules such as hydrogen, chlorine, oxygen, nitrogen, hydrogen chloride, carbon dioxide, methane and ethene » dative covalent (coordinate) bonding, including in the formation of NH_4^+, the Al_2Cl_6 molecule, CO, H_3O^+ • Explain the shapes of, and bond angles in, molecules by using the qualitative model of electron-pair repulsion (including lone pairs of electrons), using as simple examples: BF_3 (trigonal planar), CO_2 (linear), CH_4 (tetrahedral), NH_3 (pyramidal), H_2O (non-linear/v-shaped), SF_6 (octahedral), PF_5 (trigonal bipyramidal) • Use the valence shell electron pair repulsion theory to predict the shapes of, and bond angles in other molecules analogous to those specified above • Describe, interpret and predict the effect of covalent bonding on physical properties (including physical state, melting point, boiling point, solubility)	2	40–43	39–40
Sub-topic 1.3.3: Electronegativity • Explain the concept of electronegativity • 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	2	44–46	40–41

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Sub-topic 1.3.4: Intermolecular forces, electronegativity and bond properties • Describe the differences between bonding (intramolecular) and intermolecular forces • Describe that the electrostatic forces in ionic compounds are much stronger than intermolecular forces in covalent molecules • Describe that the bonding (intramolecular) forces are much stronger than intermolecular forces in covalent bonding • 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) • Describe intermolecular forces in covalent compounds and noble gases: induced dipole (Van der Waals) forces, permanent dipole forces and hydrogen bonding • Explain differences in physical properties in terms of intermolecular forces, including: » noble gases, $Br_2(l)$, » $HCl(g)$, $CHCl_3(l)$, » ammonia and water as simple examples of molecules containing N–H and O–H groups • State that when giant covalent substances melt, covalent bonds break and when simple molecular substances melt or boil, forces between molecules weaken • Describe hydrogen bonds as the strongest intermolecular force yet still weak compared with covalent bonding • 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)	2	47–50	41–42
Sub-topic 1.3.5: Metallic bonding • Describe metallic bonding in terms of a lattice of positive ions surrounded by delocalised electrons • Describe and explain the electrical conductivity, melting point and malleability/ ductility of metals in terms of their structure and bonding	1	51	42

(Sub-topic 1.3.6 on the next page)

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Sub-topic 1.3.6: Bonding, structure and physical properties • Describe, in simple terms, the lattice structure of a crystalline solid which is: » ionic, including sodium chloride, magnesium oxide » simple molecular, including iodine and the fullerene allotropes of carbon (C_{60} and nanotubes only) » giant molecular, including silicon(IV) oxide and the graphite, diamond and graphene allotropes of carbon » hydrogen-bonded, including ice » metallic, including copper • 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) • 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 • Deduce the type of bonding and structure present from given information	1	52–53	42–43
Topic 1.4: Ideal and real gases	**4**	**58–63**	**45–46**
Sub-topic 1.4.1: Ideal and real gases • State the basic assumptions of the kinetic theory as applied to an ideal gas • Explain qualitatively in terms of intermolecular forces and molecular size: » the conditions necessary for a gas to approach ideal behaviour » the limitations of ideality at very high pressures and very low temperatures • Recall and use the general gas equation $PV = nRT$ in calculations, including the determination of M_r (NOTE: $R = 8.31\ J{\cdot}K^{-1}{\cdot}mol^{-1}$)	2	59–61	45-46

Theme 2 Physical chemistry

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 2.1: Chemical energetics	**10**	**66–81**	**47–51**
Sub-topic 2.1.1 Enthalpy change • Explain that chemical reactions are accompanied by energy changes, principally in the form of heat energy; the energy changes can be exothermic (ΔH is negative) or endothermic (ΔH is positive) • Explain and use the terms: » enthalpy change of reaction and standard conditions, with particular reference to: formation, combustion, hydration, solution, neutralisation, atomisation » bond energy (ΔH positive, i.e. bond breaking) • Calculate enthalpy changes from appropriate experimental results, including the use of the relationship enthalpy change, $\Delta H = -mc\Delta T$ • Outline chemical reactions in terms of energy transfers associated with the breaking and making of chemical bonds • Calculate energy changes for simple reactions using bond energies • Explain why ΔH values from calculated bond energies differ from those obtained from data booklet and experimentally determined values	5	67–74	48–49
Sub-topic 2.1.2 Hess's law • Apply Hess's law to construct simple energy cycles, and carry out calculations involving such cycles and relevant energy terms • Apply Hess's law to determine enthalpy changes that cannot be found by direct experiment, e.g. an enthalpy change of formation from enthalpy changes of combustion • Construct and interpret a reaction pathway diagram in terms of the enthalpy change of the reaction and of the activation energy	3	75–79	49–50
Topic 2.2: Electrochemistry	**7**	**82–93**	**52–55**
Sub-topic 2.2.1: Redox processes • Calculate oxidation numbers of elements in compounds and ions • Describe and explain redox processes in terms of electron transfer and changes in oxidation number • Use changes in oxidation numbers to help balance chemical equations • 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 • Use oxidation numbers to name oxyanions, including nitrate(III) NO_2^-, nitrate(V) NO_3^-, chlorate(I) ClO^-, chlorate(V) ClO_3^-	3	83–87	53–54

(Sub-topic 2.2.2 on the next page)

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Sub-topic 2.2.2: Electrolysis • 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 • Use the concept of selective discharge to identify the electrode products of aqueous solutions to include: » hydrogen ions and metal cations: silver, copper, (hydrogen), iron, zinc, sodium » non-metal anions hydroxide and chloride in dilute and concentrated solutions • Describe and outline the use of electrolysis in the extraction of metals from acidic leached solutions, for example copper and manganese • Construct ionic half equations for reactions at the cathode and anode • Describe the transfer of charge during electrolysis to include: » the movement of electrons in the metallic conductor » the removal or addition of electrons from the external circuit at the electrodes » the movement of ions in the electrolyte	2	88–91	54
Topic 2.3: Equilibria	**8**	**94–107**	**56–59**
Sub-topic 2.3.1: Chemical equilibria • Explain, in terms of rates of the forward and reverse reactions, what is meant by a reversible reaction and dynamic equilibrium • 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 • State whether changes in temperature, concentration or pressure or the presence of a catalyst affect the value of the equilibrium constant for a reaction • Deduce expressions for equilibrium constants in terms of concentrations, K_c, and partial pressures, K_p (treatment of the relationship between K_p and K_c is not required) • Calculate the values of equilibrium constants in terms of concentrations or partial pressures from appropriate data • Calculate the quantities present at equilibrium, given appropriate data (such calculations will not require the solving of quadratic equations) • 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 • Interpret data about the conditions used in industrial processes in terms of equilibrium (yield) and rate	4	95–102	56–58
Sub-topic 2.3.2: Ionic equilibria • 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 • 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 • Calculate [H^+(*aq*)] and pH-values for strong acids	2	103–105	58–59

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 2.4: Reaction kinetics	**9**	**108–123**	**60–64**
Sub-topic 2.4.1: Rates of reactions • Explain and use the term rate of reaction • Explain qualitatively, in terms of collisions, the effect of concentration changes on the rate of a reaction	2	109–111	60–61
Sub-topic 2.4.2: The effect of temperature on reaction rates and the concept of activation energy • Explain and use the term activation energy, including reference to the Boltzmann distribution • Explain qualitatively, in terms both of the Boltzmann distribution and of collision frequency, the effect of temperature change on the rate of a reaction	2	112–114	61–62
Sub-topic 2.4.3: Homogeneous and heterogeneous catalysts • Explain and use the term catalysis • Explain that catalysts can be homogeneous or heterogeneous • 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 • Describe enzymes as biological catalysts which may have specificity • Explain that reactions which use enzymes only work under specific conditions (pH and temperature)	3	115–120	62–63

Theme 3 Inorganic chemistry

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 3.1: The Periodic Table and chemical periodicity	**11**	**126–141**	**65–70**
Please note that Sub-topic 3.1.1 and Sub-topic 3.1.2 of the syllabus are both dealt with in one sub-section (pages 127–133) of the Learner's Book because of the degree of overlap in the content in these two sub-topics. We used this combined heading (shortened for easy reading) on page 127 of the LB. **Sub-topics 3.1.1–3.1.2: Periodicity of and trends in physical properties of Period 3; Groups 2 and 17**	5	127–133	65–67
• Explain and use the term ionisation energy • Explain the factors influencing ionisation • 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 • 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 subshells is not expected) • 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			
• 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 • 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 shielding (effect of paired electrons in orbitals of subshells is not expected)			
Sub-topic 3.1.3: Periodicity of the chemical properties of Period 3 elements • Describe the reactions of Period 3 elements with oxygen (to give Na_2O, MgO, Al_2O_3, P_4O_{10}, SO_2, SO_3), chlorine (to give $NaCl$, $MgCl_2$, Al_2Cl_6, $SiCl_4$, PCl_5) and water (Na and Mg only) • 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 • Describe the reactions of the oxides with water • 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) • Describe and explain the reactions of the chlorides with water • Interpret the variations and trends of the above in terms of bonding and electronegativity • Suggest the types of chemical bonding present in chlorides and oxides from observations of their chemical and physical properties	3	134–137	67–68
Sub-topic 3.1.4: Chemical periodicity of other elements • Predict the characteristic properties of an element in a given group by using knowledge of chemical periodicity • Deduce the nature, possible position in the Periodic Table and identity of unknown elements from given information about physical and chemical properties	1	138	68–69

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 3.2: Group 2 elements	**9**	**142–153**	**71–75**
Sub-topic 3.2.1: Similarities and trends in the properties of the Group 2 metals • Describe the trends in physical properties down Group 2 including melting points • Describe the reactions of the elements with oxygen, water and dilute acids • Describe the behaviour of the oxides, hydroxides and carbonates with water and dilute acids • Describe the thermal decomposition of the nitrates and carbonates • Interpret, and make predictions from, the trends in physical and chemical properties of the Group 2 elements and their compounds • Describe the variation in solubility of the hydroxides and sulfates	4	143–148	72–74
Sub-topic 3.2.2: Some uses of Group 2 compounds • Describe the addition of water to calcium oxide (lime) to form calcium hydroxide (slaked lime) • Describe and explain the use of calcium hydroxide and calcium carbonate (powdered limestone) in agriculture and manufacture of building materials (cement)	3	149–151	74–75
Topic 3.3: Transition elements	**10**	**154–169**	**76–80**
Sub-topic 3.3.1: Characteristics of typical transition elements • Explain what is meant by a transition element in terms of *d*-block elements forming one or more ions with incomplete *d*-orbitals • Represent the electronic configuration of transition elements using *s*-, *p*-, *d*-electrons in box notations • 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 • Contrast qualitatively the melting points and *d*-densities of the transition elements with those of calcium as a typical *s*-block element	3	155–159	76–77
Sub-topic 3.3.2: Extraction of transition elements from their ores • Recognise that copper, manganese and uranium are produced from ores in Namibia • Describe the reduction by carbon of metals from their ores • 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 • Describe the use of sulfuric acid as a leaching agent for example in the production of copper, manganese and uranium • Describe the extraction of pure metals, including electrolysis of leached solutions and the reduction of uranium ions using magnesium • Recognise that it is important to monitor and control waste from metal extraction including: » sulfur dioxide as a pollutant product from the roasting of metal ores » waste acids from leaching processes » toxic metal waste in water and as atmospheric particles • Discuss the finite nature of metal ores and the benefits and problems of recycling metals	5	160–167	77–79

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 3.4: Group 17 elements	**9**	**170–181**	**81–85**
Sub-topic 3.4.1: Physical properties of the Group 17 elements • Describe the colours of chlorine, bromine and iodine: » as vapours » at room temperature and pressure » in solution • Describe the trend in state of chlorine, bromine and iodine at room temperature and pressure • Interpret the volatility of the elements in terms of intermolecular forces	1	171–172	82
Sub-topic 3.4.2: Chemical properties of the elements and their hydrides • Describe the relative reactivity of the elements as oxidising agents • Describe and explain the reactions of the elements with hydrogen • Describe and explain the relative thermal stabilities of the hydrides • Interpret these relative stabilities in terms of bond energies	1	173–174	82–83
Sub-topic 3.4.3: Reactions of halide ions • Describe and explain the reactions of halide ions with: » aqueous silver ions followed by aqueous ammonia » concentrated sulfuric acid	1	175	83
Sub-topic 3.4.4: Reactions of chlorine with aqueous sodium hydroxide • Describe, in terms of changes of oxidation number, the disproportionation reaction of chlorine with cold and with hot aqueous sodium hydroxide • Describe the effects on equilibrium of changes in pH to the reactions of chlorine with sodium hydroxide	2	176–177	83–84
Sub-topic 3.4.5: Uses of halogens and halogen compounds • Explain the use of chlorine in water treatment • 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) • Relate the importance of these reactions to the use of chlorine as a bleach and the treatment of water in Namibia* *Note that this content is covered on page 177 of the Learner's Book, in Sub-topic 3.4.4, where chlorine reactions are first discussed.	2	178–179 177	84–85 84

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 3.5: Nitrogen and sulfur	**9**	**182–197**	**86–90**
Sub-topic 3.5.1 Nitrogen • Describe and explain: » the basicity of ammonia » the structure of the ammonium ion and its formation by an acid–base reaction » the displacement of ammonia from its salts • Comment on the depletion of nitrogen, phosphorus and potassium from soils by leaching and farming • 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 • Describe the changes in the oxidation number of nitrogen in the nitrogen cycle in terms of the ions and molecules involved, i.e. NH_3 (–3), N_2 (0), N_2O (+1), NO_3^- (+5) • State the industrial importance of ammonia and ammonium salts for use as fertilisers • 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 • Suggest the benefits of the use of organic fertilisers in terms of their lower solubility	5	183–191	86–88
Sub-topic 3.5.2 Sulfur • Recall that sulfur dioxide is an atmospheric pollutant formed from burning fossil fuels and from the processing of metal sulfide ores • Recall that sulfur dioxide causes breathing difficulties and acid rain • 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)	2	192–194	88–89

Theme 4 Organic chemistry and analysis

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 4.1: Foundations of organic chemistry	**10**	**200–213**	**91–94**
Sub-topic 4.1.1 Organic chemistry terminology • Interpret and use the following terminology associated with organic reactions: » functional group » homolytic fission and heterolytic fission » free radical, initiation, propagation, termination » nucleophile, electrophile » addition, substitution, elimination, hydrolysis, condensation » oxidation and reduction • 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: » numbering the carbon atoms in a direction to give the lowest prefix possible e.g. 1-chlorobutane (not 4-chlorobutane) » the use of the prefixes mono-, di-, tri-, tetra-, penta-, hexa- (In equations for organic redox reactions, the symbols [O] and [H] are acceptable for oxidising and reducing agents)	3	201–205	92
Sub-topic 4.1.2 Shapes of organic molecules • 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) • Predict the shapes of and bond angles in other related molecules	2	206–207	92–93
Sub-topic 4.1.3 Infrared spectroscopy • Analyse an infrared spectrum of a simple molecule to identify functional groups	3	208–210	93–94
Topic 4.2: Hydrocarbons	**16**	**214–233**	**95–101**
Sub-topic 4.2.1 Alkanes • Interpret and use the general, structural, displayed and skeletal formulas of the alkanes • Recall and use systematic nomenclature to name alkanes, with chain length up to six carbon atoms, e.g. 2,2-dimethylhexane • Deduce the molecular formula of alkanes, given its structural, displayed or skeletal formula • Explain the general unreactivity of alkanes, including polar reagents • Describe the chemistry of alkanes as exemplified by the following reactions of ethane: » combustion » substitution by chlorine and by bromine • Describe the mechanism of free-radical reactions with particular reference to the initiation (homolytic fission), propagation and termination reactions, including the substitution of methyl groups by halogens • Explain the use of crude oil as a source of both aliphatic and aromatic hydrocarbons • Explain that cracking can be used to obtain more useful alkanes and alkenes of lower M_r from larger hydrocarbon molecules	5	215–220	95–98

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Sub-topic 4.2.2 Alkenes • Interpret and use the general, structural, displayed and skeletal formulas of the alkenes • Recall and use systematic nomenclature to name, alkenes, with chain length up to six carbon atoms, e.g. but-1-ene, but-2-ene • Deduce the molecular formula of alkenes, given its structural, displayed or skeletal formula • 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): » addition of hydrogen, steam, hydrogen halides and halogens » oxidation by cold, dilute, acidified manganate(VII) ions to form the diol » 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 » polymerisation • Describe the concept heterolytic fission • Describe the mechanism of electrophilic addition in alkenes, using bromine/ethene and hydrogen bromide/propene as examples • Describe and explain the inductive effects of alkyl groups on the stability of cations formed during electrophilic addition • Describe the characteristics of addition polymerisation as exemplified by poly(ethene) and PVC • Deduce the repeat unit of an addition polymer obtained from a given monomer • Identify the monomer(s) present in a given section of an addition polymer molecule • Recognise the difficulty of the disposal of polyalkenes, i.e. non-biodegradability • Describe ways/ discuss approaches to dealing with waste polymers including manufacturing of biodegradable polymers • Recognise that new polymers are being developed, including biodegradable and water soluble polymers	8	221–230	98–100
Sub-topic 4.2.3 Hydrocarbons as fuels • Describe and explain how the combustion reactions of alkanes led to their use as fuels in industry, in the home and in transport • Recognise the environmental consequences of: » carbon monoxide, oxides of nitrogen and unburnt hydrocarbons arising from the internal combustion engine and of their catalytic removal » gases that contribute to the enhanced greenhouse effect » Outline the use of infrared spectroscopy in monitoring air pollution	1	231	100-101

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 4.3: Halogen derivatives	**8**	**234–247**	**102–106**
Sub-topic 4.3.1 Halogenoalkanes • Interpret and use the general, structural (condensed, semi-condensed and displayed) and skeletal formulas of the halogenoalkanes • 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-dibromobutane, 1-chlorobutane • Deduce the molecular formula of halogenoalkanes, given its structural or skeletal formula • Describe the chemistry of halogenoalkanes as exemplified by: » the following nucleophilic substitution reactions of bromoethane: hydrolysis, formation of nitriles and formation of primary amines by reaction with ammonia » the elimination of hydrogen bromide from 2-bromopropane	3	235–240	102–104
Sub-topic 4.3.2 Relative strength of the carbon–halogen bond • Interpret the differences in reactivity of halogenoalkanes (with particular reference to hydrolysis and to the relative strengths of the carbon–halogen bonds) • Explain the uses of fluoroalkanes and fluorohalogenoalkanes in terms of their relative chemical inertness • Recall that the use of chlorofluoroalkanes leads to depletion of the ozone layer • Recall the development of replacement compounds to prevent further depletion and allows the ozone layer to repair • Explain the terms bond energy, bond length and bond polarity and use them to compare covalent bond reactivity	3	241–244	104–105
Topic 4.4: Hydroxyl compounds	**7**	**248–261**	**107–110**
Sub-topic 4.4.1 Alcohols • Interpret and use the general, structural (condensed, semi-condensed and displayed) and skeletal formulas of the alcohols (primary, secondary and tertiary) • Recall and use systematic nomenclature of alcohols, with chain length up to six carbon atoms, e.g. propan-1-ol • Deduce the molecular formula of alcohols (including primary, secondary and tertiary), given its structural or skeletal formula • Recall the chemistry of alcohols, exemplified by ethanol, in the following reactions: combustion; substitution to give halogenoalkanes; reaction with sodium; oxidation to carbonyl compounds and carboxylic acids; dehydration to alkenes; formation of esters by esterification with carboxylic acids • Classify hydroxyl compounds into primary, secondary and tertiary alcohols • Suggest characteristic distinguishing reactions, e.g. mild oxidation • Deduce the presence of a $CH_3CH(OH)$ group in an alcohol from its reaction with alkaline aqueous iodine to form triiodomethane • Explain why alcohols are used as solvents, including their use in cosmetics and to remove sulfur compounds from coal	5	249–258	107–110

Topic, sub-topic and specific objectives	Lessons	LB pages	TG pages
Topic 4.5: Isomerism	**6**	**262–273**	**111—114**
Sub-topic 4.5.1: Isomerism: structural and stereoisomerism • Deduce (draw and name) the possible isomers for an organic molecule of known molecular formula • Describe structural isomerism and its division into chain, positional and functional group isomerism • Describe stereoisomerism and its division into geometrical (*cis* and *trans*) and optical isomerism (use of E, Z nomenclature is acceptable but is not required) • Describe geometrical (*cis* and *trans*) isomerism in alkenes, and explain its origin in terms of restricted rotation due to the presence of double bonds • Explain what is meant by a chiral centre and that such a centre normally gives rise to optical isomerism (NB: Learners should appreciate that compounds can contain more than one chiral centre, but knowledge of *meso* compounds, or nomenclature such as diastereoisomers is not required) • Identify chiral centres and geometrical (*cis* and *trans*) isomerism in a molecule of given structural formula	4	263–270	111–114
Topic 4.6: Carbonyl compounds	**6**	**274–283**	**115-117**
Sub-topic 4.6.1 Aldehydes and ketones • Interpret and use the general, structural (condensed, semi-condensed and displayed) and skeletal formulas of the aldehydes and ketones • Recall and use systematic nomenclature of aldehydes and ketones with chain length up to six carbon atoms, e.g. pent-2-one • Deduce the molecular formula of aldehydes and ketones, given their structural or skeletal formula • Describe the formation of aldehydes from primary and ketones from secondary alcohols using $Cr_2O_7^{2-}$/ H^+	4	275–281	115-117
Topic 4.7: Carboxylic acids and derivatives	**6**	**284–293**	**118-121**
Sub-topic 4.7.1: Carboxylic acids • Interpret and use the general, structural (condensed, semi-condensed and displayed) and skeletal formulas of the carboxylic acids • Recall and use systematic nomenclature of carboxylic acids chain length up to six carbon atoms e.g. butanoic acid • Deduce the molecular formula of carboxylic acids, given its structural or skeletal formula • Describe the formation of carboxylic acids from alcohols and aldehydes • Describe the reactions of carboxylic acids in the formation of: » salts, by the use of reactive metals, alkalis or carbonates » alkyl esters	2	285–287	118-119
Sub-topic 4.7.2: Esters and amines • Interpret and use the general, structural (condensed, semi-condensed and displayed) and skeletal formulas of the amines (primary only) and esters • Recall and use systematic nomenclature of esters and amines, with chain length up to six carbon atoms, including: » using the parent alcohol and carboxylic acid to name esters e.g. methyl ethanoate » naming amines, e.g. 2–aminobutane • Deduce the molecular formulas of esters and amines (primary only) given their structural or skeletal formula • Describe the acid and base hydrolysis of esters and draw the structure of the hydrolysis of the products of any ester given • Explain why esters are used as solvents, perfumes, flavourings	2	288–291	119-120

Section C Teaching guidelines

Theme 1 The particulate nature of matter and stoichiometry

TOPIC 1.1 Atoms, molecules and stoichiometry

Learner's Book pages 4–21

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Know relative atomic, isotopic, molecular and formula masses • Know the mole and Avogadro constant • Understand mass spectrums and calculate relative atomic mass • Know and calculate empirical and molecular formulas • Know how to construct balanced equations and apply these in stoichiometric calculations
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Road safety (the role of chemistry in the functioning of car air bags)
Inclusive education	Learners with learning difficulties or disabilities are likely to struggle with the concepts in this topic. Plan to allow these learners to work at a slower rate, or with the help of another learner or yourself when appropriate.
Suggested teaching time	11 lessons
Additional resources needed (if available)	• Calculators

Introduction to the topic

This topic revises some familiar concepts from Grades 10 and 11, but it also introduces a few new, more complex concepts. The learners' mathematical skills need to be well developed for them to be able to do the required calculations and interpret graphs.

Closely monitor the learners' progress throughout this topic. Identify learners who have difficulties with which mathematical concepts. Provide them with opportunities to work with peers to practise and master skills.

Starter activity

(LB page 4)

This starter activity revises some basic stoichiometric concepts from Grades 10 and 11 that will be applied in this topic.

Cross-cutting issue: The Road Safety Champion highlights the link between chemistry and a very unassuming aspect of road safety: the chemistry of air bags in cars.

Suggested answers

1. Learners read the given information about air bags.
2. **a)** 2 : 3

   b) $n = \frac{m}{M} = \frac{130}{(23.0 + 3 \times 14.0)} = \frac{130}{65.0} = 2.0$

   c) 2.0 moles of NaN_3 produces 3.0 moles of N_2 gas (from the balanced equation)

   d) Volume of N_2 gas produced $= 3.0 \times 24\ dm^3$
   $= 72\ dm^3$

   e) $\frac{50\ dm^3}{72\ dm^3} = \frac{x}{3}$, where x is the number of moles of N_2 gas required to inflate $50\ dm^3$

   Therefore, $x = \frac{3 \times 50\ dm^3}{72\ dm^3}$
   ≈ 2.08 mol

The ratio of sodium azide to nitrogen gas = 2 : 3, therefore the number of moles of sodium azide needed is $\frac{2.08 \times 2}{3} \approx 1.39$ mol

$n(NaN_3) = \frac{m}{M_r}$ therefore $m = M_r(NaN_3) \times n$

$= 65 \times 1.39 = 90.35$ g

Sub-topic 1.1.1 Relative masses of atoms and molecules LB pp. 5–7

Beginning these lessons

Revise as much work from Grades 10 and 11 about relative masses as possible. Do some calculations from the Grades 10 and 11 Learner's Book on the board and select learners to solve certain aspects of each. *Prior knowledge*: relative atomic mass, mole concept, molar mass, empirical formulas, isotopes, molecular and formula masses.

Masses of atoms, isotopes, molecules and compounds (LB page 5)

Teaching tips

- Let learners, in pairs, go through the content in this section and work through the worked example.
- Alternatively, go through the work as a class and select learners to solve the worked example problems on the board (with guidance from the rest of the class).
- Emphasise the formulas in calculating relative isotopic mass.

Suggested homework activities

Activity 1 Question 2. b)

Suggested answers

Activity 1 Understand relative masses (LB page 6)

1. Relative atomic mass is the average mass of an atom's isotopes, compared to the mass of a carbon-12 atom. Relative isotopic mass is the mass of an isotope, compared to the mass of a carbon-12 atom.
   a) 63.6
   b) 10.8

Informal assessment

Note: We have used the term "informal assessment" throughout, but this is also sometimes referred to as "diagnostic assessment". This is because the main purpose is to identify which learners struggle, or do well but need improvement in the mastery of certain aspects.

Do spot checks on learners' books as they complete Activity 1.

Masses of molecules and compounds (LB page 7)

Teaching tips

- Revise the concepts of relative formula mass and relative molecular mass.
- Emphasise the steps in calculating relative formula or molecular mass.

Suggested homework activities

Activity 2 Questions 5 to 8

Suggested answers

Activity 2 Understand M_r (LB page 7)

Calculations are shown in the worked example above the activity.

1. 60.0	**5.** 30.0
2. 85.0	**6.** 159.6
3. 100.1	**7.** 32.0
4. 53.5	**8.** 114.0

Informal assessment

Write the answers to Activity 2 on the board and let the learners mark their own work.

Sub-topic 1.1.2 The mole and the Avogadro constant LB p. 8

Beginning these lessons

Revise as much work from Grades 10 and 11 about the Avogadro constant and the mole concept as possible. *Prior knowledge*: mole concept, Avogadro constant, molar mass.

The mole concept (LB page 8)

Teaching tips

- Let learners, in pairs, go through the content in

this sub-topic, and work together to complete Activity 3.
- Ask learners to randomly spot questions so as to assess their basic comprehension of the concepts discussed.
- Emphasise the rearrangement of the molar mass formula. Give the learners some examples of how to use it to calculate each of the different quantities.

Suggested homework activities

Activity 3 Question 2

Suggested answers

Activity 3 The mole and the Avogadro constant (LB page 8)

Learners rearrange the molar mass equation to determine the answers.

1. **a)** 132.0 g **b)** 18.2 g
 c) 98.2 g **d)** 1.2 g
2. **a)** 0.4 mol **b)** 0.3 mol
 c) 0.2 mol **d)** 0.2 mol

Informal assessment

Select learners to write their calculations and answers on the board to serve as a memorandum for the rest of the class to mark their own work.

Sub-topic 1.1.3 Relative atomic masses LB pp. 9–11

Beginning these lessons

For the first time, the learners will find out how relative atomic masses are calculated. This is new work for the learners and it requires mathematical skills, such as graph reading, percentage calculations and calculations based on given formulas.
New concepts: mass spectrometry.

Mass spectrometry (LB page 9)

Teaching tips

- Although it is useful for the learners to know how relative atomic masses are calculated, they do not need to understand the workings of a mass spectrometer – only that it produces the mass spectrums that we use to calculate relative atomic masses.
- Refer to Figure 1.1.3 in the Learner's Book and ask the learners basic comprehension questions to gauge their understanding of what is shown in the graph.
- Do the worked example as a class, and check that all learners understand the questions and answers.
- Move on to the section about calculating percentage composition by mass. The learners can read through the text and worked example in pairs, or you can do this as a class.

Suggested homework activities

Activity 4 Question 2

Suggested answers

Activity 4 Calculate relative atomic masses (LB page 11)

1. **a)** 63
 b) Four
 c) $A_r(\text{Cu}) = 7.245 + 3.25 + 28.98 + 13.65 = 53.125$
2. **a)** $\frac{167.4}{231.4} \times 100 \approx 72.34\%$
 b) $\frac{32.1}{136.2} \times 100 \approx 23.57\%$
 c) $\frac{192.0}{342.1} \times 100 \approx 56.12\%$
 d) $\frac{72.0}{176.4} \times 100 \approx 40.82\%$

Informal assessment

Write the answers (and calculations) on the board, and let learners swap books and mark each other's work in pairs.

Sub-topic 1.1.4 Empirical and molecular formulas LB pp. 12–15

Beginning these lessons

This sub-topic revises a few concepts from Grades 10 and 11 before narrowing the focus down to finer details that were not covered in those grades.
Prior knowledge: empirical formulas, molecular formulas.
New skills: determining empirical and molecular formulas from raw data.

Chemical formulas (LB page 12)

Teaching tips

- Remind the learners about the key difference between an empirical and a molecular formula.
- Go through the content on page 12 of the Learner's Book as a class, as revision.
- Let the learners read through the rules and steps for calculating these formulas and then work through the worked examples on pages 13 and 14.

Suggested homework activities

Activity 5 Question 2

Suggested answers

Activity 5 Determine empirical and molecular formulas (LB page 14)

Calculations are shown in the worked examples above the activity.

1. a) P_2O_5
b) C_2H_6O
c) $MgSO_3$

2. a) $C_{15}H_{12}O_3$
b) $C_2H_8N_2$
c) C_9H_{12}

Informal assessment

Let the learners volunteer individual answers. Then let the rest of the class compare their answers with these.

Calculate formulas from combustion data (LB page 15)

Teaching tips

- Let the learners read through the steps for calculating formulas from combustion data, and then work through the worked example.
- Let the worked example serve as an illustration of what is meant by the term "combustion data".

Suggested homework activities

Activity 6 Question 2

Suggested answers

Activity 6 Use combustion data to determine empirical formulas (LB page 15)

1.

Molecules	S	O
Mass (g)	2.5	6.2 – 2.5 = 3.7
A_r	32.1	16.0
Moles	$\frac{2.5}{32.1} \approx 0.078$	$\frac{3.7}{16.0} \approx 0.232$
Ratio	$\frac{0.078}{0.078} = 1$	$\frac{0.232}{0.078} \approx 2.97$

Therefore, the empirical formula for the sulfur oxide is SO_3.

2.

Molecules	CO_2	H_2O
Mass (g)	1.122	0.685
M_r	12.0 + 16.0 + 16.0 = 44.0	1.0 + 1.0 + 16.0 = 18.0
Moles	$\frac{1.122}{44.0} \approx 0.026$	$\frac{0.685}{18.0} \approx 0.038$

However, in one mole of H_2O, there are two moles of H and one mole of O, so the number of moles of H in the hydrocarbon must be 0.038 × 2 = 0.076. Therefore, in the hydrocarbon:

Elements	Carbon (C)	Hydrogen (H)
Ratio	$\frac{0.026}{0.026} = 1$	$\frac{0.076}{0.026} \approx 2.92$
	1 :	3

So, the hydrocarbon's empirical formula is C_1H_3. To find the molecular formula, divide the molar mass of the compound by the empirical formula mass to find the multiplication factor:
Empirical formula mass = 12.0 + 3 × 1.0 = 15.0
Molar mass of compound = 30.08 g·mol^{-1}
$\frac{30.08}{15.0} = 2.0053 \approx 2$
Therefore, the molecular formula is twice that of the empirical formula: C_2H_6

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 6. Assess whether all the learners were able to apply this section's content to a practical problem and if their prior knowledge, mathematical skills and logic are all sound.

Sub-topic 1.1.5 Reacting masses and volumes LB pp. 16–19

Beginning these lessons

This sub-topic, like the one before, revises a few concepts from Grades 10 and 11, but extends the skills that the learners learnt then.
Prior knowledge and skills: writing chemical equations; performing calculations with masses, gases, concentrations and volumes; molar volume, rtp and stp.

Rules for writing chemical equations (LB page 16)

Teaching tips

- Since much of the content in this sub-topic is revision from previous years' work, let the learners work through the content, worked example and activity in pairs.
- Walk around the class to ask and answer questions so that you can gauge how much the learners retained from Grades 10 and 11. Dedicate some time to formal revision if you find it is needed.

Suggested homework activities

Activity 7 Question 2

Suggested answers

Activity 7 Balance chemical equations (LB page 16)

1. a) $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
b) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
c) $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
2. a) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
b) $4Ag(s) + O_2(g) \rightarrow 2Ag_2O(s)$
c) $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$
d) $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$
e) $Zn(s) + 2AgNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + 2Ag(s)$
f) $2N_2(g) + 5O_2(g) \rightarrow 2N_2O_5(g)$

Informal assessment

For Activity 7, select learners to write their answers on the board as a memorandum for the rest of the class to mark their own work.

Calculations with masses, gases, concentrations and volumes

(LB page 17)

Teaching tips

- This section continues with revision from Grades 10 and 11. Again, let the learners work through the content, worked examples and activities in pairs.
- Walk around the class to ask and answer questions so that you can gauge how much the learners retained from Grades 10 and 11. Decide whether or not you should dedicate some time to formal revision.

Suggested homework activities

Activity 8 Question 2, Activity 9 Questions 3 and 4, Activity 10 Questions 3 and 4, and Activity 11 Question 3

Suggested answers

Activity 8 Perform mass calculations (LB page 17)

1. a) $N_2 + 3H_2 \rightarrow 2NH_3$
$M_r(N_2) = 2 \times 14.0 = 28.0\ g{\cdot}mol^{-1}$;
$M_r(H_2) = 2 \times 1.0 = 2.0\ g{\cdot}mol^{-1}$;
$M_r(NH_3) = 14.0 + 3 \times 1.0 = 17.0\ g{\cdot}mol^{-1}$
$m(N_2) = n \times M_r = 1 \times 28.0 = 28.0\ g$
$m(H_2) = n \times M_r = 3 \times 2.0 = 6.0\ g$
$m(NH_3) = n \times M_r = 2 \times 17.0 = 34.0\ g$

28.0 g of N_2 reacts with 6.0 g of H_2 to form 34.0 g of NH_3. However, only 21.0 g of N_2 took part in this reaction. Therefore, divide the ratio by the mass of N_2 to get a unit value for this substance:
$\frac{28.0}{28.0} : \frac{6.0}{28.0} : \frac{34.0}{28.0} = 1 : 0.214 : 1.214$
The actual masses involved in the reaction are therefore:
$1 \times 21 : 0.214 \times 21 : 1.214 \times 21$
$= 21 : 4.494 : 25.494$
Therefore 25.5 g of ammonia were produced.

b) $4Na + O_2 \rightarrow 2Na_2O$
$M_r(Na) = 23.0\ g{\cdot}mol^{-1}$;
$M_r(O_2) = 2 \times 16.0 = 32.0\ g{\cdot}mol^{-1}$;
$M_r(Na_2O) = 23.0 \times 2 + 16.0 = 62.0\ g{\cdot}mol^{-1}$
$m(Na) = n \times M_r$
$= 4 \times 23.0$
$= 92.0\ g$
$m(O_2) = n \times M_r = 32.0\ g$
$m(Na_2O) = n \times M_r$
$= 2 \times 62.0$
$= 124.0\ g$
$\text{Ratio} = 92.0 : 32.0 : 124.0 = \frac{92.0}{32} : \frac{32.0}{32} : \frac{124.0}{32}$
$= 2.875 : 1 : 3.875$
$2.875 \times 12 : 1 \times 12 : 3.875 \times 12$
$= 34.5 : 12 : 46.5$
Therefore, the mass of the product (sodium oxide) is 46.5 g.

