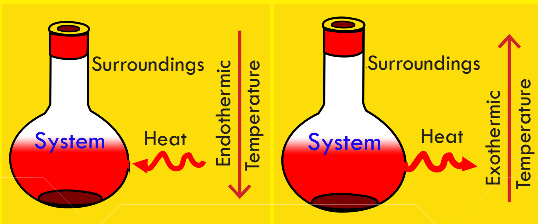
CHEMISTRY

TEACHER'S GUIDE

GRADE 10



FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF EDUCATION

CHEMISTRY

TEACHER'S GUIDE
GRADE 10

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General Information to the Teacher

The students' text is designed and prepared based on the participatory approach of the teaching – learning process. At present, it is believed that students should gain most of their knowledge from the teaching – learning process on their own and some from the teacher. The teacher is expected to give guidance and the necessary assistance, play a role as facilitator, harmonize concepts, provide students with materials required, create a conducive atmosphere for the teaching – learning process and evaluate students' performance. The teacher needs to assist students to discover facts, realize concepts, develop skills in performing experiments, solving problems etc. So, he/she should not dominate the teaching – learning process by giving lecture or explaining concepts throughout the period.

Thus, whenever you have contact with your students, you need to plan how to promote active– learning. The following information will help you understand what you are expected to do before and during the entire teaching – learning process.

1. Organizing Groups

You need to organize different groups in each section you are going to teach during your first contact with the students. To do so, you better have the list of all students in each section.

You may organize the groups based on their seats, or on their ability as slow learners, medium and fast learners or by mixing them. After organizing groups, give them group numbers as group 1, group 2 etc. and register the names of students in each group. Every group needs to have a group leader and a secretary to jot down the main points during discussions. The groups as well as their members need not be permanent throughout the year.

You can reorganize groups whenever necessary. You can do so per semester or mid-semester or even per month or two months etc.

2. Discussion

In all units, sections and subtopics, there are activities suggested for students to help them discuss and discover concepts. When you allow them to discuss points in each activity:

- ☞ follow up how every student participates in the discussion.
- ☞ be part of the discussion in some groups for a few minutes and see how the discussion among students is going on.

- give assistance and guidance when students are in need.
- give them hints when they face difficulties or have questions on the points suggested in the activities.
- ask questions related to the points in the activity to facilitate the interaction among students during discussion.

3. Presentation

Students are expected to present:

i. the concepts they gained during discussion in each activity in all units.

ii. their observation and analysis after performing experiments in groups to the class.

iii. the content prepared a specific topic. So you need to give emphasis to the following points in order to maximize student participation.

a. Groups should present their opinion turn by turn. For example, if you allow group 1 and group 2 to make a presentation on Activity 1.1, the following groups 3 and 4 or others will present Activity 1.2 etc.

b. Whenever a group gets the chance to make presentation for the second or third time, let other members of the group accomplish the task. Do not allow the same student from the same group to do so.

c. Given the opportunity to the rest of the class to ask questions or give their comments on the presentation of a particular group.

4. Experiment

Several experiments are suggested throughout the chapters. Most of these experiments should be performed by students. So, you are expected to accomplish the following tasks before or when students carry out the experiment.

a. To carry out the experiment by yourself before allowing students to do it.

b. To prepare chemicals and apparatus required for the experiment.

c. To give instruction on how students should handle chemicals and apparatus during every experiment.

d. To provide materials they need for the experiment.

e. Assist them whenever they have questions or difficulties in understanding the procedures suggested for the experiment.

f. Give instructions that students should perform the experiment only based on the procedures suggested for it.

g. Never allow them to conduct an experiment on their own other than the one they are supposed to do during the period.

h. Make them write a laboratory report in groups, present their observation to the rest of the class or submit it to you for correction as suggested in the students' text.

i. Make sure that every student in each group participates in the experiment.

5. Harmonizing Concepts

You are not expected to lecture throughout the period on most of the contents in the students' text. Your major role is harmonizing concepts suggested by students during presentations after discussing activities or performing an experiment with those they are expected to know. So, you need only to build a mini – lecture.

The concepts intended for students to discover in all activities, and answers to questions on the observation and analysis part of all experiments, are included as short notes in the subject matter presentation part of every section in this teachers' guide. So you are advised to use them. While harmonizing concepts in a mini – lecture, you better include other contents of the topic that have not been covered when students discuss activities.

6. Continuous Assessment

Previously, the performance of a student has been assessed in terms of his/ her achievements in quizzes, tests, homework, mid – semester and semester final examinations. Although these evaluation techniques are useful tools for the assessment, they may not give a clear picture of the performance of a student. Therefore, a student's work should be assessed throughout every topic, section and unit as well as during each period. So, you need to have a record of every student's work as a student performance list. You can make a record about each student in the performance list, based on the following points.

☞ Involvement in discussions.
☞ Participation in presentations after discussion.
☞ Participation in answering questions during the process of harmonizing concepts or stabilization.
☞ Role of the student in performing experiments.
☞ Role of the student in presenting concepts gained from the experiment.
☞ Presentation of the project work.
☞ Presentation of research and writing.
☞ Presentation of topics given to the group as homework.

- ☞ Answering questions accordingly given as class work, homework, quizzes, tests, mid – semester and semester final examinations

Here, it is very important to note that the assessment system is continuous assessment. That is, every performance of the student during the teaching-learning process should be given value and contributes its own share, as do quizzes, tests, mid-semester and semester final examinations, to the semester total. You are empowered to decide the percent of the contribution. However, your decision should not violate either the policy of the Ministry of Education or that of the Education Bureau of the regional state or that of your school.

7. Additional Questions

Some questions are given in this teachers' guide in each section before the answers to the exercises in the section. Use the questions indicated by an asterisk (*) for students working below the minimum requirement level, while students working above the minimum requirement level can attempt all of them. Give these questions as class work for fast learners after they complete their work during each period so that they will not sit idle and the period will not be boring for them.

8. Giving Note

You are not expected to write notes on the board related to the contents in each section. You need to give short notes on those contents left for students to discover after discussing the suggested activities and performing experiments. Be sure to offer any note that is available in the teacher's guide, but not in the students' text. However you can write short notes related to the main points as you harmonize concepts. Tell students how they can take notes, either from the text or during the teaching learning process. Tell them the main points they should emphasize, in taking notes from the text. Also tell them to jot down the main points as fast as they can as you harmonize concepts or give a mini-lecture.

9. Answers to Exercise

In all units, the answers to the suggested exercise are given at the end of each section, and answers to the review exercises in each unit at the end of the unit. So you can refer to them whenever you are in need.

10. Suggested Methodologies

Teaching all contents of grade 10 chemistry requires implementing active learning methodologies. Active learning involves providing opportunities for students to participate in meaningful talk and to listen, write and reflect on the content, ideas, issues and concerns of an academic subject. It is more of a student activity. The teacher is a facilitator. The teacher guides and directs the students.

Rationale for active learning

- an increase in academic achievements
- an increase in critical thinking skills
- increased student retention
- a more positive attitude toward the subject matter
- improvement in communication skills

There are many methods that can be used to implement active learning. However, all of them are not suitable for teaching chemistry. So, some of the methodologies that can be used to promote active learning in teaching chemistry at this level are suggested as follows.

A. Gapped Lectures

You divide your lecture into small sections (lecture for a period of 15 minutes) and give the students a quick activity of 5 to 10 minutes. After the activity, you proceed with another 15 minutes lecture followed by another activity. The activities usually emphasize the concepts included in the lecture. For example, you can apply this methodology to teach the information on the production of metals and nonmetals.

B. Cooperative (Collaborative) Learning

This is a form of group work and it is helpful in group project work and group assignments. This can be applicable for students in doing their group assignments or in doing suggested project work. For example constructing a model of ethene or a blast furnace.

C. Group Discussion

Is a simple interaction pattern in which 4 – 6 students work together on a given task and produce a written work or presentation. This method can be used in all sections and units at this level.

D. Presentation (Peer Teaching)

This is an activity where students present a topic in front of their classmates. This can be done individually or as a group. For example, you can use this method in unit 6 when discussion nomenclature, isomerism, and reactions.

E. Demonstration

This is a method where the teacher shows the students how something is done. For example, preparation of ethyne from calcium carbide and water.

F. Experiments

It usually involves a very specific and controlled method of procedures, where results are usually recorded. This method is applicable in performing laboratory experiments throughout unit 1 – 6 at this level.

G. Concept Map

It is a visual representation of ideas on any given topic. Students write the topic at the center of the page and then divide it into subtopics from which smaller branches will go off in different directions. For example, classification of organic compounds into hydrocarbons and oxygen containing hydrocarbons followed by the sub-classes and other smaller groups.

H. Question and Answer (Inquiry)

When this method is used, the teacher lectures and asks questions periodically relating to the information being given.

I. Investigation

This method is usually based on real life. For example, investigating the effects of an industry on the environment.

J. Spider Diagram

Students write a topic at the middle and write ideas related to the topic around the topic and draw a line connecting each idea to the central idea.

K. Visual-based Active Learning

This method helps students learn using real object models, pictures, drawings and charts. For example, this method can help in teaching linkage of carbon-atoms, saturated and unsaturated hydrocarbons, substitution reactions of alkanes etc.

L. Brain storming

This is an activity in which students write everything they know or think about a given topic. The ideas might be right or wrong. This can be done individually, in pairs, small groups or as a whole class with the teacher or a student recording the ideas on the board. This method is used to find out what students already know on a topic before you start teaching. For example this method can be used while beginning a new topic that is related what students learned in the previous grade. For instance, when you are going to start the topic energy changes in chemical reactions, students already learned the diffident types of chemical reactions. You can ask them to list down characteristics of chemical reactions. In this case, they should suggest temperature change as one of the characteristics.

M. Problem solving

Problems solving activities involve students finding solutions to problems. Problem solving can be done individually or in groups. The solution is not the focus. Instead, students are encouraged to explore different strategies and processes to find the solution. It creates students who are able to think for themselves or independent thinkers and look for solutions rather than become trapped in problems. This method can be applied for teaching pollution problems in the environments of students as nations continue overuse of natural gas to fulfill their energy demand (unit-6).

You can use the following websites to get more information on active-learning methodologies.

i. html/lib/bib/91-9dig.htm
ii. http:ctl.byu.edu/active-learning-techniques/
iii. strategies-to-incorporate-active-learning-into-onlineteaching
iv. IJELLOv5p215-232Pundak669.pdf

11. Motivation of students and its importance

Motivation of students means getting students to exert a high degree of effort in their learning activities. The teacher is expected to motivate the students to create a conducive atmosphere for the teaching learning process. To motivate students, the teacher needs to encourage them to get ready for the lesson, appreciate students for their attempts in answering questions or any other activity they perform during the teaching-learning process and give them recognition. Motivating students helps the teacher.

To pass information to students according to the plan

☞ to make students active participants
☞ make students realize concepts easily
☞ make his/her teaching interesting
☞ achieve the desired goals etc.

Motivation also helps students to

☞ follow the lesson attentively

☞ increase their participation
☞ enhance their understanding
☞ develop interest in the subject
☞ achieve good results in their performance

Implementing active learning methodologies has a role of its own in motivating teachers as well. It is not as tiresome as that of lecturing. Although, the teacher has a lot of tasks to accomplish when applying the methods. Using active learning methodologies during the teaching learning process motivate the teacher to:

☞ enjoy friendly and interesting relationships with students.
☞ develop new teaching skills by practicing the new teaching techniques, observing their results, and contrasting them with those of the old method of lecture-based teaching.
☞ become more interested in the teaching profession. For example, it is interesting and satisfying to develop new skills. The teaching-learning approach guides the teacher, helping him or her to develop professionally.
☞ investigate each student's talents and creativity. In this way, the teacher learns more about the age group of the students he or she teaches. This process is interesting in itself and helps the teacher develop professionally.
☞ guide students individually as they learn on their own. In this way, the teacher learns more about the dynamics of learning and also of teaching.
☞ actively engage in furthering the students' development. Because the students develop important social skills and attitudes, as well as increasing their knowledge and learning skills, the teacher has the satisfaction of contributing to their community and therefore to the country as a whole.
☞ expand his or her own creativity by developing appropriate presentations and assembling the apparatus and the local materials required for demonstrations and experiments.
☞ develops a greater interest in the teaching profession. As he or she assumes direct responsibility for each student's development.

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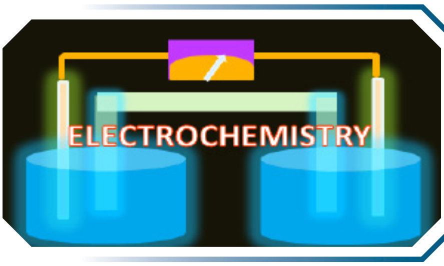

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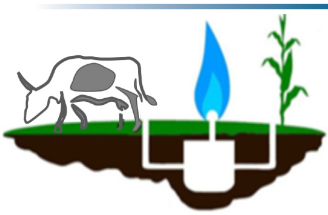
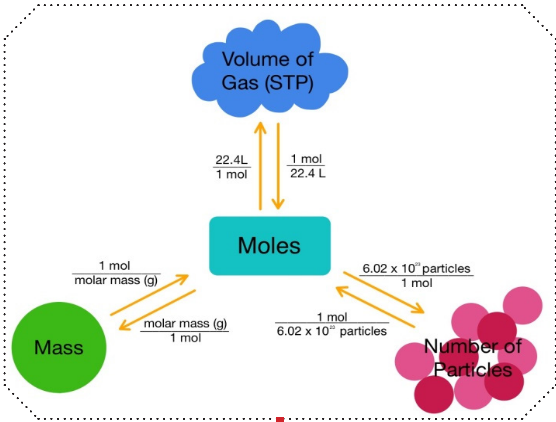




UNIT 1

CHEMICAL REACTIONS AND STOICHIOMETRY

Unit Outcomes

At the end of this unit, students will be able to

- define the basics of chemical reaction
- describe the four major types of reactions;
- develop skills in writing and balancing chemical equations;
- define oxidation - reduction reactions
- analyse redox reactions by specifying the oxidizing agent, the reducing agent, the substance reduced or oxidized;
- explaine molecular mass, formula mass, molar mass, empirical and molecular formulas;
- determine molecular mass, formula mass, molar mass, empirical and molecular formulas
- describe the mole concept
- solve problems related to moles of substances
- develop skills in solving problems based on chemical equations (mole-mole, mass - mass, volume - volume and mass - volume problems);
- develop skills in determining the limiting reactant, theoretical yield, actual yield and percentage yield;
- demonstrate scientific inquiry skills: observing, inferring, predicting, classifying comparing and contrasting, communicating, measuring, asking questions designing experiments, interpreting data, drawing conclusions, applying concepts, relating cause and effect, applying concepts, relating cause and effect, and problem-solving.

Unit Overview

This unit deals with the chemical reactions and reaction's stoichiometry. The start-up activity that provides a very general view of the unit has been given under the introduction part. The introduction part of this unit further presents the meaning of chemical reaction, reactant, product, chemical equation and reaction's stoichiometry.

The second section is about chemical equations. It introduces chemical equations and gives conventions used to write the chemical equations. It explains the reason for balancing chemical equations. It presents the different methods used to balance chemical equations as inspection method, Least common multiple (LCM) method, and the algebraic method.

The third section of the unit treats the types of chemical reactions. It provides the classification of chemical reactions as a direct combination, decomposition, displacement and double decomposition reactions. It gives the definitions and conditions for the reactions including the nature of reactants for each type of reaction.

The fourth section deals with oxidation and reduction reactions. It provides the definition of oxidation and reduction as well as oxidation number or oxidation state. It presents the rules for assigning oxidation numbers and provides the meaning of oxidizing and reducing agents. It presents the way how to balance oxidation- reduction reactions by the oxidation change method. It also presents non-redox reactions. The fifth section provides the definition of the formula and molecular masses of compounds. It shows the determination of the formula and molecular masses of compounds through examples. The section also discusses the mole concept and related terms like molar mass and Avogadro's number. It also defines empirical and molecular formulas and presents their determination from the given masses or percentages composition of elements. The section also indicates briefly the calculation of percentage composition of elements in compounds.

The sixth section is about reaction's stoichiometry. It begins with a revision of the Law of Conservation of Mass and defines reaction's stoichiometry. It provides methods how to solve mass-mass, mole-mole, mass-mole, mole-mass, mass-volume and volume-volume problems. It defines limiting reactant, excess reactant, actual yield, theoretical yield and percentage yields.

The recommended methods for teaching this unit are gapped lecture, group discussion, experiment, and inquiry. Students should do extensive exercises and their responses should be checked. Feedback and a summary of each topic should be given.

Promoting student's active learning: students must do more than just listen: They must read, write, discuss, or be engaged in solving problems. To be actively involved, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation. strategies promoting active learning are instructional activities involving students in doing things and thinking about what they are doing. Use of these techniques in the classroom is vital because of their powerful impact upon students' learning. Studies have shown that students prefer strategies promoting active learning to traditional lectures. Strategies for promoting active learning are comparable to lectures that promote content acquisition, but more than lectures that promote the development of thinking and learning skills. It is also excellent and promotes students' writing skills. With all this in mind, at the end of the unit , additional activities are suggested for each topic. Teachers can use these activities as an alternative to engage students in the teaching-learning process that facilitates active /self-study/learning.

Table 1.1 Tentative distribution of periods to each section/subsection.

SN	Unit/ Section	Section/Subsection	Activity	Experiment	Exercise			#Period suggested
					Classwork	Homework	Assignment	
1	1.1	Introduction/Start-up activity	Start-up activity		1.1			1
2	1.2	Chemical Equations	1.1		1.1			
3		Writing Chemical Equation						2
4		Balancing Chemical Equations				1.2		2
5		Balancing Chemical Equations by - Inspection Method - LCM method - Algebraic method						
6	1.3	Types of Chemical Reactions	1.2		1.3	1.4		
7		Direct combination reactions		1.1				1
8		Decomposition reactions		1.2				
9		Single replacement reactions		1.3				1
10		Double decomposition reactions		1.4				1
11	1.4	Oxidation and Reduction Reactions	1.3		1.5			
12		Oxidation Number or Oxidation State						1
13		Oxidizing and Reducing Agents	1.4					1
14		Analyzing Redox Reactions				1.6		
15		Balancing Redox Reactions: Oxidation-Number-Change Method			1.7			2
16	1.5	Molecular and Formula Masses, the Mole Concept and Chemical Formulas	1.5			1.8		3
17	1.6	Stoichiometry	1.6					
		Mole ratios in balanced chemical equations - Mass-mass Mole-mole - Mole-mass problems - Mass-mole problems - Mass-Volume problems - Volume- Volume problems - Limiting and Excess Reactants - Theoretical, Actual and Percentage Yields	1.7			1.10	1.9	2 2 2 1 1
								23
		*Projects to be carried out by students in convenient time schedule						

1. CHEMICAL REACTIONS AND STOICHIOMETRY

Total Periods Alloted: 23 Periods

1.1 Introduction

Total Period Alloted: 1 Period

At the end of this section, students will be able to

- define chemical reaction;
- give some examples of chemical reactions.
- explain physical and chemical changes using examples

Planning

We recommend that you read the contents of the section thoroughly, and make the necessary preparation and plan how your students will actively participate in the teaching-learning process. Plan how to organize your students in different groups for effective outcome and easy follow up during discussions. Students should work extensive exercises and their responses should be strictly checked.

Teaching Aid

Materials like wood or paper scrape iron, metals, raw and ripe fruits that can show a chemical change can be used.

Subject Matter Presentation

This section needs active participation of each student; hence it is advisable to use group discussion and mini-lecture methods. Use the start up activity to introduce the unit lessons. This activity helps student to define chemical reactions and identify the reactants and products for the reactions occurring their surroundings and provides a very general view of the unit.

Invite students who are volunteer to discuss the start-up activity to the class. The activity triggers students to recognize the changes taking place in their day to day activities. Changes may be reversible (physical changes) or irreversible (chemical changes). Students may identify the difference between the raw and the ripe fruit is that ripe fruits are different in color, taste and texture from immature (raw). Fermented 'Injera' is rich in eyes, soft, thin, easy to roll and sour, while 'Teff' flour is powdery, earthy, nutty and sometimes slightly sweet. Students could recognize that these changes are irreversible. The chemical changes are caused by chemical reactions. Changing dough into bread and firewood into ash are chemical changes because they are irreversible. The amount of fertilizer, the calculation of the dose of medicine for the patient, and the amount of ingredients for cooking by the chef are quantitative aspects. The quantity of reacting substances and the resulting substances can be measured. Inform the students that they will learn the quantitative aspect of chemical reactions at the end of the unit, ***Section 1.6***.

After completion of the discussion, ask students from two different groups to make a presentation on points they discussed. Next, develop your mini lecture from the suggestions of students and harmonize what they said with what you want them to know. It will be good to inform students that the burning of the candle and the rusting of iron are examples of chemical reactions. For example, before rusting iron is gray solid and attracted by a magnet. After rusting, iron loses its magnetic properties. The rust formed is a brown, powdery and a non-magnetic substance. Students should explain that this is a chemical reaction. Allow students to give more examples of chemical reactions which they may experience in their day to day activities like the burning of wood in air, digestion of food, souring of milk, photosynthesis in green plants, functioning of cells and batteries. They should identify the reactants and products of all these chemical reactions.

Introduce students the meaning of a chemical equation, reactants and products. Let the students be informed that reactants are starting materials and products are new substances and the process is indicated by the shorthand notation called chemical equation and a chemical equation uses chemical symbols to show what happens during a chemical reaction. Students should also be aware of a balanced chemical equation that it can be used to describe the relationships between amounts of reactants and products and the quantitative study of reactants and products in a chemical reaction is reaction's stoichiometry. Let the students define the reactants, products, chemical equation, chemical reaction and reaction stoichiometry using the reaction of magnesium or sulphur with oxygen as an example. If magnesium burns in oxygen, the magnesium and oxygen (reactants) are completely converted to magnesium oxide (product). Magnesium oxide is a soft, white, crumbling powder. These characteristics of magnesium oxide are completely different from the characteristics of the original substances, magnesium and oxygen. Magnesium and oxygen are no longer present in the elemental form. Students should realize that one unit of magnesium atoms combine with one unit of oxygen molecules to form 2 units of magnesium oxide and this aspect of the reaction is called the reaction' stoichiometry.

Assessment

The activity of each student should be assessed throughout the section. Monitor carefully how each student is working during discussion and explanation. Give ***Exercise 1.1*** as classwork or homework. Check their work, record their results in your students' performance list, and evaluate how many of the students achieved the minimum required level.

Additional Questions

1. Why are the growth of plants, ripening of fruits, photosynthesis of plants, and combustion of glucose in the metabolic process are considered chemical changes?
2. Discussion questions

a. How does magnesium burn ?

b. What is the color of the product formed when magnesium burns ?

c. What happens when white ash of magnesium oxide is brought in contact with a moist red litmus paper ? What conclusion do you draw from your observation ?

d. Write the chemical equation to represent the reaction when magnesium burns.

e. Why should magnesium ribbon be cleaned before burning it in air ?

Answers to Additional Questions

1. Because in all cases the original properties disappear. For example, raw and ripe fruits have different colours and different tastes.
2.

a. Magnesium burns with dazzling light.

b. A white ash of magnesium oxide is formed.

c. The moist red litmus paper turns blue. This shows that magnesium oxide has basic character.

d. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

Magnesium Oxygen Magnesium oxide

e. To remove the coating of impurity and to remove dust from the surface of magnesium ribbon.

Answers to Exercise 1.1

A. Chemical reaction is the process in which reacting substances, called reactants, are converted into new substances, called products.

B. Physical change is a change in which the substance doesn't lose identity and no new substance is formed. Examples: evaporation of a liquid, powdering of sugar, dissolution of salt. Chemical change: is the change in which the identity of the original substance is changed and a new substance is formed. Example: Ripening of fruits, growth of plants, souring of milk, digestion of food.

1.2 Chemical Equations

Total Period Alloted: 3 Periods

At the end of this section, students will be able to

- explain the conventions used to write chemical equation
- balance chemical equations using:
    - The Inspection method
    - The Least Common Multiple (LCM) method
    - The Algebraic method

Planning

Make the necessary preparation by reading this section and the related materials thoroughly and plan how to cover the contents of the section within 3 periods. Plan for students to do extensive exercises.

Teaching Aids

This section involves more writing and balancing chemical equations, thus, no experiment has been suggested. You may need to prepare a chart to summarize the three techniques of balancing chemical equations.

Subject Matter Presentation

It is recommended to use question and answer, group discussion, problem- solving and mini- lecture methods for this sub-topic.

You may start teaching this unit using ***Activity 1.1***. The activity enables students to differentiate between chemical equations and chemical reactions. The activity also helps students to realize the use of chemical equations and the need for balancing chemical equations. Allow the students to discuss ***Activity 1.1*** for a few minutes. Let some students from different groups make presentations on points they discussed. After the presentations, inform the students about the answers for the ***Activity 1.1*** as 1) chemical symbols, physical states and quantities of substances involved in the reaction could be represented using a chemical equation; 2) chemical reaction is a chemical change accompany by the formation of new substances and 3) the law applied for balancing chemical equation is the law of conservation of mass. Then continue the discussion by giving the meaning of the chemical equation as it is a short hand notation of a chemical reaction in terms of the chemical symbols and formulas along with the number of atoms and molecules of its reactants and products. Reactants are written on the left side and products on the right side of the equation. An arrow (→) is placed between the two sides to indicate the transformation of reactants into products.

Reactants → products

Let the students be informed the rule, conventions and reasons of writing balanced chemical equations as presented in the text.

Students should know that a chemical equation indicates the state of substances involved. This information is sometimes added to an equation by placing the appropriate symbols after the formulas:

(*s*) - Solid (*l*) - Liquid (*g*) - gas (*aq*)- Aqueous solution

Let the students identify clearly the three methods of balancing chemical equations: the inspection, least common multiple (LCM) and algebraic methods.

The Inspection Method: It is a trier and error method. In this method, the first skeleton equation should be written and numbers of each type atoms of reactants are made equal to the number of corresponding atoms on the right side of the equation by using coefficients if required. Students can tabulate the number of atoms of reactants and products in order to see the changes clearly.

LCM Method, the coefficients for the balanced chemical equation are obtained by taking the LCM of the total valency of reactants and products and then dividing it by the total valency of reactants and products. The following examples show all of the steps required to balance a chemical equation using the LCM Method.

Examples:

i. When aluminum reacts with oxygen, aluminum oxide is formed. Write the balanced chemical equation for the reaction

Step 1: Represent the reaction by a word equation:

Aluminum + Oxygen → Aluminum Oxide

Step 2: Write the correct symbols or formulas for the reactants and products

$Al + O_2 \rightarrow Al_2O_3$

Step 3: Place the total valency of each atom above it.

3 4 6 6

$Al + O_2 \rightarrow Al_2O_3$

From the equation we see that the valency of aluminum is 3. The total valency of oxygen is $2 \times 2 = 4$. The total valency of aluminum in Al_2O_3 is $3 \times 2 = 6$.

The total valency of oxygen in Al_2O_3 is $2 \times 3 = 6$, LCM is 12.

Step 4: Find the LCM of each total valency and place it above the arrow, here LCM is 12.

$$\overset{3}{Al} + \overset{4}{O_2} \xrightarrow[\text{LCM}]{12} \overset{6\ 6}{Al_2O_3}$$

Step 5: Divide the LCM by each total valency number to obtain the coefficients for each of the reactants and products. Place the obtained coefficients in front of the respective formulas

$4Al + 3O_2 \rightarrow 2Al_2O_3$ (Balanced)

Checking: There are 4 aluminum and 6 oxygen atoms on both sides of the equation. Hence, the chemical equation is correctly balanced

ii. When iron reacts with water, iron (III) oxide and hydrogen are produced. Write the balanced equation.

Step 1: Iron + Water → Iron(III) oxide + Hydrogen

Step 2: $\overset{3}{Fe} + \overset{2\ 2}{H_2O} \rightarrow \overset{6\ 6}{Fe_2O_3} + \overset{2}{H_2}$

Step 3: $\overset{3}{Fe} + \overset{2\ 2}{H_2O} \xrightarrow[\text{LCM}]{6} \overset{6\ 6}{Fe_2O_3} + \overset{2}{H_2}$

Step 4: $2Fe + 3H_2O \rightarrow Fe_2O_3 + 3H_2$ (Balanced)

Check: There are 2 iron, 6 hydrogen, and 3 oxygen atoms on each side of the equation. Thus, the equation is balanced.

iii. The reaction of ammonium sulphate with aluminum nitrate would form aluminum sulphate and ammonium nitrate.

Solution:

Step 1: Represent the reaction by a word equation.

Ammonium sulphate + aluminum nitrate → aluminum sulphate + ammonium nitrate

2 2 3 3 6 6 1 1

Step 2: $(NH_4)_2SO_4 + Al(NO_3)_3 \rightarrow Al_2(SO_4)_3 + NH_4NO_3$

2 2 3 3

2 2 3 3 6 6 1 1

Step 3: $(NH_4)_2SO_4 + Al(NO_3)_3 \xrightarrow[LCM]{6} Al_2(SO_4)_3 + NH_4NO_3$

2 2 3 3 6 6 1 1

Step 4: $3(NH_4)_2SO_4 + 2Al(NO_3)_3 \xrightarrow[LCM]{6} Al_2(SO_4)_3 + 6NH_4NO_3$

Step 5: $3(NH_4)_2SO_4 + 2Al(NO_3)_3 \rightarrow Al_2(SO_4)_3 + 6NH_4NO_3$ (Balanced)

There are 12 nitrogen, 24 hydrogen, 3 sulphur, 30 oxygen and 2 aluminum atoms on both sides of the equation. Thus, the equation is correctly balanced.

The Algebraic Method: This method of balancing chemical equations involves assigning algebraic variables as stoichiometric coefficients to each species in the unbalanced chemical equation. These variables are used in mathematical equations and are solved to obtain the values of each stoichiometric coefficient.

Simple chemical equations can be balanced by either the inspection method or LCM method and chemical equations can be balanced by the algebraic method if it becomes a bit difficult to balance by the former methods. Let the students do the exercises exhaustively and compare the inspection, LCM and Algebraic methods in terms of balancing wide range of chemical equations. Students should understand that chemical equations are balanced in accordance with the Law of Conservation of Mass.

Students should be informed that all balanced chemical equations may not represent the actual reaction. E.g $Cu + H_2SO_4 \rightarrow CuSO_4 + H_2$, though a balanced equation, it doesn't show the reaction as copper metal doesn't displace hydrogen. A chemical equation has some limitations for it doesn't tell us the rate of the reaction, and the time for completion. Also, it doesn't show whether the reaction is explosive or not.

Promoting Active learning

A variety of activities can be used to ensure that students acquire the expected content knowledge of this unit. Students are encouraged to participate through discussions with peers or in class using carefully designed activities. Some are identified and detailed below.

Suggested activities

- Discuss the differences between physical and chemical processes using examples of everyday life.
- Discuss why basic knowledge on chemical reactions is very essential especially in manufacturing plants, agriculture and food preservation.
- Discuss the reason why the mass of a substance remain the same after a chemical reaction.
- Discuss how chemical reactions affect life and the environment.

Activity	Elaboration
Physical and chemical changes	In groups or individuals, list some physical and chemical changes occurring in your everyday life. Discuss the main differences between physical and chemical changes
Need for knowledge of chemical reactions	In groups or individuals. Discuss the application of knowledge of chemical reaction in manufacturing industries, agriculture and food preservation.
Conservation of mass in chemical reaction	Discuss in groups or individual, the reason why the mass of a substance remain the same after a chemical reaction.
Effect of chemical reaction in the environment	Discuss in groups or individual, the effects of chemicals in soil, water or air(environment) when they are produced or disposed through examples.

Answers **for Exercise 1.2**

Balance the following chemical equation, using the inspection method:

1. a. $2Na + 2H_2O \rightarrow 2NaOH + H_2$

   b. $2KClO_3 \rightarrow 2KCl + 3O_2$

   c. $2H_2O_2 \rightarrow 2H_2O + O_2$

   d. $2Al + 2H_3PO_4 \rightarrow 2AlPO_4 + 3H_2$

   e. $2HNO_3 + 3H_2S \rightarrow 2NO + 3S + 4H_2O$

2. Write the balanced chemical equation to represent the following reactions

   a. $2NaBr + Cl_2 \rightarrow 2NaCl + Br_2$

   b. $2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$

   c. $2KClO_3 \rightarrow 2KCl + 3O_2$

   d. $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

   e. $2Ag_2O \rightarrow 4Ag + O_2$

3. Balance the following using the LCM method.

   a. $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

   b. $Fe_2(SO_4)_3 + 6KOH \rightarrow 3K_2SO_4 + 2Fe(OH)_3$

   c. $3CaCl_2 + 2Na_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6NaCl$

   d. $FeCl_3 + 3NH_4OH \rightarrow Fe(OH)_3 + 3NH_4Cl$

4. Balance the following equations using the algebraic method.

   a. $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

   b. $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$

   c. $2Zn(NO_3)_2 \rightarrow 2ZnO + 4NO_2 + O_2$

   d. $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

   e. $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

   f. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

   g. $2FeCl_3 + 3MgO \rightarrow Fe_2O_3 + 3MgCl_2$

   h. $3BaCl_2 + 2K_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6KCl$

   i. $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

1.3 Types of Chemical Reactions

Total Period Alloted: 3 Periods

At the end of this section, students will be able to

- list the four types of chemical reactions
- define combination reaction and give examples
- conduct experiments on combination reactions in groups
- define decomposition reaction and give examples
- conduct some experiments on decomposition reactions in groups
- define single displacement reaction and give examples
- conduct some experiments on simple displacement reactions in groups
- define double decomposition reaction and give examples
- conduct some experiments on double displacement reactions in group

Planning

It is advisable that you read the section content thoroughly and design a plan of your own that shows which contents and activities you will treat during each period, and when students should conduct the suggested experiments. Four ***Experiments (1.1, 1.2, 1.3 and 1.4)*** are suggested in the section.

Let the students be aware of the existence of different types of chemical reactions (section 1.3) and all chemical reactions include three types of changes in the original substances. These are changes in composition, properties and energy. Use ***Activity 1.2*** to introduce the types of chemical reactions that occur in their daily lives. In this activity varieties of chemical changes are given. Please allow the students to discuss in groups on ***Activity 1.2***. This activity may challenge students so it needs your close follow up whether they are in the correct line or not. Students should be aware of that digestion of proteins and starch are decomposition processes. The breakdown of proteins by body enzymes results in smallest forms called amino acids. Students should realize that this is a decomposition process. Similarly starch decomposes by body enzymes into glucose. You could mention that protein is built up (composition) from aminoacids and starch is built up from simple sugars called monosachrides(glucose, fructose or galactose). Similarly, 'Teji' or 'Tella' making involves the breaking down of gulcose into ethanol and carbondioxide (decomposition), photosynthesis involves the conversion of carbondioxide and water into glucose and oxygen (build up process), respiration (reverse of photosynthesis) is the breaking down of glucose in to carbon dioxide and water. The burning of kerosene results in the formation of carbondioxide and water vapor (breaking down process). Throughout your explanation, ask oral questions so that students can participate in the teaching-learning process.

It is advisable you arrange the necessary chemicals and apparatuses required to perform the experiments. Carry out the experiments beforehand. If your laboratory is well equipped, plan how students could perform the experiments by themselves in groups. You need also to plan how to follow up when students discuss the suggested activities in the section and perform the experiments. Also, plan how to implement the suggested methods for each topic in the section.

Teaching Aids

Refer to the students' text for the apparatus and chemicals required to conduct ***Experiments 1.1, 1.2, 1.3*** and ***1.4***

Subject Matter Presentation

Group discussion, question and answer, and gapped lecture are some of the methods recommended for teaching this sub-topic. Students should work on extensive exercises and their responses should be strictly checked.

Follow the following procedure, for this topic,

- Introduce the topic of the section
- Allow students to discuss ***Activity 1.2*** for few minutes. Explain them chemical reactions taking place during the processes mentioned in the activity, for example photosynthesis involves the reaction between carbon dioxide and water to give glucose and oxygen, and fermentation of 'tella' involves the decomposition of glucose in ethanol and carbon dioxide and so on.
- Continue your mini- lecture by asking students to define chemical reactions
- After students' responses, present the appropriate definition of chemical reactions as a process in which some known substances change into a new substance or new substances. The starting substances are called reactants and the new substances formed are called products.
- Present the topic that different elements and compounds react in different ways and produce different new substances. Hence, we can find different types of reactions, and such reactions are generally classified as shown in the following chart.

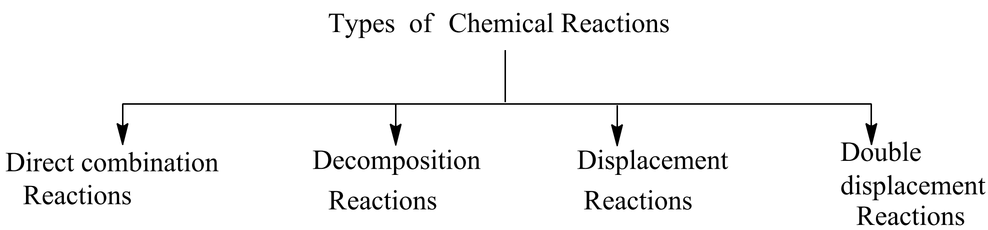


Figure 1.1 Classification of chemical reactions.

A. Direct Combination Reactions

Group discussions, question and answer, experiment, mini- lecture whenever necessary, are recommended methods for the teaching of this topic. Students need to do extensive exercises.

Introduce the topic by asking students to define and describe combination reactions through examples. Then give the correct definition of combination reactions by correcting students' responses.

Tell them that direct combination reactions are those reactions in which two types of pure substances (A and B) react directly and form a **single substance (AB)**.

$$A + B \rightarrow AB,$$

A and B could be elements or compounds. Thus, in a combination reaction, we can find

Element + element $\rightarrow$ single product

Element + compound $\rightarrow$ single product

Compound + compound $\rightarrow$ single product

Give them examples of combination reactions like the combination of hydrogen and oxygen to form water, the combination of hydrogen and nitrogen to form ammonia, a combination of calcium oxide and carbon dioxide to form calcium carbonate. Give students some known reactants and ask them to predict the product of the combination reaction.

Let the students perform ***Experiment 1.1*** in groups. They should write laboratory reports in groups and submit them to you. You can use the following note to evaluate their reports. From this experiment, the students are expected to realize that iron(II) sulfide can be prepared by the direct combination reaction of sulphur and oxygen in the presence of heat.

Laboratory Report Format

Group Number ______________ Date of experiment: ______________________

Name of students:

1. ____________________________
2. ____________________________
3. ____________________________

Experiment number: ____________________

Title of experiment: ____

Objective of the experiment: ____

____

Materials used in the experiment: ____

Chemicals: ____

Chemical reactions: ____

Observation:____

Conclusion: ____

Safety Precautions while Working in the Laboratory

1. Worn safety glasses or goggles in the laboratory
2. Laboratory coats are compulsory. Open shoes or sandals must not be worn in the laboratory. Long hair must be tied back.
3. Smoking, drinking, or eating are not permitted in the laboratory.
4. Accidents must be REPORTED IMMEDIATELY.
5. All chemicals should be treated with respect. A notation appears in the experimental instructions where any specific hazard exists. Most chemicals are potentially dangerous if mishandled or misused. For this reason:
   a. Experiments may only be carried out when a teacher is present. Read all laboratory instructions carefully.
   b. Never taste chemicals or their solutions.
   c. Do not point the mouth of a test tube towards your neighbour or yourself.
   d. Acids and alkalis are corrosive substances. Any corrosive solution on your skin must be washed immediately and thoroughly with water.

5. Note the locations of the Safety Equipment.
6. Do not wander about the laboratory unnecessarily and do not interfere with other student's work.
7. Handle all organic solvents with care. Many are flammable. Some have long-term cumulative health effects.

Experiment 1.1

Precautions : Avoid contact with skin and eyes. Do not breathe the dust. Do not breathe the vapors or spray mist. Storage : Keep in a dry, cool and well-ventilated place

Observation:

Fe	+	S	$\rightarrow$	FeS
Iron fillings(black silvery)		sulphur(yellow powdered)		Black ash

The answers to the questions that are raised in the observation and analysis part of the experiment are the following:

1. Iron is gray solid and sulphur is pale yellow
2. The color of the resulting compound after the reaction was black solid
3. $Fe + S \rightarrow FeS$
4. Combination reaction

B. Decomposition Reaction

Question and answer, group discussion, experiment, mini lecture methods are recommended for this sub-topic. After you complete the contents on combination reactions, continue the presentation of concepts on decomposition reactions.

First, let the students discuss in groups for a few minutes and let the students from two different groups present their opinions to the class. Then, harmonize the concepts suggested by students and define decomposition reaction and give examples. Tell them that decomposition reaction is the conversion of a single compound into two or more simple substances. Ask students to compare decomposition reaction with combination reaction. They should be aware that decomposition reaction is the reverse of a combination reaction.

$$AB \rightarrow A + B$$

Students also should be informed that decomposition reactions are caused by heat, electricity or light. Therefore, decomposition reactions are classified as

☞ Thermal decomposition (caused by heat)

☞ Electrical decomposition (caused by electricity)

☞ Photo decomposition (caused by light)

Give students some known reactants and ask them to predict the product of the decomposition reaction. Students should do exercises on the thermal decomposition of oxide, metal carbonates, bicarbonates, and nitrates. Students also be informed about electrical decomposition such as the decomposition of H_2O and NaCl by electrolysis (electrical decomposition) and light decomposition such as the decomposition of silver chloride, hypochlorous acid.

$$\underset{\text{Sodium chloride}}{2NaCl(l)} \xrightarrow{\text{Electric current}} \underset{\text{Sodium}}{2Na(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \text{ ----- Electrolysis}$$

$$\underset{\text{Water}}{2H_2O(l)} \xrightarrow{\text{Electric current}} \underset{\text{Hydrogen}}{2H_2(g)} + \underset{\text{Oxygen}}{O_2(g)} \text{ ------ Electrolysis}$$

$$\underset{\text{Silver chloride}}{2AgCl} \xrightarrow{\text{Sun light}} \underset{\text{Silver metal}}{2Ag(s)} + \underset{\text{Chlorine gas}}{Cl_2(g)}$$

$$2HClO \xrightarrow{\text{Sun light}} 2HCl(aq) + O_2(g)$$

Hypochlorous acid — Hydrochloric acid — Oxygen

Let the students perform ***Experiment 1.2*** in groups. They should write laboratory reports in groups and submit them to you. From this experiment, the students are expected to realize that iron(II) sulfide can be prepared by the direct combination reaction of sulphur and oxygen in the presence of heat.

Experiment 1.2

Precautions: Ensure the delivery tube in the limewater is removed as soon as heating is stopped to avoid suck-back. Wash your hands thoroughly after handling copper carbonate, which is 'harmful'. Lime water is an 'irritant'.

Observation :

$CuCO_3 \rightarrow CuO + CO_2$

Blue

The blue color of copper carbonate turns to black indicating the formation of copper (II) oxide and the lime water appear milky due to the carbon dioxide . This confirm the decomposition of copper carbonate in to CuO and CO_2.

The answers to the questions that are raised in the observation and analysis part of the experiment are the following:

1. Green
2. Dark green, Black
3. Milky mixture
4. $CuCO_3(s) \xrightarrow{\Delta} CuO(s) + CO_2(g)$

Copper carbonate (Green) — Copper oxide (Black) — Carbon dioxide (Colorlous)

C. Displacement and Double Displacement Reactions

We suggest that you use experiment and group discussion as the main methods for this lesson topic. Use a mini- lecture only when harmonizing the concepts.

After you complete the contents on combination reactions and double decomposition reactions, continue the presentation of single and double displacement reactions. Revise the types of the reactions and introduce the topic. Then, allow the students to discuss for few minutes in their group. Let one or two groups present their opinions to the class. Following their presentations, harmonize the ideas suggested by students with facts that you want them to know. A reaction in which one element displaces another element from its compound is known as a single displacement or replacement reaction. Such a reaction is represented by the following two general forms.

$$A + BC \rightarrow B + AC$$

Example: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

If A is a metal, it will displace B to form AC, provided A is a more active metal than B.

$$A + BC \rightarrow BA + C$$

Example : $2NaI + Cl_2 \rightarrow 2NaCl + I_2$

If A is a non-metal, it will displace C to form BA, provided A is a more active non-metal than C.

Inform them that in general, a more reactive element displaces a less reactive element from its compound.

Let the students perform ***Experiment 1.3*** in groups. They should write laboratory reports in groups and submit to you. From this experiment, the students are expected to realize that iron can displace copper from copper to iron sulphate solution. The color of iron rod turns to blue due to reduction of copper (II) ions to copper metal and oxidation of metal to iron (II) ions as $Cu^{2+} + Fe \rightarrow Cu + Fe^{2+}$

Experiment 1.3

Precautions : Avoid contact with skin, eyes or clothing. Do not flush into surface water or sanitary sewer system. Do not allow material to contaminate ground water system. Prevent product from entering drains.

Observation:

Fe +	$CuSO_4$	$\rightarrow$ $FeSO_4$	+ Cu
Iron nail (silvery-gray)	Blue	Red	Red brown deposit of copper on iron nail.

Therefore, the iron nail changes color from silvery -gray to red brown due to the deposition of copper.

The answers to the questions that are raised in the observation and analysis part of the experiment are the following:

1. Reddish brown color on the iron rod
2. Cu^{2+} + Fe → $FeSO_4$ + Cu
3. Fe can displace copper from copper sulphate ($CuSO_4$) solution

After completing the discussion on a single replacement reaction, continue discussion on a double displacement reaction. Start the lesson by asking students to discuss for a few minutes the difference between single and double displacement reactions. Harmonize the their conclusions and give the correct definition as double displacement reaction is a reaction in which two compounds react together to form two new compounds by exchange of the positive and negative ions of each reactant. Students should also be informed that such a reaction is also known as a double replacement reaction or metathesis. This type of reaction can be written in the following general form of an equation

$$AB + CD \rightarrow AD + CB$$

Example:

The two soluble compounds $AgNO_3$ and NaCl react to produce an insoluble precipitate of AgCl and a soluble $NaNO_3$ solution.

$AgNO_3$	+	NaCl	→	AgCl	+	$NaNO_3$
Soluble		Soluble		Insoluble		Soluble

Students should understand that a soluble salt exists in solution in the form of its ions and thus the net effect is the formation of the precipitate. So students should write molecular equation, ionic and net ionic equations, to identify the net change. For the above reaction, the net change or the driving force for the forward reaction is the formation of a solid precipitate AgCl.

$$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3 \text{ (molecular equation)}$$
$$Ag^+ + NO_3^- + Na^+ + Cl^- \rightarrow AgCl + Na^+ + NO_3^- \text{ (ionic equation)}$$
$$Ag^+ + Cl^- \rightarrow AgCl \text{ (Net ionic equation)}$$

Let the students perform ***Experiment 1.4*** in groups. They should write laboratory reports in groups and submit them to you. From this experiment, the students are expected to realize that the reaction of Na_2SO_4 and $Ba(NO_3)_2$ is an example of double displacement reaction and driven by the formation of a solid barium sulphate precipitate.

Experiment 1.4

Precautions : Avoid contact with skin and eyes. Avoid formation of dust and aerosols.

Provide appropriate exhaust ventilation at places where dust is formed. Keep away from sources of ignition - No smoking. Wear respiratory protection. Note: Repeated exposure to barium nitrate may cause kidney damage.

Observation : $Na_2SO_4\,(aq) + Ba(NO_3)_2\,(aq) \rightarrow BaSO4\,(s) + 2NaNO_3\,(aq)$

White precipitate The white precipitate indicates formation of barium sulphate due to the replacement of sodium by barium from sodium sulphate.

The answers to the questions that are raised in the observation and analysis part of the experiment are the following:

1. The precipitate is barium sulphate and the compound exist in the form of its ions is sodium nitrate
2. The color of the precipitate is white
3. $Na_2SO_4 + Ba(NO_3)_2 \rightarrow BaSO_4 + 2NaNO_3$

Promoting Active Learning

A variety of activities can be used to ensure that students acquire the expected content knowledge of this unit. Students are encouraged to participate through discussions with peers or in class using carefully designed activities. Some are identified and detailed below.

Suggested activities

- List indicators of chemical changes.
- Investigate different types of chemical reactions.
- write word equations
- write balanced chemical and ionic equations with states
- discuss oxidation-reduction reaction

Activities	Elaboration
List indicators of chemical changes	Discuss the signs or indicators of a chemical change which ever you have observed and explain why these signs are considered as signs of chemical reactions
Investigate different types of chemical reactions	Discuss how reactions could be classified based on what happens when going from reactants to products. Explain the type of reaction that occurs in photosynthesis, respiration and formation of ammonia from hydrogen and nitrogen.

Writing word equations	Write the word equations for the reactions occurring • Burning wood. • Mixing of caustic soda and hydrochloric acid. • Rusting of iron • Burning of benzene
Write balanced chemical and ionic equations with states	Discuss and write the balanced chemical and ionic equation for the reaction that occurs between barium chloride and sulfuric acid and the reaction between silver nitrate and sodium chloride
discuss oxidation-reduction reaction	Discuss the reaction occurring between iron and copper sulphate. Write the balanced net ionic equation.

Suggested assessment tasks

Practical experiments

Assessment criteria

Students will be assessed on the extent to which they can:

- demonstrate observational skills
- describe changes in color, evolving of gases and forming of precipitates
- tabulate results

Answers to Exercise 1.3

1. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
2. $Zn + Cu(NO_3)_2 \rightarrow Zn(NO_3)2 + Cu$
3. $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$
4. $Cl_2 + 2KI \rightarrow 2KCl + I_2$
5. $F_2 + CaCl_2 \rightarrow CaF_2 + Cl_2$

Answers for Exercise 1.4

1. A. Single replacement reactions: E.g. $2K + 2H_2O \rightarrow 2KOH + H_2$

   B. Combination reactions E.g $2Na + Cl_2 \rightarrow 2NaCl$

   C. Combination reactions E.g. $NaOH + HCl \rightarrow NaCl + H_2O$

   D. Decomposition reactions E.g $Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 + H_2O + CO_2$

2.

   A. $FeO + C \rightarrow Fe + CO \Rightarrow$ Single displacement

   B. $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4 \Rightarrow$ Combination reaction

   C. $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O \Rightarrow$ Double displacement reaction

D . $2Cu(NO_3)_2 \rightarrow 2CuO + 4NO_2 + O_2 \Rightarrow$ Decomposition reaction

E . $2Na_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6NaOH \Rightarrow$ Double displacement reaction

F. $CuSO_4.5H_2O \rightarrow CuSO_4 + 5H_2O \Rightarrow$ Decomposition reaction

1.4 Oxidation and Reduction Reactions

Total Alloted Period 4

AT the end of this section, students will be able to

- define redox reactions
- define the terms oxidation and reduction in terms of electron transfer
- define oxidation number (oxidation state)
- state oxidation number rules.
- determine the oxidation number of an element in a given formula

Planning

Read the section content thoroughly and design a plan of your own that shows which contents and activities you will treat during each period, and when students should do exercises

You need also to plan how to follow-up when students discuss the suggested activities in the section. Also plan how to implement the suggested methodologies for each topic in the section.

Teaching Aids

No experiment is suggested for this section. You may prepare a chart showing the characteristics of oxidizing agent and reducing agent.

Subject Matter Presentation

Group discussion, question and answer, and gapped lecture methods are recommended for teaching this sub-topic. Students should work on extensive exercises and their responses should be strictly checked.

Follow the following procedure, for this topic,

- Introduce the topic of the section
- Continue your mini lecture by asking students to define oxidation and reduction.
- After students' responses, present the appropriate definition of oxidation and reduction.

First, introduce the topic and then let the students discuss ***Activity 1.3*** for a few minutes.

This activity enables students to discover the meaning of oxidizing agent and reducing agent in terms of the analogy of towel and wetting agent. Since the towel lost water(dried) it is analogues to oxidation(lose of electrons) and the wetting agent(gained water) is analogues to reduction(gain of electrons). During the discussion of the activity, observe how every student participates in each group. Help and guide groups that need/require it. Encourage students from the different groups to present their opinions to their classmates. Appreciate the attempts made by the students in presenting their opinions. In relation to the activity, you can ask questions about the different types of reactions facing in their day-to-day activities; for example, about chemical processes like rusting of iron, burning of substances, breathing of air, digestion of food ,and so on. Tell them all these reactions are examples of redox reactions and ask them to give more examples. Finally, give them the correct definition of **oxidation** reaction as the loss of one or more electrons by an atom, and a **reduction** is the gain of one or more electrons. Oxidation and reduction occur simultaneously. Thus, an oxidation -reduction reaction, or redox reaction, is one in which electrons are transferred from one atom to another. Oxidation and reduction reactions can also be defined in terms of oxidation number. Oxidation is an increase in the oxidation number of an element and reduction is a decrease in the oxidation number. For example, in the reaction between chromium oxide and aluminum metal to form aluminum oxide and chromium metal is a redox reaction.

$Cr_2O_3(s) + 2\,Al(l) \rightarrow Al_2O_3(s) + 2\,Cr(l)$ or

$2Cr^{3+} + 2Al^0 \rightarrow 2Al^{3+} + 2Cr^0$, $2Cr^{3+}$ is reduced to $2Cr^0$ and $2Al^0$ is oxidized to $2Al^{3+}$. 3es per aluminum atom are transferred to an atom of chromium (oxidation based on electron transfer or loss) or oxidation number of aluminum is increased from 0 to + 3 (oxidation based on oxidation number). Let the students describe reduction as the reverse of oxidation.

Ask students to define oxidation numbers and the way how to assign oxidation numbers. After the response of students, tell them that oxidation number or oxidation state is the number of electrons that an atom appears to have gained or lost when it is combined with other atoms. Oxidation numbers could be integers including zero and fractional numbers and are assigned by certain convention rules. You may give them the rules along with appropriate examples and exercises in class. Define in terms of oxidation number, oxidizing agent as the substance that gains an electron and causes the oxidation and reducing agent as substance that gives up an electron and causes reduction. Let students identify oxidizing and reducing agents in a given redox reaction. For example, in the reaction between iron (II) oxide and carbon

$$FeO(s) + C(s) \rightarrow Fe(s) + CO(g)$$

Fe^{+2} is reduced to Fe^0, C^0 is oxidized to C^{2+}

Substance reduced = oxidizing agent ⇒ FeO is oxidizing agent

Substance oxidized = reducing agent ⇒ C is a reducing agent

Give the comparison and characteristics of oxidizing and reducing agents using a chart.

Reducing agent	**Oxidizing agent**
Loses one or more electrons	Gains one or more electrons
Causes reduction	Causes oxidation
Undergoes oxidation	Undergoes reduction
Becomes more positive	Becomes more negative

Allow students to discuss ***Activity 1.4*** for few minutes. This Activity helps students to identify oxidizing agents and reducing agents in a reaction and the cause of oxidation and reduction. After the response of students explain to them that a more active element reduces the less active one. For example, potassium reduces all metals (strongest reducing agent).

Give students some redox reactions and let them balance using the methods discussed above. They may struggle to balance by LCM or an algebraic method. However, most redox reactions cannot be balanced by the methods discussed. Tell them that such reactions are balanced by the oxidation change method. Give them more examples and exercise for practice.

The students should also be informed about non-redox reactions as chemical reactions where the oxidation states of chemical elements remain unchanged in reactants and products. Neutralization and double displacement reactions are examples of non-redox reactions

Answers to Exercise 1.5

1.

A.	+2	F .	+5
B.	+6	G.	+6

C. +4 H. +3

D. +2.5 I. +6

E. +7

2.

a. Reduction b. Oxidation c Reduction d. Oxidation

e. Oxidation f Reduction

Answers to Exercise 1.6

1. Transition elements at the right of the periodic table such as silver and copper can easily be reduced (strong oxidizing agents) from their compounds. Alkali metals like potassium can easily be oxidized (strong reducing agents)

2. a. oxidation number decreases
   b. oxidation number increases
   c. oxidation number increases
   d. oxidation number decreases

3. a. ZnO = oxidizing agent , C = reducing agent
   b. Fe = reducing agent S_8 = oxidizing agent
   c. Fe_2O_3 = oxidizing agent CO = reducing agent
   d. PbS = reducing agent H_2O_2 = oxidizing agent

Answers to Exercise 1.7

a. $2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$

b. $2KClO_3 \rightarrow 2KCl + 3O_2$

c. $3MnO_2 + 4Al \rightarrow 3Mn + 2Al_2O_3$

d. $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$

1.5 Molecular and Formula Masses, the Mole Concept and Chemical Formulas

Total Alloted Period: 3 Periods

At the end of this section, students will be able to

☞ explain and determine molecular mass, formula mass, molar mass, empirical and molecular formulas

☞ describe the mole concept and solve problems related to moles of substances

Planning

Before you start teaching make the following preparation for this section.

☞ This section needs extensive calculations hence read the section and make sure that you have mastered all the contents

☞ Design a plan of your own that shows which contents and activities you will treat during each period, and when students should do exercises

☞ Plan how to follow -up when students discuss the suggested activities in the section.

☞ Plan how to implement the suggested methods for each topic in the section

Teaching Aids

No experiment has been suggested for this section.

Subject Matter Presentation

Group discussion, class and homework, individual and group assignments, and gapped lecture methods are recommended for teaching this sub-topic. Students should work on extensive exercises and their responses should be strictly checked,

- Introduce the topic of the section
- Continue your mini lecture by asking students to define oxidation and reduction.
- After students' responses, present the appropriate definition of oxidation and reduction

First, introduce the topic and then let the students discuss ***Activity 1.5*** for a few minutes. This activity enables students to discover how the quantities of extremely small particles like atoms, ions or molecules could be measured or expressed. During the discussion of the activity, observe how every student participates in each group. Help and guide groups that need it. Encourage students from the different groups to present their opinions to their classmates. Appreciate the attempts made by the students in presenting their opinions. In relation to the activity, you can ask questions about the units of measurements in their day-to-day activities; for example, about 'teff', wheat or chickpeas are expressed in kilograms or 'quintals' as it is difficult to count 'teff' or wheat seeds for practical purposes. Similarly, atoms or molecules are quantified in terms of moles, molar masses. Give the students the meanings of molecular mass, formula mass, moles, empirical formula and molecular formulas. Tell them that molecular mass (MM) of a compound is the sum of masses of all the atoms present in a molecule, and formula mass (FM) is the sum of the atomic masses of all atoms present in the formula unit of the compound, whether it is molecular or ionic. However, formula mass is used mostly for ionic compounds. Further, explain to them about the mole concept as it is the concept adopted as a convenient way to deal with the tremendous amount of molecules or ions. Like atoms, ions or molecules are extremely small particles, practically impossible to count them. So, this forces us to use a very large number of atoms or molecules as one unit. This unit is mole. Mole is the amount of any substance that contains Avogadro's number of particles of the substance. 6.02×10^{23} is known as Avogadro's number (NA), in honor of Amedeo Avogadro (1776 -1856, who first proposed the concept, and who also coined the word "molecule"). Finally, inform them of the meaning of the empirical and molecular formulas. The empirical formula is the simplest ratio of atoms present in the molecule. It merely tells us the proportion of atoms in the compound, but it doesn't show the exact number of atoms present in the compound. Several molecules may have the same empirical formula, For example, all of the molecules C_2H_4, C_4H_8, C_5H_{10}, C_6H_{12} have the same empirical CH_2. Molecular formula gives the exact number of atoms present in the molecule. Tell them the rules on how they can determine the empirical and molecular formulas with appropriate examples. Students should do extensive exercise as a classwork or homework in this topic. Students should know that molecular formula can be derived from empirical formula using the relation:

$$n = \frac{\text{molar mass of molecular formula}}{\text{molar mass of empirical formula}}$$

The mass of atoms may be given either in grams or percentage composition.

$$\text{Percent composition of an element} = \frac{n \times \text{Molar Mass of the element}}{\text{Molar mass of Compound}} \times 100\ \%$$

where *n* is the number of moles of the element in 1 mole of the compound

Varieties of activities can be given for the assessment

Suggested activities

- What is the main difference among the formula mass, molecular mass and molar mass?
- Describe the difference between molar mass and formula weight

Ibuprofen, $C_{13}H_{18}O_2$, is a covalent compound and the active ingredient in several popular nonprescription pain medications, such as Advil and Motrin. What is the molecular mass (amu) for this compound?

