South Sudan

Secondary Chemistry 3

Teacher's Guide

Secondary Chemistry has been written and developed by Ministry of General Education and Instruction, Government of South Sudan in conjunction with Subjects experts. This course book provides a fun and practical approach to the subject of Chemistry, and at the same time imparting lifelong skills to the students.

The book comprehensively covers the Secondary 3 syllabus as developed by Ministry of General Education and Instruction.

Each year comprises of a Student's Book and Teacher's Guide.

The Teacher's Guide provide:

- Full coverage of the national syllabus.
- A strong grounding in the basics of chemistry.
- Clear presentation and explanation of learning points.
- A wide variety of practice exercises, often showing how chemistry can be applied to real-life situations.
- It provides opportunities for collaboration through group work activities.
- Stimulating illustrations.

All the courses in this secondary series were developed by the Ministry of General Education and Instruction, Republic of South Sudan. The books have been designed to meet the secondary school syllabus, and at the same time equiping the pupils with skills to fit in the modern day global society.

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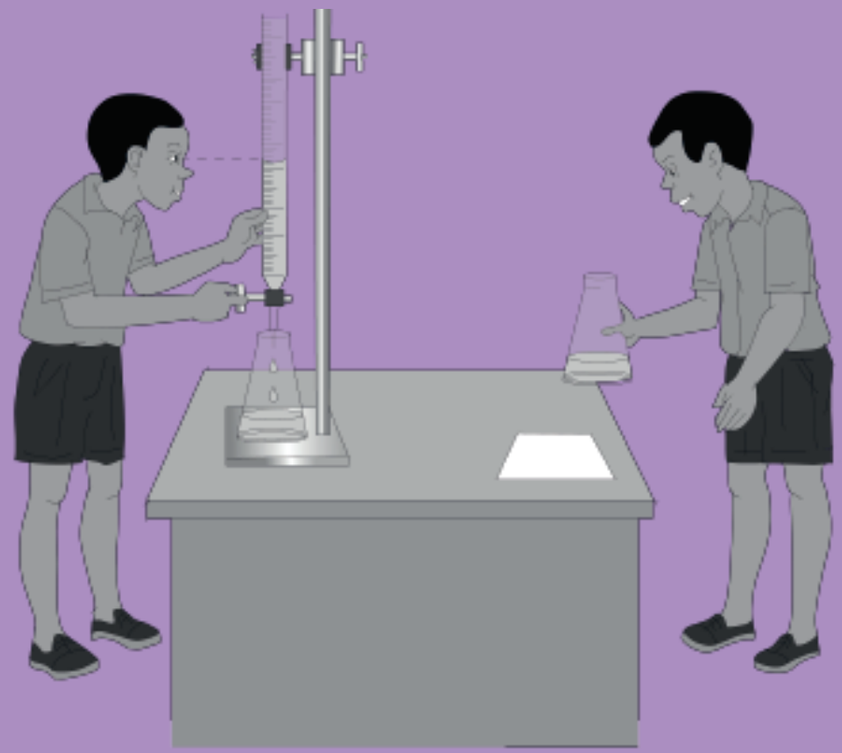

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South Sudan

Secondary 3

Chemistry

Teacher's Guide 3

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FOREWORD

I am delighted to present to you this Teacher's Guide, which is developed by the Ministry of General Education and Instruction based on the new South Sudan National Curriculum. The National Curriculum is a learner-centered curriculum that aims to meet the needs and aspirations of the new nation. In particular, it aims to develop (a) Good citizens; (b) successful lifelong learners; (c) creative, active and productive individuals; and (d) Environmentally responsible members of our society. This textbook, like many others, has been designed to contribute to achievement of these noble aims. It has been revised thoroughly by our Subject Panels, is deemed to be fit for the purpose and has been recommended to me for approval. Therefore, I hereby grant my approval. This Teacher's Guide shall be used to facilitate learning for learners in all schools of the Republic of South Sudan, except international schools, with effect from 4th February, 2019.

I am deeply grateful to the staff of the Ministry of General Education and Instruction, especially Mr Michael Lopuke Lotyam Longolio, the Undersecretary of the Ministry, the staff of the Curriculum Development Centre, under the supervision of Mr Omot Okony Olok, the Director General for Quality Assurance and Standards, the Subject Panelists, the Curriculum Foundation (UK), under the able leadership of Dr Brian Male, for providing professional guidance throughout the process of the development of National Curriculum, school textbooks and Teachers' Guides for the Republic of South Sudan since 2013. I wish to thank UNICEF South Sudan for managing the project funded by the Global Partnership in Education so well and funding the development of the National Curriculum, the new textbooks and Teachers' Guides. I am equally grateful for the support provided by Mr Tony Calderbank, the former Country Director of the British Council, South Sudan; Sir Richard Arden, Senior Education Advisor of DfID, South Sudan. I thank Longhorn and Mountain Top publishers in Kenya for working closely with the Ministry, the Subject Panels, UNICEF and the Curriculum Foundation UK to write the new textbooks. Finally, I thank the former Ministers of Education, Hon. Joseph Ukel Abango and Hon. Dr John Gai Nyuot Yoh, for supporting me, in my role as the Undersecretary, to lead the Technical Committee to develop and complete the consultations on the new National Curriculum Framework by 29 November 2013.

The Ministry of General Education and Instruction, Republic of South Sudan, is most grateful to all these key stakeholders for their overwhelming support to the design and development of this historic South Sudan National Curriculum. This historic reform in South Sudan's education system is intended to benefit the people of South Sudan, especially the children and youth and the future generations. It shall enhance the quality of education in the country to promote peace, justice, liberty and prosperity for all. I urge all Teachers to put this textbook to good use.

May God bless South Sudan. May He help our Teachers to inspire, educate and transform the lives of all the children and youth of South Sudan.

Deng Deng Hoc Yai, (Hon.)
Minister of General Education and Instruction, Republic of South Sudan

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Introduction

Book organisation

This teacher's guide is organised into two main sections.

Part 1 is the general introduction section detailing information on competence-based curriculum and pedagogical issues.

The main elements of Part are:

- **Background information** t o t h e new curriculum - It gives a brief overview of the general requirements of the new South Sudan competence-based curriculum including the guiding principles, the competences the learners are expected to acquire and cross cutting issues to be addressed during learning.

- **Basic requirements for an effective Chemistry lesson** - It highlights the teacher's and learner's roles for effective teaching and learning of Chemistry, teaching and learning resources and grouping learners for learning and teaching methods.

Part 2 provides a unit -to - unit guide to the teacher on how to facilitate learners to acquire the knowledge, skills and attitudes envisaged in each unit. This part is therefore structured into units.

The main elements of each unit guide are:

- **Unit heading**
- **Learning objectives**
- **Contribution to learner's competencies:** The section explains how the unit will facilitate the learner to acquire the specified competencies.
- Cross cutting issues to be addressed:The section outlines the specific cross cutting issues that will be addresses through infusion as the learners do activities and interact with concepts planned for the unit This is meant to make you conscious and be on the look out for suitable opportunities throughout the teaching and learning process in the entire unit to address the cited cross cutting issues. Note that a unit may not necessarily address all the cross cutting issues outlined in the curriculum.
- **Teaching methodologies**

  The section lists down the main teaching and learning methods that the teacher can employ in the unit.

- **Background information**

  This section outlines key knowledge, skills, attitudes and values that learners need to have acquired earlier that will facilitate easier acquisition of the new knowledge, skills, attitudes and values envisaged in the unit. It also guides the teacher on how to find out that the learners possess them before they start learning the concepts in the unit, and how to help learners in case they do not possess them.

- **Suggested teaching and learning activities**

  This section provides you with guidance on how to facilitate learners to learn by doing the activities outlined in the learner's book. It also guides you on how to assess the process of learning.

Background information on the new curriculum

The aim of the South Sudan Competence-based Curriculum is to develop in the learners competencies that will enable them interact with the environment in more practical ways.

It clearly defines the knowledge, skills and attitudes that the learner should acquire by doing the specified learning activities.

Learning competences to be attained

Competencies are statements of characteristics that learners should demonstrate, which indicate they have the ability to do something to the required level of performance.

The following are the four competencies envisaged in this curriculum:

1. **Critical and creative thinking**

   Biology lessons and activities facilitate learners to acquire these competencies by giving them opportunities to:

   - Plan and carry out investigations, using a range of sources to find information.
   - Sort and analyse information and come to conclusions.
   - Suggest and develop solutions to problems, using their imaginations to create new approaches.
   - Evaluate different suggested solutions.

2. **Communication**

   Biology lessons and activities facilitate learners to acquire these competencies by giving them opportunities to:

- Read and comprehend critically a variety of types and forms of texts during research activities.
- Write reports on scientific investigations and activities.
- Speak clearly and communicate ideas in Chemistry related information coherently.
- Listen and comprehend scientific facts presented by fellow classmates, group members, teachers and resources persons.
- Use a range of media, technologies and languages to communicate messages, ideas and opinions.

3. Cooperation

Chemistry lessons and activities facilitate learners to acquire these competencies by giving them opportunities to:

- Work collaboratively towards common objectives when doing activities.
- Be tolerant of others and respectful of differing views, when working together in groups.
- Adapt behaviour to suit different situations.
- Negotiate, respect others' rights and responsibilities and use strategies to resolve disputes and conflicts.
- Contribute to environmental sustainability.

4. Culture and heritage

Chemistry lessons and activities facilitate learners to acquire these competencies by allowing them to:

- Take pride in identifying the diverse nature of the South Sudan society.
- Build understanding of the South Sudan heritage in relation to the rest of the world.
- Appreciate and contribute to the development of the South Sudan culture
- Value diversity and respect people of different races, religion, communities, cultures and those with disabilities.

Cross-cutting issues to be addressed during learning

These are issues that are of high national priority and hence have been incorporated in the learning process. The three cross-cutting issues should be addressed through the teaching and learning process are:

1. Environment and sustainability

A well-conserved environment is obviously key to our health and survival. It is therefore important for you to make use of the opportunities that arise in the process of teaching and learning Biology through activities to sensitise learners on the importance of conserving the environment. One way is by ensuring that the learners always dispose off the waste materials at the end of an activity in ways that do not pollute the environment.

2. Peace education

Peace is critical for a society to flourish and for every individual to focus on personal and national development.

You need to be in the fore front in educating your learners on the need for peace, for example by encouraging group work in the learners activities and showing them ways of solving interpersonal problems peacefully that occasionally arise during interactions and discussions.

3. Life skills

Learners need to progressively acquire some skills, abilities and behaviors that will help them to effectively deal with the events and challenges of every day life. Such skills include First Aid, communication skills, conflict resolution, basic ICT skills among others. You should as much as possible facilitate the learners to acquire these skills whenever an opportunity arises in the lesson execution.

Basic requirements for an effective Chemistry lesson

1. Teacher's role and basic skills for effective Chemistry lesson

The teacher is the most important resource for an effective Chemistry lesson.

(a) Some key roles of a Chemistry teacher.

- Organising the classroom to create a suitable learning environment.
- Preparing appropriate materials and apparatus for learning activities.
- Engaging learners in a variety of practical activities.
- Encouraging and accepting learners' autonomy and initiative.

- Allowing learners' responses to drive lessons and shift instructional strategies.
- Familiarising themselves with learners' understanding of concepts before sharing their own understanding of those concepts.
- Encouraging learners to engage in dialogue, both with you and one another.
- Engaging learners in experiences that pose contradictions to their initial hypotheses and then encouraging discussions.
- Providing time for learners to construct relationships and create metaphors.
- Using a variety of teaching and assessment methods.
- Adjusting instructions to the level of the learners.
- Nurturing learners' natural curiosity.
- Motivating learners to make them ready for learning.
- Coordinate learners' activities so that the desired outcomes can be achieved.
- Assessing learners' activities and suggest solutions to their problems.
- Assist learners to consolidate their activities by summarising the key points learnt.

(b) Key skills a Chemistry teacher:

- Creativity and innovation.
- Makes connections or relations with other subjects.
- A high level of knowledge of the content.
- Effective disciplining skills to adequately manage the classroom.
- Good communicator.
- Good practical skills.

2. Learners' role in learning Biology

Learning takes place only when the learner acquires the intended knowledge, skills and attitudes. As such, learning is a highly personal and individual process.

Thus, a learner must be actively engaged in the learning and practical activities.

For active participation in learning, the learner should:

- Raise questions about what is observed.
- Suggest solutions to the problems observed.
- Take part in planning investigations with appropriate controls to answer specific questions.
- Carry out investigations to search for answers with the help of materials in search of patterns and relationships while looking for solutions to problems.
- Working collaboratively with others, communicating their own ideas and considering others' ideas.
- Expressing themselves using appropriate Chemistry terms and representations in writing and in doing practical activities.
- Engaging in lively public discussions in defense of their work and explanations.
- Applying their learning in real-life contexts.
- Reflecting critically about the processes and outcomes of their inquiries.

Teaching and learning resources

These refer to things that the teacher requires during the teaching process. They include:

- The classroom
- Textbooks
- Wall charts and wall maps
- Materials and apparatus
- Various tools and equipment
- Chemistry models
- Resource persons
- Firms such as hydroelectric power stations, engineering firms among others.

(a) Classroom as a learning environment

A Classroom generally refers to the place where learning takes place. Learners learn from everything that happens around them, such as the things that they hear, see, touch, taste, smell and manipulate.

Classroom organization

It is important you make the classroom an attractive and stimulating environment. This can be done by:

- Carefully arranging the furniture in the classroom in an organised way to allow free movement of learners and you.
- Putting up learning and teaching aids on the walls. Examples are wall charts, pictures and photographs.
- Displaying teaching models.
- Providing objects of examination for example laboratory apparatus.
- Having a display corner in the classroom where learners display their work.
- Setting a corner for storing materials so as not to obstruct learners or distract them.
- Spreading out the learners evenly so that they do not interfere with one another's activities.
- Setting up the materials or experiments for the series of lessons or activities going on for a number of days or weeks in a location where they do not interfere with other daily activities.
- Organising the sitting arrangement such that learners face the lighted areas of the room.
- Choosing the most appropriate location for you and the chalkboard such that they are visible to all learners and that you have a good view of all learners in the class.

(b) Apparatus and materials

For learners to study Chemistry effectively, a number of materials and apparatus are required. The important role played by materials in learning has been felt for centuries. This is noted for instance in the old Chinese proverb that says:

When I hear, I forget,

When I see, I remember.

When I do I understand.

Since Chemistry is a highly practical subject, materials help you to convey your points, information or develop skills simply and clearly and to achieve desired results much faster.

Some of the materials that you require for activities and investigations can be collected from the local environment.

Many others can be improvised while some have to be purchased. Whether collected, improvised or purchased, there are certain materials that are valuable to have around almost all the time.

These include:

(i) Chemistry kit

A Chemistry kit is a special box containing materials, apparatus and equipment necessary to conduct an array of experiments. The content of the kit depends on the curriculum requirements per level. Most Chemistry kits are commercially available and target particular levels of learners. However, you are encouraged to come up with a kit based on the syllabus requirements.

(ii) Models

A model refers to a three-dimensional representation of an object and is usually much smaller than the object. Several models are available commercially in shops. Examples of Biology models include models of body parts, animals among others. These models can be purchased by schools for use during Biology activities.

(iii) Resource persons

A resource person refers to anybody with better knowledge on a given field. Examples include health practitioners such as doctors, nurses and laboratory technologists, agricultural extension officers, environmental specialists among others. Depending on the topic under discussion organise to invite a resource person in that area to talk to learners about the topic. The learners should be encouraged to ask as many questions as possible to help clarify areas where they have problems on.

(iv) Improvisation

If each learner is to have a chance of experimenting, cheap resources must be made available. Complicated apparatus may not always be available in most schools. Such sophisticated equipment made by commercial manufacturers are usually expensive and majority of schools cannot afford them. You are therefore advised to improvise using locally available materials as much as possible.

(v) Scheduling learning activities and venues

Some of the activities suggested in the learner's book need good planning and scheduling in order to get accurate results. The teacher should therefore think

ahead while making the scheme of work so that the prevailing weather pattern and the most appropriate timing are considered.

Grouping learners for learning activities

Most of the Chemistry activities suggested in the Learner's book are carried out in groups and therefore the teacher should place 2 or 3 desks against each other and then have a group of learners sitting around those desks.

In certain activities, the teacher may wish to carry out a demonstration. In this case, the learners should be sitting or standing in a semicircle, or arranged around an empty shape of letter "U" such that each learner can see what you are doing clearly and without obstruction or pushing. If the learners are involved in individual work, each learner can work on the floor or on the desk or a portion of the desk if they are sharing. In this case, they need not face each other.

Grouping learners for learning has increasingly become popular in recent years. In fact, the shift from knowledge-based to competence curriculum will make grouping the norm in the teaching process.

Learning grouping can be formed based one or a number of the following considerations:

- Similar ability grouping.
- Mixed ability grouping.
- Similar interests grouping.
- Common needs grouping.
- Friendship grouping.
- Sex-based grouping.

Grouping learners in a Chemistry class has several advantages. They include:

- The individual learner's progress and needs can easily be observed.
- The teacher-learner relationship is enhanced.
- A teacher can easily attend to the needs and problems of a small group.
- Materials that were inadequate for individual work can now be easily shared.
- Learners can learn from one another.

- Cooperation among learners can easily be developed.
- Many learners accept correction from the teacher more readily and without feeling humiliated when they are in a small group rather than the whole class.
- Learners' creativity, responsibility and leadership skills can easily be developed.
- Learners can work at their own pace.

The type of "grouping" that a teacher may choose may be dictated by:

- The topic or task to be tackled.
- The materials available.
- Ability of learners in the class (fast, average, slow).

Class size

There is no method or approach to teaching that is appropriate to all lessons. A teacher should, therefore, choose wisely the method to use or a combination of methods depending on the nature of the topic or subtopic at hand.

Teaching methods

There are a variety of possible methods in which a teacher can help the learners to learn. These include:

(a) Direct exposition

(b) Discovery or practical activity

(c) Group, class or pair discussion

(d) Project method

(e) Educational visit or field trips

(f) Teacher demonstration

(g) Experimentation or research

The particular technique that you may choose to use is influenced by several factors such as the:

- Particular group of learners in the class.
- Skills, attitudes and knowledge to be learned.

- Learning and teaching aids available.
- Local environment.
- Teacher's personal preference.
- Prevailing weather condition.
- Requirements of Chemistry syllabus.

(a) Direct exposition

This is the traditional way of teaching whereby the teacher explains something while the learners listen. After the teacher has finished, the learners may ask questions. However, in a competence-based curriculum, this technique should be used very minimally.

(b) Guided Discovery

In this technique, encourage learners to find out answers to problems by themselves. You do this by:

- Giving learners specific tasks to do.

  Giving learners materials to work with.

- Asking structured
  or guided questions that lead learners to the desired outcome. Sometimes learners are given a problem to solve and then left to work in an open-ended manner until they find out for themselves.

  This is the most preferred method of teaching in the implementation of Competency- Based curriculum.

(c) Group or class discussion or pair work

In this technique, you and learners interact through question and answer sessions most of the time. Carefully select your questions so that learners are prompted to think and express their ideas freely, but along a desired line of thought. The method leads learners from the known to unknown in a logical sequence; and works well with small groups. The method boosts confidence in learners and improves interpersonal and communication skills.

The main disadvantage of this method is that some learners maybe shy or afraid to air their opinions freely in front of you or their peers. It may give them more confident learners a chance to dominate the others.

(d) Project method

In this approach, you organize and guide a group of learners or the whole class to undertake a comprehensive study of something in real life over a period of time such as a week or several weeks.

Learners using the project method of studying encounter real life problems, which cannot be realistically brought into a normal classroom situation. A project captures learners' enthusiasm, stimulates their initiative and encourages independent enquiry. If you are using the project method, ensure that the learners understand the problem to be solved and then provide them with the necessary materials and guidance to enable them carry out the study.

The main disadvantage of this method is that if a project is not closely supervised, learners easily get distracted and therefore lose track of the main objective of their study. Studying by the project method does not work well with learners who have little or no initiative.