2. a) 15.75 g of carbon and 5.25 g of hydrogen gas
b) 9.12 g of nitrogen gas and 20.88 g of oxygen gas

Activity 9 Perform concentration calculations (LB page 18)

1. a) $n = c_{mol} \times V = 0.4 \times 0.25 = 0.1\ mol$
b) 0.48 mol

2. a) $c_{mol} = \frac{n}{V} = \frac{0.5}{0.8} = 0.625\ mol{\cdot}dm^{-3}$
b) $3.571\ mol{\cdot}dm^{-3}$

3. a) $c_{mass} = \frac{m}{V} = \frac{0.0041}{0.03} = 0.137\ g{\cdot}dm^{-3}$
b) $0.016\ g{\cdot}dm^{-3}$

4. a) $V = \frac{m}{c_{mass}} = \frac{0.5}{0.02} = 25\ dm^3$
b) $0.427\ dm^3$

Activity 10 Practise your calculation skills I (LB page 19)

1. Use $n = \frac{V_{rtp}}{24\ dm^3}$
a) 0.002 mol **b)** 0.088 mol

2. Use $n = \frac{V_{stp}}{22.4\ dm^3}$
a) 0.038 mol **b)** 0.011 mol

3. a) $C + O_2 \rightarrow CO_2$ means 1 mole of C reacts with 1 mole of O_2.
If there are 0.3 moles of C, then 0.3 moles of O_2 are needed.
$V_{rtp}(O_2) = n \times 24\ dm^3 = 0.3 \times 24 = 7.2\ dm^3$
b) $S + O_2 \rightarrow SO_2$ means 1 mole of S reacts with 1 mole of O_2. If there are 0.04 moles of S, then 0.04 moles of O_2 are needed.
$V_{rtp}(O_2) = n \times 24\ dm^3 = 0.04 \times 24 = 0.96\ dm^3$
c) $2Mg + O_2 \rightarrow 2MgO$ means 2 moles of Mg react with 1 mole of O_2.
If there are 1.7 moles of Mg, then $\frac{1.7}{2} = 0.85$ moles of O_2 are needed.
$V_{rtp}(O_2) = n \times 24\ dm^3 = 0.85 \times 24 = 20.4\ dm^3$

4. $n = \frac{V_{stp}}{22.4\ dm^3} = \frac{0.25}{22.4} = 0.011\ mol$
$m = n \times M(Cl_2) = 0.011 \times (2 \times 35.5) = 0.781\ g$

Activity 11 Practise your calculation skills II (LB page 19)

1. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
2. a) 1 : 4 **b)** 1 : 3
3. a) 1 volume of C_3H_8 produces 3 volumes of CO_2 $\therefore$ 0.5 dm^3 C_3H_8 produces 1.5 dm^3 CO_2
b) 1 volume of C_3H_8 produces 4 volumes of H_2O $\therefore$ 0.5 dm^3 C_3H_8 produces 2 dm^3 H_2O
2 dm^3 H_2O contains $\frac{2}{22.4} = 0.089$ mol water molecules at stp 0.089 mol H_2O has a mass of $0.089 \times (1.0 + 1.0 + 16.0) = 1.602\ g$

Informal assessment

- For Activities 8 and 10, write the answers (and calculations) on the board, and let learners swap books and mark each other's work in pairs.
- Diagnostic activity: Take in the learners' books to mark activities 9 and 11.

Extension

Learners who need an extra challenge can type the following into the Internet search engine: "Practice Problems: Stoichiometry site:chemistry.wustl.edu" and work through the problems on the web page.

Remedial activity

Place learners in pairs so that weaker learners will work with stronger learners. Let learners type this into the search engine: "Solving Stoichiometry Problems site:csun.edu" and create summary posters about strategies for solving the basic types of stoichiometry problems.

Summary (LB page 20)

Learners can use the summary for revision and self-study before they do the self-assessment exercises. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 21)

Note: You could let the learners do this section as self-assessment and then either give them the memorandum to mark their own work or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]

2. B ✓ (1) [K]

3. A ✓ (1) [K]

4. D ✓ (1) [K]

5. a) Assume 100 g of compound, then:

40.6 g C : 5.1 g H : 54.3 g O

$= \frac{40.6}{12.0}$ C : $\frac{5.1}{1.0}$ H : $\frac{54.3}{16.0}$ O ✓✓✓

= 3.383 mol C : 5.1 mol H : 3.394 mol O

Therefore: $\frac{3.383}{3.383}$ mol C : $\frac{5.1}{3.383}$ mol H : $\frac{3.394}{3.383}$ mol O = 1 C : 1.508 H : 1.003 O ✓✓✓

To get whole numbers, multiply by 2:

2 C : 3 H : 2 O ✓

Empirical formula: $C_2H_3O_2$ ✓ (8) [An]

b) Assume 100 g of compound, then:

26.6 g K : 35.4 g Cr : 38 g O

$= \frac{26.6}{39.1}$ K : $\frac{35.4}{52.0}$ Cr : $\frac{38}{16.0}$ O ✓✓✓

= 0.680 mol K : 0.681 mol Cr : 2.375 mol O

Therefore: $\frac{0.680}{0.680}$ mol K : $\frac{0.681}{0.680}$ mol Cr : $\frac{2.375}{0.680}$ mol O = 1 K : 1 Cr : 3.49 O ✓✓✓

To get whole numbers, multiply by 2:

2 K : 2 Cr : 7 O ✓

Empirical formula: $K_2Cr_2O_7$ ✓ (8) [An]

6. a) 90 ✓ (1) [C]

b) Five ✓ (1) [C]

c) $A_r(\text{Zr}) = (\% \text{ ab.} \times A_{\text{Zr-90}}) + (\% \text{ ab.} \times A_{\text{Zr-91}}) + (\% \text{ ab.} \times A_{\text{Zr-92}}) + (\% \text{ ab.} \times A_{\text{Zr-94}}) + (\% \text{ ab.} \times A_{\text{Zr-95}})$ ✓

$= (\frac{51}{100} \times 90) + (\frac{11}{100} \times 91) + (\frac{17}{100} \times 92) + (\frac{18}{100} \times 94) + (\frac{3}{100} \times 95)$ ✓✓✓✓✓

= 45.9 + 10.01 + 15.64 + 16.92 + 2.85 ✓

= 91.3 ✓ (8) [Ap]

7. % mass of H in $C_8H_8O = \frac{A_r(\text{H}) \times n(\text{H})}{M_r(C_8H_8O)} \times 100$ ✓

$= \frac{1.0 \times 8}{(120.0)} \times 100$

$= \frac{8.0}{120.0} \times 100$ ✓

≈ 6.67% ✓

% mass of H in $C_5H_{12}O_5 = \frac{A_r(\text{H}) \times n(\text{H})}{M_r(C_5H_{12}O_5)} \times 100$

$= \frac{1.0 \times 12.0}{(152.0)} \times 100$

$= \frac{12.0}{152.0} \times 100$ ✓

≈ 7.89% ✓

Therefore, adonitol has the greater percentage by mass of hydrogen. ✓ (6) [Ap]

8. a)

Elements	Sodium (Na)	Oxygen (O)
Mass (g)	46.0	16.0
A_r	23.0	16.0
Moles	$\frac{46.0}{23.0} = 2$	$\frac{16.0}{16.0} = 1$
Ratio	2 :	1

Therefore, the empirical formula for the sodium oxide is Na_2O. ✓✓✓ (3) [C]

b) $\frac{M_r}{\text{mass}} = \frac{62}{62} = 1$ ✓

Therefore, the empirical formula is the same as the molecular formula for the sodium oxide: Na_2O. ✓ (2) [C]

9. a) $4NH_3(g)$ ✓ + $7O_2(g)$ ✓ → $4NO_2(g)$ ✓ + $6H_2O(l)$ ✓ (5) [C]

b) 2.5 g $NH_3 = \frac{2.5}{17.0}$ mol = 0.147 mol ✓

0.147 mol NH_3 produces 0.147 mol NO_2 ✓

0.147 mol NO_2 occupies a volume of 0.147 × 22.4 ✓ ≈ 3.293 dm^3 ✓ (4) [Ap]

Total: 50

TOPIC 1.2 Atomic structure

Learner's Book pages 22–35

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Know protons, neutrons and electrons; their distribution in the atom and their behaviour in electric fields • Understand nucleon number and relate it to isotopes • Know and apply the *s*-, *p*- and *d*-orbitals for principal quantum numbers 1, 2, 3 and 4
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology (the role of electrons in digital technology)
Inclusive education	Learners with learning difficulties are likely to struggle with the new concepts in this topic. Plan to allow these learners to work at a slower rate, or with the help of another learner or yourself when appropriate.
Suggested teaching time	8 lessons
Additional resources needed (if available)	• Calculators • *Low-cost resource:* See the "On the Internet" note on LB page 25.

Introduction to the topic

This topic revises some familiar concepts from Grades 10 and 11, but it also introduces a few new, more complex concepts – including a basic introduction to quantum theory. The learners will need a solid prior knowledge of the structure of the atom and the various components making up an atom.

Closely monitor the learners' progress throughout this topic. Determine where the learners' prior knowledge is lacking. Provide the opportunities for these learners to revise before continuing.

Starter activity (LB page 22)

This starter activity revises some concepts from Grades 10 and 11, but combines them with physics to pose an interesting problem for the learners to solve. *Cross-cutting issue*: The Information and Communication Technology Champion points out that it is electrons that are responsible for making digital devices work.

Suggested answers

1. Learners read the given information about electrons.
2. $q \times V = \frac{1}{2}mv^2$
   $1.6 \times 10^{-19}\ \text{C} \times 100\ \text{V} = \frac{1}{2} \times 9 \times 10^{-31}\ \text{kg} \times v^2$
   $v^2 \approx 3.56 \times 10^{13}$
   $v \approx 5\ 962\ 847\ \text{m·s}^{-1}$
3. 12 742 km = 12 742 000 m
   $v = \frac{\Delta d}{\Delta t} \therefore \Delta t = \frac{\Delta d}{v} = \frac{12\ 742\ 000\ \text{m}}{5\ 962\ 847\ \text{m·s}^{-1}}$
   ≈ 2.14 s

Sub-topic 1.2.1 Particles in the atom

LB pp. 23–25

Beginning these lessons

Revise as much work from Grades 10 and 11 about the structure of the atom as possible. Make use of the summarised content in the Learner's Book as a way to ascertain where there are gaps in the learners' prior knowledge. Reinforce concepts where necessary. *Prior knowledge*: protons, electrons, neutrons, mass and charge distribution, proton (atomic) numbers, nucleon (mass) numbers, ions (anions and cations).

Protons, neutrons and electrons (LB page 23)

Teaching tips

- Using the content provided as a checklist of concepts the learners should have mastered by now, select learners to recall definitions and facts, or explain certain concepts. Let the rest of the class assess the learners' answers.
- Ask for one or two learners to volunteer to solve the worked example questions on the board.

- Make sure that each learner in the class gets an opportunity to answer a question, assess a question, or provide a reason for one of the other learners' answers. In this way, you can gauge whether all the learners are ready for the work in the next two sub-topics.

Suggested homework activities

Activity 1 Question 3

Suggested answers

Activity 1 Understand atomic particles (LB page 25)

1. The nucleus contains the protons and neutrons. It therefore has an overall positive charge because the protons are positively charged and the neutrons have no electric charge. The electrons around the nucleus are negatively charged, so all the shells of an atom have a negative charge.
2. **a)** Incorrect: only the number of protons and neutrons contribute
   b) Incorrect: This is only true for electrically neutral atoms. The number of electrons and protons differ in ions.
   c) Correct
3. **a)** **i)** Protons: 20; neutrons: 20; electrons: 20
   ii) Protons: 33; neutrons: 42; electrons: 33
   iii) Protons: 16; neutrons: 16; electrons: 16
   b) **i)** Protons: 11; neutrons: 12; electrons: 10
   ii) Protons: 30; neutrons: 34; electrons: 28
   iii) Protons: 8; neutrons: 8; electrons: 10

Informal assessment

For Activity 1, select learners to write their answers on the board as a memorandum for the rest of the class to mark their own work.

Sub-topic 1.2.2 The nucleus of the atom

LB pp. 26–27

Beginning these lessons

Revise as much work from Grades 10 and 11 about isotopes and nuclear notation as possible.
Prior knowledge: isotopes, proton (atomic) numbers, nucleon (mass) numbers, nuclear notation.

Isotopes (LB page 26)

Teaching tips

- Let learners go through the content in this sub-topic in pairs.
- Ask learners randomly spot questions to assess their basic comprehension of the concepts discussed.
- Point out that, whereas nuclear notation always places the nucleon (mass) number above the proton (atomic) number, some Periodic Tables do not follow this convention. The learners should therefore always first check the key on the Periodic Table they work from. They should also know that they can identify the nucleon number as the larger quantity (often with decimal places) when no key is supplied.
- Use the Note box on page 27 to highlight a practical application of chemistry in the context of Namibia's archaeological heritage.

Suggested homework activities

Activity 2 Questions 3 and 4

Suggested answers

Activity 2 Understand isotopes (LB page 27)

1. An atom's proton number (*Z*) indicates the number of protons in an atom's nucleus. When this number is added to the number of neutrons in the atom's nucleus, we get its nucleon number.
2. **a)** $^{80}_{35}Br$ **b)** $^{32}_{10}Ne$ **c)** $^{76}_{34}Se$
3. **a)** $^{32}_{16}S$ **b)** $^{137}_{56}Ba$ **c)** $^{65}_{30}Zn$
   d) $^{85}_{37}Rb$
4. **a)** Cr **b)** F **c)** Mn

Informal assessment

Select learners to write their answers on the board to serve as a memorandum for the rest of the class to mark their own work.

Sub-topic 1.2.3 Electrons

LB pp. 28–33

Beginning these lessons

This sub-topic introduces a few new concepts,

such as quantum numbers. The content is of a theoretical nature and might be difficult for many learners to grasp quickly. Teach the content slowly. Check, on a regular basis, that the learners understand key points.
Prior knowledge: electron shells, filling up of shells.
New concepts: quantum numbers, quantum theory, energy levels and electron shells, subshells, orbitals, electronic configuration.

Electron shells (LB page 28)

Teaching tips

- Do some quick revision about how shells fill up with electrons. Remind the learners of Bohr structures.
- Although the importance of the four quantum numbers is not discussed in the text (this lies beyond the scope of this course), emphasise the order of the numbers and the possible values they may take for each electron in an atom.
- For your own purposes, or as a way of introducing this section of content to the learners, you may want to read up on, or watch documentaries on the development of quantum theory. Here are some suggested online resources:
  1. Read up on the history and development of quantum theory: "Introduction to Quantum Theory" on www.chem.libretexts.org
  2. Watch a short introductory lesson on quantum theory: "Intro to Quantum Theory Chemistry (CHEM101)" by Spoon Feed Me on www.youtube.com
- Let the learners work through Activity 3 in pairs, but use the form of a class discussion to let learners find and understand the correct answers.
- Teach the content on shells and subshells and remind the learners about the naming conventions of subshells.
- Explain the different types of orbitals by referring to the diagram and information on page 31.
- Use Figure 1.2.9 to explain how shells fill up and point out the filling rule of "4*s* BEFORE 3*d*".

Suggested homework activities

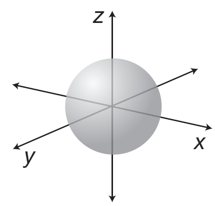
Activity 4 Question 3

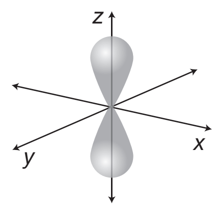
Suggested answers

Activity 3 Understand quantum numbers (LB page 29)

1. Not possible: the l-value is greater than the n-value.
2. Not possible: the m_l-value can only be 0 if the l-value is 0.
3. Possible
4. Not possible: the m_l-value can only be −1, 0 or 1 if the l-value is 1.
5. Not possible: the m_s-value can only be $-\frac{1}{2}$ or $+\frac{1}{2}$.
6. Possible

Activity 4 Understand shells, subshells and orbitals

1. **a)** s, p_x, p_y and p_z
   b) s, p_x, p_y, p_z, d_{xy}, d_{yz}, d_{zx}, d_{x2-y2} and d_{z2}
2. **a)**


   b)


3. **a)** 2 electrons
   b) 2 electrons
   c) 6 electrons
   d) 10 electrons

Informal assessment

- Select learners to give their answers to Activity 3. Let the rest of the class say if they agree or disagree and why.
- Diagnostic activity: Take in the learners' books to mark Activity 4.

Electronic configuration (LB page 32)

Teaching tips

- Explain how orbital diagrams help us to write electronic configurations by referring the learners to Table 1.2.1.

Suggested homework activities

Activity 5 Question 3

Suggested answers

Activity 5 Write electronic configurations **(LB page 33)**

1.

1s	2s	2p	3s	3p
↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑ ↑ ↑

$1s^2 2s^2 2p^6 3s^2 3p^3$

2.

1s	2s	2p	3s	3p
↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑↓ ↑↓

$1s^2 2s^2 2p^6 3s^2 3p^6$

3.

1s
↑↓

$1s^2$

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 5 so that you can check if they have all understood the basics of writing and illustrating electronic configurations.

Extension

Learners who need an extra challenge can research the following principles – either online or at a library:

1. Pauli exclusion principle
2. Hund's rule
3. Aufbau principle

Remedial activity

Refer the learners who struggle with the new concept of quantum numbers to YouTube (youtube.com), where they can search for informative lessons and explanations using the search terms "quantum numbers for beginners".

Summary (LB page 34)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate new knowledge.

Self-assessment (LB page 35)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. A ✓ (1) [K]
3. D ✓ (1) [K]
4. B ✓ (1) [K]
5. C ✓ (1) [K]
6. The electrons in shells *further* away from the nucleus have greater energy ✓ and are more likely to escape from the atom because they are less tightly held by the nucleus. ✓ (2) [C]
7. **a)** $^{56}_{26}Fe$ ✓✓
   b) $^{45}_{21}Sc$ ✓✓ (4) [C]
8. **a)** Possible ✓
   b) Not possible ✓ because the m_l-value can only be a negative or positive 1, or 0. ✓ (3) [Ap]
9. **a)**

1s	2s	2p	3s	3p
↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑ ↑ ✓✓

S: $1s^2 2s^2 2p^6 3s^2 3p^4$ ✓ (3) [Ap]

b)

1s	2s	2p
↑↓	↑↓	↑↓ ↑↓ ↑↓ ✓✓

Mg^{2+}: $1s^2 2s^2 2p^6$ ✓ (3) [Ap]

Total: 20

TOPIC 1.3 Chemical bonding

Learner's Book pages 36–57

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand ionic bonding • Understand covalent bonding and coordinate (dative covalent) bonding • Understand shapes of simple molecules including bond angles and the principle of electron-pair repulsion • Understand the reactions involving ligands and complexes • Understand the concept of electronegativity • Understand hydrogen bonding • Understand electronegativity and its applications • Understand intermolecular forces and their applications in bond properties • Understand metallic bonding • Relate different types of bonding to physical properties of substances • Show understanding of lattice structures • Relate hydrogen bonding to physical properties of substances
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Human rights and democracy (the role of human rights in the diamond trade)
Inclusive education	• Visually impaired learners will need help interpreting the numerous explanatory diagrams in this topic. Enlarge the diagrams on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learner. • Move learners with hearing impairments to the front of the class so that they can hear you better, or pair them up with a patient classmate who can write notes as you teach.
Suggested teaching time	12 lessons
Additional resources needed (if available)	• Molecular models of various crystal lattices, or three-dimensional images of these – you can find these online • *Low-cost resource:* Online videos can help to explain some of the more complex concepts in this topic. Source these before the relevant lessons. See the "On the Internet: note on LB page 42, for example.

Introduction to the topic

Understanding chemical bonding allows learners to also understand how elements react with each other and why certain compounds have specific properties. The three main types of bonding (ionic, covalent and metallic) were covered extensively in Grades 10 and 11, so much of this topic is revision. However, the content extends the learners' understanding by incorporating new concepts, such as electronegativity, shapes of molecules and intermolecular forces.

Starter activity (LB page 36)

This starter activity revises the covalent structure of diamond from Grades 10 and 11, as a link to the Cross-cutting issue.
Cross-cutting issue: The Human Rights and Democracy Champion highlights the human rights abuses that occur in the diamond trade in some parts of Africa.

Suggested answers

1. Diamond is an allotrope of carbon.
2. B
3. **a)** Incorrect
   b) Correct
   c) Incorrect
   d) Incorrect
   e) Correct
4. The covalent bonds in the diamond lattice are very strong. In addition, each carbon atom in the lattice is bonded to another four carbon atoms surrounding it. A lot of energy is needed to separate the carbon atoms in this complex, three-dimensional structure.

5. The learners should find that the DRC, South Africa, Botswana and other countries mine and sell diamonds. However, not all diamond-mining African countries produce "blood diamonds".

Sub-topic 1.3.1 Ionic bonding

LB pp. 37–39

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about ionic bonds and the properties of ionic substances.
Prior knowledge: ionic bond, ionic lattice, dissociate, hydrate, aqueous.

Ionic bonds (LB page 37)

Teaching tips

- Using the content provided as a checklist of concepts the learners should know by now, select learners to recall definitions and facts, or explain certain concepts. Let the rest of the class assess the learners' answers.
- Let one or two learners volunteer to show how an ionic bond forms (using examples of metals and non-metals that you give them) on the board – again for the rest of the class to assess.
- Make sure that each learner in the class gets an opportunity to answer a question, assess a question, or provide a reason for one of the other learners' answers. Ascertain whether all the learners are ready for the work in the next few sub-topics.

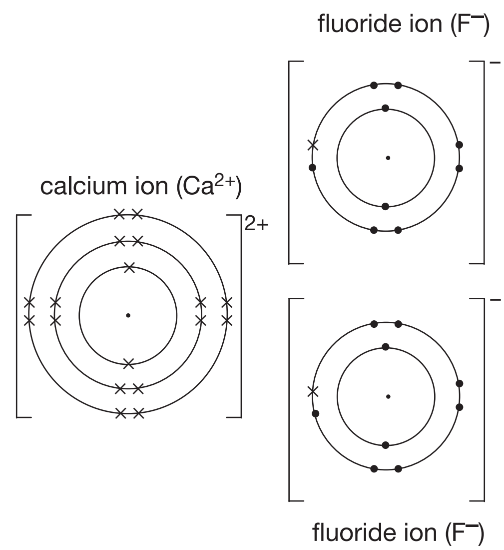
Suggested homework activities

Activity 1 Question 3 and Activity 2 Questions 3 and 4

Suggested answers

Activity 1 Understand ionic bonding (LB page 38)

1. **a)** $1s^2$
   b) $1s^22s^22p^6$
   c) $1s^22s^22p^63s^23p^6$
2. An ionic bond occurs between a metal and a non-metal. In the case of potassium (a metal) and chlorine (a non-metal), potassium needs to lose one electron in order to achieve a full outer shell, while chlorine needs to gain one. Therefore, the potassium atom transfers one of its valence electrons to the chlorine atom, so that both achieve full outer shells as ions.
3. Calcium has an electronic configuration of $1s^22s^22p^63s^23p^64s^2$, so it needs to lose two electrons to achieve a full outer $3p$-shell. Fluorine atoms need only one electron to achieve full outer shells. Therefore, two fluorine atoms must bond with one calcium atom to form calcium fluoride (CaF_2).



Activity 2 Properties of ionic compounds (LB page 39)

1. An ionic lattice is a three-dimensional structure with alternating cations and anions in all three planes. Although a giant covalent lattice also repeats its particle arrangement in all three dimensions, there are no cations or anions. Instead, atoms are covalently bonded to each other.
2. Ions with single charges have lower melting and boiling points than ions with double charges because there is less charge density (and therefore a smaller force of attraction) on the single-charge ions. The greater the charge density, the greater the force of attraction between the cations and anions will be, and the more difficult it will be to melt or boil those substances.
3. Substance X: Not ionic; ionic substances do not conduct electricity in their solid states.

Substance Y: Not ionic; ionic substances are generally hard and scratch-resistant. They also have very high melting points.

4. Ionic substances readily dissolve in water because the water molecules attract, isolate and surround both cations and anions from the ionic lattice. This is because water is a polar molecule with a slightly positive and slightly negative end. We say the ions undergo hydration. The force of attraction between the ions and the water molecules breaks the ionic bonds of the ionic lattice.

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activities 1 and 2. Note which learners struggle with the basics from Grades 10 and 11 and do additional revision with them before moving on to the next sub-topic.

Sub-topic 1.3.2 Covalent and coordinate bonding LB pp. 40–43

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about covalent and coordinate bonds. The new content in this sub-topic introduces the learners to molecular shapes.

Prior knowledge: covalent bond, coordinate bond, lone pairs, Couper notation, properties of covalent substances.

New concepts: VSEPR theory, bond angles.

Covalent bonding (LB page 40)

Teaching tips

- Ask learners randomly spot questions to assess their basic comprehension of the introductory concepts (such as covalent bonding, Couper notation, and so forth).
- Show how coordinate (or dative covalent) bonding occurs in the ammonium ion, as shown in Figure 1.3.10 in the Learner's Book.
- Move on to explain coordinate bonding in an aluminium chloride molecule using the steps and diagrams in Table 1.3.1.

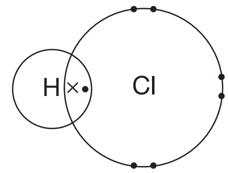
Suggested homework activities

Activity 3 Question 3

Suggested answers

Activity 3 Covalent and dative covalent bonding (LB page 42)

1. a)



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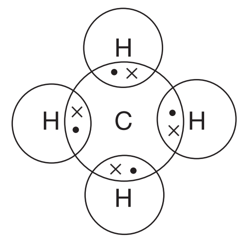
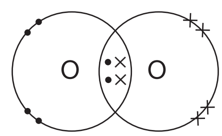
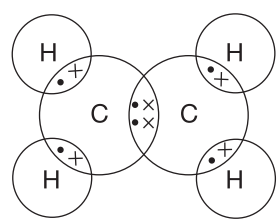


c)

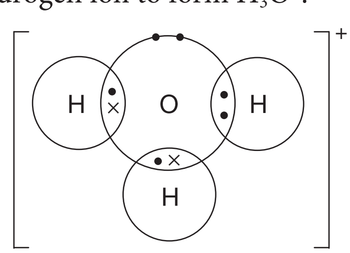


d)



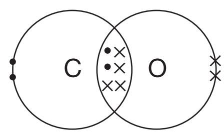
2. A covalent bond is a chemical bond between two non-metal atoms in which the two atoms share one or more pairs of electrons. A dative covalent bond is a covalent bond between two non-metal atoms in which the two atoms share a lone pair of electrons that was donated by one of the atoms.

3. a) The oxygen atom in a water molecule has two lone pairs. One of these is used to form a dative covalent bond with a hydrogen ion to form H_3O^+.



b) The carbon atom has four valence electrons, while the oxygen atom has six.

For both to achieve full outer shells, carbon needs to share in another four electrons, but oxygen only needs two. A carbon monoxide molecule therefore contains a triple bond: two regular covalent bonds and one dative covalent bond.



Informal assessment

For Activity 3, select learners to write their answers on the board to serve as a memorandum for the rest of the class to mark their own work.

The shape of a molecule (LB page 42)

Teaching tips

- Make sure the learners understand that lone pairs and bonding electrons influence the shape of a molecule, due to the forces of repulsion that are set up between them. Table 1.3.2 shows examples of each molecular shape, and describes the typical bond angles that we find in these shapes.
- Let learners revise the effects of covalent bonding on the physical properties of covalent substances in pairs.
- Note that you can skip ahead to page 206 of the Learner's Book for a step-by-step way of determining the shape of an (organic) molecule, if it helps the learners at this point.
- Let the class watch the suggested online video, if possible.

Suggested homework activities

Activity 4 Question 2 and Activity 5 Questions 1 and 2

Suggested answers

Activity 4 Predict the shapes of molecules (LB page 43)

1. **a)** Trigonal planar **b)** Linear
   c) Tetrahedral **d)** Pyramidal
   e) Trigonal planar
2. Molecule X: Tetrahedral
   Molecule Y: Pyramidal

Activity 5 Understand the physical properties of covalent substances (LB page 43)

1. Toluene will have a higher boiling point as it has a greater number of electrons resulting in stronger Van der Waals forces.
2. Nitrogen gas molecules have a very strong triple covalent bond. They are largely unreactive since these triple bonds make the molecules stable. Oxygen gas molecules have a double bond, which is relatively strong, but not as strong as a triple bond.

Informal assessment

- For Activity 4, ask learners to give their answers. Write these on the board and let learners mark each other's work in pairs.
- For Activity 5, select learners to write their answers on the board to serve as a memorandum for the rest of the class to mark their own work.

Sub-topic 1.3.3 Electronegativity

LB pp. 44–46

Beginning these lessons

This sub-topic introduces a new concept to the learners. The content covered here is of a theoretical nature and might be difficult for many learners to grasp immediately. Teach the content slowly and regularly check that the learners understand the key points.
New concepts: electronegativity, bond polarity, dipole moment.

Electronegativity (LB page 44)

Teaching tips

- Explain the concept of electronegativity to the learners using Figure 1.3.12 in the Learner's Book.
- Move on to explain how the electronegativity values of two non-similar, bonded atoms lead to bond polarity.
- Go through the worked example on the board before moving on to defining dipole moments.
- Let learners read through the section regarding oxides in pairs, but allow them to ask questions if they get stuck.

Suggested homework activities

Activity 6 Question 2 and Activity 7 Question 3

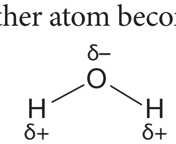
Suggested answers

Activity 6 Determine bond polarity
(LB page 45)

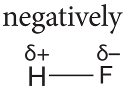
1. **a)** H–O is most polar
(H–O: 1.4; H–H: 0; H–I: 0.6)
b) Na–Cl is most polar
(Na–Cl: 2.3; Cl–Cl: 0; C–Cl: 0.5)
c) Se–Si is most polar
(Se–Si: 0.7; Se–Br: 0.2; Se–Cl: 0.4)
d) Rb–Cl is most polar
(Rb–I: 1.9; Rb–Cl: 2.2; Rb–C: 1.7)
2. Metallic bonding involves the electrostatic force of attraction between cations and electrons, not anions, so polarity cannot be determined.

Activity 7 Understand electronegativity
(LB page 46)

1. Top right corner (excluding the noble gases)
2. A polar bond is formed between two atoms of different electronegativities. The more electronegative atom pulls the bonding electrons closer to itself. This results in an unequal distribution of charge. One atom becomes slightly positively charged and the other atom becomes slightly negatively charged.
3. **a)**



b)



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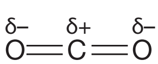

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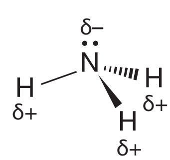


Informal assessment

- Select learners to give their answers to Activity 6, and let the rest of the class say if they agree or disagree and why.
- Diagnostic activity: Take in the learners' books to mark Activity 7.

Sub-topic 1.3.4 Intermolecular forces, electronegativity and bond properties
LB pp. 47–50

Beginning these lessons

This sub-topic introduces new content to the learners. Work through the text and diagrams slowly and make use of online resources to enrich the lessons.

New concepts: intramolecular forces, intermolecular forces, Van der Waals forces, dipole–dipole forces, induced dipole forces, hydrogen bonding.

Intermolecular and intramolecular forces
(LB page 47)

Teaching tips

- Distinguish between intermolecular and intramolecular forces using familiar examples, such as water molecules.
- Make use of the diagrams on pages 48 and 49 of the Learner's Book to help the learners solidify the new concepts. Emphasise the two types of intermolecular forces (Van der Waals forces and hydrogen bonding), and the fact that dipole–dipole and induced dipole forces form part of the Van der Waals group.
- Let the learners – individually or in pairs – go through the content about the effects of physical properties, and lead a class discussion about the findings, afterwards.

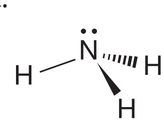
Suggested homework activities

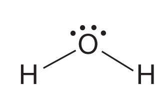
Activity 8 Questions 3 and 4

Suggested answers

Activity 8 Understand intermolecular forces
(LB page 50)

1. Even though the noble gases are monatomic gases at room temperature, weak induced dipole forces are present between the atoms in their liquid states. The strength of the induced dipole forces increases with increasing molecular weight. So, as more electrons (in shells) are added to each consecutive atom, the boiling point increases.
2. From the diagrams, we see that ammonia has only one lone pair of electrons while water has two. The greater the degree of hydrogen bonding, the higher the boiling point will be. That explains why water has the higher boiling point.





3. Both are covalent substances. The bond between the Br atoms is non-polar, whereas that between I and Cl is highly polar. Therefore, dipole–dipole forces are dominant in ICl, and induced dipole forces are dominant in Br_2. Dipole–dipole forces are stronger than induced dipole forces, so ICl is likely to have the higher melting point.
4. a) induced dipole and dipole–dipole forces
   b) $CHCl_3$; this molecule has the greater molecular weight, and therefore the stronger intermolecular forces.

Informal assessment

For Activity 8, select learners to write their answers on the board as a memorandum for the rest of the class to mark their own work.

Sub-topic 1.3.5 Metallic bonding

LB pp. p. 51

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about metallic bonds.
Prior knowledge: metallic bonding.

Bonding in metallic giant lattices

(LB page 51)

Teaching tips

- Let learners, in pairs, revise the basics of metallic bonding using the text and diagrams on page 51 of the Learner's Book.
- Select learners to answer quick questions or explain processes as they work through the content, to gauge how much of this information they retained from Grades 10 and 11.

Suggested homework activities

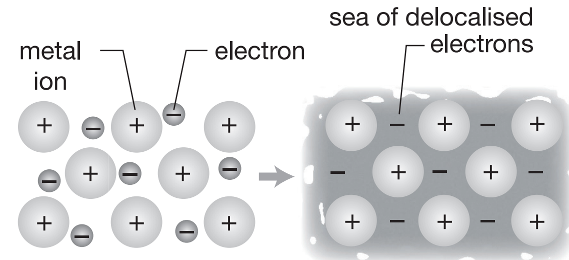
Activity 9 Questions 2 and 3

Suggested answers

Activity 9 Understand metallic bonding

(LB page 51)

1.



2. The sea of delocalised electrons can carry an electrical charge through the lattice.
3. a) The metallic bonds allow for greater malleability and ductility of metals, so aluminium can be hammered, stretched, rolled and formed into thin sheets of foil.
   b) The delocalised electrons allow for electrical conductivity, and although other metals' conductivities are greater, copper is the cheaper option.

Informal assessment

For Activity 9, write the answers on the board. Let learners swap books and mark each other's work in pairs.

Sub-topic 1.3.6 Bonding, structure and physical properties

LB pp. 52–53

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about molecular and giant lattices.
Prior knowledge: molecular lattice, giant lattice.

Lattice structures

(LB page 52)

Teaching tips

- Let learners, in pairs, revise molecular and giant lattices by reading through the text and tables and studying the diagrams in this sub-topic.
- Select learners to answer quick questions or explain processes as they work through the content, to gauge how much of this information they retained from Grades 10 and 11.

Suggested homework activities

Activity 10 Question 2. b–d)

Suggested answers

Activity 10 Understand lattice structures (LB page 53)

1. The ionic substance (MgO) will have the highest boiling point, as ionic bonds are much stronger than the bonds or intermolecular forces involved with the other molecules.
   Ar is a noble gas and therefore only has induced dipole forces acting between its atoms in the liquid state. NO_2 is a polar molecule, due to the lone pair on the N-atom.
   C_{60} is non-polar, but has a large molecular weight, so it should boil at a higher temperature than all the other substances, except for the ionic substance.
   Therefore: MgO, C_{60}, NO_2, Ar
2. **a)** Ice is a hydrogen-bonded molecular structure, so although hydrogen bonding is the strongest intermolecular force, it is still very weak compared to the electrostatic forces present in ionic compounds. Therefore, more energy is needed to overcome the ionic bonds in NaCl than the hydrogen bonds acting between the water molecules in ice.
   b) The weak Van der Waals forces between the sheets of graphite are easily overcome. This is why the sheets slide off each other when we write with a pencil. However, for the substance to melt, the very strong covalent bonds that are present in the sheets must be overcome and this requires considerable energy.
   c) Short nanotubes are able to conduct electricity because of the graphene structure that they come from. Not all electrons are involved in bonding so some are free to carry charge. Iodine is a true simple covalent structure, so it has no ions or free electrons that can conduct electricity.
   d) C_{60} has weaker intermolecular forces between the C_{60} molecules, so less energy is needed to overcome these forces in C_{60}. In order to melt diamond, the strong covalent bonds between the atoms would need to be broken.