Aluminum sulfate, $Al_2(SO_4)_3$, is an ionic compound that is used in the manufacture of paper and in various water purification processes. What is the formula mass (amu) of this compound?

Which of the following represents the least number of molecules?

a 20.0 g of H_2O (18.02 g/mol)

b 77.0 g of CH_4 (16.06 g/mol)

c 68.0 g of CaH_2 (42.09 g/mol)

d 100.0 g of N_2O (44.02 g/mol)

e 84.0 g of HF (20.01 g/mol)

Answers to Exercises 1.8

1. Refer to student textbook
2. Refer to student textbook
3. A. K_2CO_3 = 2K atoms + 1C atom + 3O atoms = 6 atoms
   = $2K^+$ ions + 1 CO_3^{2-} = 3 ions
   B. $Ba_3(PO_4)_2$ = 3Ba atoms + 2P atoms + 8 O atoms = 13 atoms
4. A 1.00 mole of $Cu_3(PO_4)_2$ = 3 moles of Cu + 2moles of P + 8 moles of O
   B. 2.5 mole of Na_2CO_3 = 2 (2.25 moles) Na, 2.5 moles of C, 3 ×2.5 moles of O
   C. 2 moles of $Al_2(SO_4)_3$ = 2×2 moles of Al, 2×3 moles S + 2×12 moles of O
5. a. NaCl b. K_2CO_3
6. A) C_6H_6 B) $C_2H_4Cl_2$
7. 408.6 g/mole
8. A CH_4 = 16 B. NO_2 = 46 C. SO_3 =80 D. C_6H_6 =78 E. Na_2SO_4 =142
   F. $Ca_3(PO_4)_2$ = 290
9. A. C = 52.2% , H=13 %, O = 34.8 % B. Na= 42.1 %, P=18.8 %, O= 39 %
   C. H = 2.04%, S =32.65 %, O =65.31 % D. $CaCO_3$ Ca = 40 %, C = 12 %, O = 48 %, E. $K_2Cr_2O_7$, K = 26.53 %. Cr = 35.37 %, O = 38.1 %

1.6 Stoichiometry

Total Alloted Period: 8 Periods

At the end of this section, students will be able to

☞ deduce mole ratios from balanced chemical equations

☞ solve mass-mass problems based on the given chemical equation

☞ define molar volume

- state Avogadro's principle
- solve mass-mass problems based on the given chemical equation
- solve mass -volume problems based on the given chemical equation
- solve volume -volume problems based on the given chemical equation
- describe limiting and excess reactants

Planning

For the teaching of this unit, the following activities are recommended

- Read the contents of this section carefully and thoroughly to get familiarized with the concepts
- Set your own plan so that the contents and activities will be covered within 8 periods
- Make the necessary arrangements for assignments and group works

Subject Matter Presentation

Group discussion, question and answer methods are recommended for teaching lessons in this section.

First, introduce the topic of the section and follow the following activities

- Let the students discuss ***Activity 1.6*** for about 3 minutes. This activity is intended for the students to revise the three laws of chemical reactions.
- Follow the discussions and observe how each student participates in the discussion. Give guidance and assistance whenever they need it.
- After the completion of the discussion, allow the students from different groups to present the details of their discussion in their groups to their classmates. Ask the group to explain the three laws of reaction to the class through examples.

Students should know that stoichiometric calculations are done only for balanced chemical equations. Chemical equations are balanced in accordance with the Law of Conservation of Mass (one of the fundamental laws of chemical equation). The group should also discuss ***Activity 1.7***. This Activity helps students to understand the Law of Conservation of Mass. When wood burns, the products are ash and carbon dioxide gas. Carbon dioxide is usually escaped into the atmosphere and the weight of ash becomes less than the weight of the reactants. But if we collect the weight of carbon dioxide and add to the weight of ash, the total mass becomes equal before and after the burning of wood.

Ask students to define reaction stoichiometry and allow them to explain to the class. Then, use a mini- lecture to harmonize their ideas with concepts that they expected to know. Correct the student's mistakes and define reaction stoichiometry as the study of the quantitative composition of substances and the relationship that exists between the reactants and the products involved in chemical reactions.

Stoichiometric Relationships

Introduce to the students the presence of different ways of determining the quantity of reactants and products involved in the reaction as mole – Mass (**1.6.1**) or Mass-Mass (**1.6.2**), Mass – volume (**1.6.3**) and Volume-Volume relationships (**1.6 4**).

Students should be informed that one mole of any substance contains 6.02×10^{23} particles of the substance. This particle could be an atom, ion or molecule, and formula units. Let the students know the inter conversion of mass and mole as:

$$\text{Number of Moles} = \frac{\text{Given mass}}{\text{Molar mass}}$$

6 g of H_2O contains 36g/(18g/mol)=2 moles $=2 \times 6.02 \times 10^{23}$ H_2O molecules

Let the students recognize the interpretation of a balanced chemical equation as shown below:

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

$$\text{1 molecule } N_2 + \text{3 molecules } H_2 \longrightarrow \text{2 molecules } NH_3 \text{ (molecular interpretation)}$$

$$\text{1mol } N_2 + \text{3 mol } H_2 \longrightarrow \text{2 mol } NH_3 \text{ (molar interpretation)}$$

$$\text{28.0g } N_2 + \text{3x 2.02g } H_2 \longrightarrow \text{2 x 17.0 g } NH_3 \text{ (mass interpretation)}$$

In mas-mass relationship, the mass of one substance is given and the mass of another substance is calculated.

For example, in the reaction

$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$, how many grams of HCl are required to react with 25.0 g of MnO_2

The mass of MnO_2 is given in grams = 25 , Mass of HCl in grams = ?

25 g y

$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$,

86.9 g 4×36.5 (146 g)

(25 g)/(86.9 g) =y/(146 g)

$\Rightarrow y = 146 \text{ g} \times 25 \text{ g}/86.9 = 42$ g of HCl

From the given mass of MnO_2, the mass of HCl was calculated, hence this is a mass-mass stoichiometric relationship.

Note that stoichiometric problems can also be solved using the mole ratio or molar mass as conversion factors. The numbers in a conversion factor come from the coefficients of the balanced chemical equation.

In general, for mole –mole problems, mole A x mole ratio = mole B

Mass-Mass problems, gram A x 1mole A/ molar mass A x mole B/mole A x molar mass B/mole B = gram B

$4Al + 3O_2 \rightarrow 2Al_2O_3$

In example 1.30 (student text), coefficients of Al and Al_2O_3 are 4 and 2 respectively

Therefore, conversion factor = mole raio = 4 mol Al/2 mol O_2. Given molar masses, 1 mole Al_2O_3 = 102 g, 1 mole Al = 27 g

The conversion sequence follows :

grams of Al_2O_3 $\rightarrow$ moles of Al_2O_3 $\rightarrow$ moles of Al $\rightarrow$ grams of Al

Conversion factor: molar mass of Al_2O_3 mole ratio molar mass of Al

20.4 g x 1 mol Al_2O_3/102 g Al_2O_3 x 4 mol Al /2 mol Al_2O_3 x 27 g Al/1mol Al = 10.8 g

In mass-volume relationship, the volume of a substance is determined from the given mass of another substance. Similarly, volume-volume relationship involves the determination of volume of a substance from the given mass of another substance.

Let the students be informed of Avogadro's law of Equal Volumes as equal numbers of particles occupy equal volumes.

The stoichiometric relationships are discussed in sections 3.5.2- 3.5.4. Students should practice solving more stoichiometric problems until they gain confidence.

Let the students be informed about the mass-mole and mole-mass problems for completeness.

In mole-mass problems, the amount of one substance is given in moles and the mass of another substance is determined ,usually in grams and in mass-mole problems, the mass of one substance is given, usually in grams and the amount of another substance is determined in moles.

Students should practice the exercise using alternative techniques (the usual one as well as using conversion factor) for better understanding of stoichiometric problems.

You may use the general sequence of conversions for a mole-mass calculation:

1mol 1st substance → mol 2nd substance → mass 2nd substance

and for mass- mole calculation :

mass1st substance → mol 2nd substance → 1mol 2nd substance.

Mass - mass calculations

grams of A → moles of B → moles of B → grams of B

Mole-mole calculations

mole A x mole ratio = Mole B

Example 1: How many grams of CO_2 are produced if 2.09 mol of HCl are reacted according to this balanced chemical equation?

$CaCO3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

Solution : This is mole-mass calculation, using the above relation

2.09 g mol HCl x 1mol CO_2/2 Mol HCl x 44 g CO_2/ 1mol CO_2 =46 g CO_2

2. Methane can react with elemental chlorine to make carbon tetrachloride. How many grams of HCl are produced by the reaction of 100.0 g of CH_4?

$CH_4 + 4Cl_2 \rightarrow CCl_4 + 4HCl$

Solution : Using the mass-mass relation; you will get

100.0 g CH_4 ×1mol CH_4/16.05 g CH_4 × 4 mol HCl/ 1 mol CH_4 × 36.46 g HCl x 1 mol HCl

= 908.7

1.6.5 Limiting and Excess Reactants

Students should be informed that in most reactions, the reactants are not present in exact stoichiometric quantities and one of the reactants is converted completely while the other still in excess. Start discussion of limiting reactant with ***Activity 1.8***. This activity shows that the number of women (9) determine the female-male pair. Out of the 14 men in the contest 6 are without females. Hence, the number of women (lower number) are analogues to the limiting reactant and number of men (higher number) are analogues to the excess reactant. Allow students to discuss and explain the meaning of the activity and relate with the chemical reactions. You may allow students to discuss ***Activity 1.8***. In the activity, five men left without partners. Therefore, the number of women limit the number of men that can dance in the contest. The number of men is in excess. The reactant which is completely consumed first limits the reaction (no more reaction). The reaction that limits the reaction is called limiting reactant and the reactant in excess is called excess reactant. Show students how limiting reactants can be identified. The yield of the reaction is simply the amount produced by the limiting reactant. Allow students to practice in class and at home.

1.6.6 Theoretical, Actual and Percentage Yields

You may start this topic using Activity 1.10. This activity is about the preparation of Ethiopian 'Shiro powder' from chickpeas or another grain. The amount of chickpeas after making the 'shiro' decreases as only the pure form is extracted. Students should relate this analogy with percentage yield of the reaction products.

Ask students whether it is possible to get 100 % yield in reactions or not. Usually, getting 100 % reaction yield is not possible. What would be the possible reason? Once you have accepted students' responses, give them the meaning of theoretical yield, actual and percentage yields. The theoretical yield is the amount calculated from the stoichiometric equation while actual yield is the amount actually measured and the relationship between the actual and theoretical yields is percentage yield.

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\ \%$$

Example: What will be the percent yield of aluminum oxide if 51 g of aluminum oxide is produced from the reaction of 54 g of Al with excess oxygen ?

Actual yield of Al_2O_3 = 25.5 g

Theoretical yield of Al_2O_3 is determined from the balanced chemical equation'

$$\begin{array}{lll} 54\text{g} & & \text{X} \\ 4\text{Al} & + 3\text{O}_2 \rightarrow & 2\text{Al}_2\text{O}_3 \\ 108\text{ g} & & 204\text{ g} \end{array}$$

$54\text{g}/108\text{g} = X/204\text{g} \Rightarrow \times = (54 \times 204)/(108\text{ g}) = 102\text{ g}$

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\ \%$$

Percentage yield = $(51/102) \times 100\ \% = 50\ \%$

Promoting Active Learning

A range of activities can be used to ensure students learn the expected content knowledge of this section. Some are identified and elaborated below.

Suggested activities

- list elements of the Periodic Table and their known isotopes and calculate the relative atomic masses of these isotopes.

- conduct exercises involving calculation of relative formula mass, relative molecular mass, percentage composition in compounds, moles and the significance of Avogadro number.
- conduct exercises to calculate the empirical and molecular formula.
- conduct exercises to compare masses or volumes of products (solids, liquids, gases) formed by a chemical reaction with the mass or volume calculated from the equation at room temperature and pressure (rtp) or at standard temperature and pressure (stp)

Activity	Elaboration
Prepare exercises involving calculation of relative formula mass, relative molecular mass, percentage composition in compounds, moles and the significance of Avogadro's number.	Teachers do an example on each type of calculation and give exercise for the students to do
List elements of the Periodic Table and their known isotopes and calculate the relative atomic masses of these isotopes.	Students calculate the relative atomic mass (RAM) by multiplying the percentage composition by the mass of each isotope.

Test or assignment

You may give students assignment or test for your assessment

Suggested topics

1. Calculate moles of substances in a given solution.
2. Calculate empirical and molecular formula.
3. Calculate amount of reactants and products from a reaction.
4. Take the reaction: $NH_3 + O_2 \rightarrow NO + H_2O$. In an experiment, 3.25 g of NH_3 are allowed to react with 3.50 g of O_2.

   A. Which reactant is the limiting reagent? O_2

   B. How many grams of NO are formed? 2.63 g NO

   C. How much of the excess reactant remains after the reaction? 1.76 g NH_3 left

Answers to Exercise 1.9

1. B   2. 2.25 mol   3. 6.6 moles   4. 0.03 mol   5. 20.82 g   6. 9.77 g

7. a) $3H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$

Given: Moles of SO_2 = 4, Molar mass of H_2S = 34g/mole, Required: Mass of H_2S

This is a mole -mass relation, thus

$$4 \text{moles } SO_2 \times \frac{3\text{moles of } H_2S}{2\text{moles of } SO_2} \times \frac{34 \text{ g } H_2S}{1\text{Mole of } H_2S} = 204\text{g of } H_2S$$

b) $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

Given Mass of $CaCO_3$ = 50 g, Molar mass of CO_2 = 44 g/mole, Required: Mass of CO_2

This is a mass -mole relation, thus

$$50 \text{ g } CaCO_3 \times \frac{1\text{moles of } CaCO_3}{100 \text{ g } CaCO_3} \times \frac{1\text{mole } CO_2}{1\text{mole}CaCO_3} = 0.5\ CO_2$$

Answers to Exercise 1.10

1. 16.8 liters of N_2 2. 9.6 liters of SO_3 3. 116 liters of NH_3 4. 168 liters of O_2
5. 2.23 moles

Answers to Exercise 1.11

1. 336 liters of O_2
2. 298.7 g
3. 0.286 g
4. 3,046 milliliters

Answers to Exercise 1.12

1. A. HCl B. 2.05 g C. 0.14 g
2. 71 g
3. 8.8 g of $CaCO_3$
4. A. Ca is the limiting reactant B. 3 moles of CaO
5. 2 g of H_2 is produced

Answers to Exercise 1.13

1. Yield = 63.4 %
2. $2SO_2 + O_2 \rightarrow 2SO_3$, the limiting reactant is SO_2 and 16.9 g of SO_3 is produced, % yield = 12/16.9 x 100 % =71 %
3. Yield = Actual yield/ theoretical yield, the calculated (theoretical) yield from the equation is 160 g, therefore the actual yield = % yield x theoretical yield = 0.855 x 160.6g = 137 g

Answers to Review Exercise

Part I:

1. True 2. False 3. False 4. True 5. True

Part II:

6. +7 7. The limiting reactant 8. Non-redox reactions

9. Molecular mass
10. Formula mass
11. Empirical formula
12. Molecular mass

Part III:

13. D 14. A 15. A 16. A

Part IV:

17. 4 moles
18. 0.6 g
19. A. NH_3 B. 58.8 g C. 52.9 g
20. 25 %
21. A. Empirical formula: CH_2 B. Molecular formula, C_2H_4 for 28.03 , C_4H_8 for 56.06
22. B_2H_6
23. The empirical formula of acetic acid is CH_2O and the molecular formula of acetic acid is $(CH_2O)_2$, or $C_2H_4O_2$
24. Balance the following equations using any method:

a. $6H_3BO_3 \rightarrow H_4B_6O_{11} + 7H_2O$

b. $10P_2I_4 + 13P_4 + 128H_2O \rightarrow 40PH_4I + 32H_3PO_4$

Let us see how it is done: $aP_2I_4 + bP_4 + cH_2O \rightarrow dPH_4I + eH_3PO_4$

P: $2a + 4b = dp + ep$

I: $4a = d$

O: $c = 4e$

H: $2c = 4d + 3e$

Simplify the equation by replacing the coefficients of Iodine(d=4a) and Oxygen(c =4e) in coefficients of phosphorous and hydrogen

P: $2a + 4b = d + e = 4a + e$

$4b = 2a + e$

H : $2 \times 4e = 4d + 3e$

$5e = 4d$

Therefore, we have now

$4b = 2a + e$

$4a = d$

$5e = 4d$

$c = 4e$

Assume, a=1. $d = 4$; $e = 16/5$, $c = 64/5$, $b = 13/10$

Multiply all by 10 to convert to whole numbers

a = 10, b = 13, c = 128, d = 40, e =32,

$10P_2I_4 + 13P_4 + 128H_2O \rightarrow 40PH_4I + 32H_3PO_4$ (balanced equation)

c. $12HClO_4 + P_4O_{10} \rightarrow 4H_3PO_4 + 6Cl_2O$

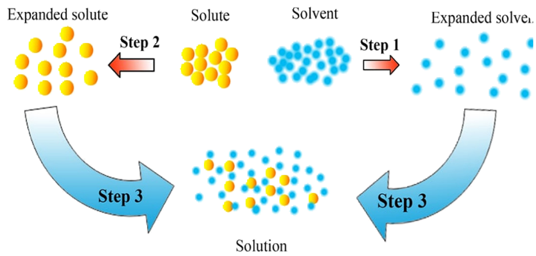
d. $3H_2S + 2HNO_3 \rightarrow 3S + 2NO + 4H_2O$

e. $H_2SO_4 + 2HBr \rightarrow SO_2 + Br_2 + 2H_2O$

f. $2KMnO_4 + 16HCl \rightarrow 2MnCl_2 + 5Cl_2 + 2KCl + 8H_2O$

g. $10K + 2KNO_3 \rightarrow N2 + 6K_2O$

UNIT 2



SOLUTIONS

Unit Outcomes

At the end of this unit, students will be able to

- explain the types of solutions;
- describe the solution formation process, the rate of dissolution, the heat of solution and solubility;
- describe the dependence of solubility on temperature & pressure of solution;
- solve problems involving concentration of solutions & express the result in various units;
- express the concentration of solutions in various units;
- describe, using the concept of equilibrium, the behavior of ionic solutes in solutions that are unsaturated, saturated and supersaturated;
- prepare solutions of required concentration by dissolving a solute or diluting a concentrated solution;
- demonstrate scientific enquiry skills along this unit: observing, classifying, comparing & contrasting, communicating, measuring, asking questions, drawing conclusion, applying concept and problem solving.

UNIT OVERVIEW

Total Periods allotted: 21 Periods

This unit deals with solutions, types of solutions, the solution process, concentration units, solution preparation, stoichiometry and reactions in solutions. The unit starts with a startup activity. Before anything, students need to set a goal and get motivated to learn the subject matter. Attempt is made to help students associate their previous knowledge with the new concept. To this end, an incomplete concept map has been included. ***Section 2.1*** deals with two types of mixtures: homogeneous and heterogeneous mixtures. ***Section 2.1.1*** deals with suspensions, solutions, and colloids. ***Section 2.2*** deals with solution processes in terms of inter-particle forces of interaction. Illustrative examples and activities are given for gases, liquid, and solid solutions. The energy changes, the effect of temperature and pressure on solubility are discussed. Solutions of liquids in liquids, the rate of dissolution and energy changes in the solution process including heat of solution and heat of hydration (ionic solids in water) are also presented. ***Section 2.3*** deals with solubility as an equilibrium process where the differences among unsaturated, saturated, and supersaturated solutions are discussed. This section also presents the effect of temperature on the solubility of solids, the effect of temperature on solubility of gases, and the effect of pressure on the solubility of gases (Henry's law). ***Section 2.4*** deals with ways of expressing the concentrations of solution including percent by mass, parts per billion, mole fraction, molarity, molality, and normality. Conversion of concentration units is also discussed in this section. ***Section 2.5*** deals with the preparation of solutions. Solution stoichiometry and describing reactions in solution are discussed in ***Section 2.6*** and ***Section 2.7*** respectively.

The unit starts with a startup activity that is designed to motivate the students, help them set their own goals on the topic, identify and relate the material they are going to learn in the topic to their daily life, clarify the path ahead and improve self-image. Remember that teachers play an unparalleled role in shaping the youth. Here, it is important to remember the quotes of Aristotle. "Aristotle says that a youth who has received a good upbringing will enjoy acting virtuously. Youth, according to Aristotle, are enslaved to their desires. Each day they seek to gratify what their appetite for pleasure dictates." Thus, in addition to the directions cited in the student textbook, you, as a teacher, have a great responsibility to give students purpose, help them set goals for success, and inspire them to do well and succeed in their life. You can influence their way of thinking, for instance, by asking them to reflect on what they are good at or bad at, and what they want to improve and how.

You may begin the unit as follows:

- Write the topic on the board
- Be highly passionate about the topic as you inform them that they are going to learn a very important topic that is quite relevant to their daily life. Use the examples cited in this section.
- Access the learners' prior knowledge and help them become engaged in the new concept through the use of the concept map; help students to activate their prior knowledge. Use a chart of the concept map as **teaching aid**.
- Organize them in groups or pairs whichever is convenient and advise them to do the start-up Activity.
- Correct students responses as A = Pure substances, B = Mixtures, C= Heterogeneous mixtures, D = Homogeneous mixtures, E = Elements, and F = Compounds

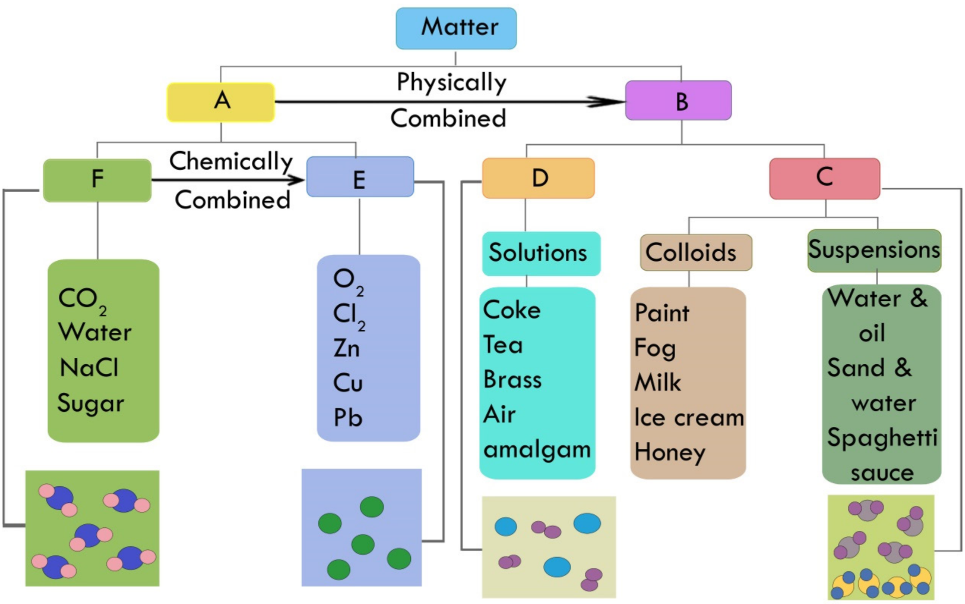


Table 2.1 Tentative distribution of periods to each section/subsection

SN	Unit/ Section	Section/Subsection	Activity	Experiment	Exercise			#Period suggested
					Classwork	Homework	Assignment	
1		Introduction/Start-up activity						1
2		Heterogeneous and Homogeneous Mixtures	2.1	2.1				
	2.1	Suspensions, Solutions, Colloids						
3		Suspensions, Solutions*				2.1		1
4		Colloids**	2.2	2.2			2.2	1
5	2.2	The Solution Process						3
		Liquid Solutions and Inter-particle Forces of Attractions (Like dissolves like rule, molecular polarity, inter-particle forces)		2.3				
6		Solutions of Ionic Solids in Water						2
		The Solubility Rules for Ionic Solids	2.3					
7		Solution of Liquids in Liquids				2.3		1
		Rate of dissolution	2.4					
8		Energy Changes in Solution Process*	2.5	2.4		2.4		2
	2.3	Solubility as an Equilibrium Process						
9		2.3.1 Unsaturated, Saturated, and Supersaturated Solutions	2.6	2.5				1
		Factors affecting solubility						
10		Effect of Temperature on Solubility of Solids		2.6				1
11		Effect of Temperature on Solubility of Gases	2.7					
12		Effect of Temperature on Solubility of Gases	2.8		2.5			
13	2.4	Ways of Expressing Concentration of Solutions						1
		2.4.1 Percent by Mass/Volume					2.6	
14		Mole Fraction			2.7			
15		Molarity				2.8		1
		Molality			2.9			
16		Normality				2.10		2
17		Conversion of Concentration Units				2.11		1
18	2.5	Preparation of Solutions						1
19		Diluting a Solution					2.12 and 2.13	
20	2.6	Solution Stoichiometry				2.14-2.16		1
21	2.7	Describing Reactions in Solution				2.17		1
								21
		*Projects to be carried out by students in convenient time schedule						

2.1 Heterogeneous and Homogeneous Mixtures

Competencies

At the end of this unit, students will be able to

- define the terms mixture, homogenous and heterogeneous mixtures, solute, solvent, solution.
- distinguish between homogenous and heterogeneous mixtures
- describe suspension and colloids
- explain the different types of solutions.
- give examples for each types of solutions
- present a report on how jewelry gold is made to class after a visit to nearby goldsmith

Planning

Read the student's textbook and other reference materials in advance to familiarize yourself with the topic and to plan your lesson. Make sure that the necessary materials are available to do the ***Experiments 2.1***. Make a plan for managing students when they experiment in groups. Prepare flashcards each bearing the names of the suggested mixtures in ***Activity 2.1*** on one side and the word HOMO or HETERO on the other side as appropriate.

Teaching Aids

Flash cards, and materials required include beakers, spatula, stirrer, table salt (NaCl), water, ethanol, lemon water, and oil.

Subject Matter Presentation

Gapped lectures process-oriented inquiry learning, demonstrations, experimentation, and discussions, are the suggested methods. Begin the section by letting students discuss ***Activity 2.1***. Let them decide as you show up each of the flash cards on what is on the reverse side of the card-HOMO or HETERO. The flash cards may be prepared as sand + water on one side and Hetero on the reverse side. Similarly you can do for, coffee (one side) = HOMO (reverse side), tea = HOMO, seawater = HOMO, air = HOMO, brass = HOMO, steel = HOMO, natural gas = HOMO, pizza = HETERO, vinegar = HOMO, vegetable salad = HETERO, and fruit punch = HETERO. Then let them try to categorize blood, milk, and cloud. For sure, they would tell you that these are HOMO. But you have to correct their responses. Although blood, butter, milk, and cloud appear homo, they are different from other HOMOs such as sea water. So, they are classified as heterogeneous. Harmonize their responses as you proceed with a gapped lecture. Start with the definitions and help the students clear their misconceptions. Arrange a laboratory session and let them ***Experiment 2.1***. If measuring balance is not available you may advise students to use a tea spoonful of the salt instead of measuring 10 g using a balance. Similarly a soup spoonful of a liquid may be used if graduated cylinders are not available and glasses for drinking water instead of beakers.

2.1.1 Suspensions, Solutions, and Colloids

Planning

Read the student's textbook and other references ahead of time to familiarize yourself with the topic and to plan your lesson. Plan how to encourage students' participation in *Activity 2.2*. Make a plan for managing students when they work in groups and arrange time and materials for ***Experiment 2.2***.

Subject Matter Presentation

Gapped lecture, discussions and inquiry-based learning are some of the suggested methods in this section. Start this lesson with an inquiry. You may, for instance, ask them if they know the differences among suspensions, solutions, and colloids. After harmonizing their responses, you can define suspensions, give one example, and ask students to suggest more examples. Again, you can ask them to suggest the properties of suspensions. After appreciating their attempts, you start to discuss the properties cited in student textbook. As you mention the first let them try the second. In this way you can make inquiry-based learning on suspensions and solutions. Construct the following table on the blackboard and invite one student at a time to fill each box with examples.

State of solute	State of solvent	State of solution	Type of solution	Examples
Gas	gas	gas	Gas-gas	
gas	liquid	liquid	Gas-liquid	
liquid	liquid	liquid	Liquid-liquid	
solid	liquid	liquid	Solid-liquid	
solid	solid	solid	Solid-solid	

Arrange a time for a visit to a nearby goldsmith for Project 2.1 which promotes inquiry-based learning. In project works, students become more responsible for their own learning. Orient them on how to form a self-managed group with assigned tasks to each member.

Colloids

Planning

Read the student's textbook and other references ahead of time to familiarize yourself with the topic and to plan your lesson. Make sure that the necessary materials are available to do ***Experiments 2.2***. Make a plan for managing students when they experiment in groups.

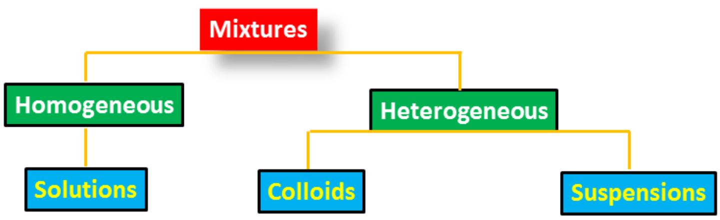
Teaching Aids

Three 100 mL beakers (can be any available beaker), sand, milk and bile.

Subject Matter Presentation

Discovery learning, gapped lecture, and discussions are suggested methods in this section. Start this lesson by asking students to define colloid and give example. Praise correct responses and write the correct definition on the board. Provide them an example and ask them to come up with more examples. Ask them whether a colloid is classified as homogeneous or heterogeneous.

Note to a teacher: Some books classify colloids as homogeneous mixtures while others classify them as heterogeneous. Correct misconceptions, if any; colloids appear uniform as if they were homogeneous. However, their particles are larger and display stable Tyndall effect. The particles of colloids are not atoms, ions, or molecules, but undissolved and dispersed fine solids. That is the distinction between a colloid and a solution (homogeneous mixture). Advise the students to have a look at Tyndall effect ***Figure 2.1*** and ask them whether they have ever come across with such observation. Write the correct definition of colloid on the board. Ask them to read on the types of colloids in the textbook. Let them copy ***Table 2.1***. Check them if they are clear with emulsion, aerosol, sol, foam, and gel. Summarize the distinction between homogeneous and heterogeneous mixtures using a chart of the following tree diagram;



Activity 2.2 focuses on the application of learned material in real world. Give them a hint as the observation is related to the properties of colloids. Let them remember the presence of colloidal particles in the atmosphere and think about what happens to the light from the sun as it passes through this colloidal system. Ask them if they know something about properties of light (diffraction, scattering, reflection, etc.,) from their physics. Harmonize their answer using the following possible answer: 'As white light passes through our atmosphere, tiny colloidal particles in the air cause it to 'scatter'. Therefore, blue light is scattered more than red light and hence the sky appears blue during the day.' Assign ***Experiment 2.2*** as homework to do in a group or individually as per their convenience to report in next class. Give bonus marks to those who did the experiment and presented it to class. Correct misconceptions, if any.

Ask them the mechanism of milk curdling or even how the cloud seeding happens to form artificial rain.

Correct their opinion and write the definition and give examples.

Write the applications (milk curdling, cloud seeding, wastewater treatment, etc.) on board. Coagulation is one of the common methods used by water treatment plants to provide safe, clean drinking water to public water customers. Coagulation is the chemical water treatment process used to remove solids from water by manipulating electrostatic charges of particles suspended in water. The coagulation process usually involves adding iron or aluminum salts, such as aluminum sulphate or ferric sulphate to the water. These chemicals are called coagulants, and have a positive charge. The positive charge of the coagulant neutralizes the negative charge of dissolved and suspended particles in the water. When this reaction occurs, the particles bind together, or coagulate (this process is sometimes also called flocculation). The larger particles, or floc, are heavy and quickly settle to the bottom of the water supply. This settling process is called sedimentation. Advise them to form a self-managed group with defined tasks as manager, recorder (photo, video), speaker, and writer consisting of 4 members each and do projects, ***Project 2.2***. Follow the same strategy for association colloids as you did for coagulation.

Advise students to do ***Project 2.3*** in a self-managed group with defined tasks as manager, recorder (photo, video), speaker, and writer consisting of 4 members each and present results in class. Give optimum time for the projects and assist them as deemed necessary. You may use alternative examples such as discussing the mechanism of milk as additional application of coagulation in their daily life. You may ask students to explain why the sedimentation step is usually preceded by a chemical process known as coagulation during water treatment. And correct their responses as "suspended particles cannot be removed completely by simple settling. Large, heavy particles settle out readily, but smaller and lighter particles settle very slowly or in some cases do not settle at all. Because of this, the coagulation step is required, after the first sedimentation by plain settling, to facilitate further sedimentation of smaller and lighter particles.

Assessment

Assess each student's work throughout ***Section 2.1***. Carefully check how every student is working in the teaching-learning process. In your permanent performance list, record each student's participation. Attention should be given to the projects. Please do not underestimate students' capacity. If you encourage them, they can do the suggested projects. From your records, see whether or not the competencies suggested for ***Section***

2.1 are achieved by most of the students. Praise students working above the minimum required level and assist those working below the minimum required level. To assess the attainment of the minimum required level, ask the students varieties of questions. For example, you can ask them about the differences between homogeneous and heterogeneous mixtures, colloids and solutions. You can also ask them to define the terms solute, solvent and solution. Assign ***Exercise 2.1*** and ***Exercise 2.2*** as homework and record the marks in your permanent mark list.

Answers to Exercise 2.1

1.

Solute	Solvent	State of the solution	Example
Gas	Gas	Gas	Producer gas, water gas, etc
Gas	Liquid	Liquid	Ammonia in water, HCl (gas) in water
Liquid	Liquid	Liquid	Carbon tetrachloride in hexane
Solid	Liquid	Liquid	Brine
Solid	Solid	Liquid	Potassium–Sodium alloy
Solid	solid	solid	Bronze (copper-tin alloy), brass (copper–zinc alloy), stainless steel (Fe, C, Cr, Ni), Solder (tin-lead alloy), Nichrome (nickel-chromium alloy)
Gas	solid	solid	H_2 in Pt
liquid	solid	solid	Mercury in zinc amalgam

2. a) Glass is a homogeneous mixture of sodium silicate and calcium silicate.

b) Sand is a heterogeneous mixture of SiO_2 and a lot of other organic and inorganic particles.

c) cement is a heterogeneous mixture of calcium silicates and aluminates

d) Water gas is a homogeneous mixture of CO and H_2.

e) Producer gas is a homogeneous mixture of CO and N_2.

3. Colloidal sulfur particles are negatively charged with thiosulphate ions, $S_2O_3^{2-}$, and other ions on the surface of the sulphur. Which of the following would be most effective in coagulating colloidal sulfur, NaCl, $MgCl_2$, or $AlCl_3$? The answer is $AlCl_3$ because of its charge (see student textbook).

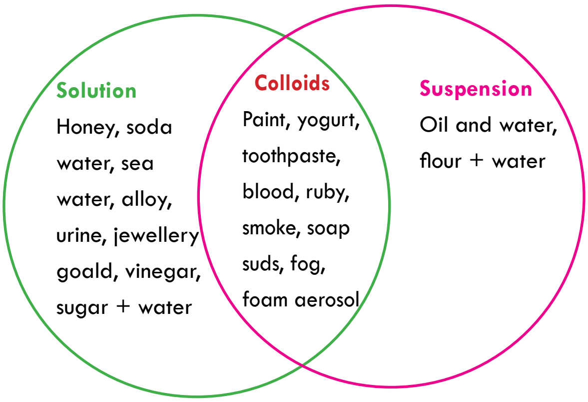
Answers to Exercise 2.2

1. Explain the cleansing action of soap (see student textbook)
2. Discuss the difference between suspension and colloid (see student textbook)

3. When a corona virus-infected patient coughs or sneezes, fine droplets of respiratory fluid containing the viral particles get dispersed in the atmosphere as a colloidal particle called__B__

A. emulsion B. aerosol C fog D. smoke (choose the correct answer)

4. A vein diagram showing the classification of mixture as solution colloid, and suspension.



2.2 The Solution Process

Competencies

- At the end of this section students will be able to
- explain how the "like dissolves like" rule depends on interparticle forces of interactions and predict relative solubilities;
- define rate of dissolution;
- define heat of solution, solvation energy and hydration energy.
- apply the concept of heat of solution to the solution of ammonium nitrate crystal.
- apply the concept of heat of solution to the solution of sodium hydroxide crystal;
- explain how heat of solution is influenced by the inter particle interaction forces.

2.2.1 Liquid Solutions and Inter-particle Forces of Attractions

Planning

Read the student's textbook and other references ahead of time to familiarize yourself with the topic and to plan your lesson. Make sure that the necessary materials are available to do ***Experiments 2.3***. Make a plan for managing students when they experiment in groups.

Teaching Aids

A chart of the conceptual map for determining intermolecular forces in a sample, measuring cylinder, test -tubes (8), test tube rack, spatulas, stirring rods, $KMnO_4$(*s*), I_2 (*s*), sucrose (*s*), vegetable oil, cyclohexane. Please inform students in advance to pay attention to the safety precautions cited in their textbook while handling harmful and flammable substances.

Subject Matter Presentation

Start this section with a question about the difference between solid, liquid, and gas. What holds solids and liquid particles intact? Why do gases expand indefinitely? Explain the answers to these questions using a gaped lecture. Ask them what they know about the dissolution of NaCl and oil in water. Which one mixes? Ask them to explain why? This will help you bridge the gap between their previous knowledge and the new concept. Then explain to them that solubility is largely dependent on these intermolecular forces of interaction and to a lesser extent on the conditions such as surface area, temperature, and pressure. Explain to them that the solution process involves three interactions using the illustrating ***Figure 2.3***.

Now, draw the following Table on the blackboard. After giving one example each, invite students to come out and write one more example of each category on the blackboard.

Solute	Solvent	Intermolecular force	Example
Polar, no O-H, N-H, or F-H bonds	Polar	Dipole-dipole	HBr and HCl
Non -polar	Polar	Dipole-induced dipole	I_2 and H_2O
Non-polar	Non- polar	Dispersion forces	I_2 in CCl_4
Ionic compound	Polar	Ion-dipole	NaCl and H_2O
Ionic Compound	Non-polar	Ion-induced dipole	$FeCl_3$ in Benzene
Polar, with O-H, N-H, or F-H bonds	Polar, with O-H, N-H, or F-H bonds	H-bonding	NH_3 and H_2O

2.2.2 Solutions of Solids in Water

Subject Matter Presentation

Make a gapped lecture on this topic. Explain to them that although the ion-dipole interaction is the expected type of force that occurs when ionic compounds dissolve in water, not all of them behave the same way. Some ionic compounds dissolve readily in water, some very slightly, and some do not at all. Why? Don't bother students with this question. Because one of the factors that affects solubility is entropy, they will learn this upper grades. But the enthalpy is discussed in the subsequent section. For now, present the solubility rule which can be used to predict the solubility of ionic compounds in water.

2.2.3 The Solubility Rules for Ionic Solids

Let them copy solubility rules. Then, you write the following compounds and ask them to decide soluble or insoluble according to the solubility rule. KNO_3, NH_4Cl, $PbCl_2$, $AgCl_2$, $BaSO_4$, $Al(OH)_3$, etc. In this way, familiarize students with how to study. Now, let them do ***Activity 2.3***.

Answers to Activity 2.3

Both quicklime (CaO) and slacked lime ($Ca(OH)_2$) are calcium-containing inorganic compounds. Since calcium fluoride is insoluble in water (see solubility rule), the Ca^{2+} from the lime combines with F- in water and removes the fluoride from the water by precipitating as CaF_2.

2.2.4 Solution of Liquids in Liquids

Briefly explain what miscible and immiscible means and let them do ***Exercise 2.3*** as a classwork.

Answers to *Exercise 2.3*

1. C
2. D
3. Due to the presence of hydrogen bonding in H_2O which is stronger than the ordinary dipole-dipole force in H_2S.
4.
   a. $BaCO_3$, insoluble
   b. $AlCl_3$, soluble
   c. MgO, insoluble
   d. $Al(OH)_3$, insoluble
   e. KI, soluble
   f. $Al_2(SO_4)_3$, soluble
   g. $Ca_3(PO_4)_2$, insoluble
   h. $PbCl_2$, insoluble
   i. $AgNO_3$, soluble
   j. $(NH_4)NO_3$, soluble
   k. NH_4Cl, soluble
5. (a) water and alcohol = miscible (b) "tej" and water = miscible (c) water and oil = immiscible (d) water and honey juice = miscible (e) water and petrol = immiscible (f) gasoline and naphtha = miscible

6.

(a) HBr and H_2S interact via dipole-dipole forces

(b) Cl_2 and CBr_4 interact via dispersion (London) forces

(c) I_2 and NO_3- interact via ion-induced dipole

(d) NH_3 and C_6H_6 interact via dipole-induced dipole

Additional Exercises

Explain each of the following

a. CO_2 has polar bonds, but the molecule is non-polar

b. H_2O has polar bonds, and the molecule is also polar

c. CCl_4 is non-polar molecule, but $CHCl_3$ is polar

Answer to Additional Exercises

a. CO_2 has zero net dipole moment because of the linear geometry that allows the dipole moments to cancel each other.

b. H_2O molecule has a net dipole moment because of the V-shape arrangement of the bonds

c. The tetrahedral arrangement of bonds in CCl_4 leads to the cancellation of dipole moment. But in $CHCl_3$, one of the four dipoles (i.e. C-H dipole) is different from the other three (C-Cl). This leads to a residual (net) dipole, though the molecule assumes tetrahedral arrangement, and makes the molecule polar.

Plan a laboratory session for ***Experiment 2.3***. Provide them with the necessary materials including test- tubes and advise them to experiment in groups (you determine the group size). Tell them to report their finding using the following format.

Solute	Solubility in Water	Solubility in cyclohexane	Interparticle forces of interaction
$KMnO_4$			
I_2			
Sucrose			
Vegetable			

2.2.7 The Rate of Dissolution

Define dissolution and briefly introduce what we mean by rate. The rate of solution is the amount of solute dissolved per unit time. It refers to how fast a solute dissolves in a given solvent. Ask them what happens when butter is added to food at cold temperature? What about when heated. Then, ask them to predict the solubility of solids as temperature increases, or decreases. Then explain to them that the rate of dissolution is largely depended upon two factors: the inter-particle forces discussed so far and, to a lesser extent, on conditions such as the surface area of the solid solute, and the temperature and the pressure of the system. Inter-particle force is the extent to which solvent molecules interact with particles of the solute. When the solvent-solute interactions are stronger than those between solute-solute and solvent-solvent particles, the dissolution process becomes easier. Increasing surface area will increase the rate of dissolution because it increases the number of solute particles in contact with the solvent. Let them do ***Activity 2.4*** in groups.

Answers to Activity 2.4

The mechanical digestion in the mouth involves a coarse reduction of the size of foodstuff particles, increasing their surface area to make their **chemical digestion** easier. It aids the dissolution and action of digestive enzymes on food.

2.2.8 Energy Changes in Solution Process

Subject Matter Presentation

Process-oriented inquiry learning, gapped lecture, and visual learning are suggested methods here. Tell them that enthalpy (heat) changes occur when a solute undergoes the physical process of dissolving into a solvent. Explain the important definitions such as dissolution, solvation, and the heat of solution also referred to as the enthalpy of solution or enthalpy of dissolution. And, explain the heat of solution equation:

$$q = m \times Cg \times \Delta T$$

Then, explain the three steps involved in the solution process:

Step 1. Solute particles separate from each other.

Step 2. Solvent particles separate from each other.

Step 3. Solute and solvent particles mix and form a solution. In each step indicate the energy change, whether the enthalpy change is negative or positive.

Students should be clear with the fact that solids and liquids particles are held together by interparticle forces. These forces must be broken and the solute particles get separated to allow dissolution. Thus, both step 1 and step 2 require energy while step 3 releases energy. If the amount of energy released is greater than the sum of the energy costs from step 1 and step 2, the dissolution is exothermic. In the opposite case, the dissolution is endothermic. Then explain to them the overall process as it is called a *thermochemical solution cycle. Then briefly introduce them* Hess's law, where we combine the three individual enthalpy changes to find the **heat** (or *enthalpy*) **of solution (ΔHsoln),** the total enthalpy change that occurs when solute and solvent form a solution:

$$\Delta H_{soln} = \Delta H_{solute} + \Delta H_{solvent} + \Delta H_{mix}$$

Explain endothermic and exothermic dissolution processes and give them at least two examples each. Examples of exothermic processes: dissolution of NaOH, KOH, mixing concentrated acid with water

Heat of Hydration (Ionic Solids in Water)

The gapped lecture method is suggested here. Explain to students that the ΔHsolvent and ΔHmix components of the solution are difficult to measure individually. Combined, they equal the enthalpy change for **solvation,** the process of surrounding a solute particle with solvent particles. Solvation in water is called **hydration.** Thus, enthalpy changes for separating the water molecules (ΔHsolvent) and mixing the separated solute with them (ΔHmix) are combined into the **heat** (or *enthalpy*) **of hydration (ΔHhydr):**

$$\Delta H_{soln} = \Delta H_{solute} + \Delta H_{solvent} + \Delta H_{mix} = \Delta H_{hydration} + \Delta H_{Latice\ energy}$$

The heat of hydration is a key factor in dissolving an ionic solid. Breaking H bonds in water is more than compensated for by forming the stronger ion-dipole forces. So, hydration of an ion is *always* exothermic.

Ask them "What is lattice energy? How can it affect the solubility of ionic solids?" Correct their misconceptions, if any. Write the definition on the blackboard and let them copy. Explain this using ***Figures 2.9***. This figure is very helpful to explain the competing effects of lattice energy and hydration. Please advise students to refer to this figure in their textbook. Define hydration and hydration shell. Check that the students are clear with the fact that hydration energy is involved in the separation of the solute particles and enhancing dissolution whereas lattice energy resists the separation of solute particles and dissolution.

Now, you can pause the lecture and talk with the students about their experiences of treating tenderness (inflammation) and other severe pains due to injuries. After harmonizing their responses, explain how colds packs and hot packs are used in hospitals for the same purpose. Explain the dissolution process and the energy changes involved. Use these as applications as a means to motivate students. Students are interested to know the application of what they are learning in real life.

Hot packs and cold packs (see ***Figure 2.10***) use this property. Many hot packs use calcium chloride, which releases heat when it dissolves, according to the equation below.

$$CaCl_2(s) \rightarrow Ca^{2+}(aq) \quad + \quad 2Cl\text{-}(aq) \ + 82.8 \text{ kJ}$$

Explain this equation to the students. Let them understand that the 82.8 kJ on the product side indicates the amount of heat released. This is true for exothermic processes. Tell them to use similar equations when they describe exothermic processes or reactions. They can simply put + ΔH on the product side of the balanced equation if the specific amount of heat released is not known.

You may use the case of cold packs to explain endothermic dissolution processes. Many cold packs use ammonium nitrate, which absorbs heat from the surroundings when it dissolves.

$$NH_4NO_3(s) \ + \ 25.7 \text{ kJ} \ \rightarrow \ NH_4^{+}(aq) \ + \ NO_3\text{-}(aq)$$

Let them understand that the 25.7 kJ on the reactant side indicates the amount of heat absorbed by the solution from the surrounding. This is true for endothermic processes. Tell them to use similar equations when they describe endothermic processes or reactions. They can simply put + ΔH on the reactant side of the balanced equation if the specific amount of heat absorbed is not known. Now, you can let them do ***Activity 2.5*** in groups and after harmonizing their responses you can arrange lab session to let them do ***Experiment 2.4*** and report the findings in class. Use project 2.5 to promote learning through inquiry.

Answers to Activity 2.5

1. Many people use **hot** and cold treatments at home to alleviate aches and pains caused by muscle or joint damage. Chemical hot packs and cold packs work because of the heats of solution of the chemicals inside them. When the bag is squeezed, an inner pouch bursts, allowing the chemical to dissolve in water. Heat is released in the hot pack and absorbed in the cold pack.

Many cold packs use ammonium nitrate, which absorbs heat from the surroundings when it dissolves.

$$NH_4NO_3(s) + 25.7\ kJ \rightarrow NH_4^+(aq) + NO_3^-(aq)$$

Cold packs are typically used to treat muscle strains and sore joints. The cold pack is activated and applied to the affected area. As the ammonium nitrate dissolves, it absorbs heat from the body and helps to limit swelling. Hot (heat) packs function in the same manner and are based on the heat released by:

$$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq) + 82.8\ kJ$$

Heat packs are used primarily for non-inflammatory body pain including duller and persistent pains associated with acute soreness, stiffness, cramping, and/or sensitivity. Heat allows blood vessels to expand and relaxes muscles. The soothing effect occurs because heat stimulates circulation and increases tissue elasticity. Please advise students to never apply heat to open wound, broken or infected skin or injured tissues. If the area in question is either bruised or swollen (or both), it may be better to use cold therapy.

2. False, because the formation of ideal solutions does not involve energy change.

Answers to Exercise 2.4

1.

i. Na^+ or Cs^+? Na^+ because of small size

ii. Mg^{2+} or Cs^+? Mg^{2+} because of multiple charges

iii. F- or Cl-? Explain. F- because of a small size.

2.3 Solubility as an Equilibrium Process

Competencies

At the end of this section students will be able to

- describe the distinctions among unsaturated, saturated and supersaturated solutions.
- prepare unsaturated and saturated solutions of sodium sulphate
- prepare supersaturated solution of sodium thiosulphate
- explain the equilibrium nature of saturated solution
- define solubility
- describe the factors that affect solubility of substances
- investigate the effect of temperature on solubility of sodium sulphate
- conduct an experiment to determine solubility of table salt and sugar

- state Henry's law
- use Henry's law to calculate concentration of gaseous solute in a solution

2.3.1 Unsaturated, Saturated, and Supersaturated Solutions

Start this lesson with the concept of equilibrium. Ask them if they have visited a kiosk to shop for some sugars, salt, or other item measured in kilos. Ask them the name of the device used to measure mass. Now, explain to them the term balance as used in this device is synonymous with equilibrium. The balance indicates the equilibrium point when the mass of the measuring unit and sugar is matched.

Write the definition of chemical equilibrium on the board. Explain how equilibrium counteracts to external input using the formula:

$$\text{Solid (solute)} \underset{\text{Crystallization}}{\overset{\text{Dissolution}}{\rightleftharpoons}} \text{Dissolved ions}$$

Inform them that they will learn about equilibrium in detail in grades 11 and 12. But for now, let them be informed about Le Châtelier's principle. Inform them not to worry about this, but appreciate its application when they discuss the effect of temperature and pressure on solubilities of substances in water. Be passionate while doing that. Demonstrate ***Experiment 2.5*** and ask them to report their answers.

Define **Solution equilibrium** as the physical state described by the opposing processes of dissolution and recrystallization occurring at the same rate.

Unsaturated, saturated, and supersaturated solutions

Start this section with definitions of unsaturated, saturated, and supersaturated solutions and explain using ***Figures 2.12*** and ***2.13***. Arrange a laboratory session so that they could conduct ***Experiment 2.5*** and answer the questions posed to them. You may simplify the topic by telling life experiences. When you have eaten less than your feel, you still want to eat more. That means you are unsaturated. When you have eaten your feel and satisfied, you don't want to eat more. Sometime, you eat too much, especially after exercise and exceed your normal capacity. Let students relate the terms unsaturated, saturated, and supersaturated to these experiences as they do ***Activity 2.6***. Regardless of the differences, these will help them to recall what the terms mean at least! Dissolution of added crystals would be observed in beaker A and precipitation is expected in beakers B and C. Since, beaker C contains supersaturated solution which is unstable, the added mass would case even more solid precipitated than the amount added.

2.3.2 Effect of Temperature on Solubility of Solids

Here, you can make a mini lecture followed by demonstration. Define solubility and demonstrate ***Experiment 2.6***.

2.3.3 Effect of Temperature on Solubility of Gases

You can make a mini lecture here. Explain them that dissolution of gasses in water involves intermolecular attractions and is exothermic. Explain the effect of temperature on solubility of gases. Tell them that as temperature increases the dissolved gases escape the solution; meaning solubility of gases decreases with increase of temperature. Then, arrange groups so that they can effectively participate in ***Activity 2.7***. This is a very important activity that is designed to help students apply their knowledge on such cross-cutting issues. Facilitate the discussion and give them supports or clues. Optionally you may also arrange a visit to nearby environmental authorities and let students hold interview on the issues. Dissolution of added crystals would be observed in beaker A and precipitation is expected in beakers B and C. Since, beaker C contains supersaturated solution which is unstable, the added mass would case even more solid precipitated than the amount added.

Answers to Activity 2.7

(a) The rise in temperature decreases the solubility of O_2 in water. As the level of O_2 gets depleted, fish may die short of O_2.

(b) Dissolved chemicals break the O_2 and H_2O molecules interaction and force the O_2 to leave the water. Consequently, the level of dissolved O_2 decreases affecting aquatic life. Other wastes such as wastes of personal care products do also cause environmental pollution and need to be disposed appropriately. They should not be thrown irresponsibly to open places or to water bodies.

2.3.4 Effect of Pressure on Solubility of Gases: Henry's Law

It would be more effective to start this section with ***Activity 2.8***. This is also a very important activity that can help them associate the topic to their life experiences. Then summarize by questioning and answering method. Make a mini -lecture on the effect of pressure on the solubility of gases with the help of examples. Ask them why pressure does not affect the solubility of solids and liquids

Henry's Law

Write Henry's law on the board to help them understand

- Explain it to students based on ***Figure 2.14***
- Let them do ***Exercise 2.5*** in pairs but submit answers individually (get feedbacks and give marks)

Answers to Activity 2.8

1. Explain each of the following observations based on Henry's law.

(a) Carbonated beverages such as coke, and pepsi fizzes (sparkles, see figure to the right) when the cap is removed

Ans: When the cap is removed the solution becomes exposed to atmospheric pressure which is much less than the pressure under which the coke was packed. As the partial pressure of carbon dioxide is reduced, gas comes out of solution, solubility decreases.

(b) Multicellular organisms need hemoglobin in red blood cells to bind and carry O_2 to support the energy needs. Why this mechanism of replenishing O_2 in biological fluid is necessary? What would happen if hemoglobin is missing?

Ans: The solubility of O_2 is too low to support the O_2 needs of cells. Hemoglobin binds O_2 molecules and transports them to where they are needed.

Answers to Exercise 2.5

1. The concentration of CO_2 in a solution is 0.032 M at 3.0 atm. What is the concentration of CO_2 at 5.0 atm of pressure?

$$C_1/P_1 = C_2/P_2$$

$$(0.032\ \text{M})/(3.0\ \text{atm}) = C_2/(5.0\ \text{atm})$$

$$C_2 = (0.032\ \text{M} \times 5.0\ \text{atm})/(3.0\ \text{atm}) = \mathbf{0.053\ M}$$

2. C

2.4 Ways of Expressing Concentration of Solution

Competencies

At the end of this section students will be able to

- define concentration of a solution
- define mass percentage, ppm and ppb of a solute in a solution
- calculate the mass percentage, ppm and ppb of a solute in a solution from a given information
- define mole fraction
- calculate mole fraction of a solute and a solvent in a solution

☞ define molarity

A similar method to the just preceding section is suggested here. A gapped lecture involving writing the definition and formula on the blackboard, explaining the formula, giving examples and asking the students to do an exercise based on the solved example is helpful. Included under this topic are mass percentage, ppm, ppb, mole fraction, molarity, molality, normality, and conversion of concentration units. A side note on a mole concept has been provided in student's textbook. It is very important that students are clear with the mole concept. The examples cited in the note are helpful. This is a prerequisite to topics such as mole fraction and mass-mole calculations.

2.5 Preparation of Solutions

Competencies

At the end of this section students will be able to

☞ prepare molar solutions of different substances

☞ calculate molarity of a solution from a given information

☞ define the terms equivalent weight, number of equivalents and normality

☞ prepare normal solutions of different substances

☞ calculate normality of a solution from a given information

☞ define molality

☞ prepare molal solutions of different substances calculate molality of a solution from a given information

☞ inter convert various concentration expressions

☞ explain dilution process

☞ calculate the volume or concentration changes during dilution of solution

☞ prepare a dilute solution from concentrated solution

This topic is recommended to be discussed as pre-lab talk. Then, students should be given the necessary materials and chemicals to conduct the suggested experiments. If circumstances do allow this approach, a teacher can follow the strategy suggested under the preceding section (ways of expressing concentration). In this case, you may write the steps, solve one example engaging students and let students do the exercises. ***Figure 2.14*** is suggested to facilitate visual learning.

2.6 Solution Stoichiometry

Competencies

At the end of this section students will be able to use stoichiometrically equivalent molar ratios to calculate amounts of reactants and products in a reaction of pure and dissolved substances

For this section too, a method similar to the one under the preceding section (i.e. on ways of expressing concentration has been suggested. Solve one example while engaging the students. Then ask them to do the exercise that immediately follows the solved example. Check students' responses and praise good performances. Help the students as they do the exercise. Provide them the necessary constants such as molecular mass, density, etc.

2.7 Describing Reactions in Solution

Competencies

At the end of this section students will be able to

- explain the relationship between reacting ions, spectator ions, precipitation and solubility
- write net ionic equations

Molecular equation and Ionic equation

You may follow the following steps while teaching this topic:

- Write the definition
- Write the formula
- Explain the formula
- Show how the formula can be rearranged
- Give examples
- Ask them to do the exercise in pairs
- Give chance to students to come out and do the exercise on the board
- Correct students answers

Answers to Exercises 2.6 to 2.17

Exercise 2.6

1. A sample of 0.892 g of potassium chloride, KCl, is dissolved in 54.6 g of water. What is the percent, by mass, of KCl in the solution?

Answer: 0.892 /(0.892 + 54.6) x 100 % = 1.61%

2. If 150 g of orange juice contains 120 mg of ascorbic acid (Vitamin C), what is the concentration of ascorbic acid, expressed in ppm?

ppm = (0.120 g/150 g) x 10^6 = 800 ppm

b Express the concentration of ascorbic acid given in (a) in ppb.

ppb = (0.120 g/150 g) x 10^9= 800,000 ppb

3. What is the (w/v)% of a solution if 24.0 g of sucrose is dissolved in a total solution of 243 mL?

(24.0 g/243 mL)x100% = 9.88%

4.How many grams of NaCl are required to make 625 mL of a 13.5% solution?

w/v% NaCl = 13.5% = (grams NaCl/625) x 100%

Mass NaCl = (13.5 x 625)/100 = 84.4

5. Find the concentration of calcium ion (in ppm) in a 3.50 g pill that contains 40.5 mg of $Ca^{2+.}$

ppm = (mass Ca^{2+}/mass pill) x10^6 =11,571 ppm

6. The label on a 300 mL beer bottle indicates 5.0 % alcohol by volume. How many liters of alcohol does the bottle of beer contain?