(e) Educational visits and trips/nature walks

This is a lesson conducted outside the school compound during which you and the learners visit a place relevant to their unit of study. An educational visit/ or nature walk enables learners to view their surroundings with a broader outlook that cannot be acquired in a classroom setting. It also allows them to learn practically through first- hand experience. In all "educational visit or nature walk lessons", learners are likely to be highly motivated and you should exploit this in ensuring effective learning. However, educational visits are time consuming and require a lot of prior preparation for them to succeed. They can also be expensive to undertake especially when learners have to travel far from the school.

(f) Demonstration lessons

In a demonstration, you or a laboratory technician show the learners an experiment, an activity or a procedure to be followed when investigating or explaining a particular problem. The learners gather around you where each learner can observe what you are doing. It is necessary to involve the learners in a demonstration, for example by:

- Asking a few learners to assist you in setting up the activity.
- Requesting them to make observations.
- Asking them questions as you progress with the demonstration.

This will help to prevent the demonstration from becoming too teacher-centred.

When is a demonstration necessary?

You may have to use a demonstration, for example when:

- The experiment or procedure is too advanced for learners to perform.
- The experiment or procedure is dangerous.
- The apparatus and materials involved are delicate for learners to handle.

UNIT 1 Volumetric analysis and Identification of gases

Refer to learner's book page 1- 37

Learn about	Key inquiry questions
Learners should build on what they already know about acids and bases and neutralization. They should investigate, in groups what is meant by concentration and how it might be determined through volumetric analysis. In doing this they should define and understand molarity, standard solutions, concentration, neutralization, end point, equivalent points, and titration. Learners should develop a secure understanding of the methods used in volumetric analysis with an emphasis on acid-base titration and redox reactions, and how to determine the concentration of unknown substances, and skills and safety in the use of the specialist equipment. They should design investigations to accurately make solutions and understand and apply their understanding about molarity to molar mass, normality and the volume of solutions. They should investigate the practical implications and applications of volumetric analysis in the formation of compounds and overcoming conditions such as 'hard water'. They should carry out practical tests to identify gases (e.g. ammonia, carbon dioxide, chlorine, hydrogen, oxygen and sulphur dioxide) using colour, smell, litmus paper and chemical tests.	▪ How can we determine concentration of unknown solutions? ▪ How to design acid-base titration to test predictions about the products? ▪ How do we explain volumetric analysis as chemical nomenclature and equations? ▪ How can we identify gases in laboratory? ▪ How can we design experiments to test a particular gas?

Learning outcomes		
Knowledge and understanding	**Skills**	**Attitudes**
▪ Understand volumetric analysis and identification of gases.	▪ Investigate what is meant by concentration and how it might be determined through volumetric analysis.	▪ Appreciate the importance of gases to life.

▪ Understand molarity, standard solutions, concentration, neutralization, end point, equivalent points, and titration.	▪ Design investigations to accurately make solutions. ▪ Investigate the practical implications and applications of volumetric analysis in the formation of compounds and overcoming conditions such as 'hard water'. ▪ Carry out practical tests to identify gases.	

Contribution to the competencies:

Critical and creative thinking: experimentation.

Communication: reporting of group work.

Co-operation: teamwork.

Links to other subjects:

Biology: finding effects of concentration of nitrate and sodium chlorine and maintaining of a balance in ecosystems.

Physics, Mathematics: measurements by volumes; greenhouse effects; emission spectrum.

Introduction to the unit

This unit deals with learning how to investigate the composition of substances and their quantities (concentration). In particular much learning shall entail determining concentration of acids and bases and to identify gases. In real life situations, this is daily occurrence in industrial manufacture of various consumer products such medicine, soft drinks, alcoholic beverages in order to establish and ensure quality products is available to the market. The unit is linked to other subjects which should be emphasized during class discussions. Mathematical skills are essential in volume measurements and accompanying calculations. In Physics and geography, knowledge of emission spectrum and greenhouse effects is important to aid learners in proper handling and disposal of waste gases in the laboratory. Chlorine, carbon dioxide and sulphur dioxide gases are greenhouse gases that their much emission into the atmosphere are responsible for depletion of ozone layer, global warming and climate change which is posing serious risks for human survival at the moment.

Cross cutting issues to be incorporated

1. Environment awareness and sustainability

This unit involves use of acids and bases as well as investigation of gases some of which are environmentally harmful and health hazards to users themselves. Acids and bases after use must be disposed in recommended way with no or minimal impact on the environment. Poisonous gases e.g. chlorine must investigated using fume chamber.

Emphasise too much release of carbon dioxide and sulphur dioxide gases into the air cause air pollution and accompanying environmental degradation.

2. Peace and values

Concentrated acids and bases are very corrosive and there have been incidences throughout the world where people have used such to harm. Reiterate to the learners on the need to respect the sanctity of human life and such evil thoughts must never be encouraged. Always, at personal level strive to promote living at peace with each other, loving one another for our good and everyone else as well as the prosperity of the South Sudan.

3. Life skills

Learners can be encouraged to be financial responsible, to appreciate expenses incurred in purchases of reagents (chemicals) and even costs of apparatus used which cannot be improvised. They should handle apparatus very careful for avoid unnecessary breakages and where there is occurrence report immediately to the teacher or laboratory technician.

Competencies to be developed

1. Co-operation

This topic involves a lot of practical (experiments). Encourage learners to work as team with no bias in terms of gender, tribe or culture. Gifted learners to appreciate their slow learning counter and provide assistance where need be. Remind learners' teamwork helps the tasks to be done much faster, more efficiently and with minimal bad incidences in the laboratory.

2. Communication

Encourage all learners irrespective of their abilities to participate in the class or group discussions, during presentations by asking questions and questions & answers sessions to either introduce or wrap up the lessons, as experiment progresses.

All learners should also be encouraged to write summary notes at the end of the lesson as this will help improve their writing skills. Tell learners that communicating results of investigations either through oral presentations or written is as critical

and important as the investigation itself in real Chemistry world. It helps the information to be consumed clearly by the intended recipients.

3. Critical and creative thinking

Encourage learners to develop inquisitive thoughts on why given investigations are done, the manner in which they are done and the need for such and even if there are alternative methods (or procedures).

It is important they appreciate the normal procedures of carrying out investigations, calculations and handling apparatus. If they think there are better or innovative ways of doing these investigations they should feel to suggest (this is what constitute Chemistry symposium in schools which aims to make learners be innovators and scientifically skilled).

1.1 - 1.4 Introduction, Standard solution, Molar solutions and their preparations

Refer to the learner's book pages 1-9

Preparation for the lesson

Arrange for the availability of required apparatus for class activities and experiments. Collect necessary charts and photographs. Ensure your notes are up to date keeping in mind difficult concepts and terms that troubles learners that such are well addressed.

Learning activities

Effectively teaching and learning of concepts in this unit shall be made possible by use of experimentation (herein referred to as activities), group discussions, use of models and charts.

1. Introduce this unit by review with the learners the previously acquired knowledge on acids and bases such as definitions of acids and bases, their properties/ characteristics, common examples of acids and bases and where they are found.
2. Invite the learners to try to state what they understand of the terms: *solutions*, *solvent*, *solutes*, *standard solutions* and *molar solutions*. Ask them to define as well the following terms: concentration and molarity.
3. Then clearly define to the class the meaning of these terms as used in Chemistry and in the context of volumetric analysis.
4. Tell the learners the importance of knowing concentrations of certain substances e.g. sugar of low concentration goes more into a cup of tea, medicine with the right concentration of active ingredients will achieve intended healing faster within expected/shorter duration unlike sub standard or generic medicines which will take longer period and consumed in larger quantities, between viscous and thin/ light porridge which one provides a lot of energy/relieves hunger much faster, e.t.c.

5. Emphasize to the learners that concentration of a solution is expressed in both ***mass*** (grammes) and ***number of moles of solute*** per any given volume. On the other hand molarity of a solution is always expressed in moles per litre of a solution. It should be pointed out to the learners that for uniformity reasons, concentration too is normally expressed in terms of moles or grams of the solute per litre of solution.
6. During the discussion assist the learners to apply the mole concept in determining both the concentration and molarities of a solution. Let the learners relate millilitre (ml) to cubic centimetre (cm^3) and the litres to cubic decimetre ($1\ dm^3 = 1000\ cm^3$).

Preparation of standard and molar solutions

1. Using a chart showing various apparatus used in preparation of standard and molar solutions or availing the actual apparatus, guide the learners in naming and stating the use of each apparatus (required in preparing the solutions) and their correct handling.
2. Let the learners attempt to explain how the standard and molar solutions can be prepared. Then outline to them the procedures involved.
3. Refer to activities 1.2 and 1.3 in the learner's book page 4-7. Emphasise all the necessary precautions involved as well as calculating and weighing the mass of the required substance. **REMEMBER** the learners are yet to learn about the mole concept, so be patient with them and briefly explaining what one mole of substance entails for the purpose of calculations of required quantities of a substance in effort to determine the concentration and molarities of solutions.
4. During the instructions, point out to the learners the significance of taking accurate measurements of both masses of solutes and the volume of solvents.
5. Let the learners notice and appreciate why it is necessary to first dissolve a solute in a little solvent before making it up to required volume. This should lead the learners to conceptualize that a molar solution may be prepared by the presence of equivalence of molar mass of a substance into appropriate volumes of the solvent. For example, a molar solution of sodium hydroxide may be prepared when:
   (a) 40 g is contained in a litre of solution,
   (b) 20 g is contained in half a litre of solution,
   (c) 10 g is contained in quarter a litre of solution,
   (d) 5 g is contained in 1/8 litre of solution.

Note: The apparatus used to prepare molar solutions are volumetric flasks, beakers, funnel, pipette, weighing balance and wash bottle. The lesson 4 below may also be combined with above discussion as is where possible.

Learning assessment

- You may ask learners some oral questions in the course of the lesson to gauge their knowledge and understanding of the concepts of standard and molar solutions.
- Learner's acquisition of skills can be assessed by asking the learners to demonstrate how to prepare standard and molar solution using provided reagents. Provide guidance and correct where necessary.
- Listen and gauge learners language competence during class discussion, experiments and correct accordingly as you encourage them to improve.
- You may consider use of self progress check, work to do, research assigments and discussion corner quizzes in the learner's book to engage their competencies and learning progress, providing remedial actions where necessary.

Answers to Check your progress 1.1

Refer to learner's book page 6

1. Volume Percentage, Molarity, mole fraction.
2. (a) Molarity is the number of moles of a solute dissolved in a liter of solution.
   (b) Standard solution is a solution containing an accurately known concentration of an element or a substance.
   (c) Concentration is the abundance of a constituent divided by the total volume of a mixture.
3. (a) $10g/dm^3$
   (b) $22.2g/dm^3$
4. $0.2g/dm^3$

Answers to Check your progress 1.2

Refer to learner's book page 9

1. 1.225g
2. (i) $0.15g/dm^3$
   (ii) $338g/dm^3$

1.5 Dilution of standard solutions

Refer to learner's book pages 9

Learning activities

1. Introduce the lesson by discussing what is dilution and its importance in life. Inform the learners that this is an everyday happening in our homes but in particular

heavily undertaken in laboratories at schools, hospitals and industrial labs. This is because most reagents used in laboratories are purchased as stock solutions and often must be diluted to the required concentrations when needed for use. At homes, highly concentrated juices are diluted to required tastes; milk used in tea preparation is diluted added to desired concentration.

2. Think of dilution activity and involve the learners in carrying the process of dilution activity 1.4.
3. Inform the learners that in laboratories, the dilution process utilizes **dilution law** in effort to correctly achieve the desired concentration (lesser molarity).
4. Guide learners on how to determine by calculations the new volume of the given quantity of standard solution to be made up to using the dilution law e.g.

   (a) $C_1V_1 = C_2V_2$

   C_1 - Concentration of 1st solution

   V_1 – Volume of 1st solution

   C_2 – Concentration of 2nd solution

   V_2 – Volume of 2nd solution

Learning assessments

- Ask learners diagnostic assessment questions to gauge their understanding of the concept of dilution and why it is done in laboratories.
- Engage them practically, to see if they know how and are able to make a diluted solution of desired concentration from a standard solution.
- Use discussion corner questions/brainteaser in the learner's book to assess their critical and creative thinking skills in the understanding of the concepts learnt or being learnt.
- Listen and gauge learners' language competence during class discussion and correct accordingly.
- Their cooperation and interpersonal skills may be assessed by finding out how they interact with other learners during activities. Encourage and enforce this by assigning tasks to every member of the group and awarding marks per groups.
- Provide the learners with calculations involving dilutions to establish if they have understood the link between amount of water (solvent) to be added and the molarity (concentration) of the solution required to be attained at the end of task.

Answers to Check your progress 1.3

Refer to learner's book page 11

1. No, 0.25g/dm^3
2. No
3. The concentration
4. (a) B
   (b) B
   (c) D

1.6 - 1.7 Volumetric analysis and understanding the titration process

Refer to learner's book page 12 - 30

Preparation for the lesson

This is activity-based lesson. It is important as a teacher to make sure all the apparatus and materials required for it successful teaching/learning are made available. Make arrangement for purchase of the items that are not available in the school. If there is possibility for borrowing/leasing within the locality, these too may be considered. Avoid the temptation to teach, in theory only, this concept. As much as possible it is prudent to carry out pilot experiment on your own before involving the rest of class.

As you shall the instruction on this sub topic, there is to guide learners in good practice and safety involved in carrying titration (volumetric analysis).

Learning activities

Titration

1. Introduce the lesson by asking learners to give their understanding of the term *titration*. Then clearly explain to them the meaning of *titration*.
2. Show them the various apparatus used in titration, guiding the learners to correctly identify them and stating uses, activity 1.5.
3. Let the learners practice how to correctly handle and use the apparatus.
4. Inform the learners of the common types of titrations in most laboratories such as: *acid-base titration*, *redox titration* and *back titration* which they are likely to encounter in the course of secondary school learning.
5. Outline the best practice procedure in titration process, allowing learners to ask questions while certain steps or things are done in particular manner. Alternatively as a teacher use questions and answer to rouse the learners' critical and creative thinking. For example why analyte is put in conical flask and not in the burette, why use of particular indicator in a given titration process, e.t.c

6. Guide learners in defining and understanding the following terms in relation to titration: end point/equivalence point, neutralization, titre, titrant, analyte, standard solution and concentration.
7. Let learners, with your supervision, practise titration (***acid-base titration***) to attain the desired manipulation skills. Ensure the learners are working in groups of suitable size, gender balance observed where applicable and all the learners are properly engaged during the activity. Put emphasis on learners ability to correctly:
   - Set up the apparatus
   - Fill up the burette and pipette
   - Read the titre volumes
   - Record the experimental data
   - Identify suitable indicator for acid base titrations
8. Let learners carry out the different types of titration (activities) provided in the learner's book. Ensure learners:
   - Conduct titration in line with the standard titration procedures as you outlined to them.
   - Take accurate volume readings and measurement of analyte and titrant, and proper recording of data in a table for later use in calculating the concentration of unknown solution.
9. The following are some titration experiments provided in the learner's book for consideration. Let the learner know these are different types of titrations.
   (a) Activity 1.6: Acid base titration
   (b) Activity 1.7: Back titration
   (c) Activity 1.8: Redox titration
10. Emphasise on the following learning points as learners carry out the various methods of titration which help stimulate learners' critical and creative thinking.
   (a) Ability of learners to remember and use titration procedures for each type of titration.
   (b) The properties of various indicators that make them suitable (choosing) for use for specific titration.
   (c) Determining titre values for use in calculating the average titrant volume. Guide the learners in calculating the average volume. Consistent values should not differ by more than 0.2.
   (d) Burette and pipette are correctly read by viewing the bottom of the meniscus at an horizontal eye level. They must also be properly handled.

(e) Constantly remind learners of the dangers of titration such as when a solution accidentally gets into a learner's mouth, one need to spit out immediately and rinse thoroughly the mouth with sufficient volumes of distilled water.

(f) Apparatus must all be clean.

(g) The end point must be carefully and correctly approached.

(h) For back titration, emphasize the need to take accurate measurements of the masses of solid reactants and the volumes of liquid reactants.

11. Point out to the learners the following about redox titration;

- Sulphuric acid is used in diluting the solutions of the oxidizing agents (acidified potassium manganate (VII), $KMnO_4$ and acidified potassium dichromate (VI), $K_2Cr_2O_7$). Hydrochloric acid is not used because it is easily oxidized to chlorine gas.
- The commonly used reducing agents are compounds of iron and oxalic acid and its salts.
- The acid-base indicators are not used in redox titrations, helping the learners to understand reason(s) of their non use.
- Why the iron compound solution must be acidified and freshly prepared.
- That redox titrations may be used to standardize solutions, determine purity of compounds as well as determining the unknown concentration of iron (II) ions in compounds.
- That writing of redox equations is not required. But use of balanced equations is essential to determine the reacting mole ratio for calculation purposes.
- Caution that the experiment should be done in a well ventilated room if chlorine gas is involved. Avoid inhaling of chlorine fumes.

12. Guide the learners on how to record data in a table as follows.

Volume of pipette used (cm^3)	**1**	**2**	**3**
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of acid used (cm^3)			

Average volume = Sum of consistent values

Number of consistent values

13. Choice of indicators on Titration

Guide learners on the importance of choosing appropriate indicator for particular titration process and the expected definite colour change in acids and bases. Inform the learners that in redox titrations no indicators are required.

Reactions	Acid-base Indicator	Example	Colour change
Strong acid + strong base	Methyl orange, phenolphthalein or litmus solution	$HCl + NaOH \longrightarrow NaCl + H_2O$	
Strong acid + weak base	Methyl orange	$HCl + NH_4OH \longrightarrow NH_4Cl + H_2O$	
Weak acid + strong base	Phenolphthalein	$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$	
Weak acid + weak base	No indicator	$CH_3COOH \longrightarrow NH_4HO$	

Learning assessment

1. You may ask learners some oral questions in the course of the oral presentation and practical sessions to gauge their knowledge and understanding of the correct titration procedure for each type of titration. See also below the brain teaser/ diagnostic assessment questions.
2. Observe how they handle can assess learners' acquisition of skills, set up and taking and recording of volume readings of titre and analyte. Provide guidance and correct where necessary.
3. Their co - operation and interpersonal skills may be assessed by finding out how they interact with other learners during experiments session and how they share responsibilities, reinforcing team work and respect for all as need be.
4. Allow learners to present their results, in groups, to the rest of class enabling them compare their findings. Offer guidance in achieving good results. This helps improve their communication skills enhancing efficiency in subsequent activities.
5. Use discussion corner questions, work to do and research assignments provided in the learner's book for continuous learning assessment.

Diagnostic assessment Questions

1. Give reasons why no indicator is used when titrating weak acid against a weak base.

Ans: *This is because the reaction involving weak acids and weak bases never go to a completion.*

2. Under what circumstance do we need to use pipette filler?

   Ans: *When the solution to be used is poisonous or when learners are sharing pipette*

3. What is standardizing a solution? Why was methyl orange used in activity 1.5 standardizing of aqueous sodium carbonate?

   ***Ans*:** *Standardizing a solution means determining its concentration. In the above reaction, methyl orange is used because at end point the solution is saturated with CO_2 making it weakly acidic(between 5-6). Methyl orange changes colour at this pH.*

Calculations involving standardisation of solutions (titrations)

This sub topic is meant to take the learners through the different methods used in determining the required quantities of substances in the solutions by titration.

1. Once the learners have successfully acquired skills in carrying out the titration process and proper recording of titration data;
2. Lead them how to use these data in determining the required concentration or information such as atomic mass and water of crystallization.
3. Emphasize on the use of full balanced and ionic chemical equations is very important in helping us to calculate reacting quantities and the reacting mole ratios which leads us to obtain the required information.
4. This discussion would lead us to define the term **basicity** of an acid and help learners appreciate why the acid and not the base is the one to be run out of the burette.
5. There are two methods used as outlined in the learner's book. Take learners through the methods carefully being patient with the slow learners. Use the sample worked titration problems provided in the learner's book and any other of your preference.
6. Consider giving the following sample titration problem below for learners to attempt to solve, gauging their solving competency and assessing areas of weakness for further address.

