CHEMISTRY

Distance Module-II

GRADE 12

CHEMISTRY GRADE 12 DISTANCE MODULE II

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA MINSTRY OF EDUCATION

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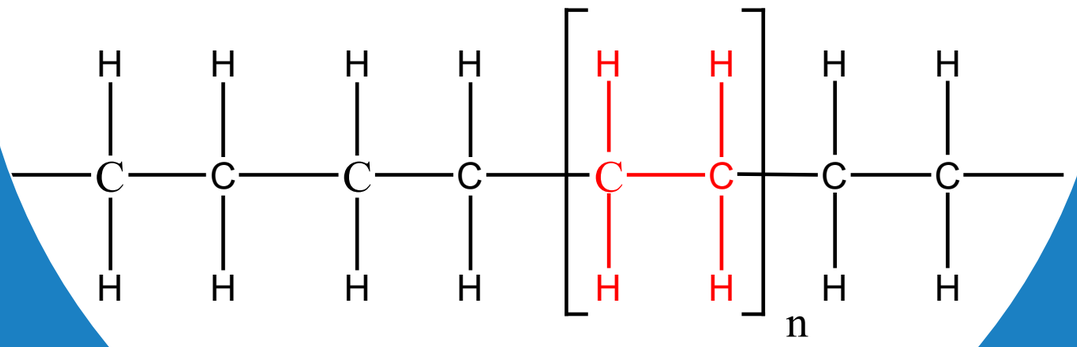

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CHEMISTRY

Distance Module - II

GRADE 12

INDUSTRIAL CHEMISTRY, POLYMER AND INTRODUCTION TO ENVIRONMENTAL CHEMISTRY

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Introduction

Dear learner, in Module I you studied about electro chemistry and acid base equilibra. Module II is a contination of Module I. In Module II you will study about industrial chemistry, polymer and introduction to environmental chemistry. The module is named as industrial chemistry, polymer and introduction to environmental chemistry, which is a combination of the three units. You are expected to study each unit in expected study time.

Dear learner, you are expected to do the continuous assessments prepared in the module effectively. If you attempt the tasks given over and over again, you will be successful at the end. Practicing a lot and doing the activities will make you to understand and love the subject.

Module Content

Module Assessment Methods

Dear learner, you are advised to read thoroughly each contents in order to meet the desired minimum learning competencies given at the beginning of the units and sections, so that you will test yourself using self-test questions. Several activities and exercises are also included. The answers for each task are attached at the end of the module. This helps you to check or evaluate how much you understand the contents. The module is also inquiring you to complete the assignment for submission, which you should work out and your tutor will return to you for detail feedbacks and comments. Any project or activities given in the module will also be submitted to your tutor along with the assignments.

There are a number of symbols in the course materials so that it guides you as you study

 This tells you there is an overview of the unit and what the unit is about.

 This tells you there is an in-text question to answer or think about in the text.

 This tells you to take note of or to remember an important point.

 This tells you there is a self-test for you to do

 This tells you there is a checklist.

 This tells you there is a written assignment

 This tells you that this is the key to the answers for the self-tests.

UNIT 3

INDUSTRIAL CHEMISTRY

Introduction

Dear learner, in your grade 10 unit five you have learned about occurrence, extraction; and uses of some important metals, in grade 12 of unit two industrial application of electrolysis have discussed. These units will give you basic information you need for this unit on industrial chemistry. 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, will deals about 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 in particular.

The second section deals with 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 is a broader section which gives emphasis to the manufacturing of valuable chemical products. The valuable chemical 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 is about 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 along with the major steps to produce products will be examined in detail.

Unit Outcomes

By the end of this unit, you 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 aluminum sulphate and di-ammonium phosphate and other nitrogen fertilizers
- 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, $(NH4)_2HPO_4$, 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 and 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

Unit Content

The Required Study Time **7 weeks**

If you set an average of one hour per day, you should be able to complete unit one by the end of the assigned week. Try to do all the learning activities. And compare your answers with the ones provided at the end of the Module.

If you do not get a particular exercise right in the first attempt, you should not get discouraged, but instead, go back and attempt it again. If you still do not get it right after several attempts, then you should seek help from your friend or even your tutor.

Unit Learning Strategies

The suggested methodology for this unit is individual study (self-study) and if you have access for internet, you can widen your mental horizon through e-learning. Each section begins with activity. You should reflect your responses and cross check whether you are right or wrong. The activity enables you to remember what you have learned in previous module or unit. Please rate the check list that are given in the end of each section and evaluate your-self by doing the self-test exercises given at the end of each section. Then check your answer at the end of the module in case if you did not achieve the minimum required level for each self- test exercise please study the section over and over again by taking additional study hours.

Section 3.1: Introduction

Dear learner, in this section you will study the basic concepts of introduction to industrial chemistry in terms of the development of industrial chemistry and its importance for the societal problem.

You will also learn the role of industrial chemistry in the society and then you end up with the general characteristics of chemical industries.

Objective

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

- define industrial chemistry
- list general characteristics of chemical industries;
- mention the role of industrial chemistry in the society

Activity 3.1

List at least five products that are manufactured by Ethiopian chemical industries.

How the development of industrial revolution has begun? What is the importance of chemistry and chemical technology for economic growth and development of a country? What does industrial chemistry mean? And what are the general characteristics of chemical industries? These are some the basic questions you should respond.

Let us began how the development of industrial chemistry began. During the 19th-century industrial revolution began the development of chemical industries at a very high rate. Following this, the demand for goods produced through chemical processes increased. Today, chemical industries in both developed and developing countries produce a number of very useful products. This includes synthetic fibers, plastics, rubber fertilizers, dyes, drugs and many other products.

Chemistry and chemical technology are very important for economic growth and development, especially for developing countries like Ethiopia. Ethiopia has minerals (metal ores) deposits which are sources of iron, lead, copper, gold, platinum, tantalum and many rare-earth metals. Moreover, rock salt gypsum, coal, and crude oil are found. So, Ethiopia needs industrial revolution to use its mineral deposits to produce various chemicals at a large scale.

So, in this context, what is industrial Chemistry?

Industrial chemistry is a branch of chemistry which applies physical and chemical procedures toward the transformation of natural raw materials and their derivatives into products that have beneficial to humanity.

Industrial chemistry differs from classical chemistry in that it closes the gap created in concepts between chemistry as it is taught in schools and chemistry as it is practiced commercially.

Industrial chemistry is the basis of the chemical industry. The chemical industry is an institution involved in producing chemical products such as food, medicine, building materials, plastics, etc. 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 to satisfy social needs. Most of these products, in turn, can be used by other chemical industries to manufacture other items or can be used directly by consumers.

Generally, chemical industries

- use naturally-available raw materials to produce the desired products.
- consume relatively large quantities of energy during the manufacturing process
- involve chemical reactions to transform raw materials into finished and semi-finished products
- 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.

√ CHECKLIST 3.1

Please put a (√) in the box for the tasks you can perform or concepts you understand

- Can you explain the reason how the development of industrial revolution began? ☐
- Can you describe briefly the importance of chemistry and chemical industry for economic growth and development of a country (a nation)? ☐
- Can you define clearly what meant by industrial chemistry? ☐
- Can you list the general characteristics of chemical industries? ☐

Self-Test Exercise 3.1

Part I. Multiple Choices

1. Which one of the following **is not true** about chemical industries?
   a. Use different methods of purifying the materials they produce
   b. Have quality control laboratories to check whether or not their products meet the desired specification.
   c. They are not energy dependent in their manufacturing processes
   d. They can cause environmental pollution unless they treat the waste products coming out of the manufacturing process
2. One of the following is a manufacturing industry found in Ethiopia
   a. Awash Tannery
   b. Addis Foam and Plastic Factory
   c. Tabor Ceramic Factory
   d. All of the above
3. One of the following is not a chemical industry found in Ethiopia
   a. Aadami Tulu Pesticide Factory
   b. Caustic Soda factory of Zeway
   c. Sulfuric Acid and Aluminum Sulphate Factory
   d. Yara fertilizer company
4. An example of chemical manufactured in Ethiopia includes:
   a. Na_2CO_3 c. cosmetics products, e. All
   b. detergents, d. Food preservatives

Part II. Give short answer for the following questions

1. Define "industrial chemistry.
2. Discuss how chemical industries are considered to be the prominent one when dealing with manufacturing industries.
3. List the characteristics of chemical industries.

Section 3.2: Natural Resources and Industry

Dear learner, When we speak about natural resources and industry, we deal about the relationship between them that is natural resources are the raw materials for the chemical industry which are obtained from the natural environment.

In this section you will learn the classification of natural resources as renewable and non-renewable and you will also learn about chemical and manufacturing industries and their classification. Then you end up this section with the classification of chemical industries based on the type of product they produced.

Objective

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

- define natural resources
- list the types of 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.

Activity 3.2

Please reflect on the following questions

1. Can fossil fuels be renewed?
2. List the importance of natural resources for chemical industries using examples

3.2.1 Natural Resources (Raw materials)

Natural resources are the raw materials for the chemical industry which are obtained from the natural environment. The raw materials are obtained from the different components of the natural environment. These are listed below

- From the atmosphere: The earth's atmosphere has approximately 5 X 10^{15} tons of gases. It is composed of different gases, namely N_2, O_2 , Ne, Ar, Kr, and Xe. They are important industrial raw materials. Thus, the natural supply of these gases is unlimited.
- From the hydrosphere: Ocean water which amounts to about 1.5 X 10^{21} liters contains about 3.5 percent by mass dissolved material. Sea water is a good source of sodium chloride, magnesium and bromine.
- From the lithosphere**:** The vast majority of elements are obtained from the earth's crust in the form of mineral ores, carbon and hydrocarbons. Coal, natural gas, and crude petroleum, besides being energy sources, are also converted to thousands of chemicals.
- From the biosphere: Vegetation and animals contribute raw materials to the so-called agro-based industries. Oils, fats, waxes, resins, sugar, natural fibers and leather are examples of thousands of natural products.

Classification of Natural Resources

Natural resources can be classified as renewable and non-renewable resources.