5.0% alcohol = (volume alcohol/volume solution)x100%

Volume alcohol = (5.0 x volume solution)/100 = 15 mL

Exercise 2.7

1. A sample of rubbing alcohol contains 142 g of isopropyl alcohol (C_3H_7OH) and 58.0 g of water. What are the mole fractions of alcohol and water?

Mole isopropyl alcohol = mass of isopropyl alcohol/molar mass of isopropyl alcohol=142g/60.1g/mol = 2.36 mol

Mole water = mass of water/molar mass of water = 58.0 g/18 g/mol =3.2 mol

Total mole = 2.36 + 3.2 = 5.56

$X_{alcohol\,=}$ 2.36/5.56 = 0.42

X_{water} = 3.2/5.56 = 0.58

2. In a solution composed of A, B, and C, if we have 1 mole of A , 1 mole of B and 2 moles of C. Find the mole fraction of each of them:

Answers: A(0.25), B(0.25), C(0.50)

Exercise 2.8

1. 5.85 g of sodium chloride (NaCl) is dissolved in 250 mL of solution. Calculate

a.the molarity of the solution.

Molarity = number of moles of solute/volume of solution in liter = (5.85g/58.5 g/

mol)/0.250L =0.400 M

b. the mass percentage of the solute.

Let's assume the density of solution is the same as the density of water = 1.0 g/mL

Then mass of solution = density x volume = 1.0 g/mL x 250 mL = 250 g

(w/w)%NaCl = (5.85/250) x100% = 2.34%

2. How would 250 ml of 0.15 M KNO_3 solution be prepared?

Formula: Molarity = number of moles of solute/volume of solution in liter

Molarity = 0.15 M

Volume of solution = 0.250 L

Number of moles of KNO_3 = 0.15 mol/Lx 0.250 L = 0.038 mol

Mass KNO_3 = mole x molar mass = 0.038 mol x 101.10 g/mol = 3.8 g

We need a 250 mL volumetric flask because the final volume of solution we want to prepare is 250 mL. . Then follow the steps 3 through 6 indicated in student text. This also illustrated in **Figure 2.15.** Please explain this figure to students too.

3. A solution of hydrochloric acid contains 36 percent HCl, by mass

Calculate the mole fraction of HCl in the solution.

36% HCl by mass means 36 g HCl in 100 g solution

Now, calculate the mole of the 36 g HCl = 36 g/36.458 g/mol = 0.99 mol

Mass water = mass of solution – mass of HCl = 100-36 = 64 g

Mole water = mass water/molar mass water = 64 g/18 g/mol = 3.6 mol

XHCl = mole HCl/total mol = 0.99/(0.99 + 3.6) = 0.22

Exercise 2.9

1. How many grams of glucose ($C_6H_{12}O_6$) must be dissolved in 563 g of ethanol (C_2H_5OH) to prepare a 2.40 x 10^{-2} m solution? Molar mass of $C_6H_{12}O_6$ is 180.156 g/mol.

Answer: mass of glucose = 2.43 g

Exercise 2.10

1. How many equivalents of solute are contained in 1 L of 2 N solution?

Normality = equivalents/volume of solution in liter

Equivalents = Normality x Volume of solution in liter

Equivalents = 2 eq/L x 1 L = 2

2. Calculate the mass of $Al_2(SO_4)_3$ in 250 mL of solution if the concentration is 0.48

N Al^{3+}.

0.48 = eq/0.25

Eq = 0.12 = (z x given mass)/molar mass , but z = 6

Mas = (molar mass x 0.12)/z = (342.14 x 0.12)/6 = 6.84 g

3. Calculate the molarity and normality of a solution that contains 16.2 g of the salt $Fe_2(SO_4)_3$ in 200 mL of solution.

Molarity = mole/litre = (16.2g/399.9g/mol)/0.20 = 0.20 M

Normality = M x z = 0.20 x 6=1.20 N

4. Calculate the normality of

a. 0.1381 M NaOH

Z = 1

N = M x z=0.1381 x 1=0.1381 N

b. 0.0521 M H_3PO_4

Z = 3

N = 3 x M = 3 x 0.0521 = 0.156 N

Exercise 2.11

Hydrogen peroxide is a powerful oxidizing agent. It is used in concentrated solutions in rocket fuel. However, it is used in hair bleach in dilute solution. An aqueous solution of H_2O_2 is 30.0% by mass and has a density of 1.11 g/mL; the molar mass of H_2O_2 is 34.02 g/mol. Calculate the

(a) molality

(b) mole fraction of H_2O_2

(c) molarity

(a) Write the formula for molality

- Determine what is given and what is missing; 30.0% by mass mean 30.0 g of H_2O_2 in 100 g of solution. Since we need mass of solvent for molality, we can calculate it as follows: mass (solution) = mass(solute) + mass (solvent); 100 g = 30.0 g + mass (solvent); ⇒ mass (solvent)=70 g = 0.07kg

  We can also calculate the moles of solute (H_2O_2) as mole = given mass/molar mass; the molar mass of H_2O_2 is 34.02 g/mol ⇒30.0 g/34.02 g.mol-1= 0.882 mol H_2O_2
- Substitute the moles of solute and mass of solvent in kg in the molality formula
- Ans:12.6 m H_2O_2

(b) To calculate the mole fraction use the formula:

$$X\ (\text{solute}) = \frac{\frac{\text{mass (solute)}}{\text{molar mass solute}}}{\text{mole (solution)}}$$

((30.0 g H_2O_2)/(34.02 g/mol))/[((30.0 g H_2O_2)/(34.02 g/mol)))+((70 g)/(18 g/mol))] =0.184

Note: molar mass of water (H_2O) is 18 g/mol

Therefore, the mole fraction of solvent (water) = 1-0.184=0.816 (Verify this using the formula for mole fraction of the solvent)

(c)

- To calculate the molarity follow these steps:
- Write the formula for molarity
- Identify what is given. We need number of moles of solute (H_2O_2) and volume of solution in litre. From Q(b) we know moles of H_2O_2 = 0.882 moles, Volume = mass/ density = 100 g/ 1.11 g.mL^{-1} = 90.1 mL = 0.0901 L, note that we are considering 30.0 g of H_2O_2 and 100 g of solution as per the given 30.0%.
- Substituting the values:

M = (0.184 moles of H_2O_2)/(0.0901 L) = 9.79 M

Exercise 2.12

1. How would you prepare 2.00 x 10^2 mL of a 0.866 M KOH solution, starting with a 5.07 M stock solution?

   Given Vf = 2.00 x 10^2 mL

   Cf = 0.866 M

   Ci = 5.07 M

   Vi = ?

   Answer Vi= (Cf x Vf)/Ci = (0.866 M x 200 mL)/5.07 M = 34.20 mL

   Steps

   1. Weigh out 34.20 mL from the stock solution using graduated or measuring cylinder
   2. Transfer the weight volume to a 200 mL volumetric flask
   3. Dilute to the mark
   4. Label it. 'Done'!

2. What is the difference between dilute and unsaturated? or concentrated and

saturated?

A dilute solution has less solute present in the larger volume of solution than a concentration solution. In other words, a dilute solution contains a larger volume of solvent than a concentrated solution for a given amount of solute. A solution is said to be unsaturated if more solute could be dissolved in a given amount of the solvent at a specified temperature. A solution is said to be saturated when no more of the solute can be dissolved in a given amount of the solvent at a specified temperature. So, the terms dilute and unsaturated are not related terms. Dilute or concentrated terms are relative to each other, but unsaturated or saturated refer to the dissolution capacity of the solution.

Exercise 2.13

a) mole NaCl = VM = 0.1 L x 0.1 mol/L = 0.01; mass NaCl required = n.Molar Mass NaCl = 0.01 mol x 58.5 g/mol = 0.585 g; So they should dissolve 0.585g NaCl in a 100 mL volumetric flask and dilute to the mark with water. b) mole NaCl = VM = 0.1 L x 0.25 mol/L = 0.025; mass NaCl required = n.Molar Mass NaCl = 0.025 mol x 58.5 g/mol = 1.46 g; So they should dissolve 1.46 g NaCl in a 100 mL volumetric flask and dilute to the mark with water c) Outline preparation of 100 mL of 0.1 M H_2SO_4 using a stock solution of 98% H_2SO_4. Density = 1.84 g/ml

Calculate initial concentration of stock solution in molarity:

98% means 98 g H_2SO_4 in 100 g of solution. Volume solution = mass/density = 100 g/1.84g/ml =54.34 mL = 0.05434 L

Mole H_2SO_4 = given mass/molar mass = 98 g/ 98.079 g/mol = 0.999 mol

Molarity of the 98% H_2SO_4 = number of moles/volume solution (L) = 0.999 mol/0.05434 L = 18.38 M

Now, we need to know what volume to withdraw from this solution

Using the dilution formula

Vi = (CfVf)/Ci = (0.1 M x0.1 L)/18.38 M = 0.540 mL= 540 µL

Measure 540 µL from stock solution using micropipette, transfer it to 100 mL volumetric flask, dilute it to the mark. Label it.

Exercise 2.14

What is the concentration of sodium hydroxide that is required to react completely with an equal volume of 0.104 M hydrochloric acid?

$NaOH + HCl = NaCl + H_2O$

Since volume is equal and the stoichiometry is 1:1, the answer is 0.104 M

Exercise 2.15

What volume of 0.512 M NaOH will react with 17.9 g of $H_2C_2O_4(s)$ according to the following chemical equation?

$$H_2C_2O_4(s) + 2NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$

Answer: 777 mL

Exercise 2.16

1. What volume of 0.5 M glucose ($C_6H_{12}O_6$) contains 3.01×10^{22} molecules of glucose?

Answer 100 mL

Exercise 2.17

1. see student text book
2. a) How are sodium carbonate and calcium hydroxide found in a water solution? (Refer to solubility rule). Write dissociation reactions for each of them.

Answer: Sodium carbonate is soluble and exists as $Na^+(aq)$ and $CO_3^{2-}(aq)$

Calcium hydroxide is slightly soluble and produces some $Ca^{2+}(aq)$ and OH-(aq)

b. Write the molecular equation for the reaction between sodium carbonate and calcium hydroxide. Are the products formed soluble in water?

$$Na_2CO_3(aq) + CaOH_2(aq) \rightarrow 2NaOH(aq) + CaCO_3(s)$$

c. Write the soluble product in ionic form. Are there the same ions in the reactant and product side?

$2Na^+(aq) + CO_3^{2-}(aq) + Ca^{2+}(aq) + 2OH^-(aq) \rightarrow 2Na^+(aq) + 2OH^-(aq) + CaCO_3(s)$

d. Na^+ and OH- are spectator ions.

e. Write the net ionic equation.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

3. For the following molecular equation write the ionic equation, and a net ionic equation. Also, identify the spectator ions.

Balanced Molecular equation:

$$2AgNO_3\ (aq) + Na_2CrO_4\ (aq) \rightarrow Ag_2CrO_4\ (s) + 2NaNO_3\ (aq)$$

Ionic equation:

$2Ag^+(aq) + 2NO_3^-(aq) + 2Na^+(aq) + Cr_2O_4^{2-}(aq) \rightarrow Ag_2CrO_4(s) + 2Na^+\ (aq) + 2NO_3^-(aq)$

Net ionic equation: $2Ag^+(aq) + Cr_2O_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$

The spectator ions are NO_3^-, and Na^+

Answers to Review Questions

Part I. Multiple Choice

1. B	6.C	11.C	16.C	21.A
2.A	7.A	12.C	17.B	22.B
3. C	8.C	13.B	18.C	23.B
4.B	9.A	14.A	19.C	24.C
5.B	10.A	15.C	20.B	

Part II: Short Answer Questions

25. Give one example for each: a gaseous solution (air), a liquid solution (beer), a solid solution (ruby). See student's textbook
26. What are the two factors needed to explain the differences in the solubilities of ionic solids in water? Answer: Lattice energy and hydration energy
27. Explain in terms of intermolecular attractions why octane is immiscible in water. Octane is non-polar while water is polar. They dislike each other.
28. Give the type of colloid (aerosol, foam, emulsion, sol, or gel) that each of the following represents.
    A. rain cloud (aerosol)
    B. milk of magnesia (sol)
    C. soapsuds (foam)
    D. silt in water (sol)
29. Sand, cement, water, and stone (rock)
30. glycerol, $CH_2OHCHOHCH_2OH$, and water are both polar. Benzene, C_6H_6, is non-polar and has very limited solubility in polar water.
31. Because of the difference in the degree of hydration and lattice energy
32. A. KBr in water, ion-dipole B. hexane, C_6H_{14}, in gasoline, dispersion force
    C. ammonia in water, dipole-dipole
33. Endothermic dissolution processes are characterized by:
    The magnitude of the energy absorbed to break up the lattice, ΔH_{lat}, is greater than the magnitude of the energy released when solute particles are surrounded by water solvent molecules, ΔH_{hyd}, so the enthalpy of solution, ΔH_{soln}, is positive,

that is, the process is endothermic.

if $|\Delta H_{lat}| > |\Delta H_{hyd}|$ then ΔH_{soln} is positive

solute (s) + water (l) → solution(aq) ΔH_{soln} = +ve

solute (s) + water (l) + ΔH → solution(aq)

Energy is absorbed, that is, energy is a reactant.

For endothermic dissolution processes, when solute is added to water, water temperature decreases.

Exothermic dissolution processes are characterized by:

The magnitude of the energy absorbed to break up the lattice is less than magnitude of the energy released when solute particles are surrounded by water solvent molecules, so the enthalpy of solution is negative, that is, the process is exothermic.

if $|\Delta H_{lat}| < |\Delta H_{hyd}|$ then ΔH_{soln} is negative

solute (s) + water (l) → solution(aq) ΔH_{soln} = -ve

solute (s) + water (l) → solution(aq) + ΔH

Energy is released, that is, energy is a product.

For exothermic dissolution processes, when solute is added to water, water temperature increases.

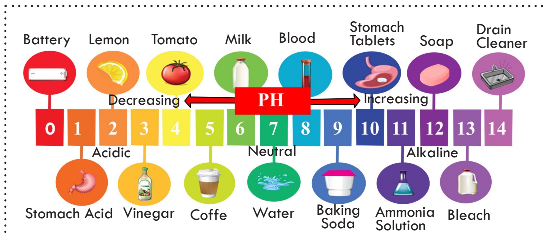
34. A. KCl in H_2O, high
    B. HF in H_2O, high
    C. KCl in CCl_4, low
    D. H_2O in CH_3OH, high
    E. NH_4Cl in C_5H_{12}, low
    F. CCl_4 in H_2O, low
35. Increases, $LiSO_4$, $CaSO_4$, $Ca(OH)_2$.
36. NaOH (exothermic), NH_4NO_3 (endothermic).
37. Decreases
38. To control pressure
39. Oxygen is compressible whereas sugar in water is not
40. Al^{3+}, highly charged
41. F^-, small size

Part III: Work Out Problems

42. 0.886 g in 100 mL at 5.5 atm
43.
    A) 0.51 M
    B) 2 M
44. 5.160 g

45. 835 mg
46. 0.36, 0.64
47. 0.012
48. 0.23, 17 m
49. 375 mL
50. 0.01
51. 0.64 M
52. 0.796 m

UNIT 3



IMPORTANT INORGANIC COMPOUNDS

Unit Outcomes

At the end of this unit, students will be able to

- classify inorganic compounds on the basis of their composition and/ or their chemistry;
- discuss types of oxides and their chemical properties;
- explain the Arrhenius concept of acids and bases;
- mention the classification of acids and salts;
- describe the general properties, preparation and uses of common acids, bases and salts;
- distinguish the differences between strong and weak acids/ bases; and concentrated and dilute acids/ bases;
- recognize the corrosive nature of acids and bases, and exercise the necessary precautions in handling and using them;
- develop skills for identifying acidic, basic and neutral compounds;
- demonstrate scientific inquiry skills: observing, classifying, comparing and contrasting, inferring, predicting, communicating, measuring, asking questions, interpreting data, drawing conclusion, applying concepts, relating cause and effect and problem solving.

Unit Overview

This unit is about important inorganic compounds namely oxides, acids, bases and salts. The start-up activity helps to introduce the unit. All the ideas of the unit are embedded under this activity, It recognizes students how acidity or basicity of food substances could be identified with the help of their tastes, For example, the sour taste of lemon and unripe orange helps to introduce acids or acidic oxides, the bitter taste of coffee and 'kosso' helps to introduce bases and basic oxides, and the salty taste of common salt helps to introduce salts. Students should be allowed to discuss in groups for few minutes and the idea of the unit should be informed to them through this activity. Following the activity, the unit continues introducing the definition of inorganic compounds. It mentions why the term 'inorganic' is used in the name of inorganic compounds and introduces the different classes of important inorganic compounds such as oxides, acids, bases and salts.

The first section of the unit deals with oxides. This section presents the classification of oxides as acidic, basic, amphoteric, neutral, and peroxides. It gives the definitions, chemical properties and differences among the different classes of oxides.

The second section of the unit is about acids it introduces the definition of acids. It also gives the classification of acids as monoprotic and polyprotic, binary and ternary, strong and weak concentrated and dilute. This section presents the general properties of acids, safety precautions in handling acids, preparation of acids and common uses of some acids.

The third section is about bases. It introduces the definition, general properties, and safety precautions for handling of bases. It also presents the relationship between pH and pOH, preparation and uses of some bases.

The fourth section deals with salts. It presents the classification, preparation and properties of salts, and the uses of some important salts.

The recommended methods for effective teaching of this unit are gapped lecture, group discussion, experiment, and inquiry. Students should do extensive exercises and their responses should be checked. Feedback and a summary of each topic should be given.

Table 3.1 Tentative distribution of periods to each section/subsection.

SN	Unit/ Section	Section/Subsection	Activity	Experiment	Exercise			#Period suggested
					Classwork	Homework	Assignment	
1		Start-up Activity						
2		3.1 Introduction			3.1			1
3	3.1-3.2	3.2 Oxides	3.1	3.1	3.2			
		- Acidic oxides	3.3	3.1	3.3			1
		- Basic oxides			3.4			1
		- Amphoteric oxides	3.4	3.2	3.5		3.6	
		- Neutral oxides	3.5					
		- Peroxides	3.6					1
5	3.3	3.3. Acids	3.7					1
		Arrhenius Definition of Acids						
6		Classification of acids	3.8 & 3.9					1
		General properties of acids		3.4-3.8				2
7		Strength of Acids (Strong and Weak Acids)	3.11					1
8		Concentrated and Dilute Acids	3.12					
9		pH and pH scale		3.9	3.8			1
		Preparation of Acids		3.10			3.9	1
12	3.4	3.4 Bases						
13		Arrhenius Definition of Bases	3.14					1
		General Properties of Bases	3.15			3.10		2
		Strength of Bases (Strong and Weak Bases)	3.16					
		Relationship Between pH and pOH	3.17					1
		Preparation of Bases		3.12 & 3.15				1
		3. Salts						
		Classification of salts	3.18	3.13	3.11			2
		General methods for the preparation of salts	3.19 3.20					
		Properties of Salts	3.21	3.14-3.18				2
		Plant Nutrients	3.22		3.13 & 3.14			1
								21

3.1. Introduction

Total Period Alloted: 1 Period

By the end of this section, students will be able to

- ☞ define inorganic compounds
- ☞ classify inorganic compounds as oxides, acids, bases and salts

Planning

It is advisable to read the contents of the section thoroughly, and make the necessary preparation and plan how your students will actively participate in the teaching-learning process. Plan how to organize your students in different groups for effective outcome and easy follow- up during discussions. Students should work extensive on exercises and their responses should be strictly checked.

Teaching Aid

A chart showing the class of organic and inorganic compounds and their differences can be used.

Subject Matter Presentation

This section needs the active participation of each student; hence it is advisable to use group discussion and mini-lecture methods

Use ***the startup activity*** to begin the lesson. This activity is designed to help students develop skills in classifying compounds as organic and inorganic and also discover some differences between these classes or compounds.

First, introduce the topic of the section and then allow the students to discuss ***startup activity*** for a few minutes in groups. Follow how every student participates in the discussion. Monitor the discussion closely and give them guidance and assistance whenever they need it from you. After a completion of the discussion, ask students from two different groups to make a presentation on points they discussed. Next, develop your mini -lecture from the suggestions of students and harmonize what they said with what you want them to know. Among the samples of compounds in the laboratory, ethanol, benzene, formaldehyde (methanol), sodium acetate, acetic acid, etc. are classified as organic compounds. The compounds such as the acids HNO_3, HCl, H_2SO_4 and salts like Na_2CO_3, $K_2Cr_2O_7$, NaCl, oxides of metals, etc. are inorganic compounds.

Introduce students to the fact that the classification of compounds is mainly based on their sources. Inorganic compounds are compounds consisting of mineral constituents of the earth or generally found in non-living things. Organic compounds are those compounds that originate from animals and plants as well as from artificially synthesised carbon compounds. Then explain the basis for the classification of inorganic compounds.

Introduce the classification based on their composition or their chemistry. They may also be classified based on the metal, non-metal or contain. Finally, explain that compounds formed by most of the known elements are inorganic and that the field of chemistry that is concerned with the study of these compounds is inorganic chemistry. Inform students that, at this level, we classify inorganic compounds generally as oxides, acids, bases, and salts. Throughout your explanation, ask an oral question so that students can participate in the teaching-learning process.

Assessment

The activity of each student should be assessed throughout the section. Monitor carefully how each student is working during discussion and explanation. Give ***Exercise 3.1*** as classwork or homework. Check their work, record their results in your students' performance list, and evaluate how many of the students achieved the minimum r any other techniques acquire any other techniques d level.

Additional Questions

1. Compounds of carbon, such as carbonates, hydrogen carbonates, cyanides and cyanates, are classified as inorganic instead of organic. Explain.
2. At present, it is becoming very difficult to make a clear boundary between organic and inorganic compounds. What do you think is the reason for this?

Answers to Additional Questions

1. This is because the properties of these compounds of carbon are more similar to those of inorganic compounds than to those of organic compounds
2. Because of the synthesis of many organic compounds containing metals such as organometallic compounds

Answers to Exercise 3.1

1. $CaCO_3$, $NaOH$, H_2SO_4, $NaCl$, HNO_3, $FesO_4$,H_2O_2, etc.
2. Inorganic chemistry
3. Non-living materials such as minerals, air, sea water (eg. salts)
4. Inorganic compounds are mostly found in nature as silicates, oxides, carbonates, sulphides, sulphates, chlorides, nitrates, etc

3.2 Oxides

Alloted Period 3 Periods

At the end of this section, students will be able to

- define and classify oxides as acidic, basic, neutral, amphoteric and peroxides
- define and give examples of acidic oxides, basic oxides, amphoteric oxides and neutral oxides
- explain the chemical properties of acidic oxides, basic oxides, amphoteric oxides and neutral oxides

- differentiate basic oxides from acidic oxides using experimental results
- compare and contrast acidic and basic oxides
- explain the salt-forming nature of acidic oxide, basic oxide and amphoteric oxide
- define neutral oxides and peroxides and give examples for each of them
- discuss the chemical properties of peroxides
- differentiate peroxides from other oxides by conducting an experiment

Planning

We suggest you read the section content thoroughly and design a plan of your own that shows which contents and activities you will treat during each period, and when students should conduct the suggested experiments. Three ***Experiments (3.1, 3.2, and 3.3)*** are suggested in the section.

Arrange the necessary chemicals and apparatuses required to perform the experiments. Carry out the experiments beforehand. If your laboratory is well equipped, plan how students could perform the experiments by themselves in groups. You need also to plan how to follow up when students discuss the suggested activities in the section and perform the experiments. Also plan how to implement the suggested methodologies for each topic in the section.

Teaching Aids

Refer to the students' text for the apparatus and chemicals required to conduct ***Experiments 3.1, 3.2 and 3.3***

Subject Matter Presentation

Group discussion, question and answer, and gapped methods are recommended for teaching this sub-topic. Students should work on extensive exercises, and their responses should be strictly checked. Follow the following procedure, for this topic,

- Introduce the topic of the section using ***Activity 3.1***. Allow the students to discuss ***Activity 3.1*** for few minutes and students may propose that oxygen is the most abundant element as it is reactive and occurs in water, air, minerals, etc.
- After students response explain them that oxygen is the most abundant element as it reacts with almost all elements and the high stability of its compounds.
- Continue your mini lecture by asking students to define what oxides are.
- After students' responses, present the appropriate definition of oxides as binary

compounds of oxygen and any other element (metal, metalloid or nonmetal) Oxygen + Element (metal, nonmetal or metalloid), where element is different from oxygen.

☞ Tell them that generally metals form basic oxides and non-metals form acidic oxides.

However, here you should note them that all non-metllicoxids are not acidic because of neutral oxides. Although CO and N_2O are non-metallic oxides they are neutral. In the other hand Al_2O_3 and ZnO are metallic oxides which show both acidic and basic.

☞ Give students few examples and let them suggest more examples of oxides

☞ you can also use ***Exercise 3.2*** as a class work for students to identify whether a given compound is an oxide or not. Check the students' work. Inform about the different classes of oxides, such as acidic, basic, amphoteric, peroxides and neutral oxides. Tell them that this classification of oxides is based on the chemical properties / and structure in case of peroxides.

Acidic Oxides

First, introduce the types of oxides and then let the students discuss ***Activity 3.2*** for a few minutes. This activity enables students to discover what acidic oxides are and their reaction with bases.

During the discussion of the activity, observe how every student participates in each group. Help and guide groups that are need/require it. Encourage students from the different groups to present their opinions to their classmates. Appreciate the attempts made by the students in presenting their opinions. Concerning the activity, you can ask questions about the number of elements composing the oxides, whether the elements carbon, nitrogen, phosphorous and sulphur are metals, non-metals and metalloids. Emphasize that these elements are non-metals and that the oxides are oxides of non-metals. You can generalize that acidic oxides are oxides of non-metals and that they are formed by the combination of oxygen and non-metals. Also, introduce that acidic oxides dissolve in water and form acids. Tell them that acidic oxides are also named acid anhydrides, Give as many examples of acidic oxides as possible. Inform them that there are acidic oxides that do not react directly with water, and acids of such oxides are formed by other methods. For example, SiO_2 is not soluble in water, but it neutralizes basic oxides, thus it is acidic

Next, continue discussion on the properties of acidic oxides such as their reaction with water to form acids and their reaction with basic oxides to form the salt. You can use the concept of ***Activity 3.2*** to explain the reaction of acidic oxides with bases. Introduce that limewater is an aqueous solution of calcium hydroxide, $Ca(OH)_2$, and it is a base. When CO_2 (acidic oxide) passes through a clear solution of lime water, the solution turns milky. This is due to the reaction of CO_2 with $Ca(OH)_2$, to form calcium carbonate, $CaCO_3$ which turns the solution white . The equation for the reaction is:

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

Let the students practice writing more chemical equations for the reactions of acidic oxides.

Basic and Amphoteric Oxides

Group discussions, experiments, mini-lecture, are the recommended methods for the teaching of this topic.

Introduce the topic by asking students to define and describe basic oxides. Then give the correct definition of basic oxides by correcting students' responses.

Support students that basic oxides may be soluble or insoluble in water. Inform them also that the term alkali refers to soluble bases. Introduce that basic anhydride is base without water. Inform them basic anhydrides combine with water to form bases (basic hydroxides).

Allow students to discuss in groups for a few minutes to predict the products for the reactions between basic oxides and a) water b) acidic oxides) C) acids as examples. You can use ***Activity 3.3*** for the discussion. This activity enables students to discover what basic oxides are and their reaction with water, acidic oxides and acids.

When they complete the discussion, let some groups present their conclusions to the class. Then harmonize the concepts suggested by the students with the facts. Let the students practice writing a chemical equation for the reactions of basic oxides. You can also give them ***Exercise 3.4***, question 1 or homework.

Let the students perform ***Experiment 3.1*** in groups after you complete basic oxides. They should write the laboratory reports in groups and submit them to you.

Experiment 3.1. Burning of magnesium or calcium

Safety precautions:

The surface of magnesium ribbon should be properly cleaned with sand paper. The white ash of magnesium oxide should not be touched. Magnesium ribbon should be held by a pair of tongs while burning it. It is better to use sun glasses to protect eyes from dazzling light of burning magnesium ribbon.

Calcium: Handle in an enclosed, controlled process. Do not allow contact with water and acids. Protect from sources of ignition.

Safety precautions while burning of sulphur

Burning of sulphur should only be conducted in a fume cupboard as SO_2 fumes are produced when sulfur is burned in oxygen which hydrolyse to sulfurous and sulfuric acid.

From this experiment, the students are expected to realize that oxides can be prepared by the reaction of metals and non-metals with oxygen. The answers to the questions that are raised in the observations and analysis part of the experiment are the following:

A)

$$S + O_2 \rightarrow SO_2$$
$$2Mg + O_2 \rightarrow 2MgO$$
$$2Ca + O_2 \rightarrow 2CaO$$

B) when water is added to these oxides, SO_2 forms H_2SO_3 , and MgO forms $Mg(OH)_2$, and CaO form $Ca(OH)_2$

C) Universal indicator turns yellow-orange in a solution of SO_2 and blue-purple in a solution of $Mg(OH)_2$, and blue litmus turns red in a solution of SO_2 and red litmus blue in a solution of $Mg(OH)_2$

D) The colour change occurred because a solution of SO_2 is acidic and that of MgO is basic. After you complete basic oxides and ***Experiment 3.1***, continue by introducing amphoteric oxides. Before you deal with the details, let the students discuss ***Activity 3.4*** in groups for some minutes. The activity enables them to discover and realize the change in properties of oxides of period III elements from basic to amphoteric and then to acidic. After their discussion, encourage one or more students from different groups to present their opinions and conclusions to their classmates. Following their responses, continue to harmonize the concepts suggested by students with the actual truth. Use the following table to show the variation in properties of oxides of period 3 elements.

Element	Na	Mg	Al	Si	P	S	Cl
Nature of the element	Metals			metalloid	Non-metals		
Nature of oxide	Basic		Amphoteric	Acidic			
	Na_2O	MgO	AL_2O_3	SiO_2	P_4O_{10}		Cl_2O_7

From this table, you can show that the behaviour of oxides changes from basic to amphoteric and then to acidic as we go from left to right along a given period. Finally, explain the properties of amphoteric oxides. Have the students write balanced chemical equations related to the chemical properties of amphoteric oxides. Have the students perform ***Experiment 3.2*** in groups and present their findings to the class. After the presentation, inform them that Al_2O_3 dissolves in solutions of both NaOH and HCl and also reacts with them. This shows that Al_2O_3 is amphoteric.

Safety Precautions

Al_2O_3: Do not breathe dust or fumes. Avoid contact with skin and eyes. Provide appropriate exhaust ventilation at places where dust can be generated. Do not create a dust cloud by using a brush or compressed air.

PbO hazards Harmful if swallowed or if inhaled. May cause damage to organs through prolonged or repeated exposure.

Precautions: Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Avoid ingestion and inhalation. Keep from contact with clothing and other combustible materials. Avoid release to the environment. Wear protective gloves.

Answers to the Experimental Questions

1. Al_2O_3 reacts with both HCl and NaOH
2. The presence of chemical reaction between Al_2O_3 and HCl as well as Al_2O_3 and NaOH
3. $Al_2O_3\ (s) + 6HCl \rightarrow 2ALCl_3 + 3H_2O(l)$

$$Al_2O_3(s) + 2NaOH \rightarrow 2NaAlO_2(aq) + H_2O(l)$$

Neutral and Peroxides

We suggest that you use experiment and group discussion as the main methods for this lesson topic. Use a mini -lecture only when harmonizing concepts.

After you complete the contents on basic and amphoteric oxides, continue the presentation of concepts on neutral oxides and peroxides.

First, let the students discuss in groups for a few minutes and

A) Distinguish the conceptual difference when the term "neutral" is used to describe the nature of substances and when it to describe material in terms of electrical charge.

B) Define neutral oxides and give examples. Use ***Activity 3.5*** for the discussion. This activity enables them to recognize the existence of some common non-metallic oxides which are neither acidic nor basic oxides and helps them to define neutral oxides.

After the discussion, let students from two different groups present their opinions to the class. In harmonizing the concepts suggested by the students, tell them that the term "neutral" in the context of this section, is used to describe oxides that are neither acidic nor basic. The term is also used to describe substances that are neither negative nor positive. Give some examples of neutral oxides (CO, N_2O, NO), and then proceed to peroxides.

Before explaining the facts about peroxides, proceed to ***Activity 3.6***. The activity is designed to help students realize some practical applications of peroxides in real life and also to enable them to discover how peroxides differ from other oxides.

Let the students discuss ***Activity 3.6*** for a few minutes and present their opinion to the class. Then, harmonize the concepts suggested by students as the actual facts by introducing that peroxides are oxides containing the peroxide link (-O-O-). Have the students notice that oxygen has an oxidation state of -1 in peroxides. Discuss their oxidizing properties and reactions with dilute acids to realize hydrogen peroxide. Based on the activity, inform students that the hydrogen peroxide can decolorize hair and that it can be obtained by reacting peroxides like Na_2O_2 and CaO_2 with water.

Have the students perform ***Experiment 3.3*** under your supervision. Have them write a report and present it to the class. Inform your students that, upon addition of Na_2O_2 or BaO_2 in third beaker, the brown color of iodine appears first due to the oxidation of I^- to I_2^0 and the turn blue up on addition of starch.

$$2KI(aq) + H_2SO_4(aq) + Na_2O_2(aq) \rightarrow K_2SO_4(aq) + Na_2SO_4(aq) + I_2(aq) + 2H_2O$$

Laboratory Report Format

Group Number _______________ Date of experiment: _______________________

Name of students:

1. ______________________________
2. ______________________________

Experiment number: ____________________

Title of experiment: ____

Objective of the experiment: ____

____

Materials used in the experiment: ____

____

Chemicals: ____

____

Chemical reactions: ____

____

Observation: ____

____

Conclusion: ____

Assessment

Assess the students work throughout the section. Record how each student is doing on your students' performance list. You may make a record of the students' participation in discussions, during explanations, in performing experiments, in presentations, and in doing class and homework. From your records of what students have done; see how many of them achieved the suggested competencies for the section. Encourage students to work above the minimum requirements and give them additional work. Assist students working below the minimum requirements either by arranging extra lesson time or giving them additional activities.

Additional Questions

1. List metallic oxides you know that are acidic in nature
2. What types of oxides (acidic, basic, neutral or amphoteric) do the metalloids such as boron, silicon and arsenic form ? Support your answer by giving examples.
3. The peroxides like Na_2O_2 and K_2O_2 react with water. What products do theyform in their reactions
4. Identify the unknown oxides A, B and C, as acidic, basic or amphoteric, based on

the following experimental results.

Table 3.1 Chemical properties of unknown oxides A, B and C

Oxide	Color of litmus in solution of the oxide		Reaction with an acid	Reaction with a base
A	Red	Red	No	Yes
B	Blue	Red	Yes	Yes
C	Blue	Blue	Yes	No

You may summarize this section using the following scheme.

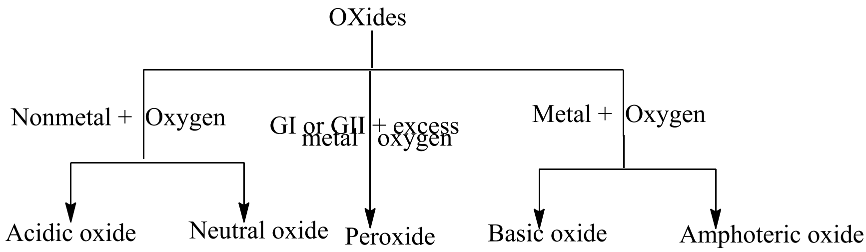


Figure 3.1 Classification of oxides

Answers to Additional Questions

1. CrO_3, Mn_2O_7, etc.

2. The metalloids boron, silicon, and arsenic form oxides with the formula B_2O_3, SiO_2 and As_2O_5

3. They produce hydrogen peroxide and bases as follows:

$$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$$
$$K_2O_2 + 2H_2O \rightarrow 2KOH + H_2O_2$$

4. A is acidic, B is amphoteric and C is basic

Answers to Exercises 3.2

A, B, D, F, H, I are oxides

Answers to Exercises 3.3

1. P_4O_{10}, NO_2. N_2O_3. N_2O_5, SO_2. etc
2. CO, N_2O
3. A. $N_2O_5 + H_2O \rightarrow 2HNO_3$ B. $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
   C. $MgO + CO_2 \rightarrow MgCO_3$ D. $Ca(OH)_2 + SO_3 \rightarrow CaSO_4 + H_2O$
   E. $2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$ F. $SrO + SO_2 \rightarrow SrSO_3$

Answers to Exercises 3.4

1.

A. $K_2O + H_2O \rightarrow 2KOH$ B. $MgO + H_2O \rightarrow Mg(OH)_2$

C. $Na_2O + CO_2 \rightarrow Na_2CO_3$ D. $Li_2O + SO_2 \rightarrow Li_2SO_3$

E. $BaO + H_2SO_4 \rightarrow BaSO_4 + H_2O$

F. $CuO + 2HCl \rightarrow CuCl_2 + H_2O$

2.

A MgO= basic B. BaO= basic C P_4O_{10}= acidic D. N_2O_5 =acidic

E Cu_2O = basic F. Fe_2O_3= basic G. K_2O = basic H SO_2 = acidic

Answers to Exercises 3.5

A. $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$

$PbO + 2NaOH \rightarrow Na_2PbO_2 + H_2O$

B. $Al_2O_3 + 6HNO_3 \rightarrow 2Al(NO_3)_3 + 3H_2O$

$PbO + 2HNO_3 \rightarrow Pb(NO_3)_2 + H_2O$

C. $Al_2O_3 + 2KOH \rightarrow 2KAlO_2 + H_2O$

$PbO + 2KOH \rightarrow K_2PbO_2 + H_2O$

D. $Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

$PbO + H_2SO_4 \rightarrow PbSO_4 + H_2O$

Answers to Exercises 3.6

1.

A. Na_2O = basic B. NO = neutral C. CO_2= acidic D. ZnO = Amphotric

E. MgO = basic F. N_2O_5 = acidic G.CaO =basic H. CO = neutral I. CaO_2 = Peroxide

J. Na_2O_2= peroxide K. Li_2O = basic L. H_3PO_4= acidic M. Al_2O_3= amphoteric N. SO_2 = acidic

2.

A. $SO_2 - H_2SO_3$ B. $SO_3 - H_2SO_4$ C. $N_2O_5 - HNO_3$

D. $CO_2 - H_2CO_3$ E. $P_2O_3 - H_3PO_3$ F. $P_2O_5 - H_3PO_4$

3.

A. $CaO-Ca(OH)_2$ B. K_2O-KOH C. $MgO-Mg(OH)_2$

D. $Na_2O - NaOH$ E. $SrO-Sr(OH)_2$ F. $BaO-Ba(OH)_2$

4. Complete and write the balanced equation for each of the following

A. $MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$

B. $3CaO + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 3H_2O$

C. $Al_2O_3 + 6HNO_3 \rightarrow 2Al(NO_3)_3 + 3H_2O$

D. $K_2O + H_2SO_4 \rightarrow K_2SO_4 + H_2O$

E. $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

F. $3ZnO + 2H_3PO_4 \rightarrow Zn_3(PO_4)_2 + 3H_2O$

5. Peroxides contain peroxide –O–O– link and oxidation state of oxygen is –1.
6. Using indicators

3.3 Acids

Total Alloted Period: 7 Periods

By the end of this section, students will be able to

- define acids in terms of the concepts of Arrhenius
- give examples of acids based on Arrhenius
- categorize acids as monoprotic and poly protic based on the number of ionizable(replaceable) hydrogen atom
- group acids as binary and ternary based on the number of elements, they contain
- gxplain the general properties of acids
- define strong and weak acids
- differentiate between strong and weak acids
- define concentrated and dilute acids
- describe the conceptual difference between strong and concentrated acids
- dxplain the conceptual difference between weak and dilute acids
- apply the necessary precautions while working with acids
- define pH
- describe the pH scale
- identify a given pH-labelled solution as acidic, basic or neutral
- perform activities to determine the pH of some common substances using universal indicators or pH meter
- calculate the pH of a given acidic solution
- calculate the concentration of hydrogen ion from the given information
- perform activities to investigate some physical properties of acids
- do activities to investigate some chemical properties of acids
- discuss the direct combination of elements, the reaction of acidic oxides with water and formation of volatile acids from non -volatile acids as the three

methods of preparation of acids

- carry out simple experiment to prepare acids in laboratory
- describe the uses of the three common laboratory acids

Planning

For the teaching of this unit, the following activities are recommended

- Read the contents of this section carefully and thoroughly to get familiarized with the concepts
- Set your own plan so that the contents and activities will be covered within 7 periods
- Make the necessary arrangements of chemicals and apparatuses required to perform the experiments
- Carry out the experiments beforehand
- Prepare a plan on how and when the students will conduct the experiments in groups

Refer to the students' text for the necessary chemicals and apparatuses required to conduct experiments.

Subject Matter Presentation

Definition of Acids

Group discussion, questionand answer methods are recommended for teaching this section.

First introduce the topic of the section and follow the following activities

- Let the students discuss ***Activity 3.7*** for about 3 minutes
- Follow the discussions and observe how each student participates in the discussion. Give guidance and assistance whenever they need it.
- After completion of the discussion, allow the students from different groups present the details of their discussion in their groups to their classmates
- Use a mini -lecture to harmonize their ideas with concepts that they expected to know.
- Introduce them to acids that we encounter in our daily life. This can include acetic acid, citric acid, lactic acid, etc.
- The bases that we encounter in our daily lives include soaps and detergents that we use daily and the toothpaste.
- Tell them also that 'injera', cheese and fruits like lemon and orange juice are

sour.

- Tell them also that injera, cheese and fruits like lemon and orange juice are sour.
- Continue with the Arrhenius definition of acids in relation to the concept in Activity 1.8. Acids release a hydronium ion, H_3O^+, in aqueous solution. This polyatomic ion is formed when an H^+ ion reacts with water as

$$H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$$

- Explain that Arrhenius Acids are those capable of releasing hydronium ion in aqueous solutions such as HCl, HNO_3, H_2SO_4, HI, HBr, and HF.
- Let students get information about the limitation of Arrhenius definition. Let them get further information that broader definitions will be given in grade 12.

Classification of Acids

It is advisable to start introducing the contents of this section using ***Activity 3.8***.

The activity is suggested to help students discover one of the bases for the classification of acids.

- Have the students discuss ***Activity 3.8*** for a few minutes in groups.
- Then have one or two students from different groups present their views.
- Then harmonize their ideas with the facts they are supposed to know.
- Tell them that H_3PO_4 has three ionisable hydrogen atoms, and hence it is triprotic
- Although the number of hydrogen atoms in CH_3COOH is four, only one of them is ionisable and hence it is monoprotic. Now introduce that acids can be classified based on the number of ionisable hydrogen atoms they possess per molecule, as monoprotic, diprotic and triprotic.

$$CH_3COOH \Leftrightarrow CH_3COO^- + H^+$$

Monoprotic

$$H_2SO_4 \rightarrow SO_4^{2-} + 2H^+$$

Diprotic

$$H_3PO_4 \Leftrightarrow PO_4^{3-} + 3H^+$$

Triprotic

- Before you conclude introducing monoprotic and polyprotic acids, use ***Activity 3.9*** to help students understand that not all compounds containing hydrogen are acids. Have the students discuss ***Activity 3.9*** in groups for a few minutes and present their opinions to the class. Then tell them that even though NH_3 contains three hydrogen atoms, it doesn't release these hydrogen atoms and is not a triprotic acid. Rather, it is a base.

- Write the chemical formulas for HCl, HF, H_2S in one column, and those for HNO_3, H_2SO_4 and $HClO_3$ in another column. Tell them that HCl, HF; H_2S are binary acids while HNO_3, H_2SO_4 and $HClO_3$ are ternary acids.
- Let the students discuss this in groups for a few minutes as they can discover the basis for the classification of acids as binary and ternary. Then invite one or two groups to present their opinions to the class.
- Inform them that acids can also be classified, based on the number of elements forming as acid, as binary and ternary acids. Give examples of each of them like

  Binary acids are composed of two types of elements namely non-metal and hydrogen. Examples, HCl, H_2S, HI

  Ternary acids are composed of three types of elements namely hydrogen, non-metal and oxygen. Inform them that ternary acids are sometimes oxoacids as they contain oxygen. Examples, H_2SO_4, HNO_3, CH_3COOH

General Properties of Acids

Teaching methods: experiment, group discussion, and question and answer are recommended for this topic.

- Check whether students could identify clearly monoprotic and polyprotic acids as well as binary and ternary acids.
- Then , start teaching the lesson using ***Activity 3.10*** which is designed to help students discover the taste of acids
- Let the students discuss ***Activity 3.10*** in groups and then have one or two students present their opinions to the class.
- Tell them that lemon and orange juice taste sour because citric acid is present in the juice.
- Next, present the general properties of acids. This should include their taste, effect on indicators, reactions with active metals, carbonates and hydrogen carbonates, sulphites and bases
- Use Experiment as your major method while dealing with the properties of acids. Hence, students should perform ***Experiments 3.4, 3.5, 3.6.***
- When they conduct ***Experiment 3.4*** to see the effect of acids on indicators, have the students write laboratory reports in groups on their observations and present to the class.

Make sure that the students'experimental results agree with the following facts

Table 3.2 Color of indicators in lemon juice, dilute HCl, HNO_3 and H_2SO_4

Indicator	Colour of indicator in			
	Lemon juice	Dilute HNO_3	Dilute HCl	Dilute H_2SO_4
phenolphthalein	Colorless	Colorless	Colorless	Colorless
litmus	Red	Red	Red	Red
Methyl red	Red	Red	Red	Red
Universal indicator	Orange-red	Red	Red	Red

In relation to the reactions of acids with active metals, have the students perform Experiment 3.5 under your supervision. Have them produce laboratory reports in Groups. Then invite students from two different groups to present their observations. Check whether or not the following points are mentioned in their reports.

- ☞ When acids are added to the given metals in each test tubes, the formation of bubbles shows that gas is a hydrogen.
- ☞ When a burning splint is brought close to the mouth of the test tube, a" popping" sound is heard. This proves that the gas is hydrogen.
- ☞ The reaction of powdered magnesium with HCl and H_2SO_4 is the most violent
- ☞ After completing the experiment and presentation, you can continue by explaining the reactions of acids and carbonates. Let the students discover the products that result from reactions of acids and carbonates by performing ***Experiment 3.6*** in groups. Encourage them to write group reports and make presentations to the class. In relation to this experiment, make sure that their reports on observation and analysis include the following points.
- ☞ The formation of bubbles indicates the release of gas.
- ☞ The change in the color of damp blue litmus to red when it is held close to the mouth of the test tube proves the gas to be acidic
- ☞ When the gas is passed through lime water, the clear solution turns milky, and this proves the gas to be carbon dioxide.
- ☞ Following ***Experiment 3.6*** and the students' presentations on their findings, tell them that the reactions of acids with sulphites produce SO_2, salt and water.
- ☞ Write some chemical equations and have the students complete and balance the equations in relation to reactions of sulphites and acids.
- ☞ Then proceed to reactions of acids with bases and basic oxides. To observe

this property of acids, have students perform ***Experiment 3.7*** in groups, write laboratory reports and submit them to you. Collect the reports and correct them.

Use the following note to check the reports of the students on their observations.

- NaOH is added one drop at a time, so we will not add more base than required to neutralize the acid
- The products formed in step 4 are NaCl and H_2O, in step 5, $CaCl_2$ and H_2O.
- When we dip blue litmus in the solutions immediately after the mixing in step –5, red the presence litmus turns blue, indicating of excess base.
- The blue litmus remains blue, and the red stays red in procedures 4 and 5 when neutralization is complete.

Strength of Acids, Dilute and Concentrated Acids

Presentation of the Lesson

You are advised to use group discussion and question and answer methodologies for this part.

- We suggest that you start teaching the lesson by using ***Activity 3.11***.
- The activity is suggested believing that students can discover the effect of acids on specific materials and can learn the precautions to be taken in chemical laboratories.
- Therefore, have the students discuss ***Activity 3.11*** in groups for a few minutes. Encourage some of them to present their opinions to the class.
- After the presentations, tell them that citric acid has no effect on the cloth but nitric acid attacks and may even damage the cloth. Therefore, nitric acid is a strong acid but citric acid is a weak acid. However, it is not possible to categorize acids as strong and weak based on their effects on other materials. Thus, you need to introduce the degree of ionization as the basis for classifying acids as strong and weak. Inform students that strong acids ionize completely in an aqueous solution, while weak acids ionize only slightly.

You can use the acids mentioned in the activity as examples. They should also know that acids are corrosive and that it is not advisable to taste. Before you start introducing concentrated and dilute acids, give the students a chance to discover what concentrated and dilute acids are on their own. Have them discuss ***Activity 3.12*** in groups for a few minutes and have two or more students from different groups present their ideas to the class. Following their presentations, harmonize the ideas suggested by students with facts that you want them to know. In the suggested activity, a solution containing 96% H_2O and the rest is H_2SO_4 is a dilute solution and a solution containing 96% H_2SO_4 and the rest is H_2O is a concentrated solution. In a car battery, if the electrolyte used is 35% H_2SO_4, then 65% of it is water. It is a dilute solution compared to concentrated sulphuric acid, which is 98% H_2SO_4 by mass. Then tell students that 'concentrated' and 'dilute' are terms used to describe the relative amount of acid present in a given quantity of acid solution. Be sure that the students understand that concentration can be expressed in terms of a number of moles per liter or molarity (M). Tell them the formula how to calculate the molarity of an acid solution.

Be sure that the students understand acids conduct electricity in aqueous solutions. This is because they ionize to positive and negative ions. The conduction of electricity through acid solutions depends on the concentration of ions. Since strong acids produce ions to a greater extent, they transmit electricity better than a solution of equal concentrations of weak acids. To prove this practically, have the students perform ***Experiment 3.8*** in groups under your supervision. They should write laboratory reports and present them to the class. Make sure that students have discovered that solutions of 1.0 M HCl and 1.0 M HNO_3 produce a bright light, while those of 1.0 M CH_3COOH produce a dim light. This result shows that HCl and HNO_3 are strong acids, while CH_3COOH is a weak acid. Following ***Experiment 3.8***, introduce the precautions for handling acids.

pH and pH Scale

We advise you to apply experiment and question and answer methodologies to this subtopic.

☞ After you check whether the students can differentiate between strong and weak acids, and dilute and concentrated acids, present the pH and pH scales.

☞ Solve some problems to show how the pH of a solution can be calculated from a given concentration of H^+ or the reverse. Let students practice calculating pH or concentration of H^+ independently. You can use ***Exercise 3.7*** for this purpose as classwork or homework

☞ Next, have the students determine the pH of the given substances in ***Experiment 3.9***. This will help students develop skills in determining whether a substance is an acid or not, from its pH value. After they complete the experiment, have one or two groups present their findings. The result they obtained should prove that the given substances are all acidic. This is because the pH values determined by the experiment are all less than 7.

Preparation and Uses of Acids

Presentation of the lesson

We advise you to use group discussion, experiment and question and answer methods for this sub -topic.

Check whether the students understand how to calculate pH from a given $[H^+]$, or the reverse, and can identify a solution as acidic or basic from its pH value. Then present the preparation of acids. First, let the students discuss in groups for a few minutes and suggest how they can prepare the following acids:

a) H_2SO_4 and HNO_3

b) HCl and HBr

Let one or two groups present their opinions to the class. After the presentations, introduce the three methods and then conduct ***Experiment 3.10***. Concerning the experiment, check whether or not the students have included the following points in their group reports. The white precipitate formed upon mixing $Ba(ClO_2)_2$ solution with dilute H_2SO_4 is $BaSO_4$. The equation for the reaction is:

$$Ba(ClO_4)_2\,(aq) + H_2SO_4\,(aq) \rightarrow BaSO_4\,(s) + 2HClO_4\,(aq)$$

TThe final solution is acidic due to the formation of chlorous acid. You can start teaching the lesson on the uses of some important acids with ***Activity 3.13***. The activity is designed to help students discover the uses of common acids in daily life and also to realize the implication of high consumption of sulphuric acid by a country. So, let the students discuss ***Activity 3.13*** in groups and present their views. In harmonizing their views with reality, tell them about the presence of citric acid in citrus fruits used as food, the use of vinegar, the use of dilute solutions of ethanoic acid as food flavoring substances, lactic acid in cheese, carbonic acid in carbonated beverages and hydrochloric acid in gastric juice that helps digestion.

Let them also know that high consumption of sulphuric acid indicates the economic growth of a given country for it is the leading industrial chemical used in the production of a wide variety of substances. Then, introduce them to the uses of HCl, HNO_3 and H_2SO_4.

Assessment

Assess the students' work throughout the section. Check how every student does during discussions, explanations, classwork and homework. Evaluate whether or not most of the students have achieved the competencies suggested for the section. Appreciate students working above the minimum required level and give them extra work. Assist those working below the minimum required level by arranging additional lesson time or giving them additional exercises on points they didn't understand.

Additional Questions

1. Classify the following acids as strong or weak.

A. HI	B. H_2SO_4	C. H_2CO_3	D. HNO_2
E. H_3PO_4	F. HNO_3	G. HCOOH	H. H_2S

2. Gastrite patients are advised to take tablets or suspensions of weak bases such as magnesium hydroxide or aluminium hydroxide. Which reaction of acids enables them get relief upon taking the weak base?
3. The acids of phosphorus, H_3PO_4, H_3PO_3 and H_3PO_2, are triprotic, diprotic and monoprotic acids, respectively. What is the reason for this?
4. Two reagent bottles, labeled A and B, are filled with solutions prepared by dissolving 49g H_2SO_4 in 250 mL solution and 122.5 g of the acid per litresolution, respectively.

   A) What is the molarity of solution A and B, respectively?

   B) When you compare the two solutions which one is

   I) more concentrated?

   II) more dilute? (molar mass of: H_2SO_4 = 98 g/mol)
5. The pH of an acid solution is 2.8. What is the hydrogen-ion concentration in the solution?
6. Aqueous solution of HCl is a good conductor of electricity. What is the reason for its electrical conductivity?

Answers to Additional Questions

1. A, B and F are strong acids.

   C, D, E, G and H are weak acids.
2. Neutralization reaction.
3. H_3PO_4, H_3PO_3 and H_3PO_2 contain three, two and one ionizable hydrogen, respectively.
4. They neither release H^+ in aqueous solutions nor donate or accept H^+.
5. a) 2M and 1.25M, respectively.

   b) I. solution in A II. solution in B

6. 1.6×10^{-3} M

7. This is due to complete dissociation of HCl to H^+ and Cl^- ions in aqueous solution.

Answers to Exercises 3.7

1. A. Organic acids – examples: CH_3COOH, CH_3CH_2COOH, $CH_3CH_2CH_2COOH$

   Inorganic acids – examples: H_2SO_4, HNO_3, $HClO_4$

   B. Inorganic acids are generally stronger than organic acids. In the above list H_2SO_4, HNO_3, $HClO_4$ are strong acids whereas CH_3COOH, CH_3CH_2COOH, $CH_3CH_2CH_2COOH$ weak acids.

2. In aqueous solution HCl and HNO_3 ionize to give hydrogen ions (H^+)

   I. $HCl(aq) \rightarrow H^+(aq) + Cl^-$

   II. $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$

Therefore, these solutions show acidic characteristics.

☞ Alcohol and glucose do not ionize and do not give hydrogen ions. Therefore, these solutions do not show acidic property.

Answers to Exercises 3.8

1. pH = 2

2. 1 mole of H_2SO_4 gives two moles of H^+ whereas one mole of HCl gives one mole of H^+

3. A. $[H^+] = 1.0 \times 10^{-2}$ M B. $[H^+] = 1.0 \times 10^{-6}$ M

   C. $[H^+] = 1.0 \times 10^{-2}$ M = 10,000 times

$[H^+]$ 1.0×10^{-6} M

Answers to Exercises 3.9

1. A, C, D, E are Arrhenius acids whereas B and F are not Arrhenius acids

2. Monoprotic acids=A, I, E, G, J, K, L

   Diprotic acids = B, C, D, F

   Triprotic acid = H

   Strong Acids = A, B, D, G, K

   Weak Acids= C, E, F, H, I, J, L

   Binary Acids= E, F, G,

   Ternary Acids= A, B, C, D, H, I, K, L

3. Use indicators

4. Degree of their dissociation

5. A. pH = 4.3 B. pH = 2.5 C. pH = 5.7

6. A. $[H^+] = 10^{-pH} = 10^{-4} = 1.0 \times 10^{-4}$mol/L B. $[H^+] = 10^{-pH} = 10^{-2} = 1.0 \times$

10^{-2} mol/L

C. $[H^+] = 10–pH = 10^{-5} = 1.0 \times 10^{-5}$mol/L

7. No. of moles = 0.075

8. A. Acidic, $[H^+] = 3.17 \times 10^{-7}$ B. Acidic $[H^+]=2\times10^{-4}$

C. Basic $[H^+] = 1.26 \times 10^{-8}$ D. Acidic $[H^+] =3.17 \times 10^{-4}$

3.4 Bases

Alloted Period 5 Periods

Competencies

After completing this section, you should be able to

- define bases in terms of the concepts of Arrhenius
- give examples of bases based on Arrhenius
- discuss the general properties of bases
- define strong and weak bases
- distinguish between strong and weak alkalis (soluble bases)
- define concentrated and dilute alkalis
- distinguish between concentrated and dilute alkalis (soluble bases)
- use the necessary precautions while working with bases
- define pOH
- show the mathematical relationship between pH and pOH
- calculate the pOH of a given basic solution
- calculate the concentration of hydroxide ion from the given information
- carry out activities to investigate some chemical properties of bases
- discuss the reaction of active metals with water, the reaction of basic oxides with water and double displacement reactions as the three methods of preparation of bases
- carry out simple experiments to prepare bases in laboratory
- explain the uses of the two common laboratory bases

Definitions of Bases

Planning

For the teaching of this unit, the following activities are recommended

- Read the contents of this section carefully and thoroughly to get familiarized with the concepts
- Set your own plan so that the contents and activities will be covered within 5

periods

- ☞ Make the necessary arrangements of chemicals and apparatuses required to perform the experiments
- ☞ Carry out the experiments beforehand
- ☞ Prepare a plan on how and when the students will conduct the experiments in groups

Refer to the students' text for the necessary chemicals and apparatuses required to conduct experiments

Subject Matter Presentation

Implement group discussion as well as question and answer methods to teach this topic. Introduce the topic of the section. The section starts with ***Activity 3.14***. The activity is suggested to help students discover the taste of bases and understand the agricultural application of bases. Let the students discuss ***Activity 3.14*** in groups. Encourage students from some groups to present their views on points they discussed to the class. After their presentations, continue the lesson on bases. First, tell them why we study bases and introduce a few uses of bases. For example, you can tell them that farmers add limestone to their soil to remove soil acidity.