In successive titrations of a standard solution of 0.12M sodium carbonate, 10cm^3 of sodium carbonate was neutralized by the following volumes of hydrochloric acid of unknown concentration 20.18 cm^3, 20.24 cm^3 and 20.15 cm^3 using methyl orange indicator. Calculate the concentration of the hydrochloric acid. (Ans = 0.119M)

1.8 Investigating percentage of water of crystallisation

1. Let the learners attempt to give the meaning of water of crystallisation and examples of substances containing water of crystallisation. Clearly define the term if no correct responses were given by the learners.
2. Guide the learners on how to carry out investigation of percentage composition of water of crystallisation in compounds by titration. You can refer to the example

provided in the learner's book or example preferred. Walk the learners step by step in calculating the percentage of water of crystallisation using sample experimental data or data obtained in experiment performed by the learners, activity 1.9 and 1.10.

3. Emphasise that the objectiveis to establish the proportions by mass the water of crystallization that is chemically combined to the sodium carbonate whichgives the hydrated salt its chemical formula. Once such a determination of the empirical formula of the compound is properly understood, it becomes easier for the learner to appreciate what is meant by hydration.
4. You can give a sample substance with water of crystallisation investigation (with specimen data) for the learners to try to solve.

Real life applications of titration

- Lead the class in discussing some of applications of titration in real life situations. Refer to some of uses outlined in the learner's book.
- Consider putting learners in groups, to do research using books and internet to find more uses of titrations and make presentation to the class.

Answers to Check your progress 1.4

Refer to learner's book page 32

1. 500 cm^3
2. Equivalence point is when the moles of a standard solution (titrant) equal the moles of a solution of unknown concentration.

   A molar solution is an aqueous solution that contains 1 mole (gram-molecular weight) of solute in 1 liter of the solution.
3. 42g
4. 0.08g litre
5. 1.75M

1.9 Qualitative test for gases

Refer to learner's book page 33

Safety precaution: Handling the acid and hydrogen peroxide carefully. If there is spillage on your skin rinse immediately with a lot of clean water. Wear goggles and an apron all the times.

Learning activities

1. Before carrying out Activity 1.11, review the properties of common gases already covered in secondary 2.

2. Guide the learners to collect and assemble all the apparatus and reagents they need for this activity. Reagents: *calcium carbonate, sodium sulphite, dilute hydrochloric acid, manganese dioxide, zinc granules, hydrogen peroxide, ammonium salt and sodium hydroxide*.
3. Leading the class, let the learners suggest how the gases to be identified can be prepared in the laboratory. Guide them appropriately as indicated below.
   - **CO_2** - To obtain carbon dioxide heat calcium carbonate in a boiling tube and pass the gas produced through lime water.
   - **SO_2** - To test for sulphur dioxide add dilute hydrochloric acid into a test tube containing sodium sulphite and test for the gas produced using a filter paper soaked in acidified potassium dichromate
   - **Cl_2** - To test for chlorine add hydrochloric acid into a test tube containing manganese dioxide and heat, test for the gas using moist red and blue litmus papers
   - **O_2** - To test for oxygen, add hydrogen peroxide to manganese dioxide and introduce a glowing splint.
   - **H_2** - To test for hydrogen, add dilute hydrochloric acid into zinc granules and introduce a burning splint.
   - **NH_3** - To test for ammonia, mix ammonium salt with sodium hydroxide and heat, introduce moist red litmus paper.
4. Let the learners proceed to perform the confirmatory tests for identification of the gases as outlined in the learner's book as well as the table below.

Gas	Procedure	Observations
Ammonia	Hold a moist red litmus paper	Red litmus turns blue
Carbon dioxide	Bubble the gas through lime water	A white precipitate is formed
Chlorine	Hold moist red and blue litmus papers	Red litmus turns blue then bleached. The blue litmus paper is as well bleached.
Hydrogen	Introduce a lighted splint in the gas	A 'pop' sound is produced
Oxygen	Introduce a glowing splint in the gas	Relights a glowing splint
Sulphur dioxide	Introduce a filter paper soaked in acidified potassium dichromate	Orange filter paper turns green

5. The learner should be assisted by the teacher to make correct observations and making conclusions. During discussions, it should be clear to the learner that the different gases are tested differently.

Additional information to the teacher

Qualitative analysis is a method by which constituent parts of a substance are identified. The changes that take place and products formed are observed closely without making precise measurements as in titration.

There are common laboratory tests for identifying gases. The general guiding principles include:

(i) Basic gas tests - look for colour, smell, effect on litmus and effect on splints (glowing and burning). Ammonia gas is the only known alkaline gas; it turns damp red litmus paper blue.

(ii) Acidic gases (SO_2, HCl, H_2S, HBr, HI) are evolved when dilute mineral acids or concentrated sulphuric (VI) acid reacts with SO_3^{2-}, Cl^-, S^{2-}, Br^-, I^- respectively. The gases turn damp blue litmus red. Carbon (IV) oxide from CO_3^{2-} is a weak acid in aqueous solution and usually does not affect blue litmus. Nitrogen (IV) oxide is brown and turns blue litmus red.

(iii) All other gases including oxygen and hydrogen are colourless. These gases do not affect litmus papers.

Remember

Smelling of gases is done by holding the mouth of the test tube about 20 cm away from the nose. The gas is the waved or wafted towards the nose and sniffed carefully.

- That litmus paper s must be damp because water(moisture) in them help in hydrolyzing the gases to yield hydrogen ions or hydroxide ions which responsible for the characteristic acidic and basic properties.
- That when testing for gases, with litmus paper, do not touch the mouth of the inner walls of the test tube
- That you should have the litmus paper, delivery tube, any other necessary apparatus before the reagent is poured into a test substance.

Answers to Check your progress 1.5

Refer to learner's book page 37

1. 0.04M
2. 2.

Unit 2 Mole Concept and Gas laws

Refer to learner's book pages 38 - 91

Learn about	Key inquiry questions
Learners should build on what they already know about volumetric analysis and the identification of gases. They should investigate and understand the mole concept, relative atomic mass and molecular mass and measure accurately masses, volumes, pressure and temperature of sample substances. Learners should calculate masses from stoichiometry equations and carry out inter conversion of moles to mass, atoms, and molecules and calculate empirical and molecular formulae, the percentage mass, *and percentage yield* and percentage purity when given appropriate information. Learners should calculate using Boyles', Charles' and Ideal gas laws and interpret the graphical presentation of the gas laws. Learners should define and understand chemical and ionic equations, and in groups they construct full balance equations and ionic equations.	• How do we determine moles of substances? • How is Boyles' law treated mathematically? • How is Charles law treated mathematically? • How do you construct full and ionic equations? • Why do we always ensure balanced chemical equations?

Learning outcomes

Knowledge and understanding	Skills	Attitudes
• Understand the mole concept and the application of gas laws. • Understand chemical and ionic equations.	• Investigate and understand the mole concept, relative atomic mass and molecular mass. • Measure accurately masses, volumes, pressure and temperature of sample substances. • Calculate masses from stoichiometry equations.	• Appreciate the importance of the gas laws.

	• Carry out inter conversion of moles to mass, atoms, and molecules. • Construct full balance equations and ionic equations.	

Contribution to the competencies

Critical and creative thinking: experimentation and calculation.

Communication: presentation of group work.

Co-operation: teamwork.

Links to other subjects:

Physics: study of gas laws, balance of chemical equations.

Biology: gaseous exchange, balance of chemical equations.

Agriculture: nutritional cycle e.g. carbon cycle.

Introduction to the unit

This unit deals much with the study of determining the amount of reacting particles in a given quantity of a substance. The learner is being introduced to the mole concept and finding masses of reacting substances as units of measurement in chemistry and as well to study of the behaviour of gases (gas laws). In real life situations, these are daily occurrence and practices of these knowledge are applied in industrial manufacture of various consumer products such medicine, manufacture and storage of commercial gases in order to establish and ensure safety and quality products are available to the market.

Mole concept may appear to be abstract knowledge but it is important to help learners appreciate that this is a unit of measurement that was conceived in the course of scientific experimentations in chemistry and later became universally adopted concept. Linked it to the units of measurement such as kilogram for mass, a litre for volume/capacity, a dozen meaning 12 items, year comprising of 12 months and not 13 months. Towards this end, learners will begin appreciating the representaion of mole to given amount/quantity of substance or particles in a given amount. Such as a kilo represent a specific quantity, a litre also represents a given amount. Therefore a mole equally represent a specific quantity of substance (particles in amount of substance), generally taken to be about 6.022×10^{23}.

Cross cutting issues to be incorporated

Endeavour in the course of classroom instruction during this unit, to incorporate the following contemporary issues to South Sudan nation, Africa and the rest of the World.

1. **Environment awareness and sustainability**

   This unit involves use of strong acids and bases e.g. concentrated hydrochloric acid and concentrated aqueous ammonia which much should not be allowed to escape into the atmosphere, nitrogen (IV) oxide is very poisonous and environmentally harmful as well as health risk, it must used within fume chamber. Proper disposal of oxides such magnesium oxide must be observed.

2. **Peace and values**

   Stress to the learners on the need to respect the sanctity of human life and such evil thoughts must never be encouraged. Always, at personal level and in groups strive to promote living at peace with each other, loving one another for our good and everyone else as well as the prosperity of the South Sudan. Learners must avoid any fracas or commotion in the laboratory at all times.

3. **Life skills**

   Learners can be encouraged to be financially responsible, to appreciate expenses incurred in purchases of reagents (chemicals) and even costs of apparatus used which cannot be improvised. They should handle apparatus very careful for avoid unnecessary breakages and where there is occurrence report immediately to the teacher or laboratory technician.

Competencies to be developed

1. **Co-operation**

   This topic involves a lot of practical (experiments). Encourage learners to work as team with no bias in terms of gender, tribe or culture. Gifted learners to appreciate their slow learning counter and provide assistance where need be. Remind learners' team work helps the tasks to be done much faster, more efficiently and with minimal bad incidences in the laboratory. In calculations, fast learners to aid their slow learning counterparts in solving various problems.

2. **Communication**

   Encourage all learners irrespective of their abilities to participate in the class or group discussions, during presentations by asking questions, use questions & answers sessions to either introduce or wrap up the lessons, as experiment progresses to engage and improve learners listening skills and ability to respond effectively.

All learners should also be encouraged to write summary notes at the end of the lesson as this will help improve their writing skills. Tell learners that communicating results of investigations either through oral presentations or written is as critical and important as the investigation itself in real Chemistry world. It helps the information to be consumed clearly by the intended recipients.

3. Critical and creative thinking

Encourage learners to develop inquisitive thoughts on why given investigations are done, the manner in which they are done and the need for such and even if there are alternative methods (or procedures). For example causes of errors in experiment leading to deviation in theoretical figures and practical results. They may as well critically to ask themselves, how can errors be eliminated or minimized leading to finding solution in future, that is what Chemistry is about/ critical and creative thinking!

It is important they appreciate the normal procedures of carrying out investigations, calculations and handling apparatus. If they think there are better or innovative ways of doing these investigations they should feel to suggest (this is what constitute Chemistry symposium in schools which aims to make learners be innovators and scientifically skilled and imaginative).

2.1 and 2.2 Introduction to mole concept

Refer to the learner's book page 38 - 41

Learning activities

Introduce the molec oncept by reviewing with the learners about particles they have learnt in chemistry such as atoms, molecules, ions. As much as possible let the lesson largely comprise of class discussion, teacher demonstration and class activities. *Remember this lesson/learning unit area is very crucial since it determines how learners will conceptualize and determine the successful learning of the rest of the work in this topic.*

1. Allow the learners to do activity 2.1 in the learner's book to help in conceptualizing about small particles constituting the large substance which are clearly visible and often we use in our everyday life. Such large quantities of iron fillings together make the huge metal bar we use in metal bridges, iron sheet and these are often weighed and standarsized for quality, safety and durability purposes. Let the learner appreciate the importance of substances they have interacted with in activity 2.1.

   Answer to Class discussion question

   All substances are made of atoms, molecules and ions bound together to make the total matter of substances.

2. Using Activity 2.2 guide the learners into understanding of what a mole is, enabling them to appreciate and know that a mole is a counting unit used in Chemistry. The teacher can start by asking the learners to state some of the counting units such as a dozen (12), pair (2), gross (144), century (100), platoon (39)' and ream (500)
3. The teacher can then pick one of these counting units, such as a pair to carry out a demonstration. The required apparatus and materials are:

   Beam balance

   Apple (2)

   Lemon (2)

   Mangoes (2)

   Note: Fruits of each type should have approximately the same mass but not equal mass. With the teacher's help, let the learners weigh a pair of each fruit i.e. 2 apples, 2 lemons and 2 mangoes. The idea here is to establish that although the counting unit is 2, these fruits have different masses. In other words same number of fruits (2) gives different masses.

   Suppose we have a fixed mass of 2 kg. Using a beam balance, find out how many fruits of each type weight 2 kg. The learner should observe that the number of fruits of each type vary because of their unit mass.

4. Further develop the concept by asking the learners to count smaller units such as beans and millet in limited amount e.g. 5g of each. The practice can be extended to very small particles such as fine table salts or sugar. The learner should notice the difficulty in counting these very small particles. What about counting atoms or molecules that we cannot see with our naked eyes?
5. At this stage, now as a teacher explains the importance of "counting by weighing". Table salt is weighed because it is difficult to count its particles. If the unit mass of one particle is known, then it is possible to estimate the number of particles there are in one kilogram of table salt without counting.

   Then introduce the term "mole" as a counting unit for very small particles such as atoms and molecules. It is a counting unit just like a "dozen" assigned number of 6.022×10^{23} particles.

   - Just like a dozen has 12 units, a mole has 6.022×10^{23} specified particles e.g.
   - A mole of oxygen molecules = 6.023×10^{23} molecules
   - A mole of oxygen atoms = 6.022×10^{23} atoms

   Remember: Always when dealing moles it is necessary to specify the units being referred to. A mole therefore refers to a quantity of a substance. However, some of these substances have very small particles whose masses are difficult to get by weighing. Can an atom of copper

be weighed? Since it is difficult to ordinarily (in most common laboratories) weigh a single particle of substances, we therefore have to weigh large numbers of a mole of particles. *It has been established that 1 mole of any substance contains the same number of particles as there are atoms in 12.000g of pure carbon-12*. Now what mass of a substance makes one mole of the substance i.e 6.023 1.023 particles? This can be established by the experiments that shall follow.

6. Emphasise that mole is an SI unit of measuring the amount of substance, which is a physical quantity. For example;
    - One mole of oxygen atom is 16g
    - One of copper is 64g
    - One mole of sodium hydroxide (NaOH) is 40g

2.3 and 2.4 Relative Atomic Mass, Relative Molecular and Formula mass

Learning activities

1. Bring to the learners how tedious is it to count large number of coins. This can be demonstrated by availing coins of small values in large quantities summing up in big money value such as 5000 or 10000. Let them count practically and experience the inconvenience, tediousness and in accuracies.
2. Then ask how the banks manage to overcome these difficulties when dealing large quantities of coins coming from many customers in their daily operations. Inform learners bank clerks count large number of coins by weighing. Similarly, where many small tablets are prescribed, pharmacists do not actually count out very small tablets by hand but uses an automatic counting machine or weighs them. Let the know that atoms too can be counted by weighing, but atoms are so light that millions are needed to reach a mass that can be recognized. Through the use instrument capable of measuring the masses of atoms, the mass of one atom is compared with that of another atom and so easier to determine the **relative masses** of the atoms.

   Hydrogen served for a long time as the reference element, the carbon isotope $^{12}_{6}$Cis used today as a reference element used to get masses of other atoms indirectly.All atomic masses are compared 1/12 of the mass of carbon a ^{12}C, which is now taken as a reference mass for measurement of masses. The instrument used for this comparison is call **mass spectrometer.**
3. Let the learners the following questions.
   (a) In groups to discuss why the masses of atoms are called relative masses.
   (b) Why are there no units for relative masses?

4. Using activity 2.4 guide learners into the desired conclusion that items of same quantities e.g. pair or a dozen may have different masses. This too applies to particles (atoms, molecules, ions) of different elements. For example, 23g of sodium atoms and 14g of nitrogen atoms though with different masses each contain the same number of atoms, which is 6.022×10^{23} atoms. Therefore one mole of each element has the same number of particles but their relative atomic masses are different.
5. Guide learners, allowing them suggest and demonstrate how to establish the **RMM**, **RFM** of compounds. Correct them as is appropriate. For example, when atoms combine they form molecules. So the molecular mass of a compound is the sum of all the atomic masses of each atom in the formula. Some compounds are made up of ions rather than atoms, hence we use the term **Formula Mass** which incorporates atomic, molecular and ionic compounds.

Calculations involving moles

Learning activities

1. Guide the learners, using examples provided in the learner's book and your own examples how to:
    - Calculate the mass or element given the number of moles.
    - Find number of moles given the mass.
    - Calculate molar mass given physical mass and number of moles. Let the learners recall the relationship: Number of moles= Mass in grams/molar mass
    - Determine molecular mass given the formula of the compound.
2. As a teacher carefully observe and ensure the acquisition of the following skills:
    - Understanding and application of inter-relationships and formulae of the different concepts.
    - Computation: accuracy, decimal places, standard form.
    - Tabulation of results.
    - Correct use of units.

2.6 Molar gas volume

Refer to the learner's book page 49

Learning activities

1. Introduce the lesson by asking the learners to name some common gases, if the gases can be measured and how it is done. From the list given by the learners, gases made up of atoms of the same element such as nitrogen, hydrogen, oxygen should be identified.

   During the discussion, the concept on how gases exist should be brought out clearly. Explain the existence of gases as monatomic, diatomic and diatomic.

2. Guide the learners in carrying out experiment/activity 2.5 in the learner's book, which is critical in achieving this learning outcome The experiment is aimed at determining the volume occupied by one mole of a gas.

   - Involve the learners in setting up of the apparatus and carrying out the experiment.
   - Consider allowing the learners to complete table provided in the learner's book

   Note: Apparatus per group - burette, ureter stand, water bath.

   Chemicals (per group) - 2M Hydrochloric acid, Magnesium ribbon 3.5 cm long.

   Safety wear for eye protection.

3. Inform the learners the volume occupied by one mole of a gas is 24 litres at room temperature and pressure; while at standard temperature and pressure, the volume is 22.4 litres. This discussion should further lead to the definition of Avogadro's law. Further bring out the relationship between mass, volume and density of a given mass of gas.

   Avogadro's law of gases states that equal volume of gases under the same conditions of temperature and pressure contain equal number of molecules.

   From this law it is concluded that one mole of any gas contain equal number of molecules and therefore would occupy the same volume under the same conditions.

4. Define the **molar gas volume** as the volume occupied by one mole of a gas. At Standard temperature and pressure (S.T.P) one mole of an ideal gas will occupy a volume of 22.4 dm^3 and at room temperature and pressure (R.T.P) the volume is 24.0 dm^3
5. Tell the learners that one mole of any gas contains Avogadro's constant, 6.022×10^{23} molecules.

Worked example

Calculate the number of molecules of gas in 5.6 dm^3 of CO_2 at STP.

Moles of the gas $= \frac{\text{volume}}{\text{molar gas volume}} = \frac{5.6}{22.4} = 0.25$ moles

Number of molecules = $6.02 \times 102^3 \times 0.25 = 1.505 \times 10^{23}$ molecules

6. Discuss the standard conditions for measuring gas volumes. The unending changes in the temperature and the pressure of a gas make it necessary to choose suitable standards of temperature and pressure to which volumes of gases can be referred; the standards fixed are 0°C or 273K and 760mm pressure. These are known as *standard temperature and pressure (S.T.P)*; and 25°C or 298K and 760mm pressure are known as *room temperature and pressure (R.T.P)*.

