CHEMISTRY
TEACHER'S GUIDE
Grade 12

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CHEMISTRY TEACHER'S GUIDE GRADE 12

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA MINSTRY OF EDUCATION

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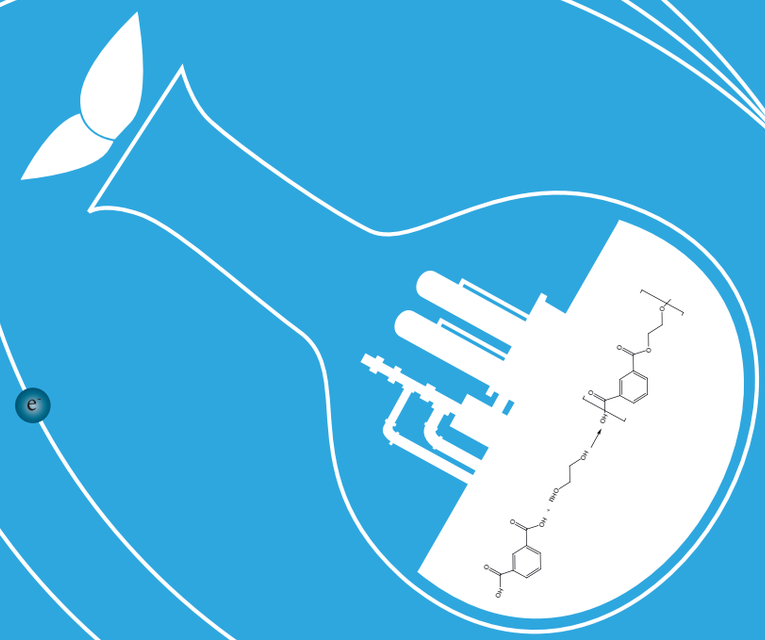

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA MINSTRY OF EDUCATION

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TEACHER'S GUIDE

GRADE 12

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Foreword

Education and development are closely related endeavors. This is the main reason why it is said that education is the key instrument in Ethiopia's development and social transformation. The fast and globalized world we now live in requires new knowledge, skill and attitude on the part of each individual. It is with this objective in view that the curriculum, which is not only the blueprint but also a reflection of a country's education system, must be responsive to changing conditions.

It has been almost three decades since Ethiopia launched and implemented new Education and Training Policy. Since the 1994 Education and Training Policy our country has recorded remarkable progress in terms of access, equity and relevance. Vigorous efforts also have been made, and continue to be made, to improve the quality of education.

To continue this progress, the Ministry of Education has developed a new General Education Curriculum Framework in 2021. The Framework covers all pre-primary, primary, Middle level and secondary level grades and subjects. It aims to reinforce the basic tenets and principles outlined in the Education and Training Policy, and provides guidance on the preparation of all subsequent curriculum materials – including this Teacher's Guide and the Student Textbook that come with it to be based on active-learning methods and a competency based approach.

In the development of this new curriculum, recommendations of the education Road Map studies conducted in 2018 are used as milestones. The new curriculum materials balance the content with students' age, incorporate indigenous knowledge where necessary, use technology for learning and teaching, integrate vocational contents, incorporate the moral education as a subject and incorporate career and technical education as a subject in order to accommodate the diverse needs of learners.

Publication of a new framework, textbooks and teacher guides are by no means the sole solution to improving the quality of education in any country. Continued improvement calls for the efforts of all stakeholders. The teacher's role must become more flexible ranging from lecturer to motivator, guider and facilitator. To assist this, teachers have been given, and will continue to receive, training on the strategies suggested in the Framework and in this teacher's guide.

Teachers are urged to read this guide carefully and to support their students by putting into action the strategies and activities suggested in it.

For systemic reform and continuous improvement in the quality of curriculum materials, the Ministry of Education welcomes comments and suggestions which will enable us to undertake further review and refinement.

ADDIS ABABA, ETHIOPIA
August 2023

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF EDUCATION

UNIT 4 POLYMER

UNIT 5 INTRODUCTION TO ENVIRONMENTAL CHEMISTRY

INTRODUCTION

According to the Educational and Training Policy of the Federal Democratic Republic of Ethiopia, Ethiopian Educational Development road map (2017-2030) of the secondary education and training will enable your students to choose subjects or areas of training which will prepare them adequately for higher education and for the world of work.

The study of chemistry at this level prepares your students academically as well as psychologically for the nation building. Studying chemistry provides students not only with specific concepts and theories in chemistry, but also with tools, confidence and attitudes for constructing their future prosperous society. Besides learning to think effectively and efficiently, your students come to understand how chemistry deals with the daily and routine lives of theirs and the people at large. Your students are also expected to realize the changing power of chemistry and its significance nationally as well as internationally.

To materialize the above stated major goals, encourage your students to apply high-level reasoning, and values to their daily life and also to their understanding of the social, economic, and cultural realities of the surrounding context. In turn, these will help the students to actively and effectively participate in the wider scope of the development activities of their nation.

At this cycle, the students are highly expected to gain solid knowledge of the fundamental theories, rules and procedures of chemistry. It is also expected that they should develop reliable skills for using this knowledge to solve problems independently and in groups.

To this end, the specific ojectives of chemistry learning at this cycle are to enable the students to:

- *gain a solid knowledge of chemistry*
- *appreciate the changing power, dynamism, structure and elegance of chemistry*
- *apply chemistry in their daily life*
- *understand the essential contributions of chemistry to the fields of engineering, science, agriculture and economics at large.*

Recent research gives strong arguments for changing the way in which chemistry has been taught. The traditional teaching-learning paradigm has been replaced by active, participatory and student-centered model. A student-centered classroom atmosphere and approach stimulates student's inquiry. Your role as a teacher in such student-centered approach would be a mentor who guides the students construct their own knowledge and skills. A primary goal when you teach a fundamental theory is for them to discover the concept by themselves, particularly as you recognize threads and patterns in the data and theories that they encounter under the teacher's guidance and supervision.

You are also encouraged to motivate your students to develop personal qualities that will help them in real life. For example, encourage students' self-confidence and their confidence in their knowledge, skills and general abilities. Motivate your students to express their ideas and observations with courage and confidence. As the students develop personal confidence and feel comfortable in the subject, they would their material in groups and express themselves and their ideas with strong conviction. Support students and give them chance to stand up before the class and present their opinions, observations and work. Similarly, create favorable conditions for students to come together in groups and exchange views and ideas about what they have investigated and about the material they have read. In this process, the students are given opportunities to openly discuss the knowledge they have acquired and to talk about issues raised in the course of the discussion.

Teamwork is one of the acceptable ways of approach in a student-centered classroom setting. For example, some experiments are performed by more than one student. Each student has a crucial role – one student might be responsible for carefully handling and mixing chemicals and another student may make quick and accurate measurements during the process. This teacher's guide helps you only as a guide. It is very helpful for budgeting and breaking down your teaching time as you plan to approach specific topics. The guide also contains procedures to manage class activities, group discussions and reflections. Answers to the review questions are indicated at the end of each topic. Every section of your teacher's guide includes student-assessment guidelines. Use them to evaluate your students' work. Based on your class's reality, you will give special attention to students who are working either above or below the standard level of achievement. Do an active follow up for each student's performance against the

learning competencies presented in the guide. Be sure to consider both the standard competencies and the minimum competencies. ***The minimum requirement level*** is not the ***standard level of achievement***. To achieve the standard level, your students must fulfill all of their grade-level's competencies successfully. When you identify students who are working either below the standard level or at the minimum level, arrange them extra support. For example, you can give them supplementary presentations and reviews of the materials in the class. Extra time to study and activities to those who are performing below the minimum level is commendable. You can also encourage high-level students with advanced activities and extra exercises. Some helpful references are listed at the end of this teacher's guide. For example, if you get an access for internet, it could be a rich resource for you. Searching for web sites is well worth your time as you browse on the subject matter you need. Use one of the many search engines that exist – for example, Yahoo and Google are widely accepted.

Do not forget that, although this guide provides many ideas and guidelines, you are encouraged to be innovative and creative in the ways you put your students into practice. Use your own full capacity, knowledge and insights in the same way as you encourage your students to use theirs.

General Information to the Teacher

The students' text is designed and prepared based on the participatory approach of the teaching–learning process. The teacher's with his professional ability is a relevant factor in preparing didactic and methodical plans, organizing and carries out work on student learning. Development in society depends on education processes which enable the development of knowledge, skills and human experience. To achieve this development we need a leader of the educational process who plan, manage and evaluate their own and other's work.

The teacher acts as a coach when students are involved in project work or self-study, acting as an organizer, encouraging them to participate and making suggestions about how students may proceed in an activity,

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 of students' performance. The teacher needs to assist students to discover facts, realize concepts, develop skills in performing experiments etc.

Teachers are educators, leaders, and role models for the students in their students and their environment. Therefore, being a teacher must have specific standards and qualities that must be met. As a teacher, it is mandatory to have a sense of responsibility, independence, authority, and discipline that can be used as examples for students. The role of the teacher as a learning resource will be related to the skills of the teacher to master the existing training material. So, when students ask something, the teacher can swiftly and responsively reply to student questions by using language that is easier to understand.

So, the teacher should not dominate the teaching learning process by giving lectures 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, have the list of all students in each section. You may organize the groups based on their seats, or on their ability, 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:

a. the concepts they gained during discussion in each activity in all units.
b. their observation and analysis after performing experiments in groups to the class.
c. the content prepared for a specific topic. So, you need to give emphasis to the following points in order to maximize student participation:
    - 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.
    - Whenever a group gets the chance to make a 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.
    - Give 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 in the first three units. 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.

- Carry out the experiment by yourself before allowing students to do it.
- Prepare chemicals and apparatus required for the experiment.
- Give instructions on how students should handle chemicals and apparatus during every experiment safty is very important.
- Provide materials they need for the experiment.
- Assist them whenever they have questions or difficulties in understanding the procedures suggested for the experiment.
- Give instructions that students should perform the experiment only based on the procedures suggested for it.
- Never allow them to conduct an experiment on their own other than the one they are supposed to do during the period.
- They should 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.
- 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, 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 corresponding with 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 teacher's 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 Exercises

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 12 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 topic concentration of solutions'.

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 doing their group assignments or suggested project work. For example, in types of solutions'.

C. Group discussion

Use 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, it could be done in all units after group discussion.

E. Demonstration

This is a method where the teacher shows the students how something is done. For example, in Unit 2 (electrochemistry).

F. Experiments

It usually involves a very specific and controlled method of procedures, where results are usually recorded.

G. Concept map

It is a systematic device or diagram of a set of concept meanings and how they relate to each other. It can help both teachers and students select and recognize the key ideas they must focus on to achieve a specific learning task.

Can provide a kind of 'road map' that shows how we link different concepts through propositions. Can help with revision: if one is drawn up after a learning-task has been completed, it will provide a diagrammatic summary of what has been learned.

Can help, if drawn up by oneself, to see clearly what we personally understand by a concept, and the limitations of our understanding.

Can help, after being drawn up by one self, to recognize new relationships and meanings (or at least meanings we were not consciously aware of before making the map). Thus, concept mapping can be a creative activity and can help to stimulate creativity for teachers and learners.

H. Question and answer (inquiry)

When this method is used, the teacher gives a lecture and asks questions periodically relating to the information being given. For example, teaching electrochemistry.

I. Investigation

This method is usually based on real life. For example, teaching students the effect of hydrogen bonding on aquatic animals.

J. Spider diagram

Students write a topic at the middle and write ideas related to the topic and draw a line connecting each idea to the central idea. For example, teaching ways of expressing concentrations of solutions.

K. Visual-based active learning

This method helps students learn using real object models, pictures, drawings and charts. For example, you can use this method in unit 2 to teach electrochemistry.

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 teach intensive properties.

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

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.

N. 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.

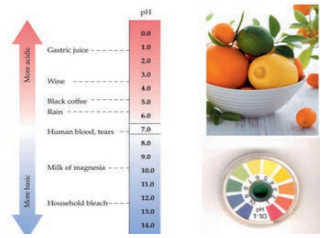
- to pass information to students according to the plan
- to make students active participants
- make students realize concepts easily
- make his/her teaching interesting
- achieve the desired goals etc.
- motivation also helps students to
- follow the lesson attentively

- 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:

- 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.
- investigate each student's talents and creativity.
- 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.

UNIT 1



Acid Base Equilibria

Unit Overview

In this unit, acids and bases are discussed. In Section 1.1 the Arrhenius, Brønsted-Lowry and Lewis acid-base concepts are given. In Section 1.2 the ionic equilibria of weak acids and bases studied. Under this section the concentration of the ionized molecule of a weak acid, its conjugate acid and base are determined from K_a, the dissociation constant of weak acid. The extent of the ionization of a weak acid in solution can be reduced by adding a compound containing the conjugate base of the weak acid (the common ion effect) or by adding another acid. This concept will be studied in Section 1.3. It also includes a buffer solution, a solution containing a mixture of an acid and its conjugate base, or of a base and its conjugate acid. Section 1.4 deals with hydrolysis of salts. The presence of a salt in water may affect the pH of a solution because the cations or the anions of the salt may react with water and produce an inbalance of H_3O^+ and OH^- ions. The last section, Section1.5, emphasizes acid-base indicators and acid-base titration. In this unit, there are suggested activities, experiments and exercises, which make the active learning method practical. To teach contents in this unit, question and answer, gapped lectures, group discussion, demonstrations and experiments are the suggested methodologies.

Unit out comes

After completing this unit, students will be able to:

- *describe the draw backs of Arrhenius acid base concepts,*
- *define Bronsted-Lowery & Lewis concepts of acids and bases*
- *describe the dissociation of water, weak mono-protic and polyprotic acids, and weak bases;*
- *solve equilibrium problems involving concentration of reactants and products, k_a, k_b, pH& pOH*
- *discuss the common ion effect, buffer solution, hydrolysis of salts, acid-base indicators and acid-base titrations*
- *explain how buffering action affects our daily lives using examples*
- *determine the equivalents of acid or base that are required to neutralize a specific amount of acid or base*
- *predict, in qualitative terms, whether a solution of a specific salt will be acidic, basic or neutral*
- *explain how to solve problems involving concentration and pH of acid-base titrations.*
- *write chemical equations to show differences in the three definitions of acids and bases'.*

1.1 Acid-Base Concepts

Periods allotted 5

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

- *define acid by the Bronsted-Lowry concept.*
- *give examples of Bronsted-Lowry acids.*
- *define base by the Bronsted-Lowry concept.*
- *give examples of Bronsted-Lowry bases.*
- *explain what conjugate acids and conjugate bases are.*
- *identify the acid-base conjugate pairs from the given reaction.*
- *write an equation for self-ionization of water and ammonia.*
- *explain what is meant by amphiprotic species.*
- *give examples of reactions of amphiprotic species.*
- *define acid by the Lewis concept.*
- *give examples of Lewis acids.*
- *define base by the Lewis concept.*
- *give examples of Lewis bases.*
- *calculate pH from $[H^+]$and $[H^+]$ from pH.*
- *calculate pOH from $[OH^-]$ and $[OH^-]$ from pOH.*

Forward Planning

Read the contents in Section 1.1 to familiarize yourself with acid-base concepts. Plan which contents and activities you are going to deal with during each period. In your plan, indicate the time you allot for group discussion, presentation, harmonizing concepts, stabilization and other activities you may perform in each period. Also plan how to manage students during group discussions and their presentations. You need to read the teacher's guide on this section to get information about the methodologies to be implemented and to gain more ideas about **Activities 1.1-1.3**.

Subject Matter Presentation

Students have some background knowledge of this concept. The *start-up activity* is given to begin the unit with what students have learned in Grade 10. The startup activity enables the students to recall that acids have a sour taste, changes the color of a few acid-base indicators and also react with metals to produce hydrogen gas. On the other hand bases are often bitter and do not react with metals like acids. Harmonize the observation of the students by giving the generalization that acids change blue litmus to red, methyl orange to red, and phenolphtalein to colorless, while bases change red litmus to blue, methyl orange to yellow and phenolphtalein to pink.

The Arrhenius Concept of Acids and Bases

To teach this topic, group discussion and gapped lecture are the suggested methodologies. As you present the lesson on *Acid-Base Concepts*, start with **Activity 1.1**. The activity enables students to recall the acid-base concepts they learned in grade 10. So, let the students discuss **Activity 1.1** in their groups for a few minutes by recalling what they have learned in Grade 10. Then have students from different groups suggest their opinions to the class. Harmonize concepts suggested by the students with the facts. Before you go to the other concept, discuss the limitations of the *Arrhenius concept* with emphasis on the following points.

The theory can be applied only to reactions that occur in water, because it defines acids and bases in terms of what happens when compounds dissolve in water. It does not give any reason why some compounds, such as HCl, dissolve in water to give acidic solutions, whereas others such as CH_4 do not. The theory states that only compounds that contain OH^- ions can be classified as Arrhenius bases. It cannot explain why other compounds, such as Na_2CO_3, have the characteristic properties of bases.

Brønsted-Lowry Concept of Acids and Bases

Use group discussion and gapped lecture to teach this topic. As you proceed to the next concept, start with **Activity 1.2.** The activity helps students to recall the Brønsted -Lowry concept of acids and bases and understand if there is a difference between this concept and that of Arrhenius. Therefore, let the students do **Activity 1.2** in groups for a few minutes to define the Brønsted-Lowry concept and compare it with that

of Arrhenius definition. Encourage some groups to present their opinion to the rest of the class. To harmonize their discussion, emphasize that the Brønsted - Lowry definition defines acids as proton donors and bases as proton acceptors. Illustrate this by taking a hypothetical acid, HA, which releases a proton and its conjugate base, A^- on dissociation:

$$\underset{\text{base}}{HA} \rightarrow \underset{\text{proton}}{H^+} + \underset{\text{conjugate acid}}{A^-}$$

If a conjugate acid releases a proton, it re-forms the base. In the course of your presentation, discuss that the Brønsted-Lowry approach can be applied to proton transfer reactions that do not happen in an aqueous medium, such as the reaction of ammonia gas with hydrogen sulphide gas:

$$H_2S + NH_3 \rightleftharpoons HS^- + NH_4^+$$

In the forward reaction, H_2S acts as an acid by donating an H^+ to NH_3, which acts as a base by accepting it. In the reverse reaction, the ammonium ion, NH_4^+, acts as an acid by donating an H^+ to the hydrogen sulphide ion, HS^-, which acts as a base. Notice that the acid, H_2S, becomes a base, HS^-, and the base, NH_3, becomes an acid, NH_4^+.

In Brønsted-Lowry terminology, H_2S and HS^- are a **conjugate acid-base pair:** HS^- is the conjugate base of the acid H_2S. Similarly, NH_3 and NH_4^+ are a conjugate acid-base pair: NH_4^+ is the conjugate acid of the base NH_3. Every acid has a conjugate base, and every base has a conjugate acid. For any conjugate acid-base pair:

- The conjugate base has one fewer H and one more minus charge than the acid.
- The conjugate acid has one more H and one fewer minus charge than the base.

Before you conclude your introduction of the Brønsted-Lowery concept of acids and bases, let the students get information about the points (1-3) in **Activity 1.2**. Tell them that all Arrhenius acids, such as HCl, HBr, HI, $HClO_4$, are Brønsted-Lowery acids. But, the reverse is not true. This is because Brønsted-Lowry acids include all substances that can donate a proton (H^+) in aqueous solution or in any other medium or in the gaseous state. Inform them that conjugate acids formed after bases accept a proton are Brøonsted-Lowry acids such as H_3O^+, NH_4^+ etc. Let them also know that all Arrhenius bases commonly contain only one Brønsted-Lowry bases, which is the OH^-. NaOH, KOH etc. are not Brønsted-Lowry bases. Only the OH^- they release is a

base. For example, NH_2^-, S^{-2}, F^-, CN^- are Brønsted-Lowry bases.

Mention the inverse relationship between the strengths of acids and their conjugate bases. The conjugate bases of strong acids tend to be relatively weak bases and the conjugate bases of weak acids tend to be strong bases. Similarly, the stronger the base the weaker is its conjugate acid and the weaker the base, the stronger is its conjugate acid.

Example

Identify the conjugate acid-base pairs.

a. $H_2PO_4^-(aq) + CO_3^{2-}(aq) \rightleftharpoons HCO^-(aq) + HPO_4^{2-}(aq)$

b. $H_2O(l) + SO_3^{2-}(aq) \rightleftharpoons OH^-(aq) + HSO_3^-(aq)$

Solution

(a) $H_2PO_4^-$ has one more H^+ than HPO_4^{2-}; CO_3^{2-} has one fewer H^+ than HCO_3^-. Therefore, $H_2PO_4^-$ and HCO_3^- are the acids, and HPO_4^{2-} and CO_3^{2-} are the bases. The conjugate acid-base pairs are $H_2PO_4^-/HPO_4^{2-}$ and HCO_3^-/CO_3^{2-}.

(b) H_2O has one more H^+ than OH^-; SO_3^{2-} has one fewer H^+ than HSO_3^-. The acids are H_2O and HSO_3^-; the bases are OH^- and SO_3^{2-}. The conjugate acid-base pairs are H_2O/OH^- and HSO_3^-/SO_3.

Autoionization of Substances and Amphiprotic Species

Molecular autoionization (or self-ionization) is a reaction between two identical neutral molecules, especially in a solution, to produce an anion and a cation. If a pure liquid partially dissociates into ions, it is said to be self-ionizing. Water, as we know, is a unique solvent. One of its special properties is its ability to act either as an acid or as a base.

$$\underset{\text{acid 1}}{H_2O} + \underset{\text{base 2}}{H_2O} \rightleftharpoons \underset{\text{acid 2}}{H_3O^+} + \underset{\text{base 1}}{OH^-}$$

Notice that a chemical species is **amphiprotic** if it either donates or accepts a proton. **Amphiprotic species** react with both acids and bases. You may ask the students to give examples of amphoteric species from the knowledge they gained in lower grades.

Lewis Concept of Acids and Bases

It is advisable to use group discussion and gapped lectures for this section. As you move to present the lesson on the *Lewis Concept* of *Acids and Bases*, encourage the students to start with **Activity 1.3**. The activity is aimed at enabling students to recall the Lewis concept of acids and bases and to discover how it differs from the Brønsted-Lowry concept. Let group representatives explain the Lewis acid-base concept to the class. Harmonize their discussion by defining the Lewis acid and Lewis base as follows.

A Lewis acid is an electron-pair acceptor, and a Lewis base is an electron-pair donor. After a Lewis acid accepts an electron pair from a Lewis base, it forms an acid-base adduct. Lewis acids are electron-deficient species such as cations, molecules that have an atom with less than eight outermost electrons and molecules that can expand their octets. Lewis bases are electron-rich species such as anions and molecules with atoms with one or more lone pairs. Let students also get the following information in relation to the points in **Activity 1.3**. Brønsted-Lowry acids are proton (H^+) donors. The Lewis concept of acids considers H^+ as one kind of acid only. According to the Lewis concept, an acid is any species that has a vacant orbital or unfilled shell and can form a coordinate covalent (dative) bond by sharing an electron pair from any other species. The Brønsted-Lowry concept considers species as bases only if they can accept a proton (H^+). For the base to accept a proton, it should have a lone pair of electrons. Thus, Brønsted-Lowry bases are also Lewis bases. However, Lewis bases include all species having a lone pair of electrons and are capable of forming a dative bond by supplying the lone pair not only with H^+, but also with other species. The Brønsted-Lowry concept restricted the definition of acids and bases to proton transfer only. It doesn't explain why species like CO_2, SO_2, Cu^{2+} etc. function as acids even if they do not contain a proton. Let the students practice how to identify Lewis acids and Lewis bases in reactions similar to the ones given in the following example.

Example Identify the Lewis acid and Lewis base in each of the following reactions:

a. $H^+ + OH^- \rightleftharpoons H_2O$

b. $Cl^- + BCl_3 \rightleftharpoons BCl_4^-$

c. $K^+ + 6H_2O \rightleftharpoons K(H_2O)_6^+$

Solution

a. The H^+ ion accepts an electron pair from the OH^- ion in forming a bond. H^+ is the acid and OH^- is the base.

b. The Cl^- ion has four lone pairs and uses one to form a new bond to the central B. BCl_3 is the acid and Cl^- is the base.

c. The K^+ ion does not have any valence electrons to provide, so the bond is formed when electron pairs from O atoms of water enter empty orbitals of K^+. Thus, K^+ is the acid and H_2O is the base.

Assessment

You can assess each student's work as you proceed through the acid-base concept (Section 1.1). To do this, you need to observe and record everything about the performance of each student. You may make a record in your permanent performance list in relation to how each student participates in:

- discussing Activities 1.1-1.3
- presenting ideas or opinions of the group after discussion
- answering questions raised during gapped lectures
- attempting activities given in between gapped lectures

Give them Exercises 1.1-1.4 as class work or homework. Check their work and record their performance. You may also ask students oral questions during stabilizing concepts in each period and record the responses of the students. From the cumulative record you have, make sure that the competencies suggested for Section 1.1 are achieved by most of the students, and praise students working above the minimum requirement level and give them extra activities. With regard to students working below the minimum requirement level, you may arrange extra lesson time or give them additional exercises. You may use questions from the Additional questions below. If necessary, you can prepare additional questions of your own.

Additional Questions

1. Identify the acid-base conjugate pairs in each of the following reactions:

   a. $CN^- + H_2O \rightleftharpoons HCN + OH^-$

   b. $NH_3 + HF \rightleftharpoons NH_4^+ + F^-$

   c. $HCO_3^- + HF \rightleftharpoons H_2CO_3 + F^-$

   d. $OH^- + HCO_3^- \rightleftharpoons H_2O + CO_3^{2-}$

   e. $H_2SO_4 + HClO_4 \rightleftharpoons H_3SO_4^+ + ClO_4^-$

   f. $CH_3NH_2 + HSO_3^- \rightleftharpoons CH_3NH_3^+ + SO_3^{2-}$

   g. $CN^- + H_2CO_3 \rightleftharpoons HCO_3^- + HCN$

2. *What is the conjugate acid or the conjugate base of:

   a. HCl?

   b. CH_3NH_2?

   c. OH^-?

   d. HCO_3^-.?

3. The acid strength of $HCN < CH_3COOH < HF < HNO_2 < HCOOH$. What is the correct increasing order in base strength of the conjugate bases of the acids?

4. Strong acids have weak conjugate bases and weak acids have strong conjugate bases. Why?

5. * Identify the amphiprotic species among the following

   a. NH_3

   b. HCO_3

   c. HS^-

   d. H_2O

   e. NH_4^+

   f. $H_2PO_4^-$

6. What is

   a. the strongest acid and

   b. the strongest base that can exist in aqueous solution?

7. * Indicate whether the following would be expected to serve as either a Lewis acid or a Lewis base:

   a. $AlCl_3$

   b. OH^-

   c. Br–

   d. CO_2

   e. Fe^{3+}

   f. Cu^{2+}

   g. PCl_5

8. In the following reactions, identify the Lewis acid and the Lewis base

   a. $Ag^+ + 2NH_3 \rightleftharpoons Ag(NH_3)_2^+$

   b. $B(OH)_3 + H_2O \rightleftharpoons B(OH)_4^- + H^+$

Answers to Additional Questions

1. a. $CN^- / HCN; H_2O / OH^-$

   b. $NH_3 / NH_4^+; HF / F^-$

   c. $HCO_3^- / H_2CO_3; HF / F^-$

   d. $OH^- / H_2O; HCO_3^- / CO_3^{2-}$

   e. $H_2SO_4 / H_3SO_4^+; HClO_4 / ClO_4^-$

   f. $CH_3NH_2 / CH_3NH_3^+; HSO_3^- / SO_3^{2-}$

   g. $CN^- / HCN; H_2CO_3 / HCO_3^-$

2. a. When HCl donates a proton, Cl^- ion is produced, and so Cl^- is the conjugate base.

   b. CH_3NH_2 is an amine and therefore a weak base. Adding a proton gives $CH_3NH_3^+$, its conjugate acid.

   c. Adding a proton to the strong base OH^- gives H_2O its conjugate acid.

   d. Hydrogen carbonate ion, HCO_3^-, is derived from a diprotic acid and is amphiprotic. Its conjugate acid is H_2CO_3, and its conjugate base is CO_3^{2-}.

3. $CN^- > CH_3COO^- > F^- > NO_2^- > HCOO^-$

4. If the acid is strong, its conjugate base has little tendency to accept a proton and vice-versa.

5. All are amphiprotic, except e

6. a. H_3O^+ b. OH^-

7. Lewis bases: b and c Lewis acids: a, d, e, f and g.

8. a. $\underset{\text{Lewis Acid}}{Ag^+} + \underset{\text{Lewis Base}}{2NH_3} \rightleftharpoons Ag(NH_3)_2^+$

   b. $\underset{\text{Lewis Acid}}{B(OH)_3} + \underset{\text{Lewis Base}}{H_2O} \rightleftharpoons B(OH)_4^- + H^+$

Answers to Exercise 1.1

a. Arrhenius acid

b. Cannot classified as an Arrhenius acid or an Arrhenius base

c. Arrhenius base

d. Arrhenius base

Answers Exercise 1.2

1. a. $\underset{acid}{HClO_2} + \underset{base}{H_2O} \rightleftharpoons \underset{conjugate\ base}{ClO_2^-} + \underset{conjugate\ aicd}{H_3O^+}$

b. $\underset{base}{OCl^-} + \underset{acid}{H_2O} \rightleftharpoons \underset{conjugate\ acid}{HOCl} + \underset{conjugate\ base}{OH^-}$

c. $\underset{base}{H_2O} + \underset{acid}{SO_3^{2-}} \rightleftharpoons \underset{conjugate\ acid}{OH^-} + \underset{conjugate\ base}{HSO_3^-}$

Answers to Exercise 1.3

1. a. Auto-ionization is a reaction that involves the transfer of a proton from one molecule to another molecule of the same substances.

   b. Amphiprotic species are molecules or ions that can act as a proton donor or proton acceptor.

2. a. $H_2PO_4^- + H_2O \rightarrow HPO_4^{2-} + H_3O^+$

   b. $H_2O + H_2PO_4^- \rightarrow OH^- + H_3PO_4$

3. a. $HClO_4 > HCl > HNO_3 > CH_3COOH$

   b. $OH^- > NH_3 > CH_3COO^- > NO_3^- > Cl^-$

4. It restricted an acid-base concept only to proton transfer

5. $NH_3 + NH_3 \rightleftharpoons NH_4^+ + NH_2^-$

Answers to Exercise 1.4

1. a. $\underset{Lewis\ acide}{H^+} + \underset{Lewis\ base}{OH^-} \rightleftharpoons H_2O$

   b. $\underset{Lewis\ base}{Cl^-} + \underset{Lewis\ acide}{BCl_3} \rightleftharpoons BCl_4^-$

   c. $\underset{Lewis\ acid}{K^+} + 6\underset{Lewis\ base}{H_2O} \rightleftharpoons K(H_2O)^+$

d. $\underset{\text{Lewis base}}{OH^-} + \underset{\text{Lewis acid}}{Al(OH)_3} \rightleftharpoons Al(HO)_4^-$

e. $\underset{\text{Lewis acid}}{CO_2} + \underset{\text{Lewis base}}{H_2O} \rightleftharpoons H_2CO_3$

f. $\underset{\text{Lewis acid}}{Ni} + \underset{\text{Lewis acid}}{4CO} \rightleftharpoons Ni(CO)_4$

1.2 Ionic Equilibria of Weak Acids and Bases

(Periods allotted 7)

At the end of this subunit, students will be able to:

- *describe the ionization of water*
- *derive the expression of ion product for water, K_w*
- *explain why water is a weak electrolyte*
- *use K_w to calculate $[H_3O^+]$ or $[OH^-]$ in aqueous solution*
- *write an expression for the percent ionization of weak acids or weak bases*
- *calculate the percent dissociation of weak acids and bases*
- *write the expression for the acid-dissociation constant, K_a*
- *calculate K_a for an acid from the concentration of a given solution and its pH*
- *calculate $[H^+]$ and pH of an acidic solution from given values of K_a and the initial concentration of the solution*
- *write the expression for the base-dissociation constant, K_b*
- *calculate K_b for a base from the concentration of a basic solution and its pOH*
- *calculate the $[OH^-]$ and pOH of a basic solution from a given value of K_b and the initial concentration of the solution.*

Forward Planning

Read the contents given in the student's textbook on the ionic equilibria of weak acids and bases thoroughly and make the appropriate preparation.