Then, continue with the definitions of bases. Before dealing with the details, ask the students to tell you what Arrhenius acids are. After they respond to your questions, ask them again if they can state Arrhenius definition of bases. Next, define bases according to Arrhenius concept. Arrhenius bases include hydroxides of alkali metals and lower members of alkaline earth metals. Examples of Arrhenius bases are LiOH, NaOH, KOH, $Ca(OH)_2$, $Ba(OH)_2$ etc.

General Properties of Bases

Group discussion and question and answer methods can be implemented in this sub-topic.

Make sure that students have understood the definition of bases according to Arrhenius and then proceed to the general properties of bases. The first statement in ***Activity 3.15*** is suggested in order to introduce the bitter taste of bases. Let them know that soap also tastes bitter since it forms a basic solution. Before you continue with other properties of bases, use ***Activity 3.15***, which is suggested to help students discover what they feel when touching bases. So, let students discuss ***Activity 3.15*** in groups and have one or two students present their opinions to the class. After the presentations, tell them that a solution of washing soda in water is basic. When one washes his hands with the solution, it gives a soapy feel. So bases feel soapy to the touch. Let the students discuss the following points in groups for a few minutes and some groups present their opinions to the class.

a. What is the effect of soluble bases on the colour of litmus, phenolphthalein,methyl red and a universal indicator?

b. Which ion do soluble bases release in an aqueous solution?

c. What products do they form when bases react with acids and acidic oxides?

d. Why do aqueous solutions of soluble bases conduct electricity?

After the presentations, harmonize the concepts suggested by the students with the facts.

Build a mini-lecture and introduce the effect of bases on indicators, the ion released by soluble bases in aqueous solution, their capacity to neutralize acids and acidic oxides and their ability to conduct electricity. Let them practice writing chemical equations on the reactions of bases.

Strong, Weak, Dilute and Concentrated Bases

We advise that, before you continue introducing the strength of bases, you implement ***Activity 3.16***. The activity helps students to realize the conceptual differences between the terms concentrated, dilute, strong and weak bases. So, let them discuss ***Activity 3.16*** for a few minutes in groups and present their opinions to the class. Then ask them to recall the basis for the classification of acids as strong and weak. Tell them that the classification of bases as weak and strong is also based on their degree of dissociation or ionization. Give examples of strong bases, such as LiOH, NaOH, KOH, $Ba(OH)_2$, and weak bases. Emphasize that a strong base is not the same as a concentrated base. A solution of a strong base can be either concentrated or dilute, and the same is true for a solution of a weak base like NH_3, $Mg(OH)_2$, etc. Again, let the students' recall what "concentrated" and "dilute" mean. Let them know that the concentration of bases is expressed in terms of the number of moles of the base per liter of solution, or molarity. Solve some problems to show them how to calculate the molarity of a basic solution. Help students to practice calculating the molarity of basic solutions by giving them additional questions. Following this, tell the students about the precautions to be taken in handling bases and then continue to present pOH

pOH

We advise you to use group discussion, question and answer, and experiment as methods for this sub-topic.

Start teaching the lesson on pOH by using ***Activity 3.17***. The activity enables students to realize the presence of H^+ and OH- in water in equal amounts and also to discover the effect of increasing $[OH^-]$ on the concentration of H^+.

Before you deal with the details about pOH, have the students discuss ***Activity 3.17*** for a few minutes in groups and present their conclusions to the class. To harmonize their ideas with the actual concepts, tell them that water can behave as an acid and a base and that it can behave as a proton donor as well as a proton acceptor. However, it contains the same concentration of H^+ and OH^-. After that, ask the students to recall the definition of pH and then let them define pOH. Introduce them to the mathematical expression of pOH.

$$pOH = - \log10[OH-]$$

Derive the relationship between pH and pOH. Inform them about the relationship as pkw = pH + pOH or pH + pOH=14 at 25°C.

Then, proceed by explaining how to use this relationship to calculate the $[H^+]$, pOH and pH from given concentrations of OH^- and values of Kw by solving some examples. Have the students practice calculating $[H^+]$, $[OH^-]$, pH and pOH from given concentrations of acids or bases. From the expression $[H^+]\ [OH^-] = 1.0 \times 10^{-14}$ mol /L, help them to realize that an increase in $[OH^-]$ in a solution is accompanied by a decrease in $[H^+]$.

When you are quite sure that students have understood how to calculate pH, pOH, $[H^+]$ or $[OH^-]$ from given information, continue with ***Experiment 3.11***. Make the necessary arrangement for students to perform it in groups.

After they complete the experiment, have them write laboratory reports on their observations and present them to the class.

Their observations and analyses should include the following points.

- Bases like NaOH and KOH melt when heated.
- Bases like $Ca(OH)_2$ decompose on heating to form an oxide and water. The equation for the decomposition of $Ca(OH)_2$ is:

  $$Ca(OH)_2 \rightarrow CaO + H_2O$$

- ☞ The formation of water is proved by using cobalt chloride paper, which turns pink in the presence of water.
- ☞ When the solution obtained after neutralization is allowed to evaporate, white crystals of KNO_3, salt will remain on the watch glass.

Preparation of Bases

Presentation of the Lesson

It is advisable to use mainly experiments and a mini-lecture to teach concepts in this lesson.

When you are dealing with the methods for the preparation of bases, use the experiment as the major methodology. Have students perform ***Experiment 3.11*** in groups to discover and understand the methods. Cut a small piece of sodium for the experiment or have students cut under your supervision. After the students complete the experiment, let them write laboratory reports on their observations in groups and present them to the class. From the experiment, make sure they have discovered that bases can be prepared by the reaction of active metals and water, metal oxides with water and by the double-displacement reaction. The answers to the questions in the observation and analysis part of the experiment are

1. The gas given off while performing procedure 1 is hydrogen

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

The solution obtained in this procedure turns red litmus blue and methyl orange yellow, and it is basic.

2. In the second procedure, when CaO or MgO dissolves in water, the resulting solution is basic and turns red litmus blue.

When a solution of K_2SO_4 or Na_2SO_4 is added to a $Ba(OH)_2$ solution, there is formation of a white precipitate, which is barium sulfate. The final solution contains either KOH or NaOH, depending on the type of sulfate used and turns red litmus to blue. If Na_2SO_4 and $Ba(OH)_2$ are used for the experiment, the reaction is as follows:

$$Na_2SO_4(aq) + Ba(OH)_2\,(aq) \rightarrow BaSO_4\,(s) + 2NaOH(aq)$$

Finally, introduce the uses of some important bases, such as NaOH, KOH, $Ca(OH)_2$ and ammonia solution.

After you conclude this section, have the students do the reading assignment, either in groups or individually, and then either submit their work for correction or present them to the class, as per your decision.

Assessment

Assess the work of each student throughout the section. You can do so by making a record in your students' performance list. To make a record, see how every student participates in discussions, in presenting the conclusions of the group after discussions, in answering questions during explanations, in answering questions given as class work and homework, and in performing experiments. You can also use quizzes or tests. From the records you have, decide whether most of the students have achieved the minimum requirement level. Appreciate students working above the minimum required level and give them additional exercises. Arrange make-up classes or give more exercises for students working below the minimum level.

Additional Questions

1. Decide whether solutions having the following pH values are acidic or basic.
   A) 2.6 B) 1.0 C) 13 D) 4 E) 9
2. Are solutions with the following pOH values acidic or basic?
   A) 1.5 B) 10 C) 5 D) 8 E) 3.0
3. What is the pOH, pH and $[H^+]$ of a solution whose hydroxide ion concentration is
   A) 2.0×10^{-4}M B) 1.0×10^{-8}M C) 4.0×10^{-3}M
4. How many grams of NaOH are contained, per liter, of solutions that have the following concentrations? (Molar mass: NaOH = 40 g/mol)
   A) 2.5M B) 1.25M C) 3.2M
5. Give one example of Arrhenius base that is not derived from a basic oxide.

Answers to Additional Questions

1. A. Acidic B.Acidic C.Basic D. Acidic E. Basic
2. A. Basic B. Acidic C. Basic D. Acidic E. Basic
3.

A. pOH = 3.7, pH = 10.3, $[H^+] = 5.0 \times 10^{-11}$ M

B. pOH = 8, pH = 6, $[H^+] = 1.0 \times 10^{-6}$ M

C. pOH = 2.4, pH = 11.6, $[H^+] = 2.5 \times 10^{-12}$ M

4. A. 100g B. 50g C. 128 g
5. NH_3

Answers to Exercises 3.10

1. pH = 5 $\Rightarrow$ pOH =9, $[OH^-] = 1.0 \times 10^{-9}$ M

   pH = 9 $\Rightarrow$ pOH =5, $[OH^-] = 1.0 \times 10^{-5}$M

   Solution with pH= 5 has higher (H_3O^+) concentration than solution with pH=9

   Solution with pH= 9 has higher $[OH^-]$ concentration than solution with pH=5

2. A. pH = 5 $\Rightarrow$ pOH =9 B. pOH = 9, pH = 5

3. A. pH = 13 $\Rightarrow$ pOH = 1 B. pH = 3 $\Rightarrow$ pOH = 11 C.pH = 8 $\Rightarrow$ pOH = 6

A is the most basic and B is the most acidic

3.5 Salts

Alloted Period 5 Periods

By the end of this section, students will be able to

- define salts
- give examples of salts
- classify salts as acidic and normal salts
- discuss the direct combination of elements, the reaction of acids with bases, neutralization and the reaction between acids and metals as the methods of salt preparation
- carry out simple experiment to prepare a salt by neutralization.
- list some important salts
- explain the uses of some important salts
- discuss the properties of salts
- explain the chemical tests of some salts by conducting activities

Planning

Read thoroughly and familiarize yourself with the contents of this section. Set a plan for the contents and activities that you need to deal with during each period so that the whole content of the section can be covered within five periods. In addition, there are seven experiments in this section, ***Experiments 3.13 – 3.19***. Arrange all the chemicals and apparatuses required to conduct the experiments. Prepare a schedule for conducting and how to organize the students in groups for a laboratory work. Carry out all the experiments before you allow students to conduct the experiments.

Subject Matter Presentation

Definition and Classification of Salts

Group discussion and question and answer methods are suggested for teaching this lesson.

Introduce the topics of the section and prepare for the teaching – learning process. Let the students discuss in groups ***Activity 3.18*** for a few minutes. After they complete their discussions, invite some groups to present their ideas. During their presentation, write the salts they know on the board. Let them also suggest properties of salts they know such as solubility in water, colour etc. After their presentations, you can add a few examples of salts like NaCl, $CaCO_3$, Na_2SO_4, KNO_3, $CaSO_4$, $(NH_4)_2$ HPO_4 $MgCl_2$ etc. Inform them that most salts are found in nature while some are manufactured industrially. For example, large deposits of NaCl and sufficient amounts KNO_3, $MgCO_3$ are found in the Dalol Depression, Afar region. NaCl is also found in the Somali region around Elkere. Sodium chloride for various consumptions in Ethiopia is obtained by evaporation of salt water from Afdera Lake located in the Afar region. $CaCO_3$, limestone is found in western Showa, near Guder at a place called Senkelle. Tell them also that most salts are white in colour, but that salts of transition metals are coloured. A few examples are hydrated copper sulphate, $CuSO_4{\bullet}5H_2O$ (blue), potassium dichromate, $K_2Cr_2O_7$ (yellow) and potassium permanganate, $KMnO_4$ (dark violet). Write the formulas of some salts on the board. Ask students to define salts. After their responses, introduce the definition of salts.

You can start introducing the classification of salts by using ***Activity 3.19***. This activity will help students to differentiate an acid salt, basic salt and normal salt. Therefore, let the students discuss this activity in groups for a few minutes. Encourage two students from different groups to present what they discussed to the class. Following their presentations, explain the three classes of salts **acidic, normal** and **basic salts.**

To harmonize their ideas with the actual concepts, write the formulas Na_2SO_4, $NaHSO_4$ and H_2SO_4 on the blackboard. Ask them in what manner the formulas of the salts differfrom the acid. Based on their responses, tell them that when all ionizable hydrogen atoms of an acid are completely replaced by a metal or ammonium ion, the resulting salt is normal salt. If the ionizable hydrogen atoms are partly replaced by a metal ion or ammonium ion, the salt that can be obtained is an acid salt. Write the formulas $ZnCl_2$, Zn(OH)Cl and $Zn(OH)_2$ on the board and proceed in the same manner as above to define basic salt. Write the formulas of some salts and let students classify the salts as acidic, basic and normal. After checking how students are doing their work, continue dealing with the preparation of salts.

Preparation of Salts

Presentation of the Lesson

Group discussion, experiment and question and answer methodologies are suggested to deal with contents of this lesson.

Start teaching the lesson on this part by using ***Activity 3.20***. The activity is designed to help students discover methods for the preparation of salts on their own. So, have students suggest some methods of preparation after they discuss ***Activity 3.20***. Following their responses, tell them that NaCl can be prepared by reacting Na and Cl_2, Na_2O and HCl or NaOH and HCl. Then, introduce the methods used in salt preparation. Have the students write balanced chemical equations for each method of preparation. Inform students that not every method can be used to prepare every salt.

Let students perform ***Experiment 3.12*** in groups to see one method of preparation of salts. After completing the experiment, students from two groups should make presentations. Check whether each presentation is in accordance with the following observation: During this experiment, CO_2 gas evolves as a byproduct in the reaction of $NaHCO_3$ with concentrated HCl. The main product NaCl is obtained by evaporation of the solution.

The equation for the reaction is:

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

Tell them to remember one property of acids is to release CO_2 in their reaction with carbonates and bicarbonates producing a salt of the acid. Inform them in nature how statues made of marble ($CaCO_3$) are damaged by acid rain because of this reaction. After the experiment, you can start introducing the uses of some important salts by using ***Activity 3.20***. The activity is aimed at helping students realize the importance of salts in medicine. Have the students discuss this activity and ask some groups to share their ideas with the class. Next, harmonize their opinions with the actual concepts and inform students that oral rehydration salt, ORS, contains glucose, sodium chloride, trisodium citrate and potassium chloride. This is the composition of ORS available in pharmacies. Inform them that homemade ORS can be prepared by mixing sugar, common salt (NaCl) and lemon juice in water.

Following this, introduce the uses of some important salts, such as NaCl, NH_4NO_3, $CuSO_4$, $FeCl_3$, and KNO_3. Then continue by explaining properties of salts.

Properties of Salts

We advise you to use a gapped lecture to teach this lesson. When dealing with the properties of salts, first introduce the group of salts that are soluble in water. Also inform them about the exceptions among the groups. Define these terms: hygroscopic, deliquescent and efflorescent. Give examples of deliquescent, hygroscopic and efflorescent salts. Explain why solutions of soluble salts conduct electricity. Then compare the thermal stability of carbonates. Ask students to suggest carbonates that undergo decomposition reaction when heated. Tell them that carbonates of sodium and potassium do not decompose easily. In addition, nitrates of sodium and potassium decompose by heat to give nitrites and oxygen gas, while those of other metals produce the metal oxide, nitrogen dioxide and oxygen. Write the chemical formulas of the reactants on the board, and have students to complete and balance the chemical equations related to decomposition of salts by heat. After completing the content on properties of salts, continue by presenting chemical tests of some ions in salts.

Chemical Tests of Some Ions in Salts

Presentation of the lesson

It is advisable to use experiment as a method while dealing with this sub-topic. We advise you to start teaching this lesson by using ***Activity 3.21***. The activity enables students to know why fireworks give different colours and realize how flame colors can be used to identify metals present in salts. Let the students discuss ***Activity 3.21*** in groups for a few minutes. Encourage students from different groups to explain their ideas to the class.

After that, give them some information on fireworks (sparks used on holiday celebrations). These fireworks produce different colors on explosion because the compounds used in their production contain different metals. For example, those containing strontium compounds produce a crimson flame color, sodium compounds orange-yellow, copper compound blue-green etc. So, chemists use flame tests and other chemical tests to know the presence of certain substances (metals). Have students conduct ***Experiment***

3.13 in groups. While performing the experiment, they should discover that certain metals produce a characteristic flame color peculiar to them. When they carry out this experiment, make sure that they obtained the following results.

The following flame colors are observed while heating the salts containing Li^+, Na^+, K^+, Ca^{2+}, Sr^{+2} and Ba^{2+}.

Metal ion in the salt Color of flame produced

lithium	Crimson
sodium	Yellow
potassium	Purple (violet)
calcium	Orange-red
strontium	Crimson
barium	green

Regarding ***Experiment 3.14***, make sure that the students obtained the following results.

1. The formation of a blue precipitate which dissolves in excess ammonia to form a deep blue solution indicates the presence of Cu^{2+} ions. The blue precipitate is $Cu(OH)_2$, which dissolves in excess ammonia to form copper (II) tetra amine, $Cu(NH_3)_4{}^{2+}$
2. The formation of a pale-green precipitate in the second test tube indicates the presence of Fe^{2+} ions.

   Fe^{2+} (aq) + $2OH^-$ (aq) $\rightarrow$ $Fe(OH)_2$ (s)

   Pale-green
3. The formation of a pale-brown precipitate in the third tube confirms the presence of Fe^{3+} ions:

   Fe^{3+}(aq) + 3OH-(aq) $\rightarrow$ $Fe(OH)_3$ (s)

   Pale-brown

In performing ***Experiment 3.15***, the following observation should be made by students. Formation of white precipitate ($BaSO_4$) indicates the presence of sulfate ions in the solution. It is formed by the reaction of Ba^{2+} and $SO_2{}^{-4}$

$$Ba^{2+} (aq) + SO_2{}^{-4} (aq) \rightarrow BaSO_4(s)$$

Some drops of dilute HCl are added to the solution to be tested to avoid confusion. That is, ions like $CO_2{}^{-3}$ can form a precipitate with Ba^{2+}. However, HCl dissolves compounds like $BaCO_3$ but not $BaSO_4$.

The observations for ***Experiment 3.16*** are:

1. After the addition of $AgNO_3$ in the presence of HNO_3

   I. The formation of white precipitate in the first test tube indicates the presence of chloride ions .The white precipitate is AgCl

   II. The formation of yellow precipitate in the second test tube proves the presence of bromide ions and the yellow precipitate is AgBr

   III. The formation of yellowish-green precipitates confirms the presence of iodide ions and the precipitate is AgI.

HNO_3 is used in this experiment to prevent unwanted precipitation by the reaction of Ag^+ and other ions.

If ammonia solution is added to each test tube, the precipitate in the first (AgCl) will dissolve, the precipitate in the second (AgBr) will dissolve partly, while the precipitate in the third (AgI) will not dissolve.

2. While conducting ***Experiment 3.17***, students will get the following result:

When dilute HCl is added to the solution of Na_2CO_3 and $NaHCO_3$, there is an evolution of carbon dioxide gas, which turns lime water milky. This is due to the formation of $CaCO_3$.

$$Ca(OH)_2(aq) + CO_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

Upon addition of calcium chloride solution, solutions of carbonates form a white precipitate of $CaCO_3$.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

Solutions of hydrogen carbonates do not form precipitate upon the addition of $CaCl_2$ solution. In testing for nitrates in ***Experiment 3.18***, students will get the following results: When concentrated sulphuric acid is poured down the side of the test tube, the acid sinks to the bottom, and a brown ring is formed where the two layers meet. The formula of the substance that forms the brown ring is $FeSO_4{\cdot}NO$.

As a summary of important inorganic compounds, list the following words on the blackboard and have students construct a concept map for the classification of inorganic compounds, using the given words.

Plant Nutrients

IIt is advisable to teach this part using group discussion and inquiry as your methods.

After completing the experiments on chemical tests of some ions in salts, continue by teaching the lesson on plant nutrients. We advise you to start the lesson by using ***Activity 3.22***. This activity will help students identify salts that are used as fertilizers, realize the form in which plants absorb nutrient elements and discover the effects of eating food materials grown using synthetic fertilizers. First, have the students discuss the activity in groups and explain what they discussed to the rest of the class. After that, suggest your own view; you may conclude that DAP and urea are common fertilizers used in Ethiopia. DAP is an inorganic salt, while urea is an organic compound. Also, tell them about the presence of many inorganic salts that are used as fertilizers, such as KCl, KNO_3, $(NH_4)_2SO_4$, NH_4NO_3 and $Ca(H_2PO_4)_2$. In relation to the second question in ***Activity 3.22***, tell them that although nitrogen is abundant in air, it is not in the form that plants can use. Also, tell them that eating organically grown food materials is better than eating food grown using synthetic fertilizers. This is because food materials grown using synthetic fertilizers may cause cancer through long-term use.

Present the elements required for the growth of plants called essential nutrients. Then, have them discuss ***Activity 3.22*** and discover the micronutrients and macronutrients required for the growth of wheat, maize and rice.

Then, introduce **macronutrients** and **micronutrients** and the elements classified in the two categories. Ask students to describe the importance and role of **nitrogen,phosphorus** and **potassium** in plant growth. Have students define fertilizers. List somecommon fertilizers and explain their importance. Introduce that fertilizers can be naturalproducts or artificial chemicals. Define complete fertilizers and NPK. Finally, list someinorganic chemicals that are used as pesticides and herbicides.

Assessment

You may assess each student's work throughout the section by supervising how he or she is doing in all activities of the teaching - learning process, by correcting their classwork and homework and by recording everything about the students in the performance list. From your records, see whether the suggested competencies for this section are achieved by most of the students. As you did in the previous sections, appreciate students working above the minimum require level and give them additional exercises. For students working below the minimum required level, assist them with what you think is important to enable them catch up with the rest of the class.

Additional Questions

1. What type of salt (acidic, basic or normal) will be formed if one mole of H_3PO_4 is allowed to react with

   A) 1 mole of NaOH? B) 2 moles of NaOH? C) 3 moles of NaOH?

2. Write the balanced chemical equation for each of the reactions (A to C) inquestion 1.

3. If a salt releases a reddish – brown gas with a disagreeable smell that turns moist blue litmus red up on heating,

   A) Which anion is most likely present in the salt?

   B) Which gas is liberate by heating the salt?

4. What symptom do plants show when they grow on nitrogen-deficient soil

5. How can you prepare

   A) calcium hydroxide B) calcium nitrate from calcium carbonate?

6. The formula of DAP (used as a fertilizer) is $(NH_4)_2\ HPO_4$.

   A) Is DAP an acid, basic or normal salt?

   B) Which acid and base should be used to produce this fertilizer?

   C) Write the balanced chemical equation for the reaction that yields DAP.

7. Which elements are considered to be primary mineral nutrients?

Answers to Additional Questions

1. A. Acidic B. Acidic C. Neutral

2. A. $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$

   B. $H_3PO_4 + 2NaOH \rightarrow Na_2HPO_4 + 2H_2O$

   C. $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$

3. A. NO_3^- B. NO_2

4. Yellow

5. $CaCO_3^{+}\ 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

   $CaCO_3 \rightarrow CaO + CO_2$

   $CaO + H_2O \rightarrow Ca(OH)_2$

6. A. Acidic salt B. NH_3 and H_3PO_4 C. $2NH_3 + H_3PO_4 \rightarrow (NH_4)_2HPO_4$

7. Nitrogen, Potassium, potassium

Answers to Exercises 3.11

A. Zinc sulphate $(ZnSO_4) = Zn(OH)_2$ & H_2SO_4

B. Calcium phosphate $Ca_3\ (PO_4)_2 = Ca(OH)_2$ & H_3PO_4

C. Silver acetate (CH_3COOAg)= Ag(OH) & CH_3COOH

D. Sodium carbonate (Na_2CO_3) =NaOH & H_2CO_3

Answers to Exercise 3.12

1. I. NaOH + phenolphthalein $\rightarrow$ Pink Color

   II. Pink color + HCl $\rightarrow$ Pink color disappears

   III. NaCl + Phenolphthalein $\rightarrow$ No change

2. A. Direct combination of elements

   B. Reaction of two different salts/ double decomposition reaction

   C. Reaction of carbonates or bicarbonates with dilute acids

3. Soluble: A, B, H, F, E

   Insoluble: G, D, C, I, J

4. Because they release positive and negative ions

5. Carbonates of group IA, Na_2CO_3 and K_2CO_3

6. Nitrates of sodium and potassium

7. A. $AgNO_3$ solution

   B. NaOH solution

   C. $BaCl_2$ or $Ba(NO_3)_2$ solution

8. Na_2CO_3

Answers to Exercise 3.13

1. Refer to the students' textbook.

2. Plants absorb nitrogen in the form of NO_3^-, phosphorus as $H_2PO_4^-$ and HPO_4^{2-} (in small amounts), and potassium as K^+

3. Energetically unfavorable for a plant to split either N_2 or P_4 molecules in order to get the raw atoms that can be used by plants.

Answers to Exercise 3.14

1. Refer student textbook

2. Synthetic fertilizers: A and C

   Organic fertilizer: B

3. No, because for acidic soil, we cannot use a fertilizer that increases its acidity. The same is also true for basic soil. Moreover, fertilizers are applied based on the deficiency of plant nutrients. So the same fertilizer can not be applied to all types of soil.

Additional Activities to Promote Active Learning

Oxides, Acids, Bases and Salts

A range of activities can be used to ensure students learn the expected content knowledge of this unit. Some are identified and elaborated below.

Suggested activities

1. Discuss how can we theoretically decide the acidic or basic nature of an oxide? What are the reasons/ factors which make an oxide acidic, basic, and amphoteric or neutral?
2. Define Arrhenius definition of acids and bases and their properties
3. conduct calculations to show the difference between strong and weak acids and bases using pH and pOH

Activity	Elaboration
Formation of oxides	Discuss how the oxides formed naturally and exist synthetized
Do calculations to show the difference between strong and weak acids and bases using pH and pOH	Students calculate pH of monoprotic, diprotic and triprotic acids using the equation: $pH = -\log [H^+]$
Arrhenius definition of bases and acids	Discuss the Arrhenius definition of bases and acids through varieties of examples. Explain clearly strong acids and weak acids based on the Arrhenius definition

Suggested assessment tasks

Practical skills

Assessment criteria

Students will be assessed on the extent to which they can:

☞ use laboratory apparatus correctly to obtain accurate measurements

☞ describe the physical and chemical properties of metals and non-metals

☞ demonstrate an understanding of the reaction of metals with acids, air and water.

☞ write balanced chemical equations for complete and incomplete neutralization of acids and bases

☞ calculate pH and pOH of solutions.

Test or assignment

Suggested topics

1. Use Arrhenius'definitions to define acids and bases.
2. Explain the differences between strong and weak acids and bases.
3. Explain the differences between concentrated and dilute acids and bases.
4. Explain the difference between monoprotic, diprotic and triprotic acids.
5. Define amphoteric and amphiprotic substances.
6. Calculate pH and pOH of solutions.

Answers to Review Exercises

Part I

1. D
2. D
3. E
4. C
5. A
6. D
7. E
8. B

Part II

9. E
10. A
11. B
12. F
13. D

Part III

14. Less
15. Basic
16. Zero
17. Greater
18. SO_2
19 greater
20. Hydrogen
21.greater

Part IV

22. C
23. B
24.C
25.C
26. A

Part V

27. pH = 5

28. A Acidic B. nonmetal

29. Monoprotic has only one ionizable H atom

30.

A. $ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$

B. $ZnO + 2NaOH \rightarrow Na_2ZnO_2 + H_2O$

31. 10 times

32.

A. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

B. $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$

C. $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$

33.

A. $CaO + 2HCl \rightarrow CaCl^{2+} H_2 O$

B. To neutralize the acid in the soil

34.

A. To increase soil productivity and get more product
B. Nitrogen, phosphorus and potassium
C. By mixing the aqueous ammonia and sulphuric acid and allowing the water to evaporate
D. Ammonium hydroxide + Nitric Acid → Ammonium Nitrate + Water

35.

A. Ammonia and sulphuric acid
B. Potassium hydroxide and phosphoric acid
C. Ammonia and nitric acid

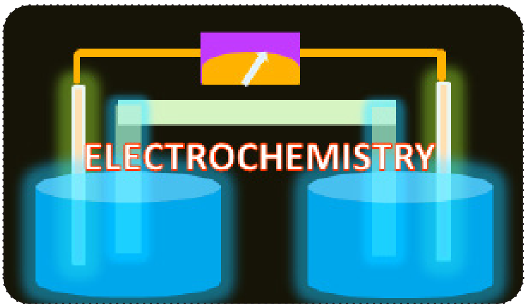
36. No, all compounds that contain H are not acids because the H atoms of these substances are not ionizable

Ex. CH_4, NH_3

All compounds containing OH are not bases, because they do not give OH ions

Ex. CH_3OH, CH_3CH_2OH,

UNIT 4



ENERGY CHANGES AND ELECTROCHEMISTRY

Unit Outcomes

At the end of this unit, students will be able to

- describe energy changes in chemical reactions;
- describe how a chemical reaction produces electric current and how electricity brings about a chemical reaction in electrochemical cells;
- distinguish the difference between metallic conduction and electrolytic conduction;
- develop skills in writing the oxidation half-reaction, reduction half-reaction and cell reaction for the electrolysis of molten electrolytes that occur in electrolytic cells;
- describe the three types of Voltaic cells;
- explain the difference between electrolytic cells and voltaic cells and
- demonstrate scientific inquiry skills: observing, classifying, comparing and contrasting, inferring, predicting, communicating, measuring, asking questions, interpreting data, drawing conclusion, applying concepts, relating cause and effect and problem solving.

Overview

This unit begins dealing with a startup activity which tries to address the new topic in the context that the students are familiar with. The context-based chemistry is intended to make chemistry learning more meaningful to students and improves students' interest and motivation in chemistry by linking the content to real-world situations. You can prepare a chart like the one shown below as a teaching aid to help students understand concepts of energy changes in chemical reactions, and proceeds to energy changes in electro-chemistry. Most of the contents in this unit are not familiar to the students even though they are expected to know some of the concepts at this stage/level. They however, must have encountered the practical application of some products of electrochemistry. Thus, it is important to support the teaching-learning process in this unit with practical activities or experiments. The unit comprises five sections. The emphasis of the first section is to familiarize students with the different types of energy changes.

The second section focuses on the definition of electrochemistry, electrochemical processes, how and where interconversion of electric energy and chemical energy to electrical energy occurs. It also introduces the importance of electrochemistry. The third section emphasizes on electrical conductivity. It introduces why metals and electrolytes transmit electricity. It also presents information on the types of electrolytes and how to differentiate weak and strong electrolytes experimentally. The fourth section is about galvanic (voltaic) cells. This section treats the meaning and types of galvanic cells and how do they produce electricity. The section further explains how one can construct simple Galvanic cells. The fifth section emphasizes electrolysis. It includes the definition of electrolysis, i components of an electrolytic cell and how to predict the products that form at the electrodes during the electrolysis. It also defines **half–cell reaction** and **cell reaction**.

Inquiry, group discussion, gapped lecture, experiment and visual-based learning are suggested as preferred methods to teach the concepts in this unit.

Table 4.1 Tentative distribution of periods to each section/subsection

SN	Unit/ Section	Section/Subsection	Activity	Experiment	Exercise			#Period suggested
					Classwork	Homework	Assignment	
1	4.1	Start-up Activity						1
2		4.1 Introduction	4.1					1
3		4.1.1 Exothermic and Endothermic Chemical Reactions	4.2	4.1			4.1	2
		4.1.2 Importance of Chemical Changes	4.3					
5	4.2	4.2 Energy Changes in Electrochemistry						
		4.2.1 Electrochemistry	4.4					1
6		4.2.2 Electrical Conductivity		4.2				2
		Metallic Conductivity						
7		Electrolytic conductivity				4.2		1
8		Electrolyte and nonelectrolytes		4.3	4.3			2
9	4.3	4.3 Electrochemical Cells	4.5					
		4.3.1 Galvanic (Voltaic) Cells**						1
10		Primary Cells (Battery Cells)					4.4	1
11		b. Secondary (Rechargeable) Cells						1
12	4.4	4.4 Electrolysis	4.6					1
13		4.4.1 Electrolysis of Molten (Fused) Electrolytes	4.7	4.4		4.6	4.5	2
		*Projects to be carried out by students in convenient time						16

Unit Outcomes

At the end of this unit, students will be able to

- describe energy changes in chemical reactions;
- describe how a chemical reaction produces electric current and how electricity brings about a chemical reaction in electrochemical cells;
- distinguish the difference between metallic conduction and electrolytic conduction;
- Write the oxidation half-reaction, reduction half-reaction and cell reaction for the electrolysis of molten electrolytes that occur in electrolytic cells;
- describe the three types of Voltaic cells;
- explain the difference between electrolytic cells and voltaic cells and
- demonstrate scientific inquiry skills: observing, classifying, comparing and contrasting, inferring, predicting, communicating, measuring, asking questions, interpreting data, drawing conclusion, applying concepts, relating cause and effect and problem solving.

4.1 Introduction

Competencies

At the end of this section, students will be able to describe energy changes in chemical reactions.

- Define endothermic reaction
- Describe endothermic reaction
- Define exothermic reaction
- Describe exothermic reaction
- Elucidate endothermic and .exothermic reactions using diagrams
- Do simple experiment to demonstrate exothermic and endothermic reactions
- Discuss the importance of chemical changes in the production of new substances and energy

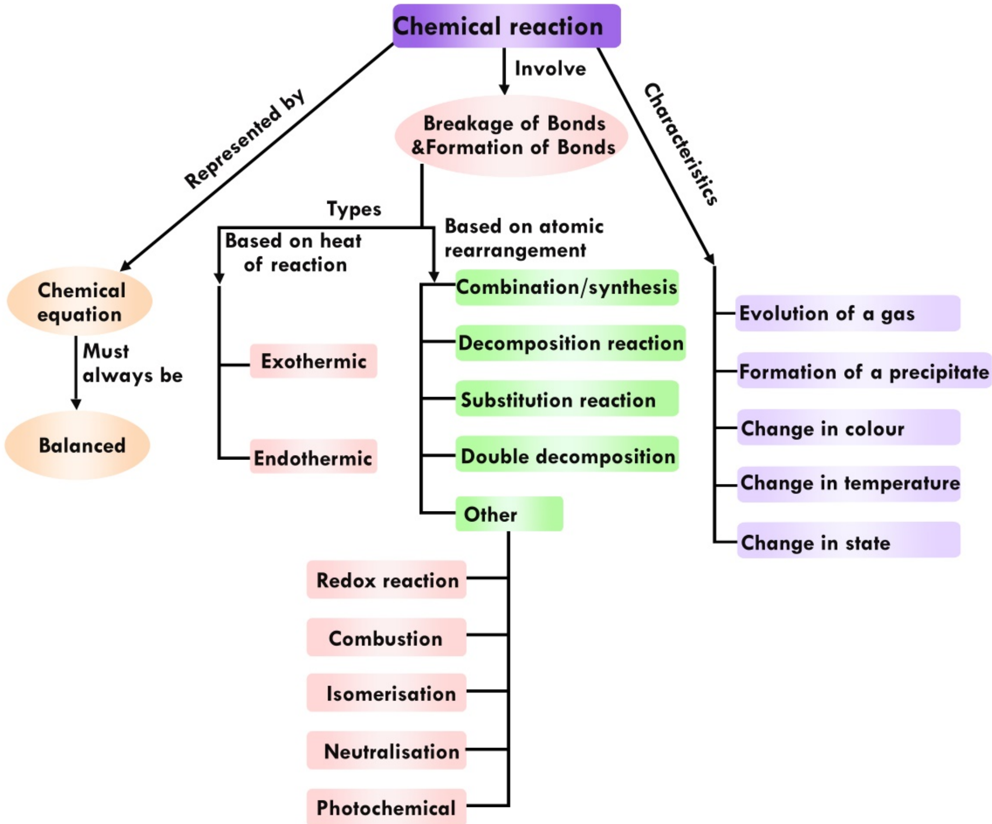
Planning

Prepare yourself by reading about energy changes in chemical reactions. This section includes ***Experiments 4.1***. Try them yourself before the class. Check whether or not the materials and chemicals are available in the laboratory for ***Experiment 4.1*** given in this sub-unit. Make a plan of your own that shows which topics, activities and experiments you will treat during each period so that you can cover the entire contents in the section within three periods. Your plan should clearly indicate how to budget your time for every activity you perform in each period.

This sub-unit requires a teaching aid. Prepare a big chart or diagrams that illustrate endothermic and exothermic reactions. Use a sturdy material – for example, cardboard for your chart.

Teaching Aids

Diagrams that illustrate endothermic and exothermic reactions - Refer to the student's text for the chemicals and apparatus required to perform ***Experiments 4.1***.



Harmonize the responses in relation to the facts.

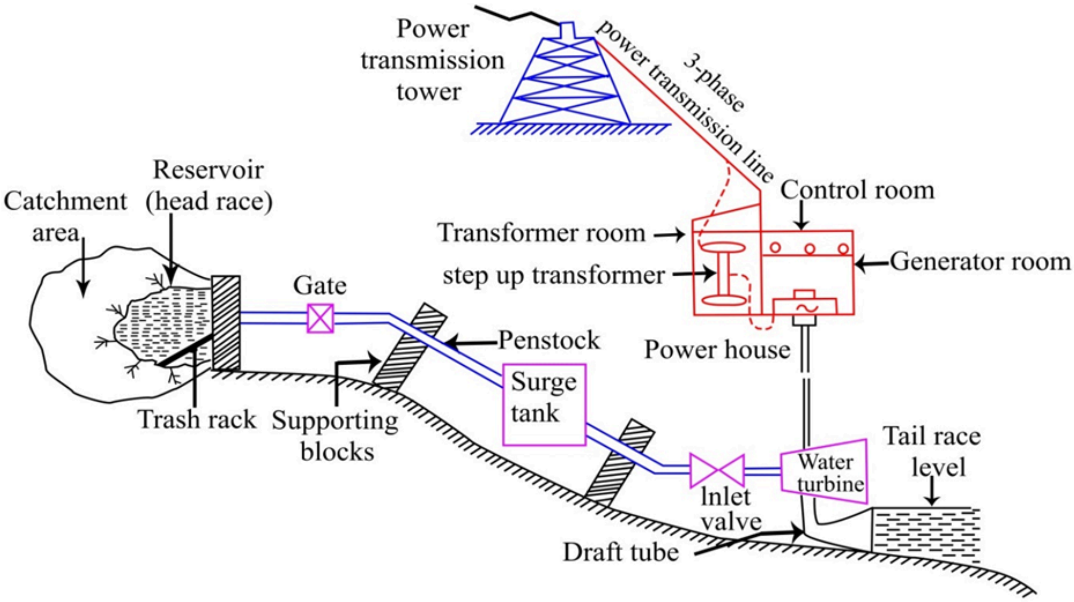
Subject Matter Presentation

Advice to the teacher! The first impression matters! Use this period to make a good start!

Remember that students learned about the different types of chemical reactions in chapter 1. Remind them this, and form a group of four students each. Let them discuss the start-up activity. Let them work on the first question. Then after 2 to 3 minutes, pause the discussion, invite their responses and harmonize their responses using the teaching aid, and explain it briefly.

Now, let them compare their responses with the list on the concept map. Intervene and advise them to emphasize on the importance of temperature change as one of the characteristics of chemical reactions. Define temperature as a degree of hotness or coldness of materials, and tell them that it is a manifestation of thermal energy. So, there is a change in temperature means change in energy. Now, let them conclude that chemical reactions involve a change in energy.

Let them move on to question 2 of the start-up activity. This is context-based chemistry intended to improve students' interest and motivation in the subject matter of energy changes. Let them discuss. Guide them by giving some hints such as the scale of energy usage and development. Industrial developments require energy. Industrialized countries are developed means they have developed their energy sector. Developing countries like Ethiopia are also trying to develop their energy sector with the ultimate goal of bringing economic development. The GERD is a specific example. Now, let students proceed to question 3. Let them recognize the importance of the GERD to our country's development. Briefly explain to them how hydroelectric energy works? You may explain this using illustration like the one below.



Most hydroelectric power plants have a reservoir of water, a gate or valve to control the amount of water that flows out of the reservoir and an outlet or place where the water ends up after flowing downward. Water gains potential energy just before it flows down a hill. The potential energy is converted into kinetic energy as water flows downhill; students are familiar with this concept from physics. The water can be used to turn the blades of a turbine that is attached to a **turbine generator which also rotates because it is attached by a rotating shaft to the spinning water turbine.**

As the generator rotates, an electric current is created and can eventually be converted into usable electricity, which is later distributed to the power plant's to reach customers. The entire process involves the conversion of potential energy to kinetic energy involving falling water, kinetic energy of falling water to mechanical energy in turbine, and mechanical energy into electrical energy by the generator. Use illustrations such as the one below to explain better. The teacher may also ask students "should Ethiopia invest more on exploring the natural gas or strengthen its effort on building dams and other renewable options? Which one is a sustainable development option? Harmonize students' responses that the best option is to strengthen the sustainable development as natural gas are nonrenewable.

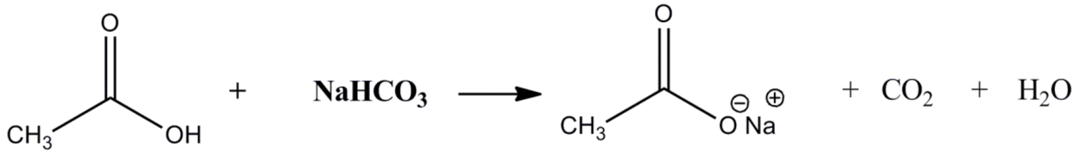
Let students read these questions and the statement that follow: “What about batteries? How do they generate electrical energy, and how do light bulbs convert it into the light? Can you make a battery? Some people do not want to think about these types of questions. They just spend money to buy one and gratify their needs. But others are very curious to learn new things and want to create their own device ***named in honor of their names*** (Made by Mr/Ms “X”). Which category are you from?” Ask them if they can answer some of the above questions. Then reassure them that they will be able to answer these questions at the end of this unit. Then briefly summarize the lesson based on the start-up activity and the teaching aids.

Finally, write the topic “**Introduction**” on the blackboard and state the objective of the lesson. Advise students to read their textbook ***Section 4.1*** and come up with answers to ***Activity 4.1*** for the next class.

In the following class, ask students to form the usual group and share their ideas on the activity questions. This activity is also familiar to them from their daily life and highly linked to the energy changes they are expected to learn. We feel warm when we stand in the sunlight because energy is being transferred from sunlight to our body. Students should be clear with the fact that they we need energy even to blink our eyes. When we perform an intensive physical exercise, heat flows out of our body cells to the surrounding via energetic (molecules having high kinetic energy) water molecules (sweet) to the surrounding. By doing so, our body tries to maintain homeostasis. From this, students should understand that our body exchanges energy with the surrounding. You may advise students to mix lemon water and baking soda in a drinking glass at their home. Let them come up with answers regarding the heating up of the glass during the dissolution.

Lemon water contains acetic acid and hence is acidic. The reaction of lemon water with $NaHCO_3$ is an energy releasing process. It will heat up the glass or test tube where the reaction is conducted. These substances are available in students’ locality and they can give it a try even at their homes.

The reaction is:



$C_2H_4O_2$ Sodium acetate

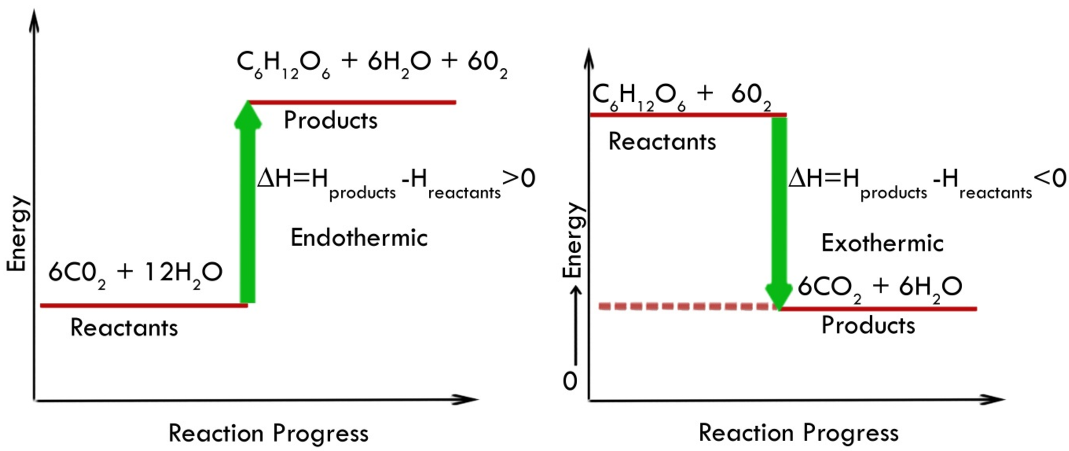
acetic acid

Students should be clear that the purpose of burning wood or charcoal at their homes is to get energy, the heat r=energy that is used to cook food or boil water. Tell them that this is a type of combustion reaction and all combustion reactions release energy. The dynamite contains chemical energy that is stored in the nitroglycerin. When dynamite explodes, the chemical energy is converted into heat energy. After harmonizing their responses you can use further examples cited in the students' textbook to illustrate energy changes during chemical reactions through a mini lecture. Explain that all chemical reactions involve energy changes. Energy is either absorbed by the reactions or released to the environment. Briefly explain the terms universe, system, surrounding, internal energy, and energy changes vs law of conservation of energy as described in the student text. Correct students answers as: we feel warm when we stand in sunlight because the energy is transferred from the sun (surrounding) to our body (system). Combustion reactions are accompanied by energy change from chemical to heat. We recognize the effect of energy or energy change by heat or work. If there is a temperature change as the reaction proceeds, it indicates a change in heat energy. If displacement is involved, it indicates work. Similarly, the chemical energy stored in the chemical bonds of nitroglycerin is converted to heat energy when dynamite explodes.

4.1.1 Exothermic and Endothermic Chemical Reactions

The section begins with ***Activity 4.2***. It emphasizes on exothermic and endothermic reactions. Get prepared ahead of time and make arrangements to form groups. Please be cautious about gender disparity while forming groups. Try to balance girl to boy ratio per group. Encourage students to interact in the class. Pay attention to shy and passive students while they do ***Activity 4.2***. Encourage them to participate by giving clues and local examples.

What happens when they cook? They should be clear that the chemical energy in the fuel or any biomass they are using is transferred in the form of heat to the food being cooked. Baking of bread and cooking food require energy supply and is endothermic. Combustion reactions are generally exothermic. Students may ask you, “Why does the reaction not take place if we mix a mixture of natural gas or any source of fuel and air in our kitchen? The reaction requires a spark or match flame to initiate it. Then, how can this reaction be classified as exothermic? ” Well, you have to read very well and get prepared to answer questions like this. Although energy from a tiny spark or a match is applied, the reaction proceeds on its own accord once initiated and the overall energy released is much greater than the tiny energy used to initiate the reaction. Let they understand that photosynthesis cannot take place without sunlight. It is endothermic. Once they are done with Q1 and Q2, introduce Q3 and Q4 to do later. Then start a mini lecture. Respiration releases energy which is supplied to the cellular process in our body. Summarize the reaction with the help of the energy diagrams:



a) Energy diagram for photosynthesis b) Energy diagram for respiration

You may ask students to fill blanks as you draw the diagram. Make a deliberate mistake like $\Delta H > 0$ instead of $\Delta H < 0$ and ask students to have a critical look at the labels in the diagram and the correct mistakes.

Note that photosynthesis is an endothermic process. The balanced equation is

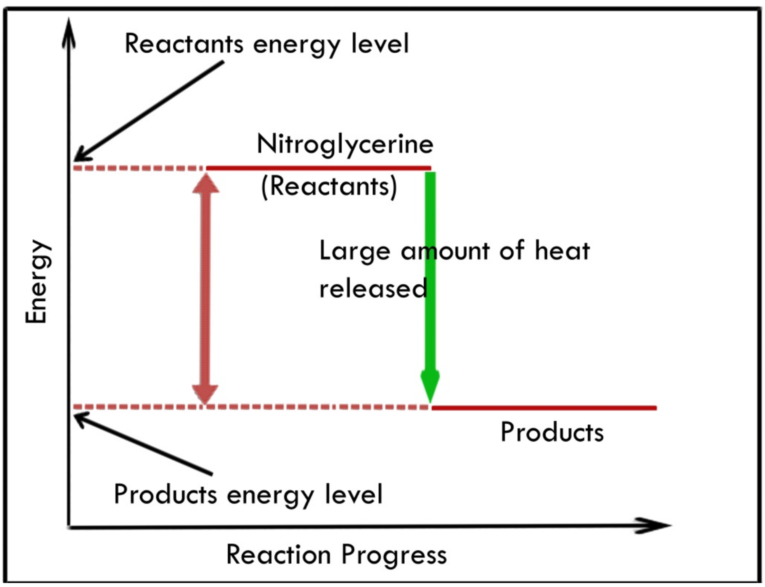
$$6CO_2(g) + 6H_2O \xrightarrow{\text{Sunlight}} \underset{\text{Glucose}}{C_6H_{12}O_6} + 6O_2$$

You may write the balanced reaction for respiration as:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Enthalpy Changes at the Molecular Level

Use this as additional not to enrich your discussion of the importance of bond making and bond breaking as the source of energy released during exothermic reaction and the reason for energy requirement for endothermic reactions. Chemical reactions may involve bond breaking or bond making. Bond breaking requires energy and bond making releases energy. If the amount of energy released is greater than amount of energy required, then the reaction is exothermic, and vice versa. For instance, chemical energy is stored in the form of ATP. It means that the energy is stored in the chemical bonds of ATP. When the ATP molecules undergo hydrolysis, the energy stored in the bonds is released and becomes available for cellular processes. Combination reactions, such as the reaction of quicklime with water, are generally exothermic; because it mainly involves bond making which releases energy. Whereas decomposition reactions involve bond breaking and are generally endothermic. Dynamite explosion is an exothermic process like any other combustion reaction. Summarize the lesson by asking someone from the class to draw an energy diagram for the dynamite explosion. Correct the answers as:



4.1.4 Importance of Chemical Changes

This section begins with ***Activity 4.3***. Now, students should be able to tell you the importance of chemical reactions. Remind them the various reactions dealt so far in the topic including

- Combustion reactions such as burning wood, combustion of fuel in internal engines of vehicles, explosive reactions, respiration

- Photosynthesis
- ATP hydrolysis

After such brief introduction let them discuss ***Activity 4.3***. After the discussion for some time, let them respond. Finally, conclude the topic by telling them that chemical reactions are conducted for two main purposes-production of energy and synthesis of useful substances such as pharmaceuticals.

4.2 Energy Changes in Electrochemistry

Competencies

At the end of this section students will be able to

- describe electrochemistry
- define electrical conductivity
- explain metallic conductivity
- explain electrolytic conductivity
- differentiate between metallic conduction and electrolytic conduction
- distinguish between strong and weak electrolytes
- use conductivity apparatus to test conductivity of substances

4.2.1 Electrochemistry

We suggest that you better start teaching the lesson by letting students discuss ***Activity 4.4***. In this case you are expected to facilitate students' discussion. Use these questions to familiarize students about what they are expected to learn in the topic. The, you make a gapped lecture. First, define electrochemistry as a field of chemistry dealing with the interconversion of chemical and electrical energy. Introduce the interconversion of chemical energy to electrical energy, or the reverse, as it takes place in electrochemical cells.

4.2.2 Electrical Conductivity

Planning

Read this section. Plan how to manage the students during their discussions and how to make students enjoy the teaching-learning process.

Teaching Aids

Refer to the students' textbook for materials required to conduct ***Experiment 4.1 and***

4.2. Prepare diagrams showing metal conductors and conduction through graphite.

Subject Matter Presentation

To teach this section, you can use visual-based active learning group discussion and experiments as methods.

We advise you to start teaching this section by asking students to define what electrical conductivity is. After their responses, give them the appropriate definition. Describe the conductivity apparatus and its basic components. Introduce metallic and electrolytic conductivity as the two types of electrical conductivity. Then continue with ***Activity 4.4.*** The purpose of this activity is to help students develop skills in identifying conductors and non-conductors practically using a conductivity apparatus. During the activity, they will learn about the anomalies of some materials like graphite in their conduction of electricity.

So, have students do ***Activity 4.4*** for a few minutes in groups. Then, have some groups present their ideas to the class. After their presentations, make sure that they can identify conductors and non-conductors. Then, introduce the structure of metals as the arrangement of positive metal ions in a sea of mobile electrons or delocalized electrons. These **delocalized valence** electrons can **move and are responsible for metallic conductivity**. Emphasize that the charge carriers in metallic conduction are the electrons. Introduce that graphite is a non-metal but conducts electricity, and explain why it is a conductor.

Then continue by presenting **electrolytic conductivity**. To teach this concept, we suggest that you use the experiment as a method. Before you deal with the details, have the students perform ***Experiment 4.2 and 4.3*** in groups and write laboratory reports. Collect the laboratory reports and correct them. Make sure that their reports show that:

The bulb glows with bright light when solutions of table salt, copper sulfate, hydrochloric acid, sodium hydroxide, and molten lead bromide are used as electrolytes.

- Solutions of acetic acid and ammonia solution produce dim light.
- Sugar solution and distilled water don't cause the bulb to glow.
- Besides this, check that they classified:
- Table salt, hydrochloric acid, as strong conductors,
- Solutions of acetic acid and ammonia as weak conductors.
- Sugar solution and distilled water as nonconductors.

☞ Harmonize what they observed in the experiment with the truth. Define electrolytes. Describe the differences between strong and weak electrolytes and give examples. Tell the students why electrolytes transmit electricity in an aqueous solution or in a molten state.

Tell them what determines the extent of conductivity in an electrolyte solution based on the experiment. Finally, be sure that the students have realized that solutions of strong electrolytes transmit electricity better than the same concentration of weak electrolytes.

Assessment

You can assess how much every student is doing by asking oral questions, giving classwork and/or homework. Check their work or supervise how they are discussing and/or experimenting. You may assign **Exercise 4.1** as group assignment and record marks.

Answers to Exercise 4.1

1. Bond formation.

2. In the form of ATP. When it is hydrolyzed.

3.

(a) exothermic (combination reactions involve only bond formation which releases energy)

(b) endothermic

(c) exothermic

See student text for sample enthalpy diagrams

4. It is due to the high specific heat capacity of water. This means water heats up slowly and stays warm for longer.

5. This is because of the low specific heat capacity of the material the stove is made up of. So, the stove that heats up slowly will stay warm for longer time.

6. Specific heat capacity

Answers to Exercise 4.2

1. Na and Ca metals conduct electricity in a solid state, but NaCl and $CaCl_2$ conduct electricity only when they are dissolved in water or when they are in the molten form, but not in the solid state? Why? Because conduction requires the movement of charged particles. In metals, valence electrons are free to move even in a solid state and conduct electricity. In salt, however, the ions are intact and not

able to move in solid- state. They become free and moveable in solution, or in molten state and conduct electricity.

2. Why are solutions of strong electrolytes better conductors of electricity than weak electrolytes? Because conductivity is proportional to the amount of charge -carrying groups-ions or electrons. Strong electrolytes produce more ions than weak electrolytes, and are better conductors than weak electrolytes which dissociate to a limited extent.
3. Which of the following substances are capable of conducting electricity? Give a reason for your answer. Answer A & D

   a. Iron
   b. Sulphur (non-metal)
   c. Solid sodium chloride
   d. Molten calcium chloride

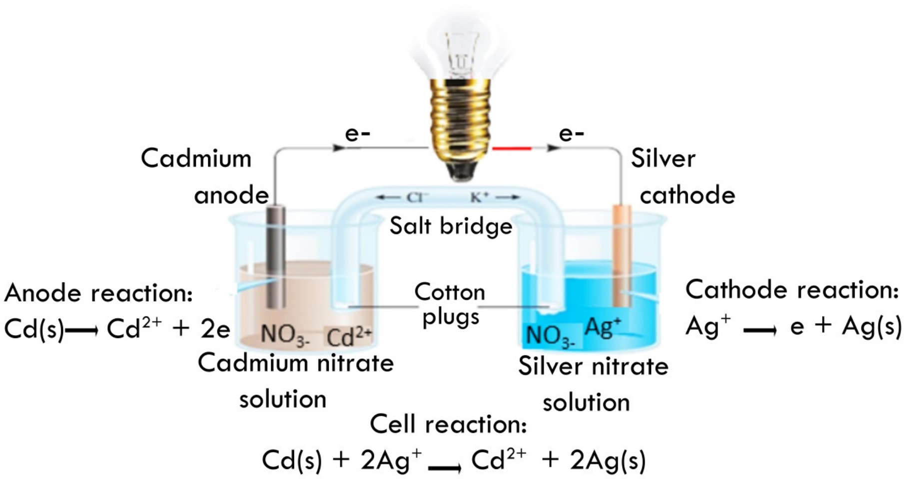
Answers to Exercise 4.3

a. Air, nonelectrolyte
b. pure water, nonelectrolyte
c. Saline solution, electrolyte
d. lemon water, weak electrolyte
e. sulphuric acid, electrolyte
f. nitric acid, electrolyte
g. ammonia solution, weak electrolyte

4.3 Electrochemical Cells

4.3.1 Voltaic (Galvanic) Cells

We suggest that you begin this section with ***Activity 4.5*** and then make a gapped lecture. Use a diagram of Daniell cell as a teaching aid. Let students try to associate the cells in our body and the chloroplasts in animals as a place where reactions take place and extend their understanding to determine that electrochemical reactions also take place in cells called electrochemical cells. You may start with a definition of an electrochemical cells and their classification into a galvanic cells and electrolytic cells. Let students be clear with the difference between these two and do ***Exercise 4.4*** as assignment in group of 3 to 5 students. You may use the following sketch to give them feedbacks. Students do not need to colour their sketch. The important things are identification of the electrode and the reactions.



Students should realize that an anode is negative and a cathode is positive in voltaic cells, which is the opposite of electrolytic cells. Although the anode is negative and cathode is positive in galvanic cells, the reverse is true in electrolytic cells. Nevertheless, oxidation occurs at the anode and reduction occurs at the cathode in both electrochemical cells. You can use the following table to compare and contrast voltaic and electrolytic cells.

Voltaic cell	Electrolytic cell
☞ The reaction is spontaneous	☞ The reaction is non-spontaneous
☞ Chemical reaction generates electricity	☞ Electrical energy brings about chemical change
☞ Converts chemical energy to electrical energy	☞ converts electrical energy to chemical energy
☞ Anode is negative	☞ Anode is positive
☞ Cathode is positive	☞ Cathode is negative

The secondary cell has lead alloy as an anode, and lead (IV) oxide in dilute sulfuric acid as electrolyte as cathode During discharging the concentration of sulphuric acid decreases. Let students be clear with the balanced redox reactions in their textbook. Give students assignment to draw a diagram of Daniell cell and Zinc-carbon dry cell (Leclanche cell) on a graph paper, label each component and give it a name. You can consider this as assignment and record marks.

4.4 Electrolysis

Learning Competencies

At the end of this section, students will be able to

☞ define the term electrolysis

- describe electrolytic cell
- draw labelled diagram of an electrolytic cell
- define the terms' half-reaction and cell reaction
- write the oxidation half-reaction, reduction half-reaction and cell reaction for the electrolysis of molten or fused electrolytes
- perform an activity to show electrolysis of molten electrolytes

Planning

Read this section thoroughly. Prepare a diagram that shows the different parts of an electrolytic cell, and assemble the materials required to conduct ***Experiment 4.4***.

Teaching Aids

- Diagram of an electrolytic cell and ***Figure 4.10*** and ***Figure 4.11***.
- Materials suggested in the students' text for performing Experiment 4.3.