Answers to Check your progress 2.1

Refer to learner's book page 52

1. It's the average of their isotopes.
2. (a) 142
   (b) 162
3. (a) 36.5, (b) 32, (c) 170
4. Relative molecular mass is the sum of the atomic masses of the atoms in the molecule. Relative formula mass is the sum of the atomic masses of the atoms in the empirical formula.
5. Molar gas volume is one mole of an ideal gas that occupies a specific volume at a particular temperature and pressure. Mole of a gas is the number of moles a gas has.
6. A mole is 6.02×10^{23} (Avogadros number) molecules of a substance. The molar mass is the amount of mass that 1 mole of that substance possesses.
7. (i) 2.76g
   (ii) 136.5g
   (iii) 25.6g
8. (i) 0.5
   (ii) 1.48
   (iii) 0.1
9. (i) 1.204×10^{24}
   (ii) 1.1055×10^{24}

2.7 Determination of chemical formulae

Refer to the learner's book page 52

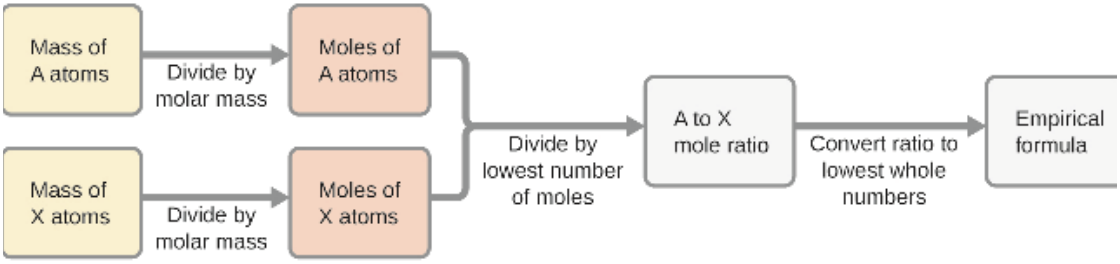
Learning activities

1. Guide the learner to understand that the concept here is to establish the proportions by mass of the elements that react so as to determine the chemical formula of the compounds formed. First the empirical formula of a compound is determined using the relationship between the mole and relative atomic masses.
2. Once determination of empirical formula is understood, show its relationship to molecular formula.
3. The recommended approach to this sub-topic is for you as teacher to make the learner to appreciate what combining ratios means.
4. Under your supervision, let the learners carry out activity 2.7 about determining empirical formula of magnesium oxide**. *Provide the caution that eye protection is essential***. This activity/experiment is meant to help learners to determine chemical formulae of a compound from experimental results.
5. The tabulation of the results should be done as shown in the learner's book.
6. Guide the learners how determine the combining ratios using the example provided in the learner's book or any other.

Additional information for the teacher

In case of lack of the adequate apparatus, the teacher can organize the learners into groups of four. After measurements are done and the apparatus have been set up, the main problem in the experiment is to hold the lid far away enough from the crucible to allow in sufficient air to completely burn the magnesium and at the same time keep the lid close enough to prevent escape of magnesium oxide. The teacher can demonstrate to the learners how to occasionally lift the lid slightly using a pair of tongs.

Indetermination of combining ratios, the teacher should make it clear that ratio is computed by dividing the number of moles of each element by the smaller number. The formula is given by the ratio obtained from the calculations. The teacher should carefully monitor the acquisition of manipulative, observation, tabulation and computation skills by learners. Learners should also remember the chart below:



Molecular formula

1. Once learners have known how to determine empirical formulae from both experimental results and given data, the learners can be informed that the empirical formula may not give the actual number of each kind of atom present in a molecule or a compound. This can be illustrated by using worked example in the learner's book.
2. The relationship between empirical formula and molecular formula can then be given as (mass of empirical formula)n = Molecular mass where n is a whole number.
3. It should be shown that for ionic compounds, empirical formula is same as the chemical formula.
4. The worked examples in the learner's book are meant to show these relationships. The teacher should assist the learners to go through each of the examples because they present various aspects of presentation of information. Meanwhile, the teacher should check to ensure that learners master the steps followed in arriving at the molecular formula starting from working out the combining ratios of the atoms.
5. Proceed now to define the terms *empirical formulae* and *molecular formulae*.
   (a) Empirical Formula is the formula which shows the simplest whole number ratio of the different types of atoms, that is the simplest ratio of the atoms present in a compound Molecular formula is the formula which shows the actual number of different atoms in a molecule, that is the actual formula for a molecule.
   (b) The molecular formula represents the compound in the way it exists. The empirical formula for many compounds is not the same as molecular formula and is not the form in which the molecule exists naturally. For these compounds there are a number of empirical formula units in one molecule. For example, there are six CH empirical formula units in C_6H_6.
6. The learners can do practice the revision questions. To establish whether the learning outcomes have been achieved.

Determining the amount of water of crystallisation in hydrated compound

Learning activities

1. Carry out activity 2.8 to determine empirical formula of hydrated copper (II) sulphate $CuSO_4.xH_2O$. The concept here is to establish the proportions by mass of water in a hydrated salt. The recommended approach to this sub-topic is for the teacher to make the learner to appreciate that water can form part of a salt.
2. In this experiment, the water of crystallization is removed from hydrated copper (II) sulphate. The mass of water is found by weighing before and after heating. This

information is used to find x in the formula: $CuSO_4.xH_2O$, using mole calculations. Involve the learners in setting up of the apparatus and carrying out the experiment.

3. Assist the learners to tabulate the results as shown in the learner's book. Carefully monitor the acquisition of manipulative, observation, tabulation and computation skills by learners.

Calculating the Percentage Composition

Percentage composition is the term used to describe the percentage by mass of each element in a compound. It is typically found using the molar mass values for both the elements in the compound and the compound itself.

$$\text{Percentage Composition} = \frac{\text{mass of the element}}{\text{mass of the compound}} \times 100$$

The teacher must ensure the acquisition of the following skills.

- Computation: accuracy, decimal places, standard form.
- Correct use of units.

Answers to Check your progress 2.2

Refer to learner's book page 59

1. Mg_2N
2. Calcium – 24.4%, Nitrogen – 17.1 %, Oxygen – 58.5%
3. Sodium- 15.2 %, carbon – 4%, oxygen – 74.2%, hydrogen – 6.6%
4. (i) Calcium-34.5%, carbon – 1.3%, oxygen – 55.2%
   (ii) Magnesium – 55.8%, oxygen – 41.9%, hydrogen – 2.3%
   (iii) Carbon – 52.2%, hydrogen – 13%, Oxygen – 34.8%
5. (i) 29.2% (ii) 17.7%

2.8 Percentage yield and percentage purity

Refer to learner's book page 60

Learning activities

1. Bring out clearly during the class discussion, the concept percentage yield and percentage purity.
2. Let the learners attempt to define percentage yield and percentage purity. Correct them as is necessary.
3. The percentage yield is the amount of product obtained from a chemical reaction. Percentage purity is the percentage of the material which is the actually desired chemical in a sample of the product.

4. Guide the learners in carrying the suggested experiments in the learner's book. In these activities we will consider how to calculate the percentage yield from a reaction and the percentage purity of the product obtained.
5. Go through the worked examples provided in learner's book allowing the learners full participation in the working steps and an opportunity to ask questions. The teacher should carefully monitor the acquisition of manipulative, observation, tabulation and computation skills by learners.

Answers to Check your progress 2.3

Refer to learner's book page 63

1. 41%
2. 56%
3. Check for correct learners arguments.
4. 60.2%
5. 59.3%

2.9 Chemical equations and mole ratios

Refer to learner's book page 64

Learning activities

1. Review with learners about chemical equation as a convenient means of representing a chemical reaction by using symbols and formulae.
2. Explain to them the mole ratio of reactants and products in a chemical reaction is used to write a balanced chemical equation for the reaction.
3. During the discussion emphasize to the learners that knowledge of the products of a chemical reaction and the chemical formula is important in order to determine a balanced full and ionic equation for a chemical reaction.
4. The discussion should enable the learners to define the terms mole ratio of a reaction and stoichiometry of a chemical reaction. They should also be able to appreciate the importance of mole ratio in a balanced chemical equation. The learners should internalize steps in balancing chemical equations and also how to read a chemical equation.
5. Take the learners through how to balance ionic equations and identify substances that contain free ions and those that do not.

Answers to Check your progress 2.4

Refer to learner's book page 70

1. Check for correct chemical equations.
2. Check for correct ionic equations.

2.10 The Gas laws

Refer to learner's book page 72

The chapter focuses on the behavior of gases when exposed to different Conditions of pressure, temperature and how these conditions affect the movement of the gas particles. In this chapter, gas laws are used to explain how gases behave under different physical conditions. The learner is therefore expected to:

- Recall and write down gas law equations.
- Apply gas laws to new situations.
- Carry out experiments on the behavior of gases.
- Use gas equations in related calculations.

Boyle's law

Activity 2.13

1. This activity is a class experiment. Each group should have five learners. The teacher should demonstrate to the learner how to draw air into the syringe. During the experiment, the teacher should ensure that the experiment is done as required and each learner has a feel of the physical property being investigated. The teacher should remind the learner to push the piston of the syringe slowly so as to avoid temperature variations.
2. Guide learners on how to make correct observations. Using sample results, the learner should be assisted to sketch the graph of pressure against volume.

   Sample Results

Pressure (K pa)	25	20	10	5
Volume (cm^3)	50	63	110	300

3. The graph enables the learner to understand inverse proportionality.
4. Point out to the learner that pushing in the piston reduces the volume occupied by air in the syringe; at the same time pressure increases. When the air is prevented from escaping, the pressure increases as the plunger is pushed down. This results in a reduction in the balloon's volume since the number of air particles does not change; the particles are only being confined to a smaller volume. This is what leads to an increase in pressure. The relationship between pressure and volume for a fixed mass of gas should lead to Boyle's law.
5. Let learners to explain the Boyle's law and express it mathematically.
6. From the experiment, learners should observe that as the water heats, the balloon expands and therefore an increase in temperature results in an increase in volume. If the absolute temperature is decreased at constant pressure, the volume consequently decreases.

7. During the experiment, the teacher should ensure that the learner is able to make correct observations. Where necessary, the teacher should allow the learner to sketch the diagram to illustrate the variations of volume with temperature.

Answers to Check your progress 2.5

Refer to learner's book page 82

1. 120K
2. 546K
3. 830.24 cm^3

Combined gas law

1. During the discussion, guide the learner on how Boyle's and Charles' laws are combined to give the ideal gas equation.
2. Use a worked example to enhance the learner's grasp of the combined Gas law equation.

Answers to Check your progress 2.6

Refer to learner's book page 84

1. 247 cm^3
2. 270mmHg
3. 262.5 cm^3

2.11 Graham's Law of diffusion.

Diffusion is a daily experience since these smelly gases can travel a long way through the air and your nose is a pretty sensitive gas detector. For example, you stand at one corner of a room and the perfume is sprayed from one end, molecules move from the original area to other parts of the room and that is why you will be able to smell the

Activity 2.16 and 2.16

1. This activity is meant to show that particles of a gas can move from more concentrated region to a low concentrated region.
2. During the experiment, the teacher should ensure that the learner is able to make correct observations

Do molecules of different gases diffuse at the same rate?

During the experiment, learners should be made aware that liquids are made up particles with spaces between them. Diffusion occurs between the particles of liquids.

In the above experiment, lead nitrate and potassium iodide dissolve to form ions, which move from a region of high concentration to a region of low concentration. When lead and iodide ions collide a reaction takes place to form yellow lead iodide.

Particles of a gas move between air particles at different rates and to different extents. Chemists refer to a gas travelling through air as diffusion in air, and the speed with which this happens is referred to as its rate.

Activity 2.17

Safety Wear safety goggles and gloves to protect the eyes and hands from the strong acid and base used in this demonstration. Keep the containers of concentrated hydrochloric acid and aqueous ammonia covered when not dipping the cotton. Work in a well ventilated area and avoid breathing the concentrated vapors of either reagent.

1. This is a teacher demonstration. During the experiment, the teacher should assist the learner in setting up the apparatus as in Learners' Book. Explain to the learner why the combustion tube is arranged horizontally and not vertically.
2. The learner should also be assisted by the teacher to make correct observations, recording of time and distance covered by the two gases. During discussions, it should be clear to the learner that the distance covered by ammonia is twice that covered by hydrogen chloride gas.
3. Bring in the question of molecular masses and how to calculate them given molecular formula of the diffusing gases.
4. The relationship between rate of diffusion and relative molecular masses should lead to Graham's Law of diffusion.
5. Assist the learner to derive diffusion equations as in Learners' book.

Answers to Check your progress 2.7

Refer to learner's book page 90

1. 16
2. 54 seconds
3. Since Charles Law says that the volume of a gas is directly related to the temperature of that gas, that when a gas is heated, like the burner in a hot air balloon, the gas expands. So when the air inside the balloon expands, it becomes less dense and provides the lift for the hot air balloon
4. Pulling back on the plunger increases the volume inside the syringe, which decreases the pressure, which then corrects when liquid, is drawn into the syringe, thereby shrinking the volume again.
5. 6 times

6. 2.1
7. 0.47 times
8. The balloon will burst
9. 580K
10. 318K

Unit 3 Properties of Elements in Period 3 and Group II and VII

Refer to learners book page 92 -210

Learn about	Key inquiry questions
Learners should know the properties of elements across period three in groups 2 and 7 and work in groups and individually to describe variations of atomic radii, sizes, ionization energy, valences and changes of metallic characters across period 3. They should understand bonds across period 3 (bonding in oxides and chlorides) and predict the properties of elements in Group II and VII and describe the trends of physical properties in group 2 and 7. They should investigate the properties of elements across period 3.	▪ How do the properties of elements vary across period and within a group? ▪ How can you predict properties of elements in groups? ▪ How do you design an experiment to prepare nitrogen and its compounds in laboratory?
Learners should design and carry out practical experiments to prepare nitrogen and its compounds and investigate the properties of compounds of nitrogen. Through research from books and the internet they should explain the pollution effects of compounds of nitrogen. They should understand how to extract sulphur from its ores and the properties of sulphur and its uses ores and differentiate between the allotropes of sulphur. They should investigate the properties of dilute and concentrated sulphuric acids and test for hydrogen sulphide and sulphate ions and understand the pollution effects caused by compounds containing sulphur.	▪ How do compounds of nitrogen, sulphur and chlorine pollute our environment? Suggest ways through which air pollution due to these compounds can be reduced. ▪ How does sulphuric acid react with other substances? ▪ How do compounds of sulphur affect environment and how can knowledge of chemistry help to reduce pollution?
Learners should explain the properties of chlorine and its compounds, prepare chlorine and carry out tests for chlorides and investigate the pollution of the environment caused by chlorine compounds.	▪ How do we prepare chlorine and hydrochloric acids in a laboratory? ▪ Why do we study chlorine and its compounds?

Learning outcomes		
Knowledge and understanding	**Skills**	**Attitudes**
▪ Explain the properties of elements in period 3 and groups 2 and 7 of the periodic table including sulphur, chlorine, nitrogen and their compounds.	▪ Predict the properties of elements in Group II and VII. ▪ Investigate the properties of elements across period 3. ▪ Investigate the properties of dilute and concentrated sulphuric acids and test for hydrogen sulphide and sulphate ions. ▪ Carry out tests for chlorides. ▪ Investigate the pollution of the environment caused by chlorine compounds.	▪ Appreciate the danger of chemical pollution.
Contribution to the competencies: Critical and creative thinking: imagination, prediction and investigations. Communication: presentation of group work.		
Links to other subjects: Biology, Agriculture: nutritional cycle of plants and the use of chlorine in water treatment. Environment and sustainability: Pollution.		

Introduction to this unit

The learners have largely learnt about the periodic table and some aspects the elements it contained e.g. their electronic configurations and its use to predict the position and periods of elements. Now they are delving into further studies of

some groups and period of the periodic table (e.g. trends in physical properties and chemical properties). As a teacher, in your teaching of this unit, it is important that you draw clear parallel between properties of groups/periods of periodic table and any developing trend observable. Stimulate learners' thinking why the study of period 3 elements specifically of all the periods. Encourage learners' analytical thinking abilities in prediction of properties of elements in the groups and how to design investigation for some of the properties of these elements

Sodium, magnesium and aluminum all have metallic structures, which accounts for their electrical conductivity and relatively high melting and boiling points. Melting and boiling points rise across the three metals because of the increasing number of electrons which each atom can contribute to the delocalized "sea of electrons". The atoms also get smaller and have more protons as you go from sodium to magnesium to aluminum.

Phosphorus, sulfur, chlorine and argon are simple molecular substances with only van der Waals attractions between the molecules. Their melting or boiling points will be lower than those of the first four members of the period which have giant structures. The presence of individual molecules prevents any possibility of electrons flowing, and so none of them conduct electricity. The sizes of the melting and boiling points are governed entirely by the sizes of the molecules

Cross cutting issues to be in cooperated

1. **Environment awareness and sustainability**

   Though there are many benefits of period 3 elements and their compounds, it must be made clear the environment impacts of the compounds of some of these elements e.g. sulphur, chlorine and nitrogen if there are properly disposed of or handled

2. **Peace and values**

   Stress to the learners on the need to respect the sanctity of human life and such evil thoughts must never be encouraged. Always, at personal level and in groups strive to promote living at peace with each other, loving one another for our good and everyone else as well as the prosperity of the South Sudan. Learners must avoid any fracas or commotion in the laboratory at all times.

3. **Life skills**

   Learners can be encouraged to be financially responsible, to appreciate expenses incurred in purchases of reagents (chemicals) and even costs of apparatus used which cannot be improvised. They should handle apparatus very careful for avoid unnecessary breakages and where there is occurrence report immediately to the teacher or laboratory technician.

Competencies to be developed

1. **Co-operation**

   Encourage each group to distribute tasks and each responsibilities to carry out experiments/investigation or any group tasks. Instil the culture of corporation in group activities to help them appreciate the value of doing so e.g. makes work easier for everyone, improves each other contribution to the overall results, promotes team work and overall success for the group and appreciation of one another.

2. **Communication**

   Ensure the learners are organised in groups during research work, practical investigations. It may be useful to foster group presentations in class to improve learners' listening skills, report writing skills, presentation skills. Questions should be asked during and at the end of group presentations.

3. **Critical and creative thinking**

   Learners are to be encouraged to be imaginative and explain occurrence in differences among elements in groups and across the periods. Promote learners' abilities to understand and give explanations for the trends in physical properties and exceptions across the period and in the group. Prompt learners to be able to predict as well design investigation for physical and chemical properties of period 3 elements, and group 2 and 7 elements of the periodic 3 elements

3.1 Introduction to Period 3 elements

Refer to learner's book page 92

Learning activities

1. Review with the learners the general information about periodic table they had previously covered such as existing groups and periods, what informs classification of elements into groups and periods. Remind the learners the importance/uses of periodic table. You can draw parallel to classification of living things in biology.
2. Introduce the study of period 3 elements of the periodic table by asking learners to list/identify/mention all the elements in period 3 they have come across in their day-to-day life. After this you can refer to the periodic table.
3. Let learners interact with period 3 elements in the laboratory. Organise them in suitable group size or as a whole class, allow the learners discuss the questions provided under the flashback section on page 93 of the Learner's book and as well do Activity 3.1.
4. Let learners practice writing electronic configuration of period 3 elements without referring to their textbooks. Ask the learner's to classify the period 3 elements as metals or non-metals.

5. Allow learners to do research work suggested to assess the similarities and differences among period 3 elements such as: same number of energy levels, existing as metals and non metals, different valency electrons, varying reactivity levels..
6. Discuss briefly the major uses of some of the period 3 elements as outlined in the learner's book. Involve the learners by asking to name some of the consumer products and objects they are aware of that comprise of these elements. For example; magnesium and aluminium hydroxide manufactured as antacids, aluminium used in electrical cables and making of utensils/aircraft parts/ motor vehicles body, chlorine in water treatment, sodium and chlorine (as sodium hypochlorite used as bleaching agent) and table salt, sulphur used as medicine for fungal infections in animals and plants, sulphur used in vulcanisation of rubber.

3.2 Properties of Period 3 elements

Refer to Learner's book page 94

Learning activities

1. Introduce the lesson by allowing learners to carry out Activity 3.2.
2. Let the learners carry out the Work to Do section in the Learner's book page 94 This exercise is to stretch the learners imaginative and critical thinking in the how to draw, place the elements correctly in their actual positions in periodic table (correct group and period). They should be able to deduce from the periodic table they have drawn that: the atomic number and mass number of each element, the group of each element, the valence electron of each element as well notice that there is large vacant space between group II and III and period 1 to 3, that transition metals start filling in from period 4 onwards.
3. Brainstorm the trends of physical properties of period 3 elements as outlined in the Learner's book. Where possible encourage the learnersto be able to identify trends in physical properties of elements in the third period.
4. While as a teacher you should lay emphasis on explanations for these trends and any exceptions thereof. Lead learners to understand why there is gradual increase or decrease in the following trends as is observed; where possible let learners research from books/internet, or even observe through practical investigations:
    - Melting and boiling points
    - Physical state
    - Ionization energies
    - Atomic and ionic radii
    - Electrical and thermal conductivity

- Electropositivity and electronegativity of the elements.