Informal assessment

For Activity 10, select learners to write their answers on the board as a memorandum for the rest of the class to mark their own work.

Extension

Give the learners the task to write a short research report on one of the intermolecular forces that they learnt about in this topic. Assess their reports based on the inclusion of these aspects:

- A full explanation of how the intermolecular force occurs
- Who the first person was to identify this force
- When this force was first identified.

Remedial activity

Let the learners who need additional help with the new (theoretical) concepts in this topic form study groups so that they can revise the more difficult concepts in Sub-topics 1.3.3 and 1.3.4. Help them find online resources and exercises from other Chemistry textbooks to complete as a group.

Summary LB page 54

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment LB page 56

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. A ✓ (1) [K]
3. B ✓ (1) [C]
4. D ✓ (1) [K]
5. C ✓ (1) [K]
6. C ✓ (1) [K]
7. D ✓ (1) [K]
8. C ✓ (1) [K]
9. D ✓ (1) [C]
10. B ✓ (1) [K]
11. The simpler aluminium chloride compound, $AlCl_3$, exists only at higher temperatures. ✓

The aluminium atom shares each of its three valence electrons with one of the chlorine atoms. ✓
Its outermost shell is not entirely full. ✓
At lower temperatures, two $AlCl_3$ molecules bond together to overcome the unfilled shell-problem for both.
The aluminium atoms do not have any more valence electrons to contribute, but the chlorine atoms do. ✓
One chlorine atom from each molecule shares a lone pair with the aluminium atom in the other molecule, and thereby forms a dative covalent bond with the other molecule. ✓
The result is a completely stable molecule, Al_2Cl_6. (5) [C]

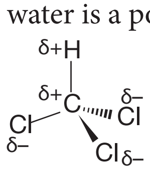
12. The strength of a metallic bond increases as:
- the positive charge on the cations increases ✓
- the atomic radius of the cations become smaller ✓
- the number of valence electrons on each atom increases. ✓ (3) [K]

13. Hydrogen bonds are the strongest type of intermolecular force. ✓ They can only exist between molecules if:
- both molecules contain a very electronegative atom, such as F, N or O ✓
- one molecule has an H-atom bonded to the F, N or O atom ✓
- the other molecule has a lone pair on its F, N or O atom. ✓ (4) [C]

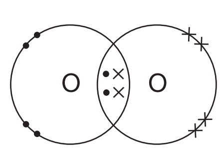
14. On the Periodic Table, electronegativity values increase from left to right across a period ✓ and they also increase from the bottom to the top of each group. ✓ The most electronegative element is fluorine. ✓ (3) [C]

15. Methanol is a polar molecule, whereas methane is a non-polar molecule. ✓ Polar substances dissolve in polar solvents, and water is a polar solvent. ✓ (2) [Ap]

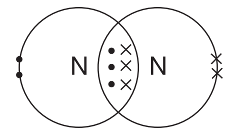
16. ✓✓✓ (3) [Ap]



17. a) ✓✓ (2) [K]



b) ✓✓ (2) [K]



c) Sodium azide is an ionic substance (since a metal and a non-metal are involved), so it is likely to have a high melting point. ✓ The atoms in nitrogen gas are strongly bonded to each other to form the diatomic gas, ✓ but there are very weak intermolecular forces holding the molecules together. ✓ Hence, nitrogen has a very low melting point. (3) [C]

d) i) Electronegavity of Ca = 1.3;
Electronegavity of O = 3.5;
Difference = 3.5 –1.3 = 2.2 ✓
Therefore the bond is ionic. (1) [Ap]

ii) Electronegavity of O = 3.5;
Difference = 0 ✓
Therefore, the bond is non-polar covalent. (1) [Ap]

18. a) Metallic ✓ (1) [K]

b) Metals form giant lattices in which the metal atoms pack together very tightly. ✓ However, their valence electrons are free to move. ✓ The valence electrons create a sea of negative charge in which the positive ions (cations) are arranged. ✓ (3) [C]

c) In metallic substances, the electrons are free to move if the substance is molten or in solution. ✓ In the body, the potassium ions are in solution, and therefore can act as electrolytes. ✓ (2) [Ap]

19. a) The three Cl-atoms are all identical and therefore the bonds between each and the B-atom are identical. ✓ Each Cl-atom (and all of its associated electrons) will try to move as far away from the other two as possible. ✓ The most stable arrangement that reduces electron repulsion is the trigonal planar arrangement. (2) [C]

b) Accept any values or ranges between 100° and 120°. ✓ (1) [K]

c) Because sulfur has a valency of 5, there must be a lone pair of electrons on it. ✓ Lone pairs repel more than bonding pairs of electrons, so the effect is seen in the relative closeness of the O-atoms and the resulting bond angle of less than 120°. ✓ (2) [C]

Total: 50

TOPIC 1.4 Ideal and real gases

Learner's Book pages 58–63

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Show understanding of ideal and real gases, and their associated conditions • Appreciate $PV = nRT$
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning (producing valuable fertilisers from waste) Entrepreneurship (finding entrepreneurial opportunities in solving problems for the wider community)
Inclusive education	Visually impaired learners will need help interpreting the various graphs in this topic. Enlarge the graphs on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learner.
Suggested teaching time	4 lessons
Additional resources needed (if available)	• Calculators • *Low-cost resource:* Online videos and animations can help to explain some of the relationships discussed in this topic. Look for good examples on youtube.com.

Introduction to the topic

Up until now, the learners have been under the impression that all gases behave in much the same way (as all liquids and all solids behave as liquids and solids). In this sub-topic, they are guided to see that there is a distinct difference between how we expect gases to behave (based on theoretical calculations) and how they behave in reality.

Starter activity

(LB page 58)

This starter activity looks at the formation, uses and disadvantages of methane gas, as a link to the Cross-cutting issues.
Cross-cutting issue: The Environmental Learning Champion highlights a useful way of solving a large global warming problem – that of agricultural methane emissions in the atmosphere. This is combined with an entrepreneurial opportunity, as the Entrepreneurship Champion points out.

Suggested answers

The answers to this starter activity are open to discussion.

1. The learners should identify northern regions of the country as more suitable than others, as this is where most farming occurs and where most of the country's population is found.
2. The learners should consider that, although cattle would produce the greatest volumes of manure, extensive cattle farming is practised in this country. This makes manure collection and transportation a problem. It is much easier to collect the manure of smaller animals that are farmed in encampments, but the volumes produced may not be enough to sustain the project.
3. The learners should identify the costs involved in setting up the project, labour, the costs of natural gas and similar fertilisers (from competitors) as well as on-going maintenance costs of the project as factors to consider when setting a selling price.

Sub-topic 1.4.1 Real and ideal gases

LB pp. 59–63

Beginning these lessons

Start this sub-topic off by revising the key points of the kinetic theory of gases. This serves as a good introduction to the new concepts that will be discussed.
New concepts: ideal gas, real gas.

The kinetic theory of gases: Ideal and real gases

(LB page 59)

Teaching tips

- Make sure that all the learners have a solid understanding of the kinetic theory of gases as a starting point.

- Move on to distinguish between real and ideal gases. Use the three gas laws stated as familiar concepts from which to derive the general gas equation.
- Go through the worked example on the board, and ask the learners to calculate and check each step of the calculations.
- Show the learners how a value of M_r can be calculated from the general gas equation, and let them appreciate the behaviour that we observe in real gases by studying the graphs on page 61.

Suggested homework activities

Activity 1 Question 3, Activity 2 Question 2 and Activity 3 Questions 1 and 2

Suggested answers

Activity 1 Use the general gas equation (LB page 61)

1. **a)** 108 480 Pa or 108.48 kPa
   b) 560 Pa
2. **a)** 4561.8 K **b)** 332.9 K
3. **a)** 0.054 m^3 **b)** 0.027 m^3

Activity 2 Determine M_r from the general gas equation (LB page 61)

1. 0.390 mol; M_r =133.4 $g.mol^{-1}$
2. **a)** 65.78 mol; M_r = 2.0 $g.mol^{-1}$
   b) Hydrogen gas

Activity 3 Understand real gases (LB page 61)

1. The temperature must be high and the pressure must be low for real gases to approach ideality.
2. The real gas graph deviates from the ideal gas graph more at higher pressures. This is because at high pressure, the gas particles are pushed closer to each other, so their individual volumes are significant in the system. (At low pressures, the particles are so far from each other that their individual volumes are not significant.)

Informal assessment

- Select learners to give their answers to Activities 1 and 2. Ask the rest of the class to compare their answers to these and guide them to a point where everyone agrees about the correct answer.
- Diagnostic activity: Take in the learners' books to mark Activity 3.

Extension

For those learners who need an extra challenge, let them derive the general gas equation mathematically.

Remedial activity

Refer the learners who struggle with the distinction between ideal and real gases to YouTube (www.youtube.com), where they can search for informative lessons and explanations using the search terms "real and ideal gases".

Summary (LB page 62)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This will not only support their study skills, but help consolidate what they have learnt.

Self-assessment (LB page 63)

Note: You could let the learners do this section as self-assessment and then either give them the memorandum to mark their own work or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. A ✓ (1) [K]
3. D ✓ (1) [C]
4. C ✓ (1) [K]
5. B ✓ (1) [K]
6. Real gases do have some attraction between their particles, ✓ and the particles (whether atoms or molecules) do have volume, ✓ and these volumes cannot be ignored. (2) [K]
7. 0.026 mol; ✓✓ 16.98 Pa ✓✓✓ (5) [Ap]
8. 39.91 mol; ✓✓ M_r = 18.0 $g{\cdot}mol^{-1}$ ✓✓✓ (5) [Ap]
9. At high temperatures, the particles have enough energy to overcome the attractive forces between them. ✓ This allows them to behave more like ideal gases, ✓ as the kinetic theory of matter assumes that there are no attractive forces between the particles in ideal gases. ✓ (3) [C]

Total: 20

Theme 2 Physical chemistry

TOPIC 2.1 Chemical energetics

Learner's Book pages 66–81

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand enthalpy change and ΔH and appreciate their applications in chemical reactions • Understand and interpret reaction pathway diagrams • Know Hess's law and apply it in calculations
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning (the role of fossil fuels in climate change)
Inclusive education	Visually impaired learners or learners with physical disabilities may need assistance with handling, setting up and reading laboratory instruments in the experiments.
Suggested teaching time	10 lessons
Additional resources needed (if available)	• Experiment 1 (per pair): 5 g hydrated copper(II) sulfate crystals; test tube rack; test tube; Bunsen burner; test tube clamp; dropper; water • Calculators

Introduction to the topic

This topic revises a number of concepts that the learners were introduced to in Grades 10 and 11, but also introduces a few new, more complex concepts. The new content in Sub-topic 2.1.2 is quite advanced compared to the learners' base knowledge. Teach these new aspects slowly, and give the learners many opportunities to discuss and learn in pairs and groups.

Whereas Theme 1 did not require the learners to do any experiments, Theme 2 does – starting with Topic 2.1. Remind the learners about safety in the laboratory and handling instruments and equipment with respect.

Starter activity (LB page 66)

This starter activity investigates fossil and renewable fuels in terms of their heat contents as a means of linking with the Cross-cutting issue. *Cross-cutting issue*: The Environmental Learning Champion highlights the link between unsustainable use of fossil fuels and climate change.

Suggested answers

1.

Fossil fuel	Heat content ($kJ{\cdot}g^{-1}$)
a) Diesel	C 45
b) Black coal	D 34
c) Natural gas	A 54
d) Brown coal	E 16
e) Petrol	B 48

2.

Renewable fuel	Heat content ($kJ{\cdot}g^{-1}$)
a) Manure	E 12
b) Bioethanol	C 30
c) Gasohol	A 44
d) Biogas	D 26
e) Biodiesel	B 42

3. a) Fossil fuels contain more energy per gram than renewable fuels so that fossil fuels are more powerful fuels by comparison. The renewable fuels are not as energy-rich as fossil fuels, so we need more (by mass) to achieve the same power outputs.

b) Wind, solar and hydropower are the cleanest energy technologies available. We can use these to generate electricity, and use electricity to power vehicles and machines instead of burning fossil fuels.

Sub-topic 2.1.1 Enthalpy change

LB pp. 67–74

Beginning these lessons

This section starts by revising exothermic and endothermic reactions as a lead-in to the key concept of this sub-topic – that of enthalpy. Remind the learners that energy is required to break bonds, while energy is released when new bonds form.

Prior knowledge: endothermic reactions, exothermic reactions, enthalpy, bond energy.

Chemical reactions and energy changes (LB page 67)

Teaching tips

- Let learners, in their pairs, read through and discuss the introductory content in this sub-topic. The learners should be familiar with the concepts of exothermic and endothermic reactions and the examples shown in the Learner's Book as these have been covered in previous grades.
- Let the learners do Experiment 1 to remind them of the difference between exothermic and endothermic reactions. However, only let them do this experiment if there is time.
- Remind the learners that, whereas enthalpy is a quantity (H), we are more interested in the change in enthalpy between the start of a reaction and its completion. This change in enthalpy is represented by ΔH.
- This section then explores the energy changes that take place when a reaction occurs and the types of enthalpy changes. Let the learners study Table 2.1.2 in pairs and find easy ways to distinguish between the different types and commit them to memory.
- Go through the Worked example as a class to remind the learners how to apply the heat energy equation to problems.

Suggested homework activities

Activity 1 Questions 1 and 2, Activity 2 Questions 2. c–d) and Activity 3 Question 2

Suggested answers

Experiment 1 Investigating exothermic and endothermic reactions (LB page 68)

The learners should find that blue copper(II) sulfate crystals turn white when heated and that the crystals turn blue again when water is added to them.

1. The crystals turned white.
2. The heat dehydrated the copper(II) sulfate crystals, so water was released from the crystals.
3. An increase in the temperature of the test tube can be detected.
4. Exothermic: adding water; endothermic: heating over a flame
5. $CuSO_4 + 5H_2O \rightarrow CuSO_4{\cdot}5H_2O$

Activity 1 Understand exothermic and endothermic reactions (LB page 69)

1. a) A reaction that gives off energy in the form of heat
   b) A reaction that takes in energy in the form of heat
2. a) Endothermic b) Exothermic
   c) Endothermic d) Exothermic

Activity 2 Understand types of enthalpy changes (LB page 71)

1. a) Enthalpy: the total heat content of a system
   b) Activation energy: the amount of energy needed for a chemical reaction to start
2. a) Decomposition b) Combustion
   c) Solution d) Neutralisation

Activity 3 Calculate enthalpy changes (LB page 72)

Approximate the mass of water using the density of water (1 $g{\cdot}cm^{-3}$), therefore 250 g in both cases.

1. a) $\Delta H = mc\Delta T$
   $= 250 \times 4.18 \times (60 - 5)$
   $= 57\ 475$ J
   $= 57.475$ kJ
   b) $\Delta H = mc\Delta T$
   $= 250 \times 4.18 \times (95 - 25)$
   $= 73\ 150$ J
   $= 73.150$ kJ
2. $\Delta H = mc\Delta T$
   $= 200 \times 4.18 \times 10$
   $= 8\ 360$ J (or 8.360 kJ)
   $n(C_2H_5OH) = \frac{m}{M_r} = \frac{0.53}{46} = 0.0115$ mol
   Energy per mole $= \frac{8.360}{0.0115} = 726.96\ kJ{\cdot}mol^{-1}$

Informal assessment

- Do spot checks on the pairs of learners as they complete Experiment 1 (including their written answers).
- Ask selected learners to write their answers on the board for Activities 1 and 2, and let the learners mark their own work.
- Diagnostic activity: Take in the learners' books to mark Activity 3.

Bond energy (LB page 72)

Teaching tips

- Although the key concept in this section will be familiar to the learners, teach the section slowly and thoroughly.
- Go through the Worked example as a class to show the learners how to approach bond energy problems.
- Find additional problems (online or in other textbooks) for the learners to solve in pairs.

Suggested homework activities

Activity 4 Questions 2 and 3

Suggested answers

Activity 4 Calculate bond energies (LB page 74)

1. a) Reactants: 436 + 193 = 629 kJ·mol^{-1}
Products: 2(366) = 732 kJ·mol^{-1}
ΔH = 629 – 732 = –103 kJ·mol^{-1}
b) Exothermic

2. a) Reactants: 4(413) + 614 + 2(464)
= 3 194 kJ·mol^{-1}
Products: 346 + 5(411) + 358 + 464
= 3 223 kJ·mol^{-1}
ΔH = 3194 – 3223 = –29 kJ·mol^{-1}
b) Exothermic

3. Reactants: 740 + 2(436) = 1 612 kJ·mol^{-1}
Products: 3(413) + 358 + 464 = 2 061 kJ·mol^{-1}
ΔH = 1 612 – 2 061 = –449 kJ·mol^{-1}

Informal assessment

Let one or two learners volunteer to write their calculations on the board, and let the rest of the class assess this and compare the answers with their own.

Sub-topic 2.1.2 Hess's law

LB pp. 75–79

Beginning these lessons

This sub-topic covers quite a lot of new content. Follow the content (text, diagrams and Worked examples) in the Learner's Book closely as you teach. *New concepts*: Hess's law, energy cycles, activated complex.

Hess's law and the conservation of energy (LB page 75)

Teaching tips

- Use Figure 2.1.7 to help explain Hess's law. Enlarge the diagram on the board, so that the learners can refer to it as they listen.
- Go through the steps and Worked example to introduce and consolidate simple energy cycles.
- Let learners work through the next Worked example (regarding other calculations with Hess's law) in pairs and then answer any questions they may have.
- Show the learners the suggested online lesson (in On the Internet note), if possible.

Suggested homework activities

Activity 5 and Activity 6 Question 3

Suggested answers

Activity 5 Use energy cycles to calculate enthalpy changes (LB page 77)

Learners should draw the energy cycle diagram, and perform the calculation as follows:
2(−951) − 1 132 + ΔH = −393.5 − 285.5
ΔH = −393.5 − 285.5 + 2(951) + 1 132
= 2 355 kJ·mol^{-1}

Activity 6 Use Hess's law (LB page 78)

1. Multiply the first equation by 2 to get 2C(*s*) on the reactant side:
$2C(s) + 2O_2(g) \rightarrow 2CO_2(g)$, ΔH = –787.0 kJ·mol^{-1}
Flip the second equation around
$2CO_2(g) \rightarrow 2CO(g) + O_2(g)$, ΔH = +566.0 kJ·mol^{-1}

$2C(s) + 2O_2(g) \rightarrow 2CO_2(g)$, ΔH = –787.0 kJ·mol^{-1}
$2CO_2(g) \rightarrow 2CO(g) + O_2(g)$, ΔH = +566.0 kJ·mol^{-1}

$2C(s) + O_2(g) \rightarrow 2CO(g)$, ΔH = –221.0 kJ·mol^{-1}

2. Flip the first equation around, multiply it by 3 and divide it by 2:
$3NO_2(g) \rightarrow 3NO(g) + \frac{3}{2}O_2(g)$, $\Delta H = +116$ kJ
Divide the second equation by 2:
$N_2(g) + \frac{5}{2}O_2(g) + H_2O(l) \rightarrow 2HNO_3(aq)$,
$\Delta H = -128$ kJ
Flip the third equation:
$2NO(g) \rightarrow N_2(g) + O_2(g)$, $\Delta H = -183$ kJ
Add the three together:
$3NO_2(g) + H_2O(l) \rightarrow NO(g) + 2HNO_3(aq)$
$\Delta H = 116 + (-128) + (-183)$
$= -195$ kJ

3. Leave the first equation, flip the second and multiply the third by $\frac{3}{2}$:
$2Fe(s) + 6H_2O(l) \rightarrow 2Fe(OH)_3(s) + 3H_2(g)$,
$\Delta H = +324$ kJ
$2Fe(OH)_3(s) \rightarrow Fe_2O_3(s) + 3H_2O(l)$, $\Delta H = -285$ kJ
$3H_2(g) + \frac{3}{2}O_2(g) \rightarrow 3H_2O(g)$, $\Delta H = -852$ kJ
$2Fe(s) + \frac{3}{2}O_2(g) \rightarrow Fe_2O_3(s)$, $\Delta H = -813$ kJ

Informal assessment

- Write the answer to Activity 5 on the board and let the learners mark their own work.
- For Activity 6, ask selected learners to write their calculations and answers on the board to serve as a memorandum for the rest of the class to mark their own work.

Reaction pathway diagrams

(LB page 78)

Teaching tips

- If possible, revise the work done in Topic 2.1 regarding activation energy and diagrams that show how a reaction proceeds from reactants to products.
- Introduce the new concept "activated complex" and refer to Figures 2.1.8 and 2.1.9 as you teach.
- Treat Activity 7 as a diagnostic assessment task to see whether all learners have consolidated the new content in this sub-topic.

Suggested homework activities

Activity 7 Question 2

Suggested answers

Activity 7 Interpret reaction pathway diagrams **(LB page 79)**

1. a)	Incorrect	**b)**	Correct
c)	Incorrect	**d)**	Correct
2. a)	44 kJ	**b)**	−18 kJ
c)	Activated complex	**d)**	HF
e)	62 kJ		

Informal assessment

Diagnostic activity: Take in the learner's books to mark Activity 7. Assess which learners need remedial assistance and arrange for peer learning, group-learning or one-on-one teaching (by you), if necessary.

Extension

For those learners who need an extra challenge, let them search for problems on Hess's law by typing the following in their web browser: "Hess's Law probs site:uscupstate.edu". They can work through these either individually or in pairs.

Remedial activity

Refer the learners to the following web page that can be found by typing in "Hess' law site:chemteam.info" in the web browser. Learners can work through the problems in pairs or groups. Each solution is provided, along with a strategy or steps that show exactly how the answer was obtained.

Summary (LB page 80)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 81)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. D ✓ (1) [K]
2. D ✓ (1) [K]
3. B ✓ (1) [K]
4. C ✓ (1) [C]
5. The total enthalpy change of a chemical reaction remains that same regardless of the route that the chemical change takes ✓ – as long as the initial and the final conditions of the reaction remain the same. ✓ (2) [K]
6. The standard enthalpy change of a reaction is the enthalpy change that occurs when set numbers of moles of reactants ✓ react under standard conditions. ✓
   Accept any ONE of the following standard conditions:
   - Temperature: 298 K (25 °C)
   - Pressure: 1 atmosphere (approximately 100 kPa)
   - Concentration in volume of solution: 1 mol dm^{-3} ✓ (3) [K]
7. $\Delta H_f = +21.75$ kJ·mol^{-1} ✓✓ (2) [C]
8. $\Delta H = -2\ 429.3$ kJ ✓✓ (2) [C]
9. $\Delta H = mc\Delta T$
   $= 75 \times 4.18 \times 9.7$ ✓
   $= 3\ 040.95$J (or 3.04095 kJ) ✓
   $n(CuSO_4) = \frac{m}{M_r} = \frac{16}{159.6} = 0.1002$ ✓
   Therefore, energy per mole $= \frac{3.04095}{0.1002}$ ✓
   $= 30.35$ kJ·mol^{-1} ✓
   (5) [Ap]
10. a) Reactants: $436 + 240 = 676$ kJ·mol^{-1} ✓
    Products: $2(433) = 866$ kJ·mol^{-1} ✓
    Difference $= 676 - 866 = -190$ kJ·mol^{-1} ✓
    (3) [C]
    b) Exothermic ✓ (1) [K]
11. Flip the first equation and multiply it by $\frac{3}{2}$, divide the second equation by 2 and flip the third equation:
    $3NO_2(g) \rightarrow 3NO(g) + \frac{3}{2}O_2(g)$, ✓ $\Delta H = +168$ kJ ✓
    $N_2(g) + \frac{5}{2}O_2(g) + H_2O(l) \rightarrow 2HNO_3(aq)$, ✓
    $\Delta H = -130.5$ kJ ✓
    $2NO(g) \rightarrow N_2(g) + O_2(g)$, ✓ $\Delta H = -185$ kJ ✓

    $3NO_2(g) + H_2O(l) \rightarrow NO(g) + 2HNO_3(aq)$, ✓
    $\Delta H = 147.5$ kJ ✓ (8) [Ap]

Total: 30

TOPIC 2.2 Electrochemistry

Learner's Book pages 82–93

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Know redox processes and apply them in calculation of oxidation numbers and in balancing chemical equations • Understand electrolysis and its application
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology (the role of redox reactions in batteries for digital devices)
Inclusive education	Learners with learning difficulties are likely to struggle with the new concepts in this topic. Plan to allow these learners to work at a slower rate, or with the help of another learner or yourself when appropriate.
Suggested teaching time	7 lessons
Additional resources needed (if available)	• Experiment 1 (per pair): test tube rack; 6 × test tubes with stoppers; 2 × droppers; 3 × unidentified solutions (A = water, B = potassium manganate(VII) solution and C = potassium iodide solution) to be tested; aqueous potassium; iodide solution; acidified potassium; manganate solution (Note that if it is not possible for the learners to complete this experiment due to lack of resources, find the same experiment on www.youtube.com to show the learners instead.) • Calculators

Introduction to the topic

This topic revises a number of concepts that will be familiar to the learners from Grades 10 and 11, but also introduces a few new, more complex concepts – including how to balance redox reactions using oxidation numbers, a basic introduction to testing for oxidising and reducing agents, and the selective discharge of ions. The learners will need a solid prior knowledge on redox reactions, the names of oxyanions and electrolysis.

Closely monitor the learners' progress through this topic, and determine where the learners' prior knowledge is lacking. Provide the opportunities for these learners to revise before continuing.

Starter activity (LB page 82)

This starter activity revises some concepts from Grades 10 and 11, but combines them with an interesting aspect of ITC to link the content to the champion's speech.

Cross-cutting issue: The Information and Communication Technology Champion points out that oxidation–reduction reactions play a critical part in powering digital devices such as smartphones, laptops and tablets.

Suggested answers

1. a) $CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$

b) $LiC_6 \rightarrow C_6 + Li^+ + e^-$

2. Reduction and oxidation in terms of oxygen:
- Oxidation is the gain of one or more oxygen atoms.
- Reduction is the loss of one or more oxygen atoms.

Reduction and oxidation in terms of electron exchange:
- Oxidation is the loss (donation) of one or more electrons.
- Reduction is the gain (acceptance) of one or more electrons.

3. This question is for enrichment purposes only. It only applies if the learners have access to the Internet in their classrooms (or after school, for a homework task). A lithium ion battery contains a liquid electrolyte, which can store large amounts of energy. A solid-state battery contains a solid electrolyte, that cannot store the same amounts of energy, but which can be recharged must faster and have a much longer life span than lithium ion batteries.

Sub-topic 2.2.1 Redox processes

LB pp. 83–87

Beginning these lessons

Revise as much work from Grades 10 and 11 about oxidation–reduction reactions and balancing equations as possible. Make use of the summarised content in the Learner's Book as a way to assess whether all the learners' prior knowledge is complete. *Prior knowledge*: redox reactions (in terms of electron exchange and oxygen), oxidation numbers, balancing chemical equations.

Redox reactions: Revision: Oxidation numbers (LB pages 83–84)

Teaching tips

- Using the introductory (revision) content provided as a checklist of concepts that the learners should know by now, ask selected learners to recall definitions and facts, or explain certain concepts. Let the rest of the class assess the learners' answers.
- Go through the rules for assigning oxidation numbers with the class. Do a few examples on the board after letting the learners go through the Worked example in pairs.
- Go through the steps involved in determining which species in a redox reaction is oxidised and which is reduced. Let the learners work through the Worked example, but then provide additional examples for selected learners to solve on the board.
- Teach the learners how to use oxidation numbers to balance redox reaction equations using the steps provided and the Worked example.
- Finally, go through the oxyanion-naming content, and let the learners find creative ways of committing these rules and names to memory.

Suggested homework activities

Activity 1 Question 2, Activity 2 Questions 2 and 3, and Activity 3 Questions 4 and 5

Suggested answers

Activity 1 Assign oxidation numbers (LB page 84)

1. a) C = +4, O = −2
b) K = +1, Mn = +7, O = −2
c) Na = +1, Cl = −1
d) Mg = +2, O = −2, H = +1)

2. a) N = +5 **b)** Ba = +2
c) P = −3 **d)** Na = +1

Activity 2 Use oxidation numbers to balance equations (LB page 86)

1. $Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$
2. $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$
3. $4NH_3(g) + 5O_2(g) \rightarrow 4NO_2(g) + 6H_2O(g)$

Activity 3 Name oxyanions (LB page 87)

1. phosphate
2. chromate
3. iodate
4. phosphite
5. perbromate
6. sulfite

Informal assessment

- For Activity 1, ask selected learners to write their answers on the board as a memo for the rest of the class to mark their own work.
- For Activity 2, ask selected learners to give their answers, and let the rest of the class assess their answers.
- For Activity 3, write the answers on the board and let the learners mark their own work.

Testing for oxidising and reducing agents (LB page 87)

Teaching tips

- The focal point of this lesson is on the experiment (Experiment 1).
- Go through the tests for oxidising and reducing agents (as shown in the text) very briefly, and then let the learners perform the experiment in pairs.
- For the experiment, you will need to supply each pair of learners with the following, unlabelled solutions:
- A: water
- B: potassium manganate(VII) solution
- C: potassium iodide solution

Suggested homework activities

Experiment 1 Questions 1 and 2

Suggested answers

Experiment 1 Testing for oxidising and reducing agents (LB page 87)

1. A contained neither; B contained an oxidising agent; C contained a reducing agent
2. **a)** C **b)** B **c)** A

Informal assessment

- Walk around the class as the learners conduct the experiment. Ask questions and be prepared to answer questions the learners may have. Gauge how well they have applied the theoretical (the rules in the Learner's Book) to the practical work that they are doing.
- For the answers, ask selected learners to write their answers on the board to serve as a memorandum for the rest of the class.

Sub-topic 2.2.2 Electrolysis

LB pp. 88–91

Beginning these lessons

Revise the work done in Grades 10 and 11 regarding electrolysis very briefly before starting this lesson.
Prior knowledge: electrolysis, anode, cathode, oxidation, reduction, half equation.
New concepts: selective discharge.

Electrolysis revision (LB page 88)

Teaching tips

- Use the text and Figure 2.2.5 on pages 88 and 89 to revise the basics from Grades 10 and 11.
- Let learners go through the factors that influence selective discharge of an ion in pairs. Thereafter, give the learners (as a class) some scenarios in which they have to apply what they have read about.
- Ask random learners to tell the rest of the class what they remember from previous grades regarding the electrolysis and refining of metals.
- Go through the sections on the extraction of copper and manganese.
- Lastly, go through the section about half equations and overall equations. Let the learners self-study this content, and then practise these skills in Activity 5.

Suggested homework activities

Activity 4 Question 3 and Activity 5 Question 2

Suggested answers

Activity 4 Identify products of selective discharge (LB page 90)

1. **a)** chlorine gas **b)** hydrogen gas
2. **a)** oxygen gas **b)** hydrogen gas
3. **a)** chlorine gas **b)** copper metal

Activity 5 Write half equations and overall equations (LB page 91)

1. **a)** **i)** $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
   ii) $Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$
   b) **i)** $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
   ii) $I_2(s) + 2e^- \rightarrow 2I^-(aq)$
2. Oxidation: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$
   Reduction: $Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$
   $2Cl^-(aq) + Mg^{2+}(aq) + 2e^- \rightarrow Cl_2(g) + 2e^- + Mg(s)$

Informal assessment

- Let the learners volunteer an answer (each) to Activity 4, for the rest of the class to assess.
- Ask selected learners to write their answers to Activity 5 on the board to serve as a memorandum for the rest of the class to mark their own work.

Extension

For those learners who need an extra challenge, let them use other textbooks, resource books at a library or the Internet to set up a few test questions on using oxidation numbers to balance equations. Let them distribute their test among the other learners in this group, and see who can complete all the tests correctly.

Remedial activity

Refer the learners who are still not confident in balancing equations to tutorials on the Internet, which can explain the process in a step-by-step manner (that is often animated). Let them search for appropriate tutorials on YouTube (www.youtube.com) or elsewhere.

Summary (LB page 92)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 93)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]

2. D ✓ (1) [K]

3. A ✓ (1) [C]

4. C ✓ (1) [K]

5. A ✓ (1) [K]

6. If the oxidation number of a compound, atom or ion increases from the left to the right ✓ of the reaction, it has been oxidised. ✓ If the oxidation number of a compound, atom or ion decreases from the left to the right of the reaction, ✓ it has been reduced. ✓ (4) [K]

7. a) Na = +1, ✓ Cr = +6, ✓ O = −2 ✓ (3) [Ap]

b) Mg = +2, ✓ C = +4, ✓ O = −2 ✓ (3) [Ap]

8. MnO_4^- ✓ + $2H_2O$ ✓ + Al ✓ → $Al(OH)_4^-$ ✓ + MnO_2 ✓ (5) [C]

9. a) Electrolysis is the breaking down of ionic substances into their component ions by passing an electrical current through the substance (either in solution or in its molten state). ✓ (1) [K]

b) $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ ✓✓ (2) [C]

c) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ ✓✓ (2) [C]

Total: 25

TOPIC 2.3 Equilibria

Learner's Book pages 94–107

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand reversible reactions, dynamic equilibrium and Le Chatelier's principle • Understand equilibrium constants and apply them in calculations • Understand the application of chemical equilibria in the Haber and Contact processes • Understand ionic equilibria in acids and bases
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Human rights and democracy (the role of fertilisers in the context of commercial farming, for food security and the right to food)
Inclusive education	• Visually impaired learners will need help interpreting the explanatory diagrams in this topic. Enlarge the diagrams on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learner. • Visually impaired learners or learners with physical disabilities may need assistance with handling, setting up and reading laboratory instruments in the experiments.
Suggested teaching time	8 lessons
Additional resources needed (if available)	• Experiment 1 (per pair): 2 × sealed NO_2 gas equilibrium tubes; 2 × large beakers; water; ice; hot plate (Note that if it is not possible for the learners to complete this experiment due to lack of resources, find the same experiment on www.youtube.com to show the learners instead.) • Calculators • *Low-cost resource:* See the "On the Internet" note on LB page 98.

Introduction to the topic

The learners were introduced to chemical equilibria in Grades 10 and 11, so they should be familiar with the terms and concepts involved. In this topic, the focus moves away from descriptive language to practical and industrial applications, as well as calculating equilibrium constants. Sub-topic 2.3.1 revisits acids and bases, but with greater emphasis on mathematical calculations.

Starter activity (LB page 94)

This starter activity revises some work on reaction rates and acids and bases.
Cross-cutting issue: The Human Rights and Democracy Champion highlights the human right to food and the issue of food security in the context of large-scale commercial farming (and its reliance on synthetic fertilisers).

Suggested answers

1. **a)** Learners may state any relevant ideas, such as the use of a catalyst, increasing the temperature at which the reaction proceeds, and so forth.
   b) If we know the rate of reaction, we can determine the output per time unit and extrapolate for hours, days, weeks, and so on to determine what a production plant's monthly or annual output will be.
2. **a)** $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
   b) $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$
   c) $H_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow BaSO_4(aq) + 2H_2O(l)$
3. **a)** 2–4 **b)** 4–6 **c)** 7

Sub-topic 2.3.1 Chemical equilibria

LB pp. 95–102

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about reversible reactions, Le Chatelier's principle, the Haber and contact processes. The new concepts that are introduced require a good understanding of mathematical principles and insight regarding the meaning of calculated answers.

Prior knowledge: reversible reactions, Le Chatelier's principle, the Haber–Bosch process, the contact process.
New concepts: equilibrium constants of concentration and pressure.

Reversible reactions (LB page 95)

Teaching tips

- Using the content provided as a checklist of concepts that the learners should know by now, ask selected learners to recall definitions and facts, or explain what they see in Figure 2.3.1. Let the rest of the class assess the learners' answers.
- Briefly revise Le Chatelier's principle, and let learners study Table 2.3.1 in pairs before they complete Activity 1 individually.

Suggested homework activities

Activity 1 Questions 2 and 3

Suggested answers

Activity 1 Understand Le Chatelier's principle (LB page 97)

1. a) Equilibrium shifts to the left.
b) Equilibrium shifts to the right.
2. a) It decreased.
b) It stayed the same.
3. a) Incorrect **b)** Correct
c) Incorrect

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 1. Note which learners show signs of not understanding the basics from Grades 10 and 11, and do additional revision with them before moving on to the next sub-topic.

Industrial reactions and Le Chatelier's principle (LB page 97)

Teaching tips

- Depending on how much of Grade 11's coverage of the Haber–Bosch and contact processes the learners can recall, do some basic revision with them regarding the basic steps of the processes, and the ideal conditions.
- In this section of the sub-topic, the learners are expected to apply what they know about Le Chatelier's principle to explain why the specific conditions for the two processes were chosen.
- Let learners study the tables and text on pages 97 to 99 of the Learner's Book in pairs.