Design a plan that shows which contents and activities you are going to deal with in each period in such a manner that you can complete the entire contents within the allotted time. In your plan, indicate the duration of time you may allot for group discussion, presentation, gapped lecture and other activities you perform in each period. In addition, read the teacher's guide on this section to help you get information about the methodologies you can implement to teach this section and to gain more ideas about Activities 1.4-1.6.

Plan how to manage students during discussion and presentation. Make sure that there is a pH meter or a universal indicator paper in your school chemistry laboratory. Prepare the materials required for students to do **Activity 1.5**. You may tell them to bring these materials before the period you intend to deal with this activity.

Subject Matter Presentation

Ionization of Water

Use group discussion and gapped lectures to teach the contents in this topic. As you start the lesson on ionization of water, you may ask the in-text question. Continue your explanation by deriving the ion product of water, K_w, from self-ionization of water. Then let the students know that, in any aqueous solution at 25°C, the product of $[H^+]$ and $[OH^-]$ must always equal 1.0×10^{-14}. Based on this expression, ask the students to write the relationship between $[H^+]$ and $[OH^-]$ in neutral, acidic and basic solutions. Then proceed to **Activity 1.4**. The activity is designed to help students understand how they can write dissociation constant expressions for self-ionization of other substances and identify the strongest acid and base that can exist in liquid ammonia. Encourage the students to derive the K_c for ammonia in analogous to that of K_w starting from self-ionization of ammonia (**Activity 1.4**).

a. $2NH_3 \rightleftharpoons NH_4^+ + NH_2^-$

$$K_c = \frac{\left[NH_4^+\right]\left[NH_2^-\right]}{\left[NH_3\right]^2}$$

b. In liquid ammonia, NH_4^+ is the strongest acid, and NH_2^- is the strongest base.

c. A solution with $\left[NH_4^+\right] > \left[NH_2^-\right]$ is acidic.

The pH Scale

It is preferable to implement gapped lecture inquiry-based learning and group discussion to teach contents in this topic. Start teaching this lesson by using **Activity 1.5**. The activity helps students to learn how to determine the pH of different substances using a paper. Students use litmus paper to do **Activity 1.5**. Tell them to collect the materials given in the table and determine whether they are acidic, basic or neutral from their color changes. Harmonize their discussion by comparing their results with the following table.

Substance	Color Change	Acidic, Basic or Neutral
Beer	Red color	Acidic
Milk of magnesia	Blue color	Basic
Tomato juice	Red color	Acidic
Lemon juice	Red color	Acidic
Drinking water	Colorless	Maybe acidic, basic or neutral

Measures of Strength of Acids and Bases in Aqueous Solution

It is advisable to use group discussion, gapped lecture, and question-and-answer as methodologies to teach the contents in this topic. After introducing Measures of the Strengths of Acids and Bases in Aqueous Solution, continue with **Activity 1.6.** The activity helps students to recall strong and weak acids, and strong and weak bases. So, let your students get involved in presenting their work on **Activity 1.6**. It is recommended that this activity be assigned ahead of time. In connection with to this activity, explain to them that the strength of acids and bases can be measured by the concentration of hydrogen ion and hydroxide ion, pH and pOH, percent ionization, and information from the student's textbook. Illustrate, with several numerical examples, how to calculate the dissociation constant from the concentration of the solution and vice versa. **Tables 1.2** and **1.3** in the student's textbook list some weak acids and bases and their Ka and Kb values respectively. Important guidelines are given in the student's text to help the students to solve weak acid dissociation problems. Explain to the students that such problems can be treated in two ways: the approximation method and the second is the quadratic equation if the approximation is not valid.

You can use the examples given in the students' textbook to illustrate the calculations.

Assessment

Assess each student's work as you proceed throughout Section 1.2, Ionic equilibria of Weak Acids and Bases. You can do this by recording how every student is doing, using your permanent performance list. Your records can be based on how every student:

- participates in discussing and performing Activities 1.4-1.6
- participates in presenting opinions and findings of the group after discussion
- in answering questions raised during the process of harmonizing concepts or during gapped lectures
- in performing activities given between the gapped lectures.

Give them Exercises 1.5, 1.6 and 1.8 as homework. Check their work and record their performances. You may also give them a test on this section. Correct it and record their achievements. From the record you have, check whether or not the competencies suggested for this section are achieved by most of the students. Praise students working above the minimum requirement level and give them Exercise 1.7 as an additional exercise. For students working below the minimum requirement level, you may give the following exercise.

1. What is the hydroxide ion concentration in a solution that has 0.10 M H_3O^+?
2. A student prepared a 0.01 M solution of formic acid, methanoic acid, $HCHO_2$, and measured its pH using a pH meter. The pH at 25 ^oC was found to be 2.38.
   a. Calculate Ka value for formic acid at this temperature.
   b. What percent of the acid is ionized in this 0.10M solution?

You can also give them the questions recommended for low ability.

Additional Questions

1. A sample of orange juice has a hydronium-ion concentration of 2.9×10^{-4} M. What is the pH? Is the solution acidic?
2. The pH of human arterial blood is 7.40. What is the hydronium-ion concentration?
3. Nicotinic acid (niacin) is a monoprotic acid with the formula $HC_6H_4NO_2$. A solution that is 0.012 M in nicotinic acid has a pH of 3.39 at 25 ^{0}C. What is the acid-ionization constant, Ka, for this acid at 25 ^{0}C? What is the degree of ionization of nicotinic acid in this solution?
4. Morphine, $C_{17}H_{19}NO_3$, is administered medically to relieve pain. It is a naturally occurring base, or alkaloid. What is the pH of a 0.0075 *M* solution of morphine at 25 ^{0}C? The base ionization constant, K_b, is 1.6×10^6 at 25 ^{0}C.
5. The degree of ionization of acetic acid, $HC_2H_3O_2$, in a 0.10 M aqueous solution at 25 ^{0}C is 0.013. *Ka* at this temperature is 1.7×10^{-5}. Calculate the degree of ionization of $HC_2H_3O_2$ in a 0.10 M solution at 25 ^{0}C to which sufficient HCl is added to make it 0.010 M HCl. How is the degree of ionization affected?
6. A solution is prepared to be 0.10 M acetic acid, $HC_2H_3O_2$, and 0.20 M sodium acetate, $NaC_2H_3O_2$. What is the pH of this solution at 25 ^{0}C? K_a for acetic acid (ethanoic acid) at 25 ^{0}C is 1.7×10^{-5}
7. A 0.1M solution of nitrous acid (HNO_2) is 7.1% ionized at equilibrium. What is the
   a. $[H^+]$ and pH
   b. Ka value and HNO_2
   c. $[OH^-]$ and pOH
8. The pH of a 0.012 M solution of a weak based, BOH, was determined to be 11.40. What is the K_b value of the base?
9. The Ka values of CH_3COOH, HCOOH, HOCl and HOBr are 1.8×10^{-5}, 1.7×10^{-14}, 3.0×10^{-8} and 2.5×10^{-9}, respectively. A 0.06 M solution of which acid solution
   a. is the most acidic
   b. has the smallest pH value
   c. contains the lowest concentration of H^+
   d. the lowest pOH value?

Answers to additional questions

1. pH = 3.54, the pH is less than 7.00, so the solution is acidic (as you expect for orange juice).
2. $[H_3O^+] = 4.0 \times 10^{-8}$ M
3. Percent ionization = 0.034
4. pH = 10.04
5. The degree of ionization of $HC_2H_3O_2$ = 0.0017. This is much smaller than the value for 0.10 *M* H $C_2H_3O_2$ (0.013), because the addition of HCl represses the ionization of $HC_2H_3O_2$.
6. pH = 5.07
7. a. $[H^+] = 7.1 \times 10^{-3}$ M; pH = 2.15 b. Ka = 5.4×10^{-4}
   c. $[OH^-] = 1.4 \times 10^{-12}$ M; pOH = 11.85
8. $K_b = 6.6 \times 10^{-4}$
9. a. HCOOH b. HCOOH c. HOBr d. HOBr.

Answer to Exercise 1.5

1. a. $[OH^-] = 1.0$ x1 0^{-7}M, neutral
   b. $[H^+] = 1.0 \times 10^{-10}$ M, basic
   c. $[H^+] = 1.0 \times 10^{-4}$ M, acidic
2. a. 5.0×10^{-10} M
   b. 5.0×10^{-7} M
   c. 1.0×10^{-8} M
3. 1.49×10^{-12}, basic
4. Because, it dissociates only slightly.

Answers to Exercise 1.6

1. $[H^+] = 6.6 \times 10^{-10}$
   $[OH^-] = 1.5 \times 10^{-5}$
   pOH = 4.82
2. For 2.0 M HNO_3
   $[H^+]$ = 2.0 M, pH = -0.30, pOH = 14.30, $[OH^-] = 5.0 \times 10^{-5}$ M
   For 0.30 M HNO_3
   $[H^+]$ = 0.3 M, pH = 0.52, pOH = 13.48, $[OH^-] = 3.3 \times 10^{-14}$ M
   For 0.0063 M HNO_3
   $[H^+]$ = 0.0063 M, pH = 2.20, pOH = 11.80, $[OH^-] = 1.6 \times 10^{-12}$ M

Answer to Exercise 1.7

1. percent ionization = 1.29 %
2. pH = 2.87
3. a. $HNO_2 + H_2O \rightleftharpoons NO_2^-(aq) + H_3O^+(aq)$
   b. X = $[H_3O^+] = 4.0 \times 10^{-3}$ M

   Test for approximation $\frac{4.0 \times 10^{-3}}{0.036} \times 100 = 11\%$
   c. Using quadratic equation
   X = $[H_3O^+] = 3.8 \times 10^{-3}$ M
   d. pH = 2.42

Answer to Exercise 1.8

1. a. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
   b. $[NH_4^+] = [OH^-] = 2.7 \times 10^{-3}$ M

   c. Approximation $\frac{2.7 \times 10^{-3}}{0.40} \times 100 = 0.68\%$ Approximation is valid
   d. pOH = 2.57
   pH = 11.43

1.3 Common Ion Effect and Buffer Solution

(Periods allotted 6)

At the end of this subunit, students will be able to:

- *define the common-ion effect*
- *explain the importance of the common-ion effect*
- *define buffer solution*
- *give some common examples of buffer systems*
- *explain the action of buffer solutions and its importance in chemical processes*
- *calculate the pH of a given buffer solution*
- *demonstrate the buffer action of CH_3COOH/CH_3COONa.*

Forward Planning

Read the contents in the students' text thoroughly on common ion effect and buffer solutions. This will help you to recall Le Chatelier's principles, since it is related to the common ion effect. There is also information about buffer solutions. Next, prepare a plan of your own that shows the contents, activities and experiments you are going to deal with during each period so that you can cover the entire contents of the section within the allotted time. In your plan, indicate the duration of time required for group discussion, presentation, gapped lecture and other activities you perform during every period. Read the teacher's guide on this section to get more information about Activities 1.7 and 1.8 and the methodologies you use to teach the contents. Prepare the chemicals, apparatus and other materials required to perform Experiment 1.1.

Teaching Aids

Refer to the text for the materials required to carry out Experiment 1.1.

Subject Matter Presentation

The Common ion Effect

You can use group discussion, enquire learning and question-and-answer methods to teach contents in this part. As you start teaching The Common ion Effect, let the students review Le Chatelier's principle by doing **Activity 1.7.** This activity helps the students to see the effect of concentration, temperature and pressure on chemical equilibrium. Let them read Grade 11 chemistry book and other references to do this activity. After they discuss and present their report to the class, harmonize their discussion. Connect the common ion effect with **Activity 1.7** by using the example given in the students' textbook. In this example, the addition of sodium acetate (sodium ethanoate), $NaC_2H_3O_2$, to a solution of acetic acid(ethanoic acid), $HC_2H_3O_2$, at equilibrium causes the equilibrium to shift to the left, thereby decreasing the equilibrium concentration of $H^+(aq)$. This indicates that the dissociation of a weak electrolyte is decreased by adding to the solution a strong electrolyte that has an ion in common with the weak electrolyte. Give them additional dissociation reactions of weak electrolytes and let them discuss the effect of adding strong electrolytes having common ions with the weak electrolytes. You can use Question number 1 from the additional questions and let students suggest the effect of adding a solution of HCOOK to that of HCOOH. Then, harmonize their suggestion based on the answer given in this guide

Buffer Solutions

Use group discussion, question-and-answer, and experiment as methodologies to teach this part. Start you discussion on *Buffer Solution* by defining the term "buffer". The acetic acid/sodium acetate solution can be used to explain the common ion effect. A buffer solution is a solution that changes pH only slightly when a small amount of a strong acid or a strong base is added. Buffered solutions contain a conjugate weak acid-base pair. The acidic member consumes a small amount of added base, while the basic member consumes small amounts of added acid. In the students' textbook, you can get information about how buffers work. Read this part and explain it to the students. Explain briefly the use of buffered solutions by taking human blood as an example. Buffers are important in our blood and other body fluids. Cells in living organisms must maintain a proper pH in order to carry out essential life processes,

primarily because enzyme function is sharply dependent on pH. The normal pH value of blood plasma is 7.4. Sustained variations of a few tenths of pH unit can cause severe illness or death. Decrease in blood pH causes the condition called "acidosis" which can be brought on by heart failure, kidney failure, diabetes, persistent diarrhea or other factors. Similarly, alkalosis, characterized by an increase in the pH of blood may result from severe vomiting, excessive breathing (hyperventilation), and others. The major buffer system used to control the pH of blood is the carbonic acid-bicarbonate buffer system. Carbonic acid, H_2CO_3, and bicarbonate, HCO_3^-, form a conjugate acid base pair.

Note for the Teacher

The Henderson-Hasselbalch equation may be applied to solve buffer-system problems. This equation can be derived by considering the acid dissociation reaction of *HA*:

$$HA + H_2O \rightleftharpoons H_3O^+ + A^-$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

The key variable that determines $[H_3O^+]$ is the concentration ratio of acid species to base species, so, rearranging to isolate $[H_3O^+]$ gives.

$$[H_3O^+] = K_a \frac{[HA]}{[A^-]}$$

Taking the negative common (base 10) logarithm of both sides gives

$$-\log[H_3O^+] = -\log K_a - \log\left(\frac{[HA]}{[A^-]}\right)$$

from which definitions gives $pH = pK_a - \log\frac{[HA]}{[A^-]}$

Then, because of the nature of logarithms, when we invert the buffer-component concentration ratio, the sign of the logarithm changes, to give.

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

Generalizing the previous equation for any conjugate acid-base pair gives the Henderson-Hasselbalch equation:

$$pH = pK_a + \log\left(\frac{[base]}{[acid]}\right)$$

This relationship is very useful for two reasons.

1. It allows us to solve directly for pH instead of having to calculate $[H_3O^+]$ first.
2. It allows us to prepare a buffer of a desired pH just by mixing the appropriate amounts of A^- and HA.

Example

a. What is the pH of a buffer solution that is 0.25 M in HF and 0.50 M in NaF?

b. What is the final pH if 3.0 mL of 2.0 M HCl is added to 100 mL of the buffer solution in (a) above?

Solution:

a. To determine the pH in part (a), we will use the same method that we used in introducing the common ion effect, although we could use the Henderson Hasselblach equation. Because NaF is a strong electrolyte and dissociates completely, 0.50 M NaF gives 0.50 M F^-. [HF] = 0.25 M. Substituting these values in a Henderson - Hasselbalch equation.

$$pH = pK_a + \log\left(\frac{[base]}{[acid]}\right)$$

$$\text{pH} = -\log 6.8 \times 10^{-4} + \log\left(\frac{0.50}{0.25}\right)$$

$$pH = 3.15 + \log\left(\frac{0.50}{0.25}\right) = 3.45$$

b. Since HCl is a strong electrolyte, it is completely ionized to give H^+, which consumes F^- ions and generates additional HF. The number of moles of H^+ added in the form of HCl is:

$0.003\ L \times 2.0\ M = 0.006\ mol\ H^+$.

The number of moles of HF originally present in 100 mL of buffer is:

$0.100\ L \times 0.25\ mol/L = 0.025\ mol\ HF$

The number of moles of F^- originally present in 100 mL of buffer is:

$0.100\ L \times 0.50\ mol/L = 0.050\ mol\ F^-$

After the addition of 0.006 moles of H^+, 0.006 mol H^+ consumes 0.006 mol F^- and generates 0.006 mol HF.

Therefore, the number of moles of HF is: $0.025 + 0.006 = 0.031$ mol.

The number of moles of F^- is: $0.050 - 0.006 = 0.044$ mol.

Then we find the [HF] and [F^-] in the total volume of 3.0 mL + 100 mL = 103 mL = 0.103L.

$$[HF] = \frac{0.031\ mol}{0.103\ L}$$

$$[F^-] = \frac{0.044\ mol}{0.103\ L}$$

Using the equation:

$$pH = pK_a + \log \frac{[F^-]}{[HF]}$$

$$pH = 3.15 + \log \frac{\left[0.044\ mol/L \,/\, 0.103L\right]}{\left[0.031 \,/\, 0.103L\right]} = 3.30$$

Assessment

Assess each student's work as you proceed through the contents of section 1.3. Your close follow-up is crucial. See how every student is working during the teaching learning process. To do this, use your permanent performance list to record how every student:

- participates in discussing Activities 1.7
- participates in presenting opinions of the group to the rest of the class
- answers questions raised during the process of harmonizing concepts, mini lectures and stabilization
- takes part in performing Experiment 1.1
- participates in presenting results and observations from the experiment

Give Exercise 1.9 to low ability students and Exercise 1.10 to higher ability students. Check their exercise books and rescore their results. From the record you have, check whether or not the competencies suggested for Section1.3 are accomplished by most of the students. Praise students working above the minimum requirement level and encourage them to continue working hard. Arrange extra lesson time or give additional exercises to students working below the minimum requirement level. You may use questions recommended to them from the Additional questions given below to help these students catch up with the rest of the class.

Additional Questions

1. * Which of the following solutions can be classified as buffer systems?
   a. KH_2PO_4/H_3PO_4 b. $NaClO_4/HClO_4$
2. *a. Calculate the pH of a buffer system containing 1.0 M CH_3COOH and 1.0 M CH_3COONa.
   b. What is the pH of the buffer system after the addition of 0.10 mole of gaseous HCl to 1.0 L of the solution? Assume that the volume of the solution does not change when the HCl is added.
3. * What is the effect of adding potassium formate, HCOOK, to a 0.1M solution of formic acid, HCOOH? Explain the effect on:
   a. the dissociation of HCOOH,
   b. the $[H^+]$,
   c. the pH value of the solution.

4. What are the components of a buffer solution?
5. A buffer solution consists of 0.5 M CH_3COOH and 0.5 M CH_3COONa. Using a chemical equation, show how this buffer resists the change in pH upon addition of little amount of
   a. NaOH to the buffer
   b. HCl to the buffer

Answers to additional questions

1. a. H_3PO_4 is a weak acid, and its conjugate base, $H_2PO_4^-$, is a weak base. Therefore, this is a buffer system.

   b. Because $HClO_4$ is a strong acid, its conjugate base, ClO_4^- , is an extremely weak base. This means that the ClO^- ion will not combine with a H^+ ion in solution to form $HClO_4$. Thus, the system cannot act as a buffer system.

2. a. pH = 4.74
   b. pH = 4.66
3. a. The dissociation HCOOH decreases due to the common ion $HCOO^-$, which shifts the equilibrium to the left.
   b. The [H+] decreases. That is because it combines with $HCOO^-$ to for HCOOH.
   c. c. The PH value of the solution increases.
4. A weak acid and its conjugate base or a weak base and its conjugate acid.
5. a. $CH_3COOH + OH^- \rightleftharpoons CH_3COO^- + H_2O$
   b. $CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$

Answer to Exercises 1.9

1. pH = 4.92
2. pH = 2.72

Answers to Exercises 1.10

1. a. 4.74
   b. 4.74
   c. 4.75
   d. 4.74
   e. i. 10.99
      ii. 3.0

1.4 Hydrolysis of Salts

Periods allotted 2

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

- *define hydrolysis*
- *explain why a salt of weak acid and strong base gives a basic solution*
- *explain why a salt of strong acid and weak base gives an acidic solution*
- *explain why salts of weak acids and weak bases give acidic, basic or neutral solutions.*

Forward Planning

Make the necessary preparations for the hydrolysis reaction of different types of salts with water. You may read the students' textbook and other relevant reference materials to do this. See below for information about Activities 1.8 and 1.9 and to learn how you can present the contents.

Subject Matter Presentation

Use group discussion and gapped lectures to teach the contents in this section. Start this subtopic with the definition of salt hydrolysis. We can assume that, when salts dissolve in water, they are completely ionized; nearly all salts are strong electrolytes. Consequently, the acid–base properties of salt solutions are due to the behavior of their cations and anions. Many ions are able to react with water to generate $H^+(aq)$ or $OH^-(aq)$. This type of reaction is often called **hydrolysis**. After introducing these concepts, write the formula of sodium chloride, NaCl, on the board. Then ask the students to write the ionization of NaCl in solution and predict what the nature of its aqueous solution would be. Invite one or two students to present their opinion. Following their presentation, tell them that NaCl is a salt of strong acid (HCl), and strong base, NaOH which ionizes as follows:

$$NaCl(aq) \rightarrow Na^+(aq) + Cl^-(aq)$$

Neither Na^+ nor Cl^- reach with water. Thus, a solution of NaCl in water is neutral.

After that, continue with hydrolysis of salts of weak acids and strong bases. Start the lesson on this topic with **Activity 1.8**. The activity may help the students to identify the nature of the solution that a given salt forms by knowing the acid and base from which the salt is formed. Have the students discuss **Activity 1.8** for a few minutes and some groups present their opinions to the class. After the presentations, harmonize concepts. Tell them that Na_2CO_3 is a salt of a strong base, sodium hydroxide, and a weak acid, carbonic acid. So, its solution in water will be basic. This is because the anions of the salt react with water and produce OH^- as follows:

$$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$$

In relation to hydrolysis of salts of strong acids and weak bases, write the formula $(NH_4)_2 SO_4$ on the blackboard and let students identify the parent acid and base, the ion that can be hydrolyzed and the nature of the solution. Invite one or two students to suggest their opinions. After their responses, have them know that $(NH_4)_2 SO_4$ is a salt of a weak base, NH_3 and a strong acid, H_2SO_4. So, it ionizes in aqueous solution into NH_4^+ and SO_4^{2-}. The NH_4^+ is a conjugate acid of a weak base and hydrolyzes to a greater extent and make the solution acidic. The hydrolysis reaction is:

$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$$

Next, continue with hydrolysis of salts of weak acids and weak bases. Start this lesson with **Activity 1.9**. The activity is given to students so that they can compare the K_a and K_b values of the anions and cations in order to know whether the salts under consideration form acidic, basic or neutral solutions. Have the students discuss this activity in groups for a few minutes and some groups present their opinion to the class. To harmonize concepts, tell them that, if $K_a > K_b$, the salt solution is acidic, and if $K_b > K_a$, the salt solution is basic, and if $K_a = K_b$ the salt solution is neutral. So, the solution of NH_4F is acidic because $K_a > K_b$, the solution of NH_4CNS is basic because $K_b > K_a$, and the solution of CH_3COONH_4 is neutral because $K_a = K_b$.

Assessment

Use **Activity 1.8** and **Activity 1.9** as a means of assessment. Check whether they did these activities and record their results. You may give them the Additional Questions from below and check their work and record their achievements. Based on this, see whether or not the competencies suggested for Section 1.4 are achieved by most of the students.

Additional Questions

1. What is salt hydrolysis?
2. *Identify the salts whose aqueous solutions are acidic, basic or neutral among the following:
   a. K_2SO_4
   b. K_2CO_3
   c. $(NH_4)_2SO_4$
   d. NH_4Cl
   e. $NaNO_3$
   f. NaCN

Answers to Additional Questions

1. The reaction of cation or anion or both with water.
2. 'a' and 'e' form neutral solution. 'b' and 'f' form basic solution. 'c' and 'd' acidic solutions.

1.5 Acid–Base Indicators and Titrations

Periods allotted 6

At the end of this subunit, students will be able to::

- *define acid–base indicators*
- *write some examples of acid–base indicators*
- *suggest a suitable indicator for a given acid–base titration*
- *explain the equivalents of acids and bases*
- *calculate the normality of a given acidic or basic solution*
- *define acid–base titration*
- *distinguish between end point and equivalent point*
- *discuss the different types of titration curves.*

Forward Planning

Read the student's textbook and other relevant references in order to understand acid-base indicators, equivalents of acids and bases and acid-base titration. Make a plan that shows which contents, activities and experiment you may deal with during each period in such a manner as to complete the entire contents of this section within the allotted time. In your plan, indicate the duration of time allotted for group discussion, presentation, harmonizing concepts and other activities you perform in each period.

Subject Matter Presentation

Acid–Base Indicators

Use gapped lectures as the teaching method for this topic. Here you may think of some relevant issue or question to brainstorm about with your students. Then continue by explaining to the students that an acid–base indicator is a weak acid or weak base with its corresponding conjugate pair. Mention that the molecular form of the indicator, HIn, has one color and that the ionic form, In^-, has a different color. The color that is observed in a solution of the indicator is controlled by the ratio of [HIn] to $[In^-]$, which is determined, in turn, by the H^+ concentration in the solution.

Equivalence of Acids and Bases

It is preferable to use group discussion and question and answer as the methodologies to teach this topic. Start teaching the lesson on this topic by using **Activity 1.10.** The activity is aimed at assisting students to realize what an equivalent of an acid and a base is and how to obtain their equivalent masses.

Let the students do **Activity 1.10** in their groups for a few minutes and present their opinions to the class. After the presentations, harmonize concepts. An equivalent of an acid is the mass of the acid that releases one mole in solution or reacts with one mole of completely. Likewise, an equivalent of a base is the mass of the base that produces one mole of or accepts one mole. For an oxidation reduction reaction, one equivalent is the quantity of a substance that will react with or yield 1 mol of electrons. Note that the equivalent is defined in terms of a reaction, not merely in terms of the formula of a compound.

Discuss the difference between equivalent mass and molecular mass of a substance. The equivalent mass of a substance is the mass in grams of 1 equivalent of the substances. Illustrate this by using the following examples. Sulphuric acid dissociates in water as follows:

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

From the equation, it can be noted that one mole of H_2SO_4 releases two moles of H^+. Thus, one mole of H_2SO_4 is 98 g/mol while its equivalent mass is 49 g/equivalent. From this, we can conclude that:

$$\textbf{Equivalence mass}(\textbf{g}) = \frac{\textbf{molar mass } (\textbf{g})}{\textbf{number of equivalents per mole}}$$

Write the following chemical equations on the board and let the students determine the equivalent masses of Ba $(OH)_2$ and Fe_2O_3.

a. $Ba(OH)_2(aq) \rightleftharpoons Ba^{2+}(aq) + 2OH^-(aq)$

b. $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$

Let the students know the difference between molarity and normality in relation to the difference between equivalent mass and molecular mass.

Normality = Molarity × Number of equivalents

Let the students also know that during an acid−base neutralization reaction, one equivalent of an acid can neutralize one equivalent of the base. When neutralization is complete, the number of equivalents of the acid is exactly equal to that of the base. The formula; $N_1V_1 = N_2V_2$ proves this fact. They should also know that one mole of an acid may not necessarily neutralize one mole of a base.

Additional Questions

1. * An indicator, HIn, has an ionization constant, K_{In} equal to 1×10^{-5}. If the molecular form of the indicator, HIn, is yellow, and the In^- is green, what is the color of a solution containing this indicator when its pH is:
   a. 3 b. 7 c. 5

2. In an acid–base, titration why is the pH at the equivalence point as follows:
   a. equals 7 for strong acid–strong base titration
   b. is less than7 for strong acid–weak base titration
   c. is greater than 7 for weak acid–strong base titration?

3. * 50 mL of a 0.1M HNO_3 is titrated with a 0.05M KOH solution. What is the pH of the following?
   a. the acid solution before adding KOH solution
   b. the acid solution after 50 mL of KOH solution has been added to it.

Answers to Additional Questions

1. a. yellow b. green c. yellowish–green
2. a. Neither the anion of the acid nor the cation of the base reacts with water.
   b. Because the cation divided from the base undergoes hydrolysis and increases [H+].
   b. Because the anion derived from the acid undergoes reaction with water and increases the $[OH^-]$.
3. a. pH = 1 b. pH = 1.6

Answers to Review Questions and Problems

Part I

1	a	5	b	9	b	13. c
2	a	6	c	10	a	14. a
3	b	7	b	11	b	15. c
4	c	8	d	12.	c	

Part II

1. a. Arrhenius concept

   An acid is the substance that releases H^+ or H_3O^+ in aqueous solution. A base is the substance that releases the hydroxide ion, OH^-, in aqueous solution.

   b. Brønsted−Lowry concept

   An acid is a proton donor

   A base is a proton acceptor

   c. Lewis concept

   d. An acid is an electron pair acceptor, A base is an electron pair donor

2. a. HBr, Bronsted −Lowery acid; H_2O, Bronsted −Lowery base

   b. H_2O, Bronsted −Lowery acid; CN^-, Bronsted -Lowery base

3. The Bronsted -Lowery acid - base pairs

   a. $H_3PO_4/H_2PO_4^-$ and H_2O/H_3O^+

   b. CO_3^{2-}/HCO_3^- and H_2O/OH^-

   c. $H_3PO_4/H_2PO_4^-$ and $NH_3/NH4^+$

4. BF_3 ---------- acid, CO_2 ---------- acid

   F^- ---------- base, OH^- ---------- base

5. a. KOH Strong base

   b. $(CH_3)_2CHCOOH$ Weak acid

   c. H_2SeO_4 Strong acid

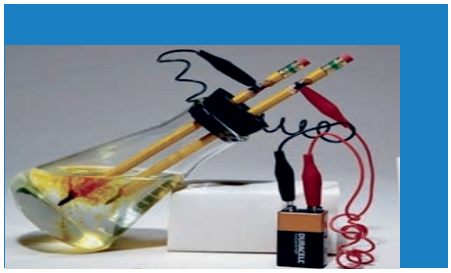
   d. $(CH_3)_2CHNH_2$ weak base

6. b, c and f
7. $[OH^-] = 3.3 \times 10^{-11}$ M

   Because $[H_3O^+] > [OH^-]$, the solution is acidic
8. Percent ionization = 6.5 %
9. $[H_3O^+] = 2.0 \times 10^{-3}$ M

   Because the $[H_3O^+] = 2.0 \times 10^{-3}$ M is larger than the $[OH^-]$ of 5.0×10^{-12} M, the solution is acidic
10. pH = 4.74

UNIT 2



Electrochemistry

Unit Overview

We know that electrochemistry studies the inter-conversion of electrical energy and chemical energy and is also highly applicable to our daily life. At tertiary education level, it is given as a separate field of study. Even at this introductory level, this unit is very broad and has five major subunits. The subunits are organized from simple to complex.

The first subunit discusses oxidation–reduction reaction and explains oxidation, reduction, and balancing redox reactions using change in oxidation number and ion electron methods. The second subunit focuses on electrolysis of aqueous solutions. This subunit deals with how electrical energy is used to bring about chemical change. To clarify this important concept, the electrolysis of molten sodium chloride and aqueous solutions of different compounds are briefly discussed and some are given in the form of activities. The third subunit explains the quantitative aspects of electrolysis. In this subunit, the Faraday's first and second laws are briefly discussed using examples. Students should apply these laws by calculating the amount of substance deposited at the cathode and anode. The fourth subunit discusses the industrial applications of electrolysis. It focuses on how electrolysis contributes to the development of corrosion resistant materials using electroplating. It also lets students explain how very reactive metals, nonmetals and important compounds are produced by electrolysis methods. The last subunit deals with galvanic or voltaic cells. It shows how galvanic cells convert chemical energy into electrical energy. It also discusses how standard reduction potentials and cell potentials can be determined practically and theoretically. It explains the different types of battery that are very useful in our daily life.