Refer to the detailed discussion outlined in the Learner's book.

5. Allow learners to engage in the Discussion corners questions that will task their analytical and critical thinking skills.
6. Let the learners do Activity 3.3, which primarily gives prelude of properties or aspect of it of some oxides/chlorides of period 3 elements. Then guide discussion on the preparations and properties of these oxides and chlorides. You can as well look at:

   - The uses/any possible trends e.g. sodium/magnesium chlorides are very solid (anhydrous and of good crystals) while aluminium chloride is somehow semi-solid;
   - Type of bonding and structure
   - Physical state
   - Acidic/basic/neutral/amphoteric nature of these oxides and chlorides.
7. Let the learners carry out the research activity proposed in the Learner's book page 95 investigating the electrical conductivity of these period 3 oxides and chlorides, providing explanations. Where possible you can organise practical sessions for the learners to do, since Chemistry is about doing rather knowledge memorisation.
8. End the lesson by reminding the learners the trend shown across the period, drawing relevant conclusions on the nature of oxides and chlorides.

Additional information to the Teacher

Remember that from the previous learning experiences from other units and classes, the learners would have come across some of the elements in the period 3.

Note: Most elements in this period are common. Argon and silicon can be dealt with theoretically. The learnersmust nothandle sodium and phosphorus. As the teacher demonstrates with these elements there should be frequent interaction through observation and questioning.

Some important concepts like size of an ion have been included in this unit because it gives a clear picture when you want to explain trends on ionization energy. Some of the physical properties like melting points, boiling points and thermal conductivity are now possible to be demonstrated experimentally.

Some extra information has been provided in the table that enables the learner to relate very easily with the physical properties. For instance physical appearance and state of the element can easily and clearly explain their melting and boiling points.

Chlorine is a gas at room temperature; automatically what comes to the learnersmind is that it has a very low melting point. The teacher can ask the learnersto check on the physical state column and predict the trends in their melting and boiling points.

The aspect of valence electrons and its effects on a number of properties of the period 3 elements e.g. physical state, atomic and ionic radii, ionization energies should be clearly brought out.

Explanation for the trend in atomic number

The trend observed is due to nuclear charge increases across the period, which causes a stronger pull of the electrons toward the nucleus resulting into a smaller atomic size. There is general increase in the positive charge across the period, but for the added electrons they are all getting into the same outer energy level. The overall effective nuclear charge causes a greater attraction for the outer electrons. Hence, it becomes progressively more difficult for these elements to loose or their outer electrons to be removed.

Answers to Check your progress 3.1

Refer to learner's book page 100

1. Moving left to right within a period or upward within a group, the first ionization energy generally increases. As the atomic radius decreases, it becomes harder to remove an electron that is closer to a more positively charged nucleus.
2. Size of atom, nuclear charge, screening effect or shielding effect, penetration effect, electronic configuration

Answers to Check your progress 3.2

Refer to learner's book page 102

1. Electrical conductivity increases going across Period 3 from sodium to aluminum (due to increase in delocalized electrons), then decreases to silicon. The remaining elements have negligible conductivity.

Answers to Check your progress 3.3

Refer to learner's book page 104

1. Check for correct table filling.
2. The giant structures (the metal oxides and silicon dioxide) will have high melting and boiling points because a lot of energy is needed to break the strong bonds (ionic or covalent) operating in three dimensions.

   The oxides of phosphorus, sulphur and chlorine consist of individual molecules

3. Solutions of metal oxides in water display properties of bases, while aqueous solutions of the non-metal oxides display the properties of acids.
4. When added to water these chlorides are hydrolysed. The vigour of the reaction increases across the period as the number of chlorine atoms attached increases.

3.3 Group II and VII elements

Refer to Learner's book page 104

Group II elements

1. This topic provides an overview of the patterns of properties of a few representatives of group II elements in the periodic table. Let the learners know that at this level they are going to focus only on beryllium, magnesium and calcium.
2. Introduce to the learners the members of alkaline-earth metals (group II elements). You can guide the learners to identify and place the group II members in their correct positions in the simple periodic table provided under activity 3.5 in the Learner's book page 104.
3. Point out the following general information at the preliminary discussion stages by asking learners questions about them.

   Main characteristics of the group II elements

   - Increase in energy levels by one as you go down the group.
   - The same number of electrons in the outermost energy levels for elements in the same group determines chemical properties.
   - Members of group 2 react by losing electrons.

   Note

   - All group II metals have 2 electrons in their outermost energy level.
   - Atomic radius increases down the group as the successive energy levels are filled.
   - Down the group, ionization energy (the energy required to remove an electron from the atom) decreases. As the atomic radii increase, the electrons in the outermost energy level are further from the nucleus, they are less attracted by the nucleus (electrons are said to be shielded).
   - Shielding effect increases down the group as more successive energy levels are filled. The positive nucleus exerts less force of attraction on electrons and so less energy is used to remove electrons.
4. Allow the learners to engage in the discussion corner suggested in the learner's book page 105 to predict and stretch their critical thinking. As well learners to predict the size of group II ions in comparison to the atoms after loss of outer most energy level.

5. When it comes to physical properties of alkaline-earth metals, there is considerable variation. Guide learners to draw models that show electrons distribution in-group II members: beryllium, magnesium and calcium atoms.
6. Discuss the trend in physical properties as outlined in the Learner's book.
7. Guide learners in conducting the various investigations involving different chemical properties of group II elements as proposed in the Learner's book.
8. The following are suggested activities which are to help the learners to investigate and understand the various chemical properties of group II elements.
   (i) Activity 3.7. It is to help compare the reactions of magnesium and calcium with air and water. The learners are expected to design, plan and conduct the investigations on their own.
   (ii) Activity 3.8 investigates reaction of group II elements with chlorine
   (iii) Activity 3.9 investigates reactions of magnesium and calcium with dilute acids.

Preparations for the activities

- Make all the apparatus and reagents available for each activity during the lessons.
- Ensure that the learners' safety is observed during the activities.
- Perform prior experiments before every lesson to ensure the workability of each activity.

Note: During the practical session of activity 3.7

1. Let the learners' discuss and develop the procedure/plan to be used in carrying out the activity, offering guidance as is appropriate.
2. Ask learners:
   - To describe/compare the appearance of magnesium ribbon before and after cleaning it.
   - Why it is important to clean the magnesium ribbon before using it.
3. Caution the learners not to look directly at the burning magnesium ribbon since the very bright light can adversely affect their eyesight.

Answers to Check your progress 3.4

Refer to learner's book page 108

1. Ionisation energy reduces from magnesium to calcium due to the force of attraction between the nucleus and outer electron is reduced so less energy is needed to remove the outer electron.
2. Going down Group 2:
   - There are more filled energy levels between the nucleus and the outer electrons.

- Therefore the outer electrons are more shielded from the attraction of the nucleus.
- So the electrons in the outer energy levels are further from the nucleus and the atomic radius increases.

Procedure I Reaction of magnesium and calcium with air

1. Using a pair of scissors, cut 6 cm magnesium ribbon.
2. Clean the outer coat of the magnesium ribbon by scratching using a sand paper or emery paper.
3. Using a pair of tongs, hold one end of the magnesium ribbon on a Bunsen burner flame until it ignites. Notice the colour of the burning magnesium.
4. Put the residue in a test tube, add 5cm^3 of water and test the solution with both red and blue litmus papers.

Note: Procedures for burning of calcium in air, reaction of magnesium and calcium with water have been outlined in the Learner's book.

General approach for the learning during the activities and experiments

1. Allow learners to first have an idea of what will be covered in the lessons. Make them study the procedures where provided for in the learner's book. If they are required to come up procedure, let them brainstorm and provide help where necessary.
2. Divide the learners in groups of 2 or 3 depending on the availability of resources and space.
3. Let the Learners observe the physical appearance of metals (calcium and magnesium) before and after cleaning. Remember that what you want to put across is the coating on the surface of the metal. The coating should not be referred to as the oxide at this point.
4. Let them compare the colour of the magnesium and calcium with the coating on the surface with magnesium and calcium metals in the bottles.

   Caution: the learners should be cautioned to look directly at a burning magnesium ribbon because the *dazzling* flame that might damage their eyes.

5. Lets the learnerswrite word equations of the reactions of calcium and magnesium with oxygen. They can then predict the reaction of beryllium with oxygen.
6. Remind the learners, how reactive a metal seems to depend on how fast the reaction occurs. The speed is controlled by factors like presence of surface coatings on the metal surface, for example the oxide on the metal. Calcium is more reactive than magnesium. Therefore, when you burn magnesium in air, it may appear as if it is more reactive than calcium because calcium metal may be coated with more oxide than magnesium prior to burning.

7. To check for the understanding of some trends in group II, ask the learnersthe following questions:
   (i) How does the atomic radius change down Group II?
   (ii) How does the atomic radius of Group II compare to that of Group I in the same period (same row of the periodic table)
   (iii) How is the reactivity of the alkaline-earth metals with air down the group?
8. End the lesson with the learners being able to describe the reactivity trend shown down the group.

Reaction of alkaline-earth metals (magnesium and calcium) with water

1. As they go through the experiment, ask the learners the questions in the Learner's book page109. This will enable the learners' to make the correct observations.
2. Learners' Use any indicator as long as you make sure that the learners' are aware of the indicator's colour changes in alkaline and acidic solutions.
3. Let the learners' predict the reaction of beryllium with water. Can the learners' predict the product and its reactivity compared to magnesium and calcium? The learners' might give products similar to those of magnesium and calcium but remind them the unique nature of beryllium.
4. Explain to the learners' that beryllium has very unique properties in the same way there are sisters or brothers in the same family who are not identical but may show certain similarities and differences. Beryllium has two energy levels with an electron arrangement of 2:2. Its outermost energy level has two electrons. It is requires a lot of energy to remove these electrons for it to form an ion. That is why beryllium is not as active as the other members of the group.

Activity 3.5 Reaction of alkaline-earth metals (magnesium and calcium) with chlorine

1. Let the learners follow the procedure as outlined in the Learner's Book page 111.
2. Caution the learners about the dangers of exposing themselves and inhaling the chlorine gas. Advise asthmatic or any learner who has respiratory problems to stay further away from the point where the gas is being prepared. If possible always use a working fume chamber or do this experiment in an open space.

Note This activity should be done first by the teacher as a class demonstration.

- Ask the Learner s the following questions to guide them on recording precise observations:
  (i) What is the colour of the product?
  (ii) What is the order of their reactivity with chlorine?
  (iii) The order of reactivity of magnesium and calcium with chlorine as

observed during the experiment could be; magnesium reacts more vigorously than calcium which is not the case. Learners should be aware that is due to the oxide coating on the calcium metal that brings its apparent slow reaction.

Activity 3.6 Reaction of alkaline earth metals with dilute acids

Caution: Reaction of calcium and dilute acids is very violent.

1. Learners to follow the procedures as outlined in the Learner's book page 112.
2. The learners can be put into groups of 2 to 4 depending on the availability a resources and space.
3. Ask questions as the experiment progress for the learners to make precise observations. The following suggested questions can guide you:
   (i) How does the earth-alkaline metal react with dilute acids? Can you rank them in order of their reactivity?
   (ii) What gas is emitted during the reaction?
4. When metals react with acids, two products are formed. One is a gas and the other is salt. Let the learners write balanced equations for the reactions of all the metals and the acids used.

Group VII elements [Halogens]

1. Introduce learners to the members of halogens. The learners can refer to the periodic table but remind them that at this level they are going to focus only on fluorine, chlorine, bromine and iodine, ie Activity 3.7.
2. The study of group VII elements here is an overview of patterns of properties of the group. Highlight the following main points as introduction:
   - Increase in energy levels by one as you go down the group.
   - The same number of electrons in the outermost energy levels for elements in the same group determines chemical properties.
   - Members of group 7 react by gaining electrons.
   - Learners predict the size of group seven ions in comparison to the atoms after adding electrons to the outer most energy level.
3. Let learners use the acquired knowledge and skills to brainstorm and make predictions about trends in physical properties of the halogens. The following suggested questions could guide you through
   - Can you write the electronic arrangement of the halogens? (Fluorine, chlorine, bromine and iodine).
   - Learners draw models that show electrons distribution in group 7 member's fluorine, chlorine, bromine and iodine

- Non-metals have relatively low melting and boiling points.The melting points and boiling points increase steadily down the group (so the change in state at room temperature is from gas to liquid to solid). This is because the intermolecular forces of attraction increase with increasing size of atom or molecule.
- They are all coloured non-metallic elements.
- The colour of the halogen gets darker as you go down the group.
- They are all poor conductors of heat and electricity, this is typical non-metal.
- When in solid form, they are brittle and crumble easily for example iodine.
- The size of the atom gets bigger as more inner energy levels are filled going down from one period to another.
- The following suggestions explain chemical features, similarities and reactivity trends of halogens.
- When a halogen atom reacts, it gains an electron to form a single negatively charged ion which has a stable noble gas electron structure.

  $Cl_{(g)} + e^- \longrightarrow Cl^-_{(g)}$

- As you go down the group from one element to the next:
  F ⟶ Cl ⟶ Br ⟶ I. The atomic radius gets bigger due to an extra filled energy level.
- The outer electrons are further and further from the nucleus and are also shielded from nuclear attraction by the extra full energy levels.
- The electrons in the outermost energy level are less strongly attracted by the positive nucleus.
- This combination of factors means that the attraction of the extra 8^{th} electron into the outermost energy level is more and more difficult. That is why the elements are less reactive. It is increasingly difficult to form the ions although the atomic number increases down the group.

4. Organise the class to carry out or demonstrate reactions of group VII elements. The following activities are suggested:
   (i) Activity 3.8 – reaction of halogens with water
   (ii) Activity 3.9 – reaction of chlorine with alkaline solution
   (iii) Activity 3.10 – reaction of halogens with metal iron
   (iv) Activity 3.11 – Demonstrating displacing power of halogens

Activity 3.10 Reactions of halogens (chlorine, bromine and iodine) with metals (sodium, zinc and iron)

1. Learners are expected to design, plan and carry out the experiment. Offer your guidance as is necessary.
2. Remind the learners the potential dangers of handling sodium and halogens.
3. The following questions will guide the learners in making precise observations.
   (i) What is the order of reactivity of halogens with metals? Write word equations.
   (ii) What are the colours of the products?
4. At the end of activity, the learners should be able to see the similarities in reactions, the different reaction power of the halogens.

Note: For learner's notes and essential discussion details always refer to the Learner's book.

Activity 3.11 To demonstrate the displacing power of halogens

1. In this activity the learners are expected to design, plan and perform the experiment. Guide them in brainstorming the proper procedure to be used and in the planning.
2. Remind the learners to take caution when handling halogens. This experiment should be done in a fume chamber or in an open area. Asthmatic learnersor any learner with respiratory diseases should keep a good distance from the fumes.
3. The following suggested questions would guide the learners to make precise observations as you demonstrate.
   - What is the colour of water with the indicator used?
   - What do you observe when water is added to chlorine, bromine or when water is added to iodine?
4. Lead them into a discussion to find out why litmus papers are bleached. When put in a solution of chlorine.
5. Let the learners note that the blue paper turns red first before it is bleached.
6. Provide explanations as to why litmus paper is bleached i.e. due to formation of chloric (I) acid (hypochlorus acid), bromic (I) acid. (Note the IUPAC names.) It is very important that you introduce the learners to the new names. They should use them every time they are referring to them.
7. Let them write the word equations for the reactions.

Additional information to the teacher

Chlorine dissolves in water forming green-yellow solution. The resulting solution has acidic properties. Both hydrochloric acid (HCl) and chloric (I) acid (HOCl) are formed in the solution. Chloric (I) acid has bleaching properties, it bleaches both red and blue litmus papers. The solution will first turn blue litmus paper red then bleaches it.

Answers to Check your progress 3.5

Refer to learner's book page 119

1. Due to bleaching action of chlorine.
2. $NaOCl + H_2O \longrightarrow NaOH + HOCl \longrightarrow Na^+ + OH^- + OCl^-$

Answers to Check your progress 3.6

Refer to learner's book page 122

1. Decreasing reactivity of the elements down Group VII.
2. Halogens are strong oxidizing agents they remove electrons from other substances. Halogens too are electronegative is a measure of the tendency of an atom to attract a bonding pair of electrons fro other substances.
3. The melting and boiling points increase down the group because of the van der Waals forces. The size of the molecules increases down the group. This increase in size means an increase in the strength of the van der Waals forces.

Answers to Check your progress 3.7

Refer to learner's book page 124

1. Halogens undergo redox reactions with metal halides in solution, displacing less reactive halogens from their compounds. These displacement reactions are used to establish an order of reactivity down Group VII of the periodic table.
2. Electronegativity is the ability of an element to attract the bonded electrons towards it. Atomic size plays a part in this as closer the electrons are to the nucleus of an atom the attraction between them increases. Thus increase in size leads to less attraction of electrons by the same nucleus. Accordingly the order of electronegativity of the given elements would be: Fluorine ⟶ Chlorine ⟶ Bromine ⟶ Iodine.

3.4 Nitrogen and its compounds

Refer to Learner's book page, 125

Learning activities

1. Introduce the study about nitrogen and its compounds by learners doing the flashback questions provided in the Learner's book. This provides basic information about nitrogen.
2. At this stage you can ask the learners about some characteristics/properties of nitrogen and other common gases they earlier learnt about in Form 2.
3. Brainstorm with the learners on methods of preparation of nitrogen and suitability.

4. Then guide the learners to proceed to carry out activity 3.14 and 3.15, on laboratory preparation of nitrogen.

Activity 3.12 (Nitrogen isolation from air)

1. Learners have been provided with apparatus and chemicals and a detailed procedure. Let them label the set up.
2. Ask one learner to state the composition of air and state approximate percentages.
3. Let learners outline the role of each substance used in the set up.
4. Let the learners brainstorm on how gases and other substances are removed and added to the air, see how much they remember of processes like photosynthesis that removes carbon (IV) oxide from air and simultaneously adds oxygen. Respiration uses oxygen from the air and during the process adds carbon (IV) oxide. Burning of hydrocarbons adds carbon (IV) oxide.
5. Ask them how some substances, for example dust particles and water vapour, can be removed from air.
    - Dust particles can be trapped by cotton wool if air is passed through it.
    - Water vapour can be removed by condensed.
6. Ask them to suggest how they can get rid of carbon (IV) oxide.
7. Let them brainstorm on how they can get rid of oxygen. After removing oxygen, the remaining portion of air will be mainly nitrogen plus traces of the noble gases.
8. Ask the learners to suggest how the noble gases can be removed.
9. Iron can be used in place of copper. Iron in form of steel wool is best. It glows during the reaction. The nitrogen gas collected will have impurities of unreacted carbon (IV) oxide, oxygen and noble gases. The most abundant noble gas will be argon. Sodium hydroxide solution can also be used to absorb carbon (IV) oxide.
10. Test the gas obtained using a burning splint.
11. Learners compare the procedure used to that of industrial preparation of nitrogen.

Activity 3.13 Laboratory preparation of nitrogen

1. Inform learners that this can be done in two ways heating of ammonium chloride alone or mixture of sodium nitrite and ammonium nitrite but the former has potential danger of explosion when remaining in small quantities, hence very risky and not preferred.
2. In groups of 3 or 4 depending on workspace and availability of resources, guide the learners to carry out activity 3.13. The learners are required to select the apparatus and chemicals needed; design, plan and carry out experiment.
3. Learners using the procedures developed to conduct the experiment.
4. Ask the learners what is formed when nitrites are heated. Let them name the nitrites, which form two products.

5. Ask learners the two or three nitrates, which on decomposition, yield three products and name them.
6. Explain that ammonium nitrite is decomposed by heat to form nitrogen and water.
7. Discuss why it is not advisable to prepare this gas by direct heating of ammonium nitrite. A lot of **caution** should be taken when heating ammonium nitrite. This salt can burn explosively and therefore it should not be kept near naked flames.
8. Learners to explain how we test physical properties of the gas, for example, colour, smell, solubility and density.
9. Introduce the test for chemical properties with a brief brainstorming on the substances that are used for example litmus papers, combustion of elements such as metals and non-metals.
10. Ask the learners to suggest a metal that they think might burn in nitrogen atoms.
11. The heat from the burning magnesium is hot enough to break the strong triple covalent bonds between the two nitrogen atoms.