Suggested homework activities

Activity 2 Question 2

Suggested answers

Activity 2 Understand reversible industrial processes (LB page 99)

1. a) Haber process; iron
b) 400–500 °C; Below this temperature range, the forwards reaction is favoured, but the reaction does not proceed at a rate high enough for industrial production of ammonia.
Within this temperature range, the catalyst that is used in the reaction (iron) works effectively.
Above this temperature range, the equilibrium shifts to favour the reverse reaction.
c) Ammonia has a lower condensation point than the other gases in the reaction vessel. So, when the gas mixture leaves the heated reaction vessel, all the gases cool down. When the temperature of the gases reaches that of the condensation point of ammonia, the ammonia liquefies making it easy for it to be separated from the rest of the gases.
2. a) Since this reaction is exothermic, by increasing the temperature, the equilibrium will shift to the left (to favour the endothermic reaction).
b) There are three gas molecules on the left and two on the right, so by decreasing the pressure, the equilibrium will shift to the left.
c) Removal of sulfur trioxide would shift the equilibrium to the right to encourage its production, even though this is not done in practice.

Informal assessment

If the learners complete this activity in class, walk around the classroom as they work and do spot checks on selected learner's books. Ask other learners to read out their answers. Simply check that they all understand the fundamental concepts of this section of work, and that they are able to communicate their knowledge in writing.

Equilibrium constants (LB page 100)

Teaching tips

- In this section of the sub-topic, the learners are introduced to the concept of equilibrium constants.
- Let pairs or groups of learners replicate the mathematical derivation of the equilibrium constant of concentration's expression.
- Teach the learners about partial pressures, and show them how the equilibrium constant of pressure's expression is used, by going through the Worked example.
- Let the learners do Experiment 1 if there is time.

Suggested homework activities

Activity 3 Question 4

Suggested answers

Activity 3 Solve problems with equilibrium constants (LB page 102)

1. Correct
2. $K_p = \frac{(pO_2)(pNO_2)^4}{(pN_2O_5)^2} = 0.435$
3. $[CO_2] = 3.41\ mol{\cdot}dm^{-3}$
4. $[NH_3] = 0.21\ mol{\cdot}dm^{-3}$

Experiment 1 Demonstrate the effect of temperature on an equilibrium system (LB page 102)

1. In the tube that was in the ice water.
2. The colour of the gas in the heated tube is darker than that of the other gas. The heated tube contains NO_2, because heat will shift the equilibrium in favour of this gas.

Informal assessment

- For Activity 3, let some learners write their answers on the board, and let the rest of the class assess and compare.
- For Experiment 1, walk around the classroom as the learners work, and do spot checks on their experiment set ups and answers.

Sub-topic 2.3.2 Ionic equilibria

LB pp. 103–105

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about the various theories of acids and bases. The new content in this sub-topic introduces the learners to calculations involving pH and concentrations of acids and alkalis.
Prior knowledge: Brønsted–Lowry theory, amphoteric substances, strengths of acids and bases, pH.
New concepts and skills: conjugate pairs, calculations with pH-values.

The Brønsted–Lowry theory of acids and bases (LB page 103)

Teaching tips

- Ask random learners to answer spot questions, to assess their basic comprehension of the introductory concepts (such as what the Brønsted–Lowry theory tells us, what amphoteric substances are, and so forth).
- Show how a typical acid–base reaction can be separated into conjugate pairs, as shown in Figure 2.3.7 in the Learner's Book.

Suggested homework activities

Activity 4 Question 2

Suggested answers

Activity 4 Understand Brønsted–Lowry acids and bases (LB page 104)

1. **a)** Cl^- **b)** H_3O^+
2. Conjugate pair I (acid I base I): CH_3COOH and CH_3COO^-
   Conjugate pair 2 (acid II base II): NH_3 and NH_2^-

Informal assessment

For Activity 4, ask selected learners to write their answers on the board to serve as a memorandum for the rest of the class to mark their own work.

Strengths of acids and bases

(LB page 104)

Teaching tips

- Go through the colour-coded informative boxes, text and Worked examples with the learners.
- As you teach, ask spot questions to gauge the learners' comprehension.
- Give the learners additional pH calculation problems to solve on the board.

Suggested homework activities

Activity 5 Questions 1. b) and 2. b)

Suggested answers

Activity 5 Calculate pH-values and concentrations (LB page 105)

1. a)	pH = 0.7	**b)**	pH = 11.7
2. a)	0.3 mol dm^{-3}	**b)**	0.005 mol dm^{-3}

Informal assessment

For Activity 5, write the answers on the board and let learners swap books so that they can mark each other's work.

Extension

Let the learners write a short research report on one of the industrial processes discussed in this topic. Their reports should include:

- A short historical account of how the process was developed
- Who the key people involved in the development were
- The basic steps of the process
- The ideal conditions required for the process.

Remedial activity

Let the learners who need additional help with the new (theoretical) concepts in this topic form study groups so that they can revise the more difficult concepts and mathematical derivations. Help them find online resources and exercises from other Chemistry textbooks to complete as a group.

Summary (LB page 106)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 107)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. D ✓ (1) [K]
3. D ✓ (1) [K]
4. A ✓ (1) [K]
5. C ✓ (1) [K]
6. a) The rate will decrease. ✓ The particles have less kinetic energy resulting in fewer effective collisions. ✓ (2) [C]
b) The amount would decrease. ✓ (1) [An]
c) The amount would decrease. ✓ (1) [An]
7. a) The increased pressure will:
- increase the rate of the reaction ✓
- shift the equilibrium position to the right ✓
- increase the yield of SO_3 gas. ✓ (3) [Ap]

b) The increased temperature will:
- increase the rate of both the forward and reverse reactions ✓
- shift the equilibrium position to the left ✓
- decrease the yield of SO_3 gas. ✓ (3) [Ap]

8. $K_p = \frac{(pNH_3)^2}{(pN_2)(pH_2)^3}$ ✓✓ (2) [C]

9. $K_c = \frac{[C]}{[A][B]^2} = 2.5$ ✓

$\frac{[C]}{(0.1)(0.05)^2} = 2.5$ ✓

$[C] = 0.000625\ mol{\cdot}dm^{-3}$ ✓✓ (4) [Ap]

10. H_3PO_4 = acid I, $H_2PO_4^-$ = base I; ✓
H_2O = base II, H_3O^+ = acid II ✓ (2) [C]

11. $pH = -\log[H_3O^+] = -\log(1.13 \times 10^{-3})$ ✓
$= 2.95$ ✓ (2) [Ap]

Total: 25

TOPIC 2.4 Reaction kinetics

Learner's Book pages 108–123

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Know rates of reactions and how concentration affects rate of reaction • Understand how temperature affects rates of reactions • Understand homogeneous and heterogeneous catalysts including enzymes and their applications
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning (the role of enzymes in the production of biofuels)
Inclusive education	Visually impaired learners will need help interpreting the various graphs and diagrams in this topic. Enlarge the graphs on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learner.
Suggested teaching time	9 lessons
Additional resources needed (if available)	• Experiment 1 (per pair): 4 × test-tubes; pipette; water bath (or any large waterproof container); thermometer; stopwatch; 1 $mol{\cdot}dm^{-3}$ hydrochloric acid; magnesium ribbon • Experiment 2 (per pair): filtering flask with stopper (Buchner flask); string or thread; test tube; delivery tubes; large beaker; water; hydrogen peroxide; manganese oxide; stopwatch; measuring cylinder

Introduction to the topic

In this sub-topic, the learners revise reaction rates, collision theory, catalysts and enzymes, and springboard from this familiar territory to understand some applications and mathematical functions.

Starter activity (LB page 108)

This starter activity revises key concepts from Grades 10 and 11 regarding rates of reactions.
Cross-cutting issue: The Environmental Learning Champion highlights the fact that the production of biodiesel requires an enzyme catalyst, as a way of introducing new content to the learners in an accessible and practical manner.

Suggested answers

1. **a)** Learners' own responses. The learners must provide examples from everyday life, such as:
   a) the ignition of fuel in a vehicle's engine
   b) frying an egg
   c) baking **d)** rusting
2. Learners can mention and discuss any of the following: concentration, pressure, temperature, surface area, using a catalyst, light (for photochemical reactions), using enzymes.

Sub-topic 2.4.1 Rates of reactions

LB pp. 109–111

Beginning these lessons

Start this sub-topic off by discussing the photographs on page 109 of the Learner's Book. Use this as a way to remind the learners what they covered in previous grades regarding rates of reactions.
Prior knowledge: rates of reactions, collision theory, the effect of concentration on the rate of a reaction.

Reaction rates (LB page 109)

Teaching tips

- Emphasise that the rate of reaction formula is not a single formula, but rather a collection of formulas that can all indicate speed using different measurable variables.
- The collision theory is used to explain why increasing factors such as surface area, temperature and concentration will increase the rate of a reaction.
- Work through the Worked examples as a class, and ask the learners to calculate and check each step of the calculations.
- Let the learners read through the rest of this sub-topic individually or in pairs.

Suggested homework activities

Activity 1 Questions 3 and 4

Suggested answers

Activity 1 Explain the effect of concentration on reaction rates (LB page 111)

1. The rate of any reaction is the speed at which reactants are used up, or products are formed.
2. Rate of reaction $= \frac{\Delta c}{\Delta t}$
   $= \frac{0.65 - 0.1}{40 - 5}$
   $= 0.016 \text{ mol·dm}^{-3}\text{·s}^{-1}$
3. Rate of reaction $= \frac{-\Delta c}{\Delta t}$
   $= -(\frac{0.006 - 0.023}{500 - 200})$
   $= 5.67 \times 10^{-5} \text{ mol·dm}^{-3}\text{·s}^{-1}$
4. The particles of the reacting substances in a reaction will collide more often if there are more of them in a given volume. So, the frequency at which particles collide increases with increased concentration of particles.

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 1. Make sure that all the learners are confident in working with these equations and calculations before moving on to the next sub-topic.

Sub-topic 2.4.2 The effect of temperature on reaction rates and the concept of activation energy

LB pp. 112–114

Beginning these lessons

Start this sub-topic off by revising activation energy from Topic 2.1. This serves as a good introduction to the new concepts that will be discussed.
New concepts: Maxwell–Boltzmann distribution, the effect of temperature on reaction rates.

Activation energy: The Maxwell–Boltzmann distribution (LB page 112)

Teaching tips

- Teach the new content in this lesson slowly and thoroughly. It is important that the learners grasp what the distribution curves represent, and that they can interpret these graphs accurately.
- Refer to Figures 2.4.5 and 2.4.6 as you teach. Point out the differences between the two graphs in Figure 2.4.6 on page 113 of the Learner's Book.
- Let the learners do Experiment 1 to remind them of the effect of temperature on reaction rate.

Suggested homework activities

Activity 1 Questions 1 and 2, Activity 2 Questions 2. c) and Activity 3 Question 2

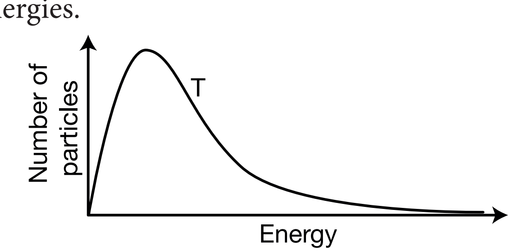
Suggested answers

Experiment 1 Investigate the effect of temperature on reaction rate (LB page 114)

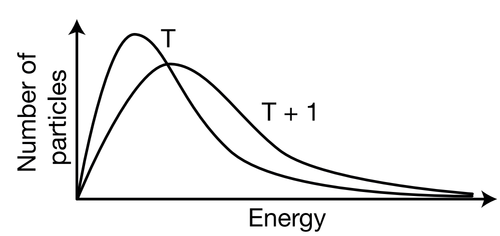
Conclusion: The rate of reaction is dependent on the temperature: the higher the temperature, the faster the rate of reaction.

Activity 2 Explain and use Boltzmann distributions (LB page 114)

1. The Boltzmann distribution is a curved graph that describes the range of speeds or kinetic energies of a mass of particles. The area under the graph represents the number of particles. The majority of particles have an intermediate kinetic energy, whereas small numbers of particles have very high or very low kinetic energies.
2. a)



b)



c) The number of particles with sufficiently high energy (greater than the activation energy) is shown by the area under the graph to the right of the point that represents the activation energy. Since the distribution for the higher temperature is almost twice the value of the original temperature's distribution at the point represented by the activation energy, the number of particles that have more energy than the required activation energy doubles. Note that this is the only area on the graph where the new graph is almost twice as high as the original graph – at all other points on the graphs, the difference between the two is minimal.

Informal assessment

- Do spot checks on the pairs of learners as they complete Experiment 1 (including their written conclusions).
- Diagnostic activity: Take in the learners' books to mark Activity 2.

Sub-topic 2.4.3 Homogeneous and heterogeneous catalysts LB pp. 115–120

Beginning these lessons

Remind the learners about what catalysts are, as they learnt about catalysts and inhibitors in Grade 11. Introduce the content in this sub-topic by explaining to the learners that there are different types and categories of catalysts.
New concepts: positive catalyst, negative catalyst, homogenous catalyst, heterogeneous catalyst, reaction intermediates.

Catalysts (LB page 115)

Teaching tips

- Define positive and negative catalysts, and emphasise the examples that are given in the Learner's Book.
- Explain that catalysts are also categorised according to the phase in which they and the reacting substances are in. Define homogeneous and heterogeneous catalysts using the text in the Learner's Book.
- Let learners study Figure 2.4.7 in pairs to understand the role of chlorine in the decomposition of ozone in the ozone layer.
- Go through the section on catalyst reaction mechanisms, and emphasise the steps using Figures 2.4.8 and 2.4.9 in the Learner's Book to illustrate as you teach.
- Let the learners do Experiment 2 if there is time.

Suggested homework activities

Activity 3 Question 2 (see Extension activity below) and Experiment 2 Questions 1 and 2

Suggested answers

Activity 3 Understand catalysts (LB page 117)

1. A homogeneous catalyst is a catalyst that is in the same phase as the reactants. In other words, all the reactants and the catalyst are either all in the liquid state or gas state in a solution. A heterogeneous catalyst is a catalyst that is not in the same phase as the reactants.
2. Learners must research any applicable homogeneous and heterogeneous catalysts that are used in industrial or commercial applications, and write a short report.

Experiment 2 Investigate the effect of a catalyst on reaction rate (LB page 118)

1. Learners plot graphs of their experimental results.
2. The decomposition of hydrogen peroxide is faster in the presence of the catalyst, manganese oxide.

Activity 4 Understand the effects of catalysts (LB page 118)

1. Homogeneous (all the reactants, products and the catalyst itself are in the aqueous phase)
2. The reaction would need a collision between two negative ions, which repel each other.
3. The persulfate ions oxidise the iron(II) ions to iron(III) ions, and are themselves reduced to sulfate ions. The iron(III) ions oxidise the iodide ions to iodine, and are themselves reduced back to iron(II) ions, which regenerates the catalyst.
   $2Fe^{2+}(aq) + S_2O_8^{2-}(aq) \rightarrow 2Fe^{3+}(aq) + 2SO_4^{2-}(aq)$
   $2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$

Informal assessment

- Let the learners volunteer an answer (each) to Activities 3 and 4, for the rest of the class to assess.
- Take in the learner's books to mark their answers for Experiment 2.

Enzymes (LB page 119)

Teaching tips

- Remind the learners about what they learnt in Grade 11 regarding enzymes.

- Teach this section slowly and thoroughly – particularly for the benefit of those learners who do not have a background in Biology. For their benefit, explain the phenomenon of lactose-intolerance in the following way:
  Some people's bodies do not make enough lactase so that they struggle to digest milk products. We say they are lactose intolerant. Instead of lactose being broken down into glucose and galactose, it ferments in the large intestine of lactose-intolerant people.
  Today, dairy producers add lactose to dairy products so that people who are lactose-intolerant can enjoy lactose-free dairy products.
- Let learners refer to Figure 2.4.11 as they read through the steps of the enzyme mechanism and the characteristics of enzymes described in the Learner's Book in their pairs.
- Go through the section on the factors that affect enzyme activity as a class, and ask selected learners to explain the effects of each of the changes, so that you can gauge how well they have understood.

Suggested homework activities

Activity 5 Question 2

Suggested answers

Activity 5 Understand enzymes (LB page 120)

1. a) An enzyme is a substance that is produced by a living thing and which acts as a biological catalyst in biochemical reactions.
   b) An active site is an area on the surface of an enzyme that binds to a substrate during a reaction.
   c) Specificity is the ability of an enzyme to bind with a particular substrate in a reaction.
2. a) In an acidic environment, the hydrogen bonds within the enzyme may be broken. This leaves the enzyme denatured (that is, unable to function as an enzyme, as it cannot bind to the substrate).
   b) At temperatures above 40 °C, the atoms which make up the enzyme molecules vibrate more violently. Eventually, this overpowers the forces that hold the atoms in place in the molecules, and the enzyme's active site loses its shape. The enzyme is said to become denatured and loses its catalytic activity forever.

Informal assessment

Let selected learners read out one of their answers to Activity 5 for the rest of the class to assess, and to correct if necessary.

Extension

1. Let the learners do some research online or at a library regarding one of the following industrial catalysts:
   - Aluminosilicates (used in cracking long-chain hydrocarbons)
   - Platinum and alumina (used in the dehydrogenation of butane into butene).
2. You could treat Activity 3 Question 2 as an extension or research project for the whole class.

Remedial activity

A number of concepts and processes in this topic may prove difficult for some learners to grasp immediately. Refer those learners to the following online tutorials on www.youtube.com or to others that you have found yourself:
"Chemical equilibria and reaction quotients" by professor Dave.
"Maxwell–Boltzmann distributions" by Advanced Chemistry.

Summary (LB page 121)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 122)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. D ✓ (1) [K]
2. D ✓ (1) [K]

3. C ✓ (1) [K]
4. C ✓ (1) [K]
5. A ✓ (1) [K]
6. D ✓ (1) [K]
7. A ✓ (1) [K]

8. a) The rate of a reaction is the speed at which reactants are used up, or products are formed. ✓ (1) [K]

b) Accept any three relevant factors, such as concentration, pressure, particles size, temperature, the use of a catalyst, and so forth. ✓✓✓ (3) [K]

c) Rate of reaction $= -\frac{\Delta c}{\Delta t}$ ✓

$= -\frac{0.45 - 0.5}{0.1}$ ✓

$= 0.5\ \text{mol·dm}^{-3}\text{·s}^{-1}$ ✓(3) [Ap]

9. a) The catalyst provides an alternative route/mechanism for the reaction, which lowers the activation energy, to make the reaction more efficient. ✓✓ (2) [C]

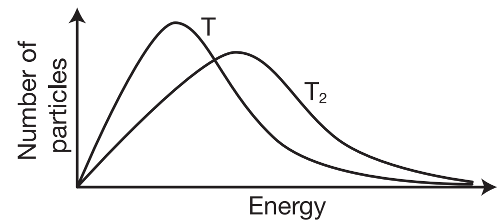
b) Heterogeneous; vanadium(V) oxide is a solid, whereas all the reactants and products are gases. ✓✓ (2) [K]

10. a) A catalyst is a substance which speeds up a reaction, but is chemically unchanged at the end of the reaction. ✓ (1) [K]

b) A catalyst provides an alternative route ✓ with a lower activation energy. ✓ (2) [K]

c) With the catalyst present, there are many more particles which have energies greater than the activation energy for the alternative route, ✓ so the area under the curve to the right of the catalytic activation energy is much larger. ✓ Therefore, the reaction is much faster. ✓ (3) [C]

11. a)



The peak of the new curve must be displaced to the right. All the following are accepted: the new curve starts at the origin, the peak of the new curve is lower than the original and the new curve must not start to diverge from the original curve. ✓✓✓ (3) [An]

b) With an increase in temperature there is an increase in the proportion of particles with kinetic energy that is greater than or equal to E_A, so more particles have sufficient energy to react. ✓ (1) [C]

12. a) An enzyme is a protein ✓ that acts as a catalyst. ✓ (2) [K]

b) Specificity is the ability of an enzyme to bind ✓ with a particular substrate in a reaction. ✓ (2) [K]

c) The enzyme, lactase, has an active site that has a shape that perfectly matches that of the lactose (substrate). ✓ The enzyme combines with its substrate to form an enzyme–substrate complex. The substrate undergoes a chemical change. ✓ Afterwards, it no longer fits the active site, so the enzyme rejects it, so the enzyme becomes available again to combine with another substrate molecule. ✓ (3) [C]

Total: 35

Theme 3 Inorganic chemistry

TOPIC 3.1 The Periodic Table and chemical periodicity

Learner's Book pages 126–141

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand the periodicity of physical properties of elements in Period 3 • Understand ionisation energy • Understand the periodicity of physical properties of elements down Group 2 and Group 17 • Understand the periodicity of chemical properties of elements in Period 3 • Appreciate chemical periodicity of other elements given appropriate information
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Special needs education (the role of chemistry in bones and their fractures)
Inclusive education	Visually impaired learners will need help interpreting the numerous explanatory diagrams in this topic. Enlarge the diagrams on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learner.
Suggested teaching time	11 lessons
Additional resources needed (if available)	None suggested

Introduction to the topic

This topic continues where Grades 10 and 11 left off regarding periodicity and group properties. In Grades 10 and 11, the learners studied the properties of Group 1, 2, 17 and 18 together with Period 2. This year, they revisit Group 2 and 17 at a more advanced level and learn about the properties of the Period 3 elements. Note that the properties of the Group 2 elements are discussed further in Topic 3.2.

There are very many trends that the learners are expected to remember and explain, making it easy for learners to become confused as to which trend belongs to which group or period. Take time to consolidate after each group or period is discussed in class. Encourage the learners to find creative ways of committing these facts to memory.

Starter activity (LB page 126)

This starter activity revises some properties of the Period 3 elements, based on what the learners learnt about the groups of the Periodic Table in previous years.

Cross-cutting issue: The Champion for Special Needs highlights the link between certain Period 3 and Group 2 and 17 elements and the biology of the bones in the body.

Suggested answers

1. Sodium (Na), magnesium (Mg), aluminium (Al), silicon (Si), phosphorus (P), sulfur (S), chlorine (Cl), argon (Ar)
2. **a)** Na **b)** Cl
3. Na: $1s^22s^22p^63s^1$ Mg: $1s^22s^22p^63s^2$
   Al: $1s^22s^22p^63s^23p^1$ Si: $1s^22s^22p^63s^23p^2$
   P: $1s^22s^22p^63s^23p^3$ S: $1s^22s^22p^63s^23p^4$
   Cl: $1s^22s^22p^63s^23p^5$ Ar: $1s^22s^22p^63s^23p^6$
4. They both have filled outer orbitals (Mg has a filled 2*s*-orbital and Ar has a filled 2*p*-orbital)
5. **a)** $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$
   b) $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$

Sub-topics 3.1.1–3.1.2 Periodicity of and trends in physical properties of Period 3; Groups 2 and 17 LB pp. 127–133

Please note that Sub-topic 3.1.1 and Sub-topic 3.1.2 of the syllabus are both covered in Sub-topic 3.1.1–3.1.2 of the Learner's Book because of the degree of overlap in the content in these two sub-topics.

Beginning these lessons

Revise as much work from Grades 10 and 11 about general trends in physical properties down the groups and across the periods as possible. Also remind the learners of the work covered in Topic 1.3 about electronegativity, types of lattices and intermolecular forces.
Prior knowledge: atomic radius, ionic radius, electronegativity, electrical conductivity.
New concepts: ionisation energy, shielding, Period 3 elements' reactions.

Ionisation energy (LB page 127)

Teaching tips

- Go through the content in this section as a class. Pay particular attention to the various graphs and diagrams shown in the Learner's Book.
- Introduce ionisation energy to the learners by drawing Bohr structures of sodium and chlorine on the board. Ask the learners to say which valence electron (that of sodium or any one of the seven of chlorine) would be easier to pull away from the atom. They should identify the valence electron of sodium, and should be able to give a reason for their answer.
- Use Figure 3.1.4 to help you explain the concept of shielding.
- Let the learners study Table 3.1.1 in pairs.

Suggested homework activities

Activity 1 Question 3 and 4

Suggested answers

Activity 1 Predict trends in ionisation energy (LB page 130)

1. Ionisation energy is the energy required to remove the most loosely bound electron (a valence electron) from an atom, ion or molecule.
2. Down a group, ionisation energy decreases: As you move down the group, the valence electrons are further from the nucleus and therefore experience more shielding. This results in a weaker nuclear attraction.
3. Across a period, ionisation energy increases: As you move across the period, there is an increase in nuclear charge due to an increase in the number of protons. This results in a stronger nuclear attraction. The electrons experience similar shielding as the elements all have the same number of energy shells.
4. Moving down from beryllium to radium or, from fluorine to astatine, the ionisation energy decreases. This is because the lower down the element, the further away from the nucleus the valence electrons are found. There is also an increase in shielding, which outweighs the effect of the increasing nuclear charge.

Informal assessment

Select learners to read out their answers to Activity 1, and let the rest of the class assess this to formulate a model answer to each question.

Variations in atomic radius, ionic radius and electronegativity (LB page 130)

Teaching tips

- Start by letting learners go through the text, graphs and table in this section in pairs.
- Then ask random pairs to summarise one aspect of the content they have just learnt to encourage a class discussion.

Suggested homework activities

Activity 2 Questions 2 and 3

Suggested answers

Activity 2 Explain variations in radius and electronegativity (LB page 132)

1. a) The electronegativity of a covalently-bonded atom is a measure of its ability to attract and hold bonding electrons to itself.
   b) The ionic radius of an ion is the measure of its radius when in a crystal lattice.
2. a) The force of attraction between the protons in the atom's nucleus and the electrons around the nucleus
   b) The increasing number of shells as one moves from element to element down a group

3. Electronegativity generally increases across a period from left to right. Elements towards the left of a period have 1 to 2 valence electrons, and would rather give those few valence electrons away in order to achieve noble gas configuration than attract another atom's electrons. As a result, they have low electronegativity. Elements towards the right of a period only require a few electrons to achieve noble gas configuration, so they have strong desire to attract another atom's electrons.

Informal assessment

Write the answers to Activity 2 on the board and let the learners mark their own work.

Variations in melting point and conductivity in Period 3 *(for enrichment)*

(LB pages 132–133)

Teaching tips

- Go through the content in this section as a class, paying particular attention to Figure 3.1.9 in the Learner's Book.
- Then ask random pairs to summarise one aspect of the content they have just learnt to gauge their understanding.

Sub-topic 3.1.3 Periodicity of the chemical properties of Period 3 elements

LB pp. 134–137

Beginning these lessons

This sub-topic covers a wide variety of reaction types. The learners are expected to remember these and predict products for similar reactions. Gauge the learners' understanding as you teach by asking random, spot questions. This will give you an indication of whether or not you should rather devote a lesson to revision of Grade 11 work before continuing with these lessons.
Prior knowledge: metals, metalloids, non-metals, reactions with oxygen, reactions with chlorine, oxides, hydroxides, chlorides.

Period 3 elements and their compounds/The oxides of Period 3 elements/Acid and base behaviour of Period 3 oxides and hydroxides

(LB pages 134–136)

Teaching tips

- The learners will benefit greatly from online video clips, animations and summaries used as supplementary teaching resources. Find some of these before the lessons start.
- Go through the section as a class and stop to explore similar reactions on the board so that the learners are given the opportunity to apply what they have learnt. This will give you immediate feedback regarding their understanding of various chemical reactions and chemical properties of substances.

Suggested homework activities

Activity 3 Questions 2 and 3

Suggested answers

Activity 3 Understand Period 3 reactions (LB page 137)

1. **a)** $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
   b) $2P(s) + 5Cl_2(g) \rightarrow 2PCl_5(s)$
   c) $4H_2SiCl_2(l) + 4H_2O(l) \rightarrow H_8Si_4O_4(s) + 8HCl(aq)$
2. Sodium oxide contains O^{2-} ions. These react with water to form OH^- ions, which increases the pH of the solution.
3. $P_4O_{10}(aq) + 12OH^-(aq) \rightarrow 4PO_4^{3-}(aq) + 6H_2O(l)$

Informal assessment

Ask some learners to write their equations (answers) on the board to serve as a memorandum for the rest of the class to use to mark their own work.

The chlorides of Period 3 elements

(LB page 137)

Teaching tips

- Let learners study the text and table in this section in pairs.
- Ask random learners to answer basic comprehension questions about what they have just learnt, to gauge their understanding.

Suggested homework activities

Activity 4 Questions 2 and 3

Suggested answers

Activity 4 Understand Period 3 chloride reactions (LB page 137)

1. The electronic configuration for Na is $1s^22s^22p^63s^1$ and that of Ar is $1s^22s^22p^63s^23p^6$. Each successive element from Na to Ar gains one more electron in its outer shell. Each additional electron is available for bonding, so the oxidation numbers increase as we move across Period 3.
2. Across Period 3, we move from typically ionic bonding in compounds to typically covalent bonding in compounds. The covalently bonded compounds are more likely to be hydrolysed, so they react with water instead of dissolving in it (to give acidic solutions).

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 4.

Sub-topic 3.1.4 Chemical periodicity of other elements LB p. 138

Beginning these lessons

For the first time in this topic, the learners will have to show that they are able to apply the theoretical work that they have covered in this topic so far to different problems and contexts. *Prior knowledge*: group and period trends.

Knowledge of chemical periodicity

(LB page 138)

Teaching tips

- Let the learners work in groups to answer the problems in the lengthy Activity 6.
- Walk around the class as the groups discuss and answer the questions. Ask them to explain their reasons for a certain answer, or to state the rule or principle that they used to answer another question.

Suggested homework activities

Any questions in Activity 5 that were not completed in class will be suitable.

Suggested answers

Activity 5 Apply knowledge of chemical periodicity to other elements (LB page 138)

1. a) There is an increase in atomic radius as the proton number increases down the group. The nuclear force is completely outweighed by the size increase that occurs because each member of the group has one more shell than the last. The effect of shielding, due to the increased number of shells, also lessens the effect of the attractive force of the nucleus.
   b) This trend is explained by the increase in atomic radius (and therefore, the number of shells) from element to element. Because the valence electrons are always found in the outer shell, with each consecutive element they move further away from the nucleus. So, the attractive force of the nucleus on the valence electrons is less.
2. a) Rubidium is a metal, so it forms a cation. The ionic radius of any cation is smaller than that of the parent atom because it has fewer electrons and one less energy shell. This means the atomic radius of an Rb atom is greater than the ionic radius of an Rb ion.
   b) The gallium atom will have a greater atomic radius than the Br atom, because it is positioned more to the left in the period.

c) Selenium is a non-metal, so it forms an anion. The ionic radius of any anion is bigger than that of its parent atom because the addition of one or more electrons creates more repulsion between the electrons. This causes the ion to increase in size, and causes a decrease in the force of attraction from the nucleus.

3. a) Calcium oxide
b) Calcium oxide is an ionic compound.
c) $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$
d) Selenium dioxide
e) Covalent
f) $SeO_2(s) + H_2O(l) \rightarrow H_2SeO_3(aq)$

Informal assessment

Diagnostic activity: Take in the learners' books to mark Questions 1 and 2, but ask one member of each group to write an answer to Question 3 on the board to act as a memorandum for the rest of the class.

Extension

Ask the learners to do some research on the Internet or at a library to find out what the major use of aluminium trichloride ($AlCl_3$) is (commercially or industrially). Let them write a short report on their findings, and outline the use in very basic terms (that is, without including the actual mechanism). Answer: Friedel–Crafts reactions (both alkylations and acylations).

Remedial activity

Revise the major trends across a period and down a group with the learners again. Make use of online video clips to enrich these revision lessons, such as, "The Periodic Table: Atomic Radius, Ionization Energy, and Electronegativity" by professor Dave on www.youtube.com.

Summary (LB page 139)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 140)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. D ✓ (1) [K]
2. B ✓ (1) [K]
3. B ✓ (1) [K]
4. C ✓ (1) [K]
5. D ✓ (1) [K]
6. a) Na ✓ (1) [K]
b) Ar ✓ (1) [K]
c) S ✓ (1) [K]
7. a) +3 ✓ (1) [K]
b) Silicon ✓ (1) [K]
c) Across the period, the atomic number increases. With the increase in atomic number (protons) comes an increase in nuclear charge. ✓ The nucleus of the Mg atom has a greater positive charge, and therefore wants to hold on more tightly to its two valence electrons. ✓ There is no difference between the shielding that occurs in Na and Mg, because they have the same number of inner electrons. Therefore, Mg requires more ionisation energy to remove its first valence electron. ✓ (3) [C]
8. a) Potassium has an additional energy shell. This leads to increased shielding resulting in a greater atomic radius.✓✓ (2) [K]
b) As we move across the period, the number of protons increases. This leads to a greater nuclear charge resulting in a stronger nuclear attraction. This leads to a smaller atomic radius. ✓✓ (2) [K]
9. a) $SO_2(g)$ ✓ + $H_2O(l)$ ✓ → $H_2SO_3(aq)$ ✓ (3) [C]
b) $PCl_5(s)$ ✓ + $4H_2O(l)$ ✓ → $H_3PO_4(aq)$ ✓ + $5HCl(aq)$ ✓ (4) [C]

10. a) Mg and Al form oxides in which the bonding is ionic. ✓ S forms either SO_2 or SO_3 in which the bonding is covalent. ✓ (2) [C]

b) MgO: magnesium hydroxide is formed, which is alkaline ✓
Al_2O_3: no reaction with water because it is insoluble ✓
SO_2/SO_3: sulfurous acid or sulfuric acid is formed, which are both acidic ✓ (3) [Ap]

11. a) $4K(s) + O_2(g) \rightarrow 2K_2O(s)$ ✓✓✓ (3) [C]

b) $2K(s) + Cl_2(g) \rightarrow 2KCl(s)$ ✓✓✓ (3) [C]

12. a) BOTH ✓ (1) [C]

b) Aluminium oxide is amphoteric: it reacts with both acids and alkalis. ✓ (1) [C]

c) LEFT ✓ (1) [C]

d) $MgO(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$ ✓✓ (2) [C]

Total: 40

TOPIC 3.2 Group 2 elements

Learner's Book pages 142–153

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand the trends in properties of the Group 2 elements, magnesium to barium, and their compounds • Appreciate the uses of calcium hydroxide and calcium carbonate in agriculture
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	• Entrepreneurship (the economic value of limestone, including job opportunities) • Environmental learning (the environmental degradation associated with limestone mining)
Inclusive education	Learners with fine motor skill impairments are likely to struggle with setting up the experiments in this topic. Pair or group these learners with supportive learners, who will assist these learners in a patient and helpful manner.
Suggested teaching time	9 lessons
Additional resources needed (if available)	• Experiment 1 (per pair): Bunsen burner; tongs; watch glass; 2 × Erlenmeyer flasks; pipette; measuring cylinder; water; dilute hydrochloric acid; magnesium ribbon; calcium pieces; safety goggles • Experiment 2 (per pair): tripod and gauze; Bunsen burner; tongs; 2 × boiling tubes; test tube rack; drinking straw; dropper; funnel; filter paper; universal indicator; water; calcium carbonate crystals; safety goggles • *Low-cost resource:* See the "On the Internet" note on LB page 143.

Introduction to the topic

This topic revises a number of concepts that will be familiar to the learners from Grades 10 and 11 regarding the Group 2 elements. It also introduces a few more complex concepts relating to the reactions of these elements and their compounds. The learners will need a solid prior knowledge of the trends in general group properties, as well as ionic and covalent reaction mechanisms.

Closely monitor the learners' progress through this topic, and determine where the learners' prior knowledge is lacking. Provide the opportunities for these learners to revise before continuing.

Starter activity (LB page 142)

This starter activity revises some concepts from Grades 10 and 11, as well as earlier in this course. *Cross-cutting issue*: The Entrepreneurship Champion points out that limestone has a number of economic uses and great value as a job provider. On the other hand, the Environmental Learning Champion reminds us of the cost of limestone mining to the environment.

Suggested answers

1. a) Calcium carbonate is an essential ingredient in the manufacture of cement, and therefore concrete and mortar, too. All of these products are necessary in constructing homes, schools, offices and factories. It is also used – together with asphalt – in road construction. Inside homes and offices, pure limestone is also used for tiles and countertops, as it offers a very durable walking or work surface.
   b) Calcium hydroxide is a strong base. It neutralises acidity in soil and water, which creates a good environment for crops to grow.
2. a) The lower down the element is found in the group, the further away from the nucleus the valence electrons are found. There is also an increase in shielding, which outweighs the effect of the increasing nuclear charge.
   b) The force of attraction between the positively charged nucleus and the electrons around the nucleus is completely outweighed by the size increase that occurs because each member of the group has one more energy shell than the last. The effect of shielding, due to the increased number of shells, also lessens the effect of the attractive force of the nucleus.

c) The elements near the top of Group 2 have few electrons, so every electron is of great value. These elements have a strong desire to attract more electrons. Elements near the bottom of the group have so many electrons that they readily lose an electron.