Finally, it introduces corrosion and gives opportunity to the students to discuss mechanisms of preventing corrosion. In these days, the methods of teaching are shifted from traditional lecture method, which gives little emphasis to students' participation in teaching-learning process, to active learning methods. The key concept in active learning is that *knowledge* is not transferred; information is transferred but *knowledge is created* when a student thinks about the information. Hence in active learning you should provide your students with opportunities to do some work based on the ideas you have given them or from what they already know.

Generally, this unit acquaints students with new concepts that they might not encounter in lower grades. Therefore, active learning methods such as group discussion, gapped lecture, role play, brainstorming, independent work, and other appropriate methods are highly recommended to help the students grasp the concepts of this unit.

Unit Outcomes

After completing this unit, students will be able to:

- *describe the fundamental concepts related to oxidation-reduction reaction*
- *explain the application of redox reactions in production of new substances and energy*
- *demonstrate an understanding of fundamental concepts related to the interconversion of chemical and electrical energy*
- *distinguish between metallic conduction and electrolytic conduction;*
- *identify and describe the functioning of the components of electrolytic and galvanic cells*
- *distinguish difference between electrolytic and galvanic cells;*
- *apply Faradays laws to solve problems associated with electrolysis experiment*
- *measure through experimentation the mass of metal deposited by electroplating (e.g.:- copper from copper (II) sulphate), and apply Faraday's law to relate the mass of metal deposited to the amount of charge passed*
- *predict the spontaneity of redox reactions and overall cell potentials by studying a table of half-cell reduction potentials.*

- *determine the emf of an electrochemical cell experimentally or from given data*
- *explain the application of electrochemistry in our daily lives and in industry*
- *explain corrosion as an electrochemical process, and describe corrosion-inhibiting techniques (e.g. painting, galvanizing, cathodic protection)*
- *describe examples of common galvanic cells & evaluate their environmental and social impact*
- *demonstrate scientific enquiry skills along this unit: observing, classifying, comparing and contrasting, communicating, asking question, measuring, relating cause and effect and problem solving.*

2.1 Oxidation-Reduction Reaction

Periods allotted 5

Competencies

At the end of this subunit, students will be able to:

- *define a redox reaction*
- *define oxidation in terms of electron transfer and change in oxidation number*
- *define reduction in terms of electron transfer and change in oxidation number*
- *describe the oxidizing and reducing agents*
- *identify the species that are oxidized and reduced in a given redox reaction and determine the oxidizing and reducing agents.*

Forward Planning

This section requires your previous reading about oxidation-reduction reactions and balancing redox reactions using change in oxidation number and ion electron methods. The contents of this topic are thoroughly discussed in the student text. So, read the text before you begin this subunit. Make sure that all the necessary materials and chemicals are available for the reaction of iron key with copper (II) sulphate solution.

Teaching Aids

Small beakers, iron metal or iron key, and 1M copper (II)sulphate solution

Subject Matter Presentation

For this subunit, it is possible to use gapped lecture, group discussion, presentation, and demonstration as active learning methods. You can start this topic by grouping students and letting them discuss the **start-up activity**. The start-up activity helps them to define oxidation-reduction reactions, and to identify redox reactions occurring in their body and the surroundsings. In addition, it motivates them to associate redox reactions with their daily life. You can facilitate their discussion by clarifying misconceptions (if any). After their discussion, allow them to share their ideas with other groups. The answers for the start-up activity questions are:

1. Redox reactions involve loss and gain of electrons simultaneously by atoms, molecules or ions.
2. Some of the redox reactions occurring in our body, and the surroundings are: respiration, photosynthesis, corrosion, decay and combustion. Since students have learnt redox reactions in Grade 10 Chemistry, they are expected to define redox reactions and give examples of redox reactions. At this stage, students are familiar with respiration (oxidation of glucose) in biology lessons and they may give it as an example. Ask them to identify the oxidizing and reducing agents in respiration.

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

In respiration, glucose is oxidized (reducing agent) and oxygen is reduced (oxidizing agent). Alternatively, you can give brief lecture about redox reactions for fifteen minutes (gabbed lecture) and then give them the chance to list down redox reactions from their daily life. Encourage them to form groups and do **Activity 2.1.** This activity is intended to help students to:

1. distinguish redox and non-redox reactions.
2. identify oxidized substance (reducing agent) and reduced substance (oxidizing agent)
3. calculate the oxidation state of each atom in a given chemical formula.

Inform them to assign group representatives for class presentation. You can help them by facilitating group presentations and giving feedback to the class. Try to harmonize their views by providing the following answers of **Activity 2.1.**

1. The reaction in (a) is redox reaction. In this reaction, Ca is oxidized and hydrogen is reduced. However, the reaction in (b) and (c) are non-redox reactions because there is no change in oxidation state.
2. a. Mg b. Zn^{2+} c. Zn^{2+} d. Mg
3. a. +3 b. +6 c. +7

Balancing Oxidation-Reduction (Redox) Reactions

For this topic, it is advisable to use gapped lecture, group discussion, and presentation as active learning methods. This section requires the concepts of the previous section. Therefore, make sure that students do not have problems in identifying redox reactions and in determining oxidation numbers. The change in oxidation number method requires different steps. Discuss these steps with them and illustrate the application of these steps using **Examples 2.1 and 2.2**. Then, group the students and give them **Exercise 2.1** to balance the equations. Finally, provide an opportunity to students to show how they balanced the chemical equations on the blackboard. Similarly, the ion–electron method requires different steps. Explain these steps to the students and show them how equations are balanced by this method in acidic media**.** Then, tell students to balance the half reactions in **Exercise 2.2** independently, and finally give a chance to the students to present how they balanced the chemical equations to their classmates on the blackboard. Give them feedback in each case.

Note for the Teacher

A substance that accepts electrons (*being reduced*) causes another substance to oxidize, and it is called the **oxidizing agent**. A substance that loses electrons (being oxidized) causes another substance to get reduced, and it is called a **reducing agent**. We find oxidation-reduction reactions in our everyday life. For example, photosynthesis, respiration, corrosion, decay, and combustion are among the many natural processes that involve redox reactions. Redox reaction also occurs in batteries when these are used to provide electrical power, when bleaches are used to remove stains and when antiseptics are used on wounds etc.

Assessment

Assess each student's work continuously throughout the subunit. This can be achieved by recording the performance of every student. You can make records based on students' performance in: discussing the Start-up activity and **Activity 2.1**, and presenting their views after discussion answering the questions in Exercise 2.1 and Exercise 2.2. By observing their performances from the record, provide them feedback to improve students' learning (formative assessment). In addition, you can use self-assessment and peer assessment methods to enhance students' performance. Appreciate students working above the minimum required level and encourage them to continue working hard. For lower ability students, identify their learning difficulties and help them to achieve the minimum required level for this subunit.

Additional Questions

1. When do we say a substance is reduced or oxidized?
2. Is it possible to identify an oxidizing agent and reducing agent? How?
3. Use the following chemical equation to answer the questions that follow

   $2Ag^{+}(aq) + Zn(s) \rightarrow 2Ag(s) + Zn^{2+}(aq)$

   Write the:

   a. oxidized substance
   b. reduced substance
   c. oxidizing agent
   d. reducing agent

4. Balance the reaction in (a) using change in oxidation number method and in (b) using ion- electron method

   a. $Cu(s) + H_2SO_4(aq) \rightarrow CuSO_4(s) + SO_2(g) + H_2O(l)$

   b. $MnO^{4-}(aq) + SO_3{}^{2-}(aq) \rightarrow SO_4{}^{2-}(aq) + Mn^{2+}(aq)$ in acidic media

   c. $Sn + HNO_3 \rightarrow Sn(NO_3)_2 + NO_2 + H_2O$

Answers to Additional Questions

1. A substance is reduced if it gains electrons and a substance is oxidized if it loses electrons.
2. Yes it is. By calculating changes in oxidation numbers: If a species decreases its oxidation state in a reaction, it becomes oxidizing agent. Conversely, if a species increases its oxidation state in a reaction, it becomes reducing agent
3. a. Zn b. Ag+ c. Ag+ d. Zn
4. a. $Cu(s) + 2H_2SO_4(aq) \rightarrow CuSO_4(s) + SO_2(g) + 2H_2O(l)$

   b. $2MnO^{4-}(aq) + 5SO_3^{2-}(aq) + 6H^+ \rightarrow 5SO_4^{2-}(aq) + 2Mn^{2+}(aq) + 3H_2O$

   c. $Sn + 4HNO_3 \rightarrow Sn(NO_3)_2 + 2NO_2 + 2H_2O$

Answers to Exercise 2.1

1. Use the oxidation number method to balance the following equations and then identify the oxidizing and reducing agents:

   a. $2HNO_3 + 3H_3AsO_3(aq) \rightarrow 2NO(g) + 3H_3AsO_4(aq) + H_2O(l)$

   b. $KClO_3 + 6HBr \rightarrow 3Br_2 + 3H_2O + KCl$

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

Answers to Exercise 2.2

1. Balance the following equation for the reaction in an acidic medium by the half-reaction method:

   a. $5H_2C_2O_4 + 6H^+ + 2MnO_4^- \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$

   b. $14H^+ + Cr_2O_7^{2-} + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$

   c. $3H^+ + 3H_5IO_6 + 2Cr \rightarrow 2Cr^{3+} + 3IO_3^- + 9H_2O$

   d. $2HNO_3 + 3H_2O_2 \rightarrow 2NO + 4H_2O + 3O_2$

   e. $6H^+ + BrO_3^- + 6Fe^{2+} \rightarrow 6Fe^{3+} + Br^- + 3H_2O$

2.2 Electrolysis of Aqueous solution

(Periods allotted 6)

After completing this subunit, the students will be able to:

- *explain metallic conductivity, electrolytic conductivity and electrolysis of molten electrolytes*
- *draw labeled diagrams of an electrolytic cell*
- *define preferential discharge*
- *explain factors that affect preferential discharge.*
- *describe the effect of nature of the ions on the electrolysis of aqueous solutions of dil. H_2SO_4 and NaOH*
- *describe the effect of concentration of the ions on the electrolysis of dilute and concentrated solutions of NaCl*
- *describe the effects of types of electrodes on the electrolysis of $CuSO_4$ solution using Ni electrodes and Cu electrodes.*
- *write electrode half reactions and overall reactions for the electrolysis of dil. H_2SO_4, NaOH, dilNaCl, conc. NaCl and $CuSO_4$ solutions*
- *distinguish between molten electrolytes and aqueous electrolytic solutions.*

Forward Planning

Prior reading about the principle of conduction of metals and electrolytes is very useful. Moreover, before you start the subunit, it is advisable to familiarize yourself with preferential discharge, electrolysis of molten and aqueous solution of the different compounds listed in the student text. A conductivity test (**Experiment 2.1**) is used to let students verify the conduction of metals and electrolytes. Therefore, make sure that all the following materials and solutions for the experiment are ready. In addition, you need to prepare a diagram that shows the components of an electrolytic cell.

Teaching Aids

Copper wire, light bulb, power supply (DC) or dry cells, scotch tape, distilled water, file or sand paper, 1 M NaCl, 1 M H_2SO_4, 1 M CH_3COOH, 1 M sugar solutions, magnesium ribbon, an iron nail and electrolytic cell diagram.

Subject Matter Presentation

For this subunit, it is possible to use gapped lecture, group discussion, presentation, and experiment as active learning methods. Students have learned metallic and electrolytic conductivity in Grade 10 Chemistry. Hence it is advisable to start this subunit by letting them recall what they learned in Grade 10 Chemistry. Encourage them to form groups and discuss the questions in **Activity 2.2**. Then, allow them to present what they discussed to the class by assigning group representatives. You can help them by facilitating group formations and harmonizing group discussions. The activity helps them to identify the charge carriers in metals and electrolytes. Let them come up with general agreements by providing the following answers for **Activity 2.2**.

1. Conduction in metals is due to the movement of delocalized electrons, but the conduction of electrolytes is caused by the migration of ions to oppositely charged electrodes.
2. To conduct an electric current, a substance should have either delocalized electrons or free mobile ions.
3. Ionic compounds do not conduct electric current in solid state because cations and anions are not free to move.

Before students start to conduct **Experiment 2.1,** perform the experiment by yourself and make sure that it gives the expected results. The procedure is indicated in the student text. If a material is plugged to complete the circuit of Figure 2.2 (a) and the bulb gives light, the material is conductor. Otherwise, it is non-conductor or insulator. It is important to polish the surfaces of magnesium ribbon and iron nail because their surfaces are covered with oxide layer. As a result, the oxide layer precludes electrical conductivity.

To distinguish strong electrolytes, weak electrolytes and non-electrolytes, you need to have two dry cells (here higher potential difference is required to see observable changes). This is because the resistance of an electrolyte solution is higher than a solid conductor and four beakers or they may use one beaker by washing it with water. For the experiment, they need 1M sodium chloride solution, 1M sugar solution, 1M acetic acid solution and 1M sulphuric acid(ethanoic acid) solution. Students should immerse the open ends of the circuit in each solution. Ask them to classify these solutions as strong electrolytes, weak electrolytes and non-electrolytes based on the brightness of the bulb.

The brighter the bulb, the stronger the electrolyte, and the dimmer the bulb, the weaker the electrolyte. The bulb does not glow at all for non-electrolytes. The anode is the terminal that attached to the positive terminal of the battery and the cathode is the one attached to the negative terminal of the battery. Students usually have difficulties identifying cathodes and anodes practically. This is a great opportunity for the students to internalize the concepts. Tell them to note down their observations on the experiment and write a report. Then, give **Exercise 2.3** to the students to have them classify substances as insulators and conductors. Students should be aware that metallic conduction is a physical process while electrolytic conduction brings chemical change that occurs on the surfaces of electrodes.

Electrolytic cells

For this subtopic, it is advisable to use group discussion and presentation as active learning methods. Help students to form groups and discuss the questions in **Activity 2.3**, and after their discussion, encourage them to present their answers to the class. The activity helps them to recapitulate some of the concepts they learnt in **Experiment 2.1.** To check their progress, you can use a diagram of an electrolytic cell and ask them to label the components of the cell. Harmonize their views using the following answers for **Activity 2.3**:

1. Ions usually migrate towards oppositely charged electrodes. Hence, cations migrate towards the cathode and anions to the anode.
2. a. The anode is the electrode that is attached to the positive terminal of the battery while the cathode is attached to the negative terminal of the battery.

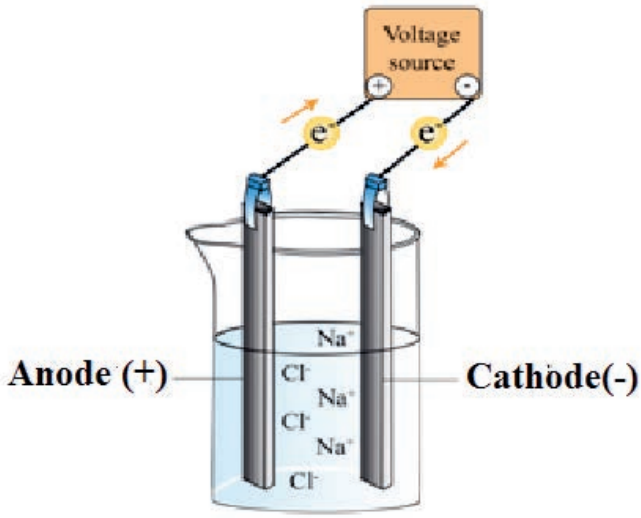


Figure 2.1 Electrolytic cell

b. Cathode (reduction): $2Na^{+}(l) + 2e^{-} \rightarrow 2Na(l)$

Anode (oxidation): $2Cl^{-}(l) \rightarrow Cl_2(g) + 2e^{-}$

Overall reaction: $2Na^{+}(l) + 2Cl^{-}(l) \rightarrow 2Na(l) + Cl_2(g)$

Preferential Discharge

For this subtopic, it is recommended to use group discussion, presentation and independent work as active learning methods. The subject of this section may be new for students. Therefore, explain preferential discharge and the three major factors that affect the preferential discharge of ions. Check their progress by giving **Exercise 2.4** to work on independently and show their answers to you. Then, give your comments to them. Students have learned the electrolysis of molten salts in Grade 10 chemistry. Hence, it is advisable to encourage them to do **Activity 2.4** in groups or they can do the activity independently and present their answers to the class. This Activity lets students emphasize preferential discharge of ions. Harmonize their discussion by providing the following answers.

1. Solid sodium chloride does not conduct electricity, because there are no free ions in solid sodium chloride. However, in molten state, there are free ions to conduct electricity.

2. a. Anode (oxidation): $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

   b. Cathode (reduction): $2K^+(aq) + 2e^- \rightarrow 2K(s)$

   c. Overall reaction: $2Cl^-(l) + 2K^+(aq) \rightarrow Cl_2(g) + 2K(s)$

3. H^+ is discharged in preference to Na^+ because its reduction potential is less negative. For concentrated solutions Cl^- is discharged in preference to OH^-. That is when the solution is concentrated enough in Cl^-, Cl_2 is the product, but in dilute solution, O_2 is the product.

The ease of discharge of H^+ is much greater than Na^+. Similarly, the ease of discharge of OH^- is greater than Cl^- (see Table 2.1 in the student text). But if the solution is concentrated, due to high concentration of Cl^- ions, the chloride ions are discharged in preference to OH^- ions. In the electrolysis of molten ionic compounds, students should be aware that there are only two kinds of ions and we do not need to talk about preferential discharge. However, in the electrolysis of aqueous solutions, the three major factors which affect preferential discharge should be taken into consideration to predict the preferential discharge of ions. To help students internalize these concepts, the electrolysis of sodium chloride solution, the electrolysis of sulphuric acid solution and the electrolysis of copper sulphate (II) solution are treated. In the electrolysis of brine solution, tell them to read the content in their text book independently and explain what they read to their classmates. Help them by clarifying concepts that are not clear for them (if any).

Electrolysis of Some Selected Aqueous Solutions

For this subtopic, it is better to use group discussion, presentation and gapped lecture as active learning methods.

In **Activity 2.5**, help them to form groups and then facilitate their group discussions by encouraging each group member to participate actively in his/her group. Then, allow them to present their answers to the class. Praise the presenters and give them feedback. Students are expected to define dilute solution, identify the ionic species in dilute sodium chloride solution, and the reduction half-reaction.

Harmonize the students' discussion by providing them the following answers.

1. a. Dilute sodium chloride solution contains Na^+, Cl^-, H^+ and OH^- ions.

   b. Na^+ and H^+ ions migrate towards the cathode, and Cl^- and OH^- ions migrate towards the anode.

   c. At the cathode, the H^+ ions are discharged in preference to the Na^+ ions. Since the concentration of the Cl^- ions is very small in dilute sodium chloride solution, the OH^- ions are discharged in preference to the Cl^- ions.

   Cathode(reduction): $4H^+(aq) + 4e^- \rightarrow 2H_2(g)$

   Anode(oxidation): $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$

   Overall reaction: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

In **Experiment 2.2**, students will electrolyze sodium chloride solution. Hence, help them to construct the electrolytic cell found in the Student Text. Tell them to record their observations and write a laboratory report about the experiment.

Answers to the Questions in Experiment 2.2

1. Bubbling of gases will be observed on the surfaces of the electrodes.
2. The graphite electrode attached to the positive terminal of the battery becomes the anode and the other connected to the negative terminal becomes the cathode.
3. Hydrogen gas discharges at the cathode and oxygen gas discharges at the anode. However, in concentrated sodium chloride solution, hydrogen gas discharges at the cathode and chlorine gas discharges at the anode.
4. Anode (+) : $4OH^-(aq) + 4e^- \rightarrow O_2(g) + H_2O(l)$

   Cathode (-): $4H^+(aq) + 4e^- \rightarrow 2H_2(g)$

You can use gapped lecture to teach the electrolysis of dilute sulphuric acid solution and the electrolysis of copper (II) sulphate solution, using inert electrodes. Then, give them **Activity 2.6** to discuss in groups or independently and present to the class. This activity is designed to help them to explain inert and reactive electrodes, and discuss the effects of the electrodes in the electrolysis of copper (II) sulphate solution. Harmonize group discussions by providing the following answers.

1. Reactive electrodes.
2. Anode: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
   Cathode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
3. If the copper slab attached to the anode contains more reactive impurities, such as iron or zinc, the concentration of copper (II) sulphate decreases because the more reactive metals are oxidized at the anode, equal moles of copper metal are deposited at the anode. However, if the impurities are less reactive metals like gold and silver, after electrolysis the concentration of copper (II) sulphate solution is almost constant because copper electrode is oxidized at the anode and an equal amount of copper (II) ions are reduced at the cathode.

Assessment

Assess each student's work continuously throughout the subunit. This can be achieved by recording the performance of every student. You can make records based on students' performance in:

- discussing from Activities 2.2 to 2.6,
- In addition, you can assess their performance by letting them reflect their laboratory reports for **Experiment 2.1** and **Experiment 2.2**. By observing their performances from the record, provide them feedback to improve students' learning. In addition, you can use self-assessment and peer assessment methods to enhance students' performance. Appreciate students working above the minimum required level and encourage them to continue working hard. For low achievers, identify their learning difficulties and help them to achieve the minimum required level for this subunit.

Additional Questions

1. A teacher adds Na_2SO_4 to water to facilitate its electrolysis in a class demonstration.
   a. What is the purpose of Na_2SO_4?
   b. Why is the water electrolyzed instead of the salt?
2. What property allows copper to be purified in the presence of iron and nickel impurities?

3. In the electrolysis of molten NaBr:
   a. What product forms at the anode?
   b. In addition, for low achievers identify their learning difficulties and help them until they achieve the minimum required level.

Answers to Additional Questions

1. a. to increase the conductivity of water.
   b. if you look at the preferential discharge of ions: hydrogen ion is discharged in preference to sodium ion and hydroxide ion is discharged in preference to sulphate ion
   3. Its ease of discharge or its reduction potential is higher than iron and nickel.
   4. a. bromine b. sodium

Answers to Exercise 2.3

1. a. Iron is a metal and conducts electricity.
   b. Sulphur is a non-metal and is an insulator.
   c. Solid NaCl does not conduct electricity because there are no free ions.
   d. Molten sodium chloride can conduct electricity due to the presence of free ions.

Answers to Exercise 2.4

1. a. Preferential discharge is the ease in which ions are discharged in preference other ions during electrolysis.
   b. An inert electrode is an electrode that does not affect the product of electrolysis.
   c. An active or reactive electrode is an electrode that affects the product of electrolysis.
2. Chlorine gas is liberated at the anode and Hydrogen gas is liberated at the cathode

   Anode reaction: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

   Cathode reaction: $2H^+(aq) + 2e^- \rightarrow H_2(g)$

   Overall reaction: $2H^+(aq) + 2Cl^-(aq) \rightarrow H_2(g) + Cl_2(g)$

Answers to Exercise 2.5

1. a. Anode Reaction: $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$

   Cathode Reaction: $4H^+(aq) + 4e^- \rightarrow 2H_2(g)$

   b. Overall Reaction: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$
2. The concentration of H_2SO_4 increases because water is electrolyzed and its amount decreases.
3. The copper (II) sulfate solution is decreased. Because copper (II) ion from sulfuric acid discharged at the cathode to form copper metal.

2.3 Quantitative Aspects of Electrolysis

(Periods allotted 3)

After completing this subunit, students will be able to:

- *state Faraday's first law of electrolysis*
- *write the mathematical expressions for the Faraday's first law of electrolysis*
- *do calculations related to Faraday's first law of electrolysis*
- *state Faraday's second law of electrolysis*
- *write the mathematical expressions for Faraday's second law of electrolysis*
- *do calculations related to Faraday's second law of electrolysis.*

Forward Planning

Prior reading about the statements of Faraday's Laws of electrolysis and their associated mathematical derivates helps you to identify learning difficulties while conducting the lessons. Before you start this subtopic, look into the contents of the Faraday's laws and the examples from the student text.

Subject Matter Presentation

For this subunit, it is possible to use gapped lecture, question and answer, and problem solving as active learning methods. You can begin this subunit by stating the Faraday's first law and discussing the relationship between charge, current and time (gapped lecture). Show them how the charge of one mole of an electrons is calculated and this is the basis for calculating the amount of substance produced during electrolysis. The steps that help to calculate the amount of substance produced are the following.

Step 1. Calculate the charge passed through the solution ($Q = It$)

Step 2. Change the charge to number of moles of electrons.

Step 3. Convert the mole of electrons derived in step 2 to mole of the element produced at the cathode or anode.

Step 4. Convert number of moles obtained in step 3 to mass in grams.

To understand these four steps, encourage students to carefully look into the examples and identify the steps. Alternatively, they can use the formula:

$$m = \frac{MIt}{nF}$$

where m is mass of the substance deposited or librated,

I is current, t is time,

F is Faraday's constant,

n is the number of moles of electrons lost or gained, and

M is the molar mass of the substance.

However, it is better to use the first method because it helps students to understand the concepts rather than merely memorizing the formula. Let them solve the problems in **Exercises 2.6** and **2.7** and ask willing students to show the solutions of the problems on the blackboard. Praise them and give your comments on stheir answers. Similarly, state Faraday's second law, and show the derivation of the mathematical equation.

Assessment

Assess each student's work continuously throughout the subunit. This can be achieved by recording the performance of every student as usual. You can make records based on students' participation in answering the questions in **Exercise 2.6** and **Exercise 2.7.** By observing their performances from the record, provide them feedback to improve students' learning. In addition, you can use self-assessment and peer assessment methods to enhance students' performance. Appreciate students working above the minimum required level and encourage them to continue working hard. For lower achievers, identify their learning difficulties and help them to achieve the minimum required level for this subunit as usual.

Additional Questions

1. How long will it take to deposit the cadmium from 300 mL of a 0.4 M $CdSO_4$ solution, using a current of 2 A?
2. What will be the concentration of Cd $(NO_3)_2$ in a solution after 3 A has passed for 5 hours through 900 mL of a solution that was originally 0.3 M (platinum electrodes are used)?
3. What current is required to plate out 0.020 mol of gold from $AuCl_3$ solution in 3 hours?
4. How many grams of Na and Cl_2 would be produced if a current of 25 A is passed for 8 hours into molten NaCl?

Answers to Additional Questions

1. 193 min
2. 0.0411 M.
3. 0.536 A.
4. 172 g Na and 265 g Cl_2.

Answers to Exercises 2.6

1. Volume of hydrogen is 9.05 L and that of oxygen is 4.52 L. Note that the volume of oxygen is half of hydrogen.
2. Mass of copper deposited at the cathode is 1.78 g and the volume of oxygen gas librated at the anode is 0.345 L.
3. Mass of Al is 0.672 g.

Answer to Exercise 2.7

1. The mass of silver is 216 g.
2. Mass of Ag = 21.6 g, mass of Zn = 6.5 g and mass of Fe = 3.73 g

2.4 Industrial Applications of Electrolysis

(Periods allotted 2)

After completing this subunit, the students will be able to:

- *mention the industrial applications of electrochemistry*
- *explain electroplating and electro refining*
- *demonstrate copper refining*
- *explain how electrolysis is used in the production of some metals, nonmetals and compounds.*

Forward Planning

Since this subunit is treated in the form of activities, prior reading about the industrial applications of electrolysis is very important. Read the note in notes and reference books available in the school library.

Subject Matter Presentation

For this subunit, it is possible to use group discussion, presentation and independent work as active learning methods. Let them form groups and do **Activity 2.7.** Help them by facilitating group formations and presentations. Help them to come up with consensus by providing the following answers.

1. Alkali metals, alkaline earth metals and aluminium are extracted by electrolysis.
2. Since active metals are highly reactive, they cannot be reduced from their compounds using the common reducing agents like carbon.
3. This is due to the fact that molten metal chlorides have lower melting points than other readily available salts. After they come up with answers, let them form groups and do **Activity 2.8**, **Activity 2.9**. Help them by facilitating group formations and presentations. Tell them to assign group representatives and present to the class. Help them to come up with the following answers for **Activity 2.8**.

1. Electrolytic refining is a process of refining a metal (mainly copper) by the process of electrolysis.
2. The main purpose of electro-refining is to purify the metals.
3. In electro-refining the pure metal acts as cathode and impure metal acts as the anode whereas the electrolyte is soluble salt of the same metal. By passing the electricity the pre metal from anode is deposited over the cathode. The impurities are settled as anode mud.

After they come up with answers for **Activity 2.8**, help them to give the Answer for **Activity 2.9**.

1. Non-metals such as fluorine, chlorine, hydrogen and oxygen are prepared by electrolysis. Electrolysis is also used in the preparation of compounds such as sodium hydroxide.

2. Anode (oxidation): $2F^{-}(aq) \rightarrow F_2(g)$

   Cathode (reduction): $2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$

   Overall reaction: $2H^{+}(aq) + 2F^{-}(aq) \rightarrow H_2(g) + F_2(g)$

3. Pure water is a poor conductor of electricity, so a small amount of ionic solute is added to increase its electrical conductivity. Conclude this section by recapitulating the main points.

1. A compound such as MnO_2 is prepared by electrolysis

2. Oxidation : $Mn^{2+} + 2H_2O \rightarrow MnO_2 + 4H^{+} + 2e^{-}$

   Reduction : $2H^{+} + 2e^{-} \rightarrow H_2$

   Overall reaction : $Mn^{2+} + 2H_2O \rightarrow MnO_2 + 2H^{+} + H_2$

Conclude this section by recapitulating the main points.

Before students start to conduct **Experiment 2.3**, perform the experiment by yourself using the procedures indicated in the student text and make sure that it gives the expected result. After you perform the experiment, help them to construct the electrolytic cell found in the student text. Tell them to record their observations and write a laboratory report about the experiment.

Answers to the Questions in Experiment 2.3

1. Electroplating is widely used in various industries for coating metal objects with a thin layer of a different metal. The layer of metal deposited has some desired property, which the metal of the object lacks. For example, chromium plating is done on many objects such as car parts, bath taps, kitchen gas burners, wheel rims and many others for the fact that chromium is very corrosion-resistant, and thus prolongs the life of the parts. It is also used in making expensive jeweler.
2. It is important to polish the surfaces of copper plate and iron spoons before use because their surfaces are covered with an oxide layer. As a result, the oxide layer precludes electrical conductivity.
3. The iron key has got reddish layer of copper metal all over its surface.
4. The dissolved copper metal present in the copper sulphate solution as positively copper ions gets attracted to the negatively charged electrode iron key. The positively charged copper ions lose their positive charge on coming in contact with the negatively charged iron key and form copper atoms. These copper atoms deposit on the iron key to form a thin layer of copper metal all over the surface of iron key. In this way, copper metal in the electrolyte comes out of the solution and forms a thin layer on the iron key
5. The copper metal of positively charged copper plate electrode dissolves by forming positively charged copper ions. The copper ions thus formed go in to the copper sulphate solution.

Note for the Teacher

Electroplating is a process in which a metal is electrolytically deposited or "plated out" on the surface of another metal. It is often done to protect the base metal from corrosion or simply to give it a more pleasant or richer appearance. The electrolyte contains the plating metal in the form of dissolved ions. The anode is often made of the plating metal, while the cathode is usually the metal being plated. One of the most familiar examples of electroplating is "chrome plating" in which a thin layer of chromium is deposited on another metal. The electrolyte is prepared by dissolving CrO_3 in dilute sulphuric acid. The electrolysis reduces chromium (VI) first to chromium (III) and then to chromium metal, the overall reduction being:

$$CrO_3(aq) + 6H^+(aq) + 6e^- \rightarrow Cr(s) + 3H_2O(l)$$

The chromium deposits on the cathode as a hard protective film. Electorefining (purification of metals) is another important application of electrolysis. For example, impure copper from the chemical reduction of copper ore is cast into large slabs that serve as the anodes for electrolytic cells. Aqueous copper sulphate is the electrolyte, and thin sheets of ultrapure copper function as the cathode. The main reaction at the anode is:

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

Other metals, such as iron and zinc, are also oxidized from the impure anode

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$$

The Cu^{2+} ions from the solution are preferentially deposited on to the cathode $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$, producing copper that is 99.95 % pure.