    $N \equiv N \xrightarrow{\text{heat}}$ 2N two atoms

    These atoms react with magnesium atoms to form magnesium nitride. But remind learners, nitrogen does not support combustion.
12. Conclude the discussion by asking learners to describe the procedure to laboratory preparation of nitrogen and outline properties of nitrogen.

Compounds of nitrogen

1. Inform the learners the compounds of nitrogen to be studied at this level; that is ammonia, nitrogen dioxide and nitric acids. Allow the learners to list all the compounds of nitrogen they are aware of. See the listing in the Learner's book.
2. You can ask the learners to do the research activity proposed in the Learner's book as introduction to this sub topic.

(a) Ammonia

Learning activities

1. Review with the learners some of the experience they have encountered with ammonia gas.
2. Let the learner give their experiences with smell from barns and stables where farm animals are housed.

Activity 3.14 and 3.15 Laboratory preparation of ammonia gas

1. It is usually prepared using ammonium salt and a base.
2. Ask the learner to observe the liquid formed on the cool part of the flask and record the observations in their notebooks.
3. Probe to find out whether the learnersknow why the flask should be sloping.

4. Ask them to explain how to identify the colourless liquid.
5. Let them predict the density of the gas in relation to air according to the method of collection.
6. They should also predict the solubility of the gas according to the method of collection.
7. Ask them why ammonia is dried with calcium oxide and not concentrated sulphuric acid or calcium chloride.
8. Point out that concentrated sulphuric acid and calcium chloride react with ammonia.

   Note: Calcium oxide should be closely packed for effective drying of ammonia gas. Powdered calcium oxide should not be used otherwise; no gas will pass through the drying tower.

Properties of ammonia gas

Physical properties

Activity 3.16 Investigating some physical properties of ammonia gas

1. Let them follow procedure as outlined in the Learner's book.
2. Let them observe and record their observations and conclusions.
3. Guide the learner to state how we test for physical properties of a gas.
4. Let them explain how they can tell a gas has dissolved.
5. Let them brainstorm and then perform the experiment.
6. Ask the learners why the water forms a fountain during the experiment. (-atmospheric pressure forces water up to occupy partial vacuum).

The solubility of ammonia is so great such that 1cm^3 of water dissolves about 700cm^3 of ammonia. Atmospheric pressure might break the flask. Therefore, you must use a thick walled flask.

Chemical properties of ammonia

Activity 3.17 Reaction of ammonia with air/oxygen

1. Learners to follow the procedure as outlined in the Learner's book.
2. Ask learners what happens when ammonia is burnt in air and also air enriched with oxygen.
3. Let learners observe and record their observations in their notebooks.
4. With your guidance let learners make appropriate/logical conclusions. Ammonia burns only in air enriched with oxygen i.e. emphasize that ammonia does not burn in air unless it is enriched with oxygen. It also does not support burning.
5. Explain the reaction, which takes place when ammonia burns in air enriched with oxygen. Use a chemical equation to explain the reaction.

Note: The reaction of ammonia and oxygen is a **redox** reaction. Ammonia is the reducing agent.

Activity 3.18 Catalytic oxidation of ammonia

In this activity the learners are required to design, plan and carry out the activity. Decide whether the learners do this in their respective groups or brainstorming done as a whole class on the apparatus required, procedure to be used, time allocation and risk assessment if any before proceeding to carry out the experiment.

Caution: The reaction can sometimes be explosive.

1. Let the learners test the red-brown fumes coming out of the beaker with moist blue litmus paper. They should give you the colour change and also their conclusion.
2. Let learners to record these observations and conclusions in their notebooks.
3. Let the learners also test the resulting solution with a blue litmus paper and give out their observation conclusion.
4. Explain the main reaction-taking place using the chemical equation.
5. Lead them to write chemical equations of the above reactions.

The platinum coil should not touch the ammonia solution; otherwise its temperature can go down. Make the learners aware that this principle of catalytic oxidation of ammonia is used in the manufacture of nitric acid (will be discussed later in the unit).

Activity 3.19 Reaction of ammonia with copper (II) oxide

1. Learners to follow the procedure as outlined in the Learner's book.
2. Ask the learners what they have observed in the combustion tube.
3. Let them record their observations in their notebooks.
4. Point out that copper (II) oxide (black) has been converted to copper (red-brown).
5. Let the learners to test the liquid in the U-tube as instructed in the activity.
6. Let the learners test for the gas produced by the elimination method. Discuss the results.
7. Note that copper (II) oxides reacts with ammonia is to produce copper, water and nitrogen.

The unreacted ammonia dissolves in the water in the U-tube and the water in the trough. In this activity copper (II) oxide is reduced by the ammonia gas.

Reaction of ammonia with hydrogen chloride

This is additional activity, which you as teacher can organise for the learners to do if there are resources.

Learning resources

- Gas jars full of ammonia

- Wooden splints
- Trough
- Glass rod
- Concentrated hydrochloric acid

Learning activities

1. Learners them follow procedures as outlined in experiment … in the Learners book.
2. Let them observe and record their observations and conclusions they have drawn.
3. Ask learners to state how we test for physical properties of a gas.
4. Let them suggest how we test for chemical properties of a gas.

Avoid keeping an open container, which has concentrated hydrochloric acid near ammonia gas or concentrated ammonia solution.

(a) Nitric acid

Activity 3.20 Laboratory preparation of nitric (V) acid and investigating its properties

Caution: The nitrogen (IV) oxide produced is poisonous especially to people who are asthmatic. Nitric acid is also very corrosive.

1. Learners to follow the procedure as outlined in the Learner's book.
2. Let learners know why all the apparatus used for this experiment must be made of glass.
3. Let Learners observe what happens in the retort as the heating goes on. They should record their observations in their notebooks.
4. Let them state the use of tap water and what they collect in the round or flat-bottomed flask.
5. Explain all the reactions taking place, using chemical equations as outlined in the Learner's book page 138.
6. Remove the yellow colour of the prepared nitric (V) acid by bubbling air through it.
7. Nitric (V) acid is familiar mineral acid in the school laboratory. Discuss with the Learners so as to realize that the nitric (V) acid that is being discussed is the one that they have been using in the laboratory to do many experiments.

Manufacture of nitric acid by Ostwald process

Inform learners that this process is used in industrial manufacture of nitric acid.

Learning resources

A flow chart for the manufacture of ammonia

Learning activities

1. Revise the catalytic oxidation of ammonia and the raw materials needed in Ostwald process.
2. Learners to identify the source of these raw materials, such as ammonia gas.
3. Let them note the optimum conditions needed in this process.
4. Discuss why air/ammonia must be dry and pure.
5. Use the flow chart to explain the chemical reactions taking place in all the stages. Use chemical equations.
6. Emphasize on the recycling of the unreacted gases.
7. Learners identify the catalyst used in the manufacture of this acid, State the optimum temperature.
8. Learners write all the four main equations of the reactions, which take place leading to the formation of nitric acid.

Note: Let the learners know that the main reason for use of specific temperature in this process will be explained later on during the course. The environmental effect of this process will also be discussed later.

Properties of dilute nitric acid

Activity 3.21 Investigating properties of dilute nitric acid

1. Divide the learners into groups of not more than five.
2. Let the learners follow the procedure as outlined in the Learner's book.
3. Divide the activities required in this experiment among learners to make sure that they all participate.
4. Ask learners to record their observations and draw relevant conclusions.
5. Discuss/clarify the learners' observations and conclusions making any necessary clarification/corrections.
6. Explain the reactions which take place using chemical equations where appropriate.
7. Learners to write a balanced chemical equation for the reaction which takes place when dilute and cold nitric acid reacts with magnesium.
8. Explain why in most reactions of dilute nitric acid and metals, water is produced instead of hydrogen.

Properties of concentrated nitric acid

You can organise activities to demonstrate the reactions of concentrated/fuming nitric acid.

Reaction of concentrated nitric acid with iron (II) sulphate, copper or/and sulphur

1. Divide the learners into groups of not more than five.
2. Giving or brainstorm with the learners appropriate procedure to follow.
3. Let each group come with their observations and conclusions.
4. Learners should be able
    - Explain the colour changes of iron (II) sulphate solution when reacted with a few drops of dilute sulphuric acid and concentrated nitric acid. Which reactions take place when
        (a) 50% concentrated nitric acid.
        (b) Concentrated nitric (V) acid reacts with copper turnings?
    - Write the chemical equation for the reaction of sulphur and concentrated nitric acid.
        (a) How is the presence of sulphate ions (SO_4^{2-}) tested?
        (b) Write ionic equations for the reaction of sulphuric acid and lead (II) nitrate solution.
5. Discuss their results and conclusions.
6. Explain the reactions, which have taken place, as outlined in the learner's book for iron (II) sulphate, copper and also sulphur.
7. Lead the learner s to write chemical equations for the above reactions.
8. Nitric acid is an oxidizing agent. It is reduced to either nitrogen (II) oxide or nitrogen (IV) oxide.

Answers to Check your progress 3.8

Refer to learner's book page 142

1. Refer to learner's book page 129.
2. (a) Nitric acid has a lower boiling point.
   (b) Due to decomposition into oxides of nitrogen and water.
   (c) By carrying out the procedure in a dark place.

Nitrogen (IV) oxide

Activity 3.22 Laboratory preparation of nitrogen (IV) oxide

Caution: Nitrogen (IV) oxide is poisonous. This experiment should be therefore be done in a fume cupboard or in an open field.

1. Learners to follow the procedure as outlined in the Learner's book.

2. As the experiment progresses, engage the learners with the following questions:
   (a) What is the colour of the gas?
   (b) Does the gas have a smell?
   (c) Predict the density of the gas by its method of collection.
   (d) Is it soluble in water?
3. Let the learners record their observations in their notebooks.
4. They should make conclusions from their observations and record these in their notebooks.
5. Point out to the learners that the gas is red-brown, has a choking smell and is soluble in water to form an acidic solution.
6. Lead them to write chemical reactions for the reaction of copper and concentrated nitric acid.

   Note: Nitrogen (IV) oxide can be dried by passing it over concentrated sulphuric acid in a wash bottle.

Lesson assessment

Learners should be able to:

(i) Describe and name the colour of the remaining solution when concentrated nitric acid is reacted with copper?

(ii) Write the chemical equations of the reaction taking place during this preparation.

Properties of nitrogen (IV) oxide

Note: This activity is suggested by teacher demonstration only.

1. Discuss your plan and procedure with the learners for this activity.
2. Allow the learners to participate by asking them questions as you carry the demonstration.
3. Let the learners make observations and draw conclusions and record in their notebooks.
4. Point out that nitrogen (IV) oxide does not support combustion but heat decomposes it such that nitrogen (II) oxide and oxygen are formed. The oxygen formed then supports combustion. That is why burning substances like magnesium continue to burn in a gas jar of nitrogen (IV) oxide.
5. The learners should also realize that nitrogen (IV) oxide is an oxidizing agent since it releases its oxygen which then combines with other substances.

Lesson assessment

Learners should be able to:

- State physical properties of nitrogen (IV) oxide.

- Which two acids are formed when nitrogen (IV) oxide reacts with water?

Pollution effects of nitrogen compounds on the environment

1. You can divide the learners into appropriate groups size.
2. Let them brainstorm among themselves on the pollution effects on nitrogen compounds on the environment, i.e their locality if any, South Sudan and worldwide.
    - Identify some of the nitrogen compounds in the environment that can cause pollution.
    - What is formed when nitrogen (I) oxide reacts with atmospheric oxygen?
    - Describe how nitrogen compound can form acid rain.
    - Explain the effects of acid rain on the environment.
    - Identify various types of fertilisers.
    - How are these fertilisers a threat to the environment?
3. Learners suggest recommendations about the environment conservation.
4. Ask each group to appoint a chairperson to lead the brainstorming session and a secretary to record responses from the group.
5. Brainstorm with the learnerson what they already know about fertilisers.
6. Ask them about the fertilisers that they are using on their farms and then introduce the fertilisers.
7. Let the learnersdiscuss their experiences with the fertilisers they have come across.
8. Discuss the advantages and disadvantages of quick and slow acting fertilisers.
9. Give them about 15-20 minutes of brainstorming.
10. Let the secretaries from each group present their results to the class as you record them on the chalkboard.
11. Discuss with them their findings as you clarify issues, which are not clear.
12. Point out that oxide of nitrogen and nitrate fertilizers are a major cause of pollution in the environment.

Lesson assessment

The learners should be able to:

- Explain how oxides of nitrogen in the atmosphere add nitrates to our soils and water bodies.
- Explain the effects of nitrates in drinking water.
- Explain the effects of nitrogen compounds on the environment.

Answers to Check your progress 3.9

Refer to learner's book page 147

1. (i) Absorb carbon dioxide.
   (ii) Remove oxygen from the air.
   (iii) $2Cu(s) + O_2(g) \longrightarrow 2CuO(s)$.
   (iv) Nitrogen
   (v) Noble gases
2. (i) Pb^{2+} and NO_3^-
   (i) $2Pb(NO_3)_2(s) \xrightarrow{heat} 2PbO(s) + 4NO_2(g) + O_2(g)$
   (ii) Nitric (v) acid and Nitrous acid.
3. (i) Nitrogen monoxide.
   (i) Nitrogen (iv) oxide.
   (ii) $Cu(s) + 4HNO_3(l) \longrightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$
   (iii) It is quickly turns into nitrogen (ii) oxide
4. (i) Magnesium continued burning. A white solid is formed.
   (ii) When heated to decomposition, toxic fumes of nitrogen oxides are emitted. May ignite other combustible materials.
5. (a) (i) Calcium hydroxide and ammonium chloride (ii) Calcium oxide
   (b) (i) Less dense that air (ii) reacts with conc sulphuric acid
   (c) (i) 0.005moles. (ii) $3400cm^3$

3.5 Sulphur and its compounds

Refer to learner's book page 148

Learners have already come across sulphur. You can review what they have learnt about sulphur in the previous classes.

Emerging issues

Sulphur and its compounds have several effects on the environment. It is important for the teacher to emphasize these emerging issues. The learners should appreciate that they enjoy the environment and that they have a major role to play in working towards conserving it. Learner shave been part of the society for some time and they have a lot of information on this topic, especially with examples of their own environment. The teacher should give them a chance to role-play the policy makers and suggest strategies and measures that can be put in place to improve the quality

of our environment. This will make the learners feel responsible and take action. It will also change their attitudes towards taking care of our environment.

Learning activities

1. Through brainstorming, find out whether the learners know how you can obtain sulphur from its ores.
    - Ask them how the environment smells around hot springs.
    - These regions will have that smell of sulphur because considerable amounts of sulphur are found in such regions.
    - Explain the three main occurrences as listed in the learner's Books page 149.
2. Bring out the principles of Frasch process as follows:
    - Sulphur is melted underground
    - It is pumped up the surface of the earth.
    - How is this process achieved? You can construct a model of how the pipes are
3. Arrange to give a good picture when the same arrangement is discussed as illustrated in the Learner's Book.
4. Incorporate the use of the model you have constructed to demonstrate the extraction of sulphur by Frasch process.

Lesson assessment

The learners should be able to answer the following questions.

- What is the source of sulphur in the described process of extraction of sulphur by Frasch process?
- What are the functions of the inner pipe, middle pipe and the outer pipe in the Frasch process?
- Describe the extraction of sulphur by Frasch process.

Allotropes of sulphur

Refer to learners book page 150

It is best to use discovery approach in this situation. This will allow the learners to participate in observing and making deductions. They will also be able to learn from the mistakes that they make. It makes the teaching and learning of this concept very interesting

Activity 3.23 To prepare rhombic and monoclinic allotropes of sulphur

Caution: This experiment should be performed in a fume cupboard with close supervision by the teacher.

1. Divide the learners into groups of 5.
2. Follow the procedure as outlined in the activity.
3. Ask learners to observe and draw one of the crystals they have prepared.
4. They should be able to describe the shape of the crystals.
5. The following characteristics should come out clearly from the description from the learners' observations.
   - octahedral shape
   - yellow crystalline nature of the rhombic sulphur.
6. Let them observe and draw the shape of the crystals. They should also be able to describe the shape of the crystals that they have drawn

   The following characteristics should come out very clearly from the descriptions.
   - Yellow crystalline nature of the solid.
   - Long prism shape of monoclinic sulphur.
7. Thereafter discuss with learners the physical or chemical properties of sulphur as they take short notes.

Chemical properties of sulphur

Activities 3.24 and 3.25

1. Follow the procedure as outlined in the Learner's Book.
   - This experiment can be used to remind them what they did when they were learning about properties of oxygen.
   - Let them explain what happened when the burning sulphur was lowered into a gas jar full of oxygen. They should be able to remember that the blue flame was brighter and there was production of sulphur(IV) oxide.
2. Explain to them that it also directly combines with other non-metals like hydrogen to form sulphides e.g. hydrogen sulphide.

Sulphur (iv) oxide

Activity 3.26 Laboratory preparation of Sulphur (iv) oxide

1. You can introduce sulphur (IV) oxide by referring to the products of burning sulphur in air or in oxygen.

2. Let them know that there are other methods of obtaining sulphur (IV) oxide apart from reacting sulphur directly with oxygen and this can be done in the laboratory.
3. Introduce them to the preparation of sulphur (IV) oxide in the laboratory.

   Note: In the Learner's Book, there are two methods of preparing sulphur (IV) oxide. You are supposed to choose any of the methods and explain theoretically how you can achieve the same using the other method.

   The two methods given are outlined in procedure A and B respectively

   A– preparation of sulphur(IV) oxide from concentrated sulphuric acid and copper turnings.

   B– preparation of sulphur(IV) oxide from dilute hydrochloric acid and sodium sulphite.

   Whichever method you would like to use, follow the procedure as outlined

   Note: Remember that the gas produced is poisonous and the experiment should be done in a fume chamber or an open space.

4. Discuss with the learners the reactions that occur during preparation of sulphur (IV) oxide when the two methods are used. Mention the reagents that are used, the observations made during the process of the reaction and the products formed. Write balanced equations for the reactions as shown in the Learner's Book.
5. Engage the learners with the following questions as you prepare the gas.
   - What is the colour of the gas?
   - Does it smell?
   - Predict the density of the gas through the method of collection.
   - Let the learners record these observations and conclusions in their notebooks.
   - After the preparation, let the learners compare their results with the physical properties listed in the Learner's Book.

Sulphur (VI) oxide

Activity 3.27 Laboratory preparation of sulphur (vi) oxide and investigating its properties

1. Explain to the learner show sulphur (VI) oxide can be prepared by following the procedures as outlined in the in the Learner's Book.
2. There are also other methods that can be used to prepare sulphur (VI) oxide. Discuss with the learners these methods as outlined on page 168 in their book.
3. Although you may not be able to prepare the gas in the laboratory, it will be important to describe the properties of sulphur (VI) oxide. Sulphur(VI) oxide is a very unstable gas.

- We have described the colour of the gas.
- The chemical properties of the gas are few because the gas reacts with water to give sulphuric acid immediately.
- The gas can also react directly with basic oxides. You can give examples of other basic oxides.
- The major use of sulphur(VI) oxide is in the manufacture of sulphuric acid.

4. Let the learners discuss and research to find out whether there are other uses of sulphur(VI) oxide

Additional information to the teacher

In the preparation of sulphur(VI) oxide in the laboratory, there are points that should come out very clearly.

- Sulphur (VI) oxide formed is very reactive with water and that the experiment can be very dangerous if not handled with care because when the crystals are added to water, a reaction occurs which is extremely vigorous and with a loud hissing sound. A corrosive vapour of sulphuric acid is given off.
- The inverted funnel prevents sucking back and also provides a large surface area for the reaction.
- The reaction is exothermic and produces an acid spray.

Sulphuric acid

Since the learner shave already learnt the preparation of sulphuric acid in the laboratory, it is easy to use what they have learned as an entry point to the introduction of industrial manufacture of sulphuric acid.

1. The concept being used is the same and that is conversion of sulphur (IV) oxide to sulphur (VI) oxide then dissolve in water. This is achieved industrially through the contact process.
2. Let the learners realise that the contact process has three main stages.
   - Production of sulphur (IV) oxide from sulphur directly. Much of the sulphur is obtained by extraction from crude oil. This has the added advantage that if the sulphur is removed from oil, there is less chance of sulphur(IV) oxide air pollution when the oil is burned.
   - Conversion of sulphur (IV) oxide to sulphur (VI) oxide. This is achieved by mixing the sulphur(IV) oxide with air and passing over a catalyst called vanadium(V) oxide at 450°C. To be able to achieve the above process there are other small processes like the cleaning and drying process which ensures that the catalyst is not poisoned for its effectivity.