Sub-topic 3.2.1 Similarities and trends in the properties of the Group 2 metals

LB pp. 143–148

Beginning these lessons

Before you start these lessons, quickly revise what the learners learnt in the previous sub-topic regarding group trends and concepts such as ionisation energy. *Prior knowledge*: atomic radius, ionisation energy, density, melting point, reactions of Group 2 elements, the formation of Group 2 compounds. *New concepts*: thermal decomposition, the reactions and properties of Group 2 compounds.

Trends in the physical properties of the Group 2 elements (LB page 143)

Teaching tips

- Treat this introductory section as a revision and diagnostic assessment tool.
- Let pairs or groups of learners go through the content and discuss aspects of it.
- Then, ask the pairs or groups to answer, explain or describe questions or trends in the Group 2 elements. Give as many learners as possible the opportunity to answer your questions, so that you can gauge how the class assimilated the information in the previous topic.

Suggested homework activities

Activity 1 Question 2

Suggested answers

Activity 1 Describe the property trends of the Group 2 elements (LB page 144)

1. a) Graph to indicate correct axis with dependent variable (Melting point) and independent variable (Group 2 elements).
   b) The anomalous melting point is that of magnesium. It should have a melting point of around 1 000 °C for it to follow the trend of the rest of the group's elements.
   c) In general, as the size of the atoms increase as we move down the group from magnesium to barium, the distance of the delocalised electrons from the nuclear centres increase, which causes a decrease in the force of attraction. Hence the melting points decrease as we move down the group.
2. a) All the elements in Group 2 have two valence electrons. As we move down the group from top to bottom, these are in different electron shells. So, the element at the bottom of the group has more electron shells than those elements above it. More electron shells mean a greater atomic radius, so the size of the atom also increases as we move down a group.
   b) Graph to indicate correct axis with dependent variable (Atomic radius) and independent variable (Group 2 elements).

Informal assessment

Diagnostic activity: For Activity 1, take in the learners' books to check their graphs and answers.

Reactions of Group 2 elements

(LB page 144)

Teaching tips

- The learners will be familiar with the reactions of Group 2 elements with oxygen, as they saw these experiments in Grade 11. Revise the flame colours with the learners.
- Go through the rest of the content in this section, making sure that the learners can apply the general equations to specific Group 2 elements that you name, and that they can identify the exceptions.
- Let the learners do Experiment 1 if there is time.

Suggested homework activities

Experiment 1 Question 3, Activity 2 Question 2

Suggested answers

Experiment 1 Investigate the reactions of Group 2 elements (LB page 145)

1. a) The calcium burns with an intense red–orange flame and leaves a white, solid product.
   b) $2Ca + O_2 \rightarrow 2CaO$
   c) The other Group 2 elements should also burn easily in oxygen, and should produce solid oxide products.
2. a) No reaction occurs; the magnesium metal remains unaffected in the water.
   b) $Mg(s)$ + cold $H_2O(l) \rightarrow$ no reaction
   c) Although magnesium does not react with cold water, one would expect the other elements in Group 2 to react with water to form a hydroxide salt.
3. a) Small bubbles formed on the magnesium metal, and over a few minutes, the piece of metal dissolved in the acid.
   b) $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
   c) One would expect that all the other Group 2 elements dissolve in dilute acid to form a salt and hydrogen gas, as all metals react in this way.

Activity 2 Describe trends in Group 2 physical properties (LB page 145)

1. $2Ba(s) + O_2(g) \rightarrow 2BaO(s)$
2. Moving down the group, the reactions with oxygen (to form oxides), water (to form hydroxides and hydrogen gas) and hydrochloric acid (to form salts and hydrogen gas) all become more vigorous.

Informal assessment

For Experiment 1, walk around the classroom as the learners work to do spot checks on their experiment set-ups and their answers.

For Activity 2, let some learners write their answers on the board, and let the rest of the class assess and compare.

Reactions of the Group 2 compounds (LB page 146)

Teaching tips

- Let pairs of learners go through the work on the reactions of the Group 2 compounds with water and acids.
- Let the learners volunteer to predict the products of a reaction between two reactants that you state.
- Teach the new content about thermal decomposition of the Group 2 nitrates and carbonates slowly and thoroughly. Make use of online video clips or animations to enrich the learning experience.
- Do as many specific examples as possible with the learners, whereby learners can volunteer to predict, write and balance equations.

Suggested homework activities

Activity 3 Question 2

Suggested answers

Activity 3 Describe trends in Group 2 carbonates and nitrates (LB page 147)

1. a) $BaCO_3(s) \xrightarrow{\text{heat}} BaO(s) + CO_2(g)$
   b) $2Be(NO_3)_2(s) \xrightarrow{\text{heat}}$ $2BeO(s) + 4NO_2(g) + O_2(g)$
2. Moving down the group, a higher temperature is needed to decompose the nitrates. This is because of the change in size of the Group 2 cations. The greater the size of the cation, the more stable the nitrate. The nitrate is also more stable at lower temperatures.

Informal assessment

For Activity 2, walk around the class and do spot checks on the learners' answers.

Trends in properties of Group 2 elements and their other compounds: The solubility of Group 2 hydroxides and sulfates

(LB pages 146–147)

Teaching tips

- Again, teach this new content slowly and thoroughly. Be sure to emphasise the reason given for each phenomenon discussed. Regularly test the learners on their comprehension as you teach, by asking quick questions and assessing their responses.
- Let the learners study Figure 3.2.4 carefully. It summarises all the key points of the Group 2 reactions, using calcium as an example.

Suggested homework activities

Activity 4 Questions 2 and 3

Suggested answers

Activity 4 Predict properties of Group 2 compounds (LB page 148)

1. a) $Sr(s) + 2HNO_3(aq) \rightarrow Sr(NO_3)_2(aq) + H_2(g)$

   b) Strontium oxide, nitrogen dioxide gas and oxygen gas

   c) $2Sr(NO_3)_2(s) \xrightarrow{\text{heat}} 2SrO(s) + 4NO_2(g) + O_2(g)$

   d) Strontium hydroxide will be more alkaline.
2. a) $BaSO_4$ b) $Ba(OH)_2$
3. The degree of solubility increases down the group.

Informal assessment

For Activity 4, select learners to write their answers on the board to serve as a memorandum for the rest of the class to use to mark their own work.

Sub-topic 3.2.2 Uses of Group 2 compounds LB pp. 149–151

Beginning these lessons

Revise as much work from Grades 10 and 11 about cement manufacturing and other uses of calcium compounds in general as possible.
Prior knowledge: calcination, thermal decomposition.

The formation of calcium hydroxide (LB page 149)

Teaching tips

- Let learners, in pairs, go through the content in this section.
- Ask random learners to answer spot questions, to assess their basic comprehension of the concepts discussed.
- Emphasise the steps involved in the cement manufacturing process.

Suggested homework activities

Activity 5 Questions 1 and 2

Suggested answers

Activity 5 Understand the formation of calcium hydroxide (LB page 150)

1. The decomposition of calcium carbonate by heat to form calcium oxide and carbon dioxide
2. $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

Informal assessment

Select some learners to read their answers for the rest of the class to assess.

Uses of calcium carbonate and calcium hydroxide (LB page 150)

Teaching tips

- Let learners, in pairs, go through the content in this section and read up about the various uses of these calcium compounds.
- Let the learners do Experiment 2 in groups or pairs, depending on the availability of the resources.

Suggested homework activities

Activity 6 (research assignment)

Suggested answers

Activity 6 Research the uses of calcium compounds (LB page 151)

1. It is used as a filler because it is cheaper than wood fibre. Printing and writing paper can contain up to 20% ground calcium carbonate.
2. Slurries of calcium oxide are used to remove sulfur dioxide from exhaust gases in FGS.
3. It is used in the preparation of ammonia gas by reacting with ammonium chloride.
   $Ca(OH)_2(aq) + 2NH_4Cl(aq) \rightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(l)$

Informal assessment

The learners must hand in written reports for Activity 6. The general findings are given in the suggested answers above, but you should assess the reports using a suitable rubric.

Extension

You could include additional aspects for the learners to include in their research assignment in Activity 6.

Remedial activity

Make use of peer teaching for those learners who struggle with certain aspects of the work covered in this topic. Let learners revise and discuss the content in pairs. Or let the learners, in pairs, create a mind map as a summary of the key points in this topic.

Summary (LB page 152)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 153)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

1. B ✓ (1) [K]
2. A ✓ (1) [K]
3. B ✓ (1) [K]
4. C ✓ (1) [K]
5. D ✓ (1) [K]
6. Melting points decrease as we move down the group. The Group 2 elements are metallic. In general, as the size of the ions increases as we move down the group, so the distance between the delocalised electrons and the nuclei increases. This causes a decrease in the force of attraction, and therefore, a decrease in melting point. ✓✓✓ (3) [C]
7. **a)** $Ba(s) + 2H_2O(l)$ ✓ $\rightarrow Ba(OH)_2(aq) + H_2(g)$ ✓, one mark for balancing (3) [C]
   b) $2Mg(NO_3)_2(s)$ ✓ $\xrightarrow{heat} 2MgO(s) + 4NO_2(g) + O_2(g)$ ✓, one mark for balancing (3) [C]
   c) $Ca(OH)_2(s) + 2HCl(aq)$ ✓ $\rightarrow CaCl_2(aq) + 2H_2O(l)$ ✓, one mark for balancing (3) [C]
8. Magnesium oxide, ✓ nitrogen dioxide gas ✓ and oxygen gas ✓ (3) [C]
9. **a)** Hydroxide solubility increases as we move down the group. ✓ (1) [K]
   b) As we move down the group, the energy needed to break up the lattice decreases as the cations increase in size. ✓ The bigger the cations, the larger the distance between them in the lattice, and the weaker the forces are that hold them together. ✓
   So, it is easier to break apart a barium hydroxide lattice than it is to break apart a magnesium hydroxide lattice.
   Therefore, barium hydroxide is more soluble than the other hydroxides of Group 2. ✓ (3) [Ap]
   c) Accept any TWO of:
   - in water treatment as a flocculant
   - in food processing as a clarifier or preserver
   - in the manufacture of cement
   - in agriculture as a soil acid neutraliser. ✓✓ (2) [K]
10. **a)** Ammonium chloride ✓ (1) [K]
    b) Water ✓ (1) [K]
    c) The calcium oxide reacts with water to remove it from the gas column. (It acts as a dehydrating agent.) ✓ (1) [C]
    d) $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$ ✓ (1) [C]

Total: 30

TOPIC 3.3 Transition elements

Learner's Book pages 154–169

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Know the characteristics of the first series transition elements • Understand the extraction of transition elements from their ores
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning (the role of mine waste in environmental degradation)
Inclusive education	Group learners with visual or hearing impairments with patient classmates who can assist them during the discussions and writing of the research activity (Activity 6).
Suggested teaching time	10 lessons
Additional resources needed (if available)	Online videos and tutorials relating to the extraction of the metals dealt with in this topic

Introduction to the topic

The learners will extend their knowledge of the properties of the transition metals in this topic. This topic also takes a closer look at the extraction methods used by mining companies regarding transition metals such as uranium, aluminium, copper and manganese.

Starter activity (LB page 154)

This starter activity revises the concepts of ores, the extraction of ores and the distribution of certain ores in our country from Grades 10 and 11, as a link to the Cross-cutting issue.
Cross-cutting issue: The Environmental Learning Champion highlights the devastating environmental impacts of mining waste in some countries – particularly those that have gold, iron ore, nickel and cobalt mines.

Suggested answers

1. An ore is a metal that is found in the crust of the Earth and which occurs naturally combined with other elements and compounds. It is something which can be mined, extracted and refined to produce a pure metal of economic value.
2. Copper: pyrite, cuprite or malachite; uranium: uranium oxide (pitchblende); lead: lead(II) sulfide (galena)
3. Learners can state any relevant metal, as well as its location. For example, uranium and lead at Rössing/Erongo region; tin at Uis, copper at Tsumeb and Tschudi, etc.
4. Metals that are moderately to very reactive (according to the reactivity series) require electrolysis to extract the valuable metal from the rest of the ore. This is because these ores are not reduced by carbon (or any of the other methods that work for metals lower down on the reactivity series).

Sub-topic 3.3.1 Characteristics of typical transition elements

LB pp. 155–159

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about the transition elements and their properties.
Prior knowledge: electronic configuration, oxidation states, properties of transition elements.

Transition elements (LB page 155)

Teaching tips

- Select learners to recall definitions and facts or explain certain concepts relating to the content provided in this section. Let the rest of the class assess the learners' answers.
- Let one or two learners volunteer to write electronic configurations of transition elements that you give as examples, on the board – again for the rest of the class to assess.

- Teach the content about the variable oxidation states of the transition elements, and let the learners work through the worked example in pairs.
- Make sure that each learner in the class gets an opportunity to answer a question, assess a question, or provide a reason for one of the other learners' answers.

Suggested homework activities

Activity 1 Questions 2 and 3

Suggested answers

Activity 1 Write electronic configurations for the transition elements (LB page 157)

1. a) [Ar]$3d^84s^2$ b) [Ar]$3d^5$
   c) [Ar]$3d^24s^2$ d) [Ar]$3d^9$
2. Note: Learners must draw orbital diagrams that correspond with the following electronic configurations:
   a) [Ar]$3d^54s^1$ b) [Ar]$3d^{10}$
   c) [Ar]$3d^5$ d) [Ar]$3d^14s^2$
3. a) Manganese(III) oxide
   b) Scandium(III) chloride
   c) Iron(II) oxide
   d) Titanium(IV) iodide

Informal assessment

Ask some learners to come to the board to write an answer to one of the questions. Let the rest of the class mark their own work, using the answers on the board as the memorandum.

Properties of the transition elements (LB page 158)

Teaching tips

- Revise the familiar properties of the transition elements with the learners, and remind them of the variable oxidation states.
- Teach the small section about coordination complexes: emphasise the terminology and show the learners other examples of coordination complexes, which you can source online.
- Let the learners go through the content about the comparison between *d*-block and *s*-block elements in pairs.

Suggested homework activities

Activity 2 Questions 2 and 3

Suggested answers

Activity 2 Understand the properties of the transition elements (LB page 159)

1. The different solutions contain manganese ions of different oxidation numbers. Each type of manganese ion has a characteristic colour associated with it.
2. Calcium has only two electrons per atom available for delocalisation, while iron has up to six. The greater the number of available electrons, the stronger the metallic bond in that substance is. Therefore, the metallic bonding in iron is much greater than that in calcium, which means that it takes far more heat to break the bonds in the lattice.
3. Coordination complexes are large compounds that consist of a central atom or ion (which is often a transition metal) with ligands attached to it. The ligands bond to the central atom or ion by coordinate covalent bonds. The central atom or ion can accept as many of these coordinate bonds as its empty orbitals will allow.

Informal assessment

Diagnostic activity: Take in the learners' books to mark their answers to Activity 2.

Sub-topic 3.3.2 Extraction of transition elements from their ores

LB pp. 160–167

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from Grades 10 and 11 about the extraction of ores in Namibia. The new content in this sub-topic introduces the learners to specific reaction mechanisms that are used in some extraction processes.
Prior knowledge: metal ores, coke, hygroscopic.
New concepts: the extraction of uranium, acid leaching, the electrolysis of leached solutions.

Metal ores in Namibia: Displacement of metals from their ores through carbon reduction

(LB pages 160–161)

Teaching tips

- Revise the metal ores that are mined and extracted in Namibia with the learners as an introduction to this sub-topic.
- Teach the content about copper and manganese extraction (by reduction with carbon), paying special attention to the chemical reactions and changes.

Suggested homework activities

Activity 3 Question 3

Suggested answers

Activity 3 Describe the reduction of ores by carbon (LB page 162)

1. The most reactive metals combine with air, moisture, carbon dioxide and numerous non-metals to form stable compounds such as oxides, sulfides, carbonates, halides and silicates. These often need to be extracted using electrolysis. The moderately reactive metals (such as zinc, copper and lead) combine as oxides or sulfides. Often, these can be extracted by carbon reduction.
2. $2CuO(s) + C(s) \xrightarrow{\text{heat}} 2Cu(s) + CO_2(g)$
3. Ferromanganese is easily produced in a blast or electric furnace by heating manganese(IV) oxide (MnO_2) and iron(III) oxide (Fe_2O_3) with coke and coal as reducers.

Informal assessment

For Activity 3, ask learners you select to write their answers on the board to serve as a memorandum for the rest of the class to use to mark their own work.

The extraction of pure metals

(LB page 162)

Teaching tips

- Briefly revise the work from Topic 2.2 about the extraction of copper and manganese, as a means of reminding the learners about the role of sulfuric acid in certain extraction methods.
- Move on to explain the extraction of uranium through acid leaching, referring to the steps provided in the Learner's Book.
- Ask learners randomly spot questions to assess their basic comprehension of these new concepts and processes.
- Let the learners read through the content on the electrolysis of leached solutions in pairs. Ask selected learners to explain or describe certain aspects, to gauge their understanding.

Suggested homework activities

Activity 4 Questions 3 and 4

Suggested answers

Activity 4 Appreciate the extraction of pure metals (LB page 164)

1. When roasted, the uranium in the ore is in a reduced state. This makes it quite insoluble, so manganese dioxide (MnO_2) is also added to oxidise the uranium – and make it more soluble in the process of treating it with sulfuric acid.
2. UO_3 and U_3O_8
3. The UF_4 is reduced to pure metal by magnesium metal in a heated reaction vessel, where all the reactants and products are in their molten states.
   $UF_4(l) + 2Mg(l) \rightarrow U(l) + 2MgF_2(l)$
4. Both the anode and cathode are made of copper, but the anode is made of impure copper (blister copper) and the cathode is made of pure copper. When the electrodes are placed in the copper sulfate solution and an electric current is passed through the system, copper ions from the anode go into solution and copper ions from the solution settle on the cathode.

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 4.

The control of waste in metal extraction processes: Metal recycling

(LB pages 164–166)

Teaching tips

- This section of the sub-topic is largely learning content which the learners can go through in pairs or in groups.

- Many of the facts should be familiar to the learners from Grades 10 and 11. However, walk around the class as the learners explore the content. Ask them questions and answer questions from them.

Suggested homework activities

Activity 5 Questions 3 and 4

Suggested answers

Activity 5 Understand the environmental consequences of mining activities (LB page 167)

1. Vehicle and metal smelting emissions and the extraction of metals from sulfide ores
2. Sulfur dioxide produces acidic sulfate aerosols (fine particles) when it reacts with oxygen and moisture in the air. The aerosols fall back to the earth as acid rain.
3. Acids of any kind continue with their leaching action on rocks and ores that they come into contact with. Typically, they leach out heavy metals that have been contained in the rock in forms that are not harmful to the environment, and release these into the soil as heavy metal pollutants. Any above-normal increase in metals, such as cadmium, arsenic, cobalt, lead and zinc, in soils has the potential to destroy the soil's fertility.
4. Heavy metal pollutants can enter soil and water systems directly by being leached into them, or they can be blown into the air and transported far away before being deposited on the landscape.

Activity 6 Investigate metal recycling in Namibia (LB page 167)

In this activity, the learners have to use the Internet or any other available resources to find out where in Namibia programmes have been established to recycle metals. In particular, they need to find out:

1. which metals are currently being recycled
2. where these recycling projects are located.

They then write a short report to hand in.

Informal assessment

- For Activity 5, select learners to read out their answers and let the rest of the class agree or disagree with the responses.
- Take in the groups' reports to mark Activity 6. Make use of a rubric.

Extension

You can use Activity 6 as an extension project for certain learners instead of a research project for everyone in the class.

Remedial activity

The work in this topic is part revision, part new – but learning – work. Help the learners who struggle to associate the correct process or equation with the correct metal ore or mining process by doing additional consolidation lessons after class, or let them draw up mind maps of the content in each sub-topic.

Summary (LB page 168)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 169)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. C ✓ (1) [K]
3. A ✓ (1) [K]
4. C ✓ (1) [K]
5. D ✓ (1) [K]
6. a) [Ar]$3d^8 4s^2$ ✓✓ (2) [C]
   b) [Ar]$3d^2 4s^2$ ✓✓ (2) [C]
7. Accept any THREE of the following: they have variable oxidation states, they form coloured compounds, they form coordination complexes, and they can act as catalysts. ✓✓✓ (3) [K]
8. The most reactive metals combine with air, moisture, carbon dioxide and numerous non-metals to form stable compounds. ✓

These often need to be extracted using electrolysis. ✓ The moderately reactive metals (such as zinc, copper and lead) combine as oxides or sulfides. Often, these can be extracted by carbon reduction. ✓ (3) [C]

9. a) Accept any TWO of the following: sulfur dioxide emissions, greenhouse gas emissions (from diesel-run vehicles and machinery), heavy metal particles in the atmosphere, waste acid spills, acid mine drainage. ✓✓ (2) [K]

b) The ore is heaped so that sulfuric acid can be sprayed on it. ✓ This leaches the copper from the ore and leaves behind most of the impurities. ✓ (2) [K]

c) Ions ✓ (1) [K]

d) $Cu^{2+} + 2e^{-} \rightarrow Cu$ ✓✓ (2) [C]

10. a) The uranium is reduced when roasted. ✓ (1) [K]

b) Step 2: The roasted ore is treated with sulfuric acid. ✓ Manganese dioxide (MnO_2) is also added to oxidise the uranium – and make it more soluble. The solution that results contains a number of metallic ions, such as iron, aluminium, calcium and copper. ✓ Through the acid reaction, the uranium is converted to the form of a sulfate-containing ion. $UO_2(SO_4)_3^{4-}$ ✓ (3) [C]

11. a) Sulfuric acid ✓ (1) [K]

b) The solution that is electrolysed is that of manganese sulfate ($MnSO_4$). ✓ The pure manganese metal is deposited onto a stainless steel sheet that acts as the cathode. ✓ The manganese-coated cathodes are removed every so often, and the pure metal is removed from them by hammering. ✓ (3) [C]

Total: 30

TOPIC 3.4 Group 17 elements

Learner's Book pages 170–181

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Know the physical properties of the Group 17 elements • Know the chemical properties of Group 17 elements and their hydrides • Know some reactions of halide ions • Understand the reactions of chlorine with aqueous sodium hydroxide • Appreciate some industrial applications of halogens
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology (the role of halogen compounds in protecting ITC devices from fire)
Inclusive education	Visually impaired learners will need help interpreting the various diagrams and graphs in this topic. Enlarge the images on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learner.
Suggested teaching time	8 lessons
Additional resources needed (if available)	• Online videos of experiments can help the learners visualise the colour changes or characteristic colours of some of the substances discussed in this topic. Look for good examples on www.youtube.com. Also see the "On the Internet" note on LB page 175. • *Low-cost resource:* See the "On the Internet" note on LB page 179.

Introduction to the topic

This topic covers the properties of the Group 17 elements (the halogens), their reactions and their uses. Much of the content in this topic is revision, but the learners will be introduced to a few more advanced aspects to extend their prior knowledge.

Starter activity (LB page 170)

This starter activity revises the work done in Grades 10 and 11 regarding the halogens, as a link to the Cross-cutting issue.

Cross-cutting issue: The Information and Communication Technology Champion highlights the use of halogen compounds in ITC as flame-retardant substances.

Suggested answers

1. a) Incorrect **b)** Correct
c) Incorrect **d)** Incorrect
e) Correct

2.

		Halogen (molecule) to be added to the aqueous solution:				
		Fl	Cl	Br	I	As
Halogen ion in a compound in an aqueous solution	Fl		No reaction	No reaction	No reaction	No reaction
	Cl	Cl is displaced		No reaction	No reaction	No reaction
	Br	Br is displaced	Br is displaced		No reaction	No reaction
	I	I is displaced	I is displaced	I is displaced		No reaction
	As	As is displaced	As is displaced	As is displaced	As is displaced	

Sub-topic 3.4.1 Physical properties of the Group 17 elements LB pp. 171–172

Beginning these lessons

This sub-topic continues where the content in Grades 10 and 11 left off in terms of the halogens. Two physical properties, namely colour and volatility are discussed in further detail.
Prior knowledge: volatility.

The colours of the halogens

(LB page 171)

Teaching tips

- Go through the text and tables regarding the colours of the halogens in different states. Find additional content online to help enrich and consolidate this information.
- Move on to discuss the concept of volatility. Make sure that the learners can explain differences in halogen volatility using intermolecular force theory.

Suggested homework activities

Activity 1 Questions 3, 4 and 5

Suggested answers

Activity 1 Know the physical properties of the halogens (LB page 172)

1. Accept any FOUR of the following:
   - The halogens are non-metals.
   - The halogens are diatomic molecules.
   - They can be in their solid, liquid or gas states at room temperature.
   - The densities, melting points and boiling points of these elements increase as you move down the group.
   - The halogens have characteristic colours to their vapours, states at room temperature and pressure, and in solution.
2. Most groups' elements are found in the same state at room temperature and pressure. However, the halogens occur naturally as gases (such as chlorine), liquids (such as bromine) and solids (such as iodine) at rtp.
3. These simple diatomic molecules only have weak Van der Waals forces acting between them. As we move down the group, the molecules contain more electrons. A greater number of electrons in a molecule means that there is a greater chance of instantaneous dipoles (and induced dipoles) forming.
4. The colours of the halogen vapours go from light (pale yellow–green for chlorine) to dark (purple for iodine when sublimed), with an intermediary red–brown colour for bromine's vapour.
5. Black or very dark brown

Informal assessment

Select learners to give their answers to Activity 1. Then let the rest of the class compare and assess until consensus is reached.

Sub-topic 3.4.2 Chemical properties of the elements and their hydrides LB pp. 173–174

Beginning these lessons

The chemical properties of the halogens are discussed in further detail in this sub-topic.
Prior knowledge: displacement reactions, bond energies.

Reactivity of the halogens (LB page 173)

Teaching tips

- Let the learners go through the text, diagrams and tables in pairs. Walk around the classroom as they do this and ask and answer questions to gauge whether the learners have consolidated the work from Grades 10 and 11 with the new content.
- Refer the learners back to Topic 2.1 to remind them of what bond energies are, and how we interpret and work with them.

Suggested homework activities

Activity 2 Question 3

Suggested answers

Activity 2 Know the chemical properties of the halogens (LB page 174)

1. Accept the following:
   - The halogens have seven valence electrons.
   - The halogens' reactivity decreases as we

move down the group.
- The halogens undergo displacement reactions.
- All the halogens are oxidising agents.
- The halogens form hydrogen halides when reacted with hydrogen gas

2. a) $Cl_2(g) + 2NaI(aq) \rightarrow 2NaCl(aq) + I_2(aq)$
   b) $3F_2(g) + KBr(aq) \rightarrow KF(aq) + BrF_5(aq)$
3. The thermal stability of the halogen hydrides decreases with the increasing atomic number. So, hydrogen fluoride is the most stable halogen hydride, while hydrogen iodide is the least. This is due to the fact that the halogens higher up in the group form stronger bonds with hydrogen than those lower down. Therefore, it takes more energy to break halogen–hydrogen bonds when the halogen in question is found higher up in the group.

Informal assessment

Select learners to give their answers to Activity 2 (or let them write their answers on the board), and let the rest of the class compare and assess until consensus is achieved.

Sub-topic 3.4.3 Reactions of halide ions

LB p. 175

Beginning these lessons

The reactions of the halide ions are discussed in detail in this sub-topic, as a continuation of work covered in Grades 10 and 11.
Prior knowledge: displacement reactions, tests for halide ions.

The tests for halide ions (LB page 175)

Teaching tips

- Remind the learners of the subtle colour differences between the three halide ions that we typically work within the laboratory. Show the learners the online video described in the Note box.
- Discuss and consolidate the reactions of the halide ions with concentrated sulfuric acid with the learners.

Suggested homework activities

Activity 3 Questions 1 and 2

Suggested answers

Activity 3 Understand the reactions of the halide ions (LB page 175)

1. $KI(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgI(s)$
2. $8NaI(s) + 9H_2SO_4(l) \rightarrow 4I_2(g) + H_2S(g) + 8NaHSO_4(s) + 4H_2O(g)$

Informal assessment

Write the correct equations on the board, and let learners swap books to mark each other's work.

Sub-topic 3.4.4 Reactions of chlorine with aqueous sodium hydroxide

LB pp. 176–177

Beginning these lessons

In this sub-topic, the learners are introduced to some new concepts and reactions involving chlorine.
Prior knowledge: water treatment processes.
New concepts: disproportionation.

Chlorine reactions (LB page 176)

Teaching tips

- Explain the concept of disproportionation by following the text in the Learner's Book. Find other examples of substances that can undergo disproportionation online, and let the learners describe the mechanism to show that they have understood the concept correctly.
- Move on to discuss chlorine reactions and changes in pH. Make use of the graph in Figure 3.4.4 as you teach.

Suggested homework activities

Activity 4 Question 3

Suggested answers

Activity 4 Understand the reactions of chlorine and sodium hydroxide (LB page 177)

1. Disproportionation occurs when an element undergoes oxidation and reduction at the same time in a reaction.

2. Chlorine reacts with sodium hydroxide to form sodium chloride, sodium chlorate(V) and water. $3Cl_2(aq) + 6NaOH(aq) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$
3. At temperatures below 20 °C, chlorine reacts with sodium hydroxide to form sodium chloride, sodium chlorate(I) and water. At temperatures above 65 °C, sodium chlorate(V) forms instead of sodium chlorate(I).

Informal assessment

Write the correct equations on the board, and let learners swap books to mark each other's work.

Sub-topic 3.4.5 Uses of halogens and halogen compounds LB pp. 178–179

Beginning these lessons

The halogens and their compounds are discussed in further detail in this sub-topic.
Prior knowledge: uses of halogens.

Uses of halogens and halogen compounds (LB page 178)

Teaching tips

- Let the learners read through the text about bleaches and PVC, and make notes in groups or pairs.
- After you have dealt with bleaches, revise the content on page 177 (about chlorine in water treatment) again with the learners.
- Move on to discuss the halogenated hydrocarbons as a class. Emphasise the evolution of refrigerants and aerosols, and the impact on the ozone layer of the earlier generations.

Suggested homework activities

Activity 5 Questions 1 to 3

Suggested answers

Activity 5 Appreciate the uses of halogens and halogen compounds (LB page 179)

1. Learners may state (and explain) any of the following uses of fluorine (or others, if applicable):
   - nuclear material production
   - insulation of electrical towers
   - plastics manufacture (for example Teflon)
   - fluorination of drinking water (for dental health).
2. A chlorine atom in a CFC molecule is split away from the molecule due to UV radiation. The free chlorine atom reacts with an ozone molecule to form chlorine monoxide and oxygen.
   The chlorine monoxide reacts with a free oxygen atom from the stratosphere to form oxygen gas, and frees the chlorine atom again, so that it can start the cycle again. We call this mechanism the chlorine-catalysed ozone depletion mechanism.
   (CFC molecule) $CFCl_3 \xrightarrow{UV} CFCl_2^+ + Cl^-$
   $Cl^- + O_3$ (ozone molecule) $\rightarrow ClO + O_2$
   $ClO + O$ (free O from stratosphere) $\rightarrow Cl^- + O_2$
3. Some older texts indicate the letter "R" for refrigerant in the naming system. However, this has been phased out. Now, the refrigerant's abbreviation is used in the naming system (i.e. HFC-134a and not R-134a).
   As for the numbering system that follows the abbreviation, these digits are coded as follows:
   - The digit on the far right is the number of fluorine atoms per molecule.
   - The second digit from the right is one plus the number of hydrogen atoms per molecule.
   - The third digit from the right is the number of carbon atoms minus one. If this digit is zero, it is not written. For example, HCFC-22 has one carbon atom.
   - The fourth digit is the number of double bonds in the molecule. This is left out if zero (but this is not commonly used).
   - A suffix with a capital B and a number indicates the number of bromine atoms, when applicable.
   - A suffix of an uppercase letter (such as A, B and C) indicates different percentages of refrigerants blended together. For example, R-403A and R-403B are made up of the same substance, but with different percentages of each refrigerant present.
   - A suffix of a lower-case letter (such as a, b and c) indicates an isomer.
   - Chlorine atoms are not identified in the numbering system.

Informal assessment

Take in the learners' reports for Activity 5 to assess.

Extension

You can treat Activity 5 as an extension activity for those learners who need an additional challenge, instead of a whole-class research activity.

Remedial activity

Much of the content in this topic is revision from Grades 10 and 11. For those learners who do not show adequate mastery of the skills and information, arrange for a few revision lessons with them, in which you revisit the work covered in previous grades, and only build on the new content when you feel that the learners are suitably prepared.

Summary (LB page 180)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 181)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]

2. D ✓ (1) [K]

3. C ✓ (1) [K]

4. C ✓ (1) [K]

5. A ✓ (1) [K]

6. a) Chlorine, ✓ bromine, ✓ iodine ✓ (3) [C]

b) These simple diatomic molecules only have weak Van der Waals forces acting between them. As we move down the group, the molecules contain more electrons. ✓ A greater number of electrons in a molecule means that there is a greater chance of instantaneous dipoles (and induced dipoles) forming. ✓ (2) [An]

7. Bleach is a mixture of sodium chloride and sodium chlorate. ✓ Industrially, it is produced by reacting aqueous chlorine and sodium hydroxide.

$Cl_2(aq) + 2NaOH(aq) \rightarrow NaCl(aq) + NaClO(aq) + H_2O(l)$ ✓✓

The active ingredient in bleach is the chlorate ion, ✓ which is a powerful oxidising agent because of its oxygen atom. It is this oxygen atom that removes stains and dyes (from coloured materials). ✓ (5) [C]

8. a) $Cl_2(aq)$ ✓ + $H_2O(l)$ ✓ → $HCl(aq)$ ✓ + $HClO(aq)$ ✓ (4) [K]

b) Hydrochloric acid ✓ and hypochlorous acid ✓ (2) [K]

c) Chlorine undergoes disproportionation in this reaction. ✓ Chlorine gas has an oxidation number of 0, while the chlorine atoms in each product are –1 (HCl) ✓ and +1 (HOCl). ✓ This shows that chlorine undergoes both oxidation and reduction in the same reaction. ✓ (4) [Ap]

9. a) $HAs(g)$ ✓✓ (2) [C]

b) Black ✓ (1) [K]

c) Not very stable; it will likely decompose on heating.✓ This is because the bond energy of the As–H bond is very weak compared to that of the other halogens, so only a little heat is needed to decompose the compound. ✓ (2) [C]

10. a) Silver nitrate solution; ✓ dilute nitric acid ✓ (2) [C]

b) Place each of the test tubes in a test tube rack. ✓ Use a pipette or measuring cylinder to add 20 cm^3 of dilute nitric acid to each test tube, ✓ insert stoppers and mix or shake each. ✓ Then add a few drops of silver nitrate solution to each using a dropper. ✓ (4) [K]

c) Each test tube's mixture will have a distinctive colour, which identifies each ion as follows: ✓

- Chloride ion: pale, milky white ✓
- Bromide ion: pale, milky cream ✓
- Iodide ion: pale, milky yellow. ✓ (4) [K]

Total: 40

TOPIC 3.5 Nitrogen and sulfur

Learner's Book pages 182–197

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Show understanding of the chemistry of nitrogen and its application in industry • Show understanding of the chemistry of sulfur and its environmental implications
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Entrepreneurship (the role of small-scale farming in Namibia's economy)
Inclusive education	Learners with fine motor skill and visual impairments are likely to struggle with setting up and performing the experiment in this topic. Pair or group these learners with supportive learners, who will assist these learners in a patient and helpful manner.
Suggested teaching time	9 lessons
Additional resources needed (if available)	Experiment 1 (per pair): solid ammonium chloride; spatula; test tube; 1 cm^3 of dilute sodium hydroxide solution; pipette or small measuring cylinder; red litmus paper (damp)

Introduction to the topic

This topic investigates the chemistry of two economically important non-metals: nitrogen and sulfur. Much of the content in this topic is learning work, so the learners will benefit from making their own summaries (either written or in the form of mind maps), group or pair discussions and repetition.

Starter activity (LB page 182)

This starter activity looks at (nitrogen-containing) man-made and natural fertilisers, and sulfur as a link to both the cross-cutting issue and the two sub-topics in this topic.
Cross-cutting issue: The Entrepreneurship Champion highlights the use of natural fertilisers in the context of small-scale farming, with an aim of driving self-sufficiency (food security) and job creation in the farming sector.