The compounds of very active metals are difficult to decompose, so electrolytic reduction is the only method for obtaining such metals. Electrolysis can also be used to prepare less active metals when very pure samples are needed. Molten metal chlorides are usually used as electrolytes, because they generally have lower melting points than other readily available salts. Sodium, lithium, magnesium, calcium, barium and aluminum are among the metals produced by electrolysis. Electrolysis is also used in the manufacture of non-metals. For example**,** fluorine, the most electronegative element, is prepared by the electrolysis of a molten mixture of potassium fluoride and hydrogen fluoride. Chlorine is manufactured by the electrolysis of molten sodium chloride or concentrated sodium chloride (*brine*) solution. Hydrogen and oxygen are also prepared by electrolysis of water. Pure water is a poor conductor of electricity, so a small amount of ionic solute is added to increase its conductivity. The added ions must be more resistant to oxidation and reduction than water. Electrolysis is also used in the preparation of compounds such as sodium hydroxide.

Assessment

Assess each student's work continuously throughout the subunit. This can be achieved by recording the performance of every student. You can make records based on students' performance in: discussing the activities from **Activity 2.7** to **Activity 2.9**, presenting their views after discussion,

By observing their performances from the record, provide them feedback to improve students' learning. In addition, you can use self-assessment and peer assessment methods to enhance students' performance. Appreciate students working above the minimum required level and encourage them to continue working hard. For low achievers, identify their learning difficulties and help them to achieve the minimum required level for this subunit.

Additional Questions

1. When a piece of metal A is placed in a solution containing ions of B, metal B plates out on the piece of A.
   a. Which metal is being oxidized?
   b. Which metal is being displaced**?** If bubbles of hydrogen form when B is placed in acid, will they form if A is placed? Explain.
2. How long will it take to plate out each of the following with a current of 100 A?
   a. 1 kg Al from aqueous Al^{3+}
   b. 1 g Ni from aqueous Ni^{2+}
   c. 5 mol Ag from aqueous Ag^{+}.
3. Which of the following elements are produced primarily by electrolysis?
   a. Potassium
   b. Lead
   c. Aluminum
   d. Zinc
   e. Calcium
4. Write the anode and cathode reactions in the electrolysis of copper(II) sulphate using copper electrodes.

Answers to Additional Questions

1. a. A b. B
   hydrogen bubbles will form when A is placed in acid. Metal A is a better reducing agent than B, so if metal B reduces H+ in acid, metal will also reduce H+ ions.
2. a. 30 hrs b. 33 s c. 1.3 hr
3. a, c and e.
4. Anode : $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
   Cathode : $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

2.5 Voltaic (Galvanic Cells)

(Periods allotted 5)

After completing this subunit, the students will be able to:

- *define voltaic cell and salt bridge*
- *define electrode potential and cell potential*
- *explain how standard electrode potential is measured*
- *describe the reactivity of metal from its position in the activity series or electromotive series*
- *decide whether a given redox reaction is spontaneous or not*
- *explain the effect of concentration on cell potential*
- *mention the different types of voltaic cells*
- *give examples of each type of galvanic cell*
- *describe how a hydrogen-oxygen fuel cell operates*
- *distinguish between primary and secondary cells*
- *identify the cathode, anode and electrolyte of a given galvanic cell*
- *compare and contrast electrolytic and galvanic cells*
- *explain metallic corrosion in terms of redox reactions*
- *explain the negative effects of corrosion*
- *explain the different methods of the prevention of corrosion.*

Forward Planning

This subunit encompasses concepts associated with galvanic (voltaic) cells. Before you start to teach the topics, it is better to read all the contents of this subunit from the student text book, the Teachers Guide, and reference books available in the school library. Students will determine the cell potential of a Danielle cell (Experiment 2.4). Hence, make sure that all the materials and solutions for the experiment are ready.

Teaching Aids

Copper wire, light bulb, power supply (DC) or dry cells, scotch tape, distilled water, a file or sand paper, 1 M NaCl, 1 M H_2SO_4, 1 M CH_3COOH, 1 M sugar solutions, magnesium ribbon and iron nail.

Subject Matter Presentation

For this topic, it is possible to use group discussion and presentation as active learning methods.

Begin this subunit by helping students to form groups and do **Activity 2.10.** Help them by clarifying concepts that are not clear for them while discussing with their groups. In addition, encourage them to share their ideas with other groups. Guide them to come up with the following answers.

1. An electrochemical cell contains two electrodes immersed in their corresponding electrolyte solutions which are connected by a salt bridge. In order to do useful work, the two components of the cell should be separated and connected by a salt bridge.
2. a. Oxidation half-reaction: $Mg(s) \rightarrow Mg^{2+}(aq)$

   Reduction half-reaction: $2H^+(aq) \rightarrow H_2(aq)$

Some students may not be active in group discussions due to various reasons. So, identify these students and encourage them to participate actively in their groups. Summarize the main points and conclude this session by giving them Exercise 2.8 as a home work.

Standard Reduction Potentials

For this topic, it is better to use gapped lecture, and experiment as active learning methods. In this section, use a gapped lecture and discuss how standard reduction potentials are calculated using standard hydrogen electrode (SHE) and explain to them the physical significance or meaning of reduction potentials. If the reduction potential is a large positive value, it is a strong oxidizing agent or the ion is easily reduced. However, when the reduction potential is negative, it has fewer tendencies to be reduced. Instead, it has a high tendency to be oxidized and is a reducing agent. Help them to distinguish the difference between standard reduction potential and cell potential. To clarify these concepts, let students read the examples in their text book and discuss the differences. After finishing their discussion, encourage them to forward their views to the class. Then, to check their progress, tell them to answer the questions in **Exercise 2.8** and **Exercise 2.9**. In **Experiment 2.4**, students will determine the cell potential of Danielle cell. Help them to construct the galvanic cell found in the Student Text. Tell them to record their observation and write a report about the experiment.

Answers to the Questions in Experiment 2.4

1. The pointer of the ammeter deflects from zinc to copper half cells. This indicates electron flows from zinc to copper half cells.
2. Copper serves as cathode and Zinc serves as anode.
3. (−) Anode (oxidation): $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$

   (+) cathode (reduction): $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$
4. As time passes the intensity of copper sulphate solution decreases or it becomes light blue because the copper ions are consumed in the half-cell.

Electromotive Force

For this topic, it is advisable to use group discussion and presentation as active learning methods. Students might learn emf and potential energy in Physics lessons. So, encourage them to associate the flow of water from uphill to downhill with emf by doing **Activity 2.11**. So, ask them to explain "what makes electrons to flow in a wire?" Guide them to come up with the following answer.

As it is observed in our daily life, water flows from uphill (high potential energy) to downhill (low potential energy). Similarly, electrons flow in a wire from negative (high electrical potential energy) to positive (low electrical potential energy). In the spontaneity of reactions section, ask students to explain spontaneous and non-spontaneous processes using the topics they learnt from thermodynamics. Ask them the values of changes in Gibbs free energy for spontaneous and non-spontaneous processes. Show them the relationship between E^0_{Cell}, ΔG^0 and K by looking at the derivations in the student text book and explain to them Examples 2.7 and 2.8 that show the calculations of equilibrium constant and change in standard free energy. Finally, let students work Exercise 2.10 and give feedback for their answers. In the dependence of emf on concentration section, derive the Nernst equation or help them to derive it, and show how the cell potential is affected by the concentrations of the electrolytes using Example 2.9. Then, allow them to work through Exercise 2.11 and give them feedback.

Batteries

For this topic, it is recommended to use group discussion, presentation and project work as active learning methods. You can begin this section by letting students do **Activity 2.12**. The main advantages of batteries are their convenience and portability. It is common to say that a battery is "dead". A battery is dead when reactants are consumed. In addition, encourage them to bring "dead" batteries, and classify them as primary, secondary, dry cell etc. Then, ask students to give examples of primary and secondary batteries on the basis of the definitions. The answers of question number 3 depend on batteries collected by students. Tell them ahead of time to go to a nearby automobile garage (if possible and with permission), to collect information about the working principle of a car battery . They can also also learn the recharging principle of a car battery. Such information helps students to visualize the application of electrochemistry in their real-life situation. Students have learned about dry cell batteries in Grade 10 chemistry. Hence, help them to form groups and do **Activity 4.13.** In this activity, students are expected to write out the electrolyte, anode and cathode reactions in a dry cell battery. Harmonize their discussions and guide them to come up with the following answers:

1. The electrolyte consists of ammonium chloride and zinc chloride in water. A carbon rod serves as the cathode and zinc as anode.
2. The cell reactions are

Anode: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

Cathode: $2NH_4^+(aq) + 2MnO_2(s) + 2e^- \rightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$

Overall reaction:

$Zn(s) + 2NH_4^+(aq) + 2MnO_2(s) \rightarrow Zn^{2+}(aq) + 2NH_3(aq) + H_2O(l) + Mn_2O_3(s)$

Corrosion of Metals and Corrosion Prevention

For this subunit, it is advisable to use group discussion and presentation as active learning methods. First, help them to read independently about the corrosion of metals using their textbook. Then, encourage them to share what they discussed with their classmates. This helps them to associate corrosion with reduction potentials. Then help them to form groups and discuss the questions in **Activity 4.13.** After discussion, help them to share their ideas with other groups. Help them to reach general agreement by providing the following answers.

1. Painting, galvanizing with zinc, electroplating with less active metals like chromium.
2. All methods prevent the direct contact of iron with oxygen and water.

Finally, ask them to submit the answers of the review questions of this unit. You can use the review questions as part of your summative assessment.

Prevention of Corrosion

A number of methods have been devised to protect metals from corrosion. Most of these methods are aimed at preventing rust formation. The most obvious approach is to coat the metal surface with paint. However, if the paint is scratched, pitted, or dented to expose even the smallest area of bare metal, rust will form under the paint layer.

The simplest way to prevent corrosion is to ensure that the surface of the metal is not exposed to air and water. Iron is often covered with a coat of paint or another metal, such as tin, zinc or chromium, to protect its surface against corrosion. Tin protects iron only as long as the protective layer is not scratched or damaged. Once it is broken, and the iron is exposed to air and water, tin actually promotes the corrosion of iron.

Why? If we look at the standard reduction potentials, Fe^{2+} is more difficult to reduce than is

Sn^{2+}. $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$, $E^0_{red} = -0.14\,V$

$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$, $E^0_{red} = -0.44\,V$

As a result, **Fe(s)** is easier to oxidize than Sn(s). Thus the iron serves as the anode and tin as cathode in the electrochemical corrosion Corrosion increases when iron behaves more like the anode. When iron is in contact with a less active metal (weaker reducing agent), such as tin, it loses electrons more readily (its anodic function is enhanced). Non-conducting rubber or plastic spacers are placed between the metals to avoid this problem.

Corrosion decreases when iron behaves more like the cathode. In cathodic protection, the most effective way to prevent corrosion, iron makes contact with a *more* active metal (stronger reducing agent), such as zinc. The iron becomes the cathode and remains intact, while the zinc acts as the anode and loses electrons Coating iron with a "sacrificial" layer of zinc is called *galvanizing*. In addition to blocking physical contact with H_2O and O_2, the zinc (or other active metal) is "sacrificed" (oxidized) instead of the iron. Sacrificial anodes are used underwater and underground to protect iron and steel pipes, tanks, oil rigs, and so on.

Assessment

Assess each student's work continuously throughout the subunit as usual. This can be achieved by recording the performance of every student. You can make records based on students' performance in:

- discussing during **Activity 2.9** to **Activity 2.13**
- presenting their views after discussion
- answering oral questions raised during group discussion.
- asking questions.

In addition, give them the exercises from Exercise 2.8 to Exercise 2.13 as class work or homework and record their achievements. By observing their performances from the record, provide them feedback to improve students' learning.

You can also assess their performance by letting them reflect their reports for Experiment 2.4. Appreciate students working above the minimum required level and encourage them to continue working hard. For lower ability students, identify their learning difficulties and help them to achieve the minimum required level for this subunit. You can also use the review questions of this unit as part of summative assessment.

Additional Questions

1. Sketch the galvanic cells based on the following overall reactions. Show the direction of electron flow, the direction of ion migration through the salt bridge, and identify the cathode and anode. Assume that all concentrations are 1 M.

   $Mg + 2Ag^{+} \rightarrow Mg^{2+} + 2Ag$

2. Write the cell notation for question (1).
3. Explain why oxidation and reduction half-reactions have to be physically separated for an oxidation reaction to do work.
4. In Figure 2.5 magnesium is oxidized and silver ions are reduced.

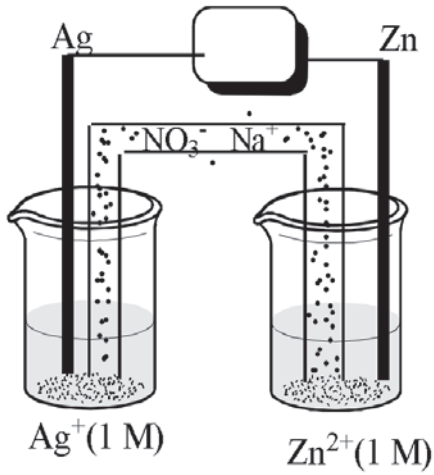


Figure 2.2: Mg-Ag Galvanic cell

   a. Label each part of the cell.
   b. Write the cell notation.
   c. Write chemical equations for the half-reactions occurring at the anode and cathode, and write an equation for the net reaction in the cell.
   d. Show the direction of electron flow and the direction of ion migration through the salt bridge.

Answers to Additional Questions

1.

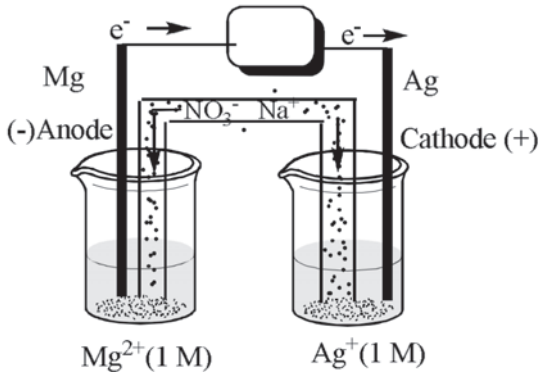


Figure 2.3 Mg-Ag Galvanic cell

2. $Mg(s)\,|\,Mg^{2+}(1M)\,||\,Ag^{+}(1M)\,|\,Ag(s)$
3. If the reactions could occur in one compartment, then the electrons would transfer directly from the reducing agent to the oxidizing agent without doing useful electrical work.
4. a.

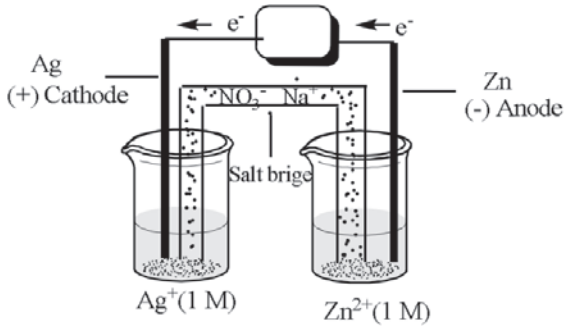


Figure 2.4 Mg-Ag Galvanic cell

b. $Zn(s)\,|\,Zn^{2+}(1M)\,||\,Ag^{+}(1M)\,|\,Ag(s)$

c. Anode: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$

Cathode: $2Ag^{+}(aq) + 2e^{-} \rightarrow 2Ag(s)$

Overall reaction: $Zn(s) + 2Ag^{+}(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$

d. Nitrate ions move from salt bridge and enter into zinc compartment, and sodium ions migrate from salt bridge and enter into silver compartment. Electrons flow from zinc half-cell to silver half-cell.

Answers to Exercise 2.8

1. $Al|Al(NO_3)_3(l\ M)\ ||AgNO_3\ (l\ M)|Ag$
2. A salt bridge is used to complete a circuit or to maintain the electro neutrality of the solution.

Answers to Exercise 2.9

1. No, because Sn is the weakest reducing agent
2. + 0. 34 V
3. a.

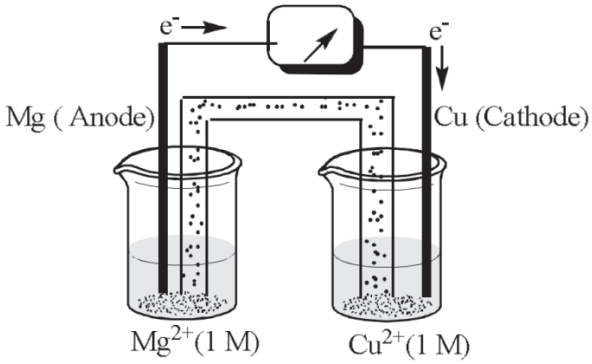


Figure 2.5 Mg-Cu Galvanic cell

b. $Mg \mid Mg^{2+}$ (1M) is the anode, and Cu^{2+} (1M) | Cu is the cathode.

c. Electrons flow from the anode (magnesium) to the cathode (copper) in the external circuit.

Answers to Exercise 2.10

1. $E_{cell} = 0.90$ V
2. $E_{cell} = 0.0828$ V
3. $E_{cell} = 1.53$ V

Answers to Exercise 2.11

1. $E_{cell} = 20.14$ V

   Because E_{cell} is negative, the reaction is not spontaneous in the direction written.
2. $E^0_{bromine} = 20.14$ V

Answers to Exercise 2.12

1. A dry cell is a primary cell which is used only once and then discarded but lead storage battery is a secondary cell and can be used more than once by recharging it.
2. **Cathode:** $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

   Anode: $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$

   Overall reaction:

   $$2PbSO_4(s) + 2H_2O(l) \rightarrow Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq)$$
3. a. Ammonium chloride and zinc chloride in water

   b. Anode (oxidation): $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

   Cathode (reduction):

   $$2NH_4^+(aq) + 2MnO_2(s) + 2e^- \rightarrow 2Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$$

Answers to Exercise 2.13

1. Corrosion is a deterioration of a metal by redox process, which converts a metal to unwanted compound.
2. Corrosion destroys metals and returns them to their natural ores. As a result, it has negative economic impact.
3. Aluminum can form a thin layer of oxide which prevents further oxidation of Aluminum. Because of this thin layer of oxide, aluminum cannot be corrode

Answers to the Review Questions

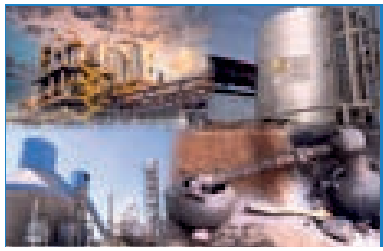
Part I Multiple Choices

1. d	5. c	9. c	13. d
2. a	6. d	10. c	14. d
3. a	7. d	11. a	15. b
4. b	8. d	12. c	

Part II: Answers to Short Answers

1. a. Oxidation is the loss of electrons and is identified by increase in oxidation number.
   b. Reduction is the gain of electrons and is identified by decrease in oxidation number.
   c. Galvanic cell is a cell that converts chemical energy to electrical energy.
   d. Electrolytic cell is a cell in which electrical energy is used to bring about chemical change.
   e. Corrosion is the deterioration of metals by redox reactions.
2. a. $2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$
   b. $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$
3. a. $ClO_3^- + 3H_2O + 3SO_2 \rightarrow 3SO_4^{2-} + Cl^- + 6H^+$
   b. $24H_2S + 16HNO_3 \rightarrow 3S_8 + 16NO + 32H_2O$
   c. $3H_2S + 2HNO_3 \rightarrow 2NO + 3S + 4H_2O$
   d. $Cu + 4H^+ + SO_4^{2-} \rightarrow Cu^{2+} + SO_2 + 2H_2O$
4. Current = 6.81×10^{-2} A
5. 6.73×10^{-3} g I_2
6. E = 20.14 V Because E is negative, the reaction is not spontaneous in the direction written.
7. ΔG^0_T = -24.1 KJ Because ΔG^0_T is negative, the reaction should be spontaneous at 1000^0C and 1 atm
8. The standard free-energy change is - 301 kJ.
9. $K_c = 2 \times 10^{37}$
10. a. Metal corrodes when it reacts with another substance such as oxygen, hydrogen, an electrical current or even dirt and bacteria. Corrosion can also happen when metals like steel are placed under too much stress causing the material to crack.
    b. Corrosion can be prevented by painting or coating a metal with zinc, tin or chromium.

UNIT 3



Industrial Chemistry

Unit Overview

Total Periods allotted: 31 periods

This unit mainly emphasizes on introducing students to the applications of chemistry in industry. It gives information that all chemical manufacturing processes involve chemical reactions.

The first section (3.1) deals with the general characteristics of chemical industries. It explains the role of chemistry for the society in general and all chemical industries use naturally available materials or materials obtained after processing natural resources as starting materials in their manufacturing activities.

The second section, 3.2, introduces the definition of natural resources and their classification as raw material from the atmosphere, hydrosphere, lithosphere and biosphere and as renewable and non-renewable. It also presents examples of raw material from the atmosphere, hydrosphere, lithosphere and biosphere and examples of renewable and non-renewable natural resources.

The third section (3.3) is a broader section which gives emphasis to the manufacturing of valuable chemical products. The valuable products include every industrial product that are either directly used or serve as raw materials to synthesize products that are important to solve the society demands in different necessities. It also explains the physical and chemical properties of these valuable chemical products as well describe the steps/process of production.

The last section (3.4) deals with some manufacturing industries in Ethiopia. It gives emphasis to glass, ceramics, cement, sugar, paper and pulp, tannery and food processing and preservation, beverage, soap and dry detergent.

Teaching this unit using the lecture method is boring and cumbersome to students. So, different teaching methods are suggested for each section and sub-topic. The major methodologies suggested for this unit are peer teaching, gapped lecture, inquiry and group discussion.

Finally introduce this unit by the Start-up activity mentioned in the text book that students learnt in Grade 10. The activity deals about the occurrence and extraction of some important metals and non-metals that are used as a raw material for the production of desired products. You can mention metals sodium, potassium, aluminium, iron, etc and from non-metals sulphur, silicon, hydrogen, nitrogen, oxygen, along with their occurrence and extraction. Then proceed to Section 3.1.

Unit outcomes

At the end this unit, students will be able to

- *list the renewable and non-renewable natural resources and appreciate their importance to the industry as raw materials*
- *describe the relationship between natural resources and industry*
- *list some chemical and related industries in Ethiopia*
- *list some important chemicals used for the manufacture of valuable products*
- *explain the major steps in the industrial production of ammonia, nitric acid, sulphuric acid, sodium hydroxide, sodium carbonate and aluminium sulphate and di-ammonium phosphate and other Nitrogen fertilizers; and*
- *list some important direct uses of NH_3, HNO_3, H_2SO_4, and Na_2CO_3 and their uses as raw materials in the production of other products*
- *list some important uses of DAP, $(NH_4)_2HPO_4$, nitrogen fertilizers, insecticides, and Herbicides*
- *prepare insecticides from locally available material*
- *describe the uses of the common insecticides and pesticides that are manufactured in chemical industries*
- *discuss the important steps in the production of glass, ceramics, cement, sugar, and paper and pulp*

- *describe the important steps in the production of soap, detergent and beverage*
- *prepare soap on a small scale from the available resources*
- *describe the tanning process*
- *apply local methods of tanning*
- *use local methods of food preservation*
- *develop inquiry skills along this unit: observing, predicting, classifying, communicating, and inferring.*

3.1 Introduction

Period Allotted 2

After completing this section, students will be able to

- *define industrial chemistry*
- *list general characteristics of chemical industries*
- *mention the role of industrial chemistry for the society.*

Forward Planning

Read the contents of this section thoroughly. Plan how to manage students when they discuss activities and make presentations. Decide which group should make presentations.

Teaching Aid

- Prepare a chart that shows a list of some chemical industries, what they use as raw materials and what they produce.

Subject Matter Presentation

The suggested methodologies for this section are peer teaching, group discussion and visual based learning. Before this section, this unit begins with Start-up activity. The activity enables the students to remember what they learned in Grade 10 to recite and write the occurrence and extraction of some important metals and non-metals. Next, you have to present for the students the historical development of industrial

chemistry. The presentation helps the students to visualize the way of life in the pre-industry society. Then introduce Section 3.1, this section starts with Activity 3.1. The activity helps students to visualize that "life would be difficult in the absence of industries. Or life would be easy if a product which is demanded by the society is produced in the adequate amount". Explain that life would have been difficult without the chemical industry is "the population has been increased in an alarming rate, so the demand for medicine, shelter, food, hygiene and entertainment has also increased. To satisfy these societal needs, the demands for goods produced through chemical processes increased. That is why the chemical industry involves the use of chemical processes such as chemical reactions and refining methods to produce a wide variety of materials with desirable properties and quality" Ask the students to prepare a list of chemicals and a list of the products that produced in Ethiopia in tabular form by taking as an example: Chemicals manufactured in Ethiopia includes, Na_2CO_3,deteregents, cosmetics products, food preservatives, sugar, glass and ceramic, beverages , cement see **Table 3.1.**

Table 3.1: List of chemicals/ products produced in Ethiopia

Serial No	Industry	Product	Location
1	Mesobo Cement Factory	Cement	Tigray
2	Muger Cement Factory	Cement	Muger (western shewa)
3	Dire Dawa Cement Factory	Cement	Dire Dawa
4	Derba Midroc Cement Factory	Cement	Northern Shewa
5	Nifas Silk Paint Factory	Paint	A. A
6	Dil Paint Factory	Paint	A. A
7	Tseday Paint Factory	Paint	A. A
8	Repi Soap and Detergent Factory	Soap and detergent	A. A
9	Gulele Soap Factory	Soap	A. A
10	Nazreth Soap Factory	Soap	Nazreth (Adama)
11	Fincha Sugar Factory	Sugar	Fincha
12	Metehara Sugar Factory	Sugar	Metehara
13	Wonji Sugar Factory	Sugar	Wonji
14	Matador Addis Coma Factory	Tyres	A. A
15	Saint George Brewery	Beer	A. A
16	Bedelle Brewery	Beer	Bedelle

Serial No	Industry	Product	Location
17	Meta Brewery	Beer	Sebeta
18	Harar Brewery	Beer	Harar
19	Dashen Brewery	Beer	Gondar
20	Awash Tannery	Processed leather	A. A
21	Mojo Tannery	Processed leather	Mojo
22	Addis Foam and Plastic Factory	Plastic	A. A
23	Ethio Plastic	Plastic	A. A
24	Adamitulu Pesticide Factory	Pesticides	Adamitulu
25	Caustic Soda factory	Caustic Soda	Hawassa
26	Tabor Ceramic Factory	Ceramics	Hawassa
27	Sulfuric Acid and Aluminum Sulphate Factory	Sulphuric acid and aluminum sulphate	Awash Melkassa
28	Ethio Gas and Carts	Plastics arts and CO_2	A. A
29	Chora Gas and Chemical Products	Oxygen, acetylene, shoe polish, floor wax	A. A
30	Addis Glass Factory	Glass	A. A
31	Nas Foods Factory	Biscuits	A. A
32	Arbaminch Textile Factory	Textile	Arbaminch
33	Almeda Textile Factory	Textile	Tigray (Adowa)

This activity helps them to acquire prior knowledge about chemical industry. Encourage students to make presentations on the contents of the section. Give them a home work to prepare this section in groups before the period in which you deal with it. Tell them the points to emphasize. This may include: definition of a chemical industry, the general characteristics of chemical industries, and their opinions on points in **Activity 3.1.** During the period in which you treat this section, let students from two different groups have presentations to the rest of the class turn by turn. After each group completes the presentation, give chance to other students to ask the groups some questions, and also give the opportunity to the groups to answer questions raised by other members of the class. Then, harmonize the ideas of the students with those which they are supposed to know. Inform them that much of our life at present relies on the materials produced by chemical industries. Define chemical industry as

an institution involved in the manufacturing of chemical substances such as soaps and detergents, beverages, sodium hydroxide, textiles, pharmaceuticals, fertilizers, pesticides, herbicides, acids, bases, cement, paper and pulp, metals and non-metals etc. Introduce to students that all chemical industries use naturally available raw materials while others use raw materials produced by other industries.

Let students realize that chemical processes (reactions) and physical processes in some cases are involved in converting the raw materials into the desired products. Chemical reactions are mostly carried out in special corrosion−resistant chambers. Inform the students those chemical industries use different methods of purifying the materials they produce and also have quality control laboratories to check whether or not their products meet the desired specification. Inform them that chemical industries also consume large amounts of energy in their manufacturing processes. They can cause environmental pollution unless they treat the waste products coming out of the manufacturing process, before they discharge them to the surroundings.

Assessment

Assess each student's work throughout the section. You can give class work or homework and check the work of every student. Also record the effort that has been made by each group during presentations. Collect the written documents prepared by other groups who didn't do a presentation. Check their works and make a record. See their achievements and make sure that the competencies suggested for the section are achieved.

Additional Questions

1. List down general characteristics of chemical industries other than those mentioned in your text book.

Answers to Additional Questions

1. They use relatively large quantities of water. Unless controlled, they release to the environment wastes in the form of gas (smoke), liquid or solid

Answers to Exercise 3.1

1. Chemical industry is an institution involved in the production of chemical products.
2. Among the essential aspects of industrial chemistry the chemical industry is the prominent one and the bases for the production of valuable products for human consumption in food, health and hygiene, shelter, environmental protection, decoration, recreation and entertainment.
3. General characteristics of chemical industries:
   - use naturally-available raw materials to produce the desired products,
   - involve chemical reactions to transform raw materials into finished and semi-finished products,
   - consume relatively large quantities of energy during the manufacturing process,
   - use safe operation methods in their manufacturing processes, and
   - test their products during and after manufacture in their quality control laboratories to ensure that the products meet the required specifications.

3.2 Natural Resources and Industry

Period Allotted 2

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

- *define natural resources*
- *list natural resources*
- *classify chemical industries based on the raw materials they use to manufacture their products*
- *classify chemical industries based on the type of product they manufactured*
- *describe the applications of minerals in industry.*

Forward Planning

You need to plan when to give group presentation as a home work for students to this section. Decide which group of students should make presentations during the period. Make the necessary arrangement on how to manage students and initiate them to be active participants.

Teaching Aids

- A chart that shows the classification of natural resources with examples.

Subject Matter Presentation

Use peer teaching and group discussion methodologies for this section. This section begins with an activity. **Activity 3.2** is designed to help students get more information about natural resources and relate concepts with their biology and geography subjects. Students are expected to have some ideas about natural resources from what they have learned in biology or geography. So, it is advisable if you implement peer teaching methodology for this part. Give them a home work to make preparation on the section in groups before you deal with it.

Let all groups in each section make preparation. Give them information about the points they should emphasize on. This may include: definition of natural resources and examples, classification of natural resources with examples, importance of natural resources for industry, the application of minerals in industry and other points mentioned in Activity 3.2. 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 3.1 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, define natural resources as materials available in nature for peoples to utilize. Examples are metal ores, soil, trees, air, food crops, crude oil, natural gas, coal, wool, cotton etc. Inform them about the basis for the classification natural resources based on the type of sources as hydrosphere, lithosphere, biosphere and atmosphere and classified as renewable and non - renewable. Inform students that renewable resources can be replenished (replaced) by natural processes while non-renewable resources cannot be replenished. For example, fossil fuels include petroleum, natural gas and coal. If these substances are completely used up, they cannot be renewed. Even their formation in the Earth's crust requires several millions of years. Write a list of natural resources on the black board and let students classify them as renewable and non- renewable. Related to these let the students discuss Activity 3.3, and inform them how chemical knowledge like recycle, energy-efficient chemical reactions can be used to tackle the problem that renewable resources can be replenished by natural processes but, they are practically getting depleted. Similarly non-renewable resources are also over used that they may be exhausted shortly.