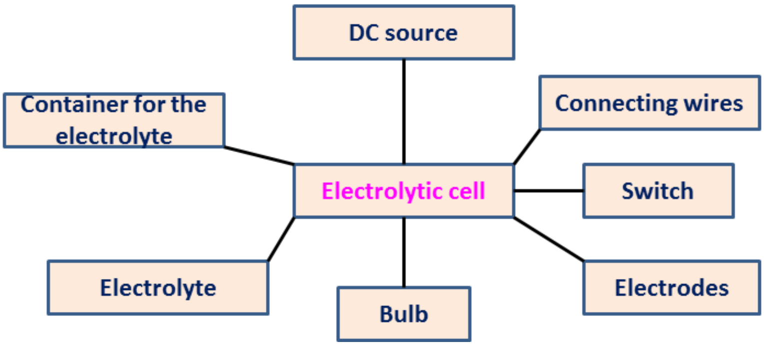
Subject Matter Presentation

The methods suggested for teaching this section are questions and answers, visual -based learning and experiment.

This sub-topic starts with ***Activity 4.6***. The activity helps students to recall their previous knowledge and make an association with the new topic. Remember that the recharging process of secondary cells operates in the same way as electrolytic cell. After the discussions and presentations, continue by harmonizing their ideas with the facts using ***Figure 4.10***. Start with the definition of electrolysis as a process that brings about chemical changes, using an electric current. Let students be aware of the fact that this process is carried out in an electrolytic cell, and that this cell converts electrical energy to chemical energy. Introduce them to the components of an electrolytic cell as a direct current source, connecting wire, electrodes, electrolyte and the container for the electrolyte, using a diagram. Define the terms electrode, anode, cathode, anions and cations. Emphasize that the anode and cathode are the electrodes attached to the positive and negative terminals of the direct current source, respectively.

4.4.1 Electrolysis of Molten (Fused) Electrolytes

Have the students to draw an electrolytic cell and label its different parts. Use ***Figure 4.11*** (Electrolysis of molten sodium chloride) very effectively to facilitate visual learning. Let students spend some time on the this figure and ask them relevant questions such as identify the anode and cathode, their polarity, the way the electrodes are connected to the batter, the direction of electron flow, the way electron enter the solution and leave the solution, the half-reactions, and the cell reaction, the migration of ions towards electrodes. Advise students to pay attention to these points and you conclude the lesson using ***Figure 4.11*** again. To make sure that the students are familiar with an electrolytic cell, have them draw a spider diagram in groups to show the different parts of an electrolytic cell. Use the following diagram for comparison.



Next, explain that during electrolysis, anions move towards the anode, lose electrons at the anode and form atoms that may combine to form molecules. At the same time, cations migrate towards the cathode (negatively charged), and gain electrons at the cathode to form atoms.

The names anion and cation are given to negative and positive ions due to their movement towards the anode and cathode respectively. Emphasize that oxidation occurs at the anode, and reduction occurs at the cathode. After introducing these basic concepts, have students to perform ***Experiment 4.4***, write laboratory reports and present them to the class. Make sure that their presentation includes the following points.

i) The bulb doesn't glow when the salt is in the solid state. But, it glows when lead bromide is fused due to its ionization. The reaction for its ionization is

$$PbBr_2 \rightarrow Pb^{2+} + 2Br^-$$

Thus, fused lead bromide conducts electricity due to the migration of Pb^{2+} and Br^- ions to the cathode and anode respectively. During electrolysis, each lead ion gains two electrons at the cathode. On the other hand, Br– ions lose one electron each, forming bromine atoms which combine r to form bromine molecules. The reactions occurring at the electrodes and the overall cell reactions are

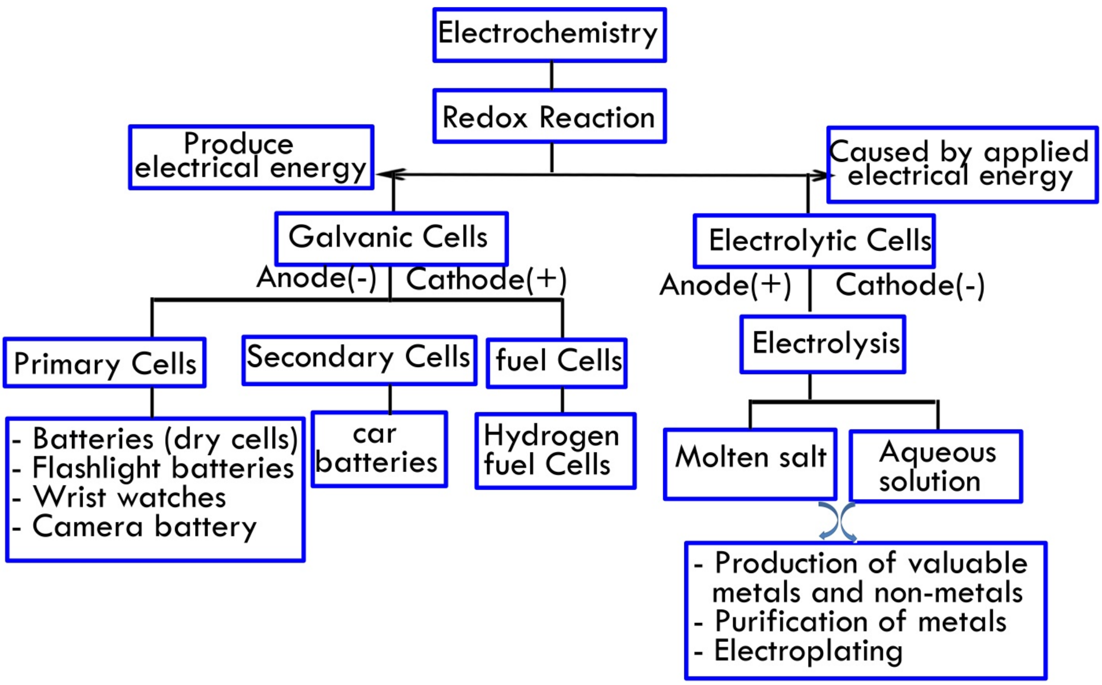
Cathode reaction: Pb^{2+} + 2e- → Pb (reduction)

Anode reaction: 2Br- → Br_2 + 2e (oxidation)

Cell reaction (during electrolysis): $PbBr_2$ → Pb + Br_2 (Redox reaction)

So, Pb deposits at the cathode and Br_2 is liberated at the anode. After the presentations, have students practice writing half-cell reactions and cell reactions for the electrolysis of fused $MgCl_2$ and fused KBr. Finally, inform students that, during the process of electrolysis in an electrolytic cell, electrons flow from anode to the cathode in the external circuit. In the electrolyte solution, there is only movement of ions. Even though there is electron transfer at the surface of the electrode, there is no direct flow of electrons from the cathode to the anode through the electrolyte solution.

Use the following concept note to summarize the topic of electrochemistry:



Last but not least is ***Activity 4.13***. This is a very important activity designed to help students understand the global trends related to energy issues. It touches on the cross-cutting issues of energy and the environment. It is expected to raise students' level of thinking and promote citizenship. Let them understand what is expected of them as youth!

Assess each student's work throughout the section. Have the students to write anode, cathode and cell reactions. Have them to describe the different parts of an electrolyte cell.

Assessment: As part of the assessment, you can give students assignment to draw the diagram of electrolytic cell on a graph paper showing electrolysis of brine.

Answers to Exercise 4.5

1.C

2. How do you know if an electrode is a cathode or an anode in voltaic cells and in electrolytic cells?

	Voltaic Cell	Electrolytic cell
Anode	Negative	Positive (connected to positive terminal of battery)
Cathode	Positive	Negative (connected to negative terminal of battery)

3. Can you suggest why positive and negative ions are named as cations and anions respectively?

The names anion and cation are given to negative and positive ions due to their movement towards the anode and cathode, respectively.

4. Distinguish between Voltaic cells and electrolytic cells.

Voltaic cell	Electrolytic cell
☞ The reaction is spontaneous	☞ The reaction is nonspontaneous
☞ Chemical reaction generates electricity	☞ Electrical energy brings about chemical change
☞ Converts chemical energy to electrical energy	☞ Convert electrical energy to chemical energy
☞ Anode is negative	☞ Anode is positive
☞ Cathode is positive	☞ Cathode is negative

5. During electrolysis of fused $PbBr_2$,

a Which ions are responsible for the conduction of electricity through the molten salt?

The Pb^{2+} and Br- ions

b What half-cell reactions occur at the anode and cathode?

Anode: 2Br- $\rightarrow$ Br_2 + 2e (Br_2 liberated at anode)

Cathode: Pb^{2+} + 2e $\rightarrow$ Pb (deposited at cathode)

Cell reaction: $PbBr_2(l) \rightarrow Pb(s) + Br_2(g)$

Answers to Exercise 4.6

1. Write the half-reactions for the electrolysis of the following molten compounds: a. KCl; b. KOH.

   Identify the substances produced at the electrodes.

a)

Anode: 2Cl- → Cl_2 + 2e (Cl_2 liberated at anode)

Cathode: $2K^+$ + 2e → 2K (deposited at cathode)

Cell reaction: 2KCl → Cl_2 + 2K

b)

Anode: 4OH- → O_2 + $2H_2O$ + 4e-

Cathode: 4K+ + 4e- → 4K;

Cell reaction: 4KOH → 4K + O_2 + $2H_2O$

2. No, see student textbook

Answers to Review Exercise

Part I

1.	A	5.	A	9.	C	13.	C
2.	C	6.	C	10.	D		
3.	B	7.	A	11.	C		
4.	D	8.	B	12.	C		

Part II

14. Under constant pressure
15. see student text.
16. Decomposition reactions involve bond breaking which requires energy whereas combination reactions involve bond formation which releases energy
17. see student text.
18. see student text.
19. Consider these changes.
    a. $Hg(l) \rightarrow Hg(g)$ endothermic
    b. $3O_2(g) \rightarrow 2O_3(g)$ endothermic
    c. $CuSO_4 .5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(g)$ endothermic
    d. $H_2(g) + F_2(g) \rightarrow 2HF(g)$ exothermic
20. see student textbook
21. see student textbook

22. see student textbook

23. During electrolysis of fused $CaCl_2$,

    a. Ca^{2+} and Cl^- ions

b. Cl^-

c. Ca^{2+}

d. Anode: $2Cl^- \rightarrow Cl_2 + 2e$

   Cathode: $Ca^{2+} + 2e^- \rightarrow Ca$

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UNIT 5

METALS AND NONMETALS

Unit Outcomes

At the end of this unit, you will be able to

- describe the general properties of metals and nonmetals;
- describe the extraction, chemical properties and uses of aluminium, iron, copper, nitrogen, phosphorus, oxygen, sulphur, and chlorine;
- demonstrate scientific inquiry skills: observing, classifying, communicating, and asking questions, applying concepts and problem solving.

Unit Overview

Total Periods Allotted 13

This unit emphasizes the production of some metals and nonmetals. It gives information about some basic characteristics and uses of some metals and nonmetals and their compounds.

The first section of the unit (5.1) provides a brief introduction about the primary source of minerals of metals and nonmetals and the type of minerals. The second section (5.2) deals with the general characteristics of metals, activity series of metals, alloys, general extraction of metals and uses of some metals. The metals to be considered in this section are aluminum, iron and copper. The third section (5.3) deals with the general characteristics of nonmetals and the uses of their common compounds. The third section also discusses the occurrences, methods of extraction and chemical properties of some non-metals. The nonmetals to be considered in this section are nitrogen, phosphorus, oxygen, sulfur and chlorine. The lecture method for this unit is somewhat boring or cumbersome for the students hence, different teaching methods are suggested for each section and sub-topic. The major methods suggested for this unit are peer teaching, gapped lecture, inquiry and group discussion.

Table 5.1 Tentative distribution of periods to each section/subsection.

SN	Unit/ Section	Section/Subsection	Activity	Experiment	Exercise			#Period suggested
					Classwork	Homework	Assignment	
1	5.1	**5.1 Introduction/Start-up activity**						1
2	5.2	**5.2 General Properties of Metals and Production of Some Metals**						
		5.2.1 Properties and Extraction of Metals	5.1					
3		5.2.2 Alloys						1
4		5.2.3 Production of Aluminum, Iron and Copper **A. Aluminum** -Occurrence and extraction -Physical & chemical Properties -Uses of Aluminum **B. Iron** -Occurrence and Extraction -Producing pig iron (impure iron) -Steel making from pig iron (purification of pig iron) - The Bessemer Converter - The Open-hearth Furnace: - Basic Oxygen Process: - Properties of iron - Uses of iron **C. Copper** -Occurrence and extraction - electrolytic refining of copper -Physical & chemical Properties -Uses of copper	5.1 5.2 5.3 5.4 5.5 5.6 5.7			5.1 5.2		2 2 1
5	5.3	5.3 **Production of Some Important Nonmetals**						1
6		**5.3.1 General Properties of Nonmetals and Common Uses of Some Nonmetallic Compounds**			5.3			
7		5.3.2 Production of Nitrogen, Phosphorous, Oxygen, Sulphur and Chlorine						
8		**A. Nitrogen** -Occurrence and production of nitrogen -Physical & chemical Properties of nitrogen -Uses of Nitrogen	5.8 5.9					1
9		**B. Phosphorous** -Occurrence and extraction of Phosphorous -Physical & chemical Properties of Phosphorous -Uses of Phosphorous	5.10 5.11					1
10		**C. Oxygen** -Occurrence and production of oxygen -Physical & chemical Properties of oxygen	5.12					1
11		**D. Sulphur** -Occurrence and Extraction of Sulphur -Allotropes of Sulphur -Uses of Sulphur	5.13					1
		E. Chlorine -Occurrence and production of chlorine -Physical & chemical Properties of chlorine -Uses of chlorine	5.14 5.15					1
								13

5.1 Introduction

By the end of this unit, you will be able to

- describe the source of metals and non-metals
- explain the natural occurrence of metals and nonmetals

Planning

We suggest you read the contents of the section and the related materials thoroughly. You need to plan when to give homework for students to make preparation in groups for the presentations. Make the necessary arrangement on how to manage students and initiate them to be active participants.

Teaching Aid

- Periodic table that shows the position of metals
- Chart showing activity series of metals
- Chart showing the general metallurgical process

Subject Matter Presentation

Use peer teaching and group discussion for this section. This section begins by introducing metals and their abundance in nature in a way that 80 % of the earth's crust is metals. Start this topic using ***Startup Activity***. This activity helps students to realize that the relationship between the properties of metals and their uses. Allow students to discuss ***Startup Activity*** for few minutes. Next, the section proceeds with ***Activity 5.1***. This activity helps students to identify metals in terms of their physical properties. Students are expected to have some background ideas about metals. The lesson includes general physical properties of metals and the uses of some common non-metals. It is advisable if you implement a peer teaching method for this part.

During the period, let students from different groups make presentations to the rest of the class. It is better if groups other than those involved in section 5.1 take part in this section. After the presentation of each group, give chances for other students to ask the group members some questions related to the points in the presentation. Let students among the group members answer the questions raised by their classmates. To harmonize concepts suggested by the students in their presentation, explain the common physical and chemical properties of metals. Examples, all metals are conductors of electricity, all metals form cations m^{+n}. Then, continue your explanation about the activity series of metals that if you add metal in a given solution of different metals, the metal displaces another metal. Metals vary in their chemical behavior. The activity series shows the relative reactivity of metals. The metal at the top in the activity series displaces the metal below in the series from its solution. Students should give varieties of examples on the displacement of less active metal by more active metal from its solution. It is advisable to give reading assignments about the uses of Na, K, Mg, Ca, and Ta and their compounds. Reading assignments should also be given to students on the alloys, occurrence and general extraction methods of metals,. Let the students discuss with their group about each topic and present it to the class. This topic requires lecture only for harmonizing students' ideas and needs more of students' participation. Students should be informed about the advantage of alloying of metals as alloying of metals increases the hardness and strength, modify the color and melting point, decreases the electrical conductivity and increase the resistance to corrosion of metals. Give them gold as an example, pure gold (24- carat, 100 %) is not strong but when it is mixed with Ag or Cu its strength improves. Students should recognize that the most active metals like potassium and sodium are usually extracted using electrolysis as there is no economic chemical reducing agent that can reduce them from their salts. Chemical reduction is possible for moderately active metals like iron, which is produced by the chemical reduction of iron ore using coke. The method of metal extraction depends on the nature of the ore and the chemical property of the metal. Noble metals Ag, Au, Bi, Cu, Pd, Pt exist in nature as an uncombined or free states. Tell them that the science and technology dealing with the commercial production of metals from their ores is metallurgy. The extraction of metals from their ore involves three principal processes:

The three principal steps in the recovery of a metal from its ore are (1) preparation (concentration) of the ore , example : oil floatation, magnetic separation, (2) production of the metal. Example: roasting, calcination, and (3) purification of the metal (last step), example: chemical reduction, electrolytic reduction. Students should identify the terms mineral, ore, gangue. Gangue is the undesired material (impurity) present in the ore. The naturally occurring compound which contains the metal is mineral. The concentrated deposit of the mineral is ore.

Assessment

Check each student`s work, record performance, and make sure the skills recommended in this section are met. Appreciate students who exceed the required minimum level and encourage them to continue their efforts. By arranging an additional time for the course, help students who are working below the minimum required level.

5.2 General Properties of Metals and Production of Some Metals

Learning Competencies

At the end of this section, students should be able to

- mention general properties of metals;
- describe the uses of some common metals.

Planning

We recommend to read about aluminum thoroughly. Prepare an appropriate assignment that invites students to participate. This section needs more students' participation so that it is advisable to use peer teaching and inquiry (question and answer).

Teaching Aid

Chart showing Hall's process

Subject Matter Presentation

Suggested methods for teaching this section are group discussion, visual-based learning and a gapped lecture.

This section starts with an activity. ***Activity 5.2*** helps students identify the applications of aluminum in the electric world. The activity shows the wide application of aluminum in the world.

You can start teaching this section by allowing students to discuss ***Activity 5.2*** for some time in groups and present their views to the class. After they have done so, give them appropriate information about the activity as follows: Steel-Cored aluminium cables are used for conducting high voltage electricity because aluminium is a good conductor. The steel core gives strength to the wire. Many materials made of aluminium such as cooking utensils are also used at home. It is also used for making water tanks, food packaging cans and wrappers. Then proceed to introduce to the students that aluminium is the third most abundant element in the earth's crust next to oxygen and silicon and is the most abundant metal. Naturally, aluminium exists only in the form of compounds such as bauxite ($Al_2O_3 \cdot 2H_2O$), orthoclase ($KAlSi_3O_8$), bery ($Be_3Al_2Si_6O_{18}$), cryolite (Na_3AlF_6 and corundum (Al_2O_3). Mention bauxite as the principal ore from which aluminium is extracted. Let them know that bauxite is purified in a series of steps such as heating with NaOH solution, treatment with an acid to precipitate $Al(OH)_3$, filtration and then heating $Al(OH)_3$ to get Al_2O_3 emphasizing the purpose of each step. Then inform them that aluminium is extracted by electrolysis of aluminium oxide mixed with cryolite by the Hall process. Here tell them about the role of cryolite. After introducing the occurrence of aluminium and the steps followed to obtain aluminium oxide from bauxite, let students discuss ***Activity 5.3*** in groups for a few minutes. Following their discussion, allow some groups to present their conclusions to the rest of the class. In this section, students from groups other than those involved in sections 5.1 and 5.2 should take part in the presentations. Next, harmonize concepts presented by the students with the facts they are expected to know. First, write the ionic equation for Al_2O_3 in the molten state:

$$2Al_2O_3 \longrightarrow 4Al^{3+} + 6O^{2-}$$

During the electrolysis, Al^{3+} move to the cathode, gain three electrons each and become aluminium atom which is collected at the cathode. O^{-2} move to the anode, lose two electrons each and become oxygen atom which in turn combine to form an oxygen molecule.

Anode reaction: $6O^{2-} \longrightarrow 3O_2 + 12e$ (Oxidation – half reaction)

Cathode reaction: $4Al^{3+} + 12e \longrightarrow 4Al$ (Reduction – half reaction)

Cell reaction: $2Al_2O_3(l) \xrightarrow{\text{Electrolysis}} 4Al(l) + 3O_2(g)$

After that, proceed to introduce some important physical properties of aluminium and its chemical properties. In treating the chemical properties of aluminium, mention that aluminium forms a protective oxide layer (film) on its surface. The thin film of oxide can be removed with mercury (II) chloride solution to make aluminium react with oxygen readily. Aluminium also reacts with dilute acids to form salts, burns in chlorine gas to form $AlCl_3$ and also reacts with NaOH. Finally, explain the uses of aluminium. Let students conduct research to discover aluminium-made materials and other points given in the research and writing part. Allow some students to present their findings to the class, and give them a reading assignment on iron.

Iron

The methods suggested to teach this part are visual-based active learning, gapped lecture and group discussion.

After completing the main points on aluminium, continue dealing with iron. Start the lesson using ***Activity 5.4***. The purpose of this activity is to enable students to relate Iron and steel so that prior experience of students will be known. Let students discuss the activity for a few minutes and let some students from different groups present their opinions to the class. Then, let certain groups present what they have prepared from the reading assignment on iron to the class. In the meantime, give chances to other groups to ask questions to make the class more interactive. Next to their presentations, introduce to them that iron is the cheapest metal because of its abundance and simpler method of extraction. Let students aware that stainless steel is an alloy containing iron, nickel, chromium and little amount of carbon. Then, introduce that iron is the 4^{th} most abundant element and the second metal in abundance in the earth's crust. Mention the naturally occurring mineral ores of iron. Let them know the extraction of iron in a blast furnace, the raw materials used (iron ore, limestone, coke and hot air), the purpose of limestone and the reactions taking place in the furnace, the formation of slag and how the slag separates from the molten iron. Give them an activity on the main points you introduced and check their works.

Then, proceed to deal with the conversion of pig iron to steel and the methods employed in the process. Then, continue treating the physical and chemical properties of iron. This should include its reaction with dilute acids, hydrogen chloride gas, chlorine, formation of rust and conditions for rusting. Inform students that iron is capable of reducing ions of less reactive metals from solutions of their salts. Let them complete and balance the equation for the reactions of iron. Finally, introduce to them some important uses of iron in the form of pig iron, as wrought iron and in the manufacture of alloys such as stainless steel.

At the end of the lesson on iron, let students discuss ***Activity 5.5*** in groups and present their views to the class. Following the presentations, tell them that steel can be used to make spoons, forks, knives, chains, chisels and other materials. Let students discuss ***Activity 5.6*** in groups. This Activity helps students to get informed about the different forms of iron. Tell them after their response that wrought iron is the purest form of iron and steel is an alloy of carbon and iron. Pig iron is the impure form of iron.

To implement the problem-solving methodology in this topic, have the students prepare samples of a protected iron bar (rods) that will not rust even when used during the rainy seasons. They can prepare the samples using any one of the methods applied during the unit to protect the iron from corrosion. Then have some students show the class the sample they prepared.

Copper

You can use a gapped lecture and group discussion to teach the lesson on this part. Before you deal with the details on copper, start the lesson using ***Activity 5.7***. The activity will help students remember and consolidate what they learnt in unit 4.

Let students discuss the activity for a few minutes. Then, encourage some students from

different groups to make presentations about the points they discussed. After the presentations, using the gapped lecture continue introducing the occurrence, method of extraction and purification of copper. Relate what the students suggested from their discussion on the purification of copper with the actual concept. Tell them also that zinc doesn't deposit on the cathode in the refining process of copper since it requires higher voltage to reduce than copper. Give them a short activity to see how students are following your presentation. Then, proceed to introduce them to the chemical properties of copper and its uses. In the case of its uses, try to relate what the students suggested after discussing ***Activity 5.7*** with the actual uses. This may include the use of copper to produce electric cables, alloys that are used to make coins, medals, hardtops and other articles.

Inform students the following answers for ***Activity 5.7*** after each of the group finish the discussion.

1. Copper is used in electrical appliances. Give two reasons based on its physical properties; (I) It is a good conductor of electricity, and (II) it is ductile.

2. A solution of copper sulphate cannot be stored in a vessel made of iron. Give a reason and justify it by a balanced ionic equation.
Iron is more reactive, it will be oxidized and thus the vessel will be spoiled.

$$Fe\ (s) + Cu^{2+} \rightarrow (Fe)^{2+} + Cu(aq)$$

3. Why is copper so important in our technological society?
Copper wiring and plumbing are integral to the appliances, heating and cooling systems, and telecommuni- cations links used every day in homes and businesses. Copper is an essential component in the motors, wiring, radiators, connectors, brakes, and bearings used in cars and trucks.

4. What common items are made of copper?

So do your household appliances: refrigerators, washing machines, dryers, microwaves, and dishwashers all contain copper wiring. Because of copper's high degree of thermal conductivity, hot water storage tanks are lined with copper plating, and household heating elements like stoves and electric kettles are copper.

5.3 Production of Some Important Nonmetals

Learning Competencies

At the end of this section, students should be able to

- mention the general properties of non-metals and their uses
- describe some common uses of compounds of nonmetals such as CO_2, Na_2CO_3, NH_3, HNO_3, H_3PO_4, $Ca_3(PO_4)_2$, SO_2 & H_2SO_4
- describe the occurrence, extraction and uses of nitrogen, phosphorous, oxygen, sulphur and chlorine

Planning

We recommend you read the contents of the section thoroughly. You need to arrange and plan to give homework to students. Decide which groups of students should make presentations during the period.

Teaching Aid

- Diagram showing the Frasch process for the extraction of sulphur

Subject Matter Presentation

This section is about the discussion of some non-metals and their compounds. It starts with the discussion of the general properties of nonmetals. Let the students revise the properties of metals and explain the reason for those properties and compare them with the non-metals. Then ask students to describe the physical and chemical properties of nonmetals. Tell them the correct properties of nonmetals for nometals have opposite properties to that of metals. Nonmetals exist in all states (gas, liquid and solid) but there is no known metal in the gaseous state at room temperature. All metals are both heat and electrical conductors whereas all nonmetals are non-conductors of heat and electricity. Students should be informed that metals are electropositive and nonmetals are electronegative elements and the electrons of metals are delocalized and can carry both heat and electrical energy. However, the electrons of nonmetals are not free and cannot transport both heat and electricity. Give students either classwork or homework to gather information about the uses of some useful compounds of nonmetals and present to the class. Tell them to discuss the uses of Carbon dioxide - CO_2: Sodium carbonate Na_2CO_3: Ammonia-NH_3 Nitric acid- HNO_3: Phosphoric acid-H_3PO_4: Calcium phosphate- $Ca_3(PO_4)$: Sulphur dioxide - SO_2: Sulphuric acid-H_2SO_4 and present to the class. Students' participation is highly recommended. Teacher's intervention for this topic is required in order to correct mistakes and harmonize the different ideas from the discussions.

Nitrogen

To teach the contents in this part, use gapped lecture, and group discussion methods. After completing the contents on general properties of nonmetals and uses of some useful compounds of nonmetals, continue with important nonmetals. First, treat the contents on nitrogen. Use ***Activity 5.8*** to start the lesson. This activity is aimed at assisting students to remember the structure of nitrogen as it has a direct impact on its chemical property and the form of nitrogen absorbed by plants. So, let students discuss ***Activity 5.9*** in groups for a few minutes. Allow some students from different groups to present their opinions. After their presentations, inform them that nitrogen is a diatomic element having the structure :N≡N:. The two atoms form a triple bond between them to complete their octet. Let them also know that plants absorb nitrogen in the form of nitrate ion, NO_3^-. Introduce to the students how nitrogen occurs in nature, its abundance as 80% by volume of air and also its presence in the form of compounds as nitrate minerals and in animals and plants as a constituent of proteins. Let them know how nitrogen is manufactured industrially by fractional distillation of liquid air starting from the purification of air to make it free from dust, CO_2 and water vapor. You better give students an activity to ensure that they realized the concepts you explained. After introducing some of its physical properties, continue with the chemical properties of nitrogen. This should include that nitrogen is inert at room temperature, its reactivity increases when heated and reacts with metals in group IA and IIA to form nitrides, with oxygen NO and NO_2. Inform students that nitrogen also forms other oxides such as N_2O and N_2O_5 even though it is not by a direct combination of nitrogen and oxygen. Let students also know that nitrogen combines directly with hydrogen in the Haber process to form ammonia. During your explanation, encourage students to write chemical equations for the reactions before you complete and balance them. At the end of your explanation, inform students about some uses of nitrogen and ammonia.

Phosphorus

After completing the content on nitrogen, proceed to deal with phosphorus. It is advisable to use group discussion and question and answer teaching methods. Start the lesson using ***Activity 5.10***. Let the students discuss the activity and make the presentation.

The purpose of this activity is to show the analogy of the light produced by phosphorus (phosphorescence) and light produced in glowing warm due to protein (bioluminescence). Before dealing with the details, after the presentation, tell students that one of the properties of white phosphorus is glowing in the dark. Glowworm also produces light as white phosphorus does. However, the emission of light by glow worm is because of a process called bioluminescence. Bioluminescence is a kind of chemical reaction that involves the oxidation of protein by a certain enzyme in an organism which results in the emission of light. Then, proceed to treating the occurrence of phosphorus. Inform students that phosphorus doesn't exist in an elemental state and that it is found in nature only in the form of compounds-principally as rock phosphate, $Ca_3(PO_4)_2$ and also in living things. Then, acquaint them with the extraction of phosphorus by the reduction of rock phosphate with coke (carbon) in presence of silica at a very high temperature in an electric furnace.

Inform students that phosphorus, P_4 obtained in the process is in the gaseous state .The gaseous P_4 is condensed, collected and stored under water as a solid. Introduce to them that the phosphorus obtained during extraction is a white phosphorus. The element exhibits two common allotropes: white and red phosphorus. Ask them to describe white and red phosphorus. After their responses, tell them that white phosphorus is a white waxy looking substance, very poisonous, unstable and consists of P_4 molecules while red phosphorus is relatively stable, and consists of P_4 molecules linked together to form a polymer. White phosphorus is stored under water while red phosphorus is not. Let students also get information about the preparation of red phosphorus by heating white phosphorus to 250^0C in the absence of air.

To discover some physical properties of white and red phosphorus, let students discuss ***Activity 5.11*** for some time and let students from some groups make presentations. Then inform them about the following properties.

White Phosphorous

Extremely poisonous

- Soluble in carbon disulfide, CS_2
- White waxy solid
- Density 1.8 g/cm^3
- Boils at 287 °C
- Glows in the dark

Red Phosphorous

Relatively non – toxic compared to the white form.

- Not appreciably soluble in CS_2
- Dark red powder.
- Density 2.16 g/cm^3
- Sublimes at 416 °C
- Doesn't glow in the dark.

Continue introducing chemical properties of phosphorus. Encourage the students to write the complete chemical equations for the reactions of phosphorus. This should include the reaction of phosphorus with limited supply of oxygen to form P_4O_6 or P_2O_3 and P_4O_{10} or P_2O_5 when reacted with excess oxygen. Besides this, inform them that the reaction of phosphorus with excess and limited amount of chlorine yields PCl_5 and PCl_3, respectively. At the end, let students get some information about the uses of phosphorus.

Oxygen

Start the lesson on this part with the suggested activity. The aim of ***Activity 5.12*** is to show the link between chemistry and biology and to get prior knowledge of students on the use of oxygen in real life. After giving a brief summary on phosphorus, continue introducing concepts on oxygen using group discussion and inquiry as your methods of teaching. First, let students discuss ***Activity 5.12*** for a few minutes and then present their views to the class. After their presentations, harmonize concepts. Let them know that glucose and carbon dioxide are the products formed in photosynthesis and respiration respectively. The chemical reaction for photosynthesis and respiration are the following:

$$6CO_2 + 6H_2O \xrightarrow{\text{Sun light}} C_6H_{12}O_6 + 6O_2 \text{ (photosynthesis)}$$

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy (Respiration)}$$

Oxygen is used in hospitals to treat patients that have difficulty in breathing. Astronauts breathe in space either wearing masks lined with potassium superoxide, KO_2 which produces oxygen when reacted with water that is released during respiration or using bottled oxygen. When you deal with the details on oxygen, introduce the presence of oxygen in an elemental state constituting about 20% by volume of the atmospheric air and 46.6% by mass of the earth's crust in the form of compounds. In dealing with the production of oxygen, emphasize that its production follows the same procedure as the production of nitrogen. It is obtained by fractional distillation of liquefied air. While treating the chemical properties of oxygen, introduce that it is relatively uncreative.

However, it forms oxides with many of the elements. It combines with metals and nonmetals to form basic and acidic oxides respectively. It is also required for the combustion of substances. Before concluding your explanation on oxygen, let students know some physical properties of oxygen such as its state at room temperature, density, solubility in water, color etc. and its uses.

Sulphur

Give a brief summary on oxygen and then continue dealing with the contents on sulphur. You can use visual-based active learning, group discussion and gapped lecture methods to teach the contents in this lesson. Allow the students to discuss in groups ***Activity 5.13*** and present their opinions to the class. After their suggestions, implement a gapped lecture method and continue introducing the occurrence of sulphur in elemental state and in the form of compounds. After introducing the occurrence of sulphur, let the students know that sulphur is extracted from underground deposits by the Frasch Process. Following the extraction, introduce rhombic and monoclinic sulphur as allotropes of sulphur consisting of S_8 molecules. You can give a short activity on the points you treated to ensure that students are following the lesson accordingly or not. Continue with your gapped lecture and inform students that about one - half of the sulphur need by industries is obtained from waste products of other industrial processes such as removal of H_2S from the refining of natural gas and crude oil and removal of SO_2 from roasting metal sulphide ores. The use of sulphur compounds produced by other industries reduces the demand for natural resources and also reduces atmospheric pollution and acid rain.

Let the students recall some physical properties of sulphur and continue dealing with the chemical properties of sulphur. Encourage students to write the chemical equations showing the chemical properties on their own. This should include the reaction of sulfur with metals when heated to form sulphides, with oxygen to form SO_2 and SO_3. Finally, inform students that sulphur is the raw material from which sulphuric acid is manufactured by the contact process. Show the steps involved in the contact process of sulphuric acid production. Conclude the lesson by giving information about the properties and uses of sulphuric acid. Finally, let the students write a flow chart to show the steps for the production of sulphuric acid. The scheme should look like the following:

$$\text{Sulphur} + O_2 \longrightarrow \text{Sulphur dioxide } (SO_2)$$

$$\text{Sulphurdioxide } (SO_2) + O_2 \ V_2O_5 \longrightarrow \text{Sulphur trioxide } (SO_3)$$

$$SO_3 \text{ absorbed in concentrated } H_2SO_4 \longrightarrow \text{Oleum } (H_2S_2O_7)$$

$$\Big\downarrow \text{ Dilution with water}$$

$$\text{Sulphuric acid } (H_2SO_4)$$

Chlorine

Check whether or not students have realized the main concepts on sulphur. Continue with the contents on chlorine. You better use gapped lecture, group discussion and independent work as your methods of teaching. Start the lesson with the suggested activity. ***Activity 5.14*** is used here to enable students get a perception about real events, about chlorine and misconceptions related with the events. It also helps to connect the lesson with real life and get their prior knowledge about the element. So, let students discuss this activity for a few minutes in groups and let some of them present their views. After this, tell them that the water turns white not because of chlorine, but due to pressure and that chlorine is used in water purification to kill bacteria. After that, introduce the occurrence of chlorine. Tell them that it is the most abundant among the halogens and doesn't exist free in nature. Then, let them know the extraction of chlorine by the electrolysis of a concentrated solution of sodium chloride (brine). Discuss the anode and cathode reactions and other products that can be obtained during the process and also inform them that NaOH and Cl_2 must be kept apart to avoid their reaction.

Before you continue on the physical properties of chlorine, let students discuss ***Activity 5.15*** in groups and present their opinions. Then, inform them that the smell of tap water is due to chlorine. Introduce some of its physical properties and continue dealing with the chemical properties. Inform them that chlorine is a powerful oxidizing agent. It reacts with heated metals to form chlorides, with hydrogen to form hydrogen chloride, displaces less reactive halide ions (Br^- and I^-) from solutions of their compounds, dissolves in water to give acidic solution and its ability to bleach coloured materials. Give them an activity to write chemical equations independently on the chemical properties of chlorine. Before concluding your explanation, let students get information about some important uses of chlorine.

Assessment

Assess each student's work throughout the section; see how every student involves in group discussions and presentations. Give class works and home works. Evaluate the performances of students by correcting their exercise books. Check that most of the students have achieved the minimum required level. Encourage the students to work above the minimum required level. Arrange the necessary assistance for students working below the minimum required level. Give them additional exercises.

Additional Questions

1. Is rusting of iron a physical or chemical change?
2. Metal M occurs in the earth's crust as its oxide M_2O_3 . An alloy of of this metal is used in making air craft. What is the metal?
3. During the extraction of iron in the blast furnace:
   I. Explains how calcium carbonate helps in the removal of impurities using chemical equations.
   II. Name the waste gases released from the furnace.
   III. Explain why the slag and the waste gases are both useful.
4. Explain why iron is converted into steel.
5. What does the term roasting sulphide ore mean?
6. Which metal turns green due to the formation of Verdigris?
7. Explain how red phosphorus can be prepared from the white form?
8. Explain why nitrous oxide, N_2O is named laughing gas?
9. What is the major use of the nitrogen compound manufactured by the Haber process?
10. What are the steps involved in contact process of sulphuric acid production?
11. What catalyst is used in contact process?
12. Explain how chlorine is manufactured industrially.

13. Explain why concentrated sulphuric acid:
    A. turns blue copper (II) sulphate white
    B. chars sugar
    C. is used to dry acidic gases

Answers to the Additional Questions

1. chemical change
2. Aluminum
3. i) $CaCO_3 (s) \rightarrow CaO(s) + CO_2 (g)$
   $CaO + SiO_2 \rightarrow CaSiO_3$
   ii) CO, CO_2, NO_2
   iii) the slag is used mostly for the manufacture of cement.
   CO_2 is used for reduction of C to carbon monoxide. Reduction of iron oxides to metallic iron by carbon monoxide
4. Because the iron recovered from the blast furnace is hard and brittle.
5. Heating the sulphide in oxygen to give sulphur dioxide.
6. Copper
7. By heating white phosphorus to 250°C in absence of air as red phosphorous is the polymer of white phosphorous.
8. Because it gives a sense of laugh when inhaled.
9. To make fertilizer.
10. See page 210 in the text book, steps 1 – 4
11. V_2O_5
12. Chlorine is produced industrially by the electrolysis of a concentrated aqueous solution of sodium chloride. The cell reaction is

$$NaCl(aq) + 2H\ O(l) \rightarrow 2NaOH\ (aq) + Cl_2\ (g) + H_2\ (g)$$

13. A) because it absorbs water from the copper (II) sulphate.
    B) Because it dehydrates sugar and converts it to carbon.
    C) Since it absorbs water

Answers to Exercises 5.1

1. Production of Aluminum needs the consumption of electrical energy which increases its cost of production. Hence, aluminum materials are expensive and their cost limits their consumption
2. Cryolite, Na_3AlF_6 is added to Al_2O_3 to reduce its melting point from 2045°C to

1000°C. Reducing the melting point implies decreasing the electrical consumption which in turn decreases the cost

3. $4Al^{3+} + 3O^{2-} \rightarrow 4Al + 3O_2$
4. Al^{3+} ions move to cathode and O^{2-} ions move to the anode during the electrolysis of molten aluminum oxide

Anode reaction: $3C(s)$ (graphite electrode) $+ 6O^{2-} \rightarrow 3CO_2(g) + 12e$

Cathode reaction: $\underline{4Al^{3+}(l) + 12e \rightarrow Al(l)}$

Over all reaction: $4Al^{3+}(l) + 6O^{2-}(l) + 3C(s) \rightarrow Al(l) + CO_2(g)$

Or $Al_2O_3(l) + 3C(s) \rightarrow Al(l) + CO_2(g)$

5. At the cathode.
6. Because of its light weight

Answers to Exercises 5.2

1. Natural = water, sunlight, land, minerals, fossil fuels

   Made by humans= statues, concrete, plastics, buildings
2. Occurrences and extraction of Copper, Aluminum and iron are shown in the following table.

Metal	Occurrence	Extraction
Copper	Copper pyrites, $CuFeS_2$, Cuprite, Cu_2O, Malachite, $CuCO_3.Cu(OH)_2$, Copper glance, Cu2S	Roasting of sulphide partially and reduction $2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$ It is self-reduction in specially designed converter. Copper is finally purified using electrolysis.
Aluminum	Bauxite, $Al_2O_3.xH_2O$ Cryolite, Na_3AlF_6 Kaolinite, $[Al_2(OH)_4Si_2O_5]$	Electrolysis of Al_2O_3
Iron	Heamatite, Fe_2O_3, Magnetite Fe_3O_4, Siderite $FeCO_3$, Iron pyrites, FeS_2, Limonite $Fe_2S_3.3H_2O$	Reduction with the help of CO and coke in a blast furnace. Chemical reduction with CO Involves Calcination followed by reduction with CO

3. Renewable resources = air, water, crops, biofuels, wood

   Nonrenewable resources = Rocks, metal ores, soil, fossil fuels

4. Aluminum is produced from its source by the electrochemical reduction. See the answers for question number 2.

5. When iron is exposed to moist air, a reddish-brown coating of hydrated Iron (III) Oxide (Fe_2O_3) is deposited on its surface. This reddish-brown coating is called rust. Iron metal does not burn in dry air even on strong heating.

   Aluminum reacts with the atmospheric oxygen and creates a protective aluminum oxide sheath and prevents corrosion. Aluminum is not attacked by dry air.

   When a copper statue (or copper vessel) is exposed to moist air for long, it acquires a dull green coating. The green material is a mixture of copper hydroxide [$Cu(OH)_2$] and copper carbonate ($CuCO_3$) formed due to the reaction of copper with moist air. Copper oxidizes to copper When copper is heated in air, it is oxidised to copper (II) oxide and the reddish brown metal turns black as the copper is oxidized to copper (II) ions. Hence the copper is changed to copper oxide.

   All copper, iron and Aluminum react with an acid to form a salt and hydrogen gas.

6. Question: Why is limestone used in steel? (Please replace the previous question with this one)

   Lime removes impurities (silica, phosphorus, sulfur) from the steel being manufactured. The lime fuses with the impurities to form slag, which separates from the steel and is removed. This process improves the quality of the steel. Lime is also used to enhance the refractory life of the furnaces.

7. Most copper is used in electrical equipment such as wiring and motors. This is because it conducts both heat and electricity very well, and can be drawn into wires. It also has uses in construction (for example roofing and plumbing), and industrial machinery (such as heat exchangers.

   Aluminium is an extremely versatile metal with a number of advantages, it is recognised for being both lightweight and flexible. It can be cast, melted, formed, machined and extruded meaning that it can be manufactured into a variety of shapes and then subsequently fabricated to suit a whole variety of uses. Aluminium is also a great conductor of electricity. And it is much cheaper than its counterpart Copper. So we often use aluminium in electric wires and other such power transmission lines.

Some of the applications of iron . Used as the primary constituent of ferrous metals/alloys and steels. Alloyed with carbon, nickel, chromium and various other elements to form cast iron or steel. Used in in magnets, fabricated metal products, industrial machinery, transportation equipment, instruments , toys and sport goods.

8. As metals are good in conducting heat, it can transfer heat very quickly and evenly. Generally, copper, aluminum metals are used for cooking vessels as they are very good conductors of heat. Due to this reason's metals are used in cooking vessels. Iron is used for cooking utensils because it is more durable than other metals. It is also cheaper material that can be used over open flame and high heat.
9. Copper and aluminium are good conductors of electricity. They have very low resistance and allow the current to flow through them easily. Hence, they are used to make wires for electrical transmissions.

Answers to Exercises 5.3

1. See student textbook
2. See student textbook
3. See student textbook
4. $Cl_2 + H_2O \rightarrow HCl + HClO$

5. Common uses of some important compounds of nonmetals

Carbon dioxide - CO_2: used as refrigerant, in fire extinguishers, carbonated beverages, blasting coal, foaming rubber and plastics.

Sodium carbonate - Na_2CO_3: used in production of glass, soaps and detergents, paper. It is also used as a laboratory reagent, cleaning agent, removal of permanent hardness of water (water softener)

Ammonia - NH_3: most of the NH_3 is used for fertilizers. NH_3 can be applied as fertilizer directly to the soil as anhydrous NH_3 or converted into solids such as ammonium nitrate NH_4NO_3, ammonium phosphate, $(NH_4)_3PO_4$, ammonium sulfate $(NH_4)_2SO_4$ and urea, H_2NCONH_2. NH_3 is an ingredient in many household cleaning products and used as a refrigerant gas and in air-conditioning equipment.

Nitric acid - HNO_3: HNO_3 is widely used in the manufacture of ammonium nitrates to manufacture plastics, dyes, and fertilizers. It is used in making explosives such as TNT, nitroglycerine, and nitrocellulose.

Phosphoric acid- H_3PO_4: H_3PO_4 is used as rust remover from metals like iron, steel, etc, is common food additive like in soft drinks. It prevents bacterial growth in bottled solutions. Most of H_3PO_4 acid produced is used in the fertilizer production. H_3PO_4 is used in the production of cleansing products, bath products, fragrances, hair care products and dyes, nail products, makeup, and other skin care products.

Calcium phosphate - $Ca_3(PO_4)$: $Ca_3(PO_4)$ is an important ingredient of triple superphosphate fertilizer, $Ca(H_2PO_4)_2$.

Sulphur dioxide - SO_2 : SO_2 is used in the manufacture of other chemical compounds, the most important of which is sodium bisulfite ($NaHSO_3$). Other compounds made from SO_2 include sulfuric acid (H_2SO_4), chlorine dioxide (ClO_2), sodium dithionate ($Na_2S_2O_6 \cdot 2H_2O$), and sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$). SO_2 is also used as a bleaching agent for a number of products, including pulp and paper, textile fibers, straw, glue, gelatin, starches, grains, and various oils.

Sulphuric acid - H_2SO_4: 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. It is used in petroleum refining to wash impurities out of gasoline and other refinery products. Sulfuric acid is used in processing metals, e.g., in pickling (cleaning) iron and steel before plating them with tin or zinc. Rayon is made with sulfuric acid. It serves as the electrolyte in the lead-acid storage battery commonly used in motor vehicles (acid for this use, containing about 33% H_2SO_4 and with specific gravity about 1.25, is often called battery acid).

Additional activities to Promote active learning

Metals and Non-metals

A varieties of activities can be used to ensure students learn the expected content knowledge of this unit. Some are identified and elaborated below.

Suggested activities

1. investigate properties of metals and non-metals
2. discuss properties of metals and non-metals
3. discuss important uses of metals and non-metals
4. discuss important uses of alloy
5. discuss the chemistry of nitrogen and nitrogen compounds
6. discuss the chemistry of sulfur and sulfur compounds
7. discuss the chemistry of phosphorus and phosphate fertilizers
8. discuss chemistry of halogen

Activity	Elaboration
Discuss the chemistry of nitrogen	In groups or individuals, research and discuss the element nitrogen. Discuss the structure, physical and chemical properties, natural occurrence, and importance of nitrogen. Students research nitrogen compounds and the production of ammonia in the Haber Process. Students discuss environmental issues where nitrogen fertilizers are being used.
Discuss the chemistry of sulphur and sulphur compounds.	In groups or individuals research and discuss the element sulphur. Discuss the structure, physical and chemical properties, natural occurrence, allotropes and importance of sulfur. Students research sulfur compounds and discuss environmental issues associated with sulphur compounds such as acid rain.
Discuss the chemistry of phosphorus	In groups or individuals, research and discuss the element phosphorus. Discuss the structure, physical and chemical properties, natural occurrence, and importance of phosphorus. Students research phosphorus compounds and the production of fertilizer containing phosphorus. Students discuss environmental issues where phosphorus fertilizers are being used.
Discuss the chemistry of halogens	In groups or individuals, research and discuss fluorine, chlorine, bromine and iodine. Discuss the physical and chemical properties, natural occurrence, and their importance. Students research their compounds and discuss environmental issues associated with their compounds.

Suggested assessment tasks

Practical Skills

Assessment criteria

Students will be assessed on the extent to which they can use laboratory apparatus correctly to obtain accurate measurements describe the physical and chemical properties of metals and non metals demonstrate an understanding of the reaction of metals with acids, air and water.

Test or assignment

Suggested topics

- Explain the composition and importance of some alloys.
- Describe the nitrogen cycle.

- Describe the environmental effects of the fertilizers.
- Explain acid rain.
- Outline the production of nitrogen and phosphorus fertilizers.
- List properties of halogens and their compounds

Answers to Review Exercises

I Multiple choice questions

1. C Gold
2. C Sodium
3. C Copper
4. B Au
5. D to remove impurity elements by oxidation
6. C petroleum
7. D all
8. C Impure copper
9. A making matches
10. C oxygen
11. C copper
12. D carbon monoxide reduces iron (III) oxide to iron
13. C react with acid impurities

II

14. A. Up on hammering, a metal will expand, but a non metal will shatter

    The bulb glows, on passing electric current through the metal but doesn't glow when passed through the nonmetal (except graphite)

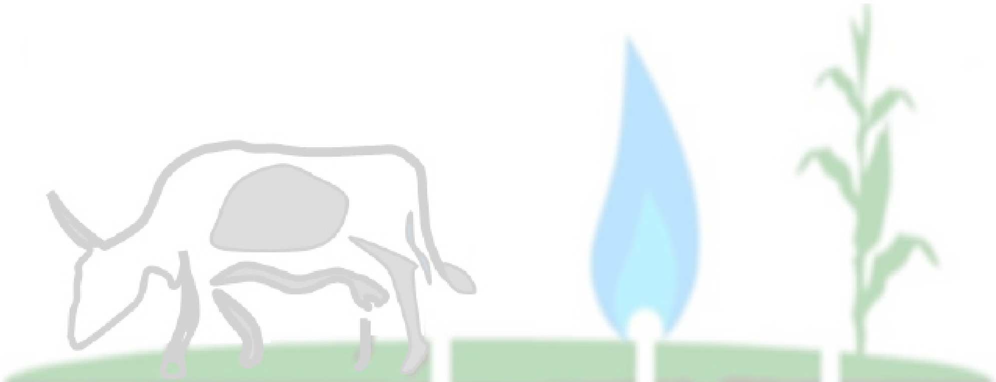
    B. The tests are useful in a majority of cases, except the graphite which is a nonmetaland yet a conductor of electricity
15. Anode : Impure metal, Cathode : A strip of pure metal, Electrolyte : An aquesous solution of the salt of the metal M
16. Painting and alloying
17. A. Aluminum oxide first formed sticks on the surface of the cooking utensils and protect them from further attack of oxygen

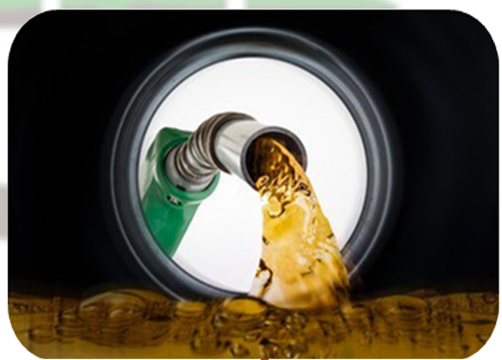
    B. Carbonates and basic hydroxide tarnish the copper vessels which are neutralized by the acid or lemmon juice or tamarind juice
18. Chlorine is a gas, bromine is a liquid, and iodine is a solid because of the differences in the strength of their dispersion forces. ... As atomic number

increases the magnitude of vander waal's forces also increases, therefore iodine is solid

19. Au
20. Ag
21. Hg and Br_2 respectively
22. Limestone is also used to remove impurities from the blast furnace when making iron. The impurities are mostly silicon dioxide (also known as sand).
23. See student textbook
24. Steel alloys are harder, tougher and heat resistant than the pure iron.
25. A. $Fe_2O_3 (s) + 3CO(g) \qquad Fe(l) + 3CO_2 (g)$

    B. $CaO(s) + SiO_2(s) \qquad CaSiO_3(s)$





UNIT 6

HYDROCARBONS AND THEIR NATURAL SOURCES

Unit Outcomes

At the end of this unit, students will be able to

- discuss the historical development of organic chemistry;
- classify organic compounds;
- write the general formulae of alkanes, alkenes and alkynes;
- name simple alkanes, branched-chain alkanes, simple alkenes, branched-chain alkenes and simple alkynes;
- write the molecular and structural formulae of simple alkanes, branched chain alkanes, simple alkenes, branched chain alkenes and simple alkynes;
- explain isomerism;
- draw the possible isomers of alkanes, alkenes, and alkynes;
- explain the physical and chemical properties; and the general methods of the preparation of alkanes; alkenes, alkynes, and benzene;
- list the major natural sources of hydrocarbons;
- demonstrate scientific inquiry skills: observing, classifying, communicating, measuring, asking questions, interpreting data, drawing conclusions, applying concepts, predicting and problem-solving.

Unit Overview

This unit focuses on a class of organic compounds called hydrocarbons. The first section of the unit (6.1) is an introductory sub-unit where the affective domains of the topic, the history of organic chemistry and classification of organic compounds are dealt with. The next sub-section (6.2) emphasizes the saturated hydrocarbons (Alkanes). It introduces what alkanes are, their nomenclature, their physical and chemical properties, their methods of preparation and the type of isomerism they exhibit. Section 6.3 deals with a detailed explanation of two of the three types of unsaturated hydrocarbons- alkenes, alkynes. It includes their nomenclature, their physical and chemical properties, isomerism in alkenes and alkynes and their methods of preparations. The third type of unsaturated hydrocarbon called aromatic hydrocarbons is dealt in a separate section (6.4). The last sub-section of the unit (6.5) focuses on the natural sources of hydrocarbons: petroleum, natural gas and coal gas.

To deal with the contents in the unit, inquiry, group discussion, gapped lecture, experiment, demonstration and visual-based learning are suggested as major methods.

Table 6.1 Tentative distribution of periods to each section/subsection.

SN	Unit/ Section	Section/Subsection	Activity	Experiment	Exercise			#Period suggested
					Classwork	Homework	Assignment	
1		6.1 Introduction/Start-up activity						1
		6.1.1 History of Organic Chemistry	6.1					
2	6.1	6.1.2 Structural Representations of Organic Molecules						1
		6.1.3 Classes of Organic Compounds	6.2					1
3		Functional Groups						
4	6.2	6.2 Saturated Hydrocarbons: Alkanes	6.3, 6.4					1
		6.2.1 Alkane Homologous Series			6.1			
5		6.2.2 Physical Properties of Alkanes	6.5			6.2		1
		6.2.3 Nomenclature of Alkanes	6.6					
6		Common Names						
		IUPAC Nomenclature			6.3			3
7		6.2.4 Isomerism in Alkanes	6.7, 6.8		6.4			1
8		6.2.5 Preparation of Alkanes*		6.1, 6.2	6.5			1
9		6.2.6 Chemical Properties of Alkanes	6.9			6.6		1
		6.2.7 Cycloalkanes (Alicyclic Hydrocarbons)						
10		6.2.8 Uses of Alkanes	6.10			6.7		1
	6.3	6.3 Unsaturated Hydrocarbons						
11		6.3.1 Alkenes or Olefins					6.8	1
		A. Homologous Series of Alkenes						
12		B. Nomenclature of Alkenes				6.9		1
13		C. Physical Properties of Alkenes	6.11					1
14		D. Isomerism in Alkenes*			2.9		6.10	1
15		E. Preparation of Alkenes		6.3		6.11		1
16		F. Chemical Properties of Alkenes	6.12		6.13	6.12		1
		G. Uses of Ethene (Ethylene)*						
		H. Cycloalkenes						
		6.3.2 Alkynes and Their Physical Properties			6.14			1
18		A. Nomenclature of Alkynes				6.15		1
		B. Isomerism in Alkynes	6.13		6.16			
19		C. Preparation of Alkynes		6.4	6.17			1
		D. Chemical Properties of Alkynes	6.14,15					
		E. Properties and uses of Acetylene or Ethyne						
20	6.4	6.4 Aromatic Hydrocarbons: Benzene						1
		6.4.1 Benzene						
		6.4.2 Nomenclature of Substituted Benzenes						
21		6.4.3 Physical Properties of Benzene						
		6.4.4 Chemical Properties of Benzene	6.16				6.18	1
	6.5	6.5 Natural Sources of Hydrocarbons	6.17				6.19	
								23
		*Projects to be carried out by students in convenient time						

6.1 Introduction

Period Allotted 4

At the end of this section, students will be able to

- narrate the historical development of organic chemistry
- classify organic compounds
- define the term functional group

Planning

The teacher is expected to read the section thoroughly and make the necessary preparations to increase students' motivation and interest in the subject. Prepare a chart that shows the different classes and functional groups of organic compounds. Set your plan for organizing students in groups, conducting discussions on the suggested activities and managing them. Also, make a plan on how to implement the suggested methods for the section.

Teaching Aids

Charts (***Table 6.1***) that show the classification of the chemical compounds and the different classes of organic compounds can be used.

Subject Matter Presentation

It is advisable to use group discussion, questioning and answering, and visual-based methods to deal with the contents of the lesson. This section begins with start-up activity. The teacher may start this class after briefly introducing the topic and forming groups of three or four students to discuss the start-up activity. The teacher may also allow students to discuss in pairs depending on the classroom situation. The teacher can use this activity to make a social construct between students' experience and the new topic. In addition, as students discuss in groups the points cited in the activity, they would be interested and motivated to study the topic ahead. Most of the students from rural areas are familiar with biogas plants. But they may not know the substance which plants produces-methane-a typical hydrocarbon. Biogas produces methane when burns in air resulting in heat and light energy. The teacher may move across the groups, takes part in the discussion, facilitates, and ask them if they have answered the questions. Finally, the teacher should invite an interested group or a member from the group to come out and present his/her idea on the biogas in the class. The students should conclude that the biogas plant produces a hydrocarbon called methane, which when burns in air produces heat and light energy. The heat energy is used to cook food, and the light energy is used to light his/her house. Now, they know at least one member of the hydrocarbon family and they can also suggest at least one use of hydrocarbon. So, let them be comfortable that what they are going to learn in the topic is something related to what they have known already. Inquire students if they have come across with plant extracts used in traditional medicine. Let them also discuss the advantages and disadvantages of using traditional medicine. Let students discuss and come up with a conclusion that using plants as a source of psychotropic chemicals is dangerous. Harmonize their response as "Although the drugs of abuse are perceived as advantageous to boost zealous, tolerance to thermal fluctuations, increase energy, and decrease fatigue, they have serious side effects such as personality disorder, low productivity, increased accidents, reduction of competitiveness, inability to cope with tasks that require higher-level judgment, constant attention, immediate memory and fine motor skills. Drug abuse occurs most frequently among young people in the 15-35 age group, with a particular concentration in the 18-25 age group. It thus includes those who have entered or who are just about to enter the workforce. Given the high unemployment rates in many countries, entry into the workforce is often a major problem. Consumption of illicit drugs limits chances of entering or remaining in the workforce, while frustration caused by failure to find adequate employment favors drug consumption, thus creating a vicious circle. Irrespective of the current level of development, societies will find it difficult to advance if they have to rely on a workforce that is impaired by large-scale drug abuse and doping. You may assign the following questions as assignment.

Q1. Describe organic compounds that have been used in doping. Discuss the socio-economic impacts of doping on a nation.