Suggested answers

1. a) Man-made fertilisers often end up in water sources because they dissolve in rainwater or irrigation water, and are carried away from the croplands by the run-off. Once in the water sources, they are pollutants, which make the water undrinkable and unusable for irrigation, and affect the aquatic ecology by means of eutrophication.

b) Accept any reasonable responses, such as the following: Farmers can use natural (organic) fertilisers instead, such as compost and manure, or they can use the man-made fertilisers more sparingly. They can also plan their fertilisation schedules better, so that they do not broadcast fertilisers just before the rain.

2. a) $[Ne]3s^2 3p^4$

b) It does not have a full outer shell, therefore it either needs to donate all four valence electrons or receive two to form a covalent bond, or share two electrons in an ionic bond with another atom or other atoms.

c) S_8

Sub-topic 3.5.1 Nitrogen LB pp. 183–191

Beginning these lessons

This sub-topic highlights a number of properties and aspects of nitrogen that help to impress upon the learners that chemistry is relevant and applicable to many different fields and careers.
Prior knowledge: unreactivity of nitrogen gas, the properties and chemistry of ammonia, the economic value of ammonia, eutrophication.
New concepts: the nitrogen cycle, environmental impacts of nitrate fertilisers.

The properties of nitrogen: unreactivity/Plant nutrients

(LB pages 183–185)

Teaching tips

- Let the learners revise the properties of nitrogen on their own.
- Go through the text and photographs regarding the role of nitrogen as a plant nutrient as a class.
- Teach the content on the nitrogen cycle slowly, as this section introduces a number of terms that learners who do not have a Biology background may find confusing. Find additional content online to help enrich and consolidate this information.
- Pay particular attention to Table 3.5.1, which shows the changes in oxidation numbers that occur in each step of the nitrogen cycle. Make sure that all the learners understand this information, and can show how the oxidation numbers were determined.

Suggested homework activities

Activity 1 Question 2 and Activity 2 Question 3

Suggested answers

Activity 1 Understand nutrient deficiencies in soils (LB page 185)

1. Nitrogen is needed to build proteins in the plant, for healthy leaf and stem growth, and for high seed and flower production.
2. Heavy rainfall events leave an excess of water on and in the soil. Most of the water drains down through the soil column until it reaches a groundwater resource, or moves through the soil under gravity until it reaches a stream- or riverbank, where it flows out of the soil and joins a surface water resource. As the water moves through the soil, it dissolves and carries away many of the soil nutrients, such as nitrates, phosphates and potassium salts, from the fertile topsoil.

Activity 2 Understand the nitrogen cycle (LB page 187)

1. Nitrogen fixation, nitrification, assimilation, ammonification, denitrification
2. Nitrogen gas to ammonia
3. $NO_3^- \rightarrow NO_2^- \rightarrow NO + N_2O \rightarrow N_2$
   $(+5 \rightarrow +3 \rightarrow +2; +1 \rightarrow 0)$

Informal assessment

Let selected learners give their answers to Activities 1 and 2, and let the rest of the class compare and assess until consensus is achieved.

Ammonia and its compounds

(LB page 187)

Teaching tips

- Let the learners revise the properties of ammonia on their own.
- Go through the text and example equation regarding the displacement of ammonia from its salts as a class.
- Let the learners do Experiment 1 if there is enough time.
- Move on to the industrial importance of ammonia and ammonium salts, by summarising the key points under the headings, "Fertilisers", "Explosives" and "Other uses".

Suggested homework activities

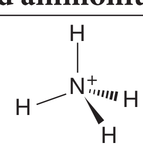
Activity 3 Questions 2 to 3

Suggested answers

Experiment 1 Investigate the displacement of ammonia from its salt (LB page 188)

1. $NH_4Cl(s) + NaOH(aq) \rightarrow NH_3(g) + H_2O(l) + NaCl(aq)$
2. Ammonia gas

Activity 3 Appreciate the uses of ammonia and ammonium compounds (LB page 189)

1. 

   When dissolved in water, ammonia easily accepts a hydrogen ion from the water to form hydroxide and ammonium ions.
2. a) Ammonium nitrate (NH_4NO_3)
   b) $NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$
   c) $NH_4NO_3(s) + H_2O(l) \rightarrow NH_4OH(aq) + HNO_3(aq)$
3. Accept any THREE of the following: nitric acid is used in the manufacture of explosives, rocket fuel, dyes/pigments and nylon.

Informal assessment

- Walk around the classroom as the learners complete Experiment 1. Check that the pairs are able to set up their experiment equipment correctly and confidently, and check their answers to the questions.
- For Activity 3, write the answers on the board, and let the learners swap books to mark each other's work.

Environmental consequences of soluble synthetic nitrate fertilisers/ The benefits of organic fertilisers

(LB page 190)

Teaching tips

- In this section, the learners first extend their understanding of synthetic fertilisers (from previous grades) by focussing in on the environmental impacts of nitrate-based fertilisers, before looking at the benefits of organic fertilisers.
- Go through the text, photographs and tables as a class.
- Let the learners ask questions when they are not sure of something. Elicit their opinions about the advantages and disadvantages of the two types of fertilisers.

Suggested homework activities

Activity 4 Question 4

Suggested answers

Activity 4 Investigate the consequences of eutrophication (LB page 191)

1. Accept any of the following (or other reasonable responses): algal blooms block sunlight, oxygen depletion of the water (leading to the destruction of the plants and animals that live in it), some algal blooms are toxic, lack of water transparency, excessive plant growth, surface water resource pollution, groundwater resource pollution, pollution of drinking water, ecosystem disruption

2–3. Accept any reasonable responses from the learners.

4. The learners must hand in a group or individual report.

Informal assessment

Take in the learners' reports for assessment. Make use of a suitable rubric.

Sub-topic 3.5.2 Sulfur LB pp. 192–193

Beginning these lessons

This short sub-topic introduces the learners to the environmental impacts of certain sulfur-based compounds.
Prior knowledge: acid rain.
New concepts: low-sulfur fuels.

The environmental effects of sulfur

(LB page 192)

Teaching tips

- Let the learners revise what they learnt about sulfur in Grades 10 and 11, before going through the text, diagrams and photographs in this sub-topic.
- Emphasise the equations relating to the formation of acid rain.

Suggested homework activities

Activity 5 Questions 4 and 5

Suggested answers

Activity 5 Understand the impacts of sulfur (LB page 194)

1. Burning of fossil fuels and mining sulfide-rich ores
2. Learners' own responses
3. Sulfur dioxide gas irritates the nose, throat, and airways when breathed in. This causes coughing, sneezing, shortness of breath, and a tight feeling around the chest.
4. Oxygen in the air combines with sulfur dioxide gas to form sulfur trioxide. However, this reaction proceeds with the help of nitrogen dioxide, which oxidises the sulfur dioxide: $SO_2(g) + NO_2(g) \rightarrow SO_3(g) + NO(g)$, while the NO gas converts back to NO_2 gas by reaction with oxygen. The sulfur trioxide goes on to react with water to form sulfuric acid – one of the acids responsible for the damage caused by acid rain.

5. By using only low-sulfur fuels, we can significantly decrease sulfur dioxide emissions globally.

Informal assessment

Let selected learners give their answers to Activity 5, and let the rest of the class compare and assess until consensus is achieved.

Extension

If you live in an area with soil that is suitable for gardening or small-scale farming, let the learners investigate whether the local community has any awareness of the benefits and disadvantages of synthetic fertilisers. The following project outline can be adapted to suit the local environment and conditions:

Step 1: Each group should identify designated areas to carry out the investigation.

Step 2: Design a questionnaire for people in the community to complete. Your questionnaire should include the following questions:
- How common is the use of fertilisers in gardens or the areas around homes?
- What types of fertilisers are used (organic or inorganic)?
- What are the reasons for using fertilisers?
- How often are the fertilisers applied?
- How much fertiliser is used in one application?

Step 3: Distribute the questionnaire to a minimum of 20 people in your area and record their responses.

Step 4: Present your findings in tables or graphs, and discuss or interpret the data.

Step 5: Compile a report on your findings.

Step 6: Communicate your findings and recommendations to the community in your research area.

Remedial activity

Much of the content in this topic is revision from Grades 10 and 11. For those learners who do not show adequate mastery of the skills and information, arrange for a few revision lessons with them, in which you revisit the work covered in previous grades, and only build on the new content when you feel that the learners are suitably prepared.

Summary (LB page 195)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 196)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. D ✓ (1) [K]
3. D ✓ (1) [K]
4. A ✓ (1) [K]
5. C ✓ (1) [K]
6. Accept any TWO of the following:
   - the contamination (acidification) of surface and groundwater resources
   - the destruction of aquatic animals that have calcium carbonate shells (due to the reaction between the carbonate and the acid)
   - the destruction of plants on a large scale
   - the leaching of aluminium in soils, which runs off into lakes and rivers
   - where it kills aquatic plants and animals
   - damage to building exteriors. ✓✓ (2) [K]
7. a) Ammonia does not ionise completely in solution, but it does produce some hydroxide and ammonium ions. ✓
   $NH_3(aq) + H_2O(l) \rightleftharpoons$
   $NH_4^+(aq) + OH^-(aq)$ ✓✓ (3) [C]
   b) Ammonium nitrate ✓ (1) [K]
   c) $NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$ ✓✓ (2) [C]
   d) Ammonium nitrate is more soluble than ammonium chloride because of the nitrate ion, so it is a greater agent of eutrophication. ✓ (1) [C]
8. a) Burning of fossil fuels ✓ and mining/smelting sulfide-rich ores ✓ (2) [K]

b) Oxygen in the air combines with sulfur dioxide gas to form sulfur trioxide: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$. ✓ In practice, however, this reaction proceeds with the help of nitrogen dioxide, ✓ which oxidises the sulfur dioxide: $SO_2(g) + NO_2(g) \rightarrow SO_3(g) + NO(g)$, ✓ while the NO gas converts back to NO_2 gas by reaction with oxygen. ✓ (4) [C]

c) Low-sulfur fuels contain much less sulfur-containing compounds, so they do not emit as much sulfur dioxide gas as sulfur-rich fuels. ✓ (1) [K]

d) Accept any ONE of: breathing difficulties, coughing, sneezing, shortness of breath, and a tight feeling around the chest. ✓ (1) [K]

9. a) **C** Fixation ✓
A Ammonification ✓
E Nitrification ✓ (3) [K]

b) The oxidation number of nitrogen in NO_2^- is +3 and in N_2 it is 0. Therefore, the change is negative, so the process is that of reduction. ✓ (1) [Ap]

c) Reduction ✓ (1) [C]

10. a) Ammonium chloride ✓ (1) [K]

b) $2NH_4Cl(s) + Ca(OH)_2(s) \rightarrow 2NH_3(g) + 2H_2O(g) + CaCl_2(s)$ ✓✓ (2) [C]

Total: 30

Theme 4 Organic chemistry and analysis

TOPIC 4.1 Foundations of organic chemistry

Learner's Book pages 200–213

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand terminology used in organic chemistry • Understand shapes of, and bond angles in, molecules • Understand infrared spectroscopy and its applications
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	HIV and AIDS (the role of organic chemistry in the treatment of HIV and AIDS)
Inclusive education	Visually impaired learners will need help interpreting the diagrams of infrared spectrums in this topic. Enlarge the graphs on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learner.
Suggested teaching time	10 lessons
Additional resources needed (if available)	• Additional examples of infrared spectrums – you can source these online • Molecular sets or homemade equivalents, such as plasticine and toothpicks

Introduction to the topic

This topic revises a number of concepts that the learners were introduced to in Grades 10 and 11, but also introduces a few new, more complex concepts. The new content in Sub-topic 4.1.3 is quite advanced, comparatively, but teaches the learners an important new skill – that of interpreting infrared spectrums. Teach these new aspects slowly, and give the learners many opportunities to discuss and practise in pairs and groups.

Starter activity (LB page 200)

This starter activity revises some basic concepts of organic chemistry from Grades 10 and 11. *Cross-cutting issue*: The HIV and AIDS Champion highlights organic chemistry as the basis of many pharmaceutical drugs, including those used to treat HIV and AIDS.

Suggested answers

1.

Compound	Formula	Organic/ Inorganic
Sodium hydroxide	NaOH	Inorganic
methane	CH_4	Organic
ethanol	CH_3CH_2OH	Organic
carbonic acid	H_2CO_3	Inorganic

Hydrogen carbonate is classified as inorganic because of its structure: there are no hydrogen atoms bonded to a central carbon atom as in organic compounds.

2. Organic molecules always contain carbon atoms and nearly always hydrogen atoms attached to the carbon atoms. Most inorganic molecules do not contain carbon atoms (with exception of, for example, CO_2 and diamond). Inorganic molecules include salts and metals.

3. a) Organic chemistry is the branch of chemistry that studies compounds formed by the element <u>carbon</u>.

b) All living organisms are made up of <u>carbon</u>-containing molecules and <u>fossil</u> fuels are also an important source of carbon.

c) The simplest organic compounds containing only carbon and hydrogen are known as <u>hydrocarbons</u>.

d) Because of its four <u>unpaired</u> (accept also:

lone) electrons, each carbon atom can form four covalent bonds with other atoms.

e) The simple open-chain structures are, depending on the type of bond between the carbon atoms, divided further into alkanes, alkenes and alkynes while the aromatic compounds are like benzene in how they react chemically.

Sub-topic 4.1.1 Organic chemistry terminology LB pp. 201–205

Beginning these lessons

This sub-topic starts by revising key concepts in organic chemistry. The learners should remember most of these terms from Grades 10 and 11, but a few concepts will require teaching and explaining.
Prior knowledge: functional group, homologous series, homologue, reaction mechanism, homolytic fission, free radical, heterolytic fission, electrophile, nucleophile.
New concepts: pi bond, sigma bond, heteroatom.

Terminology used in organic chemistry (LB page 201)

Teaching tips

- Revise the work as a class. Ask spot questions to gauge the learners' comprehension and retention from previous years. Make sure that, by the end of the sub-topic, each learner has had a chance to answer at least one of these questions.
- Emphasise the names of the functional groups in Table 4.1.1 on page 201 of the Learner's Book. The learners should, by now, be able to draw any of the functional groups' structures given the name of the functional group.
- Although the learners should have some background knowledge of certain reaction mechanisms, they may not be familiar with the method of illustrating these. Use real examples to illustrate the difference between homolytic and heterolytic fission on the board.
- Use the same method to illustrate the difference between electrophiles and nucleophiles.
- Teach the revision and new work in Table 4.1.2 on page 204 of the Learner's Book. Ask the learners to give examples of reactions (equations) for each type of reaction.
- Revise oxidation and reduction in terms of organic chemistry briefly.

Suggested homework activities

Learners can revise content at home.

Suggested answers

Activity 1 Revise the IUPAC guidelines for naming organic compounds (LB page 205)

1. From "pent-2-ene" the following must be identified: This is an alkene with 5 carbons and a double bond at C–2.
   From "4,4-dimethyl": There are 2 methyl groups both attached to C–4.
2. The general IUPAC guidelines for naming carbohydrates (for these learners' level) can be summarised in the following way:
   - Choose the longest carbon chain as the main chain.
   - Number the main chain from the end nearest to a functional group, if there is one.
   - If not, number the main chain from the end nearest to a substituent (side chain).
   - Write down the substituents alphabetically with numbers (separated by commas) and the prefixes di-, tri-, tetra- and so on, followed by the name of the main chain.

Informal assessment

Do spot checks on the learners as they complete Activity 1 in groups. Let each group choose a spokesperson to read out their steps for the rest of the class. Do all the groups agree?

Sub-topic 4.1.2 Shapes of organic molecules LB p. 206

Beginning these lessons

This sub-topic investigates a number of concepts that the learners have already encountered in previous topics in this course, but applied to organic chemistry specifically.
Prior knowledge: VSEPR theory, bond lengths, bond angles, effect of lone pairs, molecular shapes.

Determine shapes of organic molecules (LB page 206)

Teaching tips

- Although the key concepts in this section will be familiar to the learners, teach the section slowly and thoroughly.
- Use molecular models to explain the shapes and associated bond angles.
- Use the diagrams in Figure 4.1.4 to explain the steps in determining molecular shape.

Suggested homework activities

Learners can revise content at home.

Suggested answers

Activity 2 Find the molecular shape of organic molecules (LB page 207]

1. **a)** Tetrahedral (double tetrahedral) because the C–C bond is a single bond; about 109.5°
   b) Linear, because the C–C bond is a triple bond; 180°
2. (b) will have the shorter bond length, because it has a higher bond order than (a).

Informal assessment

Find examples of molecules with particular shapes online or in other textbooks. Give the learners the names of these, and let selected learners come to the board to draw the expected molecular shape. Let the rest of the class assess each learner's contribution.

Sub-topic 4.1.3 Infrared spectroscopy

LB pp. 208–210

Beginning these lessons

This sub-topic covers a reasonable amount of new content. Follow the content (text and diagrams) in the Learner's Book closely as you teach.
Prior knowledge: electromagnetic spectrum.
New concepts: infrared spectroscopy, spectrophotometer, wave number.

The electromagnetic spectrum: Spectrophotometry (LB page 208)

Teaching tips

- Briefly revise the electromagnetic spectrum with the learners.
- Introduce infrared spectroscopy by explaining how a spectrophotometer works, and how it outputs its results. Emphasise the importance of these machines as an essential tool in large laboratories for identifying organic substances.
- Move on to the interpretation of infrared spectrums. Emphasise that each peak corresponds to a certain functional group, or a characteristic of an organic compound, so a spectrum is essentially a unique identifier for each type of organic compound. We can think of it as a fingerprint for an organic compound.
- Go through the text, diagrams and tables slowly to make sure that the learners understand how to interpret these spectrums.
- Find other spectrums online or in other textbooks to give the learners examples to interpret in groups or pairs.

Suggested homework activities

Learners can revise content at home.

Suggested answers

Activity 3 Interpret infrared spectrums (LB page 210)

- The glycine molecule has the following formula: NH_2–CH_2–COOH.
- The presence of the –OH group is confirmed by the broad trough at about 3 000 cm^{-1}. The shape of the trough is more complicated than that of a carboxylic acid, because of the presence of C–H and N–H bonds.
- The C=O group is confirmed by a sharp peak at about 1 700 cm^{-1}.
- The complicated pattern between 1 400 and 800 cm^{-1} indicates the presence of C–N and C–O bonds.

Informal assessment

Assess the pair work in Activity 3 by asking selected learners to explain one aspect of their findings (and let the rest of the class agree or disagree).

Extension

For those learners who need an extra challenge regarding infrared spectrums, let them search for "IR Spectrum Table & Chart site:sigmaaldrich.com" in their web browser. This page lists all the infrared frequencies for known functional groups and bonds. Then, find more advanced infrared spectrums online for the learners to interpret, given the chart in the webpage above.

Remedial activity

For those learners who are not confident in their interpretation of infrared spectrums, let them search for "Introduction to infrared spectroscopy site:khanacademy.org" and let them work through the lesson in pairs or small groups.

Summary (LB page 211)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 212)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. B ✓ (1) [K]
3. A ✓ (1) [C]
4. C ✓ (1) [K]
5. C ✓ (1) [K]
6. A hydrolysis ✓ (1) [Ap]
B elimination ✓ (1) [Ap]
C addition ✓ (1) [Ap]
D substitution ✓ (1) [Ap]
E condensation✓ (1) [Ap]

7. a) A free radical is an unstable molecule with an unpaired electron. ✓ (1) [K]
b) A carbon atom with three bonds and a positive charge tends to be unstable and is known as a carbocation. ✓✓ (2) [K]
c) A nucleophile can donate a pair of electrons to an electrophile that has empty orbitals to form a chemical bond. ✓✓ (2) [K]

8. a) C. ✓ There is no broad –OH band. ✓ There is a distinctive peak at about 1 000 cm^{-1}, indicating a C=C bond. ✓ (3) [An]
b) B. ✓ There is a broad –OH band ✓. There is a distinctive C=O band at about 1 700 cm^{-1}.✓ The peaks around 1 500 cm^{-1} indicate C–O and C–C bonds. ✓ (4) [An]
c) A. ✓ There is a broad –OH band. ✓ There is no C=O band. ✓ (3) [An]

Total: 25

TOPIC 4.2 Hydrocarbons

Learner's Book pages 214–233

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand the chemistry of the alkanes • Understand the chemistry of the alkenes • Know the uses of hydrocarbon as fuels and appreciate the environmental implications thereof
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning (the benefits and disadvantages of electric vehicles)
Inclusive education	Visually impaired learners or those with impaired fine motor skills will need help setting up and performing the experiment in this topic. Pair these learners up with an understanding and supportive learner who can assist them.
Suggested teaching time	16 lessons
Additional resources needed (if available)	• Molecular sets or homemade equivalents, such as plasticine and toothpicks • Experiment 1 (per pair): cyclohexane; cyclohexene; bromine (in carbon tetrachloride); petrol; paraffin; five test tubes include : gas for the Bunsen burner be included • *Low-cost resources:* See the "On the Internet" notes on LB pages 219, 220 and 226.

Introduction to the topic

This topic revises a number of concepts that will be familiar to the learners from Grades 10 and 11, such as alkane structures, nomenclature, reactions and uses. The learners will therefore need a solid prior knowledge on organic chemistry nomenclature (in general), and combustion and substitution reactions.

Closely monitor the learners' progress through this topic and provide revision opportunities to learners if needed.

Starter activity (LB page 214)

This starter activity revises some concepts from Grades 10 and 11 regarding alkane properties, structures, reactions and nomenclature.

Cross-cutting issue: The Environmental Learning Champion points out that, although electric vehicles emit fewer greenhouse gases than petrol or diesel vehicles when operating, their manufacturing process emits more of these gases, comparatively.

Suggested answers

1. Gas
2. When the butane in the lighter is compressed, it turns quickly into a liquid. When the pressure reduces again, butane quickly changes back to a gas.
3. $CH_3–CH_2–CH_2–CH_3$ **4.** C_4H_{10}
5. methylpropane
6. $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$
7. There are only single bonds in butane.
8. Cyclobutane

Sub-topic 4.2.1 Alkanes LB pp. 215–220

Beginning these lessons

The key point of this sub-topic is that the alkanes are saturated hydrocarbons. Therefore, they consist of chains of carbon atoms that each have four bonds with neighbouring carbon or hydrogen atoms.

The learners need to be able to identify the different types of reactions alkanes undergo and write balanced chemical equations for these.

It is important that the learners understand that crude oil is a non-renewable resource and, although the products that are derived from it are very useful, they are fossil fuels that contribute to the impacts of climate change.

Some learners may struggle to understand how these different products are derived from one substance (crude oil). Explain the concept of crude oil as a complex mixture of all of these products. In order to use each one, it must be separated from the others by means of fractional distillation.

Prior knowledge: isomerism, structural and skeletal formulas, alkane nomenclature.
New concepts: cycloalkanes, aromatic hydrocarbon, aliphatic hydrocarbon, thermal cracking, catalytic cracking.

Hydrocarbons/Systematic nomenclature of the alkanes

(LB pages 215–217)

Teaching tips

- Remind the learners what the term "hydrocarbon" means and introduce them to the cycloalkanes using Figure 4.2.1 on page 215 of the Learner's Book.
- Revise the different types of formulas that we use to illustrate organic compounds. Make sure that all the learners can associated each type with its correct name.
- Let the learners go through the worked example in pairs.
- As a class, go through the steps in naming alkanes, as well as the worked example. Give the learners additional examples on the board. Let pairs of learners derive the correct names.

Suggested homework activities

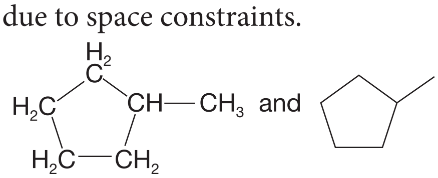
Activity 1 Question 2

Suggested answers

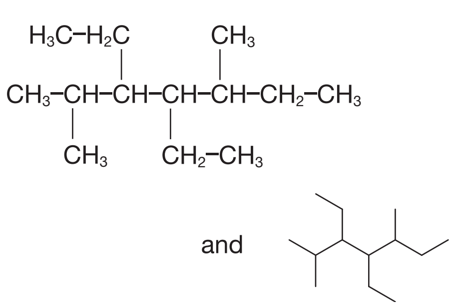
Activity 1 Write and understand IUPAC names (LB page 218)

Note: Although displayed formulas are required in many answers in this topic, condensed versions are shown due to space constraints.

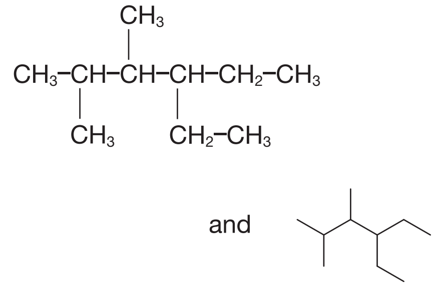
1. a)



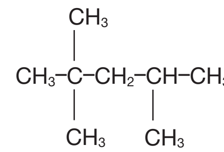
b)



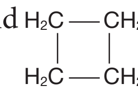
c)



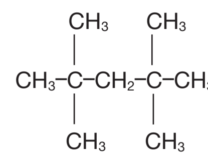
2. a) 2,2,4-trimethylpentane and



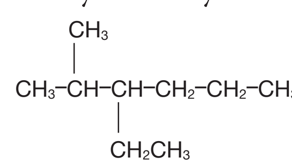
b) cyclobutane and



c) 2,2,4,4-tetramethylpentane and



d) 3-ethyl-2-methylhexane and



Informal assessment

For Activity 1, select learners to write their answers on the board for the rest of the class to use as a memorandum to mark their own work.

Reactions of alkanes (LB page 218)

Teaching tips

- Although generally unreactive, the alkanes do undergo combustion reactions and substitution reactions. Test the learners' prior knowledge on these two types of reactions, by selecting learners to write or draw examples on the board (from what they remember from previous years' work).
- Let the learners study the mechanism for homolytic fission in pairs. Then ask them questions to test their basic comprehension of the steps involved.

Suggested homework activities

Activity 2 Question 3

Suggested answers

Activity 2 Understand alkane reactions (LB page 219)

1. Alkanes contain strong carbon–carbon single bonds and strong carbon–hydrogen bonds The carbon–hydrogen bonds are only very slightly polar. The alkane molecules therefore do not attract other molecules or ions.
2. a) No reaction will take place in a dark room.
   b) **Initiation**

   $Br–Br \rightarrow Br• + Br•$

   Propagation

   $CH_3–CH_3 + Br• \rightarrow CH_3–CH_2• + H–Br$

   $\rightarrow CH_3–CH_2–Br + Br•$

   Termination

   $Br• + Br• \rightarrow Br–Br$

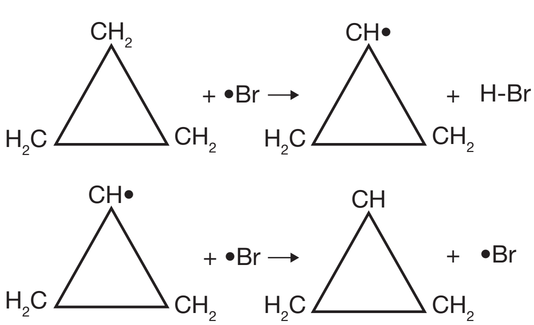
   $CH_3–CH_2• + Br• \rightarrow CH_3–CH_2–Br$

   $CH_3–CH_2• + CH_2–CH_3• \rightarrow$
   $CH_3–CH_2–CH_2–CH_3$

   c) **Initiation**

   Br–Br   Br• + Br•

   Propagation



   (Termination is similar to (b) above)
3. a) $C_3H_8 + 5O_2$ (sufficient) $\rightarrow 4H_2O + 3CO_2$
   b) $2C_3H_8 + 7O_2$ (limited) $\rightarrow 8H_2O + 6CO$

Informal assessment

For Activity 2, choose learners to write their answers on the board to serve as a memorandum for the rest of the class.

Extension

The reactions of the cycloalkanes are similar to the reactions of the alkanes. The very small cycloalkanes, such as cyclopropane, are exceptions. In the presence of UV light, cyclopropane undergoes substitution as in the case of non-cyclic alkanes. This is due to the strain these small cycloalkane experience in the ring. Bonds thus break easily and, in the absence of light, cyclopropane can even undergo addition to form, for example, 1,3-dibromopropane.

Let learners who need an extra challenge do research on the Internet to find the reaction mechanism for the addition reaction.

Crude oil as a source of aromatic and aliphatic hydrocarbons

(LB page 219)

Teaching tips

- Explain the distinction between aromatic and aliphatic hydrocarbons. Remind the learners how the fractional distillation process separates fractions of useful hydrocarbons from crude oil.
- Ask the learners to explain what cracking is and see if they can distinguish between thermal and catalytic cracking.

Suggested homework activities

Activity 3 Questions 3 to 4

Suggested answers

Activity 3 Describe the uses of alkanes (LB page 220)

1. They are compounds containing only hydrogen and carbon atoms.
2. A fractionating column is used to separate crude oil components or fractions on the basis of differences in boiling point. The vapours from the oil rise through the column and condense when cooled down enough. The liquids are extracted from the column at different heights.
   - Liquefied petroleum gases: fuel for domestic heating and cooking
   - Petrol: fuel for cars
   - Kerosene: fuel for aircrafts
   - Diesel: fuel for some cars and trains

- Heavy fuel oil: fuel for ships and power stations
- Bitumen: used for roads and roofs.

3. The shorter chain hydrocarbons are generally more useful than the longer chains. The shorter chains are more flammable and burn with a cleaner flame, making them good fuels. Cracking helps to match the supply of fractions that are in high demand.
4. <u>If a single product is given:</u> propane (C_3H_8, that is, $CH_3CH_2CH_3$).
<u>If two products are given:</u> methane (CH_4) and ethene ($CH_2{=}CH_2$)

Informal assessment

Diagnostic activity: Take in the learners' books to assess their answers for Activity 3.

Sub-topic 4.2.2 Alkenes LB pp. 221–230

Beginning these lessons

This sub-topic very briefly revises the work done in Grades 10 and 11 regarding the structural formulas and nomenclature of alkenes before moving on to the reactions of the alkenes. The latter is the most important aspect of this sub-topic, and is extensive in scope. Teach these sections slowly and thoroughly to ensure that all the learners can identify, explain and draw the mechanisms shown.
Prior knowledge: definition of alkenes, structural formulas and nomenclature of alkenes.
New concepts: addition reactions, Markovnikov's rule, hydrogenation, hydration, oxidation of alkenes, electrophilic addition, addition polymerisation.

The formulas of alkenes (LB page 221)

Teaching tips

- Briefly revise the different types of formulas (for alkenes) and remind the learners of the nomenclature involved in naming alkenes.

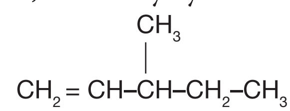
Suggested homework activities

Activity 4 Question 2

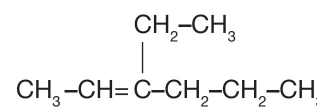
Suggested answers

Activity 4 Give the names and structures of alkenes (LB page 222)

1. **a)** pent-2-ene
 b) 3-methylpent-2-ene
 c) hex-1,4-diene
 d) 2,4-dimethylcyclohex-1-ene
2. **a)**



 b)



Informal assessment

Let the learners volunteer an answer to the questions in Activity 4 for the rest of the class to assess. Remember to write verbal answers on the board when learners agree about the correct answer.

Reactions of the alkenes (LB page 222)

Teaching tips

- Revise the basic addition reactions of the alkenes that the learners were introduced to in Grades 10 and 11 (such as, the addition of halogens, hydrogen halides and hydrogen).
- Teach Markovnikov's rule, and follow up with numerous examples of alkenes (which you can draw on the board), and let the learners predict where the hydrogen and where the halide ion will attach.
- The learners should have an understanding of hydration and hydrogenation at this point, but emphasise the mechanisms for each.
- Let learners work through the worked example in pairs.

Suggested homework activities

Activity 5

Suggested answers

Activity 5 Understand addition reactions of alkenes (LB page 224)

$CH_3CH_2CH_2CH_3$; butane; hydrogenation
$CH_3CH_2CH(OH)CH_3$; 2-butanol; hydration
$CH_3CH_2CH(Br)CH_3$; 2-bromobutane;

hydrohalogenation
$CH_3CH_2CH(Br)CH_2(Br)$; 1,2-dibromobutane; halogenation

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 5. Note which learners show signs of not understanding the basics from Grades 10 and 11. Do additional revision with them before moving on to the next section.

Oxidation of alkenes (LB page 224)

Teaching tips

- Teach this section in such a way that you make a clear distinction between the two different types of oxidation of alkenes.
- Let the learners go through the worked examples in pairs, but encourage them to ask questions if they do not understand something, or let them answer spot questions to gauge their understanding.
- As a class, go through the steps in identifying alkene compounds.
- Move on to the heterolytic fission, electrophilic addition in alkenes and inductive effects of alkyl groups. For each aspect, draw the mechanisms or examples on the board and complete or fill them in as you teach.

Suggested homework activities

Activity 6 Questions 1 to 2

Suggested answers

Activity 6 Understand the oxidation of alkenes (LB page 226)

1. There are 3 isomers:

   $CH_2{=}CH{-}CH_2{-}CH_3$ (but-1-ene)

   $CH_3{-}CH{=}CH{-}CH_3$ (but-2-ene)

   $CH_3{-}\underset{\displaystyle CH_3}{\underset{|}{C}}{=}CH_2$ (2-methylprop-1-ene)

2. Products after rupture by oxidation:
   but-1-ene → formaldehyde + another aldehyde (not formaldehyde)
   but-2-ene → an aldehyde (not formaldehyde) + another aldehyde
   2-methylprop-1-ene → ketone + formaldehyde
   Products after further oxidation:
   but-1-ene → CO_2 + acid
   but-2-ene → acid+ acid
   2-methylprop-1-ene → ketone + CO_2
   P: 2-methylpropene; Q: but-2-ene; R: but-1-ene

Informal assessment

If the learners complete Activity 6 in class, walk around the classroom as they work. Do spot checks on selected learner's books. Ask other learners to read out their answers. Simply check that they all understand the fundamental concepts of this section of work and that they are able to communicate their knowledge in writing.

Mechanism of electrophilic addition in alkenes (LB page 227)

Teaching tips

The learners have to understand the principles of Markovnikov's rule very well as this is central to many of the mechanisms in organic chemistry. Make sure that the learners can formulate the rule in their own words. Let them do this verbally and in writing.

Suggested homework activities

Learners can revise content at home.

Suggested answers

Activity 7 Understand electrophilic addition in alkenes (LB page 227)

1. Br^-
2. During an addition reaction between a hydrogen halide (HX) and an unsymmetrical alkene, the major product formed when the hydrogen atom is added to the carbon with the greater number of hydrogen atoms. X is then added to the carbon with the smaller number of hydrogen atoms.
3. A carbocation is formed.
4. It is polar due to its being unsymmetrical and there is a difference in the electronegativity of H and Br.

Informal assessment

Let the learners complete Activity 7 in pairs in class. Walk around the classroom as they work and do spot checks on selected learner's books.

Distinguishing between alkanes and alkenes (LB page 227)

Teaching tips

- In this section of the sub-topic, the learners perform the experiment to distinguish between alkanes and alkenes, based on these compounds' known reactivity and behaviour with bromine.
- Let the learners work in pairs if there are enough laboratory resources to support this.

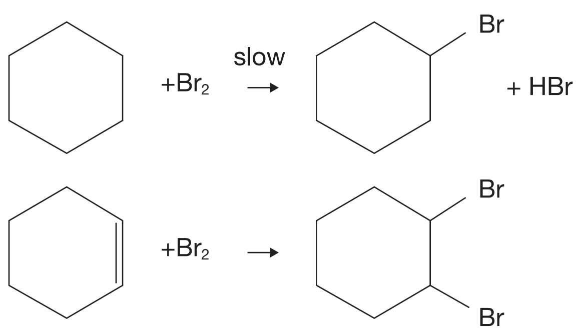
Suggested homework activities

Experiment 1 Questions 1 to 5

Suggested answers

Experiment 1 Reactions of alkanes and alkenes with bromine (LB pages 227–228)

1.



2. A bromine test is used. This involves the addition of bromine water to the unknown hydrocarbon. If the bromine water decolours, the hydrocarbon is unsaturated. If there is no colour change (or if the reaction is much slower) the hydrocarbon is saturated.
3. When treated with bromine, test tube C (containing paraffin) shows almost no colour change. There is a rapid colour change when the contents of test tube D (petrol) is treated with bromine. It can therefore be deducted that paraffin is saturated while petrol is unsaturated or a mixture of saturated and unsaturated compounds.
4. When the gas used for the Bunsen burner is tested with bromine, there is almost no colour change or a very slow reaction can be observed. This gas therefore consists of saturated carbon compounds.
5. Saturated hydrocarbons will only react with bromine under "free radical conditions", meaning you have to add UV light.