After giving correction to the works of students, continue introducing the importance of natural resources for industry. Lay emphasis on the fact that chemical industries use natural resources as starting materials (raw materials) and convert them into usable products by chemical means. Inform them that some industries may not use natural resources as raw materials directly, but materials produced by other industries. Finally, explain the application that they use of minerals in industries. For example, crude oil is fractionally distilled to give different petroleum products that are used as a fuel or to produce various petrochemicals. Air can be used as starting material for the production of O_2, N_2 and argon. Rocks such as limestone can be used in the manufacture of building materials like cement, lime and in the extraction of iron. Minerals such as metal ores are used to manufacture metals. For example, sodium chloride is used to manufacture sodium metal, sodium hydroxide and chlorine.

Assessment

Evaluate the work of every student throughout the section. Make the necessary follow-up during presentation. You can evaluate the performances of the groups involved in the presentations based on how they managed to deal with the contents in accordance with the suggested competencies for the section. For the groups who didn't get the chance to make presentations, collect the written documents they prepared and check whether they have done it well or not. Record their performances. Give class works or home works. Check the work of every student, record the performance and make sure that the suggested competencies for the section are achieved. Appreciate students working above the minimum requirement level and encourage them to continue working hard. Assist students working below the minimum requirement level by arranging additional lesson time.

Additional Questions

*1. What natural resources are available in your areas/places that can be used as raw materials can any industrial manufacturing activity? Classify these natural resources as renewable and non–renewable.

2. What materials can be manufactured by industries from the natural resources available in your areas/places?

Answers to Additional Questions

1. Answers may vary: Accept the answers which are suitable for the environment you are living in.
2. Answers may vary: Accept all answers suitable for the area where you live.

Answers to Exercise 3.2

1. The types of manufacturing industries based on the product they manufactured:
   - Food, beverages and tobacco industries
   - Textiles, wearing apparel, leather goods
   - Paper products, printing and publishing
   - Chemical, petroleum, rubber and plastic products
   - Non-metallic mineral products other than petroleum products
   - Basic metal products, machines and equipment.

2. Examples of renewable: plants, (crops and forests), and animal,
Examples of non-renewable: fossil fuels (petrol, coal etc.), metals (iron, copper, gold, silver, lead, zinc etc.), minerals and salts (carbonates, phosphates, nitrates etc.).

3.3 Manufacturing of Valuable Products/Chemicals

Period allotted 13

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

- *describe the general methods of manufacturing of valuable products in industries"*
- *explain the important steps for the production of NH_3 in Haber process*
- *use Le Chaterier's principles to explain how the yield of ammonia can be increased in the Haber process*
- *consult the internet or other reference materials to inspect some important direct uses of H_2SO_4, HNO_3 and Na_2CO_3*
- *examine the physical and chemical properties of H_2SO_4 , HNO_3 , and Na_2CO_3*
- *describe the important steps for the production of HNO_3 in the Ostwald process*
- *list the physical and chemical properties of H_2SO_4*
- *explain how the production of H_2SO_4 is considered as vital to measure the development of a nation*
- *draw the schematic diagram which shows the steps followed in the production of H_2SO_4 in the Contact process*
- *state the raw material used to manufacture Na_2CO_3*
- *draw the schematic diagram which shows the steps followed in production of Na_2CO_3 in the Solvay process*
- *discuss the uses of DAP, $(NH_4)_2HPO_4$, Nitrogen fertilizers, herbicides and insecticides in the agriculture sector*
- *apply ingenious knowledge to produce natural compost*
- *use local resources to prepare insecticides.*

Forward Planning

Read the contents of the section thoroughly. Prepare a plan that shows the contents you treat during each period so that you can cover the contents of this section within 13 periods. Besides you need to plan how to allocate your time for students to discuss in groups, make presentations, and harmonize other activities during each period. Prepare diagrams that assist you to explain the steps of production of ammonia (Haber -Bosch process), nitric acid manufacturing process, ssulphuric acid manufacturing process (contact process), manufacturing of sodium carbonate (Solvay process), manufacturing of sodium hydroxide NaOH and their properties and uses, uses and application of diammonium monohydrogen phosphate, nitrogen-based fertilizers, some common pesticide and herbicides.

Decide when to give project work 3.1 as well as how students should form groups to perform the project work. You better give them the project work a week before the period in which you intend to deal with some common pesticide and herbicides

Teaching Aids

- diagram which shows the basic steps in a manufacturing process
- diagram of the Habe-Bosch process
- diagram of the Ostwald process
- diagram of the Contact process.

Subject Matter Presentation

3.3.1 Ammonia

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture.

This section starts with an activity. Activity 3.4 helps students to discuss why ammonia is highly soluble in water, the conditions that are required to get high yield of ammonia using Le Chatelier's principle and apply the factors that affect chemical equilibrium in the synthesis of ammonia by the Haber process? You can start teaching this section by allowing students to discuss Activity 3.4 for some time in groups and present their views to the class. After they have done, give them appropriate information about the activity as follows. Ammonia is highly soluble in water because it has hydrogen bonds which are polar in nature: water is also polar in nature due to hydrogen bonds. So, with the principle polar compounds soluble with polar solvents, NH_3 is highly soluble with water. Then inform them that the number of reactant molecules is higher than the number of product molecules, so according to Le Chatelier's principle of chemical equilibrium, there would be a continuous decline in the yield as the reaction progresses. High pressure conditions are applied to overcome this effect. This pressure on the reaction mixture causes a shift in the equilibrium of the reaction toward the products, in effect, leading to a continuous, high production of ammonia. The rationale behind this occurrence is that, as the pressure increases, the system adjusts itself to accommodate this increase, and hence, produces more product, in a bid to reduce the total number of molecules contained in the system.

After that, proceed to introduce some important properties, uses, preparation of ammonia and the steps involved in ammonia production (Haber process). Let the students tell in detail about uses of ammonia. Then clearly show the diagram to illustrate the important steps in production of ammonia (Haber-Bosch process). In treating chemical properties of ammonia, first do Experiment 3.1 (i.e. preparation and testing of ammonia) and 3.2 (i.e. ammonia fountain demonstration). Discuss with the students what you and they observed from the experiment. Explain how a ammonia is highly soluble with water and also how the fountain of ammonia is formed. However, during performing Experiment 3.1 and Experiment 3.2 the following precautions should be taken:

- Ammonium chloride is HARMFUL, Calcium hydroxide is an IRRITANT, Calcium oxide is CORROSIVE,– optional concentrated hydrochloric acid is CORROSIVE.
- Wear eye protection throughout. Ammonia gas is TOXIC and DANGEROUS FOR THE ENVIRONMENT and pungent-smelling and must not be inhaled. The experiments must only be carried out in a fume cupboard or in a well-ventilated laboratory.

Following the experiment, students should write a laboratory report and submit them for correction. Collect the laboratory reports and give feedback. Check that the observation and analysis in the reports coincides with the following points:

Experiment 3.1

A. Because ammonia has a strong smell and is poisonous in quantity, pupils should ideally carry out this experiment in fume cupboards/ and well-ventilated laboratory.

B. Since the reaction to produce ammonia also produces water. The purpose of the calcium oxide is to help to prevent this water from coming out of the delivery tube as water vapor.

C. There is generally enough water on the surface of indicator papers to dissolve ammonia without having to moisten the paper.

D. Ammonia is one of the very few common alkaline gases. When it dissolves in water it reacts reversibly according to the equation:

$$NH_3(g) + H_2O(l) \Leftrightarrow NH_4^+(aq) + OH^-(aq)$$

Experiment 3.2

A. The phenolphthalein present will indicate a basic solution (pink in color).

B. The NH_3 gas will dissolve in the water and cause the water from the beaker to rise into the flask.

C. The fountain formed in the flask is due to that as the ammonia is dissolved in the flask the pressure drops.

Finally, give them a reading assignment on the production of nitric acid manufacturing process.

Subject Matter Presentation

3.3.2 Nitric acid Manufacturing Process

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with an activity. Activity 3.5 helps students to discuss why nitric acid is considered as a highly corrosive mineral acid and why nitric acid is used for the manufacture of explosives such as trinitrotoluene (TNT) and nitroglycerine. You can start teaching this section by allowing students to discuss Activity 3.5 for some time in groups and present their views to the class. After they have done, give them appropriate information about the activity as follows.

1. Mineral acids are corrosive and, if acids are inhaled, they can be destructive to mucous membrane tissues and the upper respiratory tract, which would cause burning of the throat and nose, coughing, wheezing, shortness of breath, and pulmonary edema (water retention). Skin contact causes burns and eye contact may even cause blindness. Nitric acid is a strong oxidizer that reacts with most metals, evolving either hydrogen gas or nitrogen oxides depending on the concentration and the metal.

2. **Trinitrotoluene** more commonly known as **TNT**, or more specifically **2, 4, 6-trinitrotoluene**, is a chemical compound with the formula $C_6H_2(NO_2)_3CH_3$. This yellow solid is occasionally used as a reagent in chemical synthesis, but it is best known as an explosive material with convenient handling properties. The explosive yield of TNT is considered to be the standard comparative convention of bombs and asteroid impacts. In chemistry, TNT is used to generate charge transfer salts.

After that, proceed to introduce some important properties, uses, preparation of nitric acid and the steps involved in nitric acid production (the Ostwald process). Let the students tell in detail about uses of nitric acid. Then clearly show the diagram to illustrate the important steps in production of nitric acid (the Ostwald process). In teaching the preparation of nitric acid, first do Experiment 3.3 (i.e. preparation of nitric acid in the laboratory) and Experiment 3.4 (properties of nitric acid); discuss with the students what you and they observed from the experiment. Nitric acid is highly soluble with water and forms a large number of salts, called nitrates, which are typically very soluble

in water. nitric acid is a highly corrosive mineral acid. However, during performing Experiment 3.3 and Experiment 3.3 the following precautions should be taken.

- Concentrated nitric acid is corrosive and oxidizing: wear goggles or a face shield. The use of nitrile gloves is recommended.

Following the experiment, students should write a laboratory report and submit them for correction. Collect the laboratory reports and give feedback. Check that the observation and analysis in the reports coincides with the following points.

Experiment 3.3

A. Since nitric acid is a more volatile acid than sulphuric acid it is displaced by sulphuric acid from metal nitrates and finally nitric acid is formed.

B. The reaction

$$KNO_3 + H_2SO_4 \rightarrow KHSO_4 + HNO_3$$

(Salt of more volatile acid + less volatile acid → displaces more volatile acid)

Experiment 3.4

A. The solution will rapidly turn green

B. the solution evolves nitrogen dioxide and its color is red/brown

C. $Cu(s) + 4HNO_3\,(aq) \rightarrow Cu\,(NO_3)_2\,(aq) + 2NO_2\,(g) + 2H_2O\,(l)$

Give them a reading assignment on the production and importance of nitrogen-based fertilizers.

Subject Matter Presentation

3.3.3 Nitrogen–Based Fertilizers

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with Activity **3.6:** help the students to discuss "why a large-scale use of synthetic fertilizers can be harmful to the environment, what is the purpose of adding nitrogen stabilizers in soil after addition of nitrogen-based fertilizers and what is the role of nitrifying bacteria related to the reaction of nitrogen-based fertilizers?" You can start teaching this section by allowing students discuss Activity 3.6 for some minutes in groups and present their views to the

class. After they have done so, give them appropriate information about the activity as follows.

1. Fertilizers provide crops with nutrients like potassium, phosphorus, and nitrogen, which allow crops to grow bigger, faster, and to produce more food. However, applying excessive amounts of fertilizer leads to the release of harmful greenhouse gases into the atmosphere and the eutrophication of our waterways.
2. Nitrogen−based stabilizers limit nitrogen loss through leaching or denitrification. These losses occur once the fertilizer sources are converted to nitrate. Leaching is the movement of nitrate nitrogen through the soil profile with water.
3. Nitrifying bacteria convert ammonia to nitrites or nitrates. Ammonia, nitrites, and nitrates are all fixed nitrogen and can be absorbed by plants. Denitrifying bacteria converts nitrates back to nitrogen gas.

After that, proceed to introduce some important application of nitrogen-based fertilizers for soil fertility, plant growth and soil reactions of nitrogen-based fertilizers. In treating the application of nitrogen-based fertilizers and their reaction in soil as an example

1. Anhydrous ammonia, NH_3,

$$NH_4^+ \xrightarrow{\text{Nitosomonas}} NO_2^-$$

$$NO_2^- \xrightarrow[\text{Nitrosolobus}]{\text{Nitrobacteria and}} NO_3^-$$

2. Urea

$$(NH_2)_2CO + H_2O \rightarrow CO_2 + 2NH_3$$

3. Urea-ammonium nitrate (UAN) solutions

The urea portion of UAN solutions reacts just as dry urea does (see the reaction of urea). If applied on the surface, the amide-N in the solution may incur losses due to volatilization when urease hydrolysis releases NH_3. But if UAN is incorporated by tillage or sufficient water, the NH_3, quickly reacts with soil water to form NH_4^+.

4. DAP (Diammonium monohydrogen phosphate $(NH_4)_2HPO_4$

In treating the application of DAP in soil and their preparation the reaction between ammonia and phosphoric acid by the following two steps: 1/ Anhydrous ammonia reacts with phosphoric acid to form monoammonium dihydrogen phosphate and

diammonium monohydrogen phosphate and 2/ Recycling monoammoniumdihydrogen phosphate for further reaction with anhydrous ammonia yields DAP.
Let the students tell about other uses of DAP. Then clearly show the diagram to illustrate the important steps in production of DAP.

Let students write research to discover the name of natural fertilizers that most of Ethiopian farmers use to increase the soil fertility. Ask: Do you know how it is composed?" given in research and writing part. Allow some students to present their findings to the class and give them a reading assignment on production of sulphuric acid i.e. the Contact process.

Subject Matter Presentation

3.3.4 Sulphuric acid Manufacturing Process

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with Activity 3.7, which helps students to discuss the chemical that is produced in the largest volume in the world and why it is produced. You can start teaching this section by allowing students to discuss Activity 3.7 for some minutes in groups and present their views to the class. After they have done so, give them appropriate information about the activity as follows. "Sulfuric acid (H_2SO_4) is the largest volume chemical produced in the world. It is normally manufactured twice the amount of any other chemical and is a leading economic indicator of the strength of many industrialized nations. The rate of consumption of sulphuric acid is a measure of a country's industrialization".

After that, proceed to introduce some important physical and chemical properties of sulphuric acid. Then let the students discuss Activity 3.8 about various uses of sulphuric acid referring to the internet, text and reference books. They can present their findings as a summary to the class. Give the feedback of the activity in summary form as below:

Sulfuric acid (H_2SO_4) is the largest volume chemical produced in the world. It is normally manufactured at about twice the amount of any other chemical and is a leading economic indicator of the strength of many industrialized nations. The rate of consumption of sulphuric acid is a measure of a country's industrialization. Because of these facts, sulphuric acid has many uses:

- In the fertilizer industry: It is used in the preparation of fertilizers such as ammonium phosphate, ammonium sulphate, super phosphate of lime, etc.
- In the petroleum refining: It is used for the refining of crude petroleum. The crude
- In the chemical industry: It is used for the manufacture of hundreds of other compounds such as hydrochloric acid, nitric acid, phosphoric acid, sulphates, bisulphates, diethyl ether, etc.
- In metallurgy: Sulphuric acid is used for metallurgical processes such as electrolytic refining, electroplating, galvanizing, etc. A number of metals like copper, silver, etc. are extracted from their ores using sulphuric acid.
- It is used for cleaning the surfaces of metals (picking) before electroplating.
- It is used in the manufacture of explosives such as dynamite, T.N.T. nitro cellulose products (gum, cotton), etc.
- It is also used as a drying and dehydrating agent. It is often used to dry neutral and acidic gases such as nitrogen, oxygen, and carbon dioxide
  It is used for storage batteries as an electrolyte

Sulphuric acid is soluble in all ratios with water. The sulphuric acid can be diluted by water to get acids in various strengths for different purposes. During the mixing process, sulphuric acid should be added to water. Since the dissolution of sulfuric acid in water is very exothermic, it is corrosive to the skin and is a strong oxidizing and dehydrating agent.

Let the students tell about the uses of sulphuric acid and its preparation. Then clearly show the diagram to illustrate the important steps in production of sulphuric acid i.e., the Contact process. Give them a reading assignment on some common pesticides and herbicides.

Answers to Exercise 3.3

1. $N_2 + 3H_2 \rightarrow 2NH_3$
2. Due to the exothermic nature of the reaction, the steady increase in heat over a period of time causes the gradual decomposition of ammonia. To prevent this from happening, the iron in the system is coupled with K_2O, CaO, and Al_2O_3 in order to catalyze the reaction and increase its speed. The iron adsorbs the nitrogen and hydrogen onto its surface, hence, lowering the amount of critical energy required to cleave the covalent bonds of nitrogen.
3. High temperature conditions are required in order to break the strong triple bond of the nitrogen molecules. But, due to the exothermic nature of the reaction, the steady increase in heat over a period of time causes the gradual decomposition of ammonia.
4. The product formed is ammonium gas and the reaction equation is:

$$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O + 2NH_3(g)$$

Answers to Exercise 3.4

1. Nitric acid is a colorless liquid, but it turns to brown when it is exposed to light, due to the formation of NO_2. It is a strong acid and strong oxidizing acid.
2. Step 1: Oxidation of ammonia

$$4NH_3(g) + 5O_2(g) \xrightarrow{850\,℃,\ P} 4NO(g) + 6H_2O(g)$$

Step 2: Conversion of NO to NO_2

$$2NO(g) + O_2(g) \xrightarrow{\text{cool}} 2NO_2(g)$$

Step 3: Dissolution of NO_2 with water

$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO$, NO is recycled.

3. It is mainly used for preparing fertilizers, explosives, and plastics.
4. $KNO_3 + H_2SO_4 \rightarrow KHSO_4 + HNO_3$

Answer to Exercise 3.5

1. Urea is manufactured by reacting CO_2 with NH_3 in 2 equilibrium reactions:

$$2NH_3 + CO_2 \rightarrow NH_2COONH_4 \ (\text{ammonium carbamate})$$

$$NH_2COONH_4 \xrightarrow[\text{high T}]{\text{high P}} (NH_2)_2CO + H_2O \ (\text{urea} + \text{water})$$

2. Soil Reactions - If urea is applied to the soil surface and not incorporated by water or tillage, it is subject to volatilization losses of N. This occurs as urea undergoes hydrolysis to carbon dioxide and ammonia:

$$(NH_2)_2CO + H_2O \rightarrow CO_2 + 2NH_3$$

3. Step 1: Reaction of ammonia with H_3PO_4

$$3NH_3(g) + 2H_3PO_4(l) \rightarrow NH_4H_2PO_4(s) + (NH_4)_2HPO_4(s)$$

Step 2: Recycling monoammonium phosphate

$$NH_4H_2PO_4(s) + NH_3(g) \rightarrow (NH_4)_2HPO_4(s)$$

4. DAP is a white solid which is completely soluble in water. Since it contains both nitrogen and phosphorus, it is mainly used as a fertilizer.
5. Molar mass of $(NH_4)_2HPO_4$ = 132 g/mol

$$P\% = \frac{31}{132} X\ 100\ \% = 23.48\ \%$$

$$N\% = \frac{28}{132} X\ 100\% = 21.21\ \%$$

Subject Matter Presentation

3.3.5 Some Common Pesticide and Herbicides

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with Activity 3.9; help the students to discuss about the common pesticides that are most frequently used by Ethiopian farmers and the common herbicides which are most frequently used by Ethiopian farmers.

You can start teaching this section by students discussing Activity 3.9 for some time in groups and presenting their views to the class. After they have done so, give them appropriate information about the activity as follows.

1. The common pesticides that are most frequently used by Ethiopian farmers; organochlorines, organophosphates, carbamates, pyrethroids and biological.
2. The common herbicides that are most frequently used by Ethiopian farmers are 2,4-D and 2,4,5-T; triazines such as atrazine, hexazinone, and simazine; organic **phosphorus** chemicals such as glyphosate; **amides** such as alachlor and metolachlor; thiocarbamates such as butylate; dinitroanilines such as trifuralin; chloroaliphatics such as dalapon and trichloroacetate; and inorganic chemicals such as various arsenicals, cyanates, and chlorates.

After that, proceed to introduce some important characteristics and main composition of the common pesticides. In treating this as an example organochlorine: its important characteristics is soluble in lipids, they accumulate in fatty tissue of animals are transferred through the food chain, toxic to a variety of animals and long-term persistence. Its main composition is carbon atoms, chlorine, hydrogen and oxygen. They are nonpolar and lipophilic.

Let the students tell about other types of pesticides and herbicides including Neem Leaf. Tell about the detail of Neem Leaf that used as a deterrent to pests. Let students to collect information from people and write a report about one of the common traditionally produced pesticides by Ethiopian farmers other than Neem Leaf. And to submit the report to you. Allow some students to present their findings to the class. Then give them a reading assignment on Manufacturing of sodium carbonate (the Solvay process).

Answer to Exercise 3.6

1. Step1: burning of sulphur

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

Step 2: conversion of SO_2 and SO_3

$$2SO_2(g) + O_2(g) \xrightarrow{V_2O_5,\ 400^\circ C} 2SO_3(g)$$

Step 3: passing SO_3 to sulphuric acid

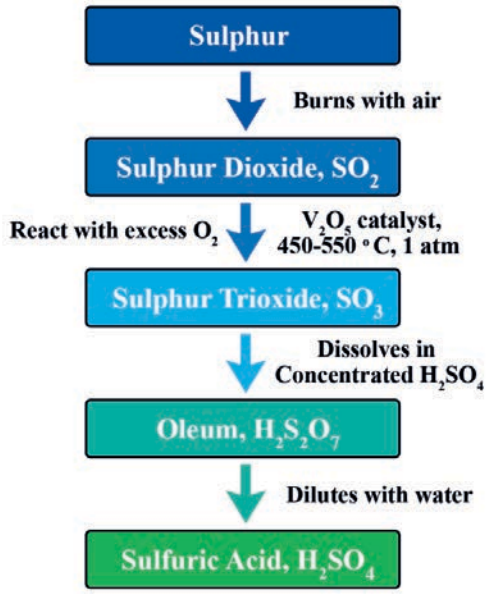
$$SO_3(g) + H_2SO_4(aq) \rightarrow H_2S_2O_7(l)$$

Step 4: addition of water to oleum

$$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$$

2. The major uses of sulphuric acid are for making fertilizers, detergents, plastics and paints.

3. The diagram shows the four major steps of production of sulphuric acid:



4. $8Al + 15\ H_2SO_4\ (conc.) \rightarrow 4Al_2(SO_4)_3 + 12H_2O + 3H_2S$

Answer to Project 3.1

Probably the name of natural fertilizer that most of Ethiopian farmers use to increase the soil fertility would be compost. This should be in report format and depends on the information each student collects from the respective body.

Answers to Exercise 3.7

1. **Insecticide**: any toxic substance that is used to kill insects. Such substances are used] primarily to control pests that infest cultivated plants or to eliminate disease carrying insects in specific areas.
2. **Types of pesticides:**
    - Insecticides (killing insects)
    - Herbicides (killing plants)
    - Fungicides (killing fungus)
    - Rodenticides (killing rodents, like mice and rats)
    - Bactericides (killing bacteria)
3. The most important chemical groups of herbicides are chlorophenoxy acids such as 2,4-D and2,4,5-T;triazines such as atrazine, hexazinone, and simazine; organic **phosphorus** chemicals such as glyphosate; **amides** such as alachlor and metolachlor; thiocarbamates such as butylate; dinitroanilines such as trifuralin; chloroaliphatics such as dalapon and trichloroacetate; and inorganic chemicals such as various arsenicals, cyanates, and chlorates.

Answers to Project 3.2

The report about one of the common traditionally produced pesticides by Ethiopian farmers other than Neem Leaf may be varied from one region to the other. So evaluate the students report based on the locality of the students.

Subject Matter Presentation

3.3.6 Sodium Carbonate

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with Activity 3.10 which helps students to discuss about the raw material for glass production and why the **Solvay** plant is situated near water.

You can start teaching this section by allowing students to discuss Activity 3.10 for some minutes in groups and present their views to the class. After they have done so, give them appropriate information about the activity as follows. The Solvay process is used to make sodium bicarbonate and sodium carbonate. These chemicals are used for glass making, cleaning formulations, and many other applications. These raw materials, i.e. sodium bicarbonate and sodium carbonate, that are used for glass production and are produced with the Solvay process are presented in the student text in Section 3.4.1. Water is used as a raw material in two steps in the Solvay process. In the ammonia absorber tower, brine solution (sea water) is fed to the tower. Brine solution is a highly concentrated aqueous NaCl solution. Therefore, there is water in this stream.

To reproduce ammonia gas from ammonium chloride, calcium hydroxide is used. In the process calcium oxide is produced in the carbon dioxide generation section. Water is added to calcium oxide to produce calcium hydroxide. Now, you can see water is a must for a Solvay plant and plant should be located near a water source. Usually, these locations are situated close to the sea.

After that, proceed to introduce some important physical and chemical properties of sodium carbonate and its uses. In treating chemical properties of sodium carbonate at low temperatures the sodium hydrogen carbonate is much less soluble than ammonium chloride and crystallizes out. In treating uses of sodium carbonate, the light ash sodium carbonate is used:

- as chemicals, metallurgical detergents
- in flat glass, glass fiber, glass container and other glass.

The "heavy ash" sodium carbonate is used in:

- Brine treatment and water purification
- Food, drinks, detergent textile and miscellaneous
- Heavy chemicals manufacturing, phosphates, silicates and chromates.

Let the students tell other uses of sodium carbonate. Then clearly show the important steps in the production of sodium carbonate (the Solvay process). Give them a reading assignment on production of sodium hydroxide (caustic soda).

Subject Matter Presentation

3.3.7 Sodium Hydroxide (NaOH)

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with Activity 3.11 which helps students to discuss the uses of Cl_2 produced during the manufacturing process of NaOH from brine, and why we take care while doing experiments that involves sodium hydroxide.

You can start teaching this section by allowing students to discuss Activity 3.11 for some minutes in groups and present their views to the class. After they have done, give them appropriate information about the activity as follows:

1. The use of Cl_2 gas which is produced during the manufacturing of sodium hydroxide from brine is:
   - to treat drinking water and swimming pool water by killing bacteria
   - 20% of chlorine produced is used to make PVC
   - used in organic chemistry processes, for example, as an oxidizing agent and a substitution for hydrogen
   - make chloroform (an anesthetic) and carbon tetrachloride (a dry-cleaning solvent).
2. NaOH is often referred to as caustic soda, due to its corrosive action on many substances: it decomposes proteins at room temperatures and may cause chemical burns to human bodies.

After that, proceed to introduce some important physical properties of sodium hydroxide and its chemical properties and uses. In treating chemical properties of sodium hydroxide is often referred to as "caustic soda", due to its corrosive action on many substances: it decomposes proteins at room temperatures and may cause chemical burns to human bodies. It dissolves readily in water; its solution has a soapy feeling commonly used as a base.

Let the students tell about uses of sodium hydroxide. Then clearly show the important steps in production of sodium hydroxide.

Assessment

Assess each student's work throughout the section; see how every student works 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 requirement level. Encourage the students working above the minimum requirement level. Arrange the necessary assistance for students working below the minimum requirement level. Give them additional exercises.

Answers to Exercise 3.8

1. The raw materials of sodium carbonate manufacturing:
   - Brine solution (NaCl)
   - Limestone ($CaCO_3$) for CO_2
   - Ammonia gas
   - Water
2. The main byproduct in manufacturing of Na_2CO_3 in the Solvay process is $CaCl_2$
3. $2NaHCO_3 + heat \rightarrow Na_2CO_3 + H_2O(g) + CO_2(g)$
4. Burning coke in the Solvay process is required to provides the heat energy to decompose the limestone (an endothermic reaction)
5. a. Washing soda: Na_2CO_3 c. Soda ash: Na_2CO_3
   b. Baking soda: $NaHCO_3$

Answers to Exercise 3.9

1. Sodium hydroxide is used in numerous industrial processes such as in pulp and paper manufacturing, alumina extraction from bauxite in aluminum production, as well as in the textiles industry and drinking water production. NaOH is also an important compound in the manufacture of soaps and detergents, in waste gases scrubbing, saponification and etherification and esterification reactions; as well as in basic catalysis.In short caustic soda is used in the following:
    - In the manufacturing of petroleum products.
    - In the manufacturing of pulp and paper.
2. Since caustic soda dissolves the grease, protein-based deposits, fats, and oil, it is added to water and heated, to use it in the cleaning of process equipment, and storage tanks.
3. NaOH is highly corrosive and strongly irritating. It causes severe burns.

3.4 Some Manufacturing Industries in Ethiopia

Period allotted 14

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

- *list some manufacturing industries in Ethiopia*
- *outline the important steps in the production of ceramics*
- *mention some uses of ceramics*
- *write the important steps in the production of cement, ceramics, glass, sugar and ethanol*
- *predict the product of sugar fermentation*
- *prepare ethanol from locally available ingredients*
- *compare and contrast the indigenous and industrial methods of: food preservation and packing, making ethanol, and processing skin and hide.*
- *compare and contrast locally made clay materials with ceramics*
- *outline the important steps in the production of pulp and paper; soaps and detergent and dry detergents*
- *explain how tanning is carried ou*
- *mention some uses of skin and hides*
- *present a report to the class after visiting a nearby food factory.*

Forward Planning

Read the contents of this section thoroughly and plan how to cover the contents within 14 periods. Your plan may include the contents and activities you should treat during each period. Also work out a plan on: how much time you need to allot for students to discuss activities, make presentations, harmonizing concepts, stabilization and evaluation during each period.

Teaching Aids

- diagram which shows the basic steps in production of different products in industries like:
  - glass, ceramics
  - sugar, food processing and qpreservation, alcohol beverages
  - paper and pulp, tannery, soap and detergent

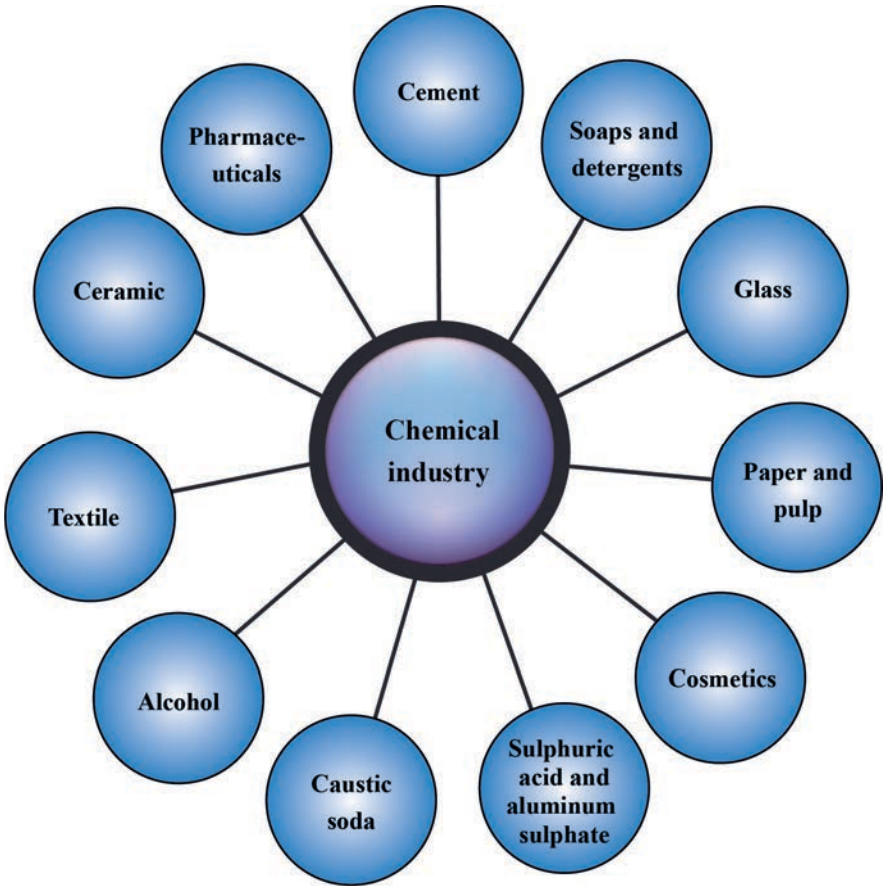
Subject Matter Presentation

To teach the contents in this part, you better use inquiry, brainstorming and group discussion as methods of teaching. You can start teaching this section, using Activity 3.12. The purpose of this activity is to enable students to get a general overview about industry, their general characteristics and the number of the industries in Ethiopia, some of them can be listed by students. This will help you to know their prior knowledge and experience of your students. So, let students discuss Activity 3.12 in groups for a few minutes. After completing their discussion, let students present their ideas in groups to the rest of the class. Following the presentations, continue harmonizing concepts suggested by students with the facts they are expected to know. When you do so, begin with the place where in Ethiopia most of chemicals /manufacturing industries are located such as Addis Abeba, Nazeret and Mujo. This includes industries that manufacture cement, soaps and detergents, pharmaceuticals, plastic products, alcohols, beverages etc. After defining an industry, list some industries in Ethiopia.