6.1.1 History of Organic Chemistry

You can start the second class on the section “History of Organic Compounds” with a mini - lecture by informing students that organic compounds are all around them. The hydrocarbon they discussed in the last class in relation to the biogas is an organic compound. So, introduce the two broad classes of chemical compounds as organic and inorganic compounds. Then introduce them to the differences between these groups of compounds according to the belief of early chemists by discussing the “vital force” theory. Emphasize the central idea of the “vital force” theory and what it states. Discuss the fact that the term organic compound currently refers to the compounds contained in and derived from plants and animals as well as those synthesized by man in the laboratory. Define organic chemistry as chemistry of carbon compounds and **cite the exceptions**. Then form a group and let the students discuss Activity 6.1. This activity is intended to increase students' understanding of the importance of useful synthetic as well as naturally made compounds. Let them have a clear understanding of the common expression "organic food" or "organic fertilizer" and have a balanced thought about organic vs synthetic, as both are useful sources. Let students discover how the linkage of carbon atoms in different ways contributed to the presence of millions of organic compounds. After the discussion of the first activity, let the students make presentations to the class.

We suggest that you begin the third class with a quiz from the previous discussion.

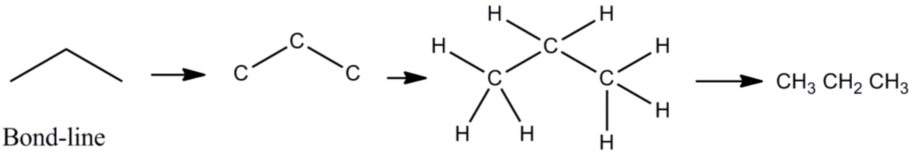
Q1. Suggest at least five carbon-containing compounds that are not organic compounds.

Q2. The main reason for the presence of many millions of carbon compounds is related to the unique property of carbon called__________________________?

Then proceed to the third class, which is assigned for the topic-structural representation of organic compounds.

6.1.2 Structural Representations of Organic Molecules

Remember that by now, students know Lewis' structure only. With this background, you cannot proceed to the nomenclature section. So, please try to help students write the four alternative ways of representing structures of organic compounds. Since this is relatively a new topic, you can make a mini -lecture supported by examples. Please make sure that students understand that in any neutral organic compound, each carbon forms four covalent bonds, which could be with hydrogen, carbon, or other atoms. Note that double bonds are counted as two bonds and the triple bonds are counted as three bonds. In the bond-line structures, only carbon atoms are shown. After counting the bonds to a particular "C" atom in the structure, students should be able to indicate the missing number of bonds as bonds to hydrogen atoms. The hydrogen and the C-H bonds are usually left as intuitive. For instance, you may draw a zig-zag line and inform them the corners and the tips (termini) of the zig-zag line represent C atoms. A "C" atom at the vertices (corner) has already two bonds to the left and to the right.



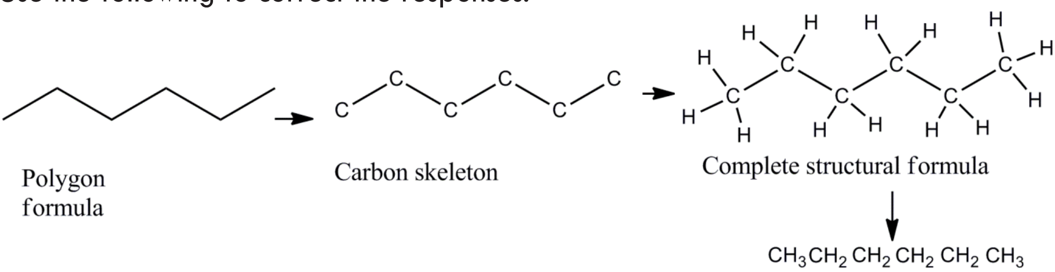
Bond-line formula

complete structural formula

Condensed structural formula

Additional two bonds are understood to be bonded to hydrogen. Please illustrate this with further examples and make sure students are able to imagine the intuitive H atoms and C-H bonds and draw them out. Remember that the valency of the H atom is 1, so it cannot form more than one bond. After explaining this, draw the following and let students draw the C skeleton, complete structural formula and condensed structural formula. Ask them to write the molecular formula too.

Use the following to correct the responses.



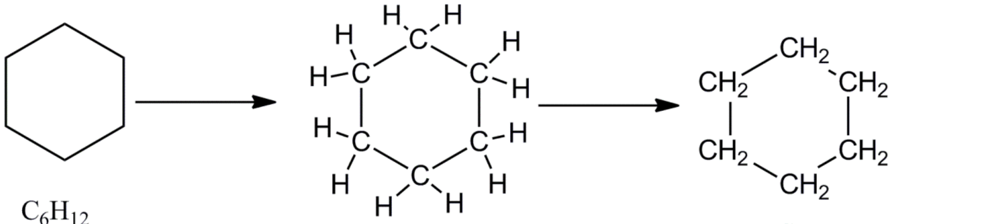
Polygon formula

Carbon skeleton

Complete structural formula

Condensed structural formula

The molecular formula for this structure is C_6H_{14}. Let students verify this. Once they are clear with the bond-line representations, polygon formulas are easy to understand. For instance, draw a hexagon, give the molecular formula C_6H_{12}, and ask them to indicate the carbons and all the intuitive hydrogen atoms along with their C-H bonds. You may use the drawing below to correct their answers. Then, let students count the number of bonds to each carbon and make sure each carbon has formed 4 covalent bonds.



C_6H_{12}

Polygon formula

C_6H_{12}

Complete structural formula

C_6H_{12}

Condensed structural formula

Begin the fourth period with a quiz from the previous topic. You may draw a pentagon as a polygon formula for an organic compound on the blackboard, and ask students to draw its complete structural formula, condensed structural formula, and molecular formula. The fourth period is assigned to the section "Classes of Organic Compounds."

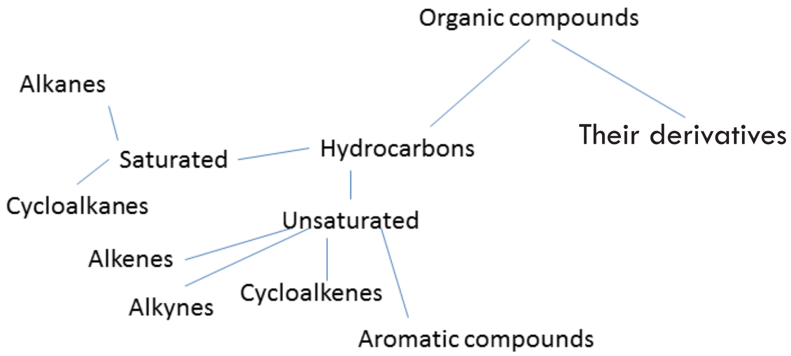
6.1.3 Classes of Organic Compounds

This section begins with ***Activity 6.2***. Let students discuss this activity in groups and present their answers to the class. You may harmonize the answers and emphasize on the following: There are over 50 million organic compounds. It is difficult to deal with each member. To save time, we can classify those showing similar characteristics as a family and study them using a representative member. The advantages of classification include saving time, making study easier, and predicting the properties of the unknown or newly discovered compound based on the properties of the known.

After the activity, you can make a mini-lecture. Continue introducing the basis for the classification of organic compounds and define the functional groups. To teach the different classes of organic compounds and their functional groups, it is advisable to use a chart prepared using ***Table 6.1*** in the student's text. After you have explained the classification of organic compounds using chart of ***Table 6.1***, list the following words on the blackboard and then ask them construct a concept map of the words. After the discussion, let a volunteer student do it on the blackboard.

- Hydrocarbons
- Saturated hydrocarbons
- Unsaturated hydrocarbons
- Organic compounds
- Oxygen-containing compounds
- Alkanes
- Alkenes
- Alkynes
- Aromatic hydrocarbons
- Aldehydes
- Alcohols
- Ethers
- Esters
- Amides
- Carboxylic acids
- Ketones
- Cycloalkanes
- Cycloalkene

Concept Mapping



Assessment

Have a list of all students in each section you are going to teach. The list serves as your students' performance list where you can make a record of how every student is working in discussion and in the teaching-learning process as a whole. You can use your own oral questions and quizzes for assessment. Check their exercise books and make a record. Make sure that the students working at the minimum required level have fulfilled the competencies suggested in the section. For students below the minimum required level, give additional lesson time. Appreciate the students working above the minimum required level.

6.2 Saturated Hydrocarbons (Alkanes)

Alloted periods 9

At the end of this section, students will be able to

- define hydrocarbons, saturated hydrocarbons and homologous series;
- drive the general formula of alkanes based on the number of hydrogen and carbon;
- write the first ten members of alkanes homologous series;
- write the molecular formulas of alkanes from the given numbers of carbon atoms;

Planning

Read this section thoroughly and prepare your own plan on how to cover the contents within the given number of periods. Your plan should be prepared in such a manner to show the sub- topics and activities to be treated during each period. You also need to prepare a plan on how to budget your time during each period for students to discuss activities, make presentations, harmonize concepts, and perform stabilization and evaluation.

In this section, two experiments and one project work are suggested in the students' text. Arrange the necessary chemicals and apparatus required for the experiments. You are advised to carry out the experiment before allowing students to do it. Arrange a trip for students to visit a biogas plant located at a nearby village or town.

Teaching Aids

See the student text for the suggested apparatus and chemicals you need for ***Experiments 6.1 and 6.2***. Prepare a chart of ***Table 6.2,*** and ***Table 6.3***.

Subject Matter Presentation

Saturated Hydrocarbons (Alkanes)

To teach the lesson, we suggest that you use group discussion, questioning-and-answering methods.

This section starts with ***Activity 6.3***. This activity is helpful to familiarize students with the structure of alkanes. Since they have already learnt the meaning of saturated in unit 2, let them link this knowledge with their understanding of the valency of carbon from grade 9 to determine whether the given structure of hydrocarbons is saturated or unsaturated. After the discussion, you purposively select a student from a group and let he/she present what they discussed in the group to the class. When you encounter shy or less expressive students, please encourage them to speak out anything she/he understood. You may also guide their answers by elaborating and simplifying the question. Also carefully note how each student is progressing. In case, you encounter students with learning difficulties and need special support inform the school principal to find solution to help such students. After introducing the topic of the lesson for this period, tell them that they have already learnt about the meaning of 'saturated' through ***Activity 6.3***. You may reinforce their understanding by defining hydrocarbons as, those organic compounds containing carbon and hydrogen atoms only and in which every carbon atom is bonded to four other atoms so that all the bonds between carbon atoms are single. In the case of unsaturated hydrocarbons, inform them that there are at least two carbon atoms that form bonds with fewer numbers of atoms than four. So, these carbon atoms form a double or a triple bond using the unshared electrons to fulfil their octet.

After introducing saturated and unsaturated hydrocarbons, proceed to ***Activity 6.4.*** Please, do not teach the activity assigned to students. Organize groups and facilitate the discussion by questioning and answering method. Pose questions and give them a couple of minutes to answer. In the first question, they are expected to determine whether the given structure is saturated or not. You facilitate their discussion by reminding them of the definition of saturated. Each carbon forms bonds with four other atoms. Harmonize their answers and give them the correct answer. Butane, pentane, and hexane are saturated. They are also alkanes. Encourage them to remember the significance of the bond-line formula and let them continue the discussion and come up with a molecular formula for the displayed structures in ***Activity 6.4*** No 1. Butane has a molecular formula of (C_4H_{10}). Similarly, Pentene (C_5H_{10}), Pentane (C_5H_{12}), and hexane (C_6H_{14}) have the indicated formulas. Also, inform them that each double bond formation requires two hydrogens removed from the corresponding alkanes. After students are done with the first question of the activity, stretch the chart of the alkane family (***Table 6.2***) and ask them to refer to the table and answer the subsequent questions. They should come up with the trends. This activity is intended to help them exercise critical thinking. For instance, ask them to see how consecutive members differ? And also they should be able to tell you from the molecular formula that as the number of carbon atoms increases by "1" unit, the number of hydrogen atoms increases by "2" units. That means they should realize that consecutive members differ by a $-CH_2-$(methylene) group. In addition, they must be able to derive the general molecular formula by looking at the molecular formulas of the first five to ten members down the series. You may give them the following mathematical puzzle, ask them find the next member, and derive an algebraic expression that can be used to predict the next number in the series. Then, ask them do the same for the C and H in alkanes after giving the first four members of the alkane series.

1 + 5 = 6	9 + 1 = 91	C_1H_4
2 + 6 = 14	8 + 2 = 75	C_2H_6
3 + 7 = 24	7 + 3 = 61	C_3H_8
4 + 8 = 36	6 + 4 = 49	C_4H_{10}
5 + 9 = +	5 + 5 = ?	$C_{11}H_?$
(x,y,z); z = xy + x	n + m = z; z = n2 + (n+2m-1)	C_nH_{2n+2}

Ask them the number of hydrogen atoms if the number of carom atoms is "11." Then, ask them derive a formula that can be used to predict the number of hydrogen atoms if the number of C atoms is given. They should come up with the formula C_nH_{2n+2}. Let them use this formula and complete the missing molecular formula for undecane through eicosane in *Table 6.2* as an exercise (homework). From the table, they can also tell you that both the family name "alkane" and specific names such as methane, ethane, butane, etc. share a common suffix "**-ane**." Tell them that this is analogous to what children inherit from their parents. You may make fun by asking them the characteristics each student has inherited from his/her parent. To illustrate the common features of the specific names methane, ethane, propane, …, etc. with their parent's name 'Alkane,' you can consider some names such as "Berihun Bekele, Seada Seid, Aster Awoke, Mukrem Mohammad, Degu Desta, etc." You may use relevant names from your students' context. Then, you ask them to come up with their friend's name having such a pattern. Regarding question 2.5, you may facilitate by inviting one student at a time to come out and write the condensed structures for methane, the other student bond-line structure for methane. You continue this for ethane up to decane. In this way, you can promote the participation of about 20 students in one activity. Please take time and let each student participate in this activity because this is a stepping-stone. Now, let them make a logical association with what they are learning in this topic with their experiences from unit 2; i.e. the word 'saturated'. You may relate the topic to their daily experience by telling them that people usually say, "I am saturated; after they have eaten their feel."

6.2.1 Alkane Homologous Series

You can now make a mini -lecture on homologous series and explain using your teaching aid (**chart** of *Table 6.2*). Define homologous series and list down the characteristics. A homologous series:

- has a constant unit between two consecutive members;
- has a general formula;
- shows trends in physical properties and
- exhibit the same reactivity. Then, let them do *Exercise 6.1* as classwork in pairs.

6.2.2 Physical Properties of Alkanes

At the end of this section, students will be able to explain the physical properties of alkanes. You may write the topic on the blackboard and let them form groups to discuss *Activity 6.5*. You may facilitate the discussion by questioning and answering method. Start with, "What is a physical property?" They should answer you that a physical property is property of a substance that we can observe or measure without altering the chemical nature of the substance. Ask them to suggest examples. Then, try to connect what they are going to learn in the topic with what they have already known. For instance, students have already studied about the physical states of substances: solid, liquid, and gases in grade 9 and in general sciences. They have also studied why particles in solids and liquids are intact while they freely move in gases. They have also learnt about interparticle forces in polar and non-polar molecules. Further, they have studied the like dissolves like rule in unit 2. Now, they should be able to tell you that alkanes are non-polar compounds. This is the starting point! If alkanes are non-polar compounds, what can the students say about their solubility? Well, they should tell you that alkanes are insoluble in water and soluble in non-polar solvents like hexane and carbon tetrachloride. Which interparticle force (dipole-dipole, ion-dipole, dipole-induced dipole, hydrogen bonding, or dispersions forces) is very important in determining the physical property of alkanes? They should be able to tell you that it is dispersion forces. Ask them what happens to the dispersion forces as molecular weight increases. Then what happens to the bp, mp, etc. as the interparticle force increases? After this activity, students are expected to discover the change in the physical state and other physical properties of alkanes with increasing carbon numbers. After such questioning and answering technique of teaching, harmonize the ideas and summarize the lesson as follows. Introduce the alkanes that exist as solid, liquid and gas at room temperature, the nature of the force existing between molecules in alkanes, the cause for their insolubility in water and the trends in densities, melting points and boiling points with increasing carbon number. Inform them that alkanes are the main constituents of petroleum and that the gaseous fuel used for stoves, gasoline, kerosene and asphalt contains alkanes. Check whether the students have realized the physical properties of alkanes or not. Summarize using a **chart** for ***Table 6.3*** and proceed to Nomenclature of alkanes. Let them do ***Exercise 6.2*** as homework.

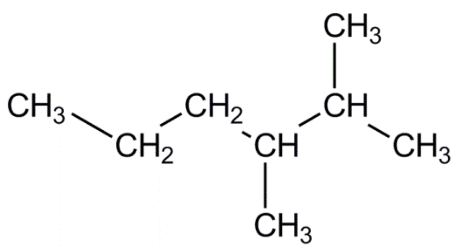
6.2.3 Nomenclature of Alkanes

At the end of this section, students will be able to

☞ apply IUPAC rules to name straight and branched -chain alkanes

☞ write the structural formulas of the first ten alkanes.

To deal with the contents in this sub-topic, we suggest that you use group discussion, question and answer methods. Before you deal with the IUPAC system of naming alkanes, let students try ***Activity 6.6*** in groups. The activity helps students to discover the importance of rules in naming organic compounds, and the basic parts used in naming organic compounds. After having the discussions, harmonize the concepts suggested by students with the facts; inform them that there are rules to be-followed in naming organic compounds so that a given compound can have the same name all over the world. As the parent names meth, eth, prop, but, pent, hex, hept, oct, etc. are used to indicate the main (or longest chain), the names of alkanes are obtained by using the parent name that indicates the number of carbon atoms in the molecules and the suffix '-ane' which signifies the presence of carbon-carbon single bonds. Upon the harmonization of the concepts, introduce alkyl groups and the significance of the symbol R. Then make a gapped lecture on the IUPAC rule. Start with the first rule, illustrate with one example and assign a task to students to name a new structure individually or in pairs following the example. Continue to the second rule illustrate with an example and assign a task to students to name a new structure individually or in pairs following the example. Introduce all the rules in the same manner and introduce ways to classify hydrogen atoms. Then proceed to ***Activity 6.7***. Let them discuss this in groups of three or four students. You may track responses from each group as they continue their discussion and record marks on the permanent list. This activity will help them to apply the rules and name alkanes. After you completed harmonizing the concepts suggested by students in relation to ***Activities 6.6*** and ***6.7***, you ask them to name the following compound individually as classwork and let them do ***Exercise 6.3*** as homework.



6.2.4 Isomerism in Alkanes

At the end of this section, students will be able to

- define isomerism
- define structural isomerism
- draw the possible structural isomers for C_4H_{10}, C_5H_{12} and C_6H_{14}.

We suggest that you use group discussion and the question and answer methods while dealing with this sub-topic. After completing the IUPAC system of nomenclature of alkanes, you can start introducing isomerism, using ***Activity 6.8***. The activity aims to enable students to identify what isomers are and in what manner they differ. Let students discuss ***Activity 6.8*** in groups for a few minutes and let students from some groups suggest their conclusions after the discussion. To harmonize their suggestions with their experiences, inform them that two similar dogs can be distinguished based on the way they behave (property) to a neighbor. Similarly, two different compounds having the same molecular formula can show different properties and they can be identified by their properties. Then, make a mini- lecture when you provide definitions and examples. Please do not for get to tell them that the chemical properties of organic compounds are related to their structure. If two compounds have different properties, it means that they have different structure. Therefore, isomers may also be defined as two compounds having the same molecular formula but different structure (meaning different properties). Then, let students discuss ***Activity 6.9*** in pairs. Check how students are doing. In the end, give them corrections. After completing this sub-topic, you may give them ***Exercise 6.4*** as a quiz and continue with the preparation of alkanes.

6.2.5 Preparation of Alkanes

At the end of this section, students will be able to

- describe the general methods for the preparation of alkanes in a laboratory
- synthesis methane in a laboratory by decarboxylation method
- carry out a project work to produce biogas from cow dung

While teaching this topic, we suggest that you use a gapped lecture, question and answer, cooperative learning and experiment as methods. When you deal with the preparation of alkanes, first inform students that alkanes are the major constituents of petroleum and natural gas. However, they can also be synthesized in the laboratory using different methods. Introduce them to the three methods suggested in the students' text. After introducing the general equation and explaining the reactant side and the product side in each case, write specific reactants and ask students to supply products after the arrow. Whenever you teach reactions, you can follow this approach! You may give them ***Exercise 6.5*** as homework.

Experiments 6.1 and 6.2. In the case of ***Experiment 6.2***, students should bring cow dung and prepare the mixture four days before the period you plan to experiment. Collect the laboratory reports and correct them accordingly.

Experiment 6.1

You can use the following information for the questions on observations and analysis of Experiment 6.1. The gas is colorless and insoluble in water. It is combustible. The equation for its combustion reaction is:

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

When $Ca(OH)_2$ is added to the gas jar in which methane is burned, the solution turns milky. This is due to the formation of calcium carbonate. The equation for the reaction is

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

There will be no change when bromine water is added to the gas jar filled with methane.

Experiment 6.2

The answers to the questions raised in the observation and analysis part of Experiment 6.2 are the following:

a. To keep the flask warm and facilitate decomposition.
b. The gas at the outlet of the tube catches fire.
c. Fermentation is responsible for the formation of methane.

Finally, let the students do the suggested project work (6.1) and present a model and a report to the class. After introducing **project 6.1** and arranging a trip day, you can proceed to deal with the chemical properties of alkanes.

6.2.6 Chemical Properties of Alkanes

At the end of this section, students will be abler to explain the chemical properties of alkanes.

To deal with the contents in this lesson, use group discussion, questioning and answering and visual-based learning methods. We suggest that you start teaching the lesson with ***Activity 6.10***. The activity enables students to determine if alkanes are reactive or less reactive compounds. This activity also reminds them of the biogas plant and the alkane used there. From this, they should be able to suggest that the most important reaction of alkanes is the combustion reaction, which is used to produce energy. First, let students discuss ***Activity 6.10*** in groups for a few minutes. Allow some groups to make presentations about their discussions. Based on their presentations, continue to harmonize their suggestions with the actual truth. First, introduce that alkanes are saturated hydrocarbons and are inert towards many reagents. However, they can undergo the following reactions.

Alkanes go through a combustion (oxidation) reaction. They burn in excess and limited amounts of oxygen to form carbon dioxide and carbon monoxide, respectively, as well as water. In the reaction, they release heat energy. This reaction is responsible for generating electricity in diesel power stations and for moving motor vehicles. Make sure that students are familiar with the fact that the combustion of alkanes gives CO_2 and water produces more energy than the same process that gives CO and H_2O. Introduce the general equation for the complete oxidation of alkanes to carbon dioxide and water. Also, tell them that this is the most important reaction of alkanes.

$$C_nH_{2n+2} + [(3n+1)/2]\ O_2 \rightarrow nCO_2 + (n+1)H_2O$$

Write the combustion reaction of methane as an illustration of the use of this formula and ask them to do the same for ethane individually for 1 minute. Praise those who did it correctly.

Inform students that petroleum refineries are built in the open air to reduce fire hazards and health problems that can be caused by gaseous petroleum fractions that escape from the refinery. To introduce substitution reactions of alkanes, you can apply a visual-based active learning method. First, provide balls and sticks, and then tell them to construct ball and stick models of methane in groups. They should use four balls of the same color (maybe blue) to represent the hydrogen atom and a ball of a different colour to represent the carbon atom. After that, let every group replace one of the balls representing a hydrogen atom with another ball having a different colour (maybe yellow). Following this, inform them that the model they obtained is a substituted product and ask them to define substitution reaction with examples. Then proceed to ***Activity 6.11***, which has been to help students to reason out why Br_2 and Cl_2 do not react with alkanes in the dark. Let them give the appropriate definition and allow them to discuss ***Activity 6.11*** for a few minutes. Let some groups present their views to the class. Harmonize their ideas with the facts. Tell them that reactions of alkanes with chlorine and bromine are photochemical reactions. Light or heat energy is required to decompose bromine and chlorine to their respective atoms, as shown in the chain-initiating step in the students' text. Unless the free radicals Cl• and Br• are formed, there cannot be a reaction. That is why Br_2 and Cl_2 cannot react with alkanes in the dark. Then proceed to elimination reaction of alkanes.

To introduce this reaction of alkanes, you need to implement a visual-based active learning method. First, let them construct the ball and stick model of ethane in groups. After they have done so, tell them to remove one ball representing a hydrogen atom from each of the carbon atoms and one of the sticks. Then, let them join the two balls representing the carbon atoms, using the stick that has remained on one of the two balls after removing the ball representing a hydrogen atom. Following this, tell them that the activity they performed can be an example of an elimination reaction. Allow them to discuss in groups for a few minutes what an elimination reaction is and the nature of the compound resulted from this reaction. Encourage some groups to present their opinion to the class.

After the presentations, inform them of the definitions of an elimination reaction and the nature of the substances obtained when alkanes undergo this type of reaction. You may assign ***Exercise 6.6*** as assignment or homework and record their performances.

6.2.7 Cycloalkanes (Alicyclic Hydrocarbons)

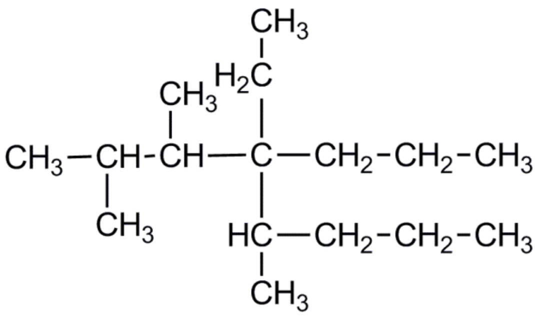
At the end of the section, students will be able to introduce cycloalkanes, their general formula, structure and names.

6.2.8 Uses of Alkanes

Briefly introduce them that alkanes are principally used as source of energy (ነዳጅ). And let them do ***Exercise 6.5*** as homework.

Assessment

Use the students' performance list to keep a record of how every student is taking part in discussion ***Activities 6.3 – 6.12***. Please do not make significant variations in marks of students from subjective assessments. You may rather consider exercises or quizzes as a reliable form of assessments. Use activities as a means to gather feedbacks and improve your lesson. Sometimes, you can give bonuses to best performing students as a strategy to motivate other low performing students to do the same get the bonus. If a student always performs below the minimum expectations, this might mean you have not done well. Try to improve your methods, the way you facilitate the discussion so that the lagging students also level with their friends' performance. In this section, you can record students' performance on ***Exercises 6.1 – 6.7*** assigned as classwork or homework. Check their exercise books to see how every student does his/her works accordingly. Register the performance of each student in your record list. Then make sure that most of the students have accomplished the competencies suggested for the section. Appreciate students working above the minimum required level. Assist students working below the minimum required level, by either arranging additional lesson time or giving more exercise.



Additional Questions

1. What is the molecular formula of an alkane containing the following carbon number?

   a) 15 b) 18 c) 26

2. Derive a formula that can be used to determine the number of isomers of alkanes containing 4 – 7 carbon atoms, based on Table 6.3.
3. Give the IUPAC name of the following alkane.
4. What are the advantages of biogas technology?

Answers to Additional Questions

1. a) $C_{15}H_{32}$ b) $C_{18}H_{38}$ c) $C_{26}H_{54}$
2. $2^{n-4} + 1$
3. 4-Ethyl-2, 3, 5-trimethyl-4-propyl octane.
4. Saving on fuel such as kerosene, wood and charcoal, decrease in deforestation, clean cooking, saving foreign currency, etc.

Answers to Exercises

Exercise 6.1

1. (a) Define homologous series. See student's textbook

   (b) Describe the characteristics of a homologous series. See student's textbook

2. Determine if each statement about the alkane homologous series is True or False.

   a) It has a general formula and a name. T

   b) Consecutive members differ by a constant ($-CH_2-$) unit. T

c) All members contain the same functional group. T

d) Consecutive members differ by a constant molecular mass of 14. T

Exercise 6.2

Explain each of the following facts about alkanes

1. Alkanes show regular increases in boiling point as molecular weight increases: See student's textbook
2. Branching decreases the boiling point of alkanes: See student textbook
3. Alkanes are insoluble in water: See student's textbook

Exercise 6.3

1. D
2. Consider n-hexane

Exercise 6.4

a) These two structures have the same molecular formula but different structures. They are isomers. Their IUPAC names n-butane and 2-methylpropane.

b) These two structures have the same molecular formula but different structures; i.e. the ways the C atoms are connected are different. Their IUPAC names are n-pentane and 2,2-dimethylpropane. So, they are isomers.

c) These two structures have same IUPAC name. They are just different representations of the same compound 2-methylpentane. The first is the bond-line formula and the second is complete structural formula of the compound 2-methylpentane.

d) The IUPAC names for both of these structures are the same. So, one is just 180o rotated version of the other. So, the structures represent the same compound 2, 3-dimethylheptane. Explain this to the student as follows. Stretch you two hands and stand facing students. Next, turn back and face to the blackboard. Tell them that it is still the same you. Students should be clear that a similar operation is also possible with molecules without violating their identity.

Exercise 6.5

Write the products when:

(a) $CH_3CH=CH_2$ reacts with hydrogen in the presence of Pt as a catalyst: Propane

(b) Ethyl bromide reacts with sodium metal. Ethane

(c) Sodium propanoate (CH_3CH_2COONa) reacts with soda lime Propane

2. The reaction of a halogenated alkane with sodium was named in honor of_ **Wűrtz**

____

Exercise 6.6

See student's text for answers

Exercise 6.7

1. Define the terms   see student's textbook

(a) Homologous series   (b) substitution reaction

(b) Alkyl radical   (d) combustion reaction

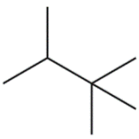
(c) Isomerism   (f) functional groups

2. Write the balanced chemical equation for the combustion of octane.

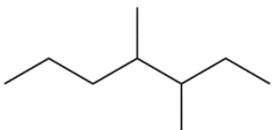
$$2C_8H_{18} \quad + \quad 25O_2 \quad \rightarrow \quad 16CO_2 \quad + \quad 18H_2O$$

3. How many chain isomers are there for an alkane that contains seven carbon atoms?
_ 9

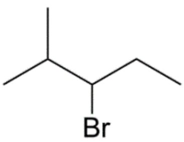
4. Write IUPAC names for the alkanes represented by the following bond-line structures.



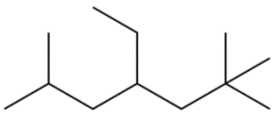
(a)



(b)



(c)



(d)

a) 2,3,3-trimethylbutane   b) 3-Ethyl-4-methylheptane

c) 3-Bromo-2-methylpentane   d) 4-Ethyl-2, 2, 6-trimethylheptane

6.3 Unsaturated Hydrocarbons: Alkenes, Alkynes, and Aromatic Hydrocarbons

Alloted Periods 9

6.3.1 Alkenes or Olefins

A. Homologous Series of Alkenes

At the end of this section, students will be able to

- define unsaturated hydrocarbon alkenes alkynes ,and geometric (cis-trans) isomerism
- write the general formula of alkenes and alkynes
- compare and contrast the properties of ethane, ethene and ethyne

Planning

Read this section thoroughly. Prepare a plan related to the contents and activities you need to treat during each period so that the whole content in the section can be covered within nine periods. In this section, two experiments and one project work are suggested in the students' text. Arrange the necessary chemicals and apparatus required for the experiments. You are advised to do the experiment before you allow students to perform it. You should plan when to conduct and how the students can participate in performing the experiments. You need to plan how to allot the time required for students to discuss activities, make presentations, harmonize concepts, and perform stabilization and evaluation during each period.

Teaching Aids

Refer to the students' textbook for the apparatus and chemicals you should use to perform the ***Experiments 6.3 and 6.4***.

Subject Matter Presentation

We suggest that you use group discussion, questioning-and-answering methods for this sub-topic. To start teaching content on this sub-topic, let students recall saturated and unsaturated hydrocarbon and suggest their definitions. After their responses, use ***Activity 6.13*** to begin with the contents. The activity enables students to derive the general formula for alkenes and identify the differences between alkenes and alkanes. Besides this, they could also discover the trends in some properties of alkenes. So allow them to discuss ***Activity 6.13*** for a few minutes. After the completion of their discussion, allow students from two different groups to suggest their opinion to the class on what they have discussed. Then, harmonize the facts they are supposed to know with the feedback of the students using a chart in ***Table 6.4***.

First, introduce the general formula for alkenes to be C_nH_{2n}. From this general formula, it can be noted that alkenes possess two hydrogen atoms less than the corresponding alkanes. Hence, they possess a carbon – carbon double bond as their functional group. The presence of a double bond makes them unsaturated hydrocarbons. Ask the students to get chemical formulas for alkenes containing 2 to 10 carbon atoms. Then continue with the physical properties of alkenes. Use the activity to help students to discover the reason why alkenes exist in different states and the trends in melting point, boiling point and density with increasing carbon numbers. Let them discuss the activity and have some groups present their opinion to the class. To harmonize concepts, introduce that the melting point, boiling point and density of alkenes increases with increasing carbon number. This is due to an increase in the strength of intermolecular forces of the attraction between molecules. Finally, explain the reason for the insolubility of alkenes in water. Alkenes are non-polar molecules and are insoluble in polar solvents like water. Make sure that students can write the molecular formulas of alkenes from a given number of carbon atoms, and that they have realized the physical properties of alkenes. Then continue with their nomenclature. You may assign ***Exercise 6.8*** as a homework and record marks and return feedbacks.

B. Nomenclature of Alkenes

At the end of this section, students will be able to

- write the structural formulas alkenes up to nine carbon atoms.
- write the molecular formula for first nine homologous series of alkenes, structural isomers for C_4H_8 and C_5H_{10}
- write the molecular formulas of alkenes from the given number of carbon atoms
- Use IUPAC rules to name straight and branched-chain alkenes.

It is advisable to implement group discussion and question and answer methods in dealing with content in this sub -topic.

In dealing with the nomenclature, introduce to them that common names of alkenes are derived from the parent name that indicates the number of carbon atoms in the molecule and the suffix '–ylene'. After introducing common names of alkenes or olefins, continue with the IUPAC system. To deal with the details, follow the same approach as you did for alkanes. In doing so, inform them that IUPAC names are obtained from parent names indicating the number of carbon atoms and the suffix '–ene', which indicates the functional group (double bond). Introduce the rules applied in the IUPAC system of naming alkenes, emphasizing that the parent structure should include the double bond, and numbering the carbon atoms of the parent structure should begin from the end closer to the double bond. While introducing the rules, write the first rule. Illustrate the rules with one example and ask students to do the same by giving them a similar structure as the example. After introducing the complete rule in this manner, let the students discuss ***Activity 6.14*** for a few minutes and let some groups present their ideas to the class. Then, continue harmonizing the concepts suggested by the students with those they are supposed to know. Let them do ***Exercise 6.9*** as homework.

C. Physical Properties of Alkenes

At the end of this section, students will be able to describe the physical properties of alkenes.

After that, let them discuss ***Activity 6.15*** in groups that are related to the physical properties of alkenes. Then, harmonize the facts they are supposed to know with the feedback of the students. Since alkenes are nonpolar like alkanes, their physical properties are similar to those of alkanes. However, note students that alkanes and alkenes have different chemical properties because the different functional groups.

D. Isomerism in Alkenes

At the end of this section, students will be able to

- give examples of molecules that show geometric isomerism
- construct models that show cis-trans isomerism

We advise you to use group discussion and short question and answer methods for this sub-topic.

After the students have understood how to name alkenes, let them recall isomerism. Ask them to define isomers and isomerism. After you get feedback from the students, remind them of the definitions and continue to deal with isomerism in alkenes. To do so, divide the blackboard into three equal parts by drawing lines. Then write the structures of 1-pentene and 2-pentene on the first part, those of 1-pentene and 2-methyl-1-butene on the second part, and those of cis-2-pentene and trans-2-pentene on the third part. Then, let the students discuss these issues in groups for a few minutes:

a. whether or not the compounds given by each pair of structures are isomers
b. in what manner each structure differs from the other in each pair. After the discussion, let two students from different groups suggest their opinions to the class.

Following the presentations, harmonize their views with the facts. In doing so, inform them that the compounds given by all structures are isomers of C_5H_{10}. 1-pentene and 2-pentene differ in the position of the double bond and hence are **position isomers.** 1-pentene and 2-methyl-1-butene differ in the arrangement of the carbon chain and are chain isomers. Cis-2-pentene and trans-2-pentene differ in the arrangement of atoms or groups about the double bond and are geometrical isomers. Then introduce to the students that alkenes exhibit chain isomerism, position isomerism and cis-trans (geometrical) isomerism.

Also, inform them that not all alkenes have geometrical (cis-trans) isomers; alkenes cannot have geometrical isomers if two identical groups are attached to any one of the carbon atoms linked by a double bond. Mention 1-butene and 1-pentene as examples of alkenes that do not exhibit geometrical isomerism. After engaging the students through the above gapped lecture g, let them do ***Activity 6.16***. Then, harmonize the facts they are supposed to know with the feedback of the students. Note that the alkenes 2,3-dimethylbut-2-ene, 2-methylbut-1-ene, and 2,3-dimethylpent-2-ene cannot exhibit cis-trans isomerism because of two identical groups attached to one of the carbon atoms linked by a double bond. Finally, let them do project work 6.2 in groups. When you allow them to do this project work in groups, you are implementing the cooperative learning method. You may assign ***Exercise 6.10*** as a homework.

E. Preparation of Alkenes

At the end of this section, students will be able to

- explain the general method for preparation of alkenes in a laboratory
- produce ethylene in a laboratory by dehydration of ethanol

To teach the contents in this sub-topic, we suggest that you better apply experiment, group discussion and question and answer methods.

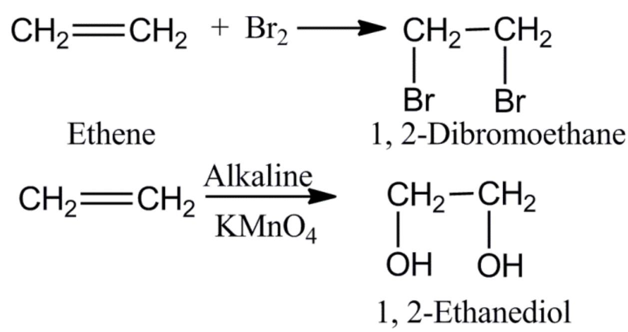
Evaluate whether students can write different structures for a given alkene, identify the types of isomers and name them. Next, present the preparation of alkenes. In treating the preparation of alkenes, explain that alkenes are primarily obtained during the fractional distillation of petroleum when the process called cracking is carried out. Let students also know that alkenes can be prepared in the laboratory. Introduce the two laboratory methods of preparation.

To realize the first method of preparation, let the students perform ***Experiment 6.3*** in groups under your supervision. Students should write a laboratory report and submit it to you. Collect the laboratory reports and correct them. Use the following note for observations and analysis of ***Experiment 6.3*** and compare it to the data in the reports of the students.

a. Colorless gas with a sweet smell.

b. Carbon dioxide.

c. It decolorizes bromine water and alkaline potassium permanganate solution. The reddish-brown color of bromine water disappears due to the addition of bromine to the double bond. The purple color of alkaline $KMnO_4$ disappears due to the oxidation of ethene. The reactions are as follows:



d. Concentrated sulphuric acid.

e. Dehydration of alcohols.

Then, continue with the second method; Dehydrohalogenation of alkyl halides with a base. First, ask the students to explain what dehydrohalogenation and alkyl halide mean. So, let them know the appropriate meanings and introduce the second method for the preparation of alkenes. After that, let the students discuss ***Activity 6.17*** in groups for a few minutes and let some groups present their ideas to the class. To harmonize their ideas with the actual concepts, inform them that in both reactions, the reactants are saturated and the products are unsaturated. Besides this, the reaction involves the removal of hydrogen and the hydroxyl group in the first method and hydrogen and a halogen in the second. Therefore, the reactions are elimination reactions. Let them do ***Exercise 6.11*** as a classwork.

F. Chemical properties of Alkenes

At the end of this section, students will be able to

☞ Test for the unsaturation of ethylene

- Explain the chemical properties of alkenes.
- Explain the uses of ethylene and acetylene.

Use group discussion, and question and answer methods to teach the content in this sub-topic. Before you introduce the chemical properties of alkenes, let the students discuss in groups ***Activity 6.18*** and the following questions for a few minutes.

a. Why are alkenes more reactive than alkanes?
b. Why do alkenes mainly undergo addition reaction and where does the addition occur?
c. What products do alkenes form when reacted with hydrogen and halogens?

When the discussion is over, let some students from different groups present their opinions to the class. After the presentation, harmonize the concepts suggested by students with the facts they are supposed to know through a mini -lecture. In addition, be sure that the students are familiar with the product of combustion reaction of alkenes, why they decolorize Br_2 in CCl_4 and alkaline potassium permanganate and what polymerization is. Inform students that the addition reaction of alkenes with hydrogen halides and water proceeds according to Markonikov's rule. You may help students recall Markonikov's rule by the aphorism "The rich get richer!" ላለዉ ይጨመራል! Let students practise predicting the products and writing their structures independently when you introduce each of the chemical properties of alkenes using ***Activity 6.19***. You may give ***Exercise 6.12*** as homework and record the mark as part of the assessment. Finally, introduce the uses of ethene.

G. Uses of Ethene (Ethylene)

Concerning the uses of ethene, use Project 6.3. The objective of the activity is to help students relate the use of ethene to real the life situations. Let the students discuss Project 6.3 in groups. Invite some groups to present their ideas to the next class. After they have responded, let them know that green tomatoes in a basket containing a ripe banana between them ripen at a faster rate. This is because the ripe banana produces ethene gas. At the end of this part, introduce cycloalkenes, their general formula, structures of some members and their names.

H. Cycloalkenes

A mini lecture is sufficient here. Inform them that cycloalkenes are unsaturated cyclic hydrocarbons. The carbon atoms are linked in such a manner as to form a closed chain or a ring structure. They contain a double bond between carbon atoms in the ring and are represented by the general formula C_nH_{2n-2}; where *n* should be equal to or greater than 3. They are isomeric with alkynes. They are named by prefixing "cyclo" to the name of alkenes containing the same number of carbon atoms. Give them some examples of cycloalkenes and illustrate that the reactions of the double bond in the cyclic structures and open chain alkenes is the same. Advise them to do ***Exercise 6.13***.

6.3.2 Alkynes and Their Physical Properties

At the end of this section, students will be able to describe the physical properties of alkynes

Apply question and answer, and group discussion methods to teach the contents in this lesson.

Ask them to define alkynes and suggest the trends in some physical properties such as density, boiling and melting points in relation to the number of carbon atoms. After they have responded, continue with your explanation.

Introduce the functional group of alkynes and their general formula (C_nH_{2n-2}). Then, you can proceed to the following part of the lesson using ***Activity 6.20***. The activity could assist students to determine molecular formulas and structures of few alkynes. It also enables them to realize the trends in the physical properties of alkynes with increasing carbon numbers. Thus, let the students discuss ***Activity 6.20*** in groups for a few minutes and listen to some groups presenting their views. After their presentation, tell them that alkynes containing 9 and 10 carbon atoms have the formulas C_9H_{16} and $C_{10}H_{18}$,and are named nonyne and decyne, respectively. The physical properties of alkynes are similar to those of alkanes and alkenes. Make sure that students can write the molecular formulas of alkynes from a given number of carbon atoms and that they have realized their physical properties. Then, continue with the nomenclature of alkynes. Let them do ***Exercise 6.14*** as classwork.

A. Nomenclature of Alkynes

At the end of this section, students will be able to

- write the structural formulas alkynes up to nine carbon atoms.
- write the molecular formula for first nine homologous series of alkynes , structural isomers for C_4H_6 and C_5H_8
- write the molecular formulas of alkynes from the given number of carbon atoms

☞ Use IUPAC rules to name straight and branched-chain alkynes.

We advise you to employ mainly group discussion and question and answer methods. Inform the students that the IUPAC system of naming alkynes is similar to that for alkenes. Write some structures of alkynes and let them practice how to name them in groups. You may assign ***Exercise 6.15*** as homework.

B. Isomerism in Alkynes

Ask them to suggest what type of isomers alkynes exhibit. Give them classwork to write all possible structures of C_6H_{10}. Name them and identify those that are to be position and chain isomers. Check how they are doing and give them corrections. ***Activity 6.21*** has been suggested to help students consolidate their knowledge of isomers. So allow them to discuss the activity and present their ideas to the class. Inform them that pentane, pentene and pentyne are not isomers. This is because their molecular formulas and functional groups are different. Then let them do ***Exercise 6.16*** as homework.

C. Preparation of Alkynes

At the end of this section, students will be able to

☞ explain the general method for preparation of alkynes in a laboratory

☞ Prepare acetylene in a laboratory by the reaction of CaC_2 with water.

To teach the contents in this sub-topic, use question and answer, and demonstration as methods. Introduce some methods for the preparation of alkynes such as dehydrohalogenation of vicinal dihalides and alkylation of sodium acetylide. In dealing with the preparation of alkynes, allow students to suggest the products after writing the formulas of the reactants on the board. You can also give ***Exercise 6.17*** as classwork or homework. Then perform ***Experiment 6.4***. Here, use demonstration as the method of teaching. Do the experiment as a demonstration. This is because of the possibility that if students are allowed to do it, they may add too much water at a time, which will lead to the release of too much gas, which again could lead to too much pressure in the flask, which in turn may cause an explosion of the flask. Students should write a laboratory report on the experiment. Collect the laboratory reports and correct them accordingly. Use the following note on the observations and analysis part of the experiment for comparison with their report.

1. The flask is hotter, the reaction is exothermic.
2. The flame is smoky and luminous due to a high carbon content.

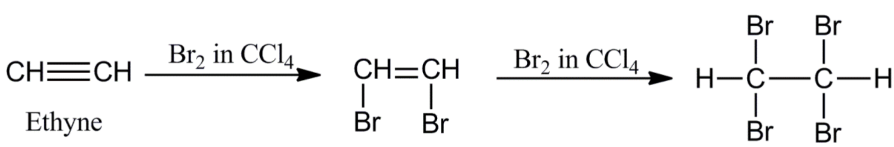
Following the experiment, continue dealing with the chemical properties of alkynes.

D. Chemical Properties of Alkynes

At the end of this section, students will be able to

- Test for the unsaturation of ethyne
- Explain the chemical properties of alkynes.
- Explain the uses of acetylene.

We suggest that you use a gapped lecture as a method to teach the lesson. You can use the suggested activities and others of your own in between the lectures. Ask students why alkynes are more reactive than alkenes and alkanes. After their response, introduce the chemical properties of alkynes. These should include combustion reaction, addition reactions (addition of H_2, halogens and hydrogen halides) and trimerization. While you are treating the chemical properties, allow the students to suggest the products of the reactions and write balanced chemical equations. When you are dealing with the addition reaction of alkynes and halogens, use ***Activity 6.22***. This activity will help students to understand how to prove the unsaturated property of alkynes. It will also help them to predict reaction products of alkynes and halogens. Let the students discuss ***Activity 6.22*** in groups for a few minutes. Allow some groups to present their ideas to the class. After their presentation, use the following note to harmonize their concepts with what they are expected to know. Alkynes also decolourize Br_2 in CCl_4, due to the addition of bromine atoms to the triple bond, forming dibromoalkenes and tetrabromoalkanes. For example, the reaction of bromine with acetylene (ethyne) is as follows:

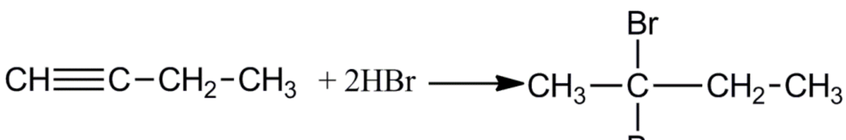


Ethyne

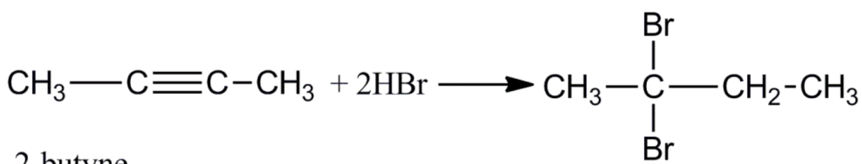
1,2-Dibromoethene

1,1,2,2-Tetrabromoethene

Before you deal with the reaction of alkynes with hydrogen halides, let the students discuss ***Activity 6.23*** in groups for a few minutes. This will help them to recall and understand Markonikov's rule, to predict formulas and structures of compounds that can be formed when a molecule of an alkyne reacts with one and two molecules of hydrogen halides. Following the discussion, encourage some groups to present their conclusions to the class. After their presentation, harmonize the concepts they suggested with what they are supposed to know. Help them understand that Markonikov's rule has been applied in the reactions of alkynes with hydrogen halides. This is because the hydrogen atom of HX in the general reaction, and that of HBr in the example, formed bonds with the carbon atoms of the multiple bonds that have a greater number of hydrogen atom(s). On the other hand, X in the general reaction, and Br in the example, formed bonds with the carbon atoms of the multiple bonds that have fewer hydrogen atoms(s). In addition to this, let the students know that the addition reaction of alkynes proceeds in two steps. The triple bond between the carbon atoms changes to a double bond in the first, and the double bond changes to a single bond in the second step. You can compare the reaction products of 1 – butyne and 2 – butyne with hydrobromic acid as follows:



1-butyne 2,2-Dibromobutane



2-butyne 2,2-Dibromobutane

In the reaction of 1-butyne with HBr, hydrogen atoms of HBr form a bond with the carbon atom of the triple bond containing one hydrogen atom. However, in the reaction of 2-butyne and HBr, hydrogen and bromine have equal chances to form bonds with any one of the carbon atoms linked by a triple bond because the two carbon atoms do not contain hydrogen. Nevertheless, the reaction product is the same in both cases.

E. Properties and uses of Acetylene or Ethyne

You may just introduce the properties and uses of acetylene. Let the students compare and contrast the properties of ethane, ethene and ethyne.

Assessment

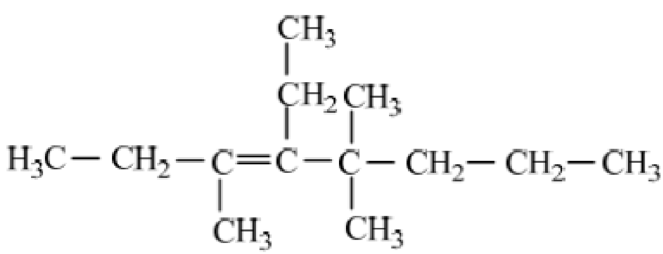
You should assess each student's work throughout the section. Using your students' performance list, monitor how every student participates in discussion and during the explanation. Give them the suggested exercises in this section; check their exercise books and see how the students perform accordingly in answering the questions. You can also give them a test on the section and make a record of their performances. Make sure that most of the students have achieved the minimum required level. Appreciate students working above the minimum required level and encourage them to work hard. In the case of students working below the minimum required level, arrange extra lesson time or give them additional exercises.. Also, make sure that you have a mix of talent levels when organizing students into groups using talent level as a criteria.

Additional Questions

1. The name olefin given to alkenes is derived from a Latin word, which means "oil forming". Explain why.
2. How many position isomers (not chain isomers) are possible for decene? Write their structures and name them.
3. Name the saturated hydrocarbon and unsaturated hydrocarbon that can be represented by the molecular formula C_6H_{12}.
4. Which of the following compounds exhibit geometrical isomerism? Draw diagrams to show the isomers and name them.

a) 1, 2-Dichloroethene b) 3-Hexene

5. Write the general equations for the combustion of alkenes and alkynes to give carbon monoxide and water.
6. Name the following Alkene.



7. Polyvinyl chloride, PVC, used as floor tiles is made by polymerizing vinyl chloride, CH_2=CHCl. How can one prepare this polymer, using ethyne and HCl as starting materials?

Answers to Additional Questions

1. This is because alkenes, like ethene, when reacted with halogens, form oily compounds of dihaloalkanes.

2. Five-position isomers

$CH_2{=}CH\text{-}(CH_2)_7\text{-}CH_3$ 1-Decene

$CH_3\text{-}CH{=}CH\text{-}(CH_2)_6\text{-}CH_3$ 2-Decene

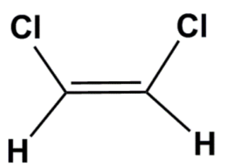
$CH_3\text{-}CH_2\text{-}CH{=}CH\text{-}(CH_2)_5\text{-}CH_3$ 3-Decene

$CH_3\text{-}(CH_2)_2\text{-}CH{=}CH\text{-}(CH_2)_4\text{-}CH_3$ 4-Decene

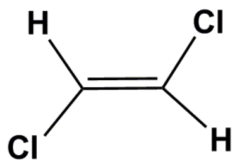
$CH_3\text{-}(CH_2)_3\text{-}CH{=}CH\text{-}(CH_2)_3\text{-}CH_3$ 5-Decene

3. The saturated hydrocarbon with the formula C_6H_{12} is cyclohexane. Unsaturated hydrocarbons having the formula C_6H_{12} can be 1-hexene, 2-hexene, 3-hexane and other branched isomers.

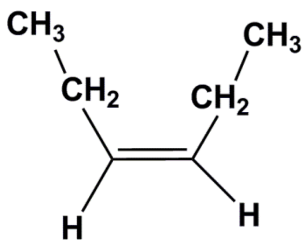
4. Both compounds have geometrical isomers.



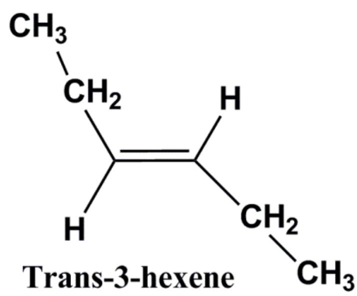
cis-1,2-dichloroethene



Trans-1,2-dichloroethene



cis-3-hexene



Trans-3-hexene

5. For the combustion of Alkenes to give carbon monoxide and water, the general equation is

$$C_nH_{2n} + (3n/2)\ O_2 \rightarrow nCO_2 + nH_2O + Heat$$

For Alkynes, the equation is

$$C_nH_{2n-2} + ((3n-1)/2)O_2 \rightarrow nCO_2 + (n-1)H_2O + Heat$$

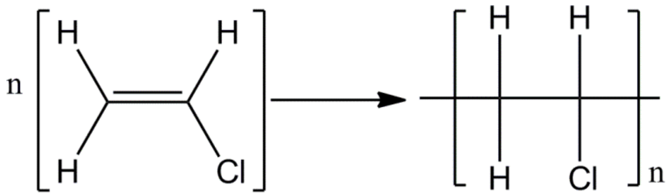
6. 4 – Ethyl – 3, 5, 5 – trimethyl – 3 – octene.

7. i) By reacting HCl and ethyne to get vinyl chloride in the first step.

$CH \equiv CH + HCl \rightarrow CH_2{=}CHCl$

ethyne vinyl chloride

ii) polymerizing vinyl chloride to get polyvinyl chloride



Vinyl chloride **Polyvinyl chloride (PVC)**

Answers to Exercise 6.8

1. See student textbook
2. Same as that of alkanes
3. CnH2n. Differs from alkane's (C_nH_{2n+2}) by 2 hydrogen atoms
4. Mp, bp, and density increases as number of carbon atoms increases. Because the only intermolecular forces in alkenes, like alkanes, is the induced dipole (London force) which increases as molecular weight increase.
5. C_2H_4, C_3H_6, C_4H_8, C_5H_{10}, C_6H_{12}, C_7H_{14}, C_8H_{16}, C_9H_{18}, $C_{10}H_{20}$.
6. See student textbook

Answers to Exercise 6.9

a. 3-heptene

b. 4-ethyl-2-methylhexene

c. 2,5-dimethyl-2-octene

d. 3,5-dimethylcyclohexene

6.4 Aromatic Hydrocarbons: Benzene

Alotted Period 2

At the end of this section, students will be able to

☞ define aromatic hydrocarbons

☞ draw the structure of benzene;

☞ describe the main physical properties of benzene;

☞ explain the chemical reactions of benzene;

☞ carry out test-tube reactions with Br_2 in CCl_4, $KMnO_4$ and concentrated H_2SO_4.

Planning

Make the necessary preparation by reading this section thoroughly, and plan how to cover the contents of the section within two periods. ***Experiment 6.5*** is suggested in this section. Arrange the necessary chemicals and apparatus for the experiment. Perform the experiment in advance and let the students do it in groups under your supervision.

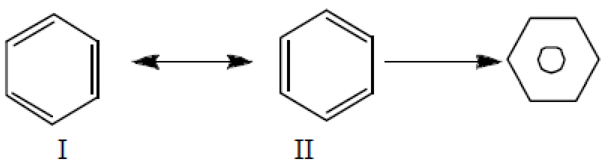
Teaching Aids

Refer to the students' text for a list of the apparatuses and chemicals required to perform ***Experiment 6.5***.

Subject Matter Presentation

Apply gapped lecture, group discussion, inquiry and experiment as methods to teach the contents of this sub-topic.

Make a gapped lecture and introduce the content to the students. Then proceed to ***Activity 6.24***. ***Activity 6.24*** is suggested to assist students to discover facts about benzene and other aromatic hydrocarbons. Let students discuss ***Activity 6.24*** for a few minutes in groups. Let members of some groups suggest their views about the points they discussed. Then proceed to harmonize students' reflection with the facts to be taught. Help them understand that most people think of the petroleum fraction used as a motor fuel when they hear the word "benzene". Then continue introducing the word "aroma" and the meaning from which the term aromatic originated. The word "aroma" means pleasant smell. Substances like rose, banana, orange, pineapple and perfume have an aroma. Tell them that the word aromatic is now used without its original significance. Define aromatic hydrocarbons as compounds containing the benzene ring. Give some examples of aromatic hydrocarbons indicating their names and structures such as benzene, Toluene, naphthalene, etc. Tell them that benzene is the simplest aromatic hydrocarbon. Ask students if they have any ideas about resonance structures and continue introducing the resonating structures of benzene suggested by Friedrich A. Kekule.



Resonance structures of benzene

Inform students that neither of the two structures is the true structures of benzene nor do they clearly describe benzene. However, each structure makes an equal contribution to the resonance hybrid. Let the students know that not all of the six bonds between carbon atoms are neither single nor double, but have an intermediate character between those of single and double bonds. Inform students that benzene and other aromatic hydrocarbons are not as unsaturated as alkenes. This is because the three double bonds in benzene are delocalized. After the students have understood about benzene, introduce its physical properties.

While you are dealing with the chemical properties of benzene, emphasize that aromatic hydrocarbons are more stable than alkenes and alkynes due to the nature of the bonds between the carbon atoms in the ring.

Let them also know why benzene burns with a smoky luminous flame. Inform students that the reactions of benzene are chiefly substitution even though it is an unsaturated hydrocarbon. Show the substitution reaction of benzene with chlorine, nitration and sulphonation using chemical equations. Finally, introduce to them that benzene can undergo an addition reaction under special conditions. Mention the reaction of benzene with hydrogen as an example. Let students perform Experiment 6.5 while you deal with the properties of benzene. Following the experiment, let them write a laboratory report. In their report, be sure that they observed a reaction occurring in the third test tube between toluene and sulphuric acid. You need to collect and correct the laboratory reports.

Assessment

Assess each student's work throughout the section. Record how every student participates in discussion during the presentation and in answering questions given as class and homework. From your record, check how many of the students have achieved the competencies suggested for the section you may also consider ***Exercise 6.18*** as a homework and record marks to see their progress. Assist students working below the minimum require level by arranging extra lesson time or giving them additional exercises.