Renewable resources: The resources that can be replenished through rapid natural cycles are known as **renewable resources.** These resources are able to increase their abundance through reproduction and utilization of simple substances. Examples of renewable resources are plants (crops and forests) and animals which are being replaced from time to time because they have the power to reproduce and maintain life cycles. There are also renewable resources without any life cycle. These include wood and wood

products, natural rubber, fibers (e.g., cotton, jute, and animal wool, silk, and synthetic fibers), pulp products, and leather. Furthermore, resources, water, and soil are also classified as renewable resources. Moreover, solar energy is considered a renewable resource as much as solar stocks are inexhaustible on the human scale.

Non-Renewable Resources: The resources that cannot be replenished (regenerated) through natural processes are known as **non-renewable resources.** These are available in limited amounts and cannot be increased. These resources include fossil fuels (petrol, coal, etc.), metals (iron, copper, gold, silver, lead, zinc, etc.), minerals, and salts (carbonates, phosphates, nitrates, etc.). Once a non-renewable resource is consumed, it is gone forever. Thus, a substitute for it is necessary.

The resources that can be replenished through rapid natural cycles are known as renewable resources whereas The resources that cannot be replenished (regenerated) through natural processes are known as non-renewable resources.

3.2.2 Industry

Industry is a well-organized facility with a high degree of automation and specialization where large-scale manufacturing of goods take place. Nevertheless, it can also include other commercial activities that provide goods and services such as agriculture, transportation, hospitality, and many others.

Manufacturing Industry: Manufacturing industry is a compartment of industry or economy which is concerned with the production or making of goods out of raw materials by means of a system of organized labor.

Classification of manufacturing industry

Manufacturing industries use different type of raw materials, skills, and technologies. As a result, different types of products are manufactured.

Chemical Industry: Chemical industry is a facility where industrial chemicals are manufactured. The products result from:

a. Chemical reaction between organic materials, or inorganic materials, or both
b. Extraction, separation, or purification of natural products, with or without the aid of chemical reactions
c. The preparation of specifically valuable materials

Classification of the chemical industry based on raw material used for production

1. Chemical industries use natural raw materials (resources)

   For example, sugar industries use sugar cane to manufacture sugar.

2. Chemical industries use products from other industries to manufacture their products. For example, detergent and soap manufacturing industries use preprocessed products like caustic soda, caustic potash, and related compounds to manufacture their products.

Do you list some manufacturing industries in your surrounding based on the product

Classification based on the product type

Examples are:

- food processing industries
- beverages industries
- textiles industries
- wearing apparel industries
- leather goods industries
- paper and chemical industries etc.

CHECKLIST 3.2

Please put a (√) in the box for the tasks you can perform or concepts you understand

- Can you define natural resources in terms of manufacturing industry? ☐
- Can you describe briefly the two types of natural resources i.e. the renewable and non-renewable? ☐
- Can you explain the difference between manufacturing industries and chemical industry? ☐
- Can you list the classes of the chemical industry based on raw material used for production? ☐
- Can you list classes of chemical industry based on the product they produced? ☐

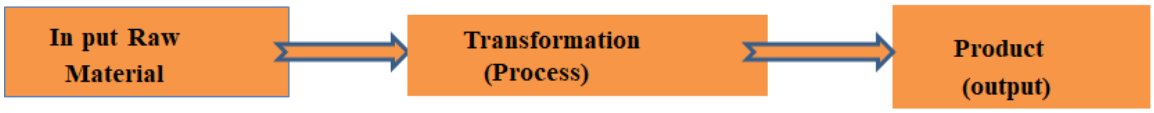
Self-Test-Exercise 3.2

Give short answer for the following Questions

1. List the types of manufacturing industries based on their products.
2. Give examples of renewable and non-renewable natural resources
3. List the types of manufacturing industries based on the raw material used for production.
4. Give examples of natural resources that obtained from the hydrosphere?

Section 3.3: Manufacturing of Valuable Chemicals

Dear learners, manufacturing of valuable products involves a number of chemical processes. The process is designed to produce a desired product from a variety of starting raw materials using energy through a succession of treatment steps integrated in a rational fashion. The treatment steps could be either physical or chemical in nature. Here is the basic step in a manufacturing process.



Valuable products include every industrial product. These products are either directly used or serve as raw materials to synthesize products that are important to solve the society demands in different necessities. Both organic and inorganic chemicals could be used in the manufacturing process.

What is by far the largest volume chemical produced in the world? WhicH chemical production is considered as a leading economic indicator of the strength for many industrialized nations?

In this section, the properties, uses and preparation steps of valuable chemicals to produce other products NH_3, Nitric acid, sulphuric acid, sodium hydroxide and sodium carbonate will be described. And also, the valuable products that are essential for the demands of the society: nitrogen-based fertilizers and some common pesticides and herb sides will be examined.

Objective

At the end of this section, you 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 Lechaterier's principles to explain how the yield of ammonia can be increased in 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 Ostwald Process
- list the physical and chemical properties of H_2SO_4
- explain how the production of H_2SO_4 is considered as the 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 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 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

3.3.1 Ammonia (NH_3)

Activity 3.3

Can you reflect the reason that ammonia is highly soluble in water?

Properties

Ammonia is lighter than air with a density of 0.769 kg/m^3 at STP. Ammonia is commercially and commonly available as an aqueous solution; the most common commercial formulation is 28–30% NH_3. In the aqueous solution ammonia is partially ionized according to the equilibrium:

$$NH_3 + H_2O \Leftrightarrow NH_4^+ + OH^-$$

and it is often referred to as **ammonium hydroxide.** It is a weak base. It is colorless with sharp and intensely irritating gas at room temperature. Its melting point is -77.7 °C . Its boiling point is -33.35 °C . Its solubility in water at 25 °C is 34% (w/w).

Uses

Ammonia is an important compound, essential to man for a variety of diverse uses. It is used as a cleaning agent, antimicrobial agent, a raw material for the production of nitrogen fertilizers, raw material in the manufacturing of explosives such as nitrocellulose and TNT, used in the production of soda ash and in the Ostwald process to get nitric acid etc. Such a diverse applicability has caused large demand for its production.

Preparation

Ammonia is easily made in the laboratory by heating an ammonium salt, such as ammonium chloride NH_4Cl with a strong alkali, such as sodium hydroxide or calcium hydroxide.

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

The gas may also be made by warming concentrated ammonium hydroxide. However, its diverse applicability has caused large demand for its production. The development of the Haber-Bosch process for ammonia production has made it possible to meet this demand. So, the principal commercial method of production of ammonia is the Haber process, the direct combination of nitrogen and hydrogen under high pressure in the presence of a catalyst.

The Haber process was found by the German chemist, Fritz Haber, in the early 20th century. It involved the practical use of atmospheric hydrogen and nitrogen to produce ammonia. Carl Bosch was tasked with scaling up the process to an industrial production. The efforts of both these men were recognized in the form of Nobel prizes that were awarded to them in 1918 and 1931, respectively. This also led to the process being called the Haber-Bosch process. Presently, about 454 million tons of nitrogen fertilizers are produced using the Haber-Bosch process. They are extensively used to increase crop yields.

Steps Involved in Ammonia Production

Step 1: The primary requirements for the production of ammonia are hydrogen (H_2) and nitrogen (N_2). H_2 was initially obtained by electrolyzing water, thus, splitting the water molecule into its components – hydrogen and oxygen. In recent times, this method has been replaced by the use of methane as a source. Methane is easily acquired from natural gas, and requires very less external energy to produce hydrogen. The other substrate, nitrogen, is obtained by carrying out fractional distillation of air.

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

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

Step 3: The hot mixture of gases is then passed through a condenser. Since ammonia condenses easily as compared to nitrogen and hydrogen, the liquefied ammonia is collected and removed, and the leftover nitrogen and hydrogen gases are re-introduced into the reactor. Thus, pressure is maintained, and there is no loss or wastage of reactants. This recycling of the raw materials allows a 97% conversion of initial reactants into ammonia, which is, then, used to produce a variety of products. The steps are shown in Figure 3.1

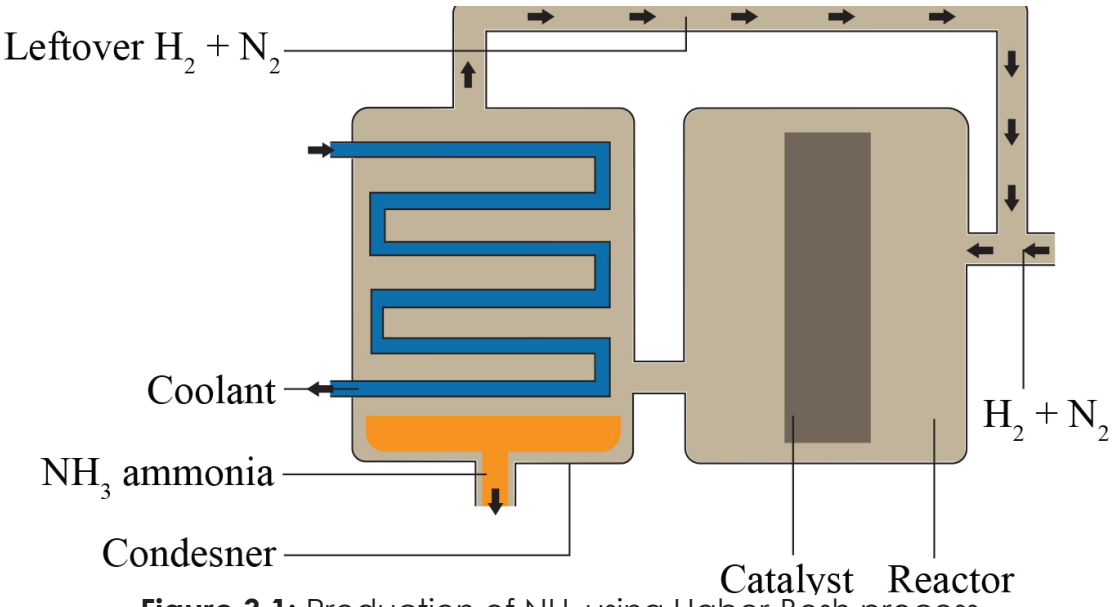


Figure 3.1: Production of NH_3 using Haber-Bosh process

Experiment 3.1

Dear learner, to have a skill of preparation of ammonia and to test its solubility and alkalaine nature perform experiment 3.1. To conduct the experiment, visit a nearby high school and request a teacher who is teaching Grade 12 chemistry to help you in performing or demonstrating the experiment. Note that the experiment should be performed only in the laboratory. If you couldn't find a high school in your area, request your tutor to get support and advices.