- This is the stage that is called the contact process because when the gases come into contact with the catalyst, the reaction between them speeds up. In industry, catalysts are used to speed up reactions and allow them to happen at a lower temperature. This saves energy and makes the production cheaper.
- Sulphur (IV) oxide is dissolved in concentrated sulphuric acid to form oleum. The mixture is then carefully diluted by addition of water to the required strength of acid.

This process is more simplified in the Learner's Book with illustration fig 3.28.

3. The sub-unit can be summarised by asking the learners to list down the optimum conditions for the contact process. They can compare their answers with what is given in their book.
4. Thereafter discuss with learner the properties of dilute and conc. sulphuric acid activity 3.28 and 3.29 as outlined in the learners book.

Test for sulphates and sulphites

1. Divide the learners into groups of at most five.
2. Let them follow the procedure as outlined in Activity 3.30 in the Learner's Book.
3. The learners should copy the table in their notebooks and record their observations and conclusions.
4. Let the learners realise that sulphates may be detected with barium salt solution. If a solution of sulphate is added to a solution of barium chloride, the sulphate ions reacts with the barium ions to form an insoluble white precipitate of barium sulphate.

Sodium sulphate + barium chloride $\longrightarrow$ barium sulphate + sodium chloride

$Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4(s) + 2NaCl(aq)$

Ionically : $SO^{2-}_4(aq) + Ba^{2+}(aq) \longrightarrow BaSO_4(s)$

Note: It is important for the learners to know that, unfortunately, sulphites have the same reactions as the sulphates. They form insoluble precipitates of barium sulphites with barium ions.

Sodium sulphite + barium chloride $\longrightarrow$ barium sulphite + sodium chloride

$Na_2SO_3(aq) + BaCl_2(aq) \longrightarrow BaSO_3(s) + 2NaCl(aq)$

Ionically: $SO_3^{2-}(aq) + Ba^{2+}(aq) \longrightarrow BaSO_3(s)$.

Pollution of the environment by compounds of sulphur

Air and water pollution by compounds of sulphur are major causes of death around the world. Before any action is taken to reduce pollutants in the environment, it is important to know what type of pollution it is and its cause.

1. Divide the learners into groups of six.
2. Raise the issue of pollution of the atmosphere by sulphur compounds by referring to some of the properties of these compounds that make them pollutants.
3. Let the groups explore the emerging issue of pollution by sulphur compounds. This includes problems that are already there and those that may occur.
4. Each group can then begin to conduct research on:
   - What scientists have come up with to arrest the situation.
   - Various conventions and agreements which have been made.
   - Each group should assess the different options available and let them discuss what should be done to arrest the situation.
   - Give each group about 30 minutes to brainstorm and then make a report on proposed action.
5. This method of teaching emerging issues especially environmental issues does the following:
   - Fosters clear awareness and concern.
   - Provide every learner with opportunities to acquire values, attitudes, commitment and skills needed to protect and improve the environment.
   - Develop and reinforce new patterns of behaviour among learners in protecting the environment against pollution.

Lesson assessment

The learners should be able to answer the following questions.

1. Explain the effects of sulphur on the environment.
2. What remedies can be put in place to protect the environment from pollution from compounds of sulphur?

Answers to Check your progress 3.10

Refer to learners book page 186

1. (a) Yellow **sulfur powder** turns into black viscous mass.
   (b) $S(s) + O_2(g) \longrightarrow SO_2(g)$
   (c) $SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$ Sulphurous acid
   (d) Turns red
   (e) $H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$
2. Sulphur (IV) oxide is used in the preparation of sulfuric acid, sulfur trioxide, and sulfites, as a disinfectant, a refrigerant, a bleach, and a food preservative, especially in dried fruits.

The major use of sulfuric acid is in the production of fertilizers, e.g., superphosphate of lime and ammonium sulfate. It is widely used in the manufacture of chemicals, e.g., in making hydrochloric acid, nitric acid, sulfate salts, synthetic detergents, dyes and pigments, explosives, and drugs.

3. Check for compelling arguments.
4. Refer to learners book page 161.
5. It is also used or is a by-product in many industrial processes such as: Petroleum production and refining.
6. (a) Refer to learner's book page 163

   (b) $Cu(s) + 2H_2SO_4 \longrightarrow CuSO_4(aq) + SO_2(g) + 2H_2O(l)$

   (c) Sulfur dioxide gas turns acidified potassium dichromate (**VI**) solution from orange to green.

   (d) (i) The solution changed from brown/yellow to light/pale green.

   (ii) $2FeCl_3(aq) + H_2S(g) \longrightarrow 2FeCl_2(aq) + 2HCl(aq) + S(s)$

   (e) Oxidising agent –Hydrogen sulphide.

3.6 Chlorine and its compounds

Refer to learner's book page 187

To introduce chlorine avail a Periodic Table.

1. Brainstorm with the learners to find out how much they can remember about chlorine.
2. Invite a student to locate the position of chlorine in the Periodic Table.
3. Let the student lead a brainstorming session to explain the period and group of chlorine.
4. Guide the learners to other questions to find out how much they can recall about chlorine.
5. Let another student record all the points suggested on the chalkboard.

Laboratory preparation of chlorine

Refer to learner's book page 187

Activity 3.31

Note: You may choose the appropriate method depending on the resources available. However, it is important to discuss the other methods.

1. Follow the procedure as outlined in activity 3.31 in the Student's Book.
2. Ask the learners to state the role of water (first wash bottle) and concentrated sulphuric acid (second wash bottle).

3. Let them make and record observations in the flask and gas jar in their notebooks.
4. Let them make conclusions and record in their notebooks.
5. The following suggested questions would clarify some of the concepts in preparation of chlorine gas.
6. Let them suggest the role of manganese (IV) oxide.
7. Let them suggest another substance which can be used in place of manganese(IV) oxide.
8. Emphasize that when potassium manganate (vii) is used, heating is not required. The reaction takes place in the cold. It is also a catalyst like manganese (IV) oxide.
9. The following points should come out clearly during the discussion:
    - the characteristic smell
    - the colour
    - density
    - solubility
10. Let the learners compare their results with the physical properties listed in the Student's Book.
11. Emphasize that the water in the first wash bottle removes fumes of hydrogen chloride gas, while the concentrated sulphuric acid dries chlorine.

Lesson assessment

The learners should be able to answer the following questions:

- List five physical properties of chlorine.
- How is chlorine dried?
- Write the chemical equations of the reactions taking place during the three methods used in the preparation of chlorine in the Student's Book.

Properties of chlorine

Caution: Chlorine is very poisonous and therefore most of its properties should be demonstrated in a fume cupboard or an open place.

1. Follow the procedure as outlined in Activity 3.32 in the Student's Book.
2. Let the learners explain why hydrogen is allowed to pass through the tube for 2 or 3 minutes before lighting it.
3. Let the learners observe and record what happens when burning hydrogen is lowered into chlorine.

4. Let the learners test the resulting gas. They should be able to make and record conclusions from their observations.
5. The learners should point out that hydrogen reacts with chlorine to form hydrogen chloride gas, which forms white fumes of ammonium chloride with ammonia gas.
6. Carry out the various activities outlined in the learner's book to investigate the various properties of chlorine and their reactions with substances.

Hydrogen Chloride

1. Follow the procedure as outlined in 3.33 in the Student's Book.
2. As the experiment progresses, engage the learners in a dialogue by asking them why lead (II), barium and calcium salts should not be used in the preparation of hydrogen chloride.
3. Let the learners observe what happens in the flask and gas jar.
4. Ask the learners to make conclusions from the above observations and record in their notebooks.
5. Explain to the learners the reaction, using chemical equations.
6. Let them record correct colour, smell, density and solubility of the gas. These observations should result from direct observation and prediction through the method of collection.
7. Let the learners compare their results with the physical properties listed in the Student's Book.
8. Lead the learners to discuss their observations and conclusions.
9. Point out that hydrogen chloride gas is acidic and reacts with ammonia chloride forming white fumes.
10. Lead them to write chemical equations for the reaction.
11. Point out to the learners that hydrochloric acid is prepared industrially by direct combination of hydrogen and chlorine. The resulting gas is then dissolved in water over glass beads to form hydrochloric acid.

Lesson assessment

The learners should be able to answer the following questions.

1. Which are the two chemicals used in the laboratory preparation of hydrogen chloride gas?
2. How is hydrogen chloride formed in (1) tested?
3. How is hydrogen chloride dried and collected?

Pollution of the environment by chlorine and its compounds

1. Let the student brainstorm on the pollution effects of chlorine and its compounds on the environment.

2. Appoint a student to lead the brainstorming session and record the points on the chalkboard.
3. The following questions can assist the student in leading the discussions:
    - Discuss and explain how chlorine pollutes the environment.
    - Explain the role of the ozone layer in controlling the amount of ultra-violet (uv) rays reaching he earth's surface from the sun.
    - Explain how CFCs deplete the ozone layer, the effect and measures being taken to prevent this depletion.
    - Explain the effects of wide use of DDT.
    - Discuss the alternative of DDT and its effects on a country's environment and economy.
4. Let them discuss the measures they would take to control environmental pollution.

Answers to Check your progress 3.11

Refer to learners book page 209

1. (a) $Cl_2(g) + 2NaOH(aq) \longrightarrow NaClO_3(aq) + NaCl(aq) + H_2O(l)$
   (b) Sodium hypochlorite is unstable.
2. (a) X- Hydrogen chloride gas, Y- Hydrochloric acid, Q-Chlorine.
   (b) Conc. sulphuric acid.
   (c) (i) Upward delivery (ii) downward delivery.
   (d) The temperature used.
3. (a) A white precipitate will be formed.
   Hydrogen chloride gas reacts with silver nitrate to form Silver Chloride, which is insoluble.
   (b) $AgNO_3(aq) + HCl(g) \longrightarrow AgCl_2(s) + HNO_3(aq)$
   (c) Check for correct ionic equation.
   (d) Using the test for carbonates.
4. (a) The HCl molecules stay together there are no H^+ ions to make the solution acidic so it is neutral.
   (b) (i) Carbon dioxide (ii) Chlorine gas
   (c) Carbon dioxide turns limewater milky, Chlorine gas, Cl_2 (g) is green-yellow in colour. Chlorine gas has a pungent choking smell. Chlorine gas turns moist

litmus paper from blue to red. Chlorine is the only gas that has a bleaching effect on paper.

(d) Hydrogen and chlorine gas.

(e) $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$

(f) Increase surface area for the reaction to take place.

(g) Formation of insoluble layer that will prevent further reactions.

UNIT 4 Transition Elements

Refer to learner's book page 211

Learn about	Key inquiry questions
Learners should know and understand the properties of transition metals and carry out practical investigations to identify the characteristics of transition metals. They should know the uses of some transition metals.	▪ How do we identify transition metals elements? ▪ How properties of transition metals differ from properties of other elements?

Learning outcomes		
Knowledge and understanding	**Skills**	**Attitudes**
▪ Explain the properties of transitional metals. ▪ Know the uses of some transition metals.	▪ Carry out practical investigations to identify the characteristics of transition metals.	▪ Appreciate the importance of transition metals.

Contribution to the competencies:

Critical and creative thinking: experimentation.

Communication: presentation of group work.

Co-operation: teamwork.

Links to other subjects:

Art: colour of pigments.

Introduction to this unit

Learners have largely learnt about the periodic table and some aspects the elements it contained e.g. their electronic configurations and its use to predict the position and periods of elements. Now they are delving into further studies of some groups and period of the periodic table (e.g. trends in physical properties and chemical properties). As a teacher, in your teaching of this unit, it is important that you draw clear parallel between properties of groups/periods of periodic table and any developing trend

observable. Stimulate learners' thinking why the study of period 3 elements specifically of all the periods. Encourage learners' analytical thinking abilities in prediction of properties of elements in the groups and how to design investigation for some of the properties of these elements

Cross cutting issues to be in cooperated

1. **Environment awareness and sustainability**

   Though there are many benefits of transition metals and their compounds, it must be made clear the environment impacts of the compounds of some of these elements.

2. **Peace and values**

   Stress to the learners on the need to respect the sanctity of human life and such evil thoughts must never be encouraged. Always, at personal level and in groups strive to promote living at peace with each other, loving one another for our good and everyone else as well as the prosperity of the South Sudan. Learners must avoid any fracas or commotion in the laboratory at all times.

3. **Life skills**

   Learners can be encouraged to be financially responsible, to appreciate expenses incurred in purchases of reagents (chemicals) and even costs of apparatus used which cannot be improvised. They should handle apparatus very careful for avoid unnecessary breakages and where there is occurrence report immediately to the teacher or laboratory technician.

Competencies to be developed

1. **Co-operation**

   Encourage each group to distribute tasks and each responsibilities to carry out experiments/investigation or any group tasks. Instil the culture of corporation in group activities to help them appreciate the value of doing so e.g. makes work easier for everyone, improves each other contribution to the overall results, promotes team work and overall success for the group and appreciation of one another.

2. **Communication**

   Ensure the learners are organized in groups during research work, practical investigations. It may be useful to foster group presentations in class to improve learners' listening skills, report writing skills, presentation skills. Questions should be asked during and at the end of group presentations.

3. **Critical and creative thinking**

   Learners are to be encouraged to be imaginative and explain occurrence in differences among elements in groups and across the periods. Promote learners'

abilities to understand and give explanations for the trends in physical properties and exceptions across the period and in the group. Prompt learners to be able to predict as well design investigation for physical and chemical properties of period 3 elements, and group 2 and 7 elements of the periodic 3 elements.

Preparation for the Unit

- Learners must be organized into suitable group sizes according the class number and resources available.
- Arrange for the availability of required apparatus for class activities. Collect necessary charts, videos, photographs of the transition metals and actual samples of easily available metals.

Introduction to transition metals

Refer to Learner's book page 211

Suggested teaching and learning activities

- Put learners in pairs or groups of four as is suitable. Provide them with a periodic table chart or refer them to examine the one shown in the learner's book page 211.
- In their groups, let them identify all the transition elements from the periodic table and proceed to do group task 4.1 in the learner's book page 211.
- Point out that transition metals consist of the largest group of elements.

Ask them questions such as:

(i) Which of the transition metals are they familiar with? **Ans**: *Copper, silver, gold, zinc and iron*.

(ii) Write electronic configuration of the mentioned transition elements.

(iii) Why are these elements so called transition elements/metals? For example every name assigned to category of elements in the period table has significance e.g. group 1 had one valence, period 3 has three energy levels.

- Brainstorm with learners some of the everyday materials that are made of using some of the transition metals they have identified.
- As you conclude the discussion on introduction of transition elements, let the learners carry out research work given in the learner's book page 212. This will prepare them for the learning content ahead as well as fully knowing what transition elements are all about.
- Let learners take down notes as you guide them. They should now begin appreciating the emerging differences between transition metals and the main

group elements, for example, consists of different/many sub groups, they have no main group naming, variable oxidation states.

Physical properties of transition elements in the Fourth period

Refer to Learner's book page 213

Suggested teaching and learning activities

- Refer learners to the research work done prior by allowing them to discuss the physical properties of transition elements.
- Let each group if possible identify and explain the trend of the various physical properties particular of the transition elements in period 4 as representative.
- Ensure learners understand the trends and are able to analyse them.
- Preferably you should concentrate on the following physical properties.
  - (i) Atomic size
  - (ii) Ionization energy
  - (iii) Melting point
  - (iv) Boiling point
  - (v) Thermal conductivity
  - (vi) Electrical conductivity
  - (vii) Density
  - (viii) Oxidation state
  - (ix) Appearance
  - (x) Hardness
  - (xi) Colour
  - (xii) Formation of complex ion.

1. Guide the discussion on physical properties and the trend, involving the learners by asking lot of questions since some of these properties the learners are much aware.
   - (i) Try to bring out the differences between the properties of transition metals and those of main groups elements (alkali metals and alkaline earth metals).
   - (ii) Jog their memory by defining terms such as oxidation state, hardness/brittle, and ionization energy.
2. Let learners make summary notes on what they have learnt during the lesson.

Answers to check your progress 4.1

Refer to learner's book page 216

1. The first transition row elements have quite a high boiling points except for zinc. This is because the elements have a large number of valence electrons and a large number of unfilled orbitals in the valence sub energy levels. Zinc has all its orbitals filled up causing it to have a low boiling point.
2. All transition metals are metals while main group elements are both metals and non-metals across the period.

   Many transition metals are paramagnetic and coloured while main group elements are ionic compounds, colourless and diamagnetic (non-magnetic).
3. Successive filling up of the third sub energy level electrons shields electrons in fourth sub energy level from the much nucleus pull. This makes the difference in metallic radius from one metal to appear relatively small.
4. This is due to the presence of unpaired d-electrons in transition elements which give rise to metallic bonds. Presence of strong metallic bonds in transition metals make them have a high melting and high boiling points.

Answers to check your progress 4.2

Refer to learner's book page 217

1. This is because transition metals have several electrons with similar energies. When one or all the electrons are removed, it results to different oxidation states.
2. (i) Copper – +1 and +2
   (ii) Manganese – +2, +3, +4, +6, and +7
   (iii) Iron – +2 and +3
3. Check at learner's response.

Answers to check your progress 4.3

Refer to learner's book page 220

1. Transition metals are relatively small sized atoms and have strong interatomic bonding which makes them hard as compared to alkali metals.
2. Transition metals have high electrical conductivity due to the delocalization of the sub energy levels electrons compared to alkali and alkaline earth metals.
3. This is because both Scandium and Zinc have only one oxidation state and a complete d-subshell.
4. They can easily lend and take electrons from other molecules.

Answers to check your progress 4.4

Refer to learner's book page 222

1. The energy absorbed by transition atom move electrons from a lower sub energy level to a higher sub energy level within an energy level. This energy correspond to the frequency which generally lies in the visible region of light. Thus colour observed corresponds to the complementary colour of the light absorbed.
2. Refer to learner's book page 220.

Chemical properties of transition elements

Refer to learner's book page 224

Suggested teaching and learning activities

- Using the research report done by the learners, guide discussion on the chemical properties of transition metals.
- Let the learners differentiate between physical properties and chemical properties of transition metals. Such as catalytic properties and colour formation.

Activity 4.2 and 4.3

Work in groups

- Organise the learners in suitable group size and suggest some chemical properties they would like to investigate; let them design, plan and carry out investigation of property of their choice. Some of possible investigations include:
  (i) Reactions of dilute acids/water/air with some transition metals.
  (ii) Combustion of the transition metals.
  (iii) Formation of hydrated and anhydrous compounds i.e. effect of water of crystallization.
  (iv) Formation of oxide/hydroxides/salts of the some of the transition metals.
- Give the learners useful tips/hints on how to carry out some of these activities/ investigations e.g. safety awareness, quantities of reagents.
- During the activities, let learners compare the reactivity of transition metals with dilute acids and with those of group II. Can they predict the reaction group I elements with dilute acids? Ask them why it is not advisable to perform reaction of group I elements with dilute acids in school laboratories (i.e. it is extremely dangerous/explosive. NEVER attempt it).
- Conclude the lesson by going through the summary of chemical properties provided in the learner's book page 224-227. You can also take them through various uses of transition metals as shown in learner's book page 227.

Class Debate

You can prompt the class to debate whether zinc and scandium should be classified as transition metals or not. This is a debate ongoing among scientists.

Formation of complexes and Uses of transition metals

- Explain to learners what complexes compounds are. Give familiar examples such as oxyhaemoglobin and carboxyhaemoglobin which they know but probably are not aware as examples of complex compounds.
- Using examples provided in the learner's book and others state the uses of complexes e.g. in softening of hard water and extraction of some metals.

Learning assessment

In this unit the following assessment methods can be helpful.

- **Observation** – This is most applicable during experiments/activities, learners making correct observations i.e. correct colour and products formed.
- **Group presentation** – You may consider learners doing research from journals, textbooks and internet, compiling a report and making presentations to the whole class. This offers a good opportunity to unearth areas not well understood for further redress. This as well will help them to improve their communication skills e.g. listening skills, articulation skills and even writing skills.
- **Evaluative/formative assessment** – Let the learners do questions provided in the learner's book at the end sub topic or under the discussion corner. These will bring to fore the content areas which might not have been well understood for further remedial studies.