Additional Questions

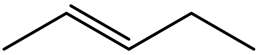
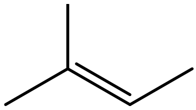
1. Write the molecular formula of naphthalene. (See ***Figure 6.6*** student's textbook).
2. Benzene is an unsaturated hydrocarbon. However, its reaction is chiefly substitution. What is the reason for this?

Answers to Additional Questions

1. $C_{10}H_8$
2. This is due to the stability of the aromatic ring. The nature of the bonds between carbon atoms in the ring is responsible for stability.

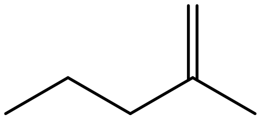
Answers to Exercise 6.10

1.

(a)  & 

2-pentene   2-methyl-2-butene

Chain Isomers

(b)  & 

1-hexene   2-methyl-1-pentene

Chain Isomers

2. Because the intermolecular forces (London Forces in this case) increases as molecular weight increases.

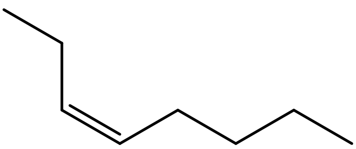
3.

1-hexene

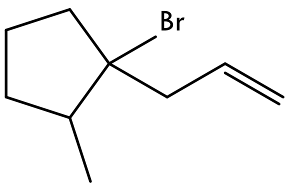
2-hexene

3-hexene

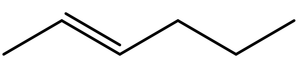
4.

(a) 

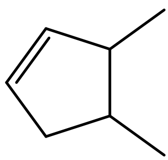
cis-3-octene

(b) 

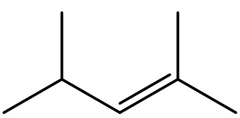
1-Bromo-2-methyl-1-(prop-2-en-1-yl) cyclopentane

(c) 

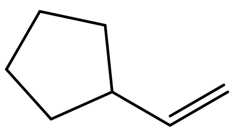
trans-2-Hexene

(d) 

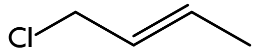
3,4-Dimethylcyclopentene

(e) 

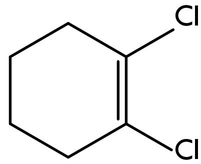
2,4-Dimethyl-2-pentene

(f) 

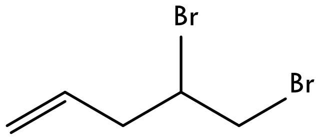
Vinylcyclopentane

(g) 

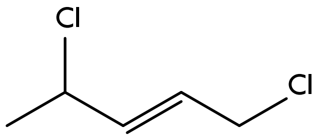
trans-1-Chlorobut-2-ene

(h) 

1,2-Dichlorocyclohexene

(i) 

4,5-Dibromo-1-pentene

(j) 

trans-1,4-Dichloro-2-pentene

6.5 Natural Sources of Hydrocarbons

Period Allotted 1

Planning

Read this section thoroughly. Plan which contents of the section to cover during each period. Prepare a diagram that shows the fractional distillation of crude oil.

Teaching Aids

No experiment has been suggested in this section. You need to prepare a chart to show the different fractions of petroleum and a diagram of the fractionating tower.

Subject Matter Presentation

We advise you to use group discussion, question and answer and visual-based learning methods for the sub-topic.

We advise you to start teaching this section using ***Activity 6.25***. The activity enables students to become familiar with the topic through the association of what they could encounter in their daily lives.. It also enables them to think as a citizen about their country's natural resources and utilization. Through the discussion, they will become aware of the environmental impact of burning natural gases in power stations. Through discussion ,students could appreciate the importance of GERD as a green energy source. Tell students that Ethiopia is gifted with water resources and often applauded as the "**water tower of Africa**" although not yet well known for oil deposits. Tell them that hydroelectric powers are renewable and are environmentally friendly.

Before you start dealing with the content in this section, allow the students to discuss ***Activity 6.25*** in groups for a few minutes. Let some students from different groups make presentations on points they discussed. After the presentations, inform them about the natural sources of hydrocarbons such as natural gas, petroleum and mineral coal. Tell students how natural gas, petroleum and coal are formed naturally. Inform students that natural gas, petroleum and coal cannot be recycled. Tell them that natural gas mainly contains methane (90%), ethane, propane, butane, higher alkanes and gases like CO_2, N_2, O_2 and H_2S in very small amounts. Let students know that petroleum is a dark-colored viscous liquid, and that its composition varies from place to place and is a complex mixture of hydrocarbons chiefly alkanes., Inform them that Petroleum also contain cycloalkanes and aromatics. Help them understand the difference between petroleum and crude oil.

Continue your explanation by asking students what petroleum refining is ,and how it is separated into different fractions. Discuss the major fractions of petroleum, their composition, boiling ranges and uses. Explain what cracking is and the importance of carrying out the process. Finally, elaborate what destructive distillation of coal is, the products obtained and the major hydrocarbons that can be separated by the fractional distillation of coal tar.

At the end of this section, let the students do the research and writing part suggested in the students' text and submit it to you for correction.

Assessment

Assess each student's work throughout the section.

Give classwork or homework (you can use questions from the suggested ***Exercise 6.19*** or your own). Correct the works of students and record their performances. Follow strictly how every student participates in discussion, presentation, and answering questions.

Correct the research done by the students and make a record in the students' performance list. From your record, see whether the competencies suggested for the section have been achieved or not.

Additional Questions

1. Petroleum fractions containing straight-chain alkanes are not good fuels and can cause engine knocking. What is the reason for this? What is engine knocking? What process is carried out to improve the quality of these petroleum fractions?
2. What are the differences among charcoal, coal, and coke?

Answers to Additional Questions

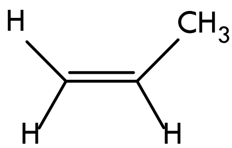
1. Engine knocking is the combustion of fuels in the combustion chamber of engines

of vehicles with explosions. Engine knocking is caused by fuels containing straight-chain alkanes such as n – heptane and n – octane. The quality of petroleum fractions containing this type of alkanes can be improved by the process known as reforming. It is a process used to convert straight- chain alkanes to branched-chain alkanes.

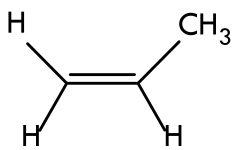
2. Charcoal is a fuel that comes from the incomplete burning of wood whereas Coal is a mineral originated in the Carboniferous era from vegetables deposited in marshes and lagoons, dating from 300 to 360 million years ago. Coke is a fuel that is obtained from the calcination or dry distillation of mineral coal. It is composed of carbon and has a high calorific value, but it is highly polluting. It is used as fuel in the blast furnaces of steel foundries.

Answers to Exercise 6.11

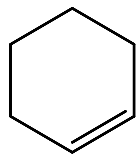
1. See student textbook
2.

(a) 

propene

(b) 

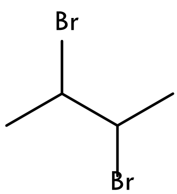
propene

(c) 

cyclohexene

Answers to Exercise 6.12

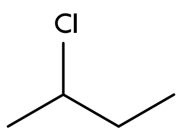
1. $C_6H_{12} + 9H_2O \rightarrow 6CO_2 + 6H_2O$
2.

(a) 

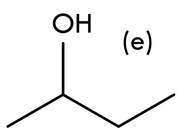
2,3-dibromobutane

(b) 

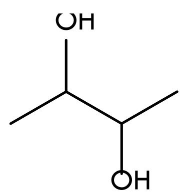
butane

(c) 

2-chlorobutane

(d) 

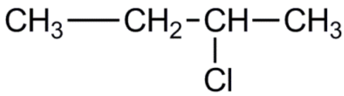
butan-2-ol

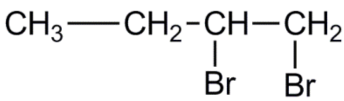
(e) 

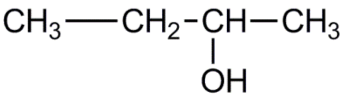
but-2,3-diol

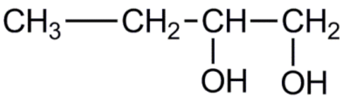
3. Because alkene are unsaturated and alkanes are saturated.
4. Reaction products are different. Types of reaction are also different-substitution in alkanes and addition in alkenes.

Answers to Exercise 6.13

a)  2-Chlorobutane

b)  1,2-Dibromobutane

c)  2-Butanol

d)  Butane-1,2-diol

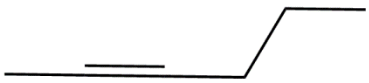
Answers to Exercise 6.14

1. Refer to student textbook
2. Same as that of alkanes and alkenes
3.

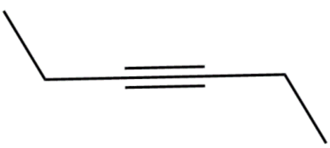
State	Alkane	Alkene	Alkyne
Gas	C_1-C_4	C_2-C_4	C_2-C_4
Liquid	C_5-C_{17}	C_5-C_{14}	C_5-C_{12}
solid	$\geq C_{18}$	$\geq C_{15}$	$\geq C_{13}$

Answers to Exercise 6.15

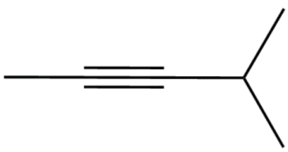
1-hexyne



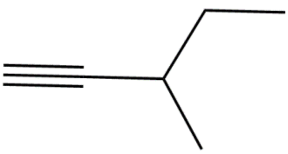
2-hexyne



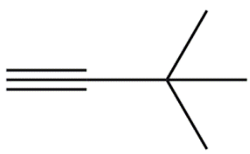
3-hexyne



4-methyl-2-pentyne



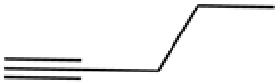
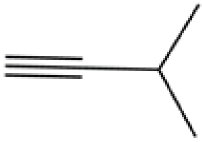
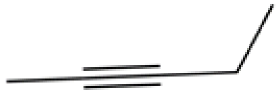
3-methyl-1-pentyne



3,3-dimethyl-1-butyne

Seven isomers are possible for hexyne

Answers to Exercise 6.16

a) 1-pentyne 3-methyl-1-butyne 2-pentyne

b) **3-methylbut-1-yne and 1-pentyne are chain isomers**

c) **1-pentyne and 2-pentyne are position isomers**

Answers to Exercise 6.17

a) $CH_3-C\equiv C-H \quad + 2KBr \quad + \quad 2H_2O$

b) $H-C\equiv C-CH_3 \quad + NaBr$

Answers to Exercise 6.18

1. A compound of carbon and hydrogen -containing a benzene ring
2. Benzene
3. Combustion, substitution
4. It neither adds bromine atoms nor is oxidized by $KMnO_4$ solution. It is stable.
5. By the reaction of

   a. Benzene with chlorine

   b. Benzene with concentrated HNO_3

   c. Benzene with concentrated H_2SO_4

Answers to Exercise 6.19

1. Petroleum, natural gas and coal.
2. Alkanes.
3. Heating substances in the absence of air.
4. Destructive distillation of coal gives coke, coal gas, ammonical liquid and coal tar. Fractional distillation of coal tar yields different aromatic hydrocarbons and related compounds.
5. Gasoline or petrol.
6. Cracking.
7. a) as a solvent.

   b) As a fuel in jet engines and kerosene stoves.

   c) Motor fuel.

d) Diesel engine fuel, furnace fuel.

e) As fuel for stoves.

Answers to Review Questions

Part I.

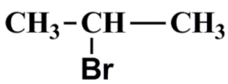
1 C
2 C
3 B
4 A
5 D
6 C
7 D
8 B
9 C
10 D
11 C
12 D
13 A
14 D
15 C
16 C

Part II

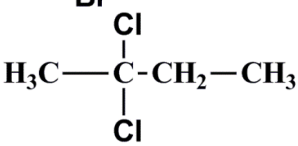
17.

(a) $CH_3—CH_3$

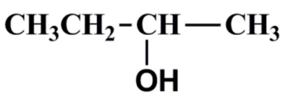
(h)



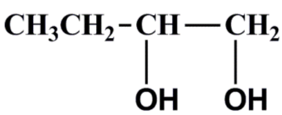
(i)



(j)



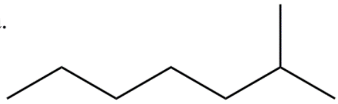
(k)



Part III

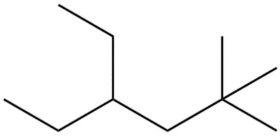
18.

a.



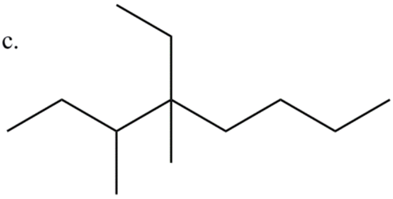
2-Methylheptane

b.



4-Ethyl-2,2-dimethylhexane

c.

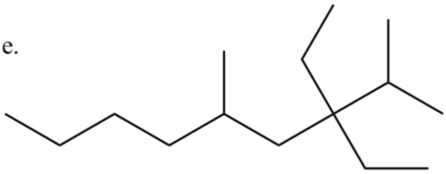


4-Ethyl-3,4-dimethyloctane

d.

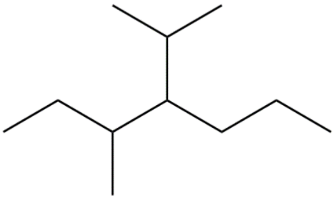
2,4,4-Trimethylheptane

e.



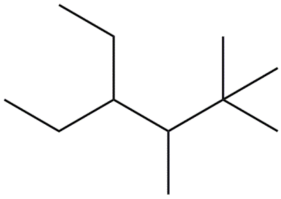
3,3-Diethyl-2,5-dimethylnonane

f.



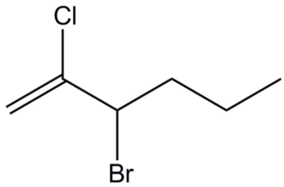
4-Isopropyl-3-methylheptane

g



4-ethyl-2,2,3-trimethylhexane

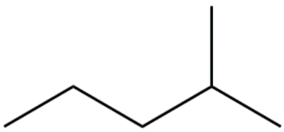
h.



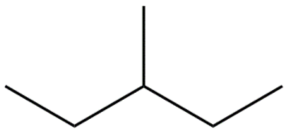
3-bromo-2-chlorohex-1-ene

19.

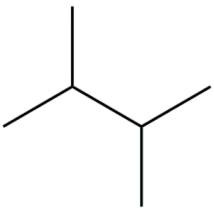
hexane



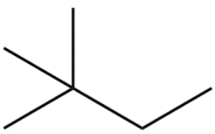
2-methylpentane



3-methylpentane



2,3-dimethylbutane



2,2-dimethylbutane

20.

(a) 2,2-Dimethyl-6-ethylheptane   The multiplying prefix 'di' should have been ignored in alphabet order. The correct name should be 6-**E**thyl-2,2-di**m**ethylheptane

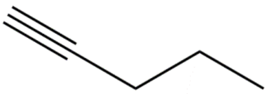
(b) 4-Ethyl-5,5-dimethylhexane;   In this case, the direction of numbering is wrong. The structure can be named as 3-ethyl-2,2-dimethylhexane

(c) 3-Ethyl-4,4-dimethylhexane; in this case too, the direction of numbering is wrong. It should be named as 4-ethyl-3,3-dimethylhexane   (d) 5,5,6-Trimethyloctane; direction of numbering wrong. Can be corrected as 3,4,4-trimethyloctane

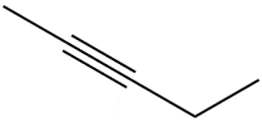
(e) 2-Isopropyl-4-methylheptane ; alphabetical problem: In deciding on alphabetical order, the prefixes such as *iso, sec, tert* should be ignored. Thus the correct name is 4-methyl-2-isopropylheptane.

21. Cyclopropane

22.



1-Pentyne



2-pentyne

23.

a. 2-methylpentane
b. 2,2-dimethylbutane
c. 2,3,3-trimethylhexane
d. 5-ethyl-2-methylheptane
e. 3,3,5-trimethyloctane
f. 2,2,3,3-tetramethylhexane
g. 2-bromo-3,6-dimethyloctane
h. 2-bromo-6-methyloct-3-yne
i. 2-bromo-5,6-dimethyloct-3-ene
j. 3,6-dimethyloct-2-ene
k. 2,3,7 - trimethylnon-4-ene
l. 7-bromo-3,4- trimethyloct-2-ene

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Chemistry Flowchart for Grades 9 - 12

Thematic Area	Grade 9	Grade 10	Grade 11	Grade 12
Macroscopic world	**1. Introduction to Chemistry** • Definition and scope of Chemistry • Relationship between Chemistry and other natural sciences • Role played by Chemistry in production and society • Some common Chemical industries in Ethiopia	**1. Introduction to inorganic compounds** • **Oxides** - Types and properties - preparation of oxides • **Acids and bases** • The pH scale • Properties, preparation and uses of acids and bases • **Salts** - Naming and classification of salts -Preparation and uses of salts		
	2. Measurements and scientific methods in Chemistry • Measurements and Units in Chemistry • SI Units: Basic and Derived			

	• Prefixes used in SI Units • Uncertainty in Measurement • Precision and Accuracy • Decimal Places • Significant Figures • Scientific Notation • Chemistry as Experimental Science • Scientific Method • Experimental Skills in Chemistry Writing a Laboratory Report			
Microscopic World	**3. Structure of the atom** • Historical development of the atomic theories of matter • Fundamental Laws of Chemical Reactions - The Law of Conservation of Mass -The Law of Definite Proportions - The Law of Multiple Proportions • Atomic theory - Dalton's atomic theory	**2. Solutions** • Homogeneous and Heterogeneous Mixtures • Types of Solutions • The Solution Process • Solubility as an Equilibrium Process • Ways of Expressing Concentrations of Solutions • Preparation of Solutions • Solution Stoichiometry • Describing Reactions		

	- Dalton's atomic model • Discoveries of the Fundamental Subatomic Particles • discovery of the electron (J.J. Thomson's model) • Discovery of the Atomic Nucleus (Rutherford's model) • discovery of the neutron (Jams Chadwick's model) - Atomic number, mass number, atomic mass and isotopes - The Bohr's atomic model • Energy level and electric configuration	in Solution		

Patterns in the Chemical World	**4. Periodic classification of the elements** • Historical development of periodic classification of the elements • Mendleev's periodic classification of the elements - Mendleev's periodic law - Periodicity • Modern periodic classification of the elements - Modern periodic law - Electronic configuration of the elements and the periodic Table (using main shells) - Periods and groups - The modern periodic table		**1. Atomic structure and Periodic properties of the elements** • Brief review of atomic structure of matter (Refer grade 9 unit 3) • Early experiments to characterize the atom - Electromagnetic Radiation (EMR) and Atomic Spectra - The Quantum Mechanical Model of the Atom - Electronic configurations and orbital diagrams - Electronic Configurations and The Periodic table of The Elements using sub-energy levels	
Chemical relationships	**5. Chemical Bonding,** • Chemical bonding • Types of chemical bonding - Ionic bonding		**2. Chemical bonding** • Brief review on the types of chemical bonding (Ionic, Covalent, and metallic bonding)	

	- Covalent bonding - Metallic bonding		(Refer grade 9 unit 6) • Molecular Geometry (VSEPR theory) • Intermolecular Forces in Covalent Compounds • Intermolecular forces and states of matter - Dipole-dipole forces - London dispersion forces - Van der wales - Hydrogen bonding • Chemical Bonding theories - Valence Bond Theory - Hybridization of atomic orbitals - Molecular Orbital Theory • Types of crystal **3. Physical states of matter** • Introduction to physical states of matter • The kinetic theory of	

			matter -The gaseous state - The Kinetic Molecular Theory of Gases - The Gas Laws • The liquid state - Phase Changes in liquids - Energy Changes in Liquids • The solid state - Phase Changes in solids - Energy Changes in Solids	
Chemical Reactions and Energy Changes		**3. Chemical reaction and stoichiometry** • Introduction to chemical reaction •. Types of chemical reactions -composition reactions -Decomposition reactions -single displacement reactions -Double displacement reactions • Chemical Equations - Writing Chemical	**4. Chemical kinetics** • Introduction to Rate of Chemical Reaction - Pre-conditions for a Chemical Reaction to occur - Factors Affecting the Rates of Chemical Reaction 5. **Chemical**	**1.Acid-Base equilibrium** • Acid-Base Concepts - Arrhenius concept - Bronsted-Lowrey concept - Lewis's concept • Acidity and basicity of solutions (pH and pOH) • Strong and weak acids and bases • Ionic Equilibria of Weak Acids and Bases • Common Ion Effect (Application of Le Chatelier's Principle) • Buffer Solutions

		Equation -Balancing Chemical Equation by inspection and LCM method • Oxidation-Reduction Reactions - Oxidation Number or Oxidation State - Oxidizing and Reducing Agents - Balancing redox - reactions using oxidation number change method Molecular and formula mass, the mole concept and chemical formula -Molecular mass and formula mass -The mole concept -Percent composition -Chemical formulas: Determination of empirical and molecular formula • Stoichiometry - Laws of conservation mass (Brief revision) -The mole concepts	**equilibrium** • Introduction • Reversible and Irreversible Reactions • Dynamic Chemical Equilibrium • Conditions for Attainment of Chemical Equilibrium • Factors affecting position of Chemical Equilibrium • Le Chatelier's Principle • Applications of Chemical Equilibrium to Industrial production	• Hydrolysis of Salts • Acid-Base Indicators **2.Electrochemistry** • Electrolysis of Aqueous Solutions • Quantitative Aspects of Electrolysis • Voltaic (Galvanic) Cells and electrolytic cells • Industrial Application of Electrolysis **3.Industrial Chemistry** • Natural resources ✓ Renewable ✓ non-renewable natural resources • Manufacturing of valuable products • Ammonia • Nitric acid • Sulphuric acid • Nitrogen based Fertilizer • Aluminum sulphate • Agrochemicals (pesticides and herbicides) • Sodium hydroxide • Sodium carbonate • Some Manufacturing industries in Ethiopia ✓ Glass production ✓ Ceramics production

		- Molar Ratios in Balanced Chemical Equation -Mole -mole relationship - Mass–Mass Relationships - Volume-Volume Relationships - Mass–Volume Relationships - Limiting and Excess Reactants - Theoretical, Actual and Percentage Yields **4. Energy changes in chemical reactions** • Introduction • Exothermic and Endothermic Reactions • Electrical energy from chemical reactions - Electrical conductivity (electrolytes and nonelectrolytes) - Electrolysis - Electrochemical cells - Electrochemical cells in daily life		✓ cement ✓ Soaps and Detergents ✓ Sugar ✓ Beverage industry ✓ Food processing and preservation ✓ Tannery

		5. Metals and non-metals • Introduction • General properties of metals • Occurrence, extraction and uses of some important metals • Alloys • General properties of nonmetals Occurrence, extraction and uses of some important nonmetals		

Compounds		**6. Hydrocarbons and their natural sources** • Introduction to organic compounds • Saturated Hydrocarbons: Alkanes and cycloalkanes • Unsaturated Hydrocarbons: Alkenes and Alkynes • Aromatic Hydrocarbons: Benzene • Natural Sources of Hydrocarbons	**6. Some important organic compounds** • Brief revision to hydrocarbons (Refer Unit 5 Grade 10) • Alcohols and Ethers • Aldehydes and Ketones • Carboxylic Acid and esters • Fats and Oils	**4.Polymers** • Introduction • Polymerization reactions • Synthetic Polymers • Natural Polymers

The Environment				**5. Introduction to Environmental Chemistry** • Introduction • Environmental pollution and methods to reduce pollution ✓ Air pollution (causes, effects mechanism to reduce) ✓ Water pollution (causes, effects and mechanism to reduce) ✓ Soil pollution (causes, effects and mechanism to reduce) • Global warming and climate change • Principle of green Chemistry and cleaner production

General Objectives of Grade 10 Chemistry

To develop understanding and acquire knowledge of:

- Classes of organic and inorganic compounds and some of their uses
- formation of chemical bonding and properties of compounds formed by different types of bonds
- extraction, chemical properties and uses of metals and nonmetals
- The interconvert ion of electrical and chemical energies and their applications
- Uses of natural resources and their protection
- extraction, chemical properties and uses of metals and nonmetals
- types, properties and processes of formation of solutions
- Importance of electrochemical cells in daily life

To develop skills and abilities of:

- Handling and using science apparatuses and laboratory substances correctly
- preparing solutions of specific concentration and solving quantitative problems involving solutions;
- conducting experiments to observe and analyze the physical properties of substance and determine the type of bonding
- Designing and conducting simple experiments appropriate to their level
- Applying conservations of mass laws to calculate relevant quantities

To develop the habit and attitude of:

- Appreciating the roles of chemistry in energy production
- Having an interest and curiosity towards natural resources
- Responsible about safety of oneself, and protection of natural resources
- Being honest and accurate in recording and validating data

Unit 1: Chemical reactions and stoichiometry (23 periods)

Unit outcomes: Students will be able to:

- Define the basics of chemical reaction and describe the four major types of reaction
- Develop skills in writing and balancing chemical equations
- Understand oxidation - reduction reactions and analyse redox reactions by specifying the oxidizing agent, the reducing agent, the substance reduced or oxidized
- Understand fundamental laws of chemical reactions and know how they are applied
- Develop skills in solving problems based on chemical equations (mass - mass, volume - volume and mass - volume problems).
- Develop skills in determining the limiting reactant, theoretical yield, actual yield and percentage yield.
- Demonstrate scientific inquiry skills: observing, inferring, predicting, classifying comparing and contrasting, communicating, measuring, asking questions designing experiments, interpreting data, drawing conclusions, applying concepts, relating cause and effect and problem - solving.

Competencies	Contents	Suggested Activities	Assessment
Students will be able to: • Define chemical reaction • Give some examples of chemical reactions	*1.* ***Chemical reactions and stoichiometry*** **1.1 Introduction** *(1 period)* **1.2 Types of chemical reactions**	Students should be asked to explain that a chemical reaction is a change that takes place when one or more substances, called reactants, react alone or with each other to produce one or more new substances, called products. Reactants → Products Students should be requested to give examples of chemical reactions. The students could also ask to describe the examples of changes brought by the chemical reactions. These could include: • Burning of wood • rusting of iron • Fermentation • Souring Tej and digestion of food Students should be asked to discuss in group classes of chemical reactions and present each group for the	Listen students responses and give feedback Listen students responses and provide summary Monitor the discussion and give summary

Competencies	*Contents*	*Suggested Activities*	*Assessment*
• List the four types of chemical reactions • Define combination reaction and give examples • Conduct some experiments on combination reactions in groups	*(3 periods)* • Combination reaction • Decomposition reaction	class Students should explain that combination or synthesis reactions involve the reaction of one element with another to form a compound. Students should discuss in group on examples of combination reactions. These could include: • Sodium + chlorine = sodium chloride • Carbon + oxygen = carbon dioxide • Copper + oxygen = copper (II) oxide • Iron + sulphur = iron sulphide • Hydrogen + oxygen = water • Magnesium + oxygen = magnesium oxide Students should discuss the general features of a combination reaction. Students could carry out some combination reactions. Students should be given a chance to explain that	Listen students responses and give feedback Monitor the discussion and give summary Monitor the discussion and give summary

Competencies	Contents	Suggested Activities	Assessment
• Define decomposition reaction and give examples • Conduct some experiments on decomposition reactions in groups • Define single displacement reaction and give	• Single displacement reaction	decomposition reactions involve a reactant breaking down to produce two or more products Students should carry out experiments on some decomposition reactions and write a report on: • Thermal decomposition of Group 1 nitrates to nitrites and oxygen • Thermal decomposition of Group 2 and Transition Metal nitrates to oxides, oxygen and nitrogen dioxide • Thermal decomposition of Group 2 and Transition Metal carbonates to oxides and carbon dioxide Students should discuss the general features of a decomposition reaction. Students could carry out some decomposition reactions. Students should explain single displacement reactions involve a more reactive element displacing a less reactive element from a compound Students should give same examples of single	Observe students activities and give feedback Listen students responses and give feedback Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
examples		displacement reactions. These could include: • Reactive metals with water – displacing hydrogen e.g., sodium + water • Reactive metals with dilute acids – displacing hydrogen e.g., zinc + dilute hydrochloric acid • Metal – metal ion reactions – atoms of a more reactive element displace ions of a less reactive metal from solution e.g., iron + copper (II) sulphate solution • Halogen – halide ion reactions – atoms of a more reactive halide displace ions of a less reactive halide from solution e.g., chloride + potassium bromide solution.	Listen students responses and give feedback Observe students activities and give feedback
		Students should discuss the general features of a single displacement reaction.	Listen students responses and give feedback
		Students could carry out some double decomposition reactions and write a report	
• Conduct some experiments on simple displacement	• Double displacement	Students should discuss in group on double	

Competencies	*Contents*	*Suggested Activities*	*Assessment*
reactions in groups • Define double decomposition reaction and give examples • Conduct some experiments on double displacement reactions in group	reaction	decomposition reactions and give same examples. These could include: • Reactions to precipitate silver halides • Reactions to precipitate lead halides • Reactions to precipitate barium sulphate Students should discuss the general features of a double decomposition reaction. Students could carry out some double displacement reactions	Observe students activities and give feedback Check on a same exercises and give feedback
• Explain the conventions used to write chemical equation	**1.3 Chemical equations** *(3 periods)* • Writing chemical equation	Students should be requested to apply the following steps to write an equation: 1.Write a word equation 2.Substitute the words by symbols and formulas 3.Balance the equation so that there are equal numbers of	Check on a same exercises and give feedback

Competencies	*Contents*	*Suggested Activities*	*Assessment*
		atoms of each type of element on each side of the equation	Listen students responses and give feedback
• Balance chemical equations using: - inspection method - the Least Common Multiple (LCM) method -algebraic method	•Balancing chemical equation	Students should be asked to balance an equation: •by inspection method •by the least common multiple method •by algebraic method	Check on a sample exercises and give feedback
• Define redox reactions • Define the terms oxidation and reduction in terms of electron transfer	**1.4 Oxidation and reduction reactions** *(5 periods)* • Oxidation • Reduction	Students should describe that a redox reaction is a reaction that involves transfer of electrons. Students should explain that the term redox' is used to describe oxidation and reduction reactions and that these reactions occur simultaneously. Students should be asked to define oxidation as a loss of electrons and reduction as a gain of electrons. They should identify in a redox reaction: • the oxidised species loses one or more electrons • the reduced species gains one or more electrons	Listen students responses and give feedback Listen students responses and give feedback Check on a sample exercises and give feedback
• Define oxidation number (oxidation		Students should describe the oxidation number or	

Competencies	Contents	Suggested Activities	Assessment
state) • State oxidation number rules. • Determine the oxidation number of an element in a given formula • Determine the oxidation number of an element in a given formula	• oxidation number	oxidation state: • is the charge that the atom carries in its compounds • refers to a single atom of the element • has both sign and numerical value Students should be asked to state oxidation number rules. Students should be requested to deduce the oxidation number of elements in compounds from their formulas Students should do simple examples e.g. $MgCl_2$ • oxidation state of Mg = +2 • oxidation state of Cl = -1 And more complex examples where an atom is part of an ion e.g. SO_4^{2-} • oxidation state of O = -2 • total oxidation state of O=4 x -2 = -8 • overall charge on the ion = -2 • oxidation state of S = -2 – (-8) = +6 Students should differentiate that an oxidising agent is one which brings about oxidation but is itself reduced.	Check on a sample exercises and give feedback Check on a sample exercises and give feedback

Competencies	Contents	Suggested Activities	Assessment
• analyse the oxidizing and reducing agents • Balance the given chemical reaction using oxidation number change method	• Oxidizing and reducing agents. • Balance redox reactions using oxidation number change method 1.5. Molecular and formula mass, the mole concept and chemical formula *(3 periods)* ▪ molecular mass and formula mass	Students should be asked to give examples of oxidising agents which they may have already met in chemical reactions such as: • chlorine • potassium manganate(VII) • potassium chromate(VI) • potassium dichromate (VI) • sodium chlorate(V) • manganese(IV) oxide Students should be asked to balance a given chemical reactions using oxidation number change method that includes the following examples: - • Sodium + chlorine = sodium chloride • Carbon + oxygen = carbon dioxide • Copper + oxygen = copper (II) oxide • Iron + sulphur = iron sulphide • Hydrogen + oxygen = water Students should be requested to relate a molecular mass	Observe students activities and give feedback Observe students activities and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Solve molecular mass and formula mass problems based on the given chemical formula of compounds • State the mole concept and describe using example • Deduce percentage composition from formula mass/molecular mass of a compound • State empirical	▪ The mole concept ▪ Percent composition ▪ Chemical formulas: Determination of empirical and molecular formula	and formula mass chemical formula of a compound. Students should solve molecular mass and formula mass from chemical formula of the compound. Students should state the mole concept and describe it using examples. The student should differentiate the terms mole, molar mass and actual mass. Students describe molar mass and apply the mole concept to determine number of moles from given mass and molar mass. Students should be requested to calculate the percentage yield of a given compound using atomic weight of a given element in the compound and the formula mass of the compound using the equation: $\%composition = \frac{A}{B} \times 100$ Where A= total atomic mass of the element in the compound and B= Formula mass of the compound	

Competencies	***Contents***	***Suggested Activities***	***Assessment***
formula and molecular formula		Students should relate empirical formula with molecular formula. Students should be asked to carry out calculations involving both empirical formula and molecular formula.	
• Solve molecular formula problems based on the given empirical formula		Students should be asked to solve molecular formula problems based on the given empirical formula	
	1.6 Stoichiometry *(8 periods)*		
• State the law of conservation of mass and illustrate using examples	1.6.1 Fundamental laws of chemical reactions	Students should be given a chance to express their feeling about "in all types of chemical reactions mass is neither created nor destroyed. Students should be able to quote the law of conservation of mass: 'Matter cannot be created nor destroyed in a chemical reaction'	Listen students responses and give summary
• Describe the law of conservation of mass using simple experiments		Students requested to carry out an experiment to prove the law of conservation of mass and write a report. For example, using the reaction between silver nitrate solution and dilute hydrochloric acid: $HCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + HNO_3$	Observe students activities and give

Competencies	Contents	Suggested Activities	Assessment
		• Place dilute hydrochloric acid in a conical flask to a depth of about 10ml • Tie a thread of cotton around the top of a test tube • Half fill the test tube with silver nitrate solution • Place the test tube inside the conical flask so that it is held on a slant by the thread and place a bung in the top of the flask to hold the thread in place • Weigh the conical flask and contents • Tilt the flask so the silver nitrate solution pours into the dilute hydrochloric acid and a white precipitate of silver chloride is produced • Reweigh the conical flask and contents From their experiment students should show that the mass of the products is equal to the mass of the reactants.	feedback
• Deduce mole ratios from balanced chemical equations	• Molar ratios in balanced chemical equations.	Students should be asked to explain that stoichiometry is the study of the different amounts of substances which react to give new substances. Students should describe the significance of the different numbers of reactant and product particles in a balanced chemical equation. Students should explain that a balanced chemical equation indicates the molar quantities of reactants and products involved in a reaction.	Listen students responses and give feed back
• Solve mass-mass	• Mass-mass relationships.	Students should be requested to interpret a balanced	Listen students responses

Competencies	***Contents***	***Suggested Activities***	***Assessment***
problems based on the given chemical equation • Define molar volume • State Avogadro's principle		chemical equation in terms of ratios of moles of the reactants and products. Students should interpret a variety of balanced equations in this way. Students should be asked to use balanced chemical equations to deduce the ratio of reacting masses and use this to calculate the actual masses. For example to find the mass of AgBr produced from 1 gm of KBr: $KBr(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgBr(s)$ 1 mole 1 mole 1 mole 1 mole 119 g 170 g 101 g 188 g • 119 g of KBr yields 188 g of AgBr • therefore 1.00 g of KBr yields 1.00 □ 188 = 1.58 g of AgBr119 Students should be asked to carry out a number of similar calculations on reacting masses using equations with different mole ratios.	and give feedback Check on a sample exercises and give feedback Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Solve volume-volume problems based on the given chemical equation	• Volume-volume relationships.	Students should identify that one mole of gas particles occupies a volume of 22.4 litre at standard temperature and pressure (STP) 0 □C and 101.325 Kpa. Students should describe Avogadro's principle which states that:'equal volumes of different gases under the same conditions of temperature and pressure contain equal numbers of particles; Students should be asked to use balanced chemical equations to deduce the ratio of reacting volumes and use this to calculate the actual volumes. For example, to find the volume of HCl produced from 100ml of H_2: $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ 1 mole 1 mole 2 moles 22.4 L 22.4 L 44.8 L • 22.4 L of H_2 yields 44.8 L of HCl • 100 ml of H_2 yields <u>0.1 □ 44.8</u> = 0.2 L = 200 ml of HCl	Check on a sample exercises and give feedback Listen students responses and give feedback Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Solve mass-volume problems based on the given chemical equation	• Mass - volume relationships.	22.4 Students should be requested to carry out a number of similar calculations on reacting volumes using equations with different mole ratios. Students should be asked to carry out calculations involving both mass and volume. For example, to find the volume of CO_2 produced from 0.50gm of $CaCO_3$ $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ 1 mole 1 mole 1 mole 100 g 56 g 44 g or 22.4 L • 100 g of $CaCO_3$ yields 56 g of CaO • 0.50 g of $CaCO_3$ yields $\frac{0.5 \square 56}{100} = 0.28$ g • 100 g of $CaCO_3$ yields 22.4 L of CO_2 • 0.50 g of $CaCO_3$ yields $\frac{0.5 \square 22.4}{100} = 0.112$ L Students should be given a chance to carry out a number of similar calculations on reacting masses and	Check on a sample exercises and give feedback

Competencies	Contents	Suggested Activities	Assessment
• Describe limiting and excess reactants • Calculate the amount of limiting and excess reactants of a given chemical reaction • Show that the amount of product of a chemical reaction is based on the limiting reactant	• Limiting and excess reactants.	volumes using equations with different mole ratios. Students should describe that in a chemical reaction involving two reactants, the reaction will stop when all of one reactant has been used up no matter how much of the second reactant remains. Students should be requested to identify that when two reactants are not in the mole ratio in which they react then one will be the limiting reactant and the other will be in excess. Students should be asked to carry out calculations on chemical reactions in which there is a limiting reactant. For example: $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ 1 mole 2 moles 1 mole 1 mole 5.00 g of zinc is reacted with 3.65g of HCl • 5.00 g of zinc is $\frac{5.00}{65.4} = 0.076$ mol • 3.65gof hydrochloric acid contains 3.65/ 36.5 = 0.1 mol. • The maximum amount of zinc that will react with 0.1 mol dilute hydrochloric acid is 0.050 mol	Listen students responses and give feedback Check on a sample exercises and give feedback Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Describe the terms theoretical yield, actual yield and percentage yield	• Theoretical, actual and percentage yields.	• The dilute hydrochloric acid is the limiting reactant • The zinc is in excess • The amount of zinc that will remain at the end of the reaction is 0.076 – 0.050 = 0.026 mol which is 65.4 x 0.026 = 1.70 g • The amount of zinc chloride formed will be 0.050 mol which is (65.4 + 2 x 35.5) x 0.05 = 6.82 g • The amount of hydrogen gas formed will be 0.050 mol which is 22.4 x 0.050 = 1.12 L at room temperature and standard pressure Students should be requested to carry out a number of similar calculations, identifying the limiting reactant and finding the maximum number of products that can be formed. Students should explain that: • given the equation for a chemical reaction and the quantities of reactants used, it is possible to calculate the yield of products that should be obtained – the theoretical yield • not all of the reactants in a chemical reaction may go to form a desired product; some may be used up in unwanted side reactions. The actual amount of product obtained is – the actual yield • the success of a reaction can be assessed by	Listen students responses and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Calculate the percentage yield of a chemical reaction from given information		comparing the ratio of the actual yield to the theoretical yield to give – the percentage yield Students should be requested to calculate the percentage yield of a chemical reaction from a given data using the equation: $\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \square 100\%$ Students should be asked to show that: • percentage yield will be between 0 – 100% • the higher the percentage yield the more successful the reacting	Check on a sample exercises and give feedback Check on a sample exercises and give feedback

Unit 2: Solutions (21 periods)

Unit out comes: Students should be able to:

- List and explain the types of solutions;
- Describe the solution formation process, the rate of solution, the heat of solution & solubility;
- Describe the dependence of solubility on temperature & pressure of solution;
- Solve problems involving concentration of solutions & express the result in various units;
- Describe, using the concept of equilibrium, the behavior of ionic solutes in solutions that are unsaturated, saturated and supersaturated;
- Prepare solutions of required concentration by dissolving a solute or diluting a concentrated solution;
- Describe scientific enquiry skills along this unit: observing, classifying, comparing & contrasting, communicating, measuring, asking questions, drawing conclusion, applying concept and problem solving.

Competencies	Contents	Suggested Activities	
Students will be able to: • Define the terms mixture, homogenous and heterogeneous mixtures, solute, solvent, solution. • distinguish between homogenous and heterogeneous mixtures • describe suspension and colloids	**2. Solutions** **2.1 Homogeneous and heterogeneous mixtures** *(1 period)* • Some basic definitions - mixture, homogeneous and heterogeneous mixtures, solute, solvent, solution • Suspension and colloids	• Student should describe that mixtures are divided in to three categories: suspensions, colloids, and solutions. A suspension is a dispersion of fine solid particles in a liquid or gas, removable by filtration. It could also separate into its components under the influence of gravity. A mixture of sand and water is an example. • Students should describe that in a solution, the particles of the solute are of the size of individual atoms, molecules or ions. • Students should identify that in a colloid the particle size is much larger than in a solution but not so large that they separate on standing. • Ask students to dissolve sand, Gentian Violet and bile in water in three different flasks. Set them aside and see if they become any clearer on standing for some time. Students might need to decant them after 30 minutes. Do you see any change upon further standing? Pass light through each mixture and see which one scatters light without separating on standing. What do you call this type of mixture? • Students should conclude that both suspension and colloid are examples of heterogeneous mixtures whereas solution is a homogeneous mixture.	Listen students responses and give feedback Observe students activities and provide feedback Listen students responses and give feedback Listen students responses and provide summary
• Explain the different types of solutions. • give examples for each	**2.2 Types of solution** *(2 periods)*	• Students should identify that a solution has at least two pure components: solute and solvent. • Students should explain that solutions can	Monitor the discussion and give summary

types of solutions • present a report on how jewelry gold is made to class after a visit to nearby goldsmith • explain how the "like dissolves like" rule depends on interparticle forces of interactions and predict relative	• Gaseous solutions • Liquid solutions • Solid solutions **2.3 The solution process** *(5 periods)* • Liquid solutions and interparticle forces of attractions	assume the three physical states of matter and should describe the general characteristics of solutions formed by various combinations of gases, liquids and solids. • Students should discuss gaseous solutions form when a gaseous solute dissolves in a gaseous solvent. They also could give an example for such solutions. For example, nitrogen is taken to be the solvent and all other gases in air to be solutes. • Students should identify liquid solutions can have gaseous, liquid and solid solutes but the solvent is always liquid and give examples for each. • Students should explain solid solutions have no restriction on the state of the solute but the solvent has to be solid. For example, an alloy is a solid solution of two or more metals or metals and non-metals. • Ask students discuss how jewelry gold is made. • Students should visit a nearby goldsmith and compile repot in group.	Check on a sample exercises and provide feedback Listen students responses and give feedback Guide the visit program and check the report Listen students responses and give feedback Monitor the discussion

solubilities; • define rate of dissolution; • define heat of solution, solvation energy and hydration energy. • apply the concept of heat of solution to the solution of ammonium nitrate crystal. • apply the concept of heat of solution to the solution of sodium hydroxide crystal; • explain how heat of solution is influenced by the inter particle interaction forces. • describe the distinctions among unsaturated, saturated and supersaturated solutions. • Prepare unsaturated and saturated solutions of sodium sulphate • prepare supersaturated solution of sodium thiosulphate	• The rate of dissolution • Energy changes in the solution process - Heats of solution - Heats of hydration of ionic solid in water	• Students should describe the factors that control the solubility of substances in liquid solvents. • Students could explain that in order for substances to be appreciably soluble in each other, they must possess similar intermolecular attractive forces. • Students should describe that when a solute particle is placed in solution it becomes solvated, which is surrounded by solvent molecules to which it is attracted. And when the solvent is water, the term hydrated is used. • Students should discuss how soaps and detergents work • Students should discuss rate of dissolution • Students should describe that the heat of solution is the energy absorbed or liberated when a solution is formed. • Students should identify for liquid solutions formed from a solvent A and solute B, ○ an ideal solution results when the A-B attractions are the same as the A-A and B-B attractions and for such a solution, $\Delta H_{soln} = 0$. ○ When the A-B attractions are greater than the A-A and B-B attractions, $\Delta H_{soln} < 0$ and the solution process is exothermic.	and give summary Listen students responses and give feedback Check on a sample exercises and give summary Check on a sample exercises and give feedback Observe students activities and give feedback

• explain the equilibrium nature of saturated solution • define solubility • describe the factors that affect solubility of substances • investigate the effect of temperature on solubility of sodium sulphate • conduct an experiment to determine solubility of table salt and sugar • state Henry's law • use Henry's law to calculate concentration of gaseous solute in a solution • define concentration of a solution	**2.3 Solubility as an equilibrium process** *(4 periods)* • Saturated, unsaturated and supersaturated solution • Effect of temperature on solubility • Effect of pressure on solubility of gases - Henery's Law **2.4Ways of expressing concentrations of solution** *(7 periods)*	○ When the A-B attractions are weaker than the A-A and B-B attractions, $\Delta H_{soln} > 0$ and the solution process is endothermic. • Students should identify that for solutions of solids in liquids the lattice energy (the energy required to separate the solute particles from a crystal) and hydration energy (or salvation energy- the energy released when the solute particle is placed into the solvent cage) must be considered. • Students should identify that solutions are mixtures but not pure compounds. They can be unsaturated, saturated or even supersaturated. • Students should prepare unsaturated and saturated solution of sodium sulfate • Students should prepare supersaturated solution of sodium thiosulphate • Students should describe that a rise in temperature increases solubility if the dissolving of additional solute is endothermic and the solubility of gases, almost always decreases with increasing temperature. • Students should tell that the solubility of most of solid solutes increase with temperature whereas those of gases invariably decrease.	Listen students responses and give feedback Listen students responses and give feedback Check on a sample exercises and provide feedback Listen students responses and give summary Check on a sample exercises and provide feedback Observe and give feedback

• define mass percentage, ppm and ppb of a solute in a solution
• calculate the mass percentage, ppm and ppb of a solute in a solution from a given information
• define mole fraction
• calculate mole fraction of a solute and a solvent in a solution
• define molarity
• prepare molar solutions of different substances
 	
• calculatemolarityof asolution from a given information
• define the terms equivalent weight, number of equivalents and normality
• prepare normal solutions of different substances
• calculate normality of a solution from a given information
• define molality
	• Mass percentage, ppm and ppb of solute
	• Mole fraction
	• Molarity
	• Normality
	• Molality
	• Conversion of concentration units
	
	2.5. Preparation of solutions
	(2 periods)
	
	• Diluting solutions
	
	2.6Solution Stoichiometry
	
	(3 periods)
	
	• Mole - mass
	• Mole - volume
	• Mole - number of particles
		• Students should explain that pressure has virtually no effect on the solubility of solids or liquids in liquid solvents and the solubility of gas molecules, are very markedly affected by pressure changes.
		
		• Students could apply Henry's law relates the concentration of a dissolved gas, Cg, to its partial pressure, Pg, over the solution.
		Cg = kgPg, where kg is Henry's law constant.
		
		• Students should describe the definitions of each concentration units.
		• Students should know that there are different ways in which the concentration of a solution can be described.
		• Students should express the concentration of a solution using appropriate units such as:
		  • Mass percentage, ppm and ppb of solute
		  • Mole fraction
		  • Molarity
		  • Normality and
		  • Molality
		• Students should prepare 1M, 1N and 1m solution of available chemical in a laboratory.
		• They should show how to convert among the different units.
			Check on a sample exercises and provide feedback
			Listen students responses and give feedback
			
			Listen students responses and give feedback
			
			Observe students activities and provide feedback
			
			Listen students responses and give feedback
			
			Listen students responses and give feedback
			
			Check on a sample exercise and give feedback

• prepare molal solutions of different substances calculate molality of a solution from a given information • Inter convert various concentration expressions • explain dilution process • calculate the volume or concentration changes during dilution of solution • prepare a dilute solution from concentrated solution • use stoichiometrically equivalent molar ratios to calculate amounts of reactants and products in a reaction of pure and dissolved substances • explain the relationship between reacting ions, spectator ions, precipitation and solubility • write net ionic equations	**2.7Describe reactions in solution** *(1 period)* • Molecular equation • Ionic equation	• Students could explain equivalent weight, number of equivalents, normality and molality • Students should discuss how to prepare normal solution, molal solution and inter conversion of various concentration expressions • Students should explain why stock solutions are usually in high concentrations. • Students should show how a concentrated stock solution is diluted • Students could prepare a 100ml of 0.1 M sucrose from 1M sucrose solution by dilution. • Students should explain the principles of stoichiometry and apply in solutions processes. • Students should explain that if a solution is diluted by simply adding solvent to it, the number of particle of reactants remains the same when doing solution stoichiometry. • Students should calculate amounts of reactants and products in a reaction of pure and dissolved substance. • Students should writethe net ionic equation for a given reaction	

		• Students should show how writing ionic equations, formulas for weak electrolytes are written in molecular form.	

Unit 3: Important Inorganic Compounds (21 periods)

Unit outcomes: Students will be able to:

- Classify inorganic compounds on the basis of their composition and/ or their chemistry;
- Discuss types of oxides and their chemical properties;
- Explain the Arrhenius concepts of acids and bases;
- Mention the classification of acids and salts;
- Describe the general properties, preparation and uses of common acids, bases and salts;
- Distinguish the differences between strong and weak acids/ bases; and concentrated and dilute acids/ bases;
- Recognize the corrosive nature of acids and bases, and exercise the necessary precautions in handling and using them;
- Develop skills for identifying acidic, basic and neutral compounds;
- Demonstrate scientific inquiry skills: observing, classifying, comparing and contrasting, inferring, predicting, communicating, measuring, asking questions, interpreting data, drawing conclusion, applying concepts, relating cause and effect and problem solving.

Competencies	***Contents***	***Suggested Activities***	
Students will be able to: • Define inorganic compounds • Classify inorganic compounds as oxides, acids, bases and salts	***3.* Important Inorganic Compounds** **3.1Introduction to Inorganic compounds***(1 period)*	Students should identify that the term 'inorganic' is used to describe chemicals that are, in the main, obtained from the ground and are not associated with living things. These chemicals are largely, but not exclusively, compounds of metals. Students should be asked to tell the names of inorganic compounds with which they are already familiar. Write these on the board. Students should identify that there are different ways of classifying compounds on the basis of their composition and/or their chemistry. For example, they could be classified on the basis of the metals they contain e.g., copper compounds, or on the basis of the groups present e.g., sulphates. Students should classifyinorganic compounds as oxides, acids, bases and salts.	Give exercise and check students replay Listen students response and give feedback Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	
• Define oxides • Classify oxides as acidic, basic, neutral, amphoteric and peroxides • Define acidic oxides • Give examples of acidic oxides • Explain the chemical properties of acidic oxides • Define basic oxides • Give examples of basic oxides • Describe the chemical properties of basic oxides	**3.2. Oxides** *(3 periods)* • Acidic oxides	Students should explain that oxides are formed when an element combines chemically with the element oxygen. They should identify that oxides themselves can be divided into different groups on the basis of their chemical behaviour and, in the case of peroxides, their structure. Students should discuss that most non-metals form oxides which exhibit acidic properties. They dissolve in water to give acidic solutions; they react with bases and basic oxides. Students could burn a small amount of sulphur or carbon on a deflagrating spoon in a gas jar of oxygen. If water is added to the gaseous product, followed by a few drops of universal indicator, the solution is red (in the case of sulphur) or yellow-orange (in the case of carbon) indicating it is acidic. $S(s) + O_2(g) \rightarrow SO_2(g)$ $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ $H_2SO_3(aq) \rightleftharpoons 2H^+(aq) + SO_3^{2-}(aq)$ Students should describe that most metals form oxides which exhibit basic properties and dissolve in water to	Listen students responses and give feedback Observe students activities and give summary

Competencies	***Contents***	***Suggested Activities***	
• Differentiate basic oxides from acidic oxides by conducting experiments • Compare and contrast acidic and basic oxides • Define amphoteric oxides • Give examples of amphoteric oxides • Discuss the chemical properties of amphoteric oxides • Explain the salt forming nature of acidic oxide, basic oxide and amphoteric oxide • Define neutral oxides • Give examples of neutral oxides	• Basic oxides	give alkaline solutions. They react with acids and acidic oxides. Students could burn a small amount magnesium or calcium on a deflagrating spoon in a gas jar of oxygen. If water is added to the ash followed by a few drops of universal indicator, the solution is blue-purple indicating it is alkaline. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$ $MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$ $Mg(OH)_2(aq) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$ Students should identify that acidic and basic oxides can be distinguished by their chemical properties. In addition to their effects on indicators acidic oxides react with bases while basic oxides react with acids. Students should be asked to identify that acids and bases are chemical opposites and react together in neutralisation reactions. Explain that: • non-metallic oxides are acidic because they will react with bases • metallic oxides are basic because they react with acids	Observe students activities and give summary Check on a sample exercises and give feedback Observe and give summary

Competencies	***Contents***	***Suggested Activities***	
	• Amphoteric oxides		
• Define peroxides • Give examples of peroxides • Discuss the chemical properties of peroxides		Students could be asked to investigate the chemical reactions of aluminium oxide. Students should react aluminium oxide with a dilute acid, such as hydrochloric acid. $Al_2O_3(s) + 6H^+(aq) \square 2Al^{3+}(aq) + 3H_2O(l)$ Students should then react Al_2O_3 with sodium hydroxide solution. $Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \square 2Al(OH)_4{}^-{}_{aq)}$ Students should explain the amphoteric behaviour of Al_2O_3. It reacts both with an acid and a base, hence the name amphoteric oxide.	Listen students responses and give feedback
• Differentiate peroxides from other oxides by conducting an experiment	• Neutral oxides	Students should identify that oxides and hydroxides which react with both bases and with acids are described as amphoteric oxides. Students could be asked to investigate the amphoteric properties of zinc oxide and of lead oxide.	
	• Peroxides	Students should explain that a small number of oxides react neither with acids nor with bases. In other words,	

Competencies	Contents	Suggested Activities	
		they don't show basic or acid properties but are neutral, and therefore described as neutral oxides. Students should recall carbon monoxide and nitrogen monoxide as examples of neutral oxides.	Observe students activities and give summary
		Students should identify that a small number of oxides exist in which two oxygen atoms are linked together as –O-O- and that this structure is called a peroxide.	
		Students should demonstrate sodium burning in sufficient oxygen to form sodium peroxide. $$2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$$	Listen students responses and give summary
		Students should explain that peroxides are powerful oxidising agents and react with the loss of oxygen. There are many organic peroxides which are important activators in polymerisation reactions.	Observe students actives and give feedback
		Students should be asked to describe the chemistry of hydrogen peroxide, which has the peroxide structure H-O-O-H.	
		Students should be encouraged to show the effect of adding hydrogen peroxide to a coloured dye. The dye is oxidised and the molecule responsible for the colour is destroyed.	