Serial No	Industry	Product	Location
1	Mesobo Cement Factory	Cement	Tigray
2	Muger Cement Factory	Cement	Muger (western shewa)
3	Dire Dawa Cement Factory	Cement	Dire Dawa
4	Derba Midroc Cement Factory	Cement	Northern Shewa
5	Nifas Silk Paint Factory	Paint	A. A
6	Dil Paint Factory	Paint	A. A
7	Tseday Paint Factory	Paint	A. A
8	Repi Soap and Detergent Factory	Soap and Detergent	A. A
9	Gulele Soap Factory	Soap	A. A
10	Nazreth Soap Factory	Soap	Nazreth (Adama)
11	Fincha Sugar Factory	Sugar	Fincha
12	Metehara Sugar Factory	Sugar	Metehara
13	Wonji Sugar Factory	Sugar	Wonji
14	Matador Addis Coma Factory	Tyres	A. A
15	Saint George Brewery	Beer	A. A
16	Bedelle Brewery	Beer	Bedelle
17	Meta Brewery	Beer	Sebeta
18	Harar Brewery	Beer	Harar
19	Dashen Brewery	Beer	Gondar
20	Awash Tannery	Processed Leather	A. A
21	Mojo Tannery	Processed Leather	Mojo
22	Addis Foam and Plastic Factory	Plastic	A. A
23	Ethio Plastic	Plastic	A. A
24	Adamitulu Pesticide Factory	Pesticides	Adamitulu
25	Caustic Soda factory	Caustic Soda	Hawassa
26	Tabor Ceramic Factory	Ceramics	Hawassa

Serial No	Industry	Product	Location
27	Sulfuric Acid and Aluminum Sulphate Factory	Sulfuric Acid and Aluminum Sulphate	Awash Melkassa
28	Ethio Gas and Carts	Plastics arts and CO_2	A. A
29	Chora Gas and Chemical Products	Oxygen, Acetylene, Shoe polish, floor wax	A. A
30	Addis Glass Factory	Glass	A. A
31	Nas Foods Factory	Biscuits	A. A
32	Arbaminch Textile Factory	Textile	Arbaminch
33	Almeda Textile Factory	Textile	Tigray (Adowa)

There are many other industries that are not mentioned here; e.g. those involved in the production of soft drinks, foods, pharmaceuticals and other products. According to ADDISBIZ.com(https://addisbiz.com/business-directory/manufacturing-industry) news of the year 2022, more than 2228 manufacturing industries are available in the country. You can give the students an activity to write a spider diagram showing materials produced by chemical industries in Ethiopia see below.



3.4.1 Glass Manufacturing

To teach the contents on glass, you better use peer teaching methodology. In order to make the teaching learning process simpler, let students do Activity 3.13, which deals with what is glass, the types of glasses with the corresponding main functions and the question: is glass manufactured in Ethiopia? Give them a chance to work on this in groups during which you teach the topic. You can allow some groups to make presentations. During the presentations, let other groups ask questions and let the group presenting the lesson answer the questions.

After the presentations, summarize the main points. Inform students that glass is an amorphous or non-crystalline solid material. Most common glasses are mixtures of two or more silicates. The **ordinary glass** used for making window pans, bottles, and dishes is called soda lime glass. It is a mixture of sodium silicate and calcium silicates with excess silica. It is made by heating together silica sand, sodium carbonate or sodium sulphate and calcium carbonate. **Quartz glass** is made by melting pure silica, SiO_2, at a temperature of about 2300 °C and pouring the molten viscous liquid into moulds. It is of high strength, low thermal expansion and highly transparent. Whereas, **Borosilicate glass** is commonly known as Pyrex. It is manufactured using boron (III) oxide, B_2O_3, instead of limestone or calcium oxide. This glass has high resistance to chemical corrosion and temperature changes and is widely used to make ovenware and laboratory equipment such as flasks, beakers, and test tubes. Also inform students that "glass is manufactured in Ethiopia in Addis Glass factory located in Addis Abeba".

You can also explain about the substances that can be added to impart different colors to glass during manufacturing as it is presented in Table 3.1.

Tables 3.1: Shows the effect of various oxides on the colour of glass.

Substance added	Colour of glass
Chromic oxide	Green
Manganese oxide	Reddish-purple
Cupric oxide	Green
Cadmium sulphide	Yellow
Cobaltous oxide	Blue
Gold and cuprous	Rubby
Oxides	Fluorescent
Uranium oxide	Yellowish green

Then, before you conclude the lesson on glass, let the students know the steps in glass production using a diagram which shows the basic steps of glass production taking place in the glass manufacturing industries.

Answers to Exercise 3.10

1. If potassium carbonate is used instead of sodium carbonate, a "hard" glass, that is, a glass needing a higher temperature to melt it, will be produced
2. a greenish tint to the glass
3. **Pot furnace:** For low-volume special glass products pot furnaces are used. It consists of a chamber in which fire clay tubes called glass pots are placed. The raw batch is charged into the hot pot and the glass is melted. Sometimes the glass is worked directly from the furnace; a small working door is constructed for this purpose near the top of the pot. Different kinds of glass can be produced at the same time. This type of furnace is similar to an **open-hearth furnace.** Only one kind of glass can be produced, but it can work continuously and can be connected with automatic machines. A tank furnace consists of a big rectangular chamber, the lower half of which is always kept full of molten glass. The space between the glass and the arched roof is the combustion space, where gas or oil and preheated air are burned. The furnace is constructed of large blocks made of fire clay or special refractory materials.

Answers to Project 3.3

The answer for this project may vary as far as students refer books in the library and other sources. This table shows a possible answer for glass to retain different colors.

Tables 3.1: shows the effect of various oxides on the color of glass.

Substance added	Color of glass
Chromic oxide	Green
Manganese oxide	Reddish-purple
Cupric oxide	Green
Cadmium sulphide	Yellow
Cobaltous oxide	Blue
Gold and cuprous	Rubby
Oxides	Fluorescent
Uranium oxide	Yellowish green

3.4.2 Manufacturing of Ceramics

To teach the contents on ceramics, you better use peer teaching and gapped lecture methodology. Give a short summary on glass and on steps in glass production and proceed to deal with concepts on ceramics. First, let the students discuss Activity 3.14 in groups for a few minutes and let some groups present their conclusions to the rest of the class. In harmonizing their ideas with the truth, let students know that pottery is one form of ceramic. And let them know the difference and similarity of pottery as "Pottery and ceramics **are one and the same**. The word ceramic derives from Greek which translates as "of pottery" or "for pottery". Both pottery and ceramic are general terms that describe objects which have been formed with clay, hardened by firing and decorated or glazed. Let them also, in our everyday life, we are surrounded by ceramics and glass. Ceramic tiles may decorate the floors of one or more rooms, as well as walls and kitchen countertops. Ceramic roof tiles are often used to insulate buildings, to create a water barrier and allow for proper water drainage**.** Some popular ceramic products are kitchenware like plates, mugs, knives and even ceramic cook tops because ceramics is heat resistant and is a thermoset. Then, introduce on the steps involved in ceramic production by using diagram which shows the basic steps of ceramic production takes place in ceramic manufacturing industries for example, mention Tabor Ceramic Factory located in the town of Hawassa.

Answers to Exercise 3.11

1. ($C_{12}H_{22}O_{11}$) is a disaccharide or double sugar
2. Each molecule of sucrose consists of a molecule of -D- glucose ($C_6H_{12}O_6$) and a molecule of ρ – D- fructose ($C_6H_{12}O_6$). A sucrose molecule is formed by a loss of a molecule of water from the two simple sugar molecules.

3.4.3 Cement

It is better to use inquiry and group discussion as teaching methods. The construction industry is growing at a faster rate in Ethiopia. For this reason, the production of cement is vital. Activity 3.15 enables students to discover how the number of cement factories is increasing in Ethiopia and also realize that industries are established around the areas where the raw materials are found. So, let the students discuss Activity 3.15 in groups and explain their views to class. After they do, introduce the presence of some cement factories in Ethiopia. These factories are located in rural areas closer to places where they get raw materials. Then, ask students to suggest if they know the raw materials used to produce cement. After their responses, introduce the raw materials for cement production and the steps followed in the process by using diagram which shows the basic steps of cement production takes place in cement production industries for example, mention Dangote, Mossobo, Moger, and Derba Cement Factory located in different parts of Ethiopia. Let students discuss the uses of cement. Finally, let students do Project 3.4.

Answers to Project 3.4

The report may vary based on the observation of your project experimental result.

3.4.4 Sugar Manufacturing

After completing the contents on cement production, continue on manufacturing of sugar. You better use inquiry and group discussion as teaching methods for this part. The topic starts with an activity. The activity is suggested to assists students to list the foods and drinks in which sugar is an ingredient and to discover the raw materials/ sources that are used in sugar production. So, you can start by letting students discuss Activity 3.16 in groups, and letting some groups present their views to the class. To harmonize the concepts of students with the fact, introduce foods and drinks. Sugar is an ingredient for; ice cream, candy, pastries, cookies, soda, fruit juices and canned fruit and the raw materials used for sugar production. These are sugarcane and sugar beet. However, inform students that more than 60% of the world's sugar is produced from sugarcane. In Ethiopia, sugar is produced from sugarcane. Then introduce the steps followed during the manufacturing process using the diagram which shows the steps of production of sugar. As much as possible, explain the purpose of each step so that students can realize the basic steps in sugar production. Explain each step of sugar production by using the diagram which clearly shows the different steps of sugar production involved in sugar industry.

3.4.5 Paper and Pulp

Revise the main points on sugar production and continue introducing concepts on paper and pulp. Use inquiry and group discussion to teach the contents.

The topic begins with an activity. The purpose of Activity 3.17 is to emphasizes that wasting of paper is equivalent to cutting trees. It also helps students realize the importance of proper management of paper. Let students discuss Activity 3.17 for some time in groups and let one or two groups present their ideas to the class. Then, introduce that paper can be recycled. So, recycling reduces cutting trees for paper production. Also, inform them that the quality of paper depends on the method used for its production. Emphasize that wood pulp can be manufactured from soft woods and hard woods. Mention some examples of soft and hard woods. Inform students about the composition of wood as lignin, cellulose, oils and resins. The production of wood pulp involves separating cellulose from other components.

Inform them about the roles of the individual steps involved in paper production. Especially, give emphasis to pulping. Mention the types of pulping as mechanical and chemical pulping. Let students be informed that there are two main types of chemical pulping. In both chemical methods of pulp production, the pulp is recovered by filtration. Then, the pulp recovered by filtration is bleached using strong oxidizing agents (bleaching agents) such as chlorine, chlorine oxide, ozone, and hydrogen peroxides. As much as possible, explain the purpose of each step so that students can realize the basic steps in paper and pulp manufacturing process. Explain each step of paper and pulp manufacturing by using a diagram which clearly shows the different steps of paper and pulp manufacturing process.

3.4.6 Tannery

After you complete the contents on paper and pulp, continue the lesson with tanning. Use inquiry and group discussion to teach the contents. Start the lesson with the suggested activity. The purpose of Activity 3.18 is to show the reality of leather products of Ethiopia. Most of us do not prefer using the products of our country because of the prejudice we have against local products. This activity will show the reality and helps the teacher to get students experience on this issue.

Let the students discuss Activity 3.18 in groups and let some groups present their opinions to the class. Following their presentations, continue harmonizing their opinion with the reality. Inform students that leather products are replaced by synthetic products because it is relatively expensive. Let them also know that most people prefer to buy imported leather products rather than those produced in Ethiopia. This is because imported leather products have beautiful appearance. Let them also traditionally, tanning used tannin, an acidic chemical compound from which the tanning process draws its name, derived from the bark of specific trees. An alternative method, developed in the 1800s, is chrome tanning, where chromium salts are used instead of natural tannins.

Then, introduce the steps followed in tanning. Let them also know the processes and purposes of each step using diagram. Revise the main points on tanning and continue with the contents on food processing and preservation

3.4.7 Food Processing and Preservation

Use inquiry and group discussion as methodology in teaching this topic.
Let the students first discuss Activity 3.19 in groups and let some groups present their opinion to the class. Following their presentation, harmonize concepts. Tell them that keeping food at cool place hinders the growth of micro-organisms which spoil food. After that, let them discuss Activity 3.20 in groups for a few minutes and let some groups present their opinions. Here, you can apply brain storming method and record the ideas suggested by each group on the board. In harmonizing concepts, inform students that the traditional method of food preservation includes salting, pickling, sugaring, smoking, drying and canning.

Explain how each method preserves food. Use the following information on the traditional methods of food preservation.

a. **Salting:** Salting or curing draws out moisture from meat through Osmosis.

b. **Pickling:** Pickling is a method of preserving food in an edible liquid that inhibits growth or kills bacteria and other micro-organisms. Typical pickling agents include brine, vinegar, alcohol, vegetable oil, etc.

c. **Sugaring:** Sugar is used to preserve fruit, either in syrup (with fruits such as apples, pears and peaches) or in crystallized forms where preserved food is cooked in sugar.

d. **Smoking:** Smoking is the process of flavouring, cooking or preserving food by exposing it to the smoke from burning or smoldering plant (wood).

e. **Drying:** Drying is one of the oldest methods of food preservation. It reduces water activity sufficiently and prevents bacterial growth. This method is used to preserve meat (to make “Quanta”) and cereal grains such as wheat, maize, oats, barley, rice and others.

f. **Canning:** Canning involves cooking food, sealing it in sterile cans or jars,

and boiling the contents to kill or weaken any remaining bacteria in the form of sterilization. In harmonizing the ideas suggested by the students during presentation, let them know that among the processes explained in traditional context, salting, smoking and drying are used in Ethiopia. After introducing the traditional methods, inform them about the modern methods of food preservation which include freezing, freeze drying and vacuum packing. Among the modern methods, freezing is widely used in Ethiopia.

Let students discuss Activity 3.21 which deals about traditional methods of meat preservation**,** in groups for a few minutes and let some groups present their opinions. Here, you can apply brain storming method and record the ideas suggested by each group on the board. In harmonizing concepts, inform students that about the traditional method of preserving meat which includes: Sun drying, smoking and salting meat with Nacl is some of the traditional methods of preserving meat for a long time. In both case NaCl lowers water activity and causes plasmolysis by withdrawing water from cells.

Let the students read the modern preservation of food presented in the student textbook and explain each method in comparison to the traditional one. Let the students also to discuss about inorganic and organic preservatives.

3.4.8 Manufacturing of Ethanol

After completing the contents on food processing and preservation, continue on production of alcoholic beverages**.**

Use inquiry and group discussion as teaching methods for this part. The topic starts with an activity. The activity is suggested to assists students to know the most common local alcohol beverages that are produced in most Ethiopian homes during a holiday.

Ask: does fermentation in the absence of oxygen mean? So, you can start by letting students discuss Activity 3.22 in groups, and let some groups present their views to the class. To harmonize the concepts of students with the fact, traditional fermented beverages are those which are indigenous to a particular area and have been developed by the people using age-old techniques from locally available raw materials. Some of Ethiopian indigenous traditional fermented beverage's products are Cheka, Keribo,

Borde, Areki, Tella, Shamita, Booka, and Korefe, in which fermentation is natural and involves mixed cultures of microbes. Fermentation without oxygen means "anaerobic respiration is a type of respiration where oxygen is not used; instead, organic or inorganic molecules are used as final electron acceptors. Fermentation includes processes that use an organic molecule to regenerate NAD^+ from NADH. For example, fermentation of glucose to produce alcohol which is ethanol. Then introduce the steps followed during the manufacturing process using a diagram which shows the steps production of each type of local as well as manufactured alcohols in industries. During explaining each step of production of alcohol please compares and contrasts the local and industrially prepared alcohols. For example, "Beer-with Tella" and Arekie with higher alcohols like, Jin, Weskiy. As much as possible, explain the purpose of each part of the local Areki distillation apparatus/setup. So that students can realize the basic parts and uses of these parts in the distillation process to produce Areki using the diagram presented in the text book. In treating preparation of ethanol using the fermentation process, first do Experiment 3.5 (i.e. Preparation of Ethanol by Fermentation); discuss with the students what you and they observed from the experiment. Ethanol is manufactured industrially by fermentation of carbohydrates as well as catalytic hydration of ethene. Most alcoholic beverage industries like Dashen beer Axion, BGI Ethiopia and other beer industries produce alcohol/ethanol by fermentation process. Even the locally produced ethanol/ Areki that is represented in Figure 3.17 used the same process i.e. fermentation of carbohydrates. Following the experiment, students should write a laboratory report and submit them for correction. Collect the laboratory reports and give feedback. Check that the observation and analysis in the reports coincides with the following points:

1. A. Yeast catalyzes the fermentation process.
   B. It serves as a food for yeast.
   C. It turns milky. Carbon−dioxide is produced.
   D. It has the smell of an alcohol.
   E. Fermentation has taken place; alcohol (ethanol) and carbon−dioxide are formed.

2. A. colorless and it has the smell of an alcohol

   B. The distillate obtained after distillation of fermented sugar solution catches fire when we bring the flame of a burning splint close to it. Finally, let students do project 3.5.

Answers to Project 3.5

The answer for this project may vary upon the local/area in which students are live. Since students will collect information from their parents, the raw materials to prepare Bordie or Tella may vary from place to place.

3.4.9 Soap and Detergent

After completing the contents on alcoholic beverages, continue on manufacturing of soaps and detergents. You better use inquiry and group discussion as teaching methods for this part. The topic starts with an activity. The activity is suggested to assist students to know local industry in their surrounding that manufactured soaps and know the raw materials that are used to manufacture soaps and also to introduce how soap and detergent act on dirt particles during the process of cleaning. So, you can start by letting students discuss Activity 3.23 in groups, and let some groups present their views to the class. To harmonize the concepts of students with the fact, introduce considerable attention has been given in the GTP-I to chemical and pharmaceutical, metal, food and beverage sectors among the manufacturing industries. In 2012/13, G.C about eight soap and detergent factories with production capacity of 156,000 tones have commenced operation in the country. Likewise, recently one soap and detergent factory has been introduced around Sebeta, south-western of Addis Ababa near a place called Repi. However, nowadays with technical and vocational school and with regional entrepreneur small scale soap and detergents production centers are built in many parts of Ethiopia by youths. These small scale as well as the large-scale soap and detergent industries used the four basic raw materials to produce soap:

- oils and fats
- soda lye or potash lye
- brine (for glycerine recovery)
- additives: sodium carbonate, sodium silicate, dyes, perfumes, etc., the use of which depends on the quality and type of soap desired.

Let also informed the students about the action of soap and detergent on dirt particles during the process of cleaning. As soaps and detergents are able to do so because they have a part that is water soluble and another part that is fat-soluble. The loosened dirt is set free and is removed from the cloth. Rinsing completes the cleaning process.

Then introduce the steps followed during the manufacturing process of soap and detergent using the diagram in the student text: **Figure 3.19** Flow chart showing the soap making process. Then also show how soap is produced in a school laboratory scale by doing Experiment 3.6 and Experiment 3.7 procedures one by one under your supervision. As much as possible, explain the purpose of each step so that students can realize the basic steps in soap and detergent production in laboratory scales.

In dealing with these Experiment 3.6 (preparation of soap) and Experiment 3.7 (investigating the chemical properties of soap) , students should get also information about: what soaps and detergents are, the raw materials used in their production, differences between hard and soft soaps and what saponification is. Students should perform the experiment under your supervision. You should give them guidance and assistance whenever needed. After they complete the experiment, they should write a report in groups on their observations. Then let students from some groups make presentations to the class. For the points in the observation and analysis part of the experiment, you can use the following information.

Experiment 3.6

A. Ethanol is used in this experiment to dissolve oil or fat and make hydrolysis occur easily.

B. Sodium chloride solution is added to reduce the solubility of soap and separate it out from the solution

Experiment 3.7

A. Detergent lathered well or easily form lather with hard water.

Hard water contains calcium and magnesium ions. Therefore, in hard water soap gets precipitated as calcium and magnesium soap which being insoluble stick to the cloth as gummy mass. Hence, soap cannot be used with hard water.

Example this reaction takes place:

$$2C_{17}H_{35}COO{-}Na\ (soap) + \ CaCl_2\ (aq) \rightarrow 2NaCl + (C_{17}H_{35}COO)_2Ca\ (insoluble\ soap)$$

On the other hand, since detergent reacts with Ca^{2+}, Mg^{2+} ions of hard water producing water-soluble calcium or magnesium salts so they easily form lather with hard water.

Then, let the students introduces about "dry detergents". This topic deals with some of our clothes like silk will turn yellow if it is treated with strong soap during laundering and also the case of a color change during laundering of such clothes. Often the instruction for cleaning clothes contains the sentence: Use only lukewarm water for cleaning. Otherwise, the quality of the product will decrease. Because natural fibers are mostly mixed with artificial ones, laundering should not be applied. Instead of laundering, dry cleaning is applied. To dry clean, means to use different chemical those are able to dissolve grease and stains in a similar manner as soaps, the only difference being that contact with water is avoided. Let the students introduce students about dry cleaning chemicals and their actions during the cleaning process, such as gasoline, tetrachloroethylene ($Cl_2C - CCl_2$), Benzene (C_6H_6) and carbon tetrachloride (CCl_4). Then let the students to do Project 3.6 and submit the report for you.

Answer to project 3.6

The submitted report by the students may vary based on the visited nearby cottage industry by the students.

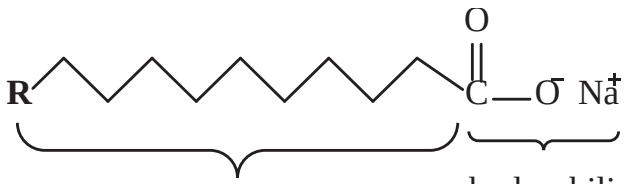
Answer to Exercise 3.12

1. See the text book Section 3.4.5 page 188 & 189 (Chemical and mechanical pulping)
2. See the second step in leather production on page Section 3.4.6 page 191
3. Freezing, freeze-drying and vacuum pacing
4. Due to the pulping process that can be accomplished as either mechanical or chemical means, the strength and grade of paper to be manufactured may be different. For example, **mechanical pulping** utilizes steam, pressure and high temperatures instead of chemicals to tear the fibres. The fibre quality is greatly reduced because mechanical pulping creates short, weak fibres that still

contain the lignin that bonds the fibres together. Paper used for newspapers are a typical product of mechanical pulping.

5. Chromium sulphate and other salts of chromium
6. By preventing the growth of bacteria, fungi and other micro-organisms, as well as reducing the oxidation of fats which causes rancidity.

7. The traditional distilled alcohol (Areki) and the liquor (Gin) are differed in way fermentation time, flavor additives in case of the liquor (gin), relatively fixed ingredients in case of the liquor and variable ingredients in case of Arekie.
8. Soaps are either sodium or potassium salts of higher (long-chain) carboxylic acids. Soaps that are sodium salts are called hard soaps and those that are potassium salts are soft soaps.
9. The water-soluble group in ordinary soap ($C_{17}H_{35}COONa$) is – COONa and the fat-soluble part is the chain of 17 carbon atoms, $C_{17}H_{35.}$ It is represented in the structure below.



hydrophobic — long hydrocarbon chain (oil soluble)

hydrophilic — short ionic part (water soluble)

Detergents are sodium salts of sulphonated long chain organic alcohols.

$R\text{-}C_6H_4SO_3Na$, where: R is an alkyl group with a chain of 10 to 18 carbon atoms. The water-soluble group is SO_3Na while the fat soluble one is the $–R\text{-}C_6H_4$ groups.

10. Detergent is better than soap for the following reasons:

Soaps are not appropriate for use with hard water. Soap does not work well in hard water since the Ca^{2+}, Mg^{2+} ions of hard water react with soap forming insoluble substance. So, it creates unnecessary wastages of soap and also does harm to the fiber of the clothes.

$RCOONa + Ca^{2+} \rightarrow (RCOO)_2Ca$

On the other hand, detergent works well both in hard acidic water and soft water, since detergent reacts with Ca^{2+}, Mg^{2+} ions of hard water producing water-soluble calcium or magnesium salts. The charged ends of detergents do not form insoluble precipitates with calcium and magnesium ions in hard water. So, no harm is done to the garments.

$R\text{-}OSO_3\text{-}Na^- + Ca^{2+}\ (R\text{-}O\text{-}SO_3)_2Ca$

Answers to Review Exercise

Part I: True or False Items

1.	True	3.	True	5.	True
2.	True	4.	False	6.	False

Part II: Multiple Choice Questions

1. a	2. c	3. e	4. b	5. a	6.e	7. c	8. a	9.e
10. d	11. d	12. d	13. d	14. e	15. a	16.b	17. b	
18. e	19. a	20. d	21. d					

Part III: Short Answer Questions

1. Since the chemical industries products are either directly used or serve as raw materials to synthesize products that are important to solve the society demands in different necessities.

2. These conditions cause the gases to react and produce ammonia, and the following reaction occurs:

   $N_2 + 3H_2 \rightarrow 2NH_3$

   The hydrogen and nitrogen are then, introduced into a chamber containing iron particles or lined internally with iron, and a pressure of 15 – 25 MPa at a temperature of 300 – 500 °C is applied to the gases.

3. Sulphuric acid is used in the production of fertilizers, detergents, plastics and paints. It is used in the production of a number of explosives. Sulphuric acid is an oxidizing agent and a good dehydrating agent. It is often used to dry neutral and acidic gases such as nitrogen, oxygen, and carbon dioxide. It is also used as electrolyte in car batteries. It is also used as a catalyst in the manufacture of many chemicals.

4. The difference in the composition of cement and glass

Chemical constituent	% By mass cement	% By mass glass
SiO_2	15.38	71.35
Al_2O_3	4.14	1.01
Fe_2O_3	3.19	0.67
CaO	56.92	8.74
MgO	2.44	3.55
SO_3	1.59	0.25
K_2O	0.21	0.37
Na_2O	0.04	11.76
TiO_2	0.21	0.05
P_2O_5	0.28	0.01
Mn_2O_5	0.04	0.01
Cr_2O_3	0.02	0.03

5. Ceramic is an inorganic, non-metallic solid prepared by the action of heat and subsequent cooling. Traditional ceramics, such as porcelain, tiles and pottery are formed from minerals such as clay, talc and feldspar. Most industrial ceramics, however, are formed from extremely pure powders of specialty chemicals, such as silicon carbide, alumina, barium titanate, and titanium carbide.

6. The main chemical equations involved in cement production takes place in three parts:

Upper Part of the Kiln

$$Raw\ Material \xrightarrow{\blacktriangle} Complete\ elimination\ of\ moisture$$

Middle Part of the Kiln

Limestone decomposes to calcium oxide

$$CaCO_3(s) \xrightarrow{\blacktriangle} CaO(s) + CO(g)$$

Lower End of the Kiln

In this part, the temperature reaches about 1600 °C; the partly fused and sintered mixture undergoes a series of chemical reactions to form calcium aluminates and silicates.

$$2CaO + 2SiO_2 \rightarrow 2CaO.SiO_2\ (di-calcium\ silicate)$$

$$3CaO + 3SiO_2 \rightarrow 3CaO.SiO_2\ (tri-calcium\ silicate)$$

$$CaO + 3Al_2O_3 \rightarrow 3CaO.Al_2O_3\ (tri-calcium\ aluminate)$$

$$4CaO + 4Al_2O_3 + 4Fe_2O_3 \rightarrow 4CaO.Al_2O_3.Fe_2O_3\ (tetra\ calcium\ aluminate\ ferrate)$$

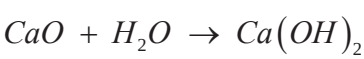
$$MgO + SiO_2 \rightarrow MgSiO_3\ (Magnesium\ silicate)$$

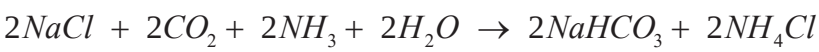
The resulting mixture of all these silicates and aluminates is called cement clinker. After cooling, it is mixed with 2-3% gypsum (calcium sulphate) and ground to a fine powder. Gypsum slows down the rate of setting of cement, so that the cement hardens adequately.

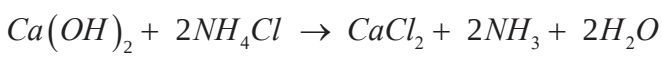
7. The Refinery process in sugar production:

Raw sugar is transported to a cane sugar refinery for the removal of molasses, minerals and other non-sugars that contaminate it. This is known as the purification process. Raw sugar is mixed with a solution of sugar and water to loosen the molasses from the outside of the raw sugar crystals, producing a thick matter known as "magma". Large machines then spin the magma, separating the molasses from the crystals. The crystals are promptly washed, dissolved and filtered to remove impurities. The golden syrup that is produced is then sent through filters, and SO_2 is passed through it to remove the colour and water. The process of removing colour is known as bleaching. What is left is concentrated, clear syrup which is again fed into a vacuum pan for evaporation.

8. Sodium bicarbonate converts to sodium carbonate. The calcium hydroxide and ammonium chloride react to form calcium chloride as the by-product. The partial reactions are shown below:





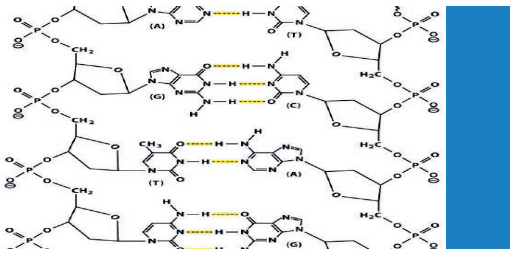


The overall reaction:

9. The positive aspect of application pesticides are preventing or control pests, diseases, weeds and other plant pathogens. It decreases yield losses, and maintain high product quality.

10. The most local alcoholic beverages in Ethiopia are Areki, Tella, Tej , Bordie, korfe and etc. Even if the basic process of production of each type of local alcoholic beverages is almost similar but it has minor difference depending their locality. Please look as an example “preparation of Areki (katical) on textbook in section 3.4.8 page 199 and 200.

UNIT 4



POLYMER

Unit Overview

Total Periods allotted: 12 periods

This unit mainly deals with polymers. Polymers are large molecules that are made from small units called monomers. They are generally prepared by either addition or condensation polymerization processes.

Based on their source, polymers can be divided into natural and synthetic. Natural polymers like carbohydrates, proteins and nucleic acids are essential for the existence of living organisms. Synthetic polymers are man–made and have wide applications. Even though synthetic polymers have many applications in the modern world, they have negative impacts to the environment.

This unit is divided into three subunits. The first subunit introduces polymers. It tries to explain the meaning of polymer.

The second subunit focuses on the two major types of polymerization reaction processes that are applied for the preparation of polymers.

The third unit discusses the classification of polymers based on source, type of polymerization and kind of monomer units.