Title: Preparation and Testing of Ammonia

Objective:

- to prepare ammonia
- to test its solubility
- to test its alkaline nature

Material Required

Eye protection or eye goggles, stand and clamp, a dried boiling tube with stopper and delivery tube (see diagram below), beaker100 mL, beaker, 250 mL or bigger, Bunsen burner, spatula and test tube to collect ammonia gas.

Chemicals Required

Ammonium chloride, Calcium hydroxide, Calcium oxide, Concentrated hydrochloric acid, red litmus paper, blue litmus paper and Universal indicator paper.

Safety Precautions

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.

Procedure

1. In a 100 ml beaker, mix 2 spatulas of the ammonium chloride with 2 spatulas of the calcium hydroxide together. The two solids begin to react immediately on mixing.
2. Hold a piece of each color of litmus paper over the mixture and observe the color change. Test also with a piece of universal indicator paper.
3. Transfer the mixture of ammonium chloride and calcium hydroxide into a boiling tube and set up the apparatus as shown in the diagram.

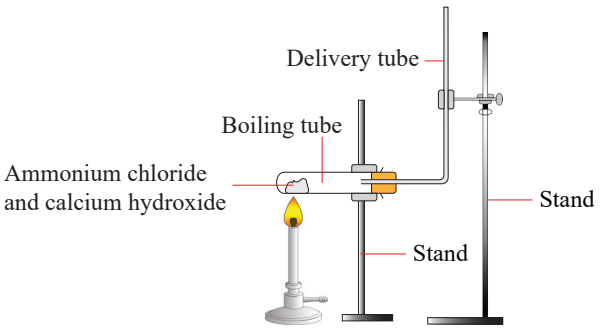


Figure 3.2: The setup required for producing ammonia gas

4. Optional: put the lump of calcium oxide into the boiling tube containing the ammonium chloride/calcium hydroxide mixture. The calcium oxide will absorb the water produced in the reaction and ensure that the ammonia gas is dry.
5. Gently warm the reaction mixture.
6. Collect a test tube which contains a few drops of concentrated hydrochloric acid. Remove the stopper from this test tube and hold the open end near the end of the ammonia gas delivery tube. Observe what happens. Replace the stopper on the test tube of hydrochloric acid and return the test tube to its original place.
7. Two-thirds fill a large beaker with water. This is needed for step 10.

8. Continue to gently warm the reaction mixture. Hold one of the dry boiling tubes in position as shown in the diagram below. Notice that the ammonia is collected with the boiling tube upside down. This is because ammonia is less dense than air.

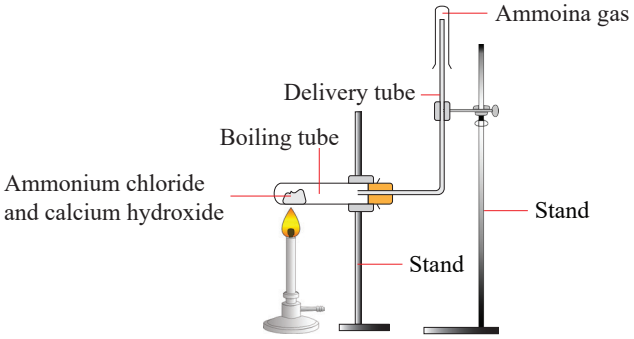


Figure 3.3: The equipment setup required to collect the ammonia gas.

9. Test around the open end of the collecting boiling tube with universal Indicator paper to check that the collecting tube is full of ammonia.
10. Hold the tube of ammonia upside down then quickly put it, mouth still downwards, into water in a beaker. The ammonia dissolves in the water and the level of the water should rise up inside the test tube. If you want to try this a second time, use a fresh dry boiling tube.

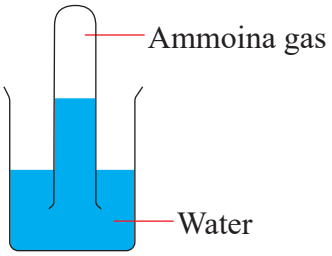


Figure 3.4: A setup showing ammonia gas dissolved in water

Observation and Analysis

A. Why a dried boiling tube is required?

B. What is the purpose of putting the lump of calcium oxide into the boiling tube containing the ammonium chloride/calcium hydroxide mixture?

C. What do you think is the white fume ('smoke') that is produced when the ammonia gas is collected into the HCl?

D. What is the nature of ammonia? Is it alkaline or acidic gas? If it is alkaline, please write the reaction equation that shows its alkalinity?

3.3.2 Nitric Acid

Activity 3.4

Could you reflect the reason why nitric acid is considered a highly corrosive mineral acid?

Properties

Pure nitric acid has a density of 1.51 g/cm^3. It is a colorless liquid, with a highly pungent odor, in appearance similar to water, but on exposure to light, it turns brown because of slight decomposition into NO_2 (brown) and O_2.

$$4HNO_3(l) \rightarrow 4NO_2(g) + O_2(g) + 2H_2O(l) brown$$

Nitric acid is a strong acid and dissociates completely to give H_3O^+ and NO_3^- in a dilute aqueous solution. Nitric acid forms a large number of salts, called nitrates, which are typically very soluble in water. **Nitric acid** is a highly corrosive mineral acid. Nitric acid and its salts are strong oxidizing agents, particularly when it is hot and concentrated. This fact explains the violence of the reactions with metals, which result in the release of hydrogen. It reacts readily with numerous substances and produces heat when dissolved in water. A significant proportion of reactions involving it are even explosive.

Concentrated nitric acid is highly hazardous to health. Upon contact with the skin, it causes severe burns and even necrosis.

Experiment 3.2

Dear learner, to investigate oxidizing property of Nitric acid perform experiment 3.2. To conduct the experiment, visit a nearby high school and request a teacher who is teaching Grade 12 chemistry to help you in performing or demonstrating the experiment. Note that the experiment should be performed only in the laboratory. If you couldn't find a high school in your area, request your tutor to get support and advices.

Title: Properties of Nitric Acid

Objective: To investigate oxidizing property of Nitric acid

Materials Required

round-bottomed borosilicate flask (Preferably thick-walled), clamp stand, delivery tube, test tube, tong, glass wool bowl or trough safety screens (if in an open lab).

Chemicals Required

5 g copper turnings and 40 ml concentrated nitric acid

Safety Precautions

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

Procedure

1. Fill the test tube flask with water and add the acid to the round-bottomed flask
2. Clamp the round bottomed flask into position and check that the delivery tube, when in place, is at the bottom of the flask
3. Loosely plug the neck of the conical flask with glass wool, leaving the delivery tube in position, ready to be removed when the copper is added
4. Add the copper and fit the delivery tube.
5. After about 80 seconds, the reaction will slow and observe what will happen
6. The setup for the experiment is represented in the figure below

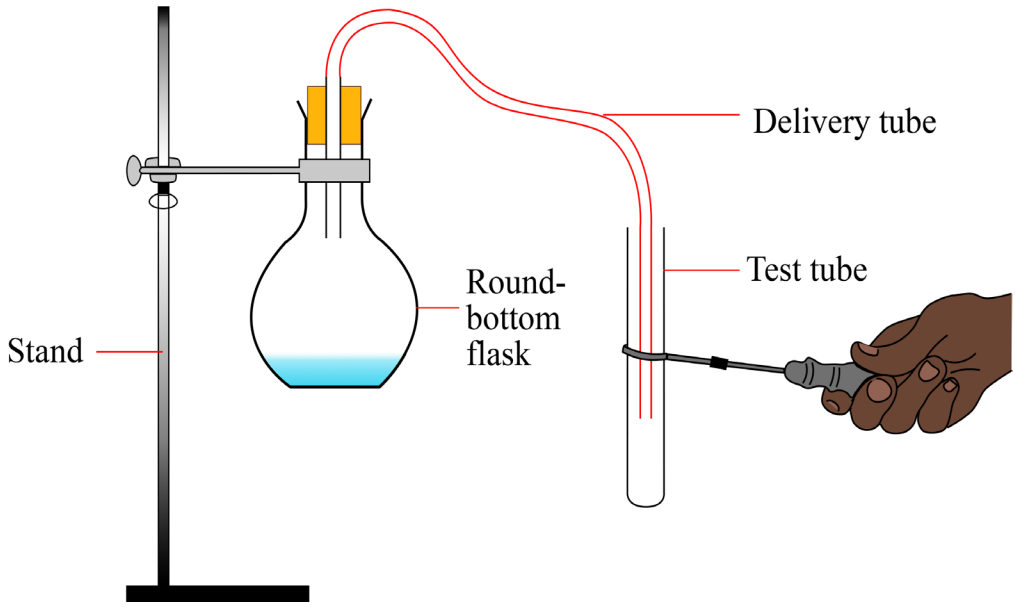


Figure 3.5: Set up for reaction of nitric acid with Copper

Observation and Analysis

A. As the copper is added, what color is observed or developed in the solution?

B. What gas evolved during the reaction? what is the color of this gas?

C. Write the reaction equation, which shows the reaction of copper with concentrated nitric acid.

Uses

Neutralization of nitric acid with ammonia results in ammonium nitrate – the most important component of mineral fertilizers used worldwide. In addition, HNO_3 can be used for soil acidification in horticulture. In the chemical industry, nitric acid is primarily a precursor to organic nitrogen compounds, such as nitro-benzenes. When combined with aromatic compounds, it yields substances used to make explosives, such as TNT and nitroglycerine.