Additional Information to the teacher

Differences between transitional metals and main group metals

1. Transition metals are electronegative than the main group metals (which are highly electropositive).
2. The formulas of the compounds of main group metals form compounds with enough negative ions to balance the charge on the positive ions e.g. NaCl, Mg_3N_2; while transition metals form compounds that are more likely to form complexes having excess number of negative ions, i.e. $FeCl_4^-$, HgI_4^{2-}
3. The ease with which transition metal s ions form stable compounds with neutral molecules such as water or ammonia. For example,

   $Cr\ Cl_3(s) + 6NH_3\ (l) \longrightarrow CrCl_3.6NH_3(s)$

Unit 5: Acids, Bases, Amphoteric oxides and Hydroxides and Solubility of Salts

Refer to learner's book page 228

Learn about	Key inquiry questions
Learners should build on what they already know and secure understanding of chemical properties of acids, bases and salts. They should design practical investigation to identify the properties of amphoteric oxides and hydroxides with acids and bases, the causes of hardness of water and methods of removing it, and explain the causes, advantages and disadvantages. Learners should understand solubility, saturated solution, investigate solubility of some salts and interpret and suggest application of solubility curves.	• How do properties of acids, bases, salts and amphoteric oxides vary? • How can you identify similarity between bases and amphoteric oxides and hydroxides? • How might you investigate the properties of amphoteric oxides and hydroxide? • Why does some water consume more soaps than other? • How can you remove hardness of water?

Learning outcomes

Knowledge and understanding	Skills	Attitudes
• Further explain the properties of acids, bases and salts. • Understand the properties of amphoteric oxides and hydroxides. • Explain the hardness of water and solubility of salts in water.	• Design practical investigation to identify the properties of amphoteric oxides and hydroxides. • Design practical investigation to identify the causes of hardness of water and methods of removing it. • Investigate solubility of some salts and interpret and suggest application of solubility curves.	• Appreciate the importance of the solubility of salts.

Contribution to the competencies:

Critical and creative thinking: investigation and experimentation.

Communication: group discussions and presentation of group findings.

Co-operation: group working.

Links to other subjects:

Agriculture, Biology: solubility of salts.

Introduction to this unit

Learners already have a lot of knowledge and understanding about acids, bases and salts. They know about properties of acids and bases, strong and weak acids/bases and their properties. In this unit, learners will be provided with further information/ study on acids, bases and salts e.g. the other definitions of acids and bases but more specifically deeper learning of amphoteric oxides and hydroxides. Learners have interacted with some of these amphoteric compounds without consciously being aware.

Cross cutting issues to be in cooperated

1. **Environment awareness and sustainability**

   Proper disposal of used amphoteric compounds or salts is important to avoid air, water, and soil pollution.

2. **Peace and values**

   Stress to learners on the need to respect the sanctity of human life and such evil thoughts must never be encouraged. Always, at personal level and in groups strive to promote living at peace with each other, loving one another for our good and everyone else as well as the prosperity of the South Sudan. Learners must avoid any fracas or commotion in the laboratory at all times.

3. **Life skills**

   Learners can be encouraged to be financially responsible, to appreciate expenses incurred in purchases of reagents (chemicals) and even costs of apparatus used which cannot be improvised. They should handle apparatus very careful to avoid unnecessary breakages and where there is occurrence report immediately to the teacher or laboratory technician.

Competencies to be developed

1. **Co-operation**

   Discuss how this is to be achieved during group working such as every group member is assigned task to carry out. The need to respect and appreciate others, their opinions and improve one another's ideas must be fostered

2. **Communication**

   Ensure the learners are organised in groups during research work, practical investigations. It may be useful to foster group presentations in class to improve

learners' listening skills, report writing skills, presentation skills. Questions should be asked during and at the end of group presentations.

3. Critical and creative thinking

This will be achieved during investigation/activities as learners are required to design, plan and carry out some investigations on their own. They will calculate, tabulate their findings, record and plot graphs. They will also be required to account for their results from the graph plotted.

Preparation for the lessons

Collect all the apparatus needed, videos/video links if available, charts and reference materials for each of the lessons. Draw learners' attention to the different definitions for acids and the importance of each definition. In fact some definitions are improving on the other.

Definitions of acids and bases

Learner's book page 228

Suggested teaching and learning activities

1. Learners have substantial information/learning experience about acids and base. Review with the students what they have learnt earlier on acids. Students can try responding to the following questions.
   (a) What happens when the acid reacts with a soluble base?
   (b) What are the products of the reaction between an acid and base?
3. Let learners attempt to define an acid in their own understanding, then using the definitions provided in the learner's book, explain that an **acid** *is a substance which dissociates in water to give hydrogen ions as the only positive ions.* Inform the students that the properties of acids they have learnt about are due to the reactions of these hydrogen ions.
4. Review with the learners what they learnt earlier about bases. They should respond to the following questions.
   (a) What are the characteristics of common soluble bases (alkalis)?
   (b) What is the difference between an acids and a bases?
   (c) Do they think there is difference between basic oxide and basic hydroxide?
5. Let the learner's attempt to explain the meaning of base according to Arrhenius and Bronsted Lowry definitions. Improving on their definitions, define bases as substances which dissociate in water to give hydroxide ions as the only negatively charged ions. Inform them that these hydroxide ions are responsible for the properties of bases they described.

6. Using a few examples of common bases, explain how bases dissociate in water to form hydroxide ions.
7. Stress the fact that all bases have hydroxide radical which dissociates in water to form hydroxide ion.
8. Ask the learners what are the products of the reaction between a base and an acid?
9. Summarise the lesson by engaging the learners to define the acids and bases using:
   (a) Arrhenius definition.
   (b) Bronsted Lowry definition.
   - Allow the learners to do research work suggested on page 231of the Learner's book on Lewis definition of acids and bases and its relevance/ contributions in the body of Chemistry.
   - You can as well organise learners to debate on the merits and shortcomings of the different definitions of acids and bases. Let them try to establish any similarities and differences between these definitions; in their judgment suggest which is the most suitable definition at this stage of learning. Stretch their minds to try to explain why there is no one universal definition for acids/bases adopted.

Additional information to the teacher

You can teach about the electrical conductivity of acids and bases. Let the learners notice the effect of strength of acids and bases on their electrical conductivity. Allow them to attempt an explanation for these observations. Provide them with the following materials and let them carry out the activity in groups of five under your close supervision.

Apparatus and chemicals

(i) 250 cm^3 beaker
(ii) Two 1.5 V cells
(iii) 2.5 V bulb
(iv) Carbon rods
(v) connecting wire
(vi) switch
(vii) 2M hydrochloric acid
(viii) 2M ethanoic acid
(ix) 2M sodium hydroxide
(x) 2M ammonia solution

Let them first classify the given solutions as either strong or weak acids and bases and make conclusions. Explain to them that electrical conductivity differ in aqueous solutions.

Inform them that it is higher in strong acids and bases but lower in weak acids and bases.

Development of skills

By the end of this sub-topic, the following skills should have been developed by the students.

- Construction as the student prepare the electrical circuit.
- Observation, as the students observe light intensity changes in bulbs and reactions around electrodes.

Additional information for the teacher

Strong electrolytes are completely ionised in aqueous solutions and allow large electric currents to pass through them. Weak electrolytes are slightly ionised in aqueous solutions and therefore allow small electric currents to pass through them.

Skills to be tested

- Recordings, results of their experiment in their notebook.
- Drawing conclusions, from their experimental results.
- Problem solving as the students relate the degree of electrical conductivity to pH values of solutions.
- Manipulation, as students manipulate the apparatus during the experiment.

Conclude the lesson by letting learners know that strong electrolytes are completely ionised in aqueous solutions and allow large electric currents to pass through them. Weak electrolytes are slightly ionised in aqueous solutions and therefore allow small electric currents to pass through them.

Answers to check your progress 5.1

Refer to learner's book page 231

1. Basicity of acid refers to the number of hydrogen ions which can be produced by one molecule of the **acid**.
2. This is because all the definitions explains many properties and reactions of acids and bases.

Amphoteric oxides and hydroxides

Refer to Learner's book page 231

- Because most learners may not be familiar with the term amphoteric, clearly explain what amphoteric oxides and hydroxides are. Link this terminology with amphibians, animals that have ability to live well both in water and on land.
- In the same way the amphoteric oxides and hydroxides have capability to react with both acids and bases to form salts; unlike their acidic oxide or basic oxide counterparts that can only react with either one (i.e. acidic oxide can only react with base, while basic oxide can only react with acidic oxide.)
- Discuss the other types of oxides: acidic oxides and basic oxides as presented in the learner's book page 231 and guide learners in carrying out activity 5.1.
- Let the learners be in pairs or suitable group size according to your class size and resources availability conduct the research and discussion, and activity proposed in the learner's book page 231.
- Review what the learners know about metal oxides and hydroxides. As they already learnt earlier about them reacting with acids to form salt and water only.
- Organise learners in groups of four or five to perform activity 5.2 which will help learners to demonstrate the properties of amphoteric oxides and hydroxides. They are required to develop fair test results i.e. control experiment must be included.You can invite their opinion on how this is to be done i.e. (basic oxide and acidic oxide must be included in the investigation plan). Let them brainstorm the design, plan and conduct (procedure of) the experiment; provide your assistance where it is most needful.
- Guide the learners in discussing the results, drawing appropriate conclusions and explaining the reactions that took place. Show them how to write the chemical equations of the reactions. At this stage learners can be reminded about the formation of complex ions they studied briefly under unit 4 (transition metals).
- From the results, discussions and conclusions from activity/experiment, learners should notice or have made the following inferences very clearly:
  - (i) Acidic oxides only react with soluble bases to form salt and water.
  - (ii) Soluble basic oxides only react with acids to salt and water.
  - (iii) Amphoteric oxides and hydroxides react with both strong acids and bases to form salt and water.
  - (iv) Certain metal oxides and hydroxides are able to react with both acids and bases i.e. zinc, aluminum, lead and iron.

- Summarise the findings and discussion as the learners take down notes as outlined in the Learner's book page 233. As well establish if the learners have acquired the following skills and understanding;
  (i) Write the formulae of the complex ions formed by amphoteric oxides/ hydroxides.
  (ii) Problem solving-being able to identify complex ions produced when specified cations react with given alkalis.

Answers to check your progress 5.2

Refer to Learner's book page 239

1. Zinc (II) oxide, lead (II) oxide, aluminum oxide, zinc hydroxide, lead (II) hydroxide, and aluminum hydroxide.
2. (i) $PbO\ (s) + 2KOH\ (aq) + H_2O\ (l) \longrightarrow K_2[Pb(OH)_4]\ (aq)$

   $ZnO\ (s) + 2KOH\ (aq) + 2H_2O\ (l) \longrightarrow K_2[Zn(OH)_4]\ (aq)$

   $Al_2O_3\ (s) + 2KOH\ (aq) + 3H_2O\ (l) \longrightarrow 2KAl(OH)_4\ (aq)$

   $Zn(OH)_{2\ (aq)} + 2KOH\ (aq) \longrightarrow K_2[Zn(OH)_4]\ (aq)$

   (ii) $PbO\ (s) + H_2SO_4\ (aq) \longrightarrow PbSO_4\ (s) + H_2O\ (l)$

   $ZnO\ (s) + H_2SO_4\ (aq) \longrightarrow ZnSO_{4\ (aq)} + H_2O\ (l)$

   $Al_2O_3\ (s) + 3H_2SO_4\ (aq) \longrightarrow Al_2(SO_4)_3\ (aq) + 3H_2O\ (l)$

   $Zn(OH)_2\ (aq) + H_2SO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + 2H_2O\ (l)$
3. Put a blue litmus paper into the solutions being tested. If it turns red then the solution is an acidic oxide. Repeat the same experiment with red litmus paper. If it turns blue then the solution is a basic oxide. Amphoteric oxides react with both acid and base to form salt and water.

Solubility of salts in water

Refer to Learner's book page 235

Suggested teaching and learning activities

- Learners are expected to know and understand solubility and calculate solubility of some salts. They are as well to appreciate this knowledge in day to day life situations such as separation of salts of different solubility.
- Introduce the lesson by reviewing with the learners what they learnt earlier on solutes, solvents and saturations.
- Explain the term saturation and its relationship with temperature.
- Invite the learners to attempt to state their understanding of what solubility is,

then improving on their responses, clearly define it.

- Guide the learners in conducting **Activity 5.3** in the learner's book page 235. Learners are expected to design, plan and execute the activity on their own. Move round the class and provide help where necessary.
- Summarize the lesson by allowing learner's to account for the differences observed in the experiment and suggest how the dissolved salt can be recovered from the solution.

Activity 5.4: To investigate the solubility of lead (II) nitrate in water

Refer to Learner's book page 237

Suggested teaching and learning activities

- Review with the learner their knowledge on solubility of different salts.
- Emphasize that fact that solubility of a salt varies with the temperature.
- Divide the learners in groups of four and provide them with the materials required for the activity and allow them to do activity 5.4 in the Learner book.
- Move round the class and observe how each group do the activity.Allow learners to make mistakes and correct where need be.
- Provide some learners with a piece of chalk to demonstrate how mass of a solvent, solute and temperature can be determined from the experiment performed in the activity on the board and assist them where need be.
- Summarise the lesson by taking learners through the facts in learner's book page 237-238.

5.5 Solubility curves

Activity 5.5 To investigate the solubility of potassium chlorate and potassium nitrate

- Introduce the activity by reminding learners about different types of curves they have come across when plotting graphs.
- Divide learners in groups of five and provide them with the materials required for the activity.
- Let them do **Activity 5.5** in the Learner's book.
- **Caution:** potassium chlorate and potassium nitrate are strong oxidizing agents hence corrosive. A lot of care is needed when dealing with these salts.
- Allow them to tabulate their results in the table provided on page 240 of the learner's book.

- Let them draw the graph of solubility against temperature and extrapolate to produce solubility curves.
- Allow them to compare their results and try to account for the shape of their graph.
- Let the learner's analyse the graphs as they predict the solubility at various temperatures. They should as well respond to questions under the discussion corner.
- Allow learner's to do **Activity 5.6** on their own as you observe them closely and providing assistance where need be.
- Discuss and explain the uses of solubility curves and its application.
- Use the worked examples in the learner's book to explain how to determine the solubility of various solutes which can be used in their separation at different.
- Summarise the lesson by:
  (i) Checking learners' ability to use recorded data for drawing of graphs and analysis of those graphs.
  (ii) Explain the uses of solubility curves.

5.6 Fractional crystallisation of salts, uses of solubility curves and their applications in salt extraction

Refer to Learner's book page 243

Suggested teaching and learning activities

- Learners are familiar with their fractional distillation. Ask them if there is any similarity between fractional distillation and fractional crystallisation.
- Guide the discussion on fractional crystallisation and links with solubility curves and its application in salt extraction. Let them respond to the following questions.
  (i) What is fractional crystallisation?
  (ii) Which role does the difference in solubility of salts play in fractional crystallisation?
  (iii) In separation of salt mixtures, is it necessary to draw the solubility curves for the salts in the mixture?
- You can then explain to them that fractional crystallisation is a method of separation whereby soluble salts are separated at different temperatures on the basis of their solubility. Inform them that the least soluble salt crystallises out first.

- Let them know that fractional crystallisation is applied industrially in the extraction of sodium carbonate (soda ash) from trona. Inform the learners that trona is a mixture of many salts i.e. sodium carbonate, sodium hydrogen carbonate, sodium chloride etc. Emphasize that these salts have different solubility property which is used in the extraction of sodium carbonate from trona.

Answers to check your progress 5.3

Refer to learner's book page 245

1. *Saturated solution*-one which will not dissolve any more of a solute at a particular temperature and *unsaturated solution* which more solute can dissolve at a given temperature.
2. The knowledge of solubility curves is used to predict the solution required to wash trona.
3. At 100^0C - 80g of X dissolved
   At 20^0C - 42g of X dissolved

   Therefore, the amount of X deposited = (80 – 42) g
   = 38g

5.7 Water hardness

Refer to Learner's book page 246

Suggested teaching and learning activities

- Brainstorm with the learners about water hardness. Ask them if there is any difference between salty water and hard water. Some learners could be coming from areas with salty water phenomenon.
- Review with the learners about solubility of salts which they learnt earlier. Then let them look in detail solubility of various calcium and magnesium salts.
- Inform learners that water hardness come about as a result of dissolved salts present in water and explain the two types of water hardness.
- Take learners through preparation of temporary and permanent water hardness as outlined in activity 5.7 in the Learner's book page 246.
- Explain to the learners how water naturally becomes hard as outlined in the Learner's book.
- Let learners do the next activity 5.8 about comparison of different water hardness in groups. In this activity, learners are required to design, plan and carry out the demonstration having been provided with list of apparatus and reagents.
- Let them analyze the results and come up with their conclusions as to which ions

cause water hardness and state the two types of water hardness. Let learners make proper inferences from the activities being clear that hard water uses a lot of soap.

- Discuss and explain the causes of the two types of water hardness using the data from the students. Explain the effect of water hardness on soap.
- Let the students give their experiences with hard water.
- Summarise the results and the conclusions of these activities.

Note:

1. Calcium hydrogen carbonate solution can be prepared by passing carbon (IV) oxide into aqueous calcium hydroxide for a long time and filtering to get calcium hydrogen carbonate solution as the filtrate.
2. The following skills should be developed by the learner.
   (i) *Manipulation of apparatus* as they perform the group's experiment.
   (ii) *Observation* - of lather formed.
   (iii) *Recording and analysis* - of data
   (iv) *Drawing conclusions* from their experimental results.
   (v) *Problem solving* - as the learner use the acquired knowledge to explain the effects of effluents from chemical industries on river or lake waters.
3. Beryllium ions in water can also cause water hardness.

Methods of removing of water hardness

Refer to Learner's book page 249

Suggested teaching and learning activities

Activity 5.9 To demonstrate the effect of sodium carbonate (soda ash) and of boiling on water hardness

- Review with the learners on precipitation reactions they learnt earlier.
- Brainstorm with learners the methods used for removing water hardness by putting more emphasis on the chemical and ionic equations of the reactions taking place.
- Review Activity 5.7 and 5.8 prompting them to think on how the water became hard. Ask them how the process can be reversed.
- Ask probing questions on water hardness. For example;
  - What will happen to hard water if calcium and magnesium ions are precipitated as carbonate salts?

- What happens when calcium or magnesium hydrogen carbonates aqueous solutions are boiled?
- What are precipitation reactions?
- Do carbonates of magnesium and calcium cause water hardness?
- How can you convert hydrogen carbonates of magnesium and calcium into carbonates?
- How can you convert sulphates of magnesium or calcium into carbonates?

- Discuss the various methods used to remove temporary water hardness, using chemical equations as outlined in learners Book page 251.
- Discuss the various methods used in removing permanent hardness.

  Emphasize that some of the methods can remove both types of water hardness apart from ion exchange method.
- Draw ion exchange column to explain ion-exchange method.
- Allow learners to do further activity in learners book page 255.
- Summarise the methods used in the removing of both types of water hardness.
- Find out the learning progress if the following understanding and skills have been developed by the learners.

  (i) *State* and *explain* the methods used in removing both types of water hardness.

  (ii) *Writing chemical equations* - of the reactions taking place during various methods of removal of water hardness.

  (iii) *Problem solving* - ask the learners to differentiate the methods used to remove temporary hardness and permanent hardness in water.

Note: The removal of water hardness using sodium carbonate is a precipitation reaction. Most modern washing powders have their own water softener added.

Answers to check your progress 5.4

Refer to learner's book page 256

1. It is important for the removal of undesirable biological contaminants, chemicals and suspended solids and gases from water. This makes water fit for a specific purpose in industry or medical applications.
2. (a) Hard water contains deposits of calcium and magnesium carbonates which form fur on electrical appliances e.g kettles, boilers thereby making them inefficient i.e. using more fuel, hence increasing power cost.

   (b) Deposits of carbonates can block pipes, boilers thereby reducing efficiency to heat conductivity, water flow and even accelerate rusting. This increases cost for replacement and maintenance in industries.

3. Excess Calcium hydroxide causes water to become hard.