To teach this unit, you can use active learning methods such as gapped lecture, group discussion, demonstration, role play and other appropriate active learning methods. Students should also be encouraged to actively participate in the teaching-learning process.

Unit Outcomes

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

- *define polymers*
- *recognize that most of the materials around you may be polymers*
- *define the term monomer*
- *list and explain a variety of synthetic polymers & natural polymers and explain their differences*
- *classify polymers based on their response to heat*
- *predict monomers of the polymers by observing their structures*
- *distinguish addition and condensation polymerization*
- *recognize the relationship between properties and uses of plastics*
- *given a monomer/monomers, write polymerization reaction*
- *write structure of a polymer given structure of a monomer/monomers*
- *classify polymers into their types based on different criterion*
- *describe the properties of the different types of polymers*
- *describe the monomers, properties and uses of plastics, rubbers, carbohydrates & proteins*
- *list the applications of the different types of polymers*
- *describe the process of addition & condensation polymerization*
- *develop inquiry skills along this unit: observing, predicting, classifying.*

4.1 Introduction to Polymers

Periods Allotted: 1 period

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

- *define the term monomer*
- *define the term polymer*
- *identify material with polymeric nature*

Forward Planning

Before you begin this lesson, it is advisable to read the contents of the topic from the Student Text Book and other reference books available in the school library. Moreover, plan a convenient way of grouping students for discussion.

Teaching Aids

Prepare a chart that shows the different classifications of polymers.

Subject Matter Presentation

For this section, it is possible to use brainstorming, group discussion, and presentation as active learning methods.

You can begin this subtopic by letting students brainstorm with the following terms:

- monomer
- polymer

Then help them to form groups and discuss on the note given in the Student Text Book and on Activity 4.1 as well. Facilitate group discussions and clarify vague concepts for them (if any). During their discussion in their group please inform them to set criteria and categorize materials like the textile fibre of your clothes, your hair and skin, the wood from which your desk is made and the glass of the window. This activity helps them to visualize how a polymer is important in many aspects. It also helps them to think at the molecular level and the chain of a number of monomer forms a polymer.

Assessment

Assess each student's work throughout this section. This can be achieved by recording the performance of every student as usual. You can make records based on students' performance in:

- discussing Activity 4.1
- presenting their views after discussion

By observing their performances from the record, provide them feedback to improve students' learning. In addition, you can use self-assessment and peer assessment methods to enhance students' performance. Appreciate students working above the minimum required level and encourage them to continue working hard. For low achievers, identify their learning difficulties and help them to achieve the minimum required level for this subunit.

4.2 Polymerization Reaction

Periods Allotted: 4 periods

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

- *describe polymerization reaction*
- *list the types of polymerization reactions*
- *give examples of addition polymers;*
- *explain common uses of addition polymers;*
- *give examples of condensation polymers;*
- *explain the uses of these condensation polymers: nylon, polyester and Bakelite*
- *list the steps in addition polymerization*
- *identify whether a given monomer undergoes addition or condensation polymerization*

Forward Planning

Plan how students will perform Activity 4.2 and present their answers to the class. In addition, read the relevant information in the student text book and refer to the answers of Exercise 4.1 and Exercise 4.2 give the additional questions in the teacher guide for students to do, as an assignment and provide the feedback. .

Subject Matter Presentation

For this subunit, it is possible to use question and answer, brainstorming, group discussion, and presentation as active learning methods.

1. Before you begin this lesson, review the main points of the previous lesson. Tell them to do Activity 4.2 and present their answers to the class. Use the analogy how long chains are made up of linkage of small metal rings (or other shapes). Harmonize their discussions and direct them to come up with the following answers:

Among the analogy they have knew, the following the following are the relevant one:

2. Just as the chain is formed by the linkage of simple rings, the large molecules are formed by chemical reaction between simple molecules
3. Train forgo, …

Then, raise the following guiding questions to the students and tell them to answer by reading the contents of their text book.

- What is polymerization?
- Can you define addition and condensation polymerization?
- What is the difference between addition and condensation polymerization?

Give minutes to answer the above questions and encourage them to present their answers to the class. If they are not clear on the concepts, give them a brief explanation about polymerization, including addition and condensation polymerizations. Use the examples indicated in the student text book to clarify vague ideas.

Second, please inform the students that functional group is a group of atoms within a molecule that have a consistent and specific behavior. When a few functional groups join a carbon chain, they create a simple molecule called a monomer. These monomers combine to form complex molecules called polymers.

Then please also ask the students, by taking an example of polymers from addition and condensation polymerization to identify the functional groups.

In dealing synthetic condensation polymers properties first do experiment 4.1 (Synthesis of Nylon and study its properties); discuss with the students what you and they observed from the experiment. Nylon can be produced by the condensation reaction of diacids and diamines. One of the most common polyamides is nylon 66 or nylon. It is a copolymer and is prepared by the condensation of 1, 6-diaminohexane (hexamethylene diamine) and 1,6-hexanedioic acid (adipic acid). The basic amine reacts with the acid to form a salt. Heating removes water and forms the amide bonds.

However, during performing Experiment 4.1 the following precautions should be taken

- Wear gloves while doing this experiment.

Following the experiment, students should write a laboratory report and submit them for correction. Collect the laboratory reports and give feedback. Check that the observation and analysis in the reports coincides with the following points:

A. Cyclohexane is a nonpolar solvent while water is a polar solvent.
B. Adipoyl chloride is more reactive than adipic acid.
C. It is very resistant to stretching and shrinking.
D. The fibre has resistance to many chemicals such as acids.
E. The fibre dries very quickly.
F. Nylon has a high melting point at 256 °C.

Then give them Exercise 4.1, and Exercise 4.2 as class work and the additional question as homework and let them present their answers to the class. Finally, provide feedback to them.

Assessment

Assess each student's work throughout the subunit. This can be achieved by recording the performance of every student as usual. You can make records based on students' performance in:

- discussing Activity 4.2
- presenting their views after discussion
- answering the questions in Exercise 4.1 and Exercise 4.2
- answering the questions of additional questions in the teacher guide

By observing their performances from the record, provide them with feedback to improve students' learning. In addition, you can use self-assessment and peer assessment methods to enhance students' performance. Appreciate students working above the minimum required level and encourage them to continue working hard. For lower ability students, identify their learning difficulties and help them to achieve the minimum required level for this subunit.

Additional Questions

1. Which types of polymers are non-biodegradable? Why?
2. What is a characteristic of all condensation polymers?
3. What monomers are most commonly used in addition polymerization?
   A. Cycloalkanes
   B. Esters
   C. Carboxylic acids
   D. Alkenes
4. What term is used to indicate a polymerization that occurs without the growth of a chain monomer by monomer, but instead occurs as monomers form dimers, dimers form tetramers, etc.?

Answers to Additional Questions

1. Addition polymers. Because the chemical bonds are very strong and cannot easily be broken by microorganisms.
2. A small molecule is lost as bonds form between the polymerizing molecules
3. D
4. step-growth or condensation polymerization

Answers to Exercise 4.1

1. Condensation polymerization and addition polymerization
2. Addition polymerization is a reaction in which a chain reaction adds new monomer units to the growing polymer molecule one at a time.
3. Styrene readily polymerizes to polystyrene by a relatively conventional free radical chain mechanism. In the presence of inert materials, styrene monomer will react with itself to form a homopolymer.

Initiation step

$Ra\cdot + C_6H_5CH{=}CH_2 \rightarrow \sim\sim\sim RaC6H5CH\text{-}CH2\cdot$

initiator monomer monomer free radical

Chain propagation step

$\sim\sim\sim RaC_6H_5CH\text{-}CH_2\cdot + RaC_6H_5CH{=}CH_2 \rightarrow \sim\sim\sim C_6H_5CH\text{-}CH_2\,C_6H_5CH\text{-}CH_2\cdot$

Chain termination step

$\sim\sim\sim RaC_6H_5CH\text{-}CH_2\cdot + \sim\sim\sim C_6H_5CH\text{-}CH_2\,C_6H_5CH\text{-}CH_2\cdot \rightarrow$

$\sim\sim\sim C_6H_5CH\text{-}CH_2\,C_6H_5CH\text{-}CH_2CH_2CHC_6H_5$

Answers to Exercise 4.2

1. a. $HOOCC_6H_5OOH$ and $HO(CH_2)_2OH$

   b. H_2NCH_2COOH

2. condensation

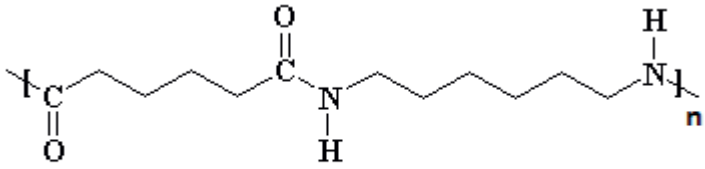
   $-[HNCH_2(CH_2)_4CH_2NH\ COCH_2(CH_2)_6CH_2CO]-n$

3. a. $-[CCl_2-CCl_2]-_n$

   b. 530, 656

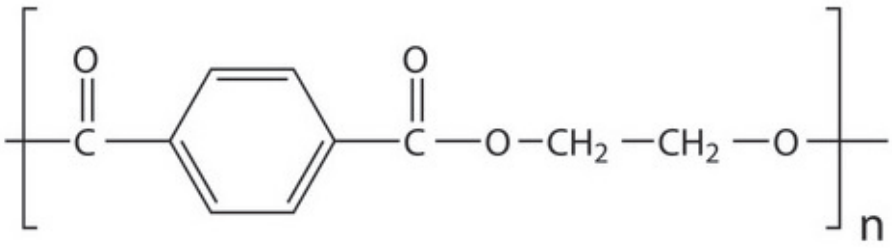
   c. % C=14.49; %Cl= 85.51

4. a.



Nylon 66

b.



Dacron

5. Nylon: electrical connecters, gears, bearings, cables, ties, rope, fishing line, automotive valve cover, sports/exercise equipment. Polyethylene terephthalate: fibres for clothing, containers for liquids and foods, and thermoforming for manufacturing, and in combination with glass fibre for engineering resins.

4.3 Classification of Polymers and their Synthesis

Periods Allotted: 7 periods

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

- *categorize a given polymer based on different criteria*
- *identify natural and synthetic polymers*
- *tell the monomer of natural rubber*
- *list the properties and applications of natural and synthetic polymers*
- *draw the structures of disaccharides*
- *describe polysaccharides*
- *draw the structure of starch and cellulose*
- *draw the structure of polyethylene, polypropylene, polyvinylchloride, polytetrafluoro ethylene and polymethyl methyl methocrylate*
- *give examples polypropylene, polyvinyl chloride and polyethylene products.*

Forward Planning

Before you begin this lesson, it is advisable to read the contents of the topic from the student text book and other reference books available in the school library. Moreover, plan a convenient way of grouping students for discussion.

Teaching Aids

Prepare a chart that shows the different classifications of polymers..

Subject Matter Presentation

For this subunit, it is possible to use brainstorming, group discussion, and presentation as active learning methods. You can begin this subtopic by letting students brainstorm with the following terms:

- Homopolymer
- Copolymer
- Natural polymer
- Synthetic polymer
- Thermoplastic polymer
- Thermoset polymers

Then help them to form groups and discuss the note given in the student text book and Activity 4.3 as well. Facilitate group discussions and clarify vague concepts for them (if any). This activity helps them to visualize that the causes of the differences between the different types of polymers are:

- The type and nature of the monomer for being the polymer is composed
- The functional group of the monomer
- The number of monomers in the polymer

Then help them to form groups and discuss the note given in the student textbook and Activity 4.4 as well. Facilitate group discussions and clarify vague concepts for them (if any). This activity helps them to visualize and to identify the challenges that arise when different types of monomers are used to synthesize a polymer with specific properties such as melting point, density etc. so, please inform the students the following points may be the challenges that arise when different types of monomers are used to synthesize a polymer:

- incompatibility of the functional group between the different monomers
- difference in solubility
- difference in reactivity of the different functional groups from the different monomers

Then help them to form groups and discuss the note given in the student text book and Activity 4.5 as well. Facilitate group discussions and clarify vague concepts for them (if any). This activity helps them to visualize:

- the similarity/difference between starch and cellulose
- the properties of natural rubber
- the similarity between wood and cotton
- the nature of your genetic material

By taking as an example starch and cellulose please inform the students that:

- There is only one difference. In starch, all the glucose repeat units are oriented in the same direction. But in cellulose, each successive glucose unit is rotated 180 degrees around the axis of the polymer backbone chain, relative to the last repeat unit and have a similarity of
- Starch and cellulose are two very similar polymers. In fact, they are both made from the same monomer, glucose, and have the same glucose-based repeat units.

For the third question of Activity 4.5, inform the students about the major properties of natural rubbers:

- Abrasion Resistance: Excellent.
- Tear Resistance: Excellent.
- Solvent Resistance: Poor.
- Oil Resistance: Poor.
- Aging Weather/Sunlight: Poor.

Alao explain the similarity of wood and cotton polymers by showing the structure of both polymers.

For the fourth question of Activity 4.5, inform the students about the nature of our genetic material that is about DNA and RNA as DNA and RNA are long linear polymers, called nucleic acids that carry information in a form that can be passed from one generation to the next. These macromolecules consist of a large number of linked nucleotides, each composed of a sugar, a phosphate, and a base.

Then help them to form groups and discuss the note given in the student text book and Activity 4.6 as well. Facilitate group discussions and clarify vague concepts for them (if any). This activity helps them to collect as much synthetic/artificial or manmade material around them, to classify as polymers and non-polymers and to give a reason for their classification. After listening the student's feedback, please inform them the material around you which have polymeric nature: example Cotton, wool, plastic bottle, Nylon cloth, silk, wool, cellulose and proteins. Among them; Nylon cloth and plastic bottles are manmade.

Finally, let students form groups and discuss the note given in the student text book and Activity 4.7 as well. Facilitate group discussions and clarify vague concepts for them (if any). This activity helps them to visualize that nylon and polyethylene are thermoplastic polymers which melt when heated and solidify when cooled.

Give Exercise 4.3 as classwork and the additional questions Part I and part II as homework.

Assessment

Assess each student's work throughout the subunit. This can be achieved by recording the performance of every student as usual. You can make records based on students' performance in:

- discussing Activity 4.3, 4.4, 4.5, 4.6 and 4.7
- presenting their views after discussion
- answering the questions of Exercise 4.3 and additional questions part I and Part II

By observing their performances from the record, provide them feedback to improve students' learning. In addition, you can use self-assessment and peer assessment methods to enhance students' performance. Appreciate students working above the minimum required level and encourage them to continue working hard. For low achievers, identify their learning difficulties and help them to achieve the minimum required level for this subunit.

Additional Questions (Part I)

1. Why are most synthetic polymers considered to be pollutants while natural polymers are not?
2. Which of the following is a copolymer?
   A. Polystyrene
   B. Teflon
   C. Natural rubber
   D. Nylon 66
3. Which of the following are homopolymers?
   A. Dacron
   B. Bakelite
   C. Natural rubber
   D. Perspex
4. * What term is used for the repeating units of a polymer?
5. * What term identifies polymers composed of identical monomer units?

Answers to Additional Questions (Part I)

1. Because most synthetic polymers are non-biodegradable but natural polymers are biodegradable.
2. D
3. C and D
4. Monomer
5. Homopolymers

Additional Questions (Part II)

1. Why do different polymers have different properties?
2. What are plasticizers?
3. Describe the main purposes of adding plasticizers in the synthesis of polymers.
4. Why are olefins (alkenes) good monomers for addition polymerization reactions? Examine samples of LDPE (squeeze bottles) and HDPE (milk jugs).
5. What are some of the differences in the physical properties of these substances? What is the role of a catalyst?
6. Which of the following is correct?
   A. A monomer is made from many polymers
   B. A polymer is made from many monomers
   C. A monomer will always dissolve in water
   D. A polymer will always react with water.
7. Most synthetic polymers are not biodegradable. This means that
   A. They are expensive
   B. They cannot be grown in soil
   C. They will not decompose in soil
   D. They only exist for a short time
8. Polyvinyl chloride is used:
   A. As a foam for fire extinguishers
   B. To make leather-like materials
   C. To conduct electricity in power stations
   D. As reflectors in streetlights
9. Explain the terms ‘thermosetting’ and ‘thermoplastic polymers’, with reference to molecular structure.

Answers to Additional Questions

1. They have different chemical compositions (different monomer units), different structures, different ways of being fabricated, etc.
2. A plasticizer is a substance, when added to a material, usually a plastic, makes it flexible, resilient and easier to handle. Early examples of plasticizers include water to soften clay. Today, modern plasticizers are manmade organic chemicals, the majority of which are esters, such as adipates and phthalates
3. The electrons in the weak pi-bonds can be used to form strong sigma bonds to other monomer units.
4. LDPE – more transparent, flexible, waxy. HDPE – more opaque, rigid, non-waxy
5. A catalyst reduces the energy of activation for a reaction by providing an alternative pathway. In this way, it speeds up the reaction and allows it to proceed under milder conditions
6. B
7. C
8. B
9. Thermosetting: once 'set' these plastics cannot be reheated to soften, shape and mold. The molecules of these plastics are cross linked in three dimensions and this is why they cannot be reshaped or recycled. The bond between the molecules is very strong. Thermoplastics: these plastics can be re-heated and therefore re-shaped in various ways due to long chain polymers that are not inter-connected. They become moldable after reheating as they do not undergo significant chemical change. Reheating and shaping can be repeated. The bond between the molecules is weak and becomes weaker when reheated, allowing reshaping. These types of plastics can be recycled.

Answers for Exercises 4.3

1. a. The small molecules used as the basic building blocks for polymers are known as monomers
   b. A polymer is a large chainlike molecule built up from many repeating smaller molecules
   c. Homopolymers are those made from only one type of monomer.
   d. A Copolymer is that prepared by polymerizing more than one kind of monomer unit.
   e. A natural polymer is on that occurs in nature and can be extracted and often referred to as biopolymer.
   f. A synthetic polymer is human-made polymer.
2. Textile fibbers, hair, skin, wood, sand (quartz), concert, ceramics, glasses, paper, plastics and rubbers etc.,
   They are hard.
3. a. The nature of the monomers from which they are made is different.
   b. Whether they monomers are identical (homopolymer) or different type (copolymers) make them different.
   c. The difference in the kind of reaction by which they are made is make them different.
4. All of them are polymers.
5. a. Wool−natural
   b. Dacron−synthetic
   c. Insulin−Natural
   d. Teflon−Synthetic
   e. Cellulose−Natural
   f. Polyvinyl chloride \−Synthetic
   g. Bakelite−synthetic.
   h. Glycogen−natural
   i. DNA−Natural
6. Thermoplastic polymers are those which melt when heated and resolidify when cooled. Example: polyethylene, polypropylene, polyvinyl chloride, teflon, polymethyl methacrylate, nylon and polyester (Dacron), polystyrene (Rubber), polyamide, Polyvinyl Chloride (PVC).
   Whereas, thermoset polymers are those which do not melt when heated, but at sufficiently high temperatures, decompose irreversibly.
   Examples: Bakelite, cyanate esters, epoxy resin, fibber glass (a fibber-reinforced thermoset), polyester resin, polyurethane, silicone resin, vinyl esters, vulcanized rubber.

7. In thermoplastics, the bond between the molecules is weak and become weaker when reheated, allowing reshaping. These types of plastics can be recycled. In thermosetting plastics, the molecules are cross linked and the bond between the molecules is very strong. This is why they cannot be reshaped or recycled

8. Polyethylene, polypropylene, polyvinyl chloride, teflon, polymethyl methacrylate, nylon and polyester (Dacron), polystyrene (Rubber), polyamide, Polyvinyl Chloride (PVC). Their properties include high strength, shrink-resistance and easy bendability, depending on the resin, they are used in the low-stress applications such as the plastic bags or high stress mechanical parts. They are lightweight and they have relatively low processing costs. Equipment's with thermoplastic components can be manufactured easily in high volumes with high precision.

9. Bakelite, cyanate esters, epoxy resin, fibber glass (a fibber-reinforced thermoset), polyester resin, polyurethane, silicone resin, vinyl esters, vulcanized rubber. Their properties include: strong and rigid structure, cannot repeatedly be softened upon reheating and hardened upon cooling, they are not soluble in the normal cleaning solvents such as acetone, methyl ethyl ketone, toluene, trichloroethylene, perchloroethylene, alcohols, etc.

ANSWER REVIEW EXERCISE FOR UNIT 4

Part I: Multiple Choices

1. c	4. d	7. d	10. b
2. d	5. a	8. c	11. b
3. b	6. b	9. d	12. c

Part II: Short Answer

1. a. A monomer is a small unit that helps to form a polymer.
   b. A polymer is a large unit formed by joining of monomer units.
   c. Carbohydrates are polyhydroxy ketones, polyhydroxy aldehydes, or compounds that give these substances upon hydrolysis.
   d. Amino acid contains amino and carboxylic acid functional groups.
2. a. Synthetic polymer
   b. Synthetic polymer
   c. Natural polymer
   d. Synthetic polymer
   e. Natural polymer
   f. Synthetic polymer
   g. Synthetic polymer
   h. Synthetic polymer
   i. Natural Polymer
   j. Synthetic polymer
3. a. Addition polymer
   b. Addition polymer
   c. Condensation polymer
   d. Condensation
   e. Condensation
   g. Addition
   f. Condensation
   h. Addition
   i. Condensation
   j. Condensation
   k. Addition
4. In addition, polymerization multiple bonds (double or triple bonds) are involved, but in condensation polymerization, carboxylic acids, amines or alcohols are commonly involved.
5. a. Polypropylene is used for making ropes, carpets and food containers.
   b. Polyvinyl chloride is used for making pipes, leather-like materials, shoes wallpaper and floor tile.
   c. The major use of Teflon is for coating utensils.
   d. Polystyrene is used for making packing materials, CD and DVD cases and architectural models.

e. Bakelite is used for making rotary – dial telephones, billiard balls and porcelain.
f. Nylons are mainly used for making parachutes, clothes, stockings and ropes.

6. The electrons in the weak p-bonds can be used to form strong s bonds to other monomer units.
7. The structure (e.g., extent of branching) determines how the individual polymer molecules can orient (or "pack") in the solid state.
8. The average value of (the number of monomer units in the polymer) and the range in individual values of n.
9. The olefin monomers are flat (two-dimensional) molecules with sp^2-hybridized carbon atoms. The polymers are three-dimensional molecules in which the carbon atoms are sp^3 hybridized.
10. $H–[O\text{-}CH_2CH_2\text{-}OOC\text{-}CH_2\text{-}CH_2\text{-}CO]_n\text{-}OH$
11. A catalyst reduces the energy of activation for a reaction by providing an alternative pathway. In this way, it speeds up the reaction and allows it to proceed under milder conditions.
12. No, in the absence of a catalyst, ethylene molecules would need to collide at very high energy in order to react with each other.
13. $n\ (CF_2 = CF_2) \rightarrow (—CF_2–CF_2—)_n$. Teflon is highly resistant to chemical attack and has a very low coefficient of friction (it is slippery). In addition, it can be used over a very wide temperature range (-73 ^oC−260 ^oC).
14. The orientation of the monomer units along the chain (head-to-tail, head-to-head, random) and the orientation of the methyl groups with respect to the polymer backbone (tacticity).
15. Orientation of the monomer units along the chain.
16. Tacticity

UNIT 5

Introduction to Environmental Chemistry

Unit Overview

Total period allotted 16 periods

This unit mainly emphasizes on introducing students to the relationship between chemistry and environment. It gives information about environmental chemistry how it deals with the origins, transport, reactions, effects and fates of chemical species in the water, air, terrestrial and living environments.

The first section of this unit (5.1) deals with the introduction of environmental chemistry in general. In this section concepts that are important to understand environmental chemistry for beginners will be defined and stated. It deals about components of the environment, natural cycles in the environment and fundamental concepts that are used to explain environmental chemistry.

The second Section 5.2 is a broader section of the unit and gives emphasis to environmental pollution. Since pollution is the major problem of the globe at present, this section will introduce types of pollution, pollutants of air, water and land, the impact of pollutions and its cause, finally the methods of reducing pollution. The third Section 5.3 deals about global warming and climate change from the perspective of chemistry. It gives emphasis to the greenhouse gases and their effects. The last Section 5.4 deals about principles of green chemistry and cleaner production. It gives emphasis to the "12 principle of green chemistry and atom economy which is the key for cleaner production in chemistry laboratory as well as at a large scale in industry.

Different teaching methods are suggested for each sections and sub-topics. The major methodologies suggested for this unit are peer teaching, gapped lecture, inquiry and group discussion.

Unit outcomes

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

- *define environmental chemistry*
- *describe the components that make the environment*
- *explain environmental pollution*
- *identify the three types of environmental pollution and names of the pollutants*
- *discuss the causes and effects of air, water and land pollution*
- *discuss air, water and soil pollution*
- *describe the main methods to reduce air, water and land pollution*
- *describe pollutants of the environment*
- *list greenhouse gases and describe their effect*
- *discuss about global warming and climate change*
- *apply pollution control mechanisms for controlling, air, water and land pollution*
- *describe the principle of Green chemistry and cleaner production*
- *apply the principle of Green chemistry and cleaner production in doing experiments*
- *design chemical reactions that go hand in hand with principles of green chemistry and cleaner production*
- *develop inquiry skills along this unit: observing, predicting, classifying, communicating, and inferring.*

5.1 Introduction to Environmental Chemistry

Period allotted 3

At the end of this subsection, students will be able to:

- *define environmental chemistry*
- *define terms related to environmental chemistry such as pollutant, contaminate, sink, biological oxygen demand and Threshold Limit Value*
- *list the components of the environment*
- *describe the components of the environment*
- *write the important reaction in each components of the environment*
- *explain how the important reaction take place in each components of the environment*
- *describe the cycle of hydrological, carbon, nitrogen, oxygen, sulphur and phosphorus*
- *explain how the cycle of hydrological, carbon, nitrogen, oxygen, sulfur and phosphorus occurred in the environment*

Forward Planning

Read the contents of this section thoroughly. Plan how to manage students when they discuss activities and make presentations. Decide which groups should make presentations.

Teaching Aid

- Prepare chart/pictures that show components of the environment and important natural cycles in the environment.

Subject Matter Presentation

The suggested methodologies for this section are peer teaching, group discussion and visual based learning. In the first period, start with startup activity presented in the text. The startup activity helps students to visualize and introduce environmental chemistry. They can recognize what come into their mind when they heard the term environmental chemistry. And they also know what area of knowledge related to environmental chemistry. This activity helps them to acquire prior knowledge about environmental chemistry and its relationship with other subjects.

Allow students to make presentations on the contents of the section. So, give them a home work to make preparation on the section in groups before the period in which you deal with it. All groups in each section need to make preparation on the section. Tell them the points on which they should lay emphasis. This may include definition of environmental chemistry, the components of the environment, draw important natural cycles in the environment, and define concepts related to the environmental chemistry and their opinions on points in **Activity 5.1** and its relation with other subjects they know. During the period, let students form two different groups in order to make presentations to the rest of the class one by one. After each group completes the presentation, give chance to other students to ask the groups some questions, and also give the opportunity to the groups to answer questions raised by other members of the class. Then, harmonize the ideas of the students with those which they are supposed to know. Inform them that environmental chemistry is an interdisciplinary science that includes atmospheric, aquatic and soil chemistry, as well as heavily relying on analytical chemistry and being related to environmental and other areas of science. And also tell the possible sources of CO_2 i.e. combustion of fuel and show that CO_2 in the atmosphere would fall back to Earth as acid rain by writing the chemical reaction $CO_2(g) + H_2O$ (water vapor) $\rightarrow H_2CO_3$. Define environmental chemistry as a branch of chemical science that deals with the production, transport, reactions, effects, and fates of chemical species in the water, air, terrestrial, and biological environment and the effects of human activities there on.

In the second period, let the students do in group the activity in 5.2 and give their suggestion on points in the **Activity 5.2**. Then, harmonize the ideas of the students presented in **Activity 5.2** with those which students' are supposed to know. And inform them by giving the summary of the discussion for **Activity 5.2** by "introducing the four components of the environment" to the students'. Then tell them the hydrosphere component of the environment includes, the water vapor, the liquid water that exists on the surface in the form of oceans, lakes and rivers. It also includes the water exist below the ground as ground water, in wells and aquifers. The biosphere refers to the realm of living organisms and their interactions with the environment (i.e. other compartments).

In the third period of this section, let students start the daily lesson and discuss in groups they should respond their answers on points mentioned in Activity 5.3. Inform them as

1. In the process of photosynthesis carbon dioxide is consumed and oxygen is produced; it serves as a sink for carbon dioxide. As a result carbon dioxide accumulation in the atmosphere is minimized which leads a decrease of global warming.
2. Nitrogen, the most abundant element in our atmosphere, is crucial to life. Nitrogen is found in soils and plants, in the water we drink, and in the air we breathe. It is also essential to life: a key building block of DNA, which determines our genetics, is essential to plant growth, and therefore necessary for the food we grow. But as with everything, balance is key: too little nitrogen and plants cannot thrive, leading to low crop yields; but too much nitrogen can be toxic to plants, and can also harm our environment. Plants that do not have enough nitrogen become yellowish and do not grow well and can have smaller flowers and fruits. Farmers can add nitrogen fertilizer to produce better crops, but too much can hurt plants and animals, and pollute our aquatic systems. Understanding the nitrogen cycle how nitrogen moves from the atmosphere to earth, through soils and back to the atmosphere in an endless cycle can help us grow healthy crops and protect our environment.

Note: while you are giving the summary of **Activity 5.3**, consider students replay in to account. Then show with diagram the important natural cycles in the environment i.e., hydrological, oxygen, nitrogen, phosphorous, sulfur and the carbon cycle. Then let students discuss on points in **Activity 5.4** and give their opinion. Inform them, they have to understand the relationship between pollutant and environmental pollution and the criteria that should be considered to level the environment is polluted..

Assessment

Assess each student's work throughout the section. You can do either by giving class work or homework and checking the work of every student. Also record the effort that has been made by each group during presentation. Collect the written documents prepared by other groups who didn't involve in presentation. Also check students' response for **Exercise 5.1** by giving for classwork or assignment. Then, check their works and make a record. See their achievements and make sure that the competencies suggested for the section are achieved or not.

Answers to Exercise 5.1

1. The hydrosphere component includes water that is on the surface of the planet, underground, and in the air. And it is collective term for all different forms of water, including oceans, seas, rivers, lakes, streams, reservoirs, glaciers, and ground waters
2. The CFCs deplete the ozone layer as follows;

   $CF_2Cl_2 + UV \longrightarrow CF_2Cl^{\bullet} + Cl^{\bullet}$

   The free chlorine $Cl\bullet$ reacts with ozone to form chlorine monoxide and oxygen.

   $Cl^{\bullet} + O_3 \longrightarrow ClO^{\bullet} + O_2$
3. Degradation of organic material: $CH_2O + O_2 \rightarrow CO_2 + H_2O$
4. Nitrogen fixation by bacteria and algae: $2N_2 + 3CH_2O + 3H_2O + 4H^+ \rightarrow 3CO_2 + 4NH_4^+$
5. Pollutant: -A substance whose concentration has increased due to human activity, ultimately having detrimental effects on the environment. Examples include sulfur dioxide (SO_2), carbon dioxide ($CO_{2)}$, ozone (O_3), Pb, Hg, excess heat, light and sound.
6. Threshold Limit Value (TLV):- Indicates the permissible level of a toxic pollutant in the atmosphere to which a healthy individual can be exposed during an 8-hour day without adverse effects. TLV is found by experimentation on animals, medical knowledge and environmental studies.
7. In hydrological cycle, there is the continuous exchange of water between environmental compartments. 10% of evaporative losses from oceans precipitate on land (groundwater). Groundwater percolates by capillary action to surface soil.
8. BOD is the capacity of the DOM (dissolved organic matter) in a sample of water to consume oxygen. Determined experimentally by measuring DO at beginning and end of a 5-day period in a sealed sample. It also gives the measure of oxygen utilized as a result of oxidation of DOM present in the water sample

5.2 Environmental Pollution

Period allotted 7

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

- *explain environmental pollution*
- *describe air, water and soil pollution*
- *describe pollutants of air, water and land*
- *describe the effects of air, water and land pollutants*
- *describe some of the main methods used to reduce air pollution*
- *discuss the causes of air, water and land pollution*
- *explain the effects of air, water and land pollution*
- *describe some of the methods used to reduce air, water and land pollution*
- *carry out a project on the effects of an industry on environment*
- *propose safe method of disposing non-biodegradable wastes*
- *recommend method of preventing pollution caused by over use of fertilizers.*

Forward Planning

Since pollution problem is becoming a global issue, teaching the contents on environmental pollution requires much emphasis. This is because the problem affects the lives of every one of us directly or indirectly. So, the teacher is expected to acquaint students with the causes of pollution, their effects and methods of reducing pollution. To get more information, you better search for books, magazines and other reference materials. With the help of the concepts in the teacher's guide and other reference materials on current issues, you can have a very good presentation on pollution.