Informal assessment

For Experiment 1, walk around the classroom as the learners work and do spot checks on their experiment set ups. If they complete their answers in class, check on these too.

Addition polymerisation of alkenes (LB page 228)

Teaching tips

- Let the learners read go through the text, photographs, diagrams and worked example in pairs.
- Afterwards, give the learners a quick oral quiz on aspects of what they have learnt about.
- Discuss the disposal of polyalkanes with the learners. Point out that polyalkanes are generally non-biodegradable, but that they are recyclable.

Suggested homework activities

Learners can revise content at home.

Extension

For those learners who need an extra challenge, let them do some research at a library or on the Internet to find out how various polyalkenes, such as the following, are recycled industrially.

- LDPE
- HDPE
- PP

Remedial activity

Refer the learners who are still not confident in interpreting or drawing reaction mechanisms to tutorials on the Internet, which can explain the process in a step-by-step manner (that is often animated). Let them search for appropriate tutorials on YouTube (www.youtube.com) or elsewhere.

Sub-topic 4.2.3 Hydrocarbons as fuels
LB p. 231

Beginning these lessons

This sub-topic links up with work that has already been discussed in Topic 4.1 and earlier sub-topics of Topic 4.2. The main aim of this sub-topic is to sensitise the learners to the responsible use of hydrocarbon fuels.

Prior knowledge: combustion of alkanes, greenhouse gases, infrared spectroscopy.

Alkanes as fuels (LB page 231)

Teaching tips

- Ask the learners to define concepts such as "renewable energy" and "sustainable development".
- Let them brainstorm ways of reducing air pollution in different settings, both outdoors and indoors.
- Briefly review inrared spectroscopy as an analytical tool to identify compounds.

Suggested homework activities

Activity 1 can be done as a research project by the whole class or in small groups.

Suggested answers

Activity 8 Research infrared spectroscopy to monitor air quality (LB page 231)

Use the rubric for research projects in Section D of this Teacher's Guide to assess each group's assignment.

Summary (LB page 232)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 233)

Note: You could let the learners do this section as self-assessment. Either give them the memorandum to mark their own work or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

1. B ✓ (1) [K]
2. D ✓ (1) [K]
3. D ✓ (1) [K]
4. D ✓ (1) [K]
5. D ✓ (1) [K]
6. **Initiation** [1] $Cl_2 \xrightarrow{hv} 2\,Cl\bullet$ ✓

   Propagation

   [2] $Cl\bullet + CH_3CH_3 \xrightarrow{slow} HCl + CH_3\dot{C}H_2$

   [3] $CH_3\dot{C}H_2 + Cl_2 \xrightarrow{fast} CH_3CH_2Cl + Cl\bullet$ ✓✓✓✓

   Termination [4] $Cl\bullet + Cl\bullet \rightarrow Cl_2$ ✓

   Any two radicals in the reaction vessels can terminate the reaction. (8) [C]

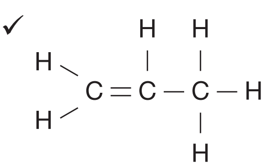
7. a) Crude oil, which is a mixture of hydrocarbons, is evaporated in a fractionating column ✓ and different fractions are condensed at different temperatures. ✓ The fractionating column is hot at the bottom ✓ and cool at the top. ✓ Substances with high boiling points condense at the bottom and substances with lower boiling points condense on the way to the top. ✓ Each fraction contains hydrocarbon molecules with more or less the same number of carbon atoms and that fall within a given range of boiling points.✓ (6) [K]

   b) A: about 50 °C ✓; B: about 350 °C ✓ (2) [C]

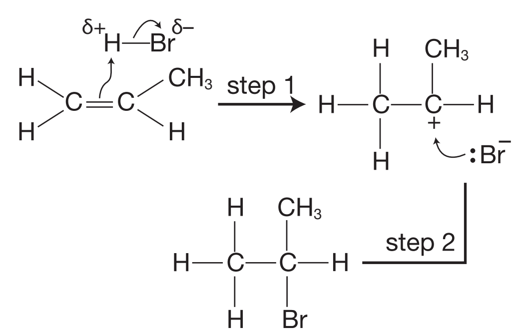
   c) 1: liquefied petroleum gas (fuel for domestic heating and cooking) ✓✓;
   2: petrol (fuel for vehicles) ✓✓;
   3: kerosene (fuel for aircrafts) ✓✓;
   4: diesel (fuel for some vehicles and trains) ✓✓;
   5: heavy fuel oil (fuel for ships and power stations) ✓✓;
   6: bitumen (used for roads and roofs) ✓✓ (12) [K]

8. a) Thermal cracking ✓ makes use of high temperatures ✓ to break down long hydrocarbon chains to shorter ones. Catalytic cracking ✓ makes use of chemical processes and catalysts ✓ to break down long hydrocarbon chains. (4) [K]

   b) propene ✓ ✓✓ (3) [Ap]



9.



✓✓✓✓ (4) [Ap]

10. a) CH_3COCH_3 ✓✓ (2) [An]

    b) CH_3CHO ✓✓ (2) [An]

    c) CH_3COOH ✓✓ (2) [An]

Total: 50

TOPIC 4.3 Halogen derivatives

Learner's Book pages 234–247

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Know the chemistry of halogenoalkanes including the mechanisms of nucleophilic substitution • Understand the chemistry of halogenoalkanes and appreciate their concerns about their effects on the ozone layer
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Human rights and democracy (the role of organohalogens in chemical warfare, and the human rights violations that are associated with chemical warfare)
Inclusive education	Visually impaired learners will need help interpreting the explanatory diagrams of mechanisms in this topic. Enlarge the diagrams on the board for the learners to see these more clearly.
Suggested teaching time	8 lessons
Additional resources needed (if available)	• Molecular sets or (*low-cost resource*) homemade equivalents, such as plasticine and toothpicks • *Low-cost resource:* See the "On the Internet" note on LB page 242.

Introduction to the topic

This topic revises a number of concepts that will be familiar to the learners from Grades 10 and 11, such as halogenoalkane structures, nomenclature and reactions. The learners will therefore need a solid prior knowledge on organic chemistry nomenclature (in general), and substitution and elimination reactions. They will also learn about the reactivity and uses of the halogenoalkanes, as well as the impact of some of these substances on the ozone layer.

Starter activity (LB page 234)

This starter activity revises some work on halogens and halogen compounds from Grades 10 and 11. *Cross-cutting issue*: The Human Rights and Democracy Champion highlights how some parties ignore international human rights regarding the use of chemical weapons in conflicts.

Suggested answers

1.

Symbol	F	Cl	Br	I
Boiling point	85 K	240 K	332 K	458 K

2. The boiling points of the halogens increase down the group. As you move down the group, there in an increase in the number of electrons. This results in an increase in the strength of the intermolecular forces, and therefore the boiling points.

3. **a)** Cl **b)** Br **c)** I **d)** I **e)** Cl **f)** F

4. **a)** Alkanes are hydrocarbon chains with saturated (single carbon–carbon) bonds. The general formula is C_nH_{2n+2}.
b) Methane

Sub-topic 4.3.1 Halogenoalkanes

LB pp. 235–240

Beginning these lessons

This sub-topic revises some of the work done in Grades 10 and 11 regarding the structural formulas and nomenclature of halogenoalkanes very briefly before moving on to their reactions (specifically, substitution and elimination reactions). The latter is the most important aspect of this sub-topic, and requires the learners to understand and replicate reaction mechanisms. Teach these sections of this sub-topic slowly and thoroughly to ensure that all the learners can identify, explain and draw the mechanisms shown.
Prior knowledge: definition of halogenoalkanes, structural formulas and nomenclature of halogenoalkanes.
New concepts: substitution reactions, reactions with ammonia, elimination reactions.

The formulas of the halogenoalkanes (LB page 235)

Teaching tips

- Remind the learners what the term "halogenoalkane" means and introduce them to the other names that are commonly used to refer to these compounds.
- Revise the different types of formulas that we use to illustrate halogenoalkane compounds. Make sure that all the learners can associate each type with its correct name.
- As a class, go through the steps in naming halogenoalkanes and work through the worked example. Give the learners additional examples on the board and let pairs of learners determine the correct names.

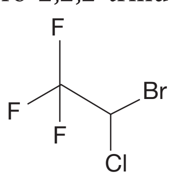
Suggested homework activities

Activity 1 Questions 3 to 4 and Activity 2

Suggested answers

Activity 1 Understand halogenoalkanes (LB page 237)

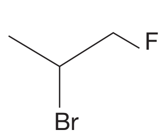
1. 1-bromo-1-chloro-2,2,2-trifluoroethane
2. $C_2HBrClF_3$ and



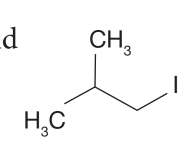
3. $M_r(C_2HBrClF_3) = 2(12.0) + 1.0 + 80.0 + 35.5 + 3(19.0) = 197.5\ g{\cdot}mol^{-1}$
4. $\frac{57}{197.5} \times 100 = 28{,}86\%$
5. a) 3,5-dichloro-3-methylheptane
   b) 1,2-dibromo-1-chlorobutane
6.

```
    Cl  F
    |   |
Cl - C - C - F
    |   |
    Cl  F
```

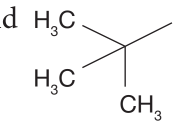
7. a) C_3H_6BrF and



   b) C_4H_9I and



   c) C_4H_9I and



Informal assessment

For Activity 1, let some learners write their answers on the board, and let the rest of the class assess and compare.

Substitution reactions/Elimination reactions (LB pages 237–240)

Teaching tips

- Revise the basic substitution reactions that the learners were introduced to in Grades 10 and 11.
- Teach the hydrolysis of halogenoalkanes by explaining the mechanism on the board, and pointing out the nucleophilic substitution of the halogen in each case.
- Move on to show how the formation of nitriles and amines occur by means of a similar mechanism (using cyanide ions and ammonia, respectively).
- Show how elimination reactions also displace the halogen from the halogenoalkane, but that no substitution occurs.
- Clearly explain how the mechanism proceeds on the board.

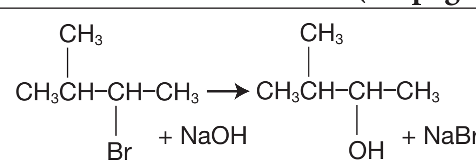
Suggested homework activities

Activity 2 Questions 3 to 4

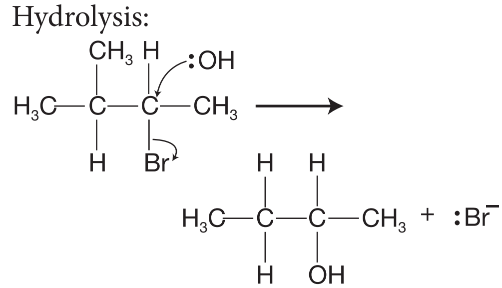
Suggested answers

Activity 2 Understand halogenoalkane reactions (LB page 240)

1. a)

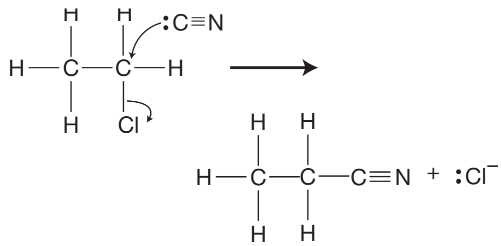


   b) Hydrolysis:



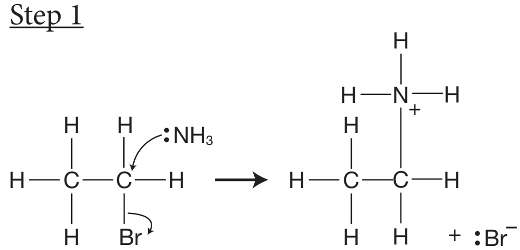
2. a) $CH_3–CH_2–Cl + KCN \rightarrow CH_3–CH_2–CN + K^+Cl^-$

b) Nucleophilic substitution:

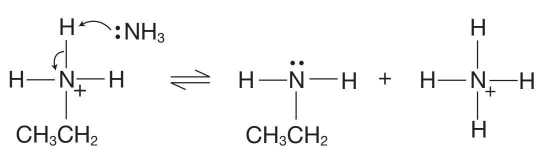


3. a) Bromoethane has a polar bond between the carbon and the bromine. The lone pair of the nitrogen will be strongly attracted to this carbon that has a partial positive (δ+) charge. When the lone pair approaches the carbon–bromine bond, the bromine is expelled as Br^-.

b) Step 1



Step 2



4. a) A high temperature (heating under reflux)
b) Concentrated hydroxide
c) Ethanol as solvent

Informal assessment

If the learners complete this activity in class, walk around the classroom as they work and do spot checks on selected learner's books. Ask other learners to read out their answers. Simply check that they all understand the fundamental concepts of this section of work, and that they are able to communicate their knowledge in writing.

Sub-topic 4.3.2 Relative strength of the carbon–halogen bond

LB pp. 241–244

Beginning these lessons

Use this sub-topic to revise and gauge the learners' prior knowledge of the work from earlier in this course, where they learnt about bond strength before starting the new work. The focal point here is on the effect of halogenoalkanes on ozone, and why this caused substantial environmental problems in the last three decades.
Prior knowledge: bond energy, bond length, bond polarity.
New concepts and skills: fluorohalogenoalkanes, chloroflurocarbons.

Reactivity of halogenoalkanes/ Uses of fluorohalogenoalkanes

(LB pages 241–242)

Teaching tips

- Teach the learners about the differences in reactivity between the various types of carbon–halogen bonds using the table and figure. Point out that this explains why some halogenoalkanes are generally more reactive than others.
- Let pairs of learners read through the content on the uses of fluorohalogenoalkanes as an introduction to the next lesson.

Suggested homework activities

Learners can revise content at home.

Chlorofluorocarbons and ozone layer depletion (LB page 242)

Teaching tips

- Explain how the ozone layer protects the Earth's surface from dangerous UV-C radiation, but allows UV-A (and some UV-B) radiation to pass through it.
- Remind the learners of the chlorine-catalysed decomposition of ozone, which they learnt about in Topic 2.4.
- Explain how this mechanism was responsible for large-scale damage to the ozone layers in earlier decades, when the use of products that contained these chlorine-containing organic compounds was widespread.
- Let pairs of learners go through the alternatives to chlorofluorocarbons, and the advantages and disadvantages of HCFCs and HFCs, in pairs.

Suggested homework activities

Learners can revise content at home.

Reactivity of covalent bonds in terms of bond energy, bond length and bond polarity (LB page 244)

Teaching tips

- Revisit the concepts of bond energy, bond length and bond polarity from earlier in this course.
- Explain how these phenomena influence the reactivity of the halogenoalkanes.

Suggested homework activities

Activity 3

Suggested answers

Activity 3 Understand halogenoalkanes

1. There is an increase in reactivity as you move down the group because the bond lengths increase, and therefore the bond energies decrease as you move down the group.
2. Advantages of HCFCs: Fewer chlorine atoms are released into the atmosphere; they are less stable and therefore have shorter lifetimes in the atmosphere (and hence, cannot do as much damage); they are not toxic at low concentrations and do not produce smog.

Informal assessment

Diagnostic activity: Take in the learners' book and mark their answers to Activity 3.

Extension

Let the learners write a short research report on the different types of (halogenoalkane-based) anaesthetics that are used in hospitals and dental practices today. They should use the Internet or a library to find this information. Their reports should include the following:

- How many different types of anaesthetics are generally used?
- Are all of them halogenoalkane-based?
- Why is it that these compounds are so effective as anaesthetics?

Remedial activity

Let the learners who need additional help with the new (theoretical) concepts in this topic form study groups so that they can revise the more difficult concepts and practise drawing reaction mechanisms. Help them find online resources and exercises from other Chemistry textbooks to complete as a group.

Summary (LB page 245)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 246)

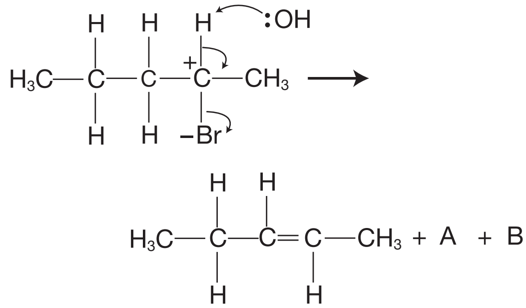
Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. C ✓ (1) [K]
3. A ✓ (1) [K]
4. a) Ideal conditions for elimination: a high temperature, a concentrated KOH (or NaOH) solution; with pure ethanol as solvent ✓✓
   Ideal conditions for substitution: a lower temperature; lower concentrations of KOH (or NaOH); with water as solvent ✓✓ (4) [K]
   b) nucleophilic substitution ✓ (1) [K]
   c) $CH_3CH(Br)CH_2CH_3 + KCN \rightarrow CH_3CH(CN)CH_2CH_3 + KBr$ ✓✓✓ (3) [C]

5. a)



✓✓✓ (3) [Ap]

b) H_2O and Br^- ✓ (1) [C]

c) elimination ✓ (1) [K]

6. The reactivity of the halogenoalkanes is dependent on the strength of the carbon–halogen bond which has to be broken. ✓
The pattern of bond strength is: C–F > C–Cl > C–Br > C–I. ✓
Because it is easier to break the bonds between C and Br, ✓ compared to the bonds between C and Cl, C–Br will be more reactive than C–Cl. ✓ (4) [Ap]

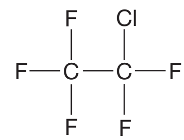
7. a) The higher the bond energy, the more likely it is for a pair of atoms to remain bonded, which corresponds to a low reactivity. ✓ (1) [Ap]

b) The stronger the bond between two atoms, the shorter the bond length and the less reactive the halogenoalkane. ✓ (1) [Ap]

c) Reactivity and polarity are directly proportional to each other. The higher the polarity, the higher the reactivity. ✓ (1) [Ap]

8 . a) This refers to the decrease in concentration of ozone in the ozone layer due to human activity and greenhouse gases ✓ and that the degree of this decrease has reached a point that the layer cannot regain ideal concentrations easily. ✓ (2) [K]

b)



✓✓✓ (3) [Ap]

c) CFCs damaging the ozone layer are substituted by HFCs (such as CF_3CH_3). The shorter life span of HFCs makes them less damaging to the ozone layer. ✓ Because fluorine does not contribute to the depletion of the ozone layer and CF_3CH_3 contains only fluorine ✓ and no chlorine or bromine, it is much safer. (2) [C]

9. a) Two layers form. ✓ (1) [C]

b) There will be no reaction. ✓ (1) [C]

c) This corresponds to the test for a bromide ion. The bromoethane reacts with OH^- to form Br^- and this results in a positive precipitation test with Ag^+. ✓ (1) [C]

d) This rules out the possibility that the precipitation could be a carbonate. ✓ (1) [C]

e) No. ✓ HCl will give a precipitate in the presence of Ag^+. ✓ (2) [C]

f) $CH_3CH_2Br + NaOH \rightarrow CH_3CH_2OH + NaBr$ ✓✓ (2) [C]

g) $Na^+ + Br^- + Ag^+ + NO_3^- \rightarrow AgBr + Na^+ + NO_3^-$ ✓✓ (2) [C]

Total: 40

TOPIC 4.4 Hydroxyl compounds

Learner's Book pages 248–261

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	Understand the chemistry of alcohols
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology (the role of alcohol-based products in the care of ITC devices)
Inclusive education	Visually impaired learners or those with impaired fine motor skills will need help setting up and performing the experiment in this topic. Pair these learners up with an understanding and supportive learner who can assist them.
Suggested teaching time	7 lessons
Additional resources needed (if available)	• Experiment 1 (per pair): acidified potassium dichromate ($K_2Cr_2O_7$); ethanol (primary alcohol); propan-2-ol (secondary alcohol); 2-methylpropan-2-ol (tertiary alcohol); three test tubes (labelled 1°, 2° and 3°) • Molecular sets or (*low-cost resource*) homemade equivalents, such as plasticine and toothpicks • *Low-cost resource:* See the "On the Internet" note on LB page 254.

Introduction to the topic

In this sub-topic, the learners study the structures, formulas, naming conventions, reactions and uses of alcohols. Early on, the topic relies on the learners' prior knowledge of alcohols, but soon moves on to new and more complex work on their reactions. Allocate more time for the later part of the topic.

Starter activity (LB page 248)

This starter activity revises key concepts from Grades 10 and 11 regarding the alcohols.
Cross-cutting issue: The Information and Communication Technology Champion highlights the fact that ITC devices contain very delicate components – many of which may not come into contact with moisture – and so require an alcohol-based cleaner.

Suggested answers

1. Ethene + water → ethanol (as the only product) The reaction can only take place when the reaction mixture is acidic and is heated.
2. $CH_3–CH_2–OH \xrightarrow{H_2SO_4} CH_2 = CH_2 + H_2O$
3. Oxidation
4. Fermentation

Sub-topic 4.4.1 Alcohols LB pp. 249–258

Beginning these lessons

Start this sub-topic off by discussing what the learners can recall about the homologous series, the alcohols, from previous grades. Use this as a way to gauge how much time you should spend on the first three sections of the topic.
Prior knowledge: different formulas of the alcohols, nomenclature of the alcohols, combustion reactions, substitution reactions, oxidation, dehydration.

The general formula of alcohols: Other formulas of alcohols

(LB page 249)

Teaching tips

- Revise all the different types of formulas with the learners, but in the context of the alcohols.
- Work through the worked examples as a class, and check that all the learners were able to draw the correct structures.

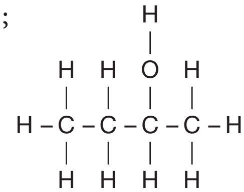
Suggested homework activities

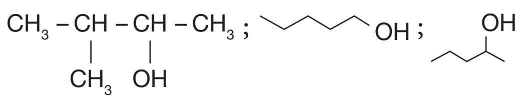
Activity 1 Question 2

Suggested answers

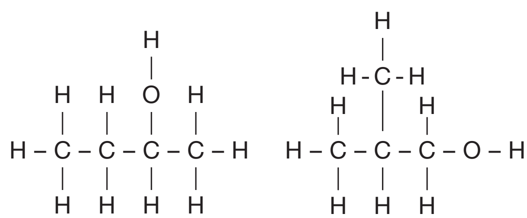
Activity 1 Interpret structural formulas (LB page 250)

1. $CH_3CH(OH)_2$;





2. a)



(butan-2-ol) (2-methylpropan-1-ol)

   b) They are isomers.

Informal assessment

Diagnostic activity: Take in the learners' books to mark Activity 1. Make sure that all the learners are confident in drawing structures of alcohols before moving on to the next section.

Nomenclature of the alcohols

(LB page 250)

Teaching tips

- Go through the steps for naming alcohols using the IUPAC conventions as a class.
- Let the learners go through the worked example in pairs.

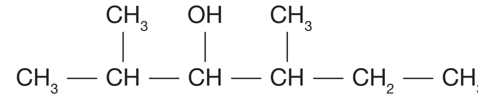
Suggested homework activities

Activity 2 Question 2

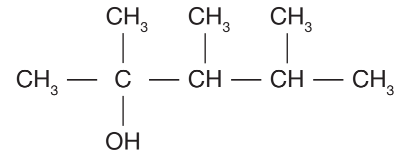
Suggested answers

Activity 2 Name alcohols (LB page 251)

1. a) 2-methylpropan-1-ol
   b) 1-methylcyclobutan-1-ol
   c) butan-1,4-diol
2. a) $CH_3–CH_2–OH$
   b)



   c)



Informal assessment

Let the learners volunteer an answer to Activity 2 for the rest of the class to assess.

Deduce the molecular formulas of alcohols from their structural formulas

(LB page 252)

Teaching tips

- Revise the steps for deducing a molecular formula, given a structural formula.
- Give the learners a few examples on the board for them to solve in pairs.

Suggested homework activities

Activity 3

Suggested answers

Activity 3 Understand the structural formulas of alcohols (LB page 252)

1. Row 2: $C_5H_{12}O$ or $C_5H_{11}OH$; 2-methylbutan-2-ol
   Row 3: $CH_3CH_2CH(CH_3)CH_2OH$; $C_5H_{12}O$
   Row 4: $C_5H_{12}O$; 3-methylbutan-2-ol
2. a) $CH_3CH(OH)CH_2CH_3$
   b) $CH_3CH_2CH(CH_3)CH_2OH$

Informal assessment

Let the learners volunteer answers and gauge their understanding in this way.

Chemical reactions of alcohols

(LB page 253)

Teaching tips

- The reactions in this section are exemplified by ethanol in each case.
- Let the learners go through the combustion and substitution reactions of the alcohols in pairs,

and gauge their understanding by asking a few spot questions afterwards.
- Teach the reactions with sodium, the oxidation and dehydration of alcohols, and the reaction of ethanol with a carboxylic acid to form an ester. In each case, write equations and mechanisms on the board so that you can refer to these as you teach.

Suggested homework activities

Learners can revise content at home.

Primary, secondary and tertiary alcohols (LB page 255)

Teaching tips

- Many kinds of organic compounds are labelled as primary, secondary or tertiary. These are not random ways of referring to compounds, but correspond to chemical behaviours.
- Teach the learners about the degrees of substitution in alcohols. Draw structures on the board to illustrate each one as you teach.
- Let the learners complete Activity 4 in class.
- Let the learners perform Experiment 1 as a way of consolidating that which they have learnt in this section.
- Move on to the steps in deducing the presence of an alcohol.

Suggested homework activities

Activity 5

Suggested answers

Activity 4 Identify primary, secondary and tertiary alcohols (LB page 255)

1. pentan-3-ol (secondary)
2. 2-methylbutan-2-ol (tertiary)
3. 2,2-dimethylpropan-1-ol (primary)
4. 3-methylbutan-2-ol (secondary)

Experiment 1 Distinguish between primary, secondary and tertiary alcohols (LB page 255)

Suggested answers

1. When adding $K_2Cr_2O_7$ the following can be observed:
   <u>Test tube 1°</u>: The orange colour turns green.
   <u>Test tube 2°</u>: The orange colour turns green.
   <u>Test tube 3°</u>: There is no colour change.
   When adding Fehling's solution the following can be observed:
   <u>Test tube 1°</u>: A brick-red precipitate forms.
   <u>Test tube 2°</u>: There is no colour change.
2. Ethanol (a primary alcohol) and propan-2-ol (a secondary alcohol) both react with oxidising agent $K_2Cr_2O_7$ and the orange dichromate is reduced to a green solution of chromium(III) ions. Ethanol is oxidised to an aldehyde and propan-2-ol to a ketone. When Fehling's solution is added to the aldehyde (test tube 1°) a precipitate is observed because of a positive iodoform reaction. Fehling's solution gives negative results in the presence of the ketone that formed in test tube 2°.
3. To distinguish between a primary, secondary and tertiary alcohol, first eliminate the tertiary alcohol. Only the primary and secondary alcohols react with oxidising agent $K_2Cr_2O_7$, where a colour change from orange to green will be observed.
   To distinguish between the primary and secondary alcohol, Fehling's solution is added to each of the oxidised products of the primary alcohol (aldehyde) and secondary alcohol (ketone). Because only the aldehyde will result in a precipitate with Fehling's solution, the primary (and therefore also secondary alcohol) will be identified.

Activity 5 Identify secondary alcohols (LB page 257)

1. Negative. Secondary alcohol, but no methyl group attached to the carbon with OH-group.
2. Positive. Secondary alcohol; methyl group attached to carbon with OH-group.
3. Positive. Secondary alcohol; methyl group attached to carbon with OH-group
4. Positive. Ethanol only primary alcohol that gives positive iodoform test.
5. Negative. Primary alcohol.
6. Negative. Secondary alcohol, no methyl group attached to carbon with OH-group.
7. Positive. Secondary alcohol, methyl group attached to carbon with OH-group.

Informal assessment

- Let selected learners read out one of their answers to Activity 4, for the rest of the class to assess and correct, if necessary.

- Diagnostic activity: Take in the learners' books to assess their answers to Experiment 1's questions.
- For Activity 5, let selected learners call out their answers, and let the rest of the class assess and compare answers.

Uses of alcohols (LB page 257)

Teaching tips

- Let the learners go through the text, diagrams and photographs in this section, in pairs.
- Encourage them to ask questions if something is not clear. Ask spot questions to gauge how well they have assimilated the information.

Suggested homework activities

Learners can revise content at home.

Extension

Let the learners do some research online or at a library on the applications of removing sulfur compounds from coal.

Remedial activity

A number of reaction mechanisms in this topic may prove difficult for some learners to grasp immediately. Refer those learners to the online tutorials and lessons, or pair them up with other learners for peer teaching.

Summary (LB page 259)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 260)

Note: You could let the learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

1. D✓ (1) [K]

2. B✓ (1) [K]

3. A✓ (1) [K]

4. D✓ (1) [K]

5. B ✓ (1) [C]

6. a) A: 2-methylhexan-3-ol; ✓✓
B: butan-2-ol ✓✓
C: butan-1-ol ✓✓
D: 2-methylpropan-2-ol ✓✓ (8) [C]

b) C ✓ butanal ✓ (2) [K]

c) In the presence of an excess of the oxidising agent, the aldehyde will be further oxidised to the corresponding carboxylic acid.
- Use an excess of alcohol so that there is no [O] to carry the reaction to the second stage. ✓
- Distil off the aldehyde as soon as it forms so that the aldehyde cannot be oxidised further. ✓ (2) [Ap]

d) i) Dehydration where water is eliminated from a reactant.✓ (1) [C]

ii) $CH_3-CH_2-CH_2-CH_2-OH \xrightarrow{\text{conc } H_2SO_4} CH_3-CH_2-CH=CH_2+H_2O$
✓✓ (2) [C]

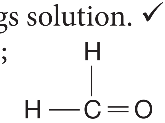
iii) The alcohol must be heated ✓ in the presence of an excess of concentrated H_2SO_4. ✓ (2) [C]

7. a) ethanal; ✓ ethanoic acid ✓ (2) [K]

b) in the presence of sulfuric acid or $K_2Cr_2O_7$ ✓✓ (2) [K]

8. a) Only the primary and secondary alcohols can be oxidised by potassium dichromate. ✓ These are $CH_3CH_2CH_2CH_2OH$ and $CH_3CH_2CH(CH_3)OH$. ✓ (2) [Ap]

b) Butan-1-ol. ✓ Only primary alcohols will form aldehydes which give a positive test with Fehlings solution. ✓ (2) [Ap]

9. a) methanal ✓;  ✓ (2) [C]

b) It is incomplete. ✓ Accept any of these two reasons: A complete oxidation would mean that methanoic acid forms. / A test with blue litmus paper is negative. ✓ (2) [An]

c) The phases of the catalyst, reactants and products are different. ✓ (1) [An]

Total: 35

TOPIC 4.5 Isomerism

Learner's Book pages 262–273

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	Understand structural and stereoisomerism
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	HIV and AIDS (the role of stereoisomers in the drugs used for the treatment of HIV and AIDS)
Inclusive education	Learners with fine motor skill impairments will struggle with building molecular models in this topic. Pair or group these learners with patient and understanding learners who can help or build the models for the learners to study.
Suggested teaching time	6 lessons
Additional resources needed (if available)	• Molecular sets or (*low cost resource*) homemade equivalents, such as plasticine and toothpicks • *Low-cost resource:* See the "On the Internet" note on LB page 264.

Introduction to the topic

In this sub-topic, the learners learn about the quality of certain organic compounds with tetrahedral centres giving rise to handedness and other types of isomerism. These are new concepts for the learners to understand, but they are gradually introduced by means of revising structural isomers, which is then extended to include types of structural isomers and then stereoisomerism.

Starter activity (LB page 262)

This practical starter activity allows the learners to explore one of the fundamental concepts of this topic through building and observing models of molecules.
Cross-cutting issue: The HIV and AIDS Champion highlights the fact that many drugs used in the treatment of HIV and AIDS have isomeric qualities.

Suggested answers

The learners should find that some group members can match their models perfectly, while another sub-group had models that could not match with the first group, but all matched with each other.

The learners should pinpoint the fact that the models they had built are tetrahedral and that this molecular shape gives rise to the inconsistency they observed.

Sub-topic 4.5.1 Isomerism: structural and stereoisomerism LB pp. 263–270

Beginning these lessons

Start this sub-topic off by reminding the learners about the type of isomerism they learnt about in Grades 10 and 11. Use this as a starting point which you can return to whenever the learners show signs that they do not understand the concepts later on.
Prior knowledge: structural isomerism.
New concepts: positional isomerism, functional group isomerism, chain isomerism, stereoisomerism, optical isomerism, chiral centre, enantiomer, chirality.

Structural isomerism (LB page 263)

Teaching tips

- Revise structural isomerism with the learners using Figure 4.5.1 and doing further examples on the board.
- Explain how the name of an isomer changes, depending on the position of the functional group. However, as Figure 4.5.2 shows, the learners need to be aware of structures that are merely horizontal or vertical "flips" of an already-identified isomer.
- Move on to the naming conventions for straight-chain alkanes as brief revision. Then teach the

learners about the four degrees of possible alkyl substitution for carbon (Figure 4.5.3).
- Let the learners go through the worked example in pairs.

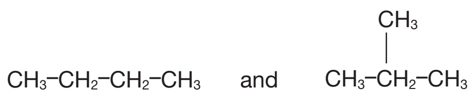
Suggested homework activities

Activity 1 Questions 2 to 3

Suggested answers

Activity 1 Understand structural isomerism (LB page 265)

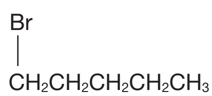
1. a)

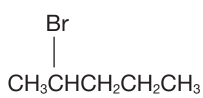


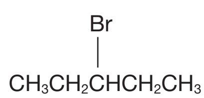
butane and 2-methylpropane

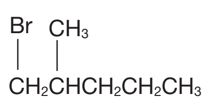
   b) Butane: C1: 1°, C2: 2°, C3: 2°, C4: 1°
   2-methylpropane: C1: 1°, C2: 3°, C3: 1°; C4: 1°

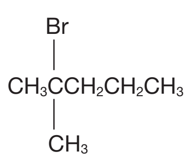
2. Accept any relevant answer, such as C_2H_6 or C_3H_8.
3. a) Accept any of the many possible isomers. The following seven are only some possibilities:

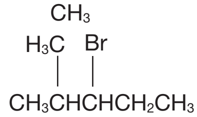
1-bromopentane 

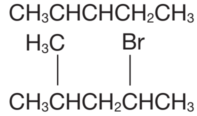
2-bromopentane 

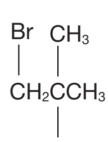
3-bromopentane 

1-bromo-2-methylbutane 

2-bromo-2-methylbutane 

3-bromo-2-methylbutane 

4-bromo-2-methylbutane 

   b) 1-bromo-2,2-dimethylpentane 

Activity 2 Test your knowledge on isomers (LB page 265)

The nine isomers of heptane are: heptane; 2-methylhexane; 3-methylhexane; 2,2-dimethylpentane; 2,3-dimethylpentane; 2,4-dimethylpentane; 3,3-dimethylpentane; 3-ethylpentane; 2,2,3-trimethylbutane
Learners need to draw these structures in addition to naming them.

Informal assessment

- Let the learners volunteer an answer to Activity 1 verbally or on the board for the rest of the class to assess. Make sure all the learners follow when verbal answers are given.
- For Activity 2, let selected learners call out the name of an isomer and let another appointed learner write these on the board.

Types of structural isomerism

(LB page 265)

Teaching tips

- In this section, the learners are introduced to positional, functional and chain isomerism.
- Explain each type using examples on the board. Ask the learners spot questions to gauge their understanding.
- Draw other sets of examples on the board. Ask groups of learners to identify which type of isomerism is apparent in each set.

Suggested homework activities

Activity 3 Question 3

Suggested answers

Activity 3 Understand types of isomerism (LB page 266)

1. No. The two positional isomers shown are the only two possible. If the –OH group moved to C3, the molecule would be but-2-ol. If the group moved to C4, the molecule would be but-1-ol.
2. Two possible functional isomers are:

$CH_3CH_2—O—CH_2CH_3$

and

$CH_3—O—CH_2CH_2CH_3$.

3. a) Accept any reasonable answer (with a diagram), such as 2-methyl-1-propanol.
b) 2-methyl-2-propanol.

Informal assessment

Diagnostic activity: Take in the learners' books to check their answers to Activity 3.