Competencies	***Contents***	***Suggested Activities***	
	3.3. Acids *(6 periods)*		
• Define acids in terms of the concepts of Arrhenius • Give examples of acids based on Arrhenius	• Definitions of acids	Students should be asked to describe the simple definition of an acid as a substance that releases hydrogen ions or protons, H^+, when in solution. Ask students to give some examples of common acids. Students should identify that this definition of an acid, first proposed by Arrhenius, is limited to the chemistry in aqueous solutions.	Listen students responses and give summary
		Demonstrate what happens when ammonia solution and hydrochloric acid are brought together and ask students to consider the reaction that takes place: $$NH_3(g) + HCl(g) \rightleftharpoons NH_4Cl(s)$$ The hydrogen chloride provides a hydrogen ion or proton but this is not released into aqueous solution since the reaction is carried out between gases.	Observe students activities and give feedback
		Students should identify that acids can be classified according to the number of hydrogen ions or protons that can be released. They should compare hydrochloric acid with sulphuric acid:	Check on a sample exercises and give feedback
• Categorize acids as			

Competencies	***Contents***	***Suggested Activities***	
monoprotic and poly protic based on the number of ionizable(replaceable) hydrogen atom • Group acids as binary and ternary based on the number of elements, they contain • Explain the general properties of acids • Define strong and weak acids • Differentiate between	• Classification of acids Based on the number of ionizable hydrogen • Classification of acids Based on the number of elements in which it is composed • General properties of acids • Strengths of acids(Strong and weak acids)	$HCl(aq) \rightleftharpoons H^+(aq) + Cl^-(aq)$ $H_2SO_4(aq) \rightleftharpoons 2H^+(aq) + SO_4^{2-}(aq)$ Students should be asked to differentiate the term 'monoprotic' to describe hydrochloric acid since it has only one replaceable hydrogen atom, and 'diprotic' (or polyprotic) to describe sulphuric acid since it has two (more than one) replaceable hydrogen atoms. Students should explain that acids can be classified as binary or tertiary depending on the number of elements, they contain e.g., hydrochloric acid is a binary acid while sulphuric acid is a ternary acid. Students should be asked to perform practical activities that show the properties of acids including: • Effect on common indicators such as litmus, phenolphthalein, methyl red, universal indicator and locally available indicators (e.g. flowers extracts) • Reaction with more reactive metals • Reaction with carbonate and hydrogencarbonates • Reaction with sulphites • Neutralisation reactions with bases/alkalis	Check on a sample exercises and give feedback Observe students activities and give feedback Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	
strong and weak acids • Define concentrated and dilute acids • Describe the conceptual difference between strong and concentrated acids • Explain the conceptual difference between weak and dilute acids	• Concentrated and diluted acids	Students should identify that some substances completely dissociate when in aqueous solution. Acids like hydrochloric acid the dissociation is almost complete: $HCl \rightarrow H^+ + Cl^-$ Hydrochloric acid is described as a strong acid because it is almost fully dissociated. Acids like ethanoic acid only a small proportion of molecules dissociate: $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ Ethanoic acid is described as a weak acid because it is only partially dissociated. Students should identify that whether an acid is described as strong or weak depends upon the degree which it dissociates and has nothing to do with its concentration.	Check on a sample exercises and give feedback
• Apply the necessary precautions while working with acids	• Precautions in handling acids	The concentration of an acid is a measure of the number of moles of the acid dissolved in 1 litter and is therefore expressed in mol dm^{-3}. Both a strong acid and a weak acid may be	Observe students activities and give feedback

Competencies	***Contents***	***Suggested Activities***	
• Define pH • Describe the pH scale • Identify a given pH-labelled solution as acidic, basic or neutral • Perform activities to determine the pH of some common substances using universal indicators or pH meter • Calculate the pH of a given acidic solution • Calculate the concentration of hydrogen ion from the given information	• pH • the relationship between pH and concentration	concentrated or dilute depending on the number of moles of acid present. Students should demonstrate the corrosive nature of strong acids and some weak acids such as ethanoic acid. Precautions should be taken when handling acids including: • Wearing eye protection • Wiping spillages straight away • Diluting any acid that gets onto clothes • Using a bellows to pipette acid Students should identify that thepH is negative logarithm of hydrogen (H^+) ion concentration. Students should demonstrate that the pH scale is used to measure acidity and alkalinity. It runs from 0 to 14 and that pH 7 is neutral. The smaller the pH value the more acidic; the larger the pH value to more alkaline. Students should identify the pH of locally available substances using universal indictor, red and blue litmus paper and a pH meter if available. Students should describe that the pH of an acid is a measure of the concentration of hydrogen ions which is	Observe students activities and give feedback Listen students responses and give feedback Check on a sample exercises and give feedback Check on a sample exercises and give feedback

Competencies	Contents	Suggested Activities	
		related to its concentration and strength	
• Perform activities to investigate some physical properties of acids		Students should give the mathematical definition of pH = - $\log_{10}[H^+]$. They should identify that pH is a logarithmic scale thus the hydrogen ion concentration of an acid of pH 3 is ten times that of an acid of pH 4. Students should be able to:	Observe students activities and give feedback
• Do activities to investigate some chemical properties of acids		• Calculate the pH of an acid given its concentration and assuming complete dissociation • Calculate the hydrogen ion concentration of a solution from its pH value	Observe students activities and give feedback
• Discuss the direct combination of elements, the reaction of acidic oxides with water and formation of volatile acids from non -volatile acids as the three methods of preparation of acids		Students should be asked to conduct an investigation into the physical properties of acids. These could include: • Effect on acid-alkali indicators • Measuring conductivity • Measuring relative density	Check on a sample exercises and give feedback
• Carry out simple experiment to prepare acids in laboratory		Students should be asked to conduct an investigation into the chemical properties of acids. These could include: • Reaction with a metal e.g., magnesium, zinc, iron • Reaction with metal carbonates and hydrogen carbonates	Observe students activities and give

Competencies	Contents	Suggested Activities	
• Describe the uses of the three common laboratory acids.	• Preparation of acids Common uses of HCl, HNO_3, H_2SO_4	• Reaction with metal oxides and hydroxides Students should be asked differentiatemethods that used to prepare acids. These could include: • The direct synthesis of hydrogen chloride gas by burning hydrogen in chlorine and the subsequent addition of water to form hydrochloric acid, HCl(aq). • The reaction of sulphur dioxide gas with water to form sulphurous acid, H_2SO_3(aq). • The reaction of concentrated sulphuric acid, H_2SO_4 , with sodium nitrate to form nitric acid, HNO_3 Students should be requested to show the preparation of chlorous acid from barium chlorite and sulphuric acid in the laboratory. Students should identify the three common acids used in the laboratory and give some uses of each: • Hydrochloric acid – present in the stomach and needed for digestion; manufacture of aniline dyes; pickling iron to clean it before galvanising and tin plating • Nitric acid – manufacture of explosives, manufacture of nitrate fertilisers • Sulphuric acid – present in car batteries, used to	feedback Check on a sample exercises and give feedback

Competencies	Contents	Suggested Activities	
		make a variety of other chemicals and products including phosphate fertilisers, detergents, paints and pigments	
	3.4. Bases *(6 periods)*		
• Define bases in terms of the concepts of Arrhenius • Give examples of bases based on Arrhenius	• Definition of bases	• Students should define a base as a substance which dissociates in aqueous solution to release hydroxide ions, OH^-. • e.g. Sodium hydroxide is a base by this definition because it releases OH^- in aqueous solution. Students should identify that an alkali is a base which is soluble in water.	Listen students responses and give feedback
• Discuss the general properties of bases	• General properties of bases	Students should be requested to describe the properties of alkalis/bases including: • Effect on common indicators such as litmus, phenolphthalein, methyl red and universal indicators • Neutralisation reactions with acids	
• Define strong and weak bases	• Strength of bases (Strong and weak bases)	Students should identify substances that dissociate in water completely like sodium hydroxide are alkaline: $NaOH \rightarrow Na^+ + OH^-$ Sodium hydroxide is described as a strong alkali because it is fully dissociated. Students should be requested to describe an alkali is	Listen students responses and give feedback

Competencies	*Contents*	*Suggested Activities*	
• Distinguish between strong and weak alkalis (soluble bases) • Define concentrated and dilute alkalis • Distinguish between concentrated and dilute alkalis (soluble bases) • Use the necessary precautions while working with bases	• Concentrated and dilute bases • Precautions in handling bases	described as strong or weak depends upon the degree which it dissociates and has nothing to do with its concentration. The concentration of an alkali is a measure of the number of moles of the alkali dissolved in 1 litre and is therefore expressed in mol $liter^{-1}$. Students should describe both a strong alkali and a weak alkali may be concentrated or dilute depending on the number of moles present. Students should identify the corrosive nature of strong alkalis and some weak alkalis such as ammonia solution. Precautions should be taken when handling alkalis including: • Wearing eye protection • Wiping spillages straight away • Diluting any alkali that gets onto clothes • Using a bellows to pipette alkali	Listen students responses and give feedback Check on a sample exercises and give feedback
• Define pOH • Show the mathematical relationship between pH and pOH • Calculate the pOH of a	• P^{OH} - Relationship between pH and pOH	Students should describe POH is a measure of the concentration of hydroxide ions in an acidic or a basic solution.	Listen students responses and give feedback

Competencies	***Contents***	***Suggested Activities***	
given basic solution • Calculate the concentration of hydroxide ion from the given information		Students should identify that the pOH scale is used to measure alkalinity or acidity and be given the mathematical definition of $pOH = -\log_{10}[OH^-]$. Students should show that pH and pOH are related mathematically as: $pH + pOH = 14$ Students could attempt to derive this using the ionic product of water, K_w, as follows: In a neutral substance such as distilled water: $K_w = [H^+][OH^-] = 10^{-14}$ $-\log_{10}\{[H^+][OH^-]\} = \log_{10}10^{-14}$	Check on a sample exercises and give feedback
• Carry out activities to investigate some chemical properties of bases • Discuss the reaction of active metals with water, the reaction of basic oxides with water and double displacement reactions as the three methods of preparation of bases		$\{-\log_{10}[H^+]\} + \{-\log_{10}[OH^-]\} = 14$ $pH + pOH = 14$ Students could be asked to determine the pOH values of concentrated and dilute, weak and strong bases. Students should be asked to: • Calculate the pOH of an alkali given its concentration and assuming complete dissociation • Calculate the hydroxide ion concentration of a	Check on a sample exercises and give feedback

Competencies	Contents	Suggested Activities	
		solution from its pOH value • Identify bases in their surroundings	Listen students responses and provide summary
• Carry out simple experiments to prepare bases in laboratory • Explain the uses of the two common laboratory bases	• Preparation of bases • Common uses of NaOH and $Ca(OH)_2$	Students should discuss different methods used to prepare bases. These could include: • The reaction of a reactive metal from Group 1 or Group 2 with water to form the hydroxide. • The reaction of a Group 1 or Group 2 metal oxides with water to form the hydroxide. • Double displacement reactions in which the products of the reaction are a soluble base and an insoluble salt e.g. $K_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow 2KOH(aq) + BaSO_4(s)$ Students could prepare the hydroxides of lithium and/or calcium by reacting the metal directly with water. Students could prepare magnesium and/or calcium hydroxide by reacting the metal oxide with water. Students could prepare NaOH or KOH by reaction of a solution of Na or K metal sulphate with barium	Observe students activities and give feedback

Competencies	***Contents***	***Suggested Activities***	
		hydroxide solution. Students should be asked to identify the two common alkalis used in the laboratory and give some uses of each: • Sodium hydroxide – soap, degreasers, various chemicals • Calcium hydroxide – lime water test for carbon dioxide, slaked lime for reducing pH of soil	
	3.5. Salts *(5 periods)*		
• Define salts • Give examples of salts		Students should be requested to explain that a salt is produced when an acid is neutralised by a base: acid + base = salt + water Students should be requested tolist some common salts. They could be able to suggest a possible combination of acid and base to prepare each salt e.g. copper (II) sulphate: sulphuric acid and copper (II) oxide.	Listen students responses and give feedback
• Classify salts as acidic and normal salts	• Classification - Acidic salts	Students should discuss that salts can be classified in three groups:	Monitor the discussion and give summary

Competencies	***Contents***	***Suggested Activities***	
• discuss the direct combination of elements, the reaction of acids with bases, neutralization and the reaction between acids and metals as the methods of salt preparation	- Normal salts - Basic salts • Preparation of salts	• Acidic salts – are salts in which not all of the hydrogen ions in an acid have been replaced e.g., sodium hydrogensulphate, $NaHSO_4$. Students should understand that when made into an aqueous solution it releases the ions Na^+, H^+, SO_4^{2-}. It releases hydrogen ions hence it is acidic. • Normal salts – are salts in which all of the hydrogen ions in an acid have been replaced e.g. sodium sulphate, Na_2SO_4. • Basic salts- are salts that contain ionizable hydroxide ions e.g Basic zinc chloride, Zn(OH)C1 Students should be asked to show different methods of preparing salts. These could include: • Metal + acid e.g. calcium, magnesium, aluminium, zinc, iron + dilute hydrochloric/nitric/sulphuric acid Students should identify that metals which are higher in the reactivity series (above calcium) are too vigorous for this method while metals below iron are either too slow or do not react at all. Students should be asked to identify that calcium sulphate is only sparingly soluble so in a reaction with dilute sulphuric acid, calcium tends to become coated with calcium sulphate which inhibits the reaction from proceeding • Metal oxide + acid e.g. transition metal oxides +	Observe students activities and give feedback Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	
• Carry out simple experiment to prepare a salt by neutralization. • List some important salts • Explain the uses of some important salts	• Some important salts and their uses	dilute hydrochloric/nitric/sulphuric acid • Metal hydroxide + acid e.g. Group 1 metal hydroxides + dilute hydrochloric/nitric/sulphuric acid • Metal carbonate + acid e.g. any metal carbonate+dilute hydrochloric/nitric/sulphuricacid • Double decomposition reactions in which two soluble reactants form soluble and an insoluble product which are easily separated e.g., lead nitrate(aq) + sodium iodide solution(aq) = lead iodide(s) + sodium nitrate(aq)	Observe and give feedback
• Discuss the properties of salts	• Properties of salts	Students should identify that not every method can be used to make every salt. Students should prepare NaCl from NaOH and HCl and obtain it by evaporation.	Listen students responses and give feedback
• Explain the chemical tests of some salts by conducting activities	• Chemical tests of salts	Students should be asked to describe the uses of some salts. These could include: • Sodium chloride – preparation and preservation of food; raw material for the manufacture of sodium hydroxide and chlorine • Ammonium nitrate – nitrogenous fertiliser • Copper (II) sulphate – Bordeaux mixture and other fungicides	Observe and give feedback

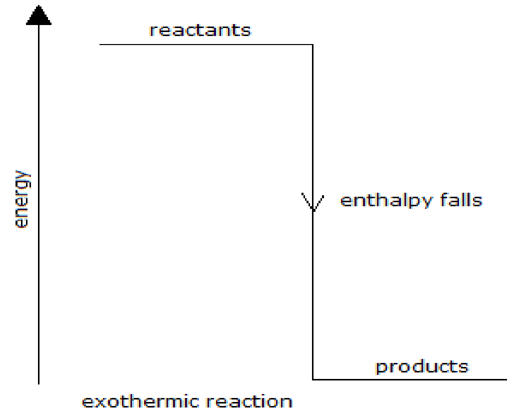
Competencies	***Contents***	***Suggested Activities***	
		• Iron (III) chloride – etching printed circuits • Potassium nitrate – explosives and fertilisers Students should demonstrate the solubility of some salts. They could use their results to derive some simple rules about solubility. Students could be asked to demonstrate the properties of salts which are: • Hygroscopic – absorb water from the atmosphere but remain solid • Deliquescent – absorb so much water from the atmosphere that they form solutions • Efflorescent – lose water to the atmosphere Students could demonstrate that when salts dissolve in water they release ions therefore the solutions conduct electricity. Students could conduct simple tests to detect the presence of specific ions in solution. These could include: • Flame tests – lithium, sodium, potassium, calcium, strontium, barium • Ammonia solution – copper(II) • Sodium hydroxide – iron(II) and iron(III) • Silver nitrate solution – halides • Barium nitrate/chloride solution – sulphates • Dilute acid – carbonates and hydrogencarbonates • Brown ring test – nitrates	Observe students activities and give feedback

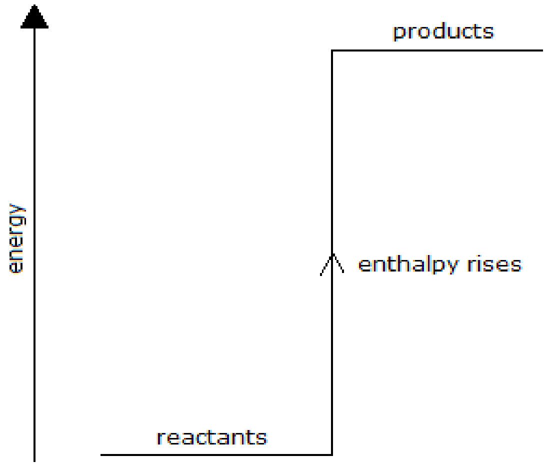
Unit 4: Energy changes in Chemical Reactions *(16 periods)*

Unit outcomes: Students will be able to:

- Describe energy changes in chemical reactions.
- Describe how a chemical reaction produces electric current and how electricity brings about a chemical reaction in electrochemical cells.
- Distinguish the difference between metallic conduction and electrolytic conduction;
- Develop skills in writing the oxidation half-reaction, reduction half-reaction and cell reaction for the electrolysis of molten electrolytes that occur in electrolytic cells;
- List and describe the three types of Voltaic cells;
- Identify the difference between electrolytic cells and voltaic cells;
- Demonstrate scientific inquiry skills: observing, classifying, comparing and contrasting, inferring, predicting, communicating, measuring, asking questions, interpreting data, drawing conclusion, applying concepts, relating cause and effect and problem solving.

Competencies	Contents	Suggested Activities	Assessment
	4. Energy changes in chemical reactions **4.1 Introduction**		
• Describe energy changes in chemical reactions	***(4 periods)***	Students should explain that changes in energy take place during a chemical reaction. Students should describe enthalpy is a measure of the internal energy of a substance. It is represented by the symbol *H*. The energy change that takes place during a chemical reaction are the result of enthalpy.	Listen students responses and provide feedback
• Define endothermic reaction • Describe endothermic reaction	• Endothermic reaction	Students should explain that in an endothermic reaction: • Heat is taken in from the surroundings • The internal energy of the reactants is less than the internal energy of the products • There is a rise in enthalpy therefore the value of ΔH is positive change in enthalpy and is represented as ΔH.	Listen students responses and give feedback
• Define exothermic reaction • Describe exothermic reaction	• Exothermic reaction	Students should describe as an exothermic reaction: • Heat is given out to the surroundings • The internal energy of the reactants is more than the	Listen students responses and give feedback

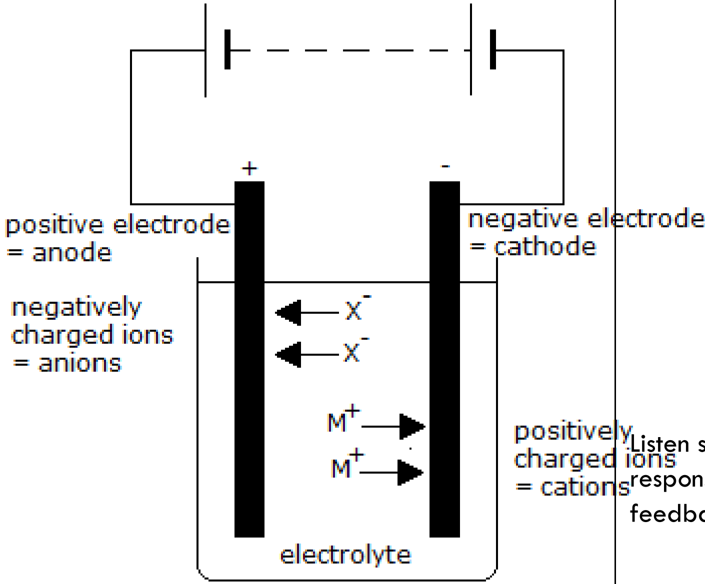
Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Elucidate endothermic and exothermic reactions using diagrams	• Energy diagrams for endothermic and exothermic reactions	internal energy of the products • There is a fall in enthalpy therefore the value of *ΔH* is negative Students should identify that most of the reactions they will see and carry out in the laboratory will be exothermic. Students should be requested to draw energy diagrams to represent exothermic and endothermic reactions. These have the general form:  H_r> H_P☐☐ H is negative	Check on a sample exercises and give feedback Observe students activities and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
Do simple experiment to demonstrate exothermic and endothermic reactions		(□H < 0) H_r - heat content of reactants H_P - heat content of products  endothermic reaction H_P> H_r□□H is positive (□H > O) Students should be asked to carry out some exothermic and endothermic reactions to identify heat is given out or taken in either by direct observation or by measuring temperature rise/fall with a thermometer. These could include:	Observe students

Competencies	Contents	Suggested Activities	Assessment
		Exothermic • Burning gas • Adding water to anhydrous copper (II) sulphate • Adding a few drops of concentrated sulphuric acid to water • Mixing dilute hydrochloric acid and sodium hydroxide solution Endothermic • Adding solid ammonium nitrate to water • Adding solid potassium nitrate to water	activity and give feedback
Discuss the importance of chemical changes in the production of new substances and energy	Importance of chemical changes	Students should discuss about the importance of the energy released in some exothermic reactions. These should include: • Combustion of fuels • Oxidation of glucose during cell respiration	Monitor the discussion and give feedback
	4.2 Energy changes in electrochemistry (8 *periods*		
• Describe electrochemistry • Define electrical conductivity • Explain metallic conductivity	• **Electrochemistry** Electrical conductivity • Metallic conductivity	Students should describe that electrochemistry is concerned with bringing about chemical change using an electric current or generating electrical energy from chemical reactions.	Listen students responses and give feedback

Competencies	Contents	Suggested Activities	Assessment
• Explain electrolytic conductivity • Differentiate between metallic conduction and electrolytic conduction • Distinguish between strong and weak electrolytes • use conductivity apparatus to test conductivity of substances • Define the term electrolysis • Define the terms electrode, anode cathode, electrolyte, anion, and cation	• Electrolytic conductivity **4.3. Electrolysis** ***(3 periods)*** • Electrolytic cell • Electrolysis of molten electrolytes	Students should explain that both metals and aqueous electrolytic solutions conduct electricity but that the process is different in each case. Students should describe that in metallic conductivity: • Metallic structure can be described as matrix of positive ions in a sea of mobile electrons • Metals contain delocalised valence electrons which are able to move • Electric charge is carried by electrons Students should check the ability of different materials to conduct electricity. Students could be requested to relate the ability of graphite, a non-metal, to conduct electricity to the delocalised electrons contained within its layered structure. Students should describe that in electrolytic conductivity: • The electrolyte contains ions • The ions are able to move in the solution • Electric charge is carried by ions Students should explain that ionic compounds are composed of ions but their ions are not mobile when the compound exists as a solid – and this is why ionic solids do not conduct an electric current.	Observe students activities and give feedback Listen students responses and give feedback Check on a sample

Competencies	Contents	Suggested Activities	Assessment
• Describe electrolytic cell • Draw labelled diagram of an electrolytic cell		Students should identify the ability of different soluble compounds to conduct electricity. These could include: • Ionic compounds such as salt Organic compounds such as glucose and sucrose This could be asked to do simple experiments using a simple circuit composed of three cells and a lamp. Students should define that electrolysis is the process of bringing about chemical change using an electric current. They should describe terminologies such as: • Anode • Anions • Cathode • Cations • Electrolyte Students should provide schematic representation of electrolytic cells and label their components	exercises and give feedback Observe students activities and give feedback Listen students responses and give feedback Observe students activities and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Define the terms' half-reaction and cell reaction			Listen students responses and give feedback
		Students should explain that the ability of an electrolyte to conduct an electric current is determined by the concentration of ions.	Observe students activities and give feedback
• Write the oxidation half-reaction, reduction half reaction and cell reaction for the electrolysis of		• Strong electrolyte – high concentration of ions e.g. very soluble ionic compound • Weak electrolyte – low concentration of ions e.g. sparingly soluble ionic compound	Monitor the discussion and give

Competencies	Contents	Suggested Activities	Assessment
molten or fused electrolytes • Perform an activity to show electrolysis of molten electrolytes		Students should be asked to draw an electrolytic cell and label: • Power source (must be d.c.) • Electrolyte • Anode • Cathode Students should discuss that during electrolysis: • Negatively charged ions or anions are attracted to the positive electrode or anode • The anions lose electrons to form atoms (that combine to form molecules) • The anions are therefore oxidised • The reaction at the anode can be shown by a half equation • Positively charged ions or cations are attracted to the negative electrode or cathode • The cations gain electrons to form atoms • The cations are therefore reduced • The reaction at the cathode can be shown by a half equation Students should be requested to conduct the electrolysis of	feedback Observe students activities and give feedback Listen students

Competencies	Contents	Suggested Activities	Assessment
• Construct a simple cell using strips of zinc, copper, ZnSO4 and CuSO4 solutions • mention different types of voltaic cells • Describe how voltaic cells can be used to make commercially useful batteries • Distinguish between voltaic cell and an electrolytic cell • Describe voltaic cell	**4.4 Electrochemical cells** ***(4 period)*** Galvanic cells (voltaic cells) Primary cells and secondary cells	molten lead bromide using graphite electrodes. Students could: • Observe bromine given off at the anode • Write a half equation for the reaction at the anode $2Br^- \rightarrow Br_2 + 2e^-$ • Identify the reaction at the anode as an oxidation reaction because it involves the loss of electrons • Observe lead produced at the cathode • Write a half equation for the reaction at the cathode $Pb^{2+} + 2e^- \rightarrow Pb$ • Identify the reaction at the cathode as a reduction reaction because it involves the gain of electrons Students should be requested to consolidate their understanding of the term's oxidation and reduction in terms of electron loss and gain. They should identify that equal number of electrons are lost at the anode and gained at the cathode, and since electrolysis overall is a redox reaction and oxidation or reduction cannot occur in isolation – if something is oxidised something else must be reduced.	responses and give feedback Observe students' performance and give feedback Listen students' responses and give summary Check students' performance and give feedback

Competencies	Contents	Suggested Activities	Assessment
		• Students should make a simple cell by inserting pieces of different metals into a lemon or lime. This could be extended by investigating which metals give the greatest voltage and which the least they related to the reactivity series • Students should explain that early cells consisted of metal rods suspended in electrolyte solutions. They are sometimes referred to as wet cells. Student could research to find out more about: - The wet Leclanché cell - The Daniell cell Students could discuss the practical problems of using wet cells and why dry cells were developed • Students should draw and label the structure of a dry Leclanché cell • Students should identify that in a dry cell: • Oxidation occurs at the negative electrode (zinc) with the reaction $Zn(s) \rightarrow Zn^{2+} + 2e^-$ • Reduction occurs at the positive electrode (carbon) with the reaction	Check students' responses and give summary

Competencies	***Contents***	***Suggested Activities***	***Assessment***
		2 $2NH_4 +$ (aq) + $2MnO_2 + 2e^- \rightarrow$ Mn_2O_3(s) + $2NH_3$(aq) + H_2O(l) When the cell is connected in a circuit electron are pumped from the negative electrode to the positive electrode • Students should explain the terms 'conventional current' and 'actual current' and the reason for them • Students should identify that dry cells are described as primary cells because they cannot be recharged. Once the chemicals in the cell are exhausted no electricity flows and the cells are replaced • Students should compare this with a secondary cell which can be recharged when it becomes exhausted. They also identify that a car battery can be used as an example of a secondary cell.	

Unit 5: Metals and non-metals (13 periods)

Unit outcomes: Students will be able to:

- Explain the renewable and non-renewable natural resources and appreciate their importance in industry as raw materials;
- Describe the extraction, chemical properties and uses of aluminium, iron, copper, nitrogen, phosphorus, oxygen, sulphur, and chlorine;
- Describe the production and chemical properties of nitrogen, phosphorus, oxygen, sulphur and chlorine;
- Demonstrate scientific inquiry skills: observing, classifying, communicating, and asking questions, applying concepts and problem solving.

Competencies	Contents	Suggested Activities	Assessments
Students will be able to:	***5. Metals and non-metals***		
	5.1 Introduction *(1 period)*		
• Define natural resources • List natural resources	• Definition of natural resources • Classification of natural resources	Students should describe that natural resources are materials that are available on Earth for people to use. Students should make a list of natural resources. This could include: • Stone, metal ores, soil, wood, air, food crops, crude oil, natural gas, coal, fibres (e.g. wool and cotton)	Listen students responses and give feedback
	• Importance of natural resources for industry	Students should discuss that natural resources provide many important raw materials which are the starting materials for industrial processes.	Monitor the discussion and summarize

Competencies	***Contents***	***Suggested Activities***	***Assessments***
• Outline the extraction of aluminium by the Hall process • Describe the main physical and chemical properties of aluminium	**5.2 Production of some important metals and non-metals** *(12 periods)* **Aluminium** - Extraction	Students should discuss about the extraction of aluminium. This should include: • The main ore of aluminium is bauxite (Al_2O_3) • Aluminium is a reactive metal and cannot be extracted simply by heating the bauxite • Aluminium is extracted by electrolysis using the Hall cell • Bauxite is first purified and converted to alumina $Al(OH)_3$ and then decomposing the alumina back to aluminium oxide • Alumina is dissolved in molten cryolite in the electrolytic cell: the reactions at the graphite electrodes are: Anode: $6O^{2-} \rightarrow 3O_2 + 12e^-$ Cathode: $4Al^{3+} + 12e^- \rightarrow 4Al$ • Under the conditions in the cell the anode is gradually oxidised to carbon dioxide and must be replaced periodically • Molten aluminium is siphoned off or tapped off from the bottom of the cell Students should describe the physical properties of aluminium	Monitor the discussion and summarize Listen students

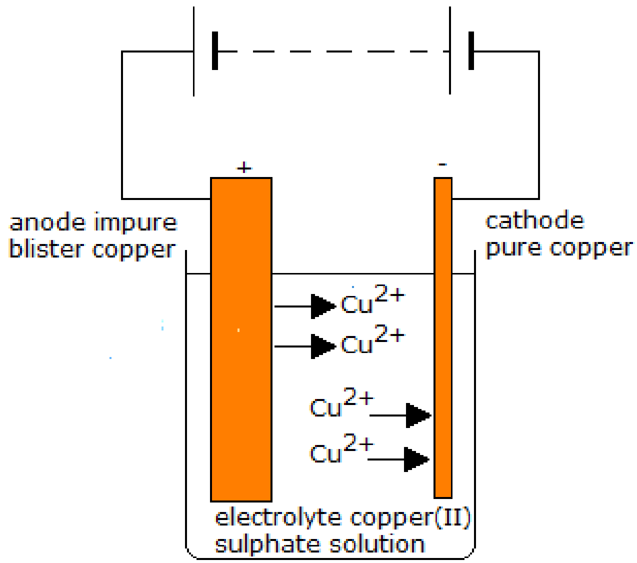
Competencies	***Contents***	***Suggested Activities***	***Assessments***
• Describe the uses of aluminium	- chemical properties	Students should describe the chemical properties of aluminium. These should include: • Aluminium is a reactive metal and rapidly reacts with oxygen from the air to form a layer of aluminium oxide. This layer of aluminium oxide inhibits the reaction of aluminium thus aluminium sometimes appears less reactive that its position in the reactivity series would suggest. This can be removed with mercury(II) chloride solution. Freshly exposed aluminium reacts rapidly with oxygen from the air to form aluminium oxide. $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$ • Aluminium reacts with dilute acids to form salts e.g. $2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$ • Aluminium burns in chlorine gas to form aluminium chloride. $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$ • Aluminium reacts with sodium hydroxide solution $2Al(s) + 2NaOH(aq) + 6H_2O(l) \rightarrow 2NaAl(OH)_4(aq) + 3H_2(g)$ Students should give examples of aluminium made materials in their surroundings Students should discuss about the uses of aluminium. These	responses and give summary

Competencies	***Contents***	***Suggested Activities***	***Assessments***
	- Uses	should include • The manufacture of light alloys e.g. duralumin • The construction of air crafts , ships and cars • The manufacture of household utensils • Window frames and roofing sheets • Packing material the food industry	Monitor the discussion and summarize
• Outline the extraction of iron by the blast furnace	• **Iron** - Extraction	Students discuss in group about the extraction of iron. This should include: • The main ores of iron are haematite (Fe_2O_3) and magnetite (Fe_3O_4) • Iron is less reactive than aluminium and can be extracted by heating the ore with a reducing agent. • Iron is extracted in a blast furnace. A mixture of iron ore, coke and limestone are heated together and air is blown through them • Coke is essentially carbon and is oxidised to carbon dioxide. The carbon dioxide then reacts with excess carbon and is reduced to carbon monoxide $C + O_2 \rightarrow CO_2$ $CO_2 + C \rightarrow 2CO$ • Carbon monoxide is the main reducing agent in the blast furnace and reduces the iron ore to iron	Monitor the discussion observe students' participation in the group activities and provide feedback

Competencies	***Contents***	***Suggested Activities***	***Assessments***
• Briefly describe conversion of pig iron to steel • Describe wrought iron	- Conversion of pig iron to steel - Wrought iron	$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ • The heat decomposes the limestone to calcium oxide and carbon dioxide $CaCO_3 \rightarrow CaO + CO_2$ • Calcium oxide reacts with acidic impurities such as silicon dioxide to form a slag. This protects the lining of the furnace from damage $CaO + SiO_2 \rightarrow CaSiO_3$ • Molten iron falls to the bottom of the furnace and is tapped off • Slag floats on top of the molten iron and is scraped off and used as a foundation for road building • Students should be given a project to construct a model which shows the blast furnace form locally available materials. Students should explain the conversion of pig iron to steel. The iron obtained from blast furnace (called pig iron) contains impurities like carbon that make it brittle. Steel can be made by blowing oxygen into molten iron to oxidize impurities and decrease the amount of carbon content. Students should identify that wrought iron is the purest form of iron with very low carbon content and other impurities.	Record students' performance and provide feedback

Competencies	Contents	Suggested Activities	Assessments
• Describe the main physical and chemical properties of iron	- Physical properties - Chemical properties	Students should describe the physical properties of iron. Students should explain about the chemical properties of iron. These should include: • Iron reacts with dilute acids to form salts e.g. $Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$ • Iron rusts in the presence of air and moisture to form a hydrated iron oxide • Iron is a transition metal and has two common oxidation states Fe(II) and Fe(III) • Iron(II) and iron(III) compounds are coloured • Solutions of some iron(II) compounds are rapidly oxidised to the corresponding iron(III) compounds by air • Heated iron reacts with hydrogen chloride gas. $Fe(s) + 2HCl(g) \rightarrow FeCl_2(s) + H_2(g)$ • Heated iron reacts with chlorine gas. $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$ • Iron will displace ions of less reactive metals from solutions of their salts $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$ Students should describe the use of iron. These could	Record students' performance and provide feedback

Competencies	***Contents***	***Suggested Activities***	***Assessments***
• Describe the uses of iron	- Uses	include: • as pig iron to make items like domestic boilers, castings and mouldings • as wrought iron to ornamental gates, door knockers, etc. • Manufacture of alloys, e.g. Carbon steels and alloy steels.	Record students' performance and provide feedback
• Outline the extraction of copper	• **Copper** - Extraction	Students should discuss in group about the extraction of copper. This should include: • Copper is an unreactive metal and can be found in the ground as native metal, but is more often found as sulphide ores such as bornite (Cu_5FeS_4), chalcopyrite ($CuFeS_2$) and chalcocite (Cu_2S) • Copper ore can be reduced to copper by roasting in air. The oxygen combines with the sulphur to form sulphur dioxide $Cu_2S(s) + O_2(g) \rightarrow 2Cu(s) + SO_2(g)$ The copper obtained by roasting is called blister copper and is too impure for use. • Blister copper is further purified by electrolysis	Monitor the discussion, record students' performance and provide feedback

Competencies	Contents	Suggested Activities	Assessments
		 Anode: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ Cathode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	

Competencies	***Contents***	***Suggested Activities***	***Assessments***
		Students should describe the physical properties of copper Students should explain about the chemical properties of copper. These should include:	
• Describe the main chemical properties of copper	- Chemical properties	Copper reacts with oxygen forming copper oxide $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$ • Over a period of time in damp air, copper turns green due to the formation of verdigris, a basic carbonate ($CuCO_3.Cu(OH)_2$) Copper is a transition metal and has two common oxidation states Cu(I) and Cu(II) Copper (II) compounds are coloured • Copper does not react with dilute acids. But it reacts with dilute and concentrated HNO_3 and hot concentrated H_2SO_4	Record students' performance and provide feedback
• Describe the uses of copper	- Uses	Students should explain about the uses of copper. These could include: • Manufacture of alloys • Electrical conductor Students should give bronze, brass, solder and steel as examples of alloys	Record students' performance and provide feedback Monitor the group

Competencies	***Contents***	***Suggested Activities***	***Assessments***
• Define alloys and give examples • Outline the production of nitrogen	• **Nitrogen** - Production	Students should discuss in group about the production of nitrogen. This should include: • Nitrogen makes up about 80% by volume of air • Nitrogen is obtained by the fractional distillation of liquid air • Water vapour and carbon dioxide are removed from air and what remains is compressed and cooled to form liquid air • The temperature of the liquid air is allowed to rise and the gases in air boil off at different temperatures; nitrogen at -196 ☐C, argon at - 186☐ C and oxygen at -183 ☐C.	discussion, record students' performance and provide feedback
		Students should describe the physical properties of nitrogen	Monitor the discussion, record students' performance and provide feedback
• Describe the main chemical properties of nitrogen	- Chemical properties	Students should discuss in group about the chemical properties of nitrogen. These should include: • Nitrogen is relatively inert • When heated with reactive metals in Groups 1and 2, nitrogen reacts to form nitrides $3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$ • Nitrogen reacts with oxygen to form a number of different oxides: N_2O, NO, NO_2 • In the Haber process nitrogen and hydrogen	

Competencies	Contents	Suggested Activities	Assessments
		combine to form ammonia $N_2(g) + 2H_2(g) \rightarrow 2NH_3(g)$	
• Outline the production of phosphorous	• **Phosphorous** - Production	Students should discuss in group about the production of phosphorus. This should include: • Phosphorus has two common allotropes: white phosphorus and red phosphorus • White phosphorus can be made in a number of ways including heating calcium phosphate in an electric furnace in the presence of carbon and silica. White phosphorus given off as vapour and collected under phosphoric acid. • Red phosphorus can be made by heating white phosphorus to 250 □C or by leaving it in sunlight	Monitor the discussion, record students' performance and provide feedback
• Describe the main chemical properties of phosphorus		Students should give the physical properties of phosphorus.	
	- Chemical properties	Students should describe about the chemical properties of phosphorus. These should include: • Phosphorus reacts with oxygen to form phosphorus oxides, P_2O_3 and P_2O_5, e.g. phosphorus(V) oxide	Record students' performance and provide feedback

Competencies	***Contents***	***Suggested Activities***	***Assessments***
		$P_4(s) + 5O_2(g) \rightarrow 2P_2O_5(s)$ • These oxides dissolve in water to form acids e.g. phosphoric(V) acid $P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(aq)$ • Phosphorus reacts with chlorine to form phosphorous chlorides, PCl_3 and PCl_5, e.g. phosphorus(V) chloride • $P_4(s) + 10Cl_2(g) \rightarrow 4PCl_5(s)$	
• Outline the production of oxygen	• **Oxygen** - Production	Students should discuss about the production of oxygen. This should include: • Oxygen makes up about 20% by volume of air • oxygen is obtained by the fractional distillation of liquid air • Water vapour and carbon dioxide are removed from air and what remains is compressed and cooled to form liquid air • The temperature of the liquid air is allowed to rise and the gases in air boil off at different temperatures; nitrogen at -196 □C, argon at - 186□C and oxygen at -183 □C.	Monitor the discussion, record students' performance and provide feedback
• Describe the main	Chemical properties	Students should know about the chemical properties of oxygen. These should include: • Oxygen is relatively reactive	

Competencies	***Contents***	***Suggested Activities***	***Assessments***
chemical properties of oxygen		• Oxygen combines with metals to form basic oxides $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$ • Oxygen combines with non-metals to form acidic oxides $S(s) + O_2(g) \rightarrow SO_2(g)$ • Oxygen is required for combustion $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	
• Outline the production of sulphur	• **Sulphur** - Production	Students should discuss in group about the extraction of sulphur. This should include: • Sulphur exists in the ground in elemental form • Elemental sulphur is extracted by the Frasch process. Hot water is pumped underground under high pressure and melts the sulphur. The molten sulphur is then brought to the surface • About half of the sulphur needed by industry is obtained as a waste product of other industrial processes. These are mainly from the removal of hydrogen sulphide from natural gas and refined crude oil, and the removal of sulphur dioxide obtained by roasting metal sulphide ores. • Using sulphur produced by other industries reduces the demand on natural resources and reduces atmospheric pollution and acid rain	Monitor the discussion, record students' performance and provide feedback
• Describe the main chemical properties of	- Chemical properties		

Competencies	Contents	Suggested Activities	Assessments
sulphur		Students should describe the physical properties of sulphur Students should describe about the chemical properties of sulphur. These should include: • When heated with metals, sulphur combines to give metal sulphides $Fe(s) + S(s) \rightarrow FeS(s)$ • Sulphur reacts with oxygen to form two different oxides: SO_2 and SO_3 • Sulphur is the raw product from which sulphuric acid is made: $S(s) + O_2(g) \rightarrow SO_2(g)$ $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $H_2SO_4(l) + SO_3(g) \rightarrow H_2S_2O_7(l)$ $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$ Students should discuss in group about the production of chlorine. This should include:	

Competencies	*Contents*	*Suggested Activities*	*Assessments*
• Outline the production of chlorine • Describe the chemical properties of chlorine	• **Chlorine** - Production - Chemical properties	• Chlorine is obtained by the electrolysis of concentrated sodium chloride solution or brine. Sodium hydroxide solution is produced at the same time Ions in solution Na^+, H^+, Cl^-, OH^- Anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ Cathode: $2H^+ + 2e^- \rightarrow H_2(g)$ Ions remaining in solution: Na^+, OH^- • Chlorine and sodium hydroxide solution must be kept apart as they react together $NaOH(aq) + Cl_2(g) \rightarrow NaOCl(aq) + HCl(aq)$ Students should describethe physical properties of chlorine Students should describe about the chemical properties of chlorine. These should include: • Chlorine is a powerful oxidising agent • Chlorine reacts with heated metals to form chlorides $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$ • Chlorine reacts with hydrogen to form hydrogen chloride	Monitor the discussion, record students' performance and provide feedback

Competencies	Contents	Suggested Activities	Assessments
		$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ • Chlorine will displace less reactive halide ions from solutions of their compounds $Cl_2(g) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$ • Chlorine dissolves in water to give an acidic solution $H_2O(l) + Cl_2(g) \rightarrow HCl(aq) + HOCl(aq)$ • Chlorine and chlorine water will bleach coloured material	

Unit 6: Hydrocarbons and their Natural sources (23 periods)

Unit outcomes: Students will be able to:

- Discuss the historical development of organic chemistry and classification of organic compounds;
- Write the general formulas of alkanes, alkenes and alkynes
- Develop skills in naming and writing the molecular and structural formulas of simple alkanes, branched chain alkanes, simple alkenes, branched chain alkenes and simple alkynes
- Explain isomerism and draw the possible isomers of alkanes and alkenes;
- Explain the physical and chemical properties; and general methods of preparation of alkanes, alkenes, alkynes, benzene and alcohols
- List the major natural sources of hydrocarbons;
- Demonstrate scientific inquiry skills: observing, classifying, communicating, measuring, asking questions, interpreting data, drawing conclusions, applying concepts, predicting and problem solving.

Competencies	*Contents*	*Suggested Activities*	*Assessment*
Students will be able to:	***6. Hydrocarbons and their natural sources*** **6.1 Introduction** *(1 period)*		
• Narrate the historical development of organic chemistry.	• History of organic chemistry	Students should describe that chemicals found in and derived from living things, both animals and plants, were once thought to contain a life force, the 'force vitals', which was absent in chemicals obtained from the ground.	Let students give their reflections and give summary
• Classify organic compounds	• Classification of organic compounds	On this basis, all chemicals were divided into two groups: • Organic chemicals • Inorganic chemicals Students should identify that, although the theory of life force has long since been discarded after Wohler's synthesis of Urea, this classification is still used but the definition of organic chemistry has changed. Organic chemistry is now described as the chemistry of carbon with the exception of the oxides of carbon, carbonates and hydrogen carbonates.	
• Define the term functional group		Students should explain that organic compounds are classified into groups on the basis of a functional group. It is the functional group in a molecule that determines much of the	Listen students responses and

Competencies	Contents	Suggested Activities	Assessment
		chemistry of a compound. The functional groups of organic chemicals studied in this unit could be given as a table.	give feedback

<table>
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<tr><td>Alkenes</td><td>$R\text{-}CH{=}CH_2$</td></tr>
<tr><td>Alkynes</td><td>$R\text{-}CH{\equiv}CH$</td></tr>
<tr><td>Aromatics</td><td>CH=CH, CH, CH, CH- CH (ring)</td></tr>
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<tr><td>Ketones</td><td>$R\text{-}C(=O)\text{-}R'$</td></tr>
<tr><td>Carboxylic acids</td><td>$R\text{-}C(=O)\text{-}OH$</td></tr>
<tr><td>Esters</td><td>$R\text{-}C(=O)\text{-}O\text{-}R'$</td></tr>
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<tr><td>• Define hydrocarbon</td><td>6.2 Saturated hydrocarbons (alkanes) (9 periods)</td><td></td><td></td></tr>
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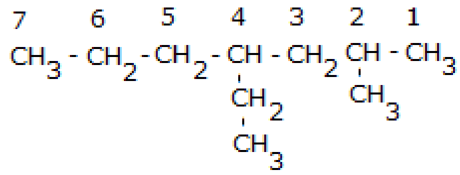
Competencies	Contents	Suggested Activities	Assessment
• Define saturated hydrocarbon • Define homologous series • Drive the general formula of alkanes and cycloalkanes from based on the number of hydrogen and carbon • Write the first ten members of alkanes and cycloalkanes homologous series • Write the molecular formulas of alkanes from the given numbers of carbon	• Homologous series • Physical properties	Students should define the term hydrocarbon is used to describe organic chemicals that contain hydrogen and carbon only. • Compounds that contain only carbon-carbon single bonds, the alkanes to be studied now, are described as saturated hydrocarbons. • Compounds that contain carbon-carbon double or triple bonds, the alkenes, alkynes and aromatic compounds to be studied later are described as unsaturated hydrocarbons. Students should identify that a series of compounds that differ by a certain same group are called a homologous series. The alkanes are a homologous series which have the general formula C_nH_{2n+2}. Whereas, cycloalkanes have the general formula of C_nH_{2n} . Students should be requested to apply the general formula to generate the chemical formulas of the first ten alkanes in the series. For example: n=1, CH_4, n=2, C_2H_6 etc. Whereas, for cycloalkanes, when n= 3; C_3H_6, n=4 C_4H_8, etc. Students should explain that there are forces of attraction between molecules in alkanes (van der Waals' forces). As the size of the molecule increases so do the forces. At room temperature:	Listen students responses and give feedback Check on a sample exercises and give feedback Listen students responses and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
atom • Explain the physical properties of alkanes • Apply IUPAC rules to name straight and branched chain alkanes.	• Nomenclature	• Alkanes up to and including C_4 are gases • Alkanes from $C_5 – C_{17}$ are liquids • Alkanes C_{18} and above are solids Students should discuss that the name of an organic chemical is derived from: • a prefix indicating the number of carbons present • a suffix indicating the functional group present Students should encouraged to learn the prefixes for compounds containing up to ten carbon atoms as these are widely used in organic chemistry.	Monitor the discussion and give feedback

Prefix	**Number of carbon atoms**	**Prefix**	**Number of carbon atoms**
Meth	1	hex	6
Eth	2	hept	7
Prop	3	oct	8
But	4	non	9
Pent	5	dec	10

Competencies	*Contents*	*Suggested Activities*	*Assessment*
• Write the structural formulas of the first ten alkanes	• Isomerism	Students should be asked to use the suffix 'ane' to generate the names of the first ten alkanes e.g. meth + ane = methane, eth + ane= ethane, etc. Students could give structures and name the first ten alkanes in the series. Students should describe the principles of naming branched chain alkanes: • identify the longest possible carbon chain which gives the base name • Number the carbon atoms in the longest carbon chain. Any side groups are on the lowest possible numbered carbon • name the side chains on the basis of the prefix which indicates the number of carbon atoms, followed by the suffix –yl • combine the side chains and the base name to give the name of the compound as one word Students should work through an example with the help of the teacher.	Check students' performances and give feedback

Competencies	*Contents*	*Suggested Activities*	*Assessment*
			
• Define isomerism as the way how compounds having the same formula differ in the way their atoms are arranged		• The longest carbon chain contains 7 carbon atoms therefore it is a heptane • The carbon chain is numbered from right to left to ensure the numbers of the carbon atoms which have groups attached are as low as possible • There is a methyl group on carbon 2 • There is an ethyl group on carbon 4 Combining this information gives 4-ethyl 2-methylheptane	Check students' performances and give feedback
• Define structural isomerism		Students should identify that the first three members of alkanes- CH_4 ,C_2H_6 and C_3H_8 etchave only one possible arrangement for their structures.	
• Draw the possible structural isomers for C_4H_{10}, C_5H_{12} and C_6H_{14}.		Students should show the possible isomers of butane, C_4H_{10}. They should appreciate that it is easier simply to draw the carbon skeletons and omit the hydrogen atoms. 	Check students'

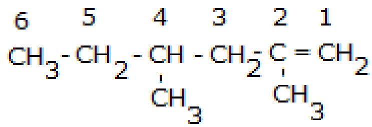
Competencies	***Contents***	***Suggested Activities***	***Assessment***
		Students should show that when the number of carbons in an alkane reaches four or more there are different ways of arranging them in a molecule. This is called isomerism. The isomers have the same chemical formula but different structures and different physical properties such as melting point and boiling point.	performances and give feedback
	• Preparation	Students should show by drawing as many possible different structures as they can for pentane, C_5H_{12} (3 isomers) and hexane, C_6H_{14} (5 isomers).	
		Students could practice this technique by naming the different isomers of pentane and hexane.	
• Describe the general methods for preparation of alkanes in a laboratory		Students should should that crude oil is a mixture of many different alkanes and that industrially, alkanes are obtained by the refining of crude oil.	
• Synthesis methane in a laboratory by decarboxylation method		In the laboratory alkanes can be made by a number of different routes including: • The hydrogenation of alkenes $R\text{-}CH{=}CH_2 + H_2 \rightarrow R\text{-}CH_2\text{-}CH_3$ • The Wurtz synthesis using halogenated hydrocarbons and sodium	Check students' performances

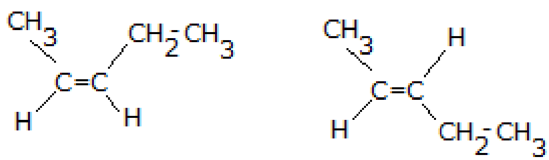
Competencies	Contents	Suggested Activities	Assessment
		$2R\text{-}Br + 2Na \rightarrow R\text{-}R + 2NaBr$ • The decarboxylation of the sodium salt of a carboxylic acid $RCOONa + NaOH \rightarrow Na_2CO_3 + R\text{-}H$ Student should appreciate evolution of methane gas in marshy areas.	and give feedback
		Students should be requested to synthesize methane by the decarboxylation of sodium ethanoate.	Listen students responses and give feedback
• Carryout a project work to produce biogas from cow dung	• Chemical properties	Students should be asked to produce methane on a small scale by the fermentation of cow dung. They should identify the significance of methane made in this way, as the main component of biogas, and how it provides a renewable source of energy	
• Explain the chemical properties of alkanes		Students should describe that alkanes are generally considered unreactive chemicals. • Like all hydrocarbons, alkanes burn in air to give carbon dioxide and water. In limited supplies of air some carbon monoxide is also formed. • Alkanes react with chlorine in the presence of sunlight to produce chloroalkanes. This is an example of a free radical reaction.	

Competencies	*Contents*	*Suggested Activities*	*Assessment*
	6.3 Unsaturated hydrocarbons – alkenes and alkynes *(9 periods)*		
• Define unsaturated hydrocarbons • Define alkenes	• Homologous series	Students should give the definition of an unsaturated hydrocarbon from the previous section in terms of the presence of carbon-carbon double or triple bonds. Students identify that alkenes are a homologous series of unsaturated hydrocarbons: • Alkenes contain the functional group C=C • The general formula for alkenes is C_nH_{2n} • The suffix used for alkenes is 'ene'	Let students give their reflections and provide feedback
• Write the general formula of alkenes • Write the molecular formula first nine homologous series of alkenes	• Nomenclature	Students should be asked to write the molecular formulas of the first nine alkenes in the series. Students could use the prefixes given in the previous section together with the suffix 'ene' to name the first nine alkenes in	Check students' performances and give

Competencies	***Contents***	***Suggested Activities***	***Assessment***
		the series.	feedback
• Define alkynes • Write the general formula of alkynes • Write the molecular formula first nine homologous series of alkynes		Students should describe that alkynes are also a homologous series of unsaturated hydrocarbons: • Alkynes contain the functional group C☐C • The general formula for alkynes is C_nH_{2n-2} • The suffix used for alkynes is 'yne' Students should be given a chance to write the molecular formulas of the first nine alkynes in the series. Students could be asked to use the prefixes given in the previous section together with the suffix 'yne' to name the first nine alkynes in the series.	Listen students responses and give feedback Check students' performances and give feedback
• Write the molecular formulas of alkenes and alkynes from the given number of carbon atoms		Students should be able to write the molecular formulas of alkenes and alkynes provided with number of carbon atoms.	
• Describe the physical properties of alkenes and alkynes	• Physical properties	Students should describe that, as was the case with alkanes, there are forces of attraction between the molecules in both alkenes and alkynes. Those with small molecules are gases at room temperature but as the carbon chain increases in size the attractive forces also increase giving higher melting points and boiling points. Alkenes and alkynes with large molecules are liquids and larger still, are solids.	Listen students responses and give feedback

Competencies	Contents	Suggested Activities	Assessment
• Write the structural formulas alkenes and alkynes up to nine carbon atoms.	• Isomerism	Students should identify that within the carbon chain of an alkene, a carbon-carbon double bond might be between any pair of adjacent carbon atoms. The same is true of the carbon-carbon triple bond in alkynes. In order to differentiate between two molecules with the same formula but in which the carbon-carbon double or triple bond is in a different position, we: • number the carbon atoms in such a way that the carbon atoms joined by the double or triple bond have the lowest number • give the number of the first carbon atom involved in the bond Students should consider some examples. C-C-C☐C C-C☐C-C but -1-yne but-2-yne (1-butyne) (2-butyne) C-C-C-C-C=C C-C-C-C=C-C C-C- C=C-C-C Hex-1-ene hex-2-ene hex-	Check on a sample exercises and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Use IUPAC rules to name straight and branched chain alkenes and alkynes.		3-ene (1-hex ene) (2-hex ene) (3-hex ene) Students could draw and name different straight chain alkenes and alkynes up to nine carbon atoms. Students should identify that the rules given for naming branched chain alkenes and alkynes are the same as those for alkanes with the additional requirement of identifying the position of the carbon-carbon double or triple bond. Students should work through an example with the help of the teacher.  • The longest carbon chain contains 6 carbon atoms therefore it is a hexene • The carbon chain is numbered from right to left to ensure the numbers of the carbon atoms which have groups attached are as low as possible • The carbon-carbon double bond is between carbons 1 and 2 • There are methyl groups on carbons 2 and 4	Check students' performances and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• Write possible structural isomers for C_4H_8 and C_5H_{10} • Define geometric (cis-trans) isomerism • Give examples of molecules that show geometric isomerism • Construct models that show cis-trans isomerism		Combining this information gives 2,4-dimethylhex-1-ene. Students could be asked to practice this technique by naming the same other branched chain alkenes. Students should show that isomers of C_5H_{10} exist because the carbon-carbon double bond can be in two different positions, giving pent-1-ene and pent-2-ene. Show students the two possible structures of pent-2-ene and point out that it is not possible to rotate about a carbon-carbon double bond. Students could show that there are branched chain isomers with the formula C_5H_{10}  cis trans Introduce the term geometric isomerism to describe this type of isomerism. Explain that we use the terms: • cis to describe when different groups are attached to the same side of a plane through the carbon-carbon double	Check students' performances and give feedback

Competencies	*Contents*	*Suggested Activities*	*Assessment*
		bond • trans to describe when different groups are attached to opposite sides of a plane through the carbon-carbon double bond Students should identify that the structures given above are cis-pent-2-ene and trans-pent-2-ene. Students should consider some other examples of alkenes that give cis and trans isomers. Students should be given a project work to construct model that show cis and trans isomerism from locally available materials	Check students' performances and give feedback
• Explain the general method for preparation of alkenes in a laboratory • Produce ethylene in a laboratory by dehydration of ethanol	• Preparation	Students should describe that alkenes are obtained on an industrial scale by the cracking of fractions obtained from the distillation of crude oil. In the laboratory alkenes can be made by a number of different routes including: • The dehydration of alcohols with alumina or concentrated sulphuric acid. $R\text{-}CH_2\text{-}CH_2\text{-}OH \rightarrow R\text{-}CH{=}CH_2 + H_2O$ • The dehydrohalogenation of haloalkanes by refluxing them with a base.	Listen students' responses and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
		$R\text{-}CH_2\text{-}CH_2\text{-}X \rightarrow R\text{-}CH{=}CH_2 + HX$	
		Students should prepare ethene by the dehydration of ethanol.	Observe students' performances and give feedback
• Describe the general method for preparation of alkynes in a laboratory.		In the laboratory alkynes can be made by a number of different routes including: • The dehydrohalogenation of 1,2-dihaloalkanes by refluxing them with a base. $R\text{-}CHX\text{-}CH_2\text{-}X \rightarrow R\text{-}C\square CH + 2HX$ • The alkylation of sodium dicarbide with a primary haloalkane $HC\square CNa + RX \rightarrow HC\square C\text{-}R + NaX$	
• Prepare acetylene in a laboratory by the reaction of CaC_2 with water.		• Ethyne can be made by the reaction of calcium carbide and water. $CaC_2 + 2H_2O \rightarrow HC\square CH + Ca(OH)_2$ Students should be given a chance to prepare ethyne by hydrolysis of calcium carbide.	Check the students' performance and give feedback
• Test for unsaturation of ethylene and		Students should carry out the addition reaction of ethene and ethynewith bromine in tetra chloromethane that is used as a test for unsaturation.	

Competencies	***Contents***	***Suggested Activities***	***Assessment***
ethyne		• $R\text{-}CH{=}CH_2 + Br_2 \rightarrow R\text{-}CHBr\text{-}CH_2Br$ • $R\text{-}C\square CH + 2Br_2 \rightarrow R\text{-}CBr_2\text{-}CHBr_2$ The tetra chloromethane loses its colour as the bromine adds across the carbon-carbon double or triple bond.	Listen students responses and give feedback
	• Chemical properties	Students should describe that alkenes are generally considered reactive chemicals and this is due to addition across the carbon-carbon double bond.	
• Explain chemical properties of alkenes		• Addition of halogens to form 1,2 dihaloalkanes $R\text{-}CH{=}CH_2 + X_2 \rightarrow R\text{-}CHX\text{-}CH_2X$ • Addition of hydrogen halides to form haloalkanes $R\text{-}CH{=}CH_2 + HX \rightarrow R\text{-}CH_2\text{-}CH_2X$ • Addition of water to form an alcohol. $R\text{-}CH{=}CH_2 + H_2O \rightarrow R\text{-}CH_2\text{-}CH_2OH$ • Oxidation with cold alkaline potassium manganate (VII) solution to form a 1,2 diol. $R\text{-}CH{=}CH_2 \rightarrow R\text{-}CHOH\text{-}CH_2OH$	
		Students should discuss that the chemical properties of alkynes are similar to those of alkenes and are determined largely by addition reactions about the triple bond.	Monitor the discussion, check the students' performance and give feedback
• Explain chemical properties of		Students should know that the addition reactions of alkynes	

Competencies	Contents	Suggested Activities	Assessment
alkynes. • Explain the uses of ethylene and acetylene. • Compare and contrast the properties of ethane, ethene and ethyne	• Uses of ethylene and acetylene.	proceed in two steps. Students should give particular attention to the combustion of ethyne (acetylene) as this has important industrial applications. $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$ + a large amount of heat Oxy-acetylene burners reach temperatures high enough to melt steel. They are widely used in metal 'cutting'. Students should identify in the importance of ethylene and acetylene /ethyne Students should be encouraged to deduce that comparing the chemistry of ethane with that of ethene and ethyne. They are: • Similar in that they undergo combustion to form carbon dioxide and water • Different because ethene and ethyne are unsaturated and take part in addition reactions whereas ethane does not	Check the students' performance and give feedback

Competencies	***Contents***	***Suggested Activities***	***Assessment***
• List the major natural sources of hydrocarbons • Describe natural gas	**6.4 Natural sources of Hydrocarbons** *(2 periods)* • Natural gas	Students should be asked to list the major natural sources of hydrocarbons- natural gas, crude oil and coal. Students should explain that natural gas is composed mainly of methane with smaller amounts of ethane and traces of carbon dioxide and nitrogen. The composition of natural gas varies depending on the source but is always over 90% methane.	Listen students responses and give feedback
• Define crude oil • Explain fractional distillation of crude oil • Mention products of fractional distillation of crude oil • Discuss the uses of petroleum products	• Crude oil	Students should differentiate that the use of the following terms: • Crude oil describes the raw material obtained from the ground • Petroleum describes the products after the refining of crude oil • Students should understand how fractions of crude oil are obtained by fractional distillation. Students should explain that crude oil is a complex mixture of alkanes which is of little use in the form in which it leaves the ground. The first stage in refining involves fractional distillation which separates the crude oil into a series of fractions which boil over different temperature ranges.	Check the students' performance and give feedback
• Identify the composition of coal • Describe destructive	• Coal	Students should give name of the main fractions and describe	

Competencies	Contents	Suggested Activities	Assessment
distillation of coal		their uses. These could include: • Refinery gases – used for heating in the refinery and bottled gases • Petroleum ether – solvents • Gasoline – petrol fuel for internal combustion engine • Kerosene – jet engine fuel • Diesel oil – fuel for diesel engines • Lubricating oil – lubricants • Paraffin wax – candles and polishes • Residue – bitumen for roof sealing and road surfaces From this discussion, students could identify that as the temperature increases the fractions become: • more coloured • more viscous • less inflammable Students should explain that coal is essentially an impure form of carbon. In addition to carbon, it contains hydrocarbons which are given off as volatiles when the coal is heated in the absence of air. What remains after heating is a purer form of carbon called coke which is used in the blast furnace for the manufacture of iron.	Check the students' performance and give feedback Listen students' responses and give feedback