Another important application is rocket fuel. For this purpose, a mixture of HNO_3, dinitrogen tetroxide and hydrogen peroxide, also known as red-fuming nitric acid, is prepared. Nitric acid's potential for plastic production is also noteworthy. Other less popular uses of nitric acid include:

- production of organic dyes and lacquers;
- pharmaceutical industry;
- production of fungicides;
- cleaning and etching of metal surfaces;
- refining of precious metals for the jewelry industry (in preparation of aquaregia);
- the artificial ageing of wood to obtain the desired shade;
- production of household cleaning products;
- detection of traces of metals in laboratory test substances.

Preparation

Nitric acid can be obtained by reacting nitrogen dioxide with water. Under laboratory conditions, an alternative production method is the reaction of potassium nitrate with sulphuric acid to produce pure nitric acid.

$$2KNO_3 + H_2SO_4 \rightarrow K_2SO_4 + 2HNO_3$$

(Salt of more volatile acid + less volatile acid → displaces more volatile acid). There is a basic principle that a more volatile acid can be displaced from its salt by a less volatile acid.

For commercial purposes, the basic production method is the so-called **Ostwald process**. This is the catalytic oxidation of ammonia to nitric oxide, which, using special absorption towers, yields concentrated HNO_3 acid. For purchase, a concentration of 65–68% is most desirable.

Ostwald processes: The principle or mechanism behind the **Ostwald process** is "the conversion of ammonia to nitric acid simply occurs as a result of oxidation. This particular oxidation reaction gives us the corresponding nitric oxide. Further, when the nitric oxide is oxidized, nitrous gases are formed, and those gases can trap water molecules. As a result, we obtain nitric acid. Catalytic oxidation involving O_2 is used where ammonia will give rise to the product."

Production of Nitric Acid

Nitric acid is produced industrially from ammonia by the three-step Ostwald process:

Step 1: Ammonia is burned in excess oxygen over a platinum catalyst to form nitric oxide (NO):

$$4NH_3(g) + 5O_2(g) \xrightarrow[5atm,\ Pt]{850\ 0c} 4NO(g) + 6H_2O(g)$$

Step 2: Additional air is added to cool the mixture and oxidize NO to NO_2:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Step 3: The NO_2 gas is bubbled into the warm water, where it reacts to give nitric acid and nitric oxide:

$$3NO_2(g) + H_2O(l) \rightarrow 2NHO_3(aq) + NO(g)$$

The nitric oxide (NO) is recycled in Step 2.

The production of nitric acid with the Ostwald process is summarized in **Figure 3.6**

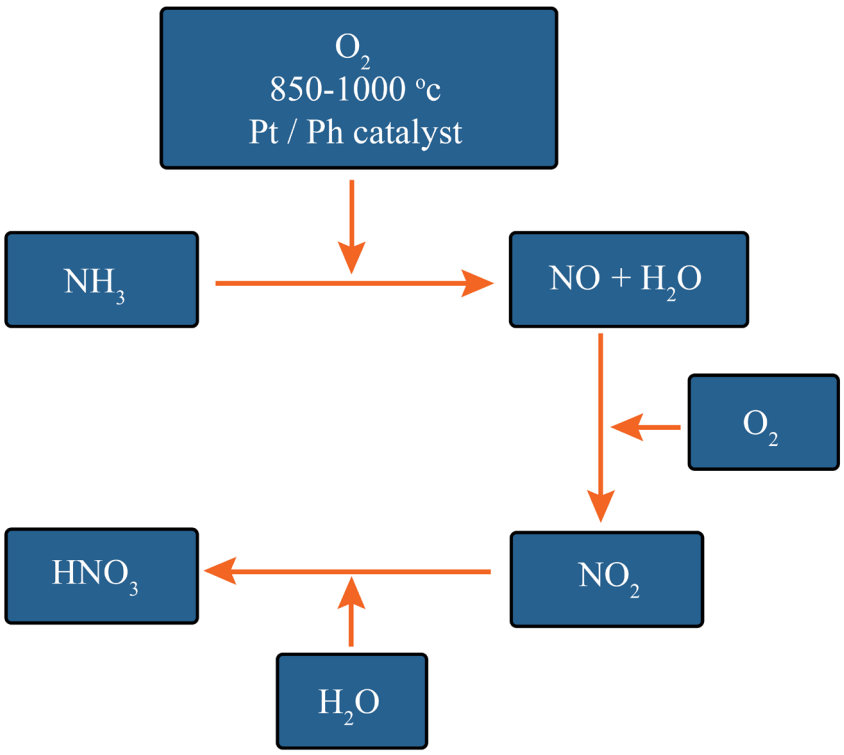


Figure 3.6: Simplified diagrams that show the Nitric acid manufacturing process

3.3.3 Nitrogen-Based Fertilizers

Activity 3.5

1. Describe why a large-scale use of synthetic fertilizers can be harmful to the environment
2. What is the role of nitrifying bacteria in the reaction of nitrogen-based fertilizers?

The common forms of nitrogen-based fertilizer include anhydrous ammonia, urea, urea-ammonium nitrate (UAN) solutions and Diammonium Monohydrogen Phosphate (DAP) with represented by chemical formula $(NH_4)_2HPO_4$.

Anhydrous Ammonia

Anhydrous ammonia (**NH_3**) is the most basic form of nitrogen fertilizer. Ammonia, a gas at atmospheric pressure, must be compressed into a liquid for transport, storage and application. Consequently, it is applied from a pressurized tank and must be injected into the soil to prevent its escape into the air.

Although almost 80 percent of the earth's atmosphere is comprised of nitrogen, it is in a chemically and biologically unusable form for plants. Using a complex method called the Haber-Bosch process (refer section 3.1 for this process), nitrogen is captured from the air, combined with a hydrogen source and converted into a form that can be used by growing plants. Ammonia in this form is also known as **ammonia gas or anhydrous** ("without water") ammonia.

Application

Anhydrous ammonia is applied by injection 6 to 8 inches below the soil surface to minimize escape of gaseous NH_3 into the air. NH_3 is a very hygroscopic compound and once in the soil, reacts quickly with water and changes to the ammonium (NH_4^+) form. As a positively charged ion, it reacts and binds with negatively charged soil constituents including clay and organic matter. Thus it is held on the soil exchange complex and is not subject to movement with water.

Soil reactions - Over time and with appropriate soil temperatures that support biological activity, NH_4^+ ions are converted to the nitrate (NO_3^-) form by the action of specific soil bacteria in a process known as **nitrification**. Nitrification generally occurs at soil temperatures above 50 , and increases as temperatures rise above this level. However, some limited activity occurs below 50 as well. Ammonium is converted first to nitrite (NO_2^-) by the action of *Nitrosomonas* bacteria, and then to nitrate by *Nitrobacter* and *Nitrosolobus* bacteria:

Urea Molecule

$$NH_4^+ \xrightarrow{Nitosomonas} NO_2^- \qquad NO_2^- \xrightarrow[\&\ Nitrosolobus]{Nitrobacteria} NO_3^-$$

Urea

Urea is a solid fertilizer with high nitrogen content (46%) that can be easily applied to many types of crops and turf. Its ease of handling, storage and transport, convenience of application by many types of equipment, and ability to blend with other solid fertilizers has made it the most widely used source of nitrogen fertilizer in the world.

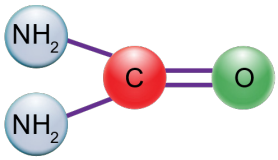
Production

Urea is manufactured by reacting CO_2 with NH_3 in the following two step reactions:

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

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

The urea molecule has 2 amide (NH_2) groups joined by a carbonyl (C=O) functional group.



Urea readily dissolves in water, including soil moisture. Thus it can be "incorporated" into the soil by sufficient rainfall or irrigation.

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

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

Urea-ammonium nitrate (UAN) Solutions

Urea-ammonium nitrate (UAN) solutions are also popular nitrogen fertilizers. These solutions are made by dissolving urea and ammonium nitrate (NH_4NO_3) in water.

Urea-ammonium nitrate (UAN) solutions are mixtures of urea, ammonium nitrate, and water in various proportions. All common UAN solutions (28%, 30% and 32%) are formulated to contain 50% of actual nitrogen as amide, (from urea), 25% as ammonium (from ammonium nitrate), and 25% as nitrate (from ammonium nitrate).

Production

Liquid urea-ammonium nitrate (UAN) fertilizer is relatively simple to produce. A heated solution containing dissolved urea is mixed with a heated solution of ammonium nitrate to make a clear liquid fertilizer. Half of the total nitrogen comes from the urea solution and half from the ammonium nitrate solution.

Soil Reactions - The urea portion of UAN solutions reacts just as dry urea does (see the reaction of urea). If applied on the surface, the amide-nitrogen in the solution may incur losses due to volatilization when urea 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^+. This ammonium, as well as the ammonium nitrogen derived from ammonium nitrate in the solution, adhere to soil components at the application site and are not subject to loss in the short term. Like nitrogen applied as anhydrous ammonia, this nitrogen will eventually be taken up by plants in the ammonium form, or if not, eventually converted to nitrate by soil bacteria.

Diammonium Monohydrogen Phosphate (DAP), $(NH_4)_2HPO_4$

Diammonium monohydrogen phosphate (DAP) is a white crystalline compound.

Production

Diammonium monohydrogen phosphate (DAP) is formed by the reaction between ammonia and phosphoric acid by the following two steps:

Step 1: Anhydrous ammonia reacts with phosphoric acid to form Monoammonium dihydrogen phosphate and diammonium monohydrogen phosphate

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

Step 2: Recycling monoammoniumdihydrogen phosphate for further reaction With anhydrous ammonia yields DAP:

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

DAP is used as a fertilizer. It temporarily increases soil acidity, but over the long term, the soil becomes more acidic than before upon nitrification of the ammonium. DAP has the advantage of having both nitrogen and phosphorus, which are essential for plant growth.

DAP can be used as fire retardant. It lowers the combustion temperature of the material, decreases weight-loss rates, and causes an increase in the production of residue or char.

DAP is also used as a yeast nutrient in wine making and beer brewing.

3.3.4 Sulphuric Acid

Activity 3.6

Which chemical do you think is produced in the largest volume in the world? And why?