Stereoisomerism (LB page 266)

Teaching tips

- In this section, the learners are introduced to stereoisomerism and revisit sigma- and pi-bonds to gain an understanding of how certain types of stereoisomers come about.
- Briefly define stereoismerism, but move on to revise sigma- and pi-bonding. Make sure that all the learners have a good understanding of these forms of bonding before you explain their role in stereoisomerism.
- In pairs, let the learners build models of ethanol. Explain geometric isomerism using the guidelines shown in Figure 4.5.9, but letting the learners move and rotate their models so that they can see the distinct differences in rotations.
- Then, let the learners build the simple molecules as shown in Figure 4.5.10. When the learners try to rotate the alkene, they will find that it is immovable (unlike the alkane).
- Distinguish between *cis* and *trans* isomers.
- The learners can complete Activity 4 in class or partly in class and partly as homework.
- Remind the learners of the molecules they built in the starter activity to this topic as a way of introducing the next type of isomerism: optical isomerism.
- Use Figure 4.5.12 or let the learners build models to assist your explanation of this type of isomerism.
- Emphasise the new terms that are introduced in this section and gauge the learners' comprehension by asking spot questions as you teach.
- Let the learners read through the content about optical isomers and plane-polarised light in pairs.

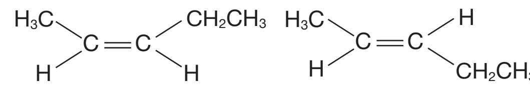
Suggested homework activities

Activity 4 Question 3

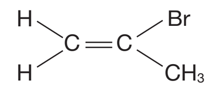
Suggested answers

Activity 4 Identify geometric isomerism (LB page 268)

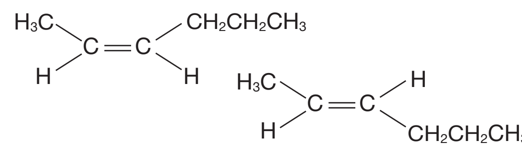
1. *Cis–trans* isomers do occur:



2. *Cis–trans* isomers do not occur:

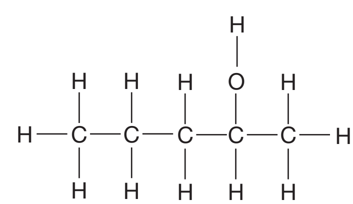


3. *Cis–trans* isomers do occur:



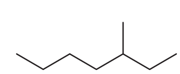
Activity 5 Understand optical isomerism (LB page 270)

1. Accept any valid structure of an alcohol, such as:



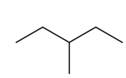
pentan-2-ol; C2 is the chiral centre

2. a)



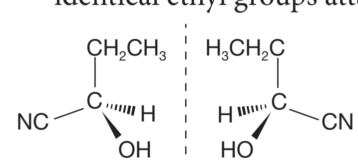
Optical isomer: C3 is the chiral centre

b)



Not an optical isomer: C3 has two identical ethyl groups attached to it.

3.



Informal assessment

- For Activity 4, ask selected learners to share their answers and let the rest of the class agree or disagree with their findings.
- For Activity 5, let learners volunteer to draw one of their answers on the board (for the rest of the class to assess).

Extension

Let the learners do some research online or at a library regarding an aspect of optical isomers that they find interesting. For example, the learners could research:

- the use of enantiomers in pharmaceutical drugs
- the side-effects caused by the non-preferred enantiomer in a pharmaceutical drug
- the science behind the manufacture of filters used in sunglasses and goggles to protect the eyes from glare.

Remedial activity

Some of the visual phenomena in this topic may prove difficult for some learners to grasp immediately. Spend additional time with these learners. Build models or let the learners build models that you can use to explain these concepts again.

Summary (LB page 271)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

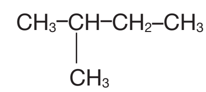
Self-assessment (LB page 272)

Note: You could let the learners do this section as self-assessment. Then give them the memorandum to mark their own work or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

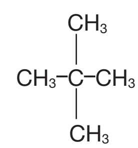
Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. D ✓ (1) [K]
2. C ✓ (1) [K]
3. A ✓ (1) [K]
4. B ✓ (1) [K]
5. C ✓ (1) [K]
6. a) $CH_3-CH_2-CH_2-CH_2-CH_3$
pentane ✓✓



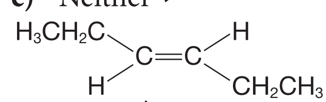
2-methylbutane ✓✓



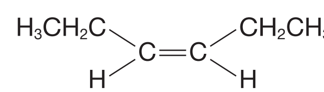
2,2-dimethylpropane ✓✓

(6) [C]

b) 4° (in 2,2-dimethylpropane) ✓ (1) [K]
7. a) *Trans* ✓ (1) [C]
b) *Cis* ✓ (1) [C]
c) Neither ✓ (1) [C]
8.



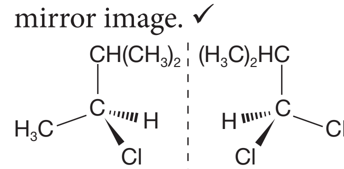
trans



cis

✓✓ ✓✓ (4)[Ap]

9. a) An optical isomer (or enantiomer) is a special type of stereoisomer ✓ that arises when a molecule is not identical to its mirror image. ✓ (2)[C]
b)



✓✓✓✓ (4)[Ap]

Total: 25

TOPIC 4.6 Carbonyl compounds

Learner's Book pages 274–283

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	Understand the chemistry of the aldehydes and ketones
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental Learning (the role of non-biodegradable materials in water pollution)
Inclusive education	Visually impaired learners will need help interpreting the diagrams of organic structures and mechanisms in this topic. Enlarge the diagrams on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learners.
Suggested teaching time	6 lessons
Additional resources needed (if available)	See the "On the Internet" note on LB page 281.

Introduction to the topic

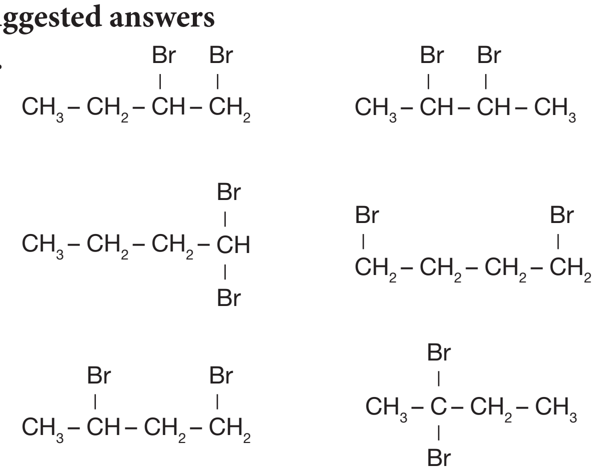
This topic introduces the learners to the nomenclature, representations and general chemistry of the aldehydes and ketones. Although the learners will be familiar with these functional groups, most of the content in this topic will be new to them. Teach slowly and thoroughly.

Starter activity (LB page 274)

This starter activity revises some basic concepts of organic chemistry from Grades 10 and 11.
Cross-cutting issue: The Environmental Learning Champion highlights the environmental cost of the convenience of plastic packaging. Let the learners discuss what communities in Namibia can do to avoid water and land pollution by plastic packaging.

Suggested answers

1.



2. a) 2-ethyl-3-methylbut-1-ene
b) 3-chloro-4-methylpentan-2-ol

Sub-topic 4.6.1 Aldehydes and ketones

LB pp. 275–281

Beginning these lessons

This sub-topic starts by revisiting the carbonyl compounds, in terms of focusing in on the aldehydes and the ketones as members of their homologous series. Spend as much time as possible on the introductory aspects of the sub-topic, to ensure that the learners assimilate the new content and are able to build on it towards the end of the sub-topic.
Prior knowledge: aldehyde, ketone.
New concepts: reactions with alcohols.

Aldehydes and ketones as carbonyl compounds (LB page 275)

Teaching tips

- Go through the introductory aspects of this sub-topic as a class. The content gives the learners the opportunity to apply concepts that they have learnt in earlier topics to a relatively unfamiliar new family of organic compounds.
- Emphasise the difference between the two groups in terms of their structures.
- Move on to the nomenclature of the aldehydes

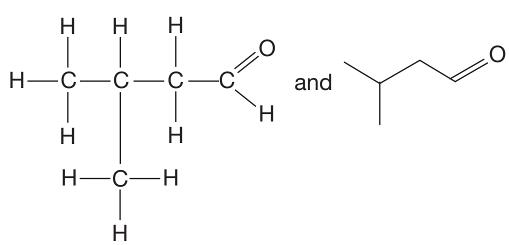
and ketones. In each case, let the learners go through the steps in pairs. Then draw structures of various aldehydes and ketones on the board for them to name.
- Let the learners go through the worked example in pairs and give them another similar example (on the board) to gauge their understanding of the difference in structures of aldehydes and ketones.

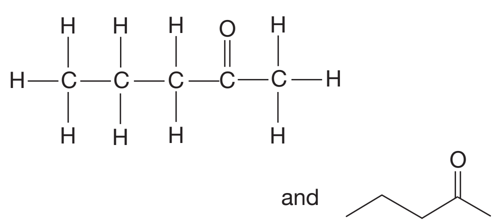
Suggested homework activities

Activity 1 Question 2

Suggested answers

Activity 1 Understand the formulas of aldehydes and ketones (LB page 279)

1. a) 

   b) 

2. a) 2-methylpentan-3-one
   b) 2,3-dichloropropanal
   c) butanal
   d) heptan-4-one

Informal assessment

Do spot checks on the learners as they complete Activity 1 in pairs.

The formation of aldehydes and ketones from alcohols (LB page 280)

Teaching tips

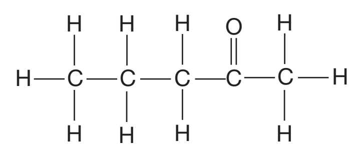
- Teach this section slowly and thoroughly: The reactions with primary and secondary alcohols must be clear in the learners' minds once you have finished this section.
- Use molecular models or draw enlarged diagrams on the board to help you explain the reaction mechanisms.
- Find online tutorials or reaction animations to enrich the learners' learning experiences.

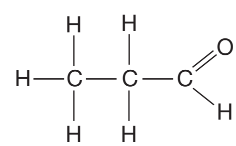
Suggested homework activities

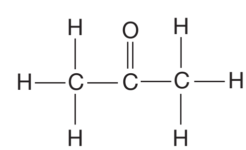
Activity 2 Question 2

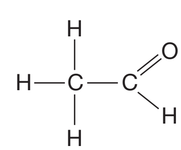
Suggested answers

Activity 2 Understand reactions involving aldehydes and ketones (LB page 281)

1. a) 

   b) 

   c) 

   d) 

2. To the left of the arrow, we find propanal. The product will thus be propanoic acid, that is, CH_3CH_2COOH.

Informal assessment

Let selected learners come to the board to draw the structural formulas and product prediction on the board. Let the rest of the class assess each learner's contribution.

Extension

For those learners who need an extra challenge regarding aldehydes and ketones, let them do some research into the uses (applications) of some of these organic compounds. For example, acetone is used as a paint thinner and some aldehydes are used as fungicides in agriculture and leather tanning.

Remedial activity

Group the learners who find it difficult to distinguish between aldehydes and ketones (or other carbonyl group-containing compounds) to watch the online materials you sourced again. Then work through introductory tutorials on aldehydes and ketones.

Summary (LB page 282)

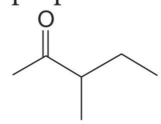
Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

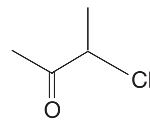
Self-assessment (LB page 283)

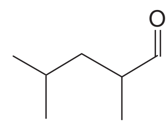
Note: You could let the learners do this section as self-assessment. You can then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

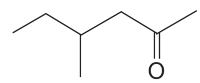
Suggested answers

Note: See page iv of this Teacher's Guide for an explanation for the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. B ✓ (1) [K]
3. B ✓ (1) [K]
4. B ✓ (1) [K]
5. a) hexan-3-one ✓✓ (2) [Ap]
b) ethanal ✓ (1) [K]
c) propanal ✓ (1) [K]
6. a) 

✓✓ (2) [Ap]
b) 

✓✓ (2) [Ap]
c) 

✓✓ (2) [Ap]
d) 

✓✓ (2) [Ap]
7. a) Oxidising agent ✓ (1) [K]
b) To acidify it ✓ (1) [K]
c) orange ✓ → green ✓ (2) [K]
d) Organic liquids can release flammable vapours that could get into contact with the flames of a Bunsen burner. The liquid itself is also flammable. ✓ The temperature can be regulated more accurately when using a heating mantle. ✓ (2) [C]
e) ethanol ✓ (1) [C]
f) propan-2-ol ✓ (1) [C]
g) With a mild reactant it is possible to control the reaction in order to form the intermediate product, an aldehyde. If the reaction does not stop halfway, the product will be the corresponding carboxylic acid. ✓ (1) [Ap]

Total: 25

TOPIC 4.7 Carboxylic acids and derivatives

Learner's Book pages 284–293

Syllabus coverage	See the syllabus grid (year plan) in Section B (pp. 11–25).
General objectives	• Understand the chemistry of the carboxylic acids • Understand the chemistry of the esters and amines
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Entrepreneurship (the entrepreneurial opportunities that carboxylic acid-based products offer)
Inclusive education	Visually impaired learners will need help interpreting the diagrams of organic structures and mechanisms in this topic. Enlarge the diagrams on paper or on the board, or find similar diagrams online so that you can zoom in on the images for the learners.
Suggested teaching time	6 lessons
Additional resources needed (if available)	None

Introduction to the topic

This topic revises the homologous series of the carboxylic acids. Most of the nomenclature, formulas, structures and basic chemistry should be familiar to the learners from Grades 10 and 11. However, this topic goes further into detail regarding the derivatives of carboxylic acids (in Sub-topic 4.7.1).

Starter activity (LB page 284)

This starter activity revises some concepts from Grades 10 and 11 regarding carboxylic acids and esters.
Cross-cutting issue: The Entrepreneurship Champion lists some of the practical uses of certain carboxylic acids and points out that there are numerous entrepreneurial opportunities in these substances and products.

Suggested answers

1.

    O – H
    |
R – C = O

2.

    O – R′
    |
R – C = O (R = R′ or R ≠ R′)

3. a) This is an ester. It corresponds to the general formula of esters with R = ethyl and R′ = methyl.

b) Concentrated sulfuric acid

c) Methyl propanoate

Sub-topic 4.7.1 Carboxylic acids

LB pp. 285–287

Beginning these lessons

Make use of these final two sub-topics in this course as a means to consolidate some of the work done in the earlier topics in this theme. By now, the learners should have a firm grip on the aspects of organic chemistry, such as nomenclature, writing formulas, drawing structures and drawing reaction mechanisms. Instead of teaching the content, let the learners work on their own or in pairs to revise the revision material and learn from each other as they go through the new concepts.
Prior knowledge: carboxylic acids, carboxyl group.
New concepts: formation of carboxylic acids, chemical reactions of carboxylic acids.

The general formula and structure of carboxylic acids (LB page 285)

Teaching tips

- Let the learners go through the introductory aspects of this sub-topic in pairs. The content gives the learners the opportunity to revise concepts that they have learnt in earlier topics and test themselves regarding their prior knowledge of nomenclature, structures and basic reactions.

- Let the learners go through the worked example in pairs and give them another similar example (on the board) to gauge their understanding of the molecular and structural formulas of carboxylic acids.
- Move on to the formation and reactions of the carboxylic acids. In each case, let the learners go through the content in pairs and then ask volunteers to come to the board to draw the structures of reactants that you give them and predict the product.

Suggested homework activities

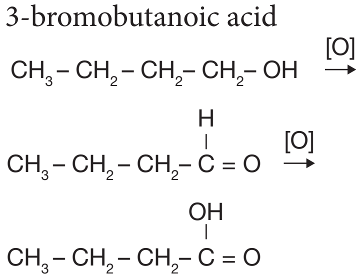
Activity 1 Question 3

Suggested answers

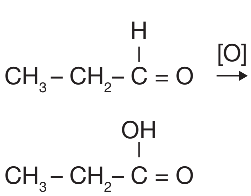
Activity 1 Understand carboxylic acids **(LB page 287)**

1. a) propanoic acid
b) hexanoic acid
c) 3-bromobutanoic acid

2. a)



b)



3. Carboxylic acids can react with the following to form carboxylic salts (alkanoates):
- a base (or alkali) to form a carboxylic salt and water
- a carbonate to form a carboxylic salt and water and carbon dioxide
- a metal to form a carboxylic salt and hydrogen.

These salts are ionic and often soluble in water.

Informal assessment

For Activity 1, ask selected learners to write their answers to Questions 1 and 2 on the board as a memo for the rest of the class to use to mark their own work. Ask selected learners to give feedback on Question 3 orally.

Sub-topic 4.7.2 Esters and amines

LB pp. 288–291

Beginning these lessons

See *Beginning these lessons* for Sub-topic 4.7.1.
Prior knowledge: esters, amines, hydrolysis of esters.

Esters (LB page 288)

Teaching tips

- Let the learners revise the esters in terms of formulas and nomenclature and go through the worked example in pairs.
- Explain the hydrolysis of esters to the class.
- Let the learners read through the uses of esters on their own.

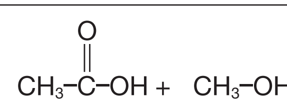
Suggested homework activities

Activity 2 Question 3

Suggested answers

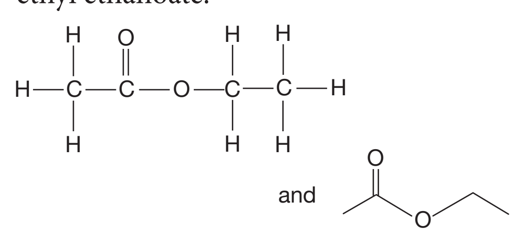
Activity 2 Understand reactions involving esters **(LB page 290)**

1. a)

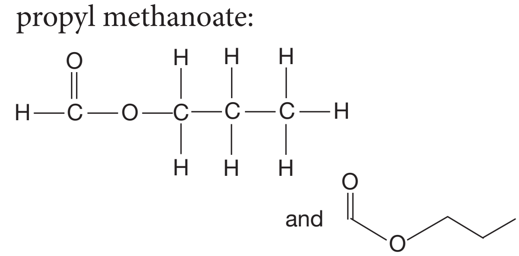


b) $CH_3COO^- K^+ + CH_3OH$

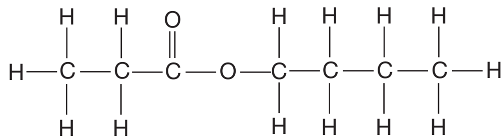
2. a) ethyl ethanoate:

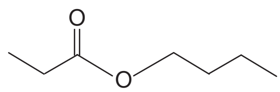


b) propyl methanoate:

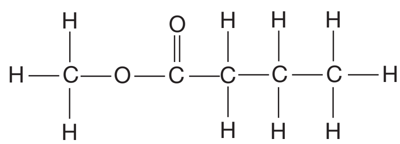


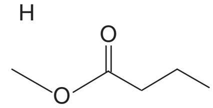
c) butyl propanoate:



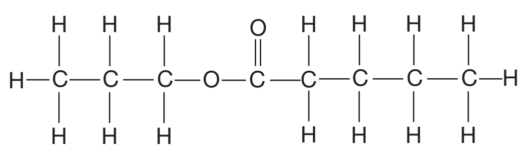
and 

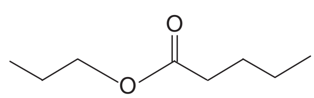
d) methyl butanoate:



and 

e) propyl pentanoate:



and 

3. The following structures must be drawn by the learners:
   a) sodium ethanoate + ethanol
   b) butanoic acid + ethanol

Informal assessment

For Activity 2, ask selected learners to write their answers on the board to serve as a memorandum for the rest of the class.

Amines (LB page 291)

Teaching tips

Let the learners revise the amines in terms of formulas and nomenclature, and go through the worked example in pairs.

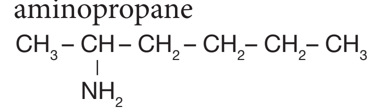
Suggested homework activities

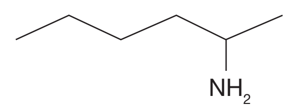
Activity 3 Question 2

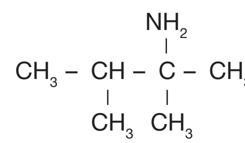
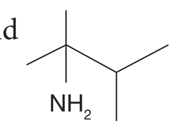
Suggested answers

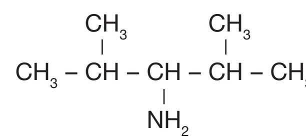
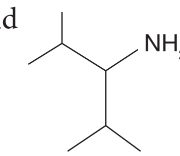
Activity 3 Understand amines (LB page 291)

1. a) 2-amino-4-methylpentane
   b) aminopropane

2. a)  and



   b)  and 

   c)  and 

Informal assessment

For Activity 3, write the answers on the board and let the learners swap books to mark each other's work.

Extension

For those learners who need an extra challenge regarding esters and amines, let them do some research into the uses (applications) of some of these organic compounds.

Remedial activity

Refer the learners who are still not confident in interpreting or drawing reaction mechanisms to tutorials on the Internet, which can explain the process in a step-by-step manner (that is often animated). Let them search for appropriate tutorials on YouTube (www.youtube.com) or elsewhere.

Summary (LB page 292)

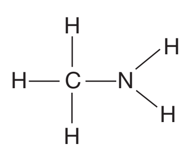
Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB page 293)

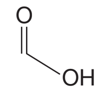
Note: You could let the learners do this section as self-assessment and then either give them the memorandum to mark their own work, or mark their work yourself and give feedback. In both cases, it could serve the purpose of diagnostic assessment.

Suggested answers

1. B ✓ (1) [K]
2. B ✓ (1) [K]
3. C ✓ (1) [K]
4. D ✓ (1) [K]
5. ✓✓✓✓ (4) [Ap]



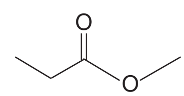
6. **a)** 2-hydroxybutanedioic acid ✓✓ (2) [Ap]
   b) It contains two carboxylic groups. ✓✓ (2) [K]
   c) ✓✓



   with –COOH as functional group. ✓✓ (4) [K]

7. **a)** C_2H_6O (ethanol) + $C_2H_4O_2$ (ethanoic acid) $\rightleftharpoons$ $C_4H_8O_2$ (ethyl ethanoate) + H_2O (water) ✓✓✓✓ (4) [Ap]
   b) It is the dehydrating agent and catalyst. ✓ (1) [C]
   c) Esterification ✓ (1) [K]
   d) A heating mantle ✓ is used as organic solutions are flammable ✓ and the temperature must be controlled ✓ more carefully than a Bunsen burner allows for. (3) [Ap]

8. **a)** ✓✓✓ (3) [Ap]



   b) Propanoic acid ✓and methanol ✓ with concentrated sulfuric acid ✓ as catalyst. (3) [K]
   c) $CH_3CH_2COOCH_3 + H_2O \overset{H+}{\rightleftharpoons} CH_3CH_2COOH + CH_3OH$ ✓✓✓✓ (4) [Ap]

Total: 35

Lesson plan template

Use this lesson plan template, or adapt it to suit your needs, to help you prepare for specific lessons.

Subject: Chemistry		
Cross-curricular links:		
Topic:	**Sub-topic:**	**Time allocation:**
General and specific objectives:		
Preparation:	**Resources:**	
Teaching guidelines:		
Comments/Follow-up:		

Generic assessment tools

In this section, you will find generic rubrics that you can adapt for use as needed.

Rubrics for experiments

- You could choose to use all the criteria listed or some of them and add your own.
- You could also change the number of marks for each criterion.

Experiment write-up rubric

Note: Decide before the learners start the experiment which skills you will assess, for example collecting data, the research, the hypothesis, the conclusion, etc.

Criteria	Marks
Work has a clear and accurate heading that indicates the aim of the experiment	1
Learner sets out work using the scientific process for the experiment	2
Learner shows evidence of having completed the experiment	2
Learner has recorded information from the experiment clearly	2
Learner has drawn a conclusion (based on the hypothesis, if relevant)	2
Work is neat with clear headings, sub-headings and labelled drawings where appropriate; all information is in a logical order	2
Skill focus 1 (See note above.)	2
Skill focus 2 (See note above.)	2
Total	**15**

Graph rubric

- You could choose to use all the criteria listed or some of them and add your own.
- You could also change the number of marks for each criterion.

Criteria	Marks (2)	Marks (1)
Graph is neat and legible		
The (collected) data have been transferred correctly to graph		
Suitable heading contains both variables		
Independent on x-axis correctly labelled		
Dependent on y-axis correctly labelled		
Scales indicated (correctly) on axes		
Correct units used	1 for yes, 0 for no	
Graph curve/line/bars accurate		
Total	**15**	

Individual learner record sheet for experiments

Compile a sheet like this for each learner. Make notes about the type of experiment and tick if the learners have achieved the objectives and skills associated with each experiment.

Date: ____________________________

Learner's name: ____________________________

Date	Experiment	Comment	Suggestions or notes

Mind map rubric

- You can choose to use all or some of these criteria, and add some of your own.
- You can change the number of marks for each criterion.

How to use this rubric

- Unless you make changes to this rubric, the maximum total marks would be 10.
- Add 1 mark or 0 marks for the visual impression.

Criteria	Marks (3)	Marks (2)	Marks (1)
Arrangement of concepts	Main concept easily identified; sub-concepts branch appropriately from main idea	Main concept easily identified; most sub-concepts branch from main idea	Main concept not clearly identified; sub-concepts do not consistently branch from main idea
Links and linking lines	Linking lines connect related terms/point in correct direction; linking words accurately describe relationship between concepts	Most linking lines connect properly; most linking words accurately describe the relationship between concepts	Linking lines do not always point in correct direction; linking words do not clarify relationships between concepts
Content	Reflects essential information; logically arranged; concepts concisely presented; no misspellings or grammatical errors	Reflects most of the essential information; generally logically arranged; concepts presented without too many excess words; fewer than three misspellings or grammatical errors	Contains extraneous information; not logically arranged; contains numerous spelling and grammatical errors
Visual impression	1		
Total	10		

Rubric for research projects

You could:

- choose to use all or some of these criteria, and add some of your own
- weight some criteria to be more important than others, for example, content detail × 2
- change the number of marks per descriptor.

Unless you make changes to this rubric, the maximum total marks would be 34 . When you assess, tick the appropriate block in each row.

Add the marks of the ticked blocks.

Criteria	1	2	3
Names	Missing/on the back	Present	
Topic/Heading	Unimaginative/ uninteresting/outdated/ vague	Polished but not attention-grabbing	Clever/controversial/ current
Flow	Unclear/illogical/ unscientific	Acceptable/good attempt /somewhat unnatural/ some misplaced headings	Good/well thought through/appropriate to topic
Use of space	Too cramped/too much blank space	Suitable spacing/little to no waste of space	
Content detail	Information duplicated/ not grouped/ignores limitations of topic	Little duplication of information/acceptable grouping/all on the topic	No duplication of information/good grouping/all relevant and covers topic well
Content range	Inadequate	Good but some relevant information is missing	Wide-ranging but within scope of topic
Accuracy of content	Many factual or scientific errors	Mostly accurate and checked	All facts from reputable sources and accurate
Presentation	Inaccessible for the reader/not much effort/not structured	Content fairly well structured, with some visuals	Content presented in logical and structured way
Visuals/images	Very few/irrelevant/unclear /captions absent	Relevant but certain vital images missing/captions poor	All relevant/no obvious omissions/good placing/ correct captions
Summary	Probably not own words	Some shortcomings	To the point/bulleted/own words
Language ability/ usage	Many grammar/ spelling mistakes	Very few mistakes	No mistakes
Referencing	Not done	Not Harvard style/ inadequate	Harvard style/adequate
Teacher's comments			
Total			

Generic record sheets

In this section, you will find generic record sheets that you can adapt for use wherever you need them.

Class record sheet

Use this sheet for recording marks.
You can write down the actual marks, for example: 5/10, or use these symbols:
A = Achieved objectives exceptionally well
B = Achieved objectives very well
C = Achieved objectives well
D = Achieved objectives satisfactorily
E = Achieved the minimum number of objectives to be considered competent
U = Ungraded

Name	Date	Specific objective tested	Marks

Group work comment sheet

Date: ____________________

Activity: ____________________

Names of learners in group: ____

____

____

Checklist	Yes	No
Did the learners listen to each other?		
Did the learners ask each other questions?		
Did the learners help and encourage each other?		
Did the learners stay on topic?		
Did the learners complete the task?		

Further notes

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Individual learner record sheet

Compile a sheet like this for each learner. Make notes about the type of task and tick if the learners have achieved the knowledge, understanding and skills associated with each task.

Date: ______________________

Subject/Activity: ______________________

Learner's name: ______________________

Date	Task/Activity	Comment	Suggestions or notes

Memoranda for practice papers

Example Paper 1: Multiple choice questions

(LB page 298)

1.	B ✓	(1) [K]
2.	B ✓	(1) [C]
3.	C ✓	(1) [C]
4.	D ✓	(1) [K]
5.	A ✓	(1) [C]
6.	C ✓	(1) [K]
7.	D ✓	(1) [K]
8.	A ✓	(1) [C]
9.	D ✓	(1) [K]
10.	B ✓	(1) [K]
11.	D ✓	(1) [C]
12.	C ✓	(1) [C]
13.	A ✓	(1) [Ap]
14.	B ✓	(1) [C]
15.	A ✓	(1) [Ap]
16.	D ✓	(1) [C]
17.	B ✓	(1) [C]
18.	C ✓	(1) [K]
19.	D ✓	(1) [K]
20.	C ✓	(1) [C]
21.	A ✓	(1) [Ap]
22.	B ✓	(1) [C]
23.	A ✓	(1) [C]
24.	C ✓	(1) [K]
25.	B ✓	(1) [C]
26.	D ✓	(1) [An]
27.	D ✓	(1) [K]
28.	A ✓	(1) [C]
29.	C ✓	(1) [K]
30.	A ✓	(1) [An]
31.	D ✓	(1) [C]
32.	B ✓	(1) [C]
33.	A ✓	(1) [Ap]
34.	A ✓	(1) [K]
35.	A ✓	(1) [K]
36.	C ✓	(1) [Ap]
37.	B ✓	(1) [Ap]
38.	D ✓	(1) [An]
39.	A ✓	(1) [An]
40.	C ✓	(1) [C]
		Total: 40

Example Paper 2: Structured questions (LB page 302)

Question 1

1. Ionic ✓ (1) [K]

2. $[He]2s^2 2p^4$ ✓ (1) [C]

3. a) Bent ✓ (1) [C]

b) Dipole–dipole ✓ (1) [K]

c) $\Delta H = 2 \times (530 \times 2) + 496 - 2 \times (R = P \times 3) = -196$

$\frac{2812}{6} = R = P$

$\therefore R = P = 469\ kJ{\cdot}mol^{-1}$ ✓✓ (2) [Ap]

4. a) $PV = nRT$

250 000 Pa ✓ × 0.002 m^3 ✓ = $n \times 8.31 \times 298$ K

= 0.202 mol ✓

$M_r = \frac{m}{n} = \frac{5.66\ g}{0.202\ mol}$ ✓ = 28.02 $g{\cdot}mol^{-1}$ ✓ (5) [Ap]

b) It is known that P is oxygen. Therefore 28.02 − 16 = 12.02, so the other atom must be carbon. The gas in the sample is carbon monoxide. ✓ (1) [C]

[12]

Question 2

1. a) $K_p = \frac{(pNH_3)^2}{(pN_2)(pH_2)^3}$ ✓ (1) [K]

b) $1.22 \times 10^{-5} = \frac{(pNH_3)^2}{(25)(58)^3}$ ✓

$(pNH_3) = 7.71$ ✓ (2) [C]

2. a) It speeds up the reaction. ✓ (1) [K]

b) A catalyst creates an alternative pathway (or mechanism) for the SO_2 and O_2 reactants to take to form the product; one that has a lower activation energy. ✓ (1) [C]

c) Heterogeneous; ✓ it is a solid whereas all the reactants are in the gaseous state. ✓ (2) [C]

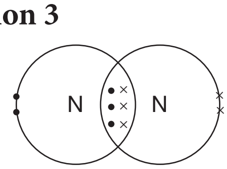
d) The rate of production of product would increase ✓ because the number of particles with energy greater than the activation energy would be present. ✓ Therefore, the number of successful collisions per unit time would increase. ✓ (3) [Ap]

e) $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$ ✓✓ (2) [An]

[12]

Question 3

1. a) ✓ (1) [C]



b) Triple bond, non-polar, needs lots of energy to break bond ✓ (1) [C]

c) Lightning provides the high activation energy needed for the reaction to occur. ✓ (1) [Ap]

d) Nitrate fertilisers dissolve in river water promoting algal bloom, which blocks sunlight. ✓ As a result, bacteria break down dead organisms, and there is a drop in the oxygen concentration in rivers. Aquatic organisms die. ✓ (2) [C]

2. a) i) $Ca(OH)_2$ ✓ (1) [C]

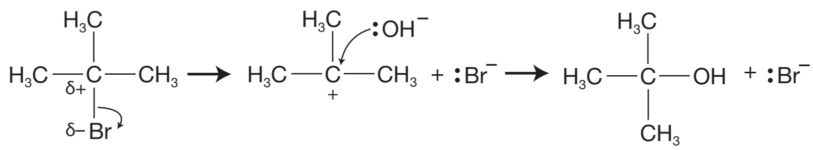
ii) $Ca(NO_3)_2$ ✓✓ (2) [C]

b) $2Mg + O_2 \rightarrow 2MgO$ ✓✓ State symbols are not necessary. (2) [C]

c) Fizzes OR bubbles OR gas produced OR effervescing DO NOT ALLOW “carbon dioxide gas produced” ✓✓ (2) [Ap]
d) Quicker OR more vigorous OR gets hotter ✓ (1) [E]
e) Strontium reacts with oxygen/strontium oxide forms/SrO forms
$2Sr + O_2 \rightarrow 2SrO$ / $Sr + \frac{1}{2}O_2 \rightarrow SrO$ ✓✓ (2) [Ap]
[15]

Question 4

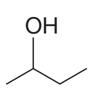
1. a)



Award 1 mark for correct dipoles on C–Br bond and curly arrow from C to Br ✓
Award 1 mark for correct intermediate ✓
Award 1 mark for curly arrow from OH lone pair to C^+ of carbocation ✓ (3) [Ap]

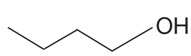
b) i) Structural isomers are molecules with the same molecular formula, but with different structural or displayed formulas. ✓ (1) [K]
ii) Chain (or skeletal), ✓ functional group ✓ and positional isomers ✓ (3) [K]

2. a) $CH_3–CH_2–CH(OH)–CH_3 \xrightarrow{Cr_2O_7^{2-}\ H^+} CH_3–CO–CH_3$ ✓ (1) [Ap]
b) A has a methyl group next to CH(OH) (i.e. it has a $CH_3CH(OH)$ group in it) which reacts with alkaline aqueous iodine to form a precipitate of triiodomethane. (1) [An]
c) In A, more alkyl groups are present to donate electron density; ✓ the secondary intermediate (carbocation) is more stable than a primary intermediate. ✓ (2) [C]
d) A:



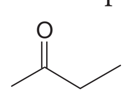
✓

B:



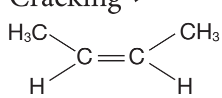
✓

C:

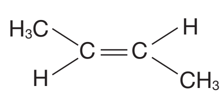


✓ (3) [C]

3. a) i) Combustion ✓ (1) [K]
ii) $C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ ✓✓ (2) [C]
b) i) Cracking ✓ (1) [K]
ii)



✓



✓ (2) [Ap]

iii) Addition polymerisation ✓ (1) [C]
[21]
Total: 60

Guidance for Paper 3: Practical skills

(LB page 305)

In preparing the learners for the practical paper, make sure they understand what types of questions to expect. In this way, the learners will not be confronted by a completely unexpected and unfamiliar situation when they have to do Paper 3.

This is why we provide guidelines to answering this paper in the Learner's Book together with an example question.

You are still advised to draw up an example practice paper for the learners to work through based on both the example papers for AS Level from the Ministry or Curriculum Centre and the resources that you have access to in your school or area.

Example question

For Experiment 1 and 2, award marks according to the following:

- initial and final readings correct ✓✓
- differences calculated correctly ✓✓
- all readings given to 1 decimal place ✓
- results similar to those obtained by the supervisor ✓ (6)

Answers to written questions:

1. Yellow ✓ to blue–black ✓ (2)
2. Solution B. ✓ It required a greater volume of solution A to neutralise it than solution C required. ✓ (2)
3. Learners should show their calculations and include the correct units. (2)
4. Accept any two of the following:
   - Using a measuring cylinder to measure solution B and C
   - Carrying out the experiments only once
   - Going beyond the end-point. ✓✓ (2)

[14]