So, this section needs to be treated with a very great concern and emphasis. To create awareness among students, it is advisable if students discover pollution problems by themselves and be part of the solution. Here, the teacher is advised to plan how to organize a peer teaching method. You better plan when to give a home work for different groups of students to make preparation on air pollution, water pollution and land/soil pollution. Since this section needs to be covered within four periods, let group 1 make preparation on **Activity 5.5,** and **5.6** and the introduction part; group 2 on air pollutants, their effects and methods of reducing air pollution

(Activity 5.7); Group 3 on water pollution and methods of reducing water pollution **(Activity 5.8),** Group 4 on land pollution and methods of reducing land pollution **(Activity 5.9 and Activity 5.10)** and Group 5 on common pollutants of the environment and their remedies. Besides, if your school is located in a small town or a rural area, prepare the necessary arrangements for students to contact experts from agriculture and rural development offices to give them some information about pollution problems that fertilizers, pesticides and weed killers can cause. If your school is in a town where there are some industries, let the student's form a group and carry out the suggested project work (Project 5.1) in this section. All students should take part in this project work. The project work should be given at least one week before the period. After students collect some information, they will present their investigation to the class. You should prepare transportation facilities, letters from the school to the industries that request their willingness to cooperate with the students to carry out their investigation. Also plan how to give assistance to students during their discussion and while doing this project work. You also need to make a plan on how to allot the duration of time for students to discuss activities, present their opinions to the class, presentation of the group who made preparation on a given topic, and for harmonizing concepts.

Teaching Aids

- Reference materials should be available in the school library which consist contents about pollution.

Subject Matter Presentation

This section should be treated with full participation of students. The main duties of the teacher are to create conducive atmosphere for the teaching-learning process, motivating students to be active participant and harmonizing the basic concepts suggested by the students with the concepts they are expected to know.

Air Pollution

You better use peer teaching, problem solving, and group discussion methodologies. To begin dealing with this section, let students discuss **Activity 5.5** in groups for a few minutes and let students from one or two groups present their opinion to the class. Again, let them discuss **Activity 5.6** in groups for a few minutes and let some groups present their opinion. Jot down the points suggested by the students related to the activities and use them when you harmonize concepts. In this section, teaching the contents are problem solving methodology. Students involve in identifying the causes of pollution, their effects and suggest solution to the problem in their environment. Next, let the first group who has made preparation on **Activity 5.5, 5.6** and introductory part of the section, explain what they have prepared to the class. After they completed the presentation, continue harmonizing concepts. First, define the terms: pollution and pollutants and continue on **Activity 5.5.** Introduce the students that the Copenhagen international climate change summit was held in 2002 E.C. An African delegation led by the let Prime Minister Meles Zenawi of Ethiopia had taken part in the summit. The solution put forward by the Prime Minister to the problem was accepted by the participants of the summit and was a promising one to Africa. In the summit, Ethiopia has been given respect by other nations. The major issue of the summit was to discuss the effects of climate change and to devise ways to overcome the problem. Besides, the summit also discussed how African countries and other developing nations can get aids (donations of money) as compensation from developed nations. This is because developed nations are responsible for global warming and for climate change since carbon dioxide released by their heavy industries is the main cause for the problem. After that, tell them if there is any activity in your area that has been done to create awareness about air pollution and global warming. In relation to **Activity 5.6**, list down the human activities which contribute to air pollution and how they do so in your environment. In addition, point out the solution and contribution of the learners to overcome the problems.

- In the following period, let students discuss **Activity 5.7** in groups for a few minutes and let one group present the idea of the group to the class. Jot down the suggested points by the group so that you can use3 them when you harmonize concepts. Then, let the second group of students (Group 2) make a presentation on air pollutants, their harmful effects and methods of reducing air pollution.

You can ask students some questions about the effects of each type of air pollutant in between the presentation in order to make the presentation more interactive. Let the students also ask the group some questions. It is better if different members of the group involve in presentation and answering questions. After the group introduces common air pollutants such as:

- Sulphur dioxide (SO_2)
- Oxides of nitrogen
- Hydrocarbons and ozone
- Carbon monoxide
- Particulates
- Chlorofluorocarbons (CFCs)
- Volatile Organic Compounds (VOCs)
- PCBs (polychlorinated biphenyls); and
- Excess carbon dioxide and their effects, ask the listeners to suggest methods of reducing air pollution.

Following their responses, let the presenters continue to introduce the methods of reducing air pollution. When the presentation is over, continue to stabilize concepts. You can do so by asking students to tell you the substances responsible for air pollution, their effects and how to reduce their harmful effects.

You can use the following note to inform methods of reducing air pollution.

Methods of Reducing Air Pollution

1. Removal of sulphur dioxide from gaseous fuels (flue-gas desulphurization), or use low-sulphur fuels.
2. Using furnaces and internal combustion engines operating at low temperatures to avoid the combing of N_2 and O_2 and reduce the amount of the oxides of nitrogen produced and released into the atmosphere.
3. Using catalytic converters fitted to car exhausts to convert unburnt hydrocarbons into CO_2 and water, carbon monoxide to carbon dioxide and the oxides of nitrogen to N_2 and O_2.
4. Increasing the air-to-fuel ratio for complete combustion of fuels.
5. Using a spray of water to wash out particles from the waste gases.
6. Passing waste gases through filters.

7. Banning the use of CFCs as aerosol propellant gases and replacing them with less harmful alternatives.
8. Reducing the use of lead paints and using lead-free fuels.
9. Reducing CO_2 emission to the atmosphere from the combustion of fossil fuels like petroleum and mineral coal, and using alternative energy sources such as hydroelectric power sources and nuclear energy.

Water Pollution

After revising the main points on air pollution, you can continue on water pollution. Peer teaching and group discussion can be used as methodology. First, let the students discuss **Activity 5.8** in groups for a few minutes and let two students from different groups present their opinion to the rest of the class. Take note on the points suggested by the groups to use them during harmonizing concepts. After that, let the third group make presentation on water pollution. In between the presentation, you better ask questions related to the topic to facilitate the teaching-learning process. At the end, you better revise the main points mentioned during presentation and others which are very important. In the process of stabilization, mention the causes of water pollution, their effects and methods of reducing the problem. Then let introduce about causes of water pollution and common pollutants of water such as domestic sewage, solid waste fertilizer, insecticides, herbicides and lead. Inform students also on the common methods of reducing water pollution. Finally, let students prepare a water conservation plan **Project 5.1** and submit it to you and then check how they managed the project work.

Land Pollution

In order to deal with the contents in this part, peer teaching, investigation and group discussion are the recommended methodologies. Investigation is suggested as a method to assist students discovers the effect of an industry on the environment. To start the lesson on this topic, let all students discuss **Activity 5.9** in groups for a few minutes and let two students from different groups present their opinion to the rest of the class. Take note on the points suggested by the groups. Then, let the fourth group who has made preparation on land pollution produce presentation to the class. Then let introduce about causes of land pollution and common pollutants of land such as Garbage, plastic and mercury.

Try to make the teaching learning process more interactive by asking students some guiding questions between the presentations, whenever you think it is important, especially, on the points of **Activity 5.10**.

After the presentation is over, harmonize the concepts suggested by the students with those they are expected to know. Use the following note on the methods of reducing land pollution. Methods of reducing land pollution are:

1. burning solid waste like paper and wood.
2. recycling plastics and other materials such as glass, aluminium and tin cans.
3. reducing the use of non-biodegradable plastics.
4. converting potentially dangerous chemical wastes into harmless substances, by combustion or by other chemical means.
5. using the waste products of one industry as raw materials in another industry. For example, SO_2 formed from the roasting of sulphide ores during the manufacture of metals can be used in the production of sulphuric acid. Similarly, the slag formed during the extraction of iron or copper can be used in the production of cement and glass.
6. using biodegradable plastics for packaging. Before you complete this section, let two other groups make presentations on their investigation about the effects of an industry on the environment. Following their presentations, give time for the rest of the class to conduct discussion on their presentation. At the end, give your own conclusion in relation to student's presentations and points mentioned in their investigation.

Then use also the following note on the potential safe methods of disposing non-biodegradable wastes:

- Take them to a local recycling facility. Separate metal, plastic, glass, and other non-biodegradable waste and store them ready for recycling.

  Note: Recycling is the best waste disposal method as it saves landfill spaces and reduces the cost of the raw materials incurred during the mining and manufacturing of new products. Besides, it saves energy and reduces global climate change.
- Combustion and energy recovery.

  This method is suitable for disposing of rubber, plastic, and other non-biodegradable wastes. Combustion is an eco-friendly process as the heat generated is converted into energy in the form of electricity.

The following are some benefits of combustion:

- Reduces trash volumes
- Saves landfill spaces
- Serves as a source of energy

- Disposal at sanitary facilities.

  Oil, petroleum, medical waste, paint, pesticides, and batteries are hazardous wastes, and they should be disposed of in a sanitary, isolated facility for chemical treatment.

- Reduce.

  We can significantly reduce the non-biodegradable waste we produce by being conscious of the products we buy. You can reduce wastage through the following ways:

  - Buy reusable bottles that you can refill with drinking water.
  - Carry your own basket when doing grocery shopping or buying takeaway food.
  - Find a way to recycle your plastics. For instance, you can use old plastic cans for planting flowers and herbs.

- Landfills.

  This is a long-term disposal solution for non-biodegradable waste. Local governments carefully situate landfills to prevent pollutants from getting contaminating the surrounding water and soil

Finally, let students prepare a water conservation plan project (5.1) and submit it to you and then check how they managed the project work.

Assessment

You can assess each student's work throughout this section by recording how each student is doing his/her daily activity. You can make a record in relation to, participation of students in discussion. Participation of students in presentation. Participation of students in answering questions. How they performed class works and home works. The results they achieved in a quiz or test. From all these records, make sure that the suggested competencies for this section are achieved by all students.

Answers to Exercise 5.2

1. a) Main causes/agents of air pollution can be categorized by source:
   - Mobile: Cars, buses, planes, trucks and trains.
   - Stationary: Power plants, oil refineries, industrial facilities and factories.
   - Area: Agricultural areas, cities and wood-burning fireplaces.
   - Natural: Wind-blown dust, wildfires and volcanoes.

   b) The main agents/causes of water pollution
   - Industrial Waste.
   - Sewage and Wastewater.
   - Mining Activities, Marine Dumping.
   - Accidental Oil Leakage.
   - The burning of fossil fuels.
   - Chemical fertilizers and pesticides.
   - Leakage from Sewer Lines.

   c) Some of main causes/agents of soil pollution include:
   - deforestation and consequent erosion,
   - agriculture, industry, mining, landfills and illegal dumping of waste as well as urbanization and construction

2. a) main effects/impacts of air pollution
   - Respiratory and Heart Problems
   - Child Health Problems
   - Global Warming.
   - Acid Rain.
   - Eutrophication.
   - Effect on Wildlife.
   - Depletion of the Ozone Layer.

   b) main effects/impacts of water pollution
   - Depletion of drinking water supplies
   - Disease
   - Eutrophication
   - Food chain disruption
   - Agriculture
   - Economic impacts

c) main effects/impacts of land pollution

- Effect on Human Health ·
- Increase in Landfill Sites ·
- Soil Pollution ·
- Air Pollution ·
- Water Pollution
- Environmental Degradation
- Effect on Tourism Industry
- Effect on wildlife

3. a) Methods of reducing air pollution

- Using public transports.
- Turn off the lights when not in use.
- Recycle and Reuse.
- No to plastic bags.
- Reduction of forest fires and smoking.
- Use of fans instead of Air Conditioner.
- Use filters for chimneys.
- Avoid usage of crackers.

b) Methods of reducing water pollution

- Treatment of water before discharge into rivers and lakes.
- To avoid unnatural temperature changes in natural water systems, industries should not discharge heat-ladened water into them.
- Recycling industrial and agricultural wastes.
- Using moderate amounts of agricultural chemicals and increasing the use of organic fertilizers and biological methods to control pests.

c) Methods of reducing land pollution

- Make people aware of the concept of Reduce, Recycle and Reuse.
- Reusing materials help to reduce the requirement of harvesting resources.
- Reduce the use of pesticides and fertilizers in agricultural activities.
- Reduce the use of non-biodegradable materials.

4. The potential method of preventing pollution caused by over use of fertilizers is a soil test based balanced and integrated nutrient management through conjunctive use of both inorganic and organic sources of plant nutrients to reduce the use of chemical fertilizers, preventing deterioration of soil health, environment and contamination of groundwater.
5. SO_2 as an ingredient of acid rain, which results in the corrosion of roofs and various health complications. The reaction that shows formation of acid rain is as follows: "SO_2 oxidized to SO_3 then $SO_3 + H_2O$ vapor during raining gives H_2SO_4 which is acid rain. $SO_2 \rightarrow$ (oxidized) SO_3

   $SO_3 + H_2O\ (g) \rightarrow H_2SO_4$ (acid rain) or

   $SO_2 + H_2O\ (g) \rightarrow H_2SO_3$ (acid rain)
6. Some pollutants are interdependence by polluting land, water and air. For example lead. Lead: - This is a dangerous toxin found across the world, in fact, in all states. The element readily dissolves in water and upon uptake leads to devastating health problems. Heavy metals: Lead contamination in the atmosphere is a result of vehicle engines that use fuels containing tetraethyl lead which is added to the fuel to reduce engine knocking. The use of lead paints also contributes towards lead contamination. High levels of lead cause damage to the brain, kidneys and liver.

5.3 Global Warming and Climate Change

Period allotted 3

After completing this section, students will be able to

- *describe global warming and climate change from the perspective of chemistry*
- *list the common greenhouse gases*
- *describe greenhouse gases and greenhouse effect*
- *discuss about the chemistry of greenhouse gases related to global warming*
- *classify greenhouse gases.*

Forward Planning

Since global warming and climate change is becoming a global issue and one of the defining sustainability challenges of our century, teaching the contents on global warming and climate changes requires much emphasis. This is because the problem of climate change affects the lives of every one of us directly or indirectly. So, the teacher is expected to acquaint students with the major issues of global warming and climate change, their effects and its relationship to chemistry of greenhouse gases. To get more information, you had better search for books, magazines and other reference materials. With the help of the concepts in teacher's guide and other reference materials on current issues, you can have good discussion between students on the relationship between global warming and climate change, global warming and chemistry of greenhouse gases, composition as well as life time of greenhouse gases in the atmosphere and contribution of greenhouse gases for global warming.

So, this section needs to be treated with a very great concern and emphasis. To create awareness among students, it is advisable to invite advocates of climate change educators. Moreover, to visualize the effect of greenhouse gases on global warming, you have to construct a greenhouse from transparent plastic in your school yards. Or if you have access of visual videos animation, please shows for the students to visualize the greenhouse effect.

Teaching Aids

- Animation video which shows the effect of global warming and climate change at regional or global level
- Animation video which shows greenhouse gases contribution for global warming
- A real greenhouse gas constructed in your school yard.

Subject Matter Presentation

Global Warming and Climate Change

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with an activity. **Activity 5.11** helps students identify the relationship between chemistry and global warming. Generally, composition and reaction of different gases in the atmosphere plays a great role on global warming. You can start teaching this section by allowing students discuss **Activity 5.1**1 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.

I. Chemistry plays an important role in determining the current state and the predictions of the future state of Earth's climate because a large number of agents that force Earth's climate is chemically active. Chemical processes in the atmosphere determine the abundances and properties of atmospheric forcing agents.

II. Human activities in our surrounding that enhance global warming are burning fossil fuels, cutting down forests, farming livestock, transportation sector and partial burning of wood for charcoal making. All these and other similar activities by human being adds enormous amounts of greenhouse gases to those naturally occurring in the atmosphere, increasing the greenhouse effect and global warming.

III. The relationship between the Green legacy, Global warming and climate change is that in recent years, in Ethiopia, increasing attention has been paid towards the worldwide climate change. Moreover, the exponential increase of carbon dioxide emissions into the atmosphere from different sources increases and making up the 86% of greenhouse gases. Carbon dioxide (CO_2) is a greenhouse gas, that Contributes to global warming and climate change Problems. So, the Green legacy reduces CO_2 accumulation from the atmosphere by sequestration.

Then proceed to introduce the students about why chemistry is vital to the response of climate change. Any human activity has a definite impact on the environment. In this context, climate change is one of the main current concerns and challenges for mankind. And show animation videos which are about the effect of global warming and climate change the environment.

Chemistry of Greenhouses Gasses and their Effects on Climate change

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with an activity. **Activity 5.12** helps students to identify the mechanism in which how the greenhouse gases increase average Earth's temperature. Generally, the greenhouse effect happens when certain gases, which are known as greenhouse gases, accumulate in Earth's atmosphere. You can start teaching this section by allowing students discuss **Activity 5.12** for some time in groups and present their views to the class. After they have done so far, give them appropriate information about the activity as follows.

I. Both N_2 (g) and O_2 (g) are present in very large amounts in the atmosphere, these gases do not absorb IR light and therefore do not contribute to the greenhouse effect. On the other hand, CO_2 (g) and H_2O (g) do absorb IR light and upon doing so gain energy which is transferred to the rest of the Earth. Even though these gases are present in small amounts, they are very good at absorbing infrared light. Thus, these atmospheric gases are the main contributors to the greenhouse effect.

II. Chemistry plays role in the composition and reactions of a variety of gases that contributes to the greenhouse effect, including solvents, chlorofluorocarbons and other volatile organic compounds (VOCs), or nitrogen and sulphur oxides. Some of them can have, intrinsically, an even greater greenhouse effect than CO_2 but, in general, are released to the atmosphere in amounts significantly lower. Besides, some of them, like nitrogen oxides, are generated concomitantly to CO_2 in combustion.

Then proceed to describe to the students how several chemical concepts, the chemical composition of the atmosphere, combustion chemistry, and solutions can all be used in a discussion of how CO_2 keeps our planet warm and how excess CO_2 warms it even more. Next let us define what does greenhouse effect mean? And show animation videos about how the greenhouse gasses increase global temperature followed by demonstration of greenhouse gases effect with the greenhouse built in school yard.

Answers to Exercise 5.3

1. Chemical reaction mainly from combustion of fuel ($C_XH_Y + O_2 \rightarrow CO_2$ + Heat energy) where X and Y are carbon and hydrogen number of hydrocarbon compound that contribute for global warming
2. Examples of greenhouse gases from anthropogenic and natural sources: Carbon dioxide, Halogenated compounds (CFCs) and HCFCs, methane, nitrous oxide and tropospheric ozone
3. The composition of atmosphere: nitrogen (78%), oxygen (21%), argon (1%), gaseous water (0 to 4%) and carbon dioxide (0.4 and increasing).
4. The greenhouse effect happens when certain gases, which are known as greenhouse gases, accumulate in Earth's atmosphere. Because these gases absorb IR light and upon doing so gain energy which is transferred to the rest of the Earth. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), H_2O vapor and fluorinated gases.

5.4 Green Chemistry and Cleaner Production

Period allotted 3

After completing this section, students will be able to

- *define the terms green chemistry and cleaner production*
- *discuss on the major principles of green chemistry and cleaner production*
- *list the importance of cleaner production*
- *explain atom economy*
- *calculate the atom economy based on the given chemical reaction*
- *apply green chemistry principles while doing laboratory activities*
- *apply atom economy principle during designing chemical reactions.*

Forward Planning

The principles of green chemistry and cleaner production are vital for preventing environmental pollution since they underline that "preventing waste production is safer than handling and managing the produced wastes. So, teaching the contents of green chemistry and cleaner production requires much emphasis. This is because the principles of green chemistry and cleaner production have link with modern methods controlling environmental pollution i.e. recycling, using biodegradable resources such as biocatalysts to speed up rate of reaction rather than using toxic catalysts. This in turn affects the lives of us directly or indirectly. So the teacher is expected to acquaint students with the "12" principles of green chemistry, cleaner production and concept of atom economy. To get more information, search for books, magazines and other reference materials. With the help of the concepts in teacher's guide and other reference materials, you can make a very good discussion between the teacher and students on the 12 principles of green chemistry, cleaner production and atom economy.

So, this section needs to be treated with a very great concern and emphasis. To create awareness among students, it is advisable to invite experts from Environmental Protection Authority and even from large scale industrial production chemical engineers. Moreover**,** to internalize the principle of green chemistry, cleaner production and atom economy on students show with diagram the use of catalysts to lower the energy requirement (one of the principles of green chemistry i.e. energy efficiency). Solve exercises related to atom economy by taking alternative reaction to produce one desired product and motivate the students to select greener or cleaner alternative among the given reactions based on the atom economy % stage.

Teaching Aids

- Diagram or graphs that shows some of the principles of green chemistry
- Animation video which shows the importance of green chemistry principle and cleaner production

Subject Matter Presentation

Principle of Green Chemistry

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with an **Activity 5.13**. **Activity 5.13** helps students to understand "Green chemistry" is a movement to make industries that involve chemicals more environmental friendly and sustainable. Green chemistry underlines with the basic principle that: "Why generate pollution if there is a greener alternative?" Next, proceed to teach this section by allowing students to discuss **Activity 5.14** for some time in groups and present their views to the class. This activity helps students to understand the relationship between principle of green chemistry and modern pollution control mechanism. After they have done, give them appropriate information about the activity as follows:

I. Yes, the principles of green chemistry are the same as modern pollution control mechanism because some of the principles in green chemistry are in line with mechanism of modern pollution control. Like prevention of wastes rather than managing produced wastes , Less hazardous chemical syntheses, designing safer chemicals, safer solvents and auxiliaries and design for energy efficiency

II. Prevention: it is better to prevent waste than to treat or clean up waste after it has been generated. And the second one is use of renewable feedstock that is to switch to the use of biomass as a feedstock and as an energy source.

Then proceed to introduce the students about developing a green alternative begins with considering the hazards of the required chemicals as well as their properties. Then inform the student's chemists can develop a manufacturing process so that every stage of product development is environmentally safe from the raw materials to what happens to the product at the end of its useful life. Show diagrams or graphs which shown some of the application of green chemistry using catalysts to lower the activation energy.

Cleaner Production in Chemistry

Methodologies suggested for teaching this section are group discussion, visual-based learning and gapped lecture. This section starts with an **Activity 5.15**. **Activity 5.15** helps students to understand that "cleaner production" is a movement to make industries that involve chemicals more environmental friendly and sustainable. Cleaner production underlines with the basic principle that: "it is a challenge for chemists and engineers to identify environmentally preferable reaction pathways that optimize the balance of all the desirable attributes." You can start teaching this section by allowing students to discuss **Activity 5.15** 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:

I. Yes, cleaner production and principle of green chemistry are the same. Because some of the principle of green chemistry is reflected "in one or another with the basic principles of cleaner production. Example, high yield, energy efficiency, use of renewable or recyclable raw materials and reagents and absence of hazardous byproducts or at least minimizing or containing them.

II. Production of local beverages "Tella and Areki" because the left over residue used as cattle's feed.

Then proceed to introduce the students about cleaner production and atom economy i.e. the atom economy (a measure of atom utilization or efficiency) is a measure of the amount of starting materials that end up as useful products. Then inform the student's chemists can develop a manufacturing process so that every stage of product development is environmentally safe from the raw materials to what happens to the product at the end of its useful life. Show the application of cleaner production by taking problems related to atom economy calculation. During this, take different reaction pathways that yield the desired product. And motivate students to select a reaction which follows a greener path.

Answers to Exercise 5.4

1. A green chemistry solution may involve using safer chemicals. Liquid carbon dioxide, for example, is starting to replace toxic organic solvents used in dry cleaning. Greening a chemical process can also involve making a process more efficient. For example, the original makers of ibuprofen, an important pain reliever, found a way to make the drug in half the number of steps.
2. Developing a green alternative or cleaner production begins with considering the hazards of the required chemicals as well as their properties. Chemists then develop a manufacturing process so that every stage of product development is environmentally safe—from the raw materials to what happens to the product at the end of its useful life. In other words, the process is "benign by design."
3. Principle of atom economy: The Atom economy is a primary criterion for green chemistry. The idea of the atom economy is to improve chemical processes, by avoiding the waste of atoms from reactants to products.
4. b 5. d 6. d
7. Atom economy = mass of desired product/ total mass of product * 100

Atom economy = $C_6H_{12}O_6 \xrightarrow{Yeast} 2C_5H_5OH + 2CO_2$

Mass of desrired product i.e, $2C_2H_5OH$ = 92 gram/mole

Total mass of product = $2C_5H_5OH + 2CO_2$ = 180 gram/mole

Atom economy = (mass of desired product/ total mass of product) * 100

= (92/180) * 100 = 51.11 %

Answer To Review Exercises

Part I: True or False

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

Part II: Multiple choice Questions

1. a	7. d	13. a	19. c
2. a	8. d	14. c	20. b
3. d	9. a	15. a	21. d
4. d	10. a	16. b	22. b
5. d	11. d	17. c	
6. b	12. b	18. a	

Part III. Give Short Answer

1. The greenhouse gases in the atmosphere act in much the same way as the glass panels of a greenhouse, which allow sunlight through and trap heat inside.
2. Each gas has different radiative properties, atmospheric chemistry, typical atmospheric lifetime, and atmospheric concentration. For example, CFC-12 is roughly 15,800 times more efficient molecule for molecule at trapping heat than CO_2. Because CFC-12 is a large, heavy molecule with many atoms and a CO_2 molecule is small and light in comparison, there are fewer molecules of CFC-12 in each ton of CFC-12 emissions than CO_2 molecules in each ton of CO_2 emissions. Each ton of CFC-12 emissions is about 5,750 times more efficient at trapping heat than each ton of CO_2. The comparatively greater amount of CO_2 in the atmosphere, however, means that it accounts for roughly half of the radiative forcing associated with the greenhouse effect.
3. It is because carbon monoxide combines with haemoglobin to form stable complex called carboxyhemoglobin. Due to its formation, the transport of oxygen from lungs to the cells is restricted. When the level of carbon monoxide reaches 1300 ppm, it is fatal. The high percent of carbon dioxide is global warming.
4. I. Some common air pollutants are: sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, hydrocarbons, particulates, chlorofluorocarbons (CFCs), and lead compounds.

II. The major water pollutants are nitrate and phosphate fertilizers washed out of the soil, phosphate detergents, untreated sewage, insecticides and herbicides, and the heavy metal ion, acidic and/or basic residues released by industrial processes.

III. Some common land/soil pollutants are: spillage of oil, leaching of harmful chemicals and heavy metal ions, and dumping of non-biodegradable wastes such as plastics

5. a. Methods of reducing air pollution
   - Using public transports.
   - Turn off the lights when not in use.
   - Recycle and Reuse.
   - Not to use plastic bags.
   - Reduction of forest fires and smoking.
   - Use of fans instead of Air Conditioner.
   - Use filters for chimneys.
   - Avoid usage of crackers.

   b. Methods of reducing water pollution
   - Treatment of water before discharge into rivers and lakes.
   - To avoid unnatural temperature changes in natural water systems, industries should not discharge heat-ladened water into them.
   - Recycling industrial and agricultural wastes.
   - Using moderate amounts of agricultural chemicals and increasing the use of organic fertilizers and biological methods to control pests.

   c. Methods of reducing land pollution
   - Make people aware of the concept of Reduce, Recycle and Reuse.
   - Reusing materials help to reduce the requirement of harvesting resources.
   - Reduce the use of pesticides and fertilizers in agricultural activities.
   - Reduce the use of non-biodegradable materials.

6. **Troposphere,** the lowermost layer of the atmosphere, traps heat by a natural process due to the presence of certain gases. This effect is called greenhouse effect. Carbon dioxide gas is mainly responsible for global warming. It contributes about 55% to global warming from greenhouse gases.

7. **Atom Economy is the ratio of** "the mass of the desired product" by "the total mass of the products", and can be expressed in percentage as illustrated in the formula below. **Good atom economy means** most of the atoms of the reactants are incorporated in the desired products and only small amounts of unwanted byproducts are formed and hence lesser problems of waste disposal or waste treatment).

8. **Principle of Prevention:** The proper definition says that it is better to prevent waste than to treat or clean up waste after it has been generated. Generally, it describes the ability to update chemical transformations in order to limit the generation of hazardous waste as a significant advancement towards contamination or pollution avoidance.

Part IV: Problems

1. **"Green chemistry"** is a movement to make industries that involve chemicals more environmental friendly and sustainable. Green chemistry asks the question: "Why generate pollution if there is a greener alternative?" Developing a green alternative begins with considering the hazards of the required chemicals as well as their properties. Chemists then develop a manufacturing process so that every stage of product development is environmentally safe from the raw materials to what happens to the product at the end of its useful life. In other words, the process is "benign by design."

2. **Heavy metals:** Lead contamination in the atmosphere is a result of vehicle engines that use fuels containing tetraethyl lead which is added to the fuel to reduce engine knocking. For example

    a. The use of lead paints also contributes towards lead contamination. High levels of lead cause damage to the brain, kidneys and liver. Moreover, **Lead** is a dangerous toxin found across the world, in fact, in all states. The element readily dissolves in water and upon uptake leads to devastating health problems.

    b. Mercury: This element is released into the environment due to mining activities, poor disposal of certain items that are either made of mercury or had mercury in them. Batteries are the main source of mercury, which is why it is essential to dispose of them carefully

3. **Reaction A:** converting ethanol to ethene

   Reaction B: ethene + water $\Rightarrow$ ethanol

   Reaction C: fermentation of sugar to make ethanol ('alcohol')

   I. Reaction A (converting ethanol to ethane)

$$C_2H_5OH \xrightarrow{dehydrating} CH_2=CH_2 + H_2O$$

Atom economy = (mass of desired product/ total mass of product) * 100

Mass of desired product i.e., CH_2=CH_2 = 28 gram/mole

Total mass of product = $CH_2=CH_2 + H_2O$ = 46 gram/mole

Atom economy = (mass of desired product/ total mass of product) * 100

= (28/46) * 100 = **60.87 %**

II. Reaction B: ethane + water $\rightarrow$ ethanol

$$CH_2=CH_2 + H_2O \xrightarrow{Hydration} C_2H_5OH$$

Atom economy = (mass of desired product/ total mass of product) * 100

Mass of desired product i.e., C_2H_5OH = 46 gram/mole

Total mass of product = C_5H_5OH = 46 gram/mole

Atom economy = (mass of desired product/ total mass of product) * 100

= (46/46) * 100 = 100 %

III. Reaction C (fermentation of sugar to make ethanol (alcohol)

Atom economy = $C_6H_{12}O_6 \xrightarrow{Yeast} 2C_5H_5OH + 2CO_2$

Atom economy = (mass of desired product/ total mass of product) * 100

Mass of desired product i.e., $2C_2H_5OH$ = 92 gram/mole

Total mass of product = $2C_5H_5OH + 2CO_2$ = 180 gram/mole

Atom economy = (mass of desired product/ total mass of product) * 100

= (92/180) * 100 = 51.11 %

Since reaction "B" is 100 % of atom economy, it is more environmentally friendly than reaction "C" which has 51.11 % of atom economy.