Properties

Anhydrous, 100% sulfuric acid is a colorless, odorless, heavy, oily liquid. It is heavier than water, with 98 gram/mole molar mass. Pure H_2SO_4 melts at 10.5 °C and boils at 338 °C. It is soluble in all ratios with water. This chemical is highly corrosive, reactive and soluble in 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, not the other way around. Since the dissolution of sulfuric acid in water is very exothermic i.e. a large amount of heat is released and the solution may even boil. It has a very high oxidizing power and thus, acts as a strong oxidizing and dehydrating agent. It can oxidize both metals as well as non-metals. Moreover, it itself reduces to sulphur dioxide.

Example: $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + H_2O$

$2H_2SO_4 + C \rightarrow 2SO_2 + CO_2 + 2H_2O$

33.5 % sulfuric acid commonly called **battery acid** while 62.18 sulphuric acid is known as **chamber acid** used for production of fertilizers

Uses

Activity 3.7

By referring different sources such as internet and reference books list the various uses of sulphuric acid.

Preparation

Sulphuric acid is manufactured industrially by the **contact Process** which involves the following four major steps:

Step 1: Burning sulphur in air (preparation of sulphur dioxide):

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

Step 2: Converting SO_2 to SO_3 (Oxidation of sulphur dioxide to prepare sulphur tri oxide)

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

The conversion of SO_2 to SO_3 is slow, but it is increased by heating the reaction mixture to 400 in the presence of V_2O_5 catalyst. Because the SO_2 and O_2 molecules react on contact with the surface of V_2O_5, the process is called the Contact process.

Step 3: Passing SO_3 into concentrated H_2SO_4 (addition reaction of sulphur trioxide and sulphuric acid to give oleum):

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

Sulfur trioxide is absorbed into 98 % sulphuric acid to form oleum which is also known as fuming sulphuric acid.

Step 4: Addition of water to oleum i.e. Dilution of oleum to produce concentrated sulphuric acid

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

Oleum is diluted with water to form concentrated sulphuric acid, as indicated in the above reaction.

The production of sulfuric acid with the **contact process** is summarized in **Figure 3.7**.

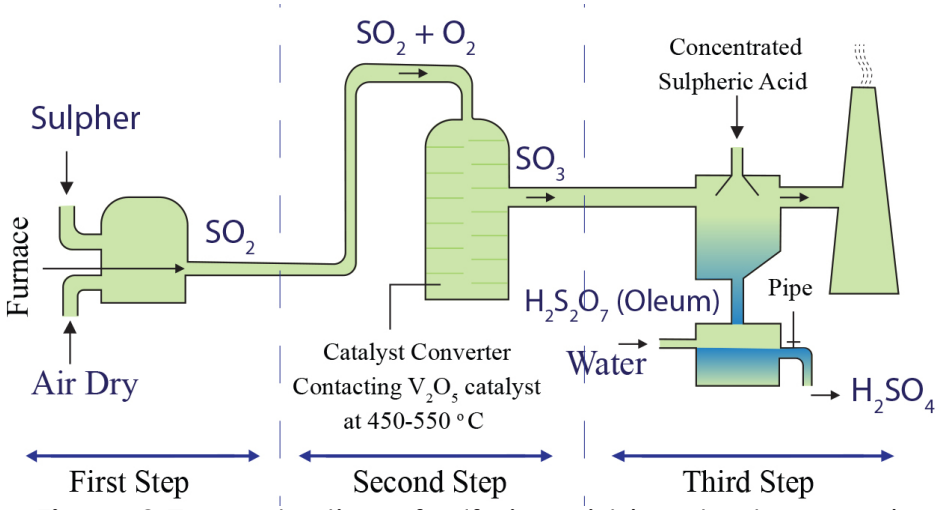


Figure 3.7: production of sulfuric acid (contact process)

Project 3.1

Write a paper, not less than three pages, comparing and contrasting natural fertilizers that are processed locally, like manures and compost, with commercial fertilizer. Tip- includes their impacts, sustainability, accessibility, and composition in your discussion. Submit a report to your tutor.

3.3.5 Some Common Pesticides and Herbicides

Activity 3.8

Please list five names and specific uses of natural and commercial pesticides and herbicides that Ethiopian farmers use to treat insect, pests and weeds? Check your answer by reading related books or browsing from internet sources

Pesticides

Pesticides are chemicals used to prevent or control pests, diseases, weeds and other plant pathogens. It decreases yield losses and maintain high product quality. Chemical pesticides can be classified according to their chemical composition. This method allows the uniform and scientific grouping of pesticides to establish a correlation between structure, activity,

toxicity and degradation mechanisms, among other characteristics. **Table 3.1.1** shows the most important pesticides and their general characteristics, and Figure **3.8** show examples of some chemical structures of pesticides.

Pesticides are chemicals used to prevent or control pests, diseases, weeds and other plant pathogens. It decreases yield losses and maintain high product quality.

Table 3.1.1 General characteristics of some pesticides

Pesticides	**Characteristics**	**Main composition**
Organochlorines	✓ Soluble in lipids ✓ They accumulate in the fatty tissue of animals. are transferred through the food chain ✓ toxic to a variety of animals ✓ long-term persistence	Composed of carbon, hydrogen, chlorine, and oxygen atoms. They are non-polar and lipophilic
Organophosphates	✓ Soluble in organic solvents but also in water ✓ They infiltrate reaching groundwater, less persistent than chlorinated hydrocarbons ✓ some affect the central nervous system ✓ They are absorbed by plants and then transferred to leaves and stems which are the supply of leaf-eating insects or feed on wise.	Possess central phosphorus atom in the molecule. In relation whit organ chlorines, these compounds are more stable and less toxic in the environment. The organophosphate pesticides can be aliphatic, cyclic and heterocyclic.
Carbamates	✓ Carbamate acid derivatives ✓ kill a limited spectrum of insects ✓ highly toxic to vertebrates ✓ Relatively low persistence	Chemical structure based on a plant alkaloid physostigma venenosum
Pyrethroids	✓ Affect the nervous system but less than compared to the other pesticides ✓ the safest in terms of their use ✓ some are used as household insecticides	Compounds similar to the synthetic pyrethrins (alkaloids obtained from petals of Chysanthemun cinerariefolium

Pesticides	Characteristics	Main composition
Biological	✓ Only the Bacillus thuringiensis (Bt) and its subspecies are used with some frequency ✓ are applied against forest pests and crops ✓ Particularly against butterflies and also affect other caterpillars	Viruses, microorganisms or their metabolic product

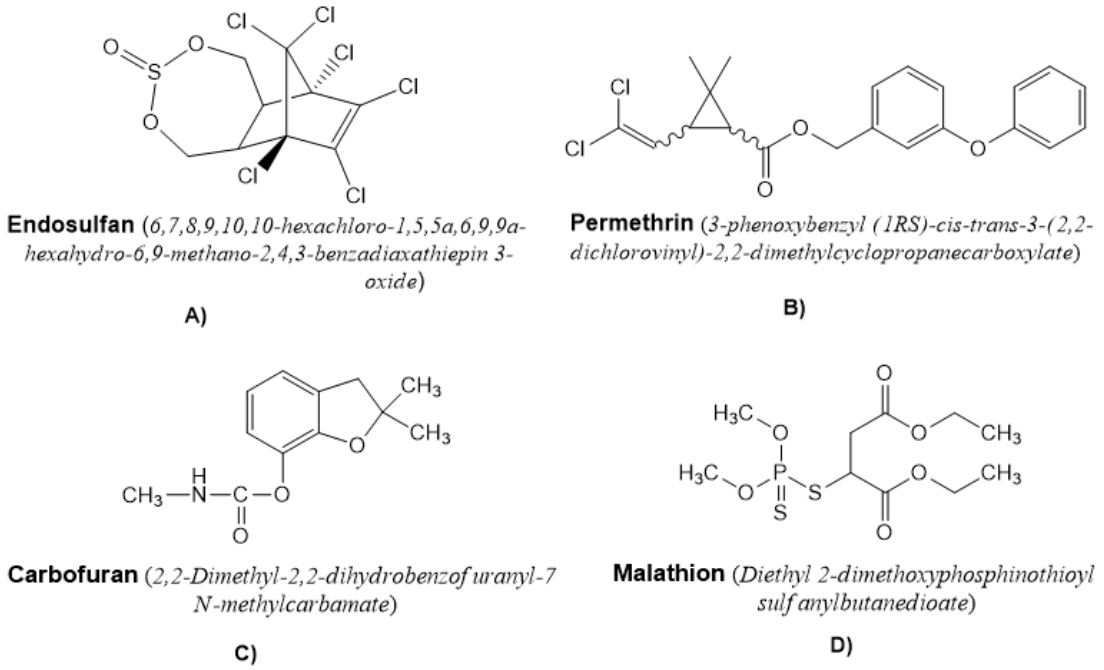


Figure 3.8. Examples of chemicals structure of pesticides (A) Organochloride (B) Pyrethroid (C) Carbamate (D) Organophosphate

On the other hand, there are also traditionally produced pesticides by Ethiopian farmers. Traditionally, farmers of different districts produce pesticides from botanical origins and then apply it to fruits, vegetables and other crops. These pesticides are called **botanical pesticides**. Botanical pesticides are extracted from various plant parts (stems, seeds, roots, leaves and flower heads) of different plant species. Botanical pesticides are hailed for having a broad spectrum of activity, being easy to process and use, having a short residual activity and for not accumulating in the environment or in fatty tissues of warm-blooded animals.

The following are some of the common natural pesticides commonly used in some areas of Ethiopia: Neem Leaf, salt spray and Onion and Garlic spray. Let us see the detail of Neem leaf, which is one of the traditionally produced pesticides.

Neem Leaf

Neem has long been used for its medicinal and culinary properties. It is also known to be used as a deterrent to pests. This medicinal herb has a bitter taste and strong odour that may keep the bugs away from your plants, but non-toxic to animals, birds, plants and humans. It›s best to spray Neem oil on young plants where it is said to be effective for about 22 days. Add some Neem oil to a dash of liquid soap and some warm water and stir slowly. Add it to a spray bottle and use it immediately. This serves as an insect/pest repellant. Even you can cut down and collect the Neem leaf around your environment and put it simply in your home /table as it serves also as pests/insect repellant. Figure 3.9 shows a Neem leaf that is grown in most gardens.

Neem has long been used for its medicinal and culinary properties. It is also known to be used as a deterrent to pests. Neem leaf serves as an insect/pest repellant.

Figure 3.9 Neem Leaf (Azadirachta indica)

Project 3.2

Please collect information from your surroundings and write a report about one of the common traditionally produced pesticides by Ethiopian farmers other than Neem leaf then submit the report to your tutor.

Herbicides (chemical weed killers)

Herbicides also commonly known as **weed killers** which are substances used to control unwanted plants. Selective herbicides control specific weed species, while leaving the desired crop relatively unharmed. Non-selective herbicides (sometimes called **total weed killers** in commercial products) since they kill all plant material with which they come into contact. Herbicides have largely replaced mechanical methods of weed control in countries where intensive and highly mechanized agriculture is practiced.

Types of Herbicides

The most important group of herbicides with their corresponding examples are given in Table 3.1.2

Table 3.1.2 Common groups of herbicides

S.No	Types of herbicide group	Examples of Herbicides
1	Chlorophenoxy acids	2,4-D and 2,4,5-T
2	Triazines	Atrazine, hexazinone, and simazine
3	Organic phosphorus chemicals	Glyphosate
4	Amides	Alachlor and metolachlor
5	Thiocarbamates	Butylate
6	Dinitroanilines	Trifuralin
7	Chloroaliphatics	Dalapon and trichloroacetate
8	Inorganic chemicals	Various arsenicals, cyanates, and chlorates

3.3.6 Sodium Carbonate

Activity 3.9

What are the raw materials for glass production? How is glass manufactured?

Properties

Sodium carbonate (washing soda) is a white crystalline solid powder. It exists as a decahydrate ($Na_2CO_3 \cdot 10H_2O$) compound. It has a density of 2.54 g/cm3, a purity of > 98 %. It has a high melting point 851°C and a high boiling point 1,600 °C. It has hygroscopic properties in nature. There are two forms of sodium carbonate available, light soda and dense soda. Light soda and dense soda are both chemically identical compounds, with the only difference being their densities and size. Light soda has a lower density of 0.7 g/ml, while dense soda has about 0.9 g/ml.

Sodium carbonate can be easily dissolved in water to form an aqueous solution with moderate alkalinity and dissolved in acids by liberating CO_2. But it is insoluble in alcohol. Anhydrous sodium carbonate is unaffected by heat. It melts without disintegrating. The release of OH^-(aq) ions during hydrolysis makes Sodium Carbonate aqueous solutions somewhat alkaline.

$$Na_2CO_3(s) + 2H_2O\ (l) \rightarrow H_2CO_3(aq) + 2Na^+(aq) + 2OH^-(aq)$$

Its aqueous solution has the property of absorbing carbon dioxide from the air, and produces sodium hydrogen carbonate.

$$Na_2CO_3(aq) + H_2O + CO_2(g) \rightarrow 2NaHCO_3(aq)$$

Uses

Sodium carbonate has wide applications in various kinds of fields around the world. One of most important application of sodium carbonate is for the manufacturing of glass. Based on statistics information, about half of the total production of sodium carbonate is used for the manufacturing of glass. During the production of glass, sodium carbonate acts as a flux in the melting of silica. It is also largely used in production of detergents and soaps. In addition, as a strong chemical base, it is used in the manufacturing of pulp and paper, textiles, drinking water. In addition, it can also be used for tissue digestion, dissolving amphoteric metals and compounds, food preparation as well as acting as a cleaning agent. It is also used in the brick industry.

Production Method (Solvay process)

Sodium carbonate at present is mostly mined from its natural deposits. It also is manufactured synthetically by **Solvay (or ammonia-soda) process**. The natural production of sodium carbonate currently has surpassed its synthetic production. The Solvay process involves a series of partial reactions. The first step is calcination of calcium carbonate to form lime and CO_2. Lime is converted to calcium hydroxide. The most crucial step of the process involves reacting brine solution with carbon dioxide and ammonia to produce sodium bicarbonate and ammonium chloride. 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:

$$CaCO_3 \rightarrow CaO + CO_2$$

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$2NaCl + 2CO_2 + 2NH_3 + 2H_2O \rightarrow 2NaHCO_3 + 2NH_4Cl$$

$$2NaHCO_3 \rightarrow \mathbf{Na_2CO_3} + H_2O + CO_2$$

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

The overall reaction:

$$CaCO_3 + 2NaCl \rightarrow \mathbf{Na_2CO_3} + CaCl_2$$

3.3.7 Sodium Hydroxide (NaOH)

Activity 3.10

During the manufacturing process of NaOH from brine, Cl_2 is produced in the process. What are the uses of this Cl_2?

Properties

Sodium hydroxide (NaOH) is a white, translucent crystalline solid with a melting point of 591 k. It is a stable compound. 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. It dissolves readily in water and moderately soluble in alcohol; its solution has bitter and has a soapy feeling". It is strongly alkaline in nature commonly used as a Base.

Manufacturing process

NaOH does not occur in nature. It has been manufactured at large scale for many years from readily obtainable raw materials. It is manufactured from sodium chloride (NaCl) and water (H_2O) in electrolysis process. Its preparation involves various methods like;

1. Castner-Kellner process
2. Nelson Diaphragm cell
3. Loewig's process

Castner-Kellner process

Principle: In the Castner-Kellner method, electrolysis of brine solution is performed in order to obtain sodium hydroxide.

Castner-Kellner cell: It is a steel tank that is rectangular. Ebonite is lined inside the tank. Titanium acts as an anode and a layer of mercury at the bottom of the tank acts as the cathode. Ionization of brine solution occurs according to the following reaction:

$$2NaCl \rightarrow 2Na^{+} + 2Cl^{-}$$

When the brine solution comes in contact with electric current, ionization takes place. As a result positive and the negative ions move towards the electrodes. Sodium ions get deposited at the mercury cathode forming a sodium amalgam. Chlorine ions move towards the anode and exit the cell from the top.

Reaction at the anode: $2Cl - 2Cl^- \rightarrow Cl_2 + 2e^-$

Reaction at the cathode: $2Na^+ + 2e^- \rightarrow 2Na$

Formation of NaOH

The amalgam formed is then transferred to another chamber called **denuder**. In the denuder, it is treated with water to obtain a sodium hydroxide solution. On evaporation of the solution, solid sodium hydroxide is formed. This is a very efficient process in order to obtain pure caustic soda.

Mercury is toxic so care must be taken to prevent mercury losses.

Safety

- Due to its strong corrosive qualities, exposure to sodium hydroxide in its solid or solution form can cause skin and eye irritation
- Pure NaOH has a high affinity for water and may form hydrates depending on the concentration. Since some hydrates have melting points greater than 0 °C, insulation or heating during storage.

Uses

It is widely 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 (i.e. a cleansing agent and in the manufacturing of washing soda), in waste gases scrubbing, saponification and etherification and esterification reactions; as well as in basic catalysis.

√ CHECKLIST 3.3

Please put a (√) in the box for the tasks you can perform or concepts you understand

- Can you explain manufacturing of valuable chemicals/products? ☐
- Can you list the three basic steps in a manufacturing process of ammonia? ☐
- Can you describe briefly uses and properties of ammonia (NH3)? ☐
- Can you describe briefly the preparation of ammonia using Haber-Bosh process? ☐
- Can you describe briefly uses and properties of nitric acid (HNO3)? ☐
- Can you describe briefly the preparation of nitric acid using Ostwald processes? ☐
- Can you list examples of nitrogen-based fertilizers? ☐
- Can you describe briefly the application of nitrogen-based fertilizers in the soil? ☐
- Can you explain briefly the uses and properties of sulphuric acid (H2SO4)? ☐
- Can you describe briefly the four major steps followed in the preparation sulphuric acid using the contact Process? ☐
- Can you list examples of some Common pesticides and herbicides? ☐
- Can you explain the uses of the common pesticides and herbicides? ☐
- Can you explain briefly the uses and properties of sulphuric acid (H2SO4)? ☐
- Can you describe briefly the four major steps followed in the preparation sulphuric acid using the contact Process? ☐
- Can you explain briefly the uses and properties of sodium carbonate (Na2CO3)? ☐
- Can you describe briefly the production method (Solvay process) to produced sodium carbonate? ☐

- Can you briefly explain the uses and properties of sodium hydroxide (NaOH)? ☐
- Can you list the three types of manufacturing process of sodium hydroxide ☐
- Can you identify the difference in the three types of manufacturing sodium hydroxide? ☐
- Can you describe briefly the principle behind the"Castner-Kellner" method of manufacturing of sodium hydroxide? ☐

Self-Test-Exercise 3.3

Give Short answer for the following questions

1. Write a balanced chemical equation for the formation of ammonia by the Haber process.
2. Why are high-temperature conditions required in the production of ammonia in the Haber process?
3. Describe the properties of nitric acid.
4. State the preparation of nitric acid by the Ostwald process.
5. What are the main uses of nitric acid?
6. Write the chemical reaction that shows the synthesis of urea?
7. Write the reaction which shows soil reactions of urea?
8. Describe the industrial production of DAP. Write the chemical equations too.
9. State the properties and major uses of sulphuric acid.
10. Draw a schematic diagram that involves the four major steps in the production of sulphuric acid along with chemical reactions.
11. List and describe the types of pesticides and herbicides.
12. List the four major raw materials that are used to manufacture Na_2CO_3 in the Solvay process.
13. What is the purpose of burning coke in the Solvay process?
14. Write the chemical formula of the following compounds:
15. a/ Washing soda b/ soda ash c/ baking soda
16. What is the role of caustic soda in the industrial cleaning process?

Section 3.4: Some Manufacturing Industries in Ethiopia

Dear Learner, do you know that the chemical industry in Ethiopia is still at a nascent stage? So, there is a strong demand to develop the chemical industry to meet the requirements of the rapidly growing Ethiopian economy. Currently, imports fulfill domestic demand for chemicals/manufacturing products. According to ADDISBIZ.com news of the year 2022, more than 2228 manufacturing industries are available in the country.

Do you know where in Ethiopia dominantly chemicals /manufacturing industries are located?

In this section, we will give emphasis to the production steps of final products like glass, cement, ceramics, sugar, alcoholic beverages, food packing and preservation, soaps and dry detergent, tanning and paper manufacturing industries found in Ethiopia.

Objective

At the end of this section, you 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 out;
- mention some uses of skin and hides;
- present a report to the class after visiting a nearby food factory

3.4.1 Glass Manufacturing

Activity 3.11

You usually use glasses in your daily life, such as for drinking water, beer etc. So,

1. What is glass?
2. List the types of glasses with their corresponding main functions.
3. Is glass manufactured in Ethiopia?

Glass is an amorphous or non-crystalline solid material. It is inexpensive to make, easy to shape when it's molten, reasonably resistant to heat when it's set, chemically inert (glass jar doesn't react with the things inside it). It can be recycled any number of time. The main component of glass is silica.

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.

Soda-lime glass is ordinary glass. It is a mixture of sodium silicate and calcium silicate. It is made by heating a mixture of silica sand, sodium carbonate or sodium sulphate and limestone. The reactions that take place in forming soda-lime glass are the following:

$$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$$

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$$

Soda-lime glass accounts for about 90% of manufactured glass. This type of glass is widely used for window panes, bottles, dishes etc.

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.

Project 3.3

Have you ever wondered how glass retains different colors? Consult books and make list of the compounds added to impart color to the glass. Submit your findings to your tutor?

Steps in glass production

i) **Batch preparation:** refers to the preparation of the raw materials according to the
appropriate combinations. The raw materials are mixed in a proportion of 60% sand, 21% sodium carbonate and 19% limestone.

ii) **Glass melting:** The raw materials and recycled glass (according to their colour) are fed into a glass-melting furnace. The materials are then heated to a temperature of about 1600°C to form a molten viscous liquid. Why glasses are separated according to the colour?
The furnace operates continuously, producing glass 24 hours a day. Substances that give the glass different colours or improved chemical and physical properties such as transparency, thermal and chemical stability and mechanical strength are added during this process.

iii) **Glass forming:** This is the stage in which the melted glass is made into a required shape.

iv) **Annealing:** This is a process that involves the removal of internal stresses by reheating the glass followed by a controlled slow-cooling cycle during which the stresses are relieved.

v) **Inspection:** It involves testing of the glass product to check whether it fulfills desired quality requirements or not.

vi) **Packing and dispatching** is the final stage before distribution

3.4.2 Manufacturing of Ceramics

Activity 3.12

Please list the answers for the following questions and compare your answer by refereeing from internet or related sources

1. List the similarities and differences between pottery and ceramics.
2. Prepare a list of ceramics products used in daily life.

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.

The minerals used to make ceramics are dug out of the earth and are then crushed and ground into a fine powder. Manufacturers often purify this powder by mixing it in a solution and allowing a chemical precipitate (a uniform solid that forms within a solution) to form. The precipitate is then separated from the solution. The powder is heated to drive off impurities including water.

The steps of manufacturing ceramics include:

A. **Moulding:** After purification, small amounts of wax are often added to bind the ceramic powder and make it more workable. Plastics may also be added to the powder to give the desired pliability and softness. The powder can be shaped into different objects by various moulding processes.

B. **Densification**: The process of densification uses intense heat to condense a ceramic object into a strong, dense product. After being moulded, the ceramic object is heated in an electric furnace to temperatures between 1000 °C and 1700 °C. As the ceramic heats, the powder particles coalesce, much as water droplets join at room temperature. As the ceramic particles merge, the object becomes increasingly dense, shrinking by up to 20 percent of its original size. The goal of this heating process is to maximize the strength of ceramic by obtaining an internal structure that is compact and extremely dense.

In general, most ceramics are hard and wear-resistant, brittle, refractory, thermal and electrical insulators, non-magnetic, oxidation-resistant, and chemically stable. Due to the wide range of properties of ceramic materials, are used for a multitude of applications.

- Well-known uses of ceramics:- they are commonly found in art sculptures, dishes, platters, and other kitchenware, kitchen tiles and bath room structures.
- Lesser-known uses for ceramics:- they are used as electrical insulators, computer parts, tools, dental replacements, engine parts, and tiles on space shuttles and to replace bones such as the bones in hips, knees, and shoulders.
- Future uses of ceramics:- In the future, ceramics might be used to remove impurities from the drinking water and to replace diseased heart valves.

? Do you know a ceramic industry in Ethiopia?

Figure 3.10 shows some photos of ceramics and pottery products in Ethiopia.

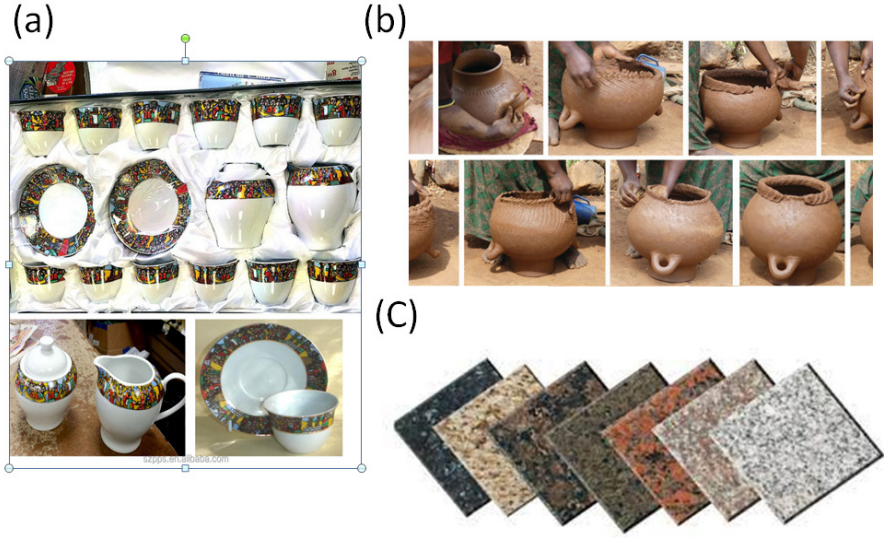


Figure 3.10 Some ceramics and pottery products in Ethiopia (A **and C)** Ceramic **(b)** Pottery

☞ Ceramic is an inorganic, non-metallic solid prepared by the action of heat and subsequent cooling.

3.4.3 Cement

Activity 3.13

Please reflect the following questions

1. Is there any cement factory in Ethiopia? If there, where are they located?
2. Could you explain the reason that most cement manufacturing plants are preferably located close to the sources of the raw material?

Cement production has been increasing because of the opening of new cement companies and also the upgrade of the old ones.

Availability of cement raw materials in Ethiopia

The raw materials for the production of cement are limestone, clay, silica sand, gypsum, calcium silicate, calcium aluminate, iron (III) oxide, magnesium oxide and pumice. Limestone is the major ingredient for the production of cement. It is abundantly available in Africa. Ethiopia has huge amounts of reserve raw materials.

Manufacturing Process

Cement is made by heating limestone (chalk), alumina (Al_2O_3) and silica-bearing materials such as clay to 1450 °C in a kiln. This process is known as **calcination**. Calcination results a hard substance called **clinker**. The clinker is then ground with a small amount of gypsum into a powder. The resulting cement is known as Ordinary Portland Cement (OPC).

When gypsum is included in the process, cement known as **Portland cement** is produced. Portland cement was first discovered in England. On setting, it hardens to a stone-like mass and was compared to the famous Portland Rock of England. For detail see figure 3.11 for the manufacturing process of cement.

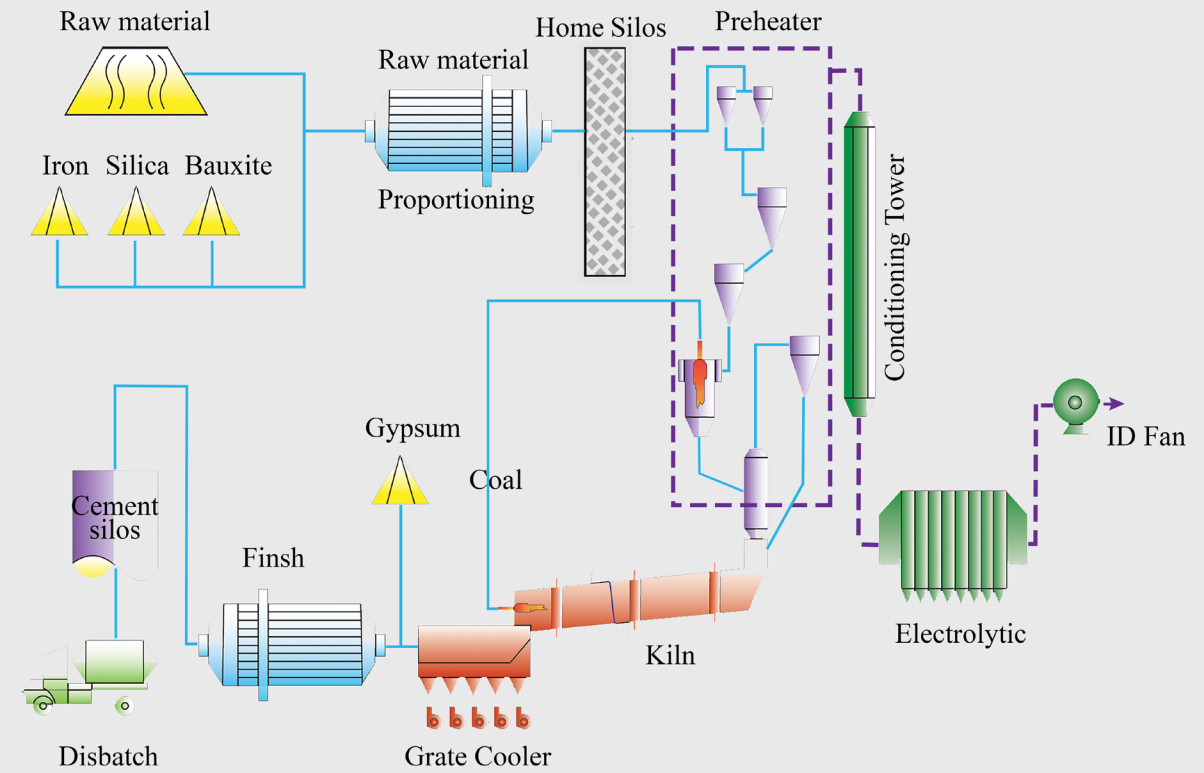


Figure 3.11 Cement manufacturing process.

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.

Table 3.2 The approximate composition of cement

Component	Percentage %
Calcium oxide (CaO)	50-60
Silica (SiO_2)	20-25
Alumina(Al_2O_3)	5-10
Magnesium Oxide (MgO)	2-3
Ferric oxide (Fe_2O_3)	1-2
Sulphur trioxide(SO_3)	1-2

Setting of Cement

When cement mixed with water, the cement first forms a plastic mass that hardens after sometime. This is due to the formation of three-dimensional cross-links between –Si–O–Si– and –Si–O– Al– chains. The first setting occurs within 24 hours, whereas the subsequent hardening requires about two weeks. In the hardening process of cement, the transition from plastic to solid state is called **setting.**

Project 3.4

Take a 0.5 kg of cement and mix it with correct proportion of sand and water. Mix the component well till a plastic mass is formed. Take this plastic mass and construct a model of any object. Start pouring water on the model starting from the second day onwards. Observe your final product.

Hint: Please try by mixing with this proportion:

1 water: 2 cement:3 sand

3.4.4 Sugar Manufacturing

Activity 3.14

Reflect your answers to the following questions

1. List the foods and drinks in which sugar is an ingredient?
2. List the different sources of sugar?

Sugarcane is a perennial herb belonging to the grass family. Native to tropical and subtropical regions of the world, this tropical grass is about 3 meters tall. And it is used commonly as raw material for production of sugar.

Planting: Sugarcane is planted in fields by workers or mechanical planters. Typical cane soil is made from the mixture of silts, clay particles and organic matter. Fertilizers are applied from the time of planting up until the beginning of the ripening period, depending on the region where the crop is planted. Cane seasons last from 8-22 months.

1. Collecting the Harvest: Mature canes are gathered by a combination of manual and mechanical methods. The cane is cut at ground level, the leaves are removed, the top is trimmed off (by cutting off the last mature joint) the canes and transported to a sugar factory.

2. Cleansing and Grinding: The stalks are thoroughly washed and cut at the sugar mill. After the cleaning process, a machine led by a series of rotating knives, shreds the cane into pieces. This is known as "grinding". During grinding, hot water is sprayed onto the sugarcane to dissolve the remaining hard sugar. The shredded cane is then spread out on a conveyer belt.

3. Juicing: The shredded sugarcane travels on the conveyor belt through a series of heavy-duty rollers which extract juice from the pulp. The pulp that remains, or "bagasse", is dried and used as a fuel. The raw juice moves on through the mill to be clarified.

4. Clarifying: Carbon dioxide and milk of lime are added to the liquid sugar mixture, which is heated until boiling. The process of clarifying begins at this stage. As the carbon dioxide moves through the liquid, it forms calcium carbonate which attracts non-sugar debris (fats, gums and waxes) from the juice, and pulls them away from the sugar juice. The juice is then pushed through a series of filters to remove any remaining impurities.

5. Evaporation: The clear juice that results from the clarifying process is put under a vacuum where the juice boils at a low temperature and the water in it begins to evaporate. It is heated until it forms into thick, brown syrup.

6. Crystallization: Crystallization is the process of evaporating the water from the sugar syrup. Pulverized sugar is fed into a sterilized vacuum pan. As the liquid evaporates, crystals form. The remaining mixture is a thick mass of large crystals. These crystals are sent to a centrifuge that spins and dries them. The dried product is raw sugar, which is edible.

7. Refinery: 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. Separation and packaging: Once the final evaporation and drying process is done, screens separate the different- sized sugar crystals. Large and small crystals are packaged and labeled as white refined sugar.

3.4.5 Pulp and Paper

Activity 3.15

Reflect for the following question. .

1. Wasting paper is like chopping down trees. Comment.
2. Some papers are cheap while others are expensive. What could be the reason?

Do you know what this textbook is made of?

Paper is not a chemical compound which can be expressed by a chemical formula. Paper is a mixture made from rags and wood pulp glued together with some additives, bleached and dried.

Wood pulp is a dry fibrous material. The timber resources used to make wood pulp are referred to as pulp wood. Wood pulp is made from soft-wood trees, such as spruce, pine, fir, larch and hemlock, and from hard woods, such as eucalyptus, aspen and birch.

Wood is composed of cellulose, lignin, oils and resins. Lignin is used to bind fibres of cellulose together. To provide wood pulp, the cellulose must be separated from the lignin.

Manufacturing of pulp and paper involves the following steps

1. **Harvesting** involves the cu++tting down of trees from their growing areas and transporting the timber to the paper and pulp industry.
2. **Preparation** for pulping is a step in which the bark of the tree is removed and then the wood is chipped and screened to provide uniform sized chips (pieces).
3. **Pulping** is a step used to make wood pulp from the chipped wood pieces. This can be accomplished by either mechanical or chemical means depending on the strength and grade of paper to be manufactured.

A. **Mechanical pulping:** It 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.

B. **Chemical pulping:** Chemical pulp is produced by combining wood chips and chemicals in large vessels called digesters. Heat and the chemicals break down the lignin which binds the cellulose fibres together without seriously degrading the cellulose fibres. Chemical pulp is manufactured using the Kraft process or the sulphite Process.

I) The Kraft Process is the dominant chemical pulping method. It is the most widely used method for making pulp from all types of trees. The process uses aqueous sodium hydroxide and sodium sulphide as a digestion solution. After digestion for about four hours at a temperature of 170, the pulp is separated by filtration. This process uses a basic digestion medium.

II) The Sulphite Process uses a cooking liquor (digestion) solution of sodium bisulphate or magnesium bisulphate digester at pH of about 3 in a pulp. The action of the hydrogen sulphide ions at 60 over 6 to 12 hours dissolves the lignin and separates it from the cellulose. After the process is complete, the pulp is recovered by filtration. The wood pulp achieved from the Sulphite or Kraft processes is washed to remove chemicals and passed through a series of screens to remove foreign materials

4. **Bleaching:** It is the process of removing colouring matter from wood pulp and increasing its brightness. The most common bleaching agents are strong oxidizing agents such as chlorine, chlorine oxide, ozone and hydrogen peroxide.

5. **Making paper from pulp:** After bleaching, the pulp is processed into liquid stock that can be transferred to a paper mill. The suspension is poured onto a continuously moving screen belt and the liquor is allowed to seep away by gravity to produce paper sheet. The continuous sheet then moves through additional rollers that compress the fibres and remove the residual water to produce fine paper.

3.4.6 Tannery

Activity 3.16

Reflect for the following question

1. Why are leather products being replaced by synthetic products?
2. Do you know the traditional way of Tanning in Ethiopia? What are the procedures to be followed when it is compared to the modern method?

Tanning is a process of converting raw animal hides and skin to leather.

Tanning is a process of converting raw animal hides and skin to leather, using tannin. Leather is a durable and flexible material created by the tanning of animal hides and skin. Tannin is an acidic chemical that permanently alters the protein structure of a skin so that it can never return to raw hide or skin again.

Leather production involves various preparatory stages, tanning, and crusting

1. **Preparatory stages** are those in which the hide or skin is prepared for tanning. This stage includes curing, soaking, flesh removal, hair removal, scudding, and deliming.

a. **Curing:** This process involves salting or drying the hide once it has been removed from the animal. Curing is employed to prevent putrefaction of the protein substance, collagen, from bacterial infection. Curing also removes excess water from the hide and skin. Brine curing is the simplest and fastest method.

b. **Soaking:** In this process, cured hides are soaked in water for several hours to several days to remove salt, dirt, debris, blood and excess animal fat from the skin.

c. **Flesh removal:** In this process, animal hides are moved through a machine that strips the flesh from the surface of the hide.

d. **Hair removal:** In this step, the soaked hides and skins are transported to large vats where they are immersed in a mixture of lime and water. This process is called liming. It loosens the hair from the skin and makes hair-removal easier. After 1–10 days soaking, the hair is mechanically removed from the hide by a hair-removing machine.

e. **Scudding:** This is the process in which hair and fat missed by the machines are removed from the hide with a plastic tool or dull knife.

f. **Deliming:** This process involves the removal of lime from the skin or hides in a vat of acid. After this preparatory process, the skin or hide is ready for tanning.

2. **Tanning** is a process that converts the protein of the raw hide or skin into a stable material. There are two main types of tanning:

   a. **Vegetable or natural tanning:** The skin is placed in a solution of tannin. Tannins occur naturally in the barks and leaves of many plants. The primary barks used in modern times are chestnut, oak, tanoak, hemlock, quebracho, mangrove, wattle (acacia) and myrobalan. Naturally tanned hide is flexible and is used for making shoes, luggage and furniture.

   b. **Mineral tanning:** In this process, the skin is placed in solutions of chemicals such as chromium sulphate and other salts of chromium. Chrome tanning is faster than natural (vegetable) tanning and requires only twenty four hours. The leather is greenish-blue in colour derived from the chromium. This process produces stretchable leather that is used for making garments and handbags.

3. **Crusting:** This is the final stage in leather manufacturing and includes dyeing, rolling the leather to make it strong, stretching it in a heat-controlled room and performing a process that involves covering the grain surface with chemical compounds such as wax, oil, glazes etc. to make the leather very attractive.

3.4.7 Food Processing and Preservation

Activity 3.17

What could be the reason for the rate of spoilage of food is faster in open air in comparison to foods kept inside the refrigerator.

Food preservation is the process of treating and handling food to stop or greatly reduce spoilage, loss of quality, edibility or nutritive value caused or accelerated by microorganisms. Preservation usually involves preventing the growth of bacteria, fungi and other microorganisms, as well as reducing the oxidation of fats which causes rancidity.

Activity 3.18

Reflect your ideas for your own and compare your ideas with literature written in this module.

1. What are the traditional methods used to preserve food for a long time without spoil at your home?

Food preservation is the process of treating and handling food to stop or greatly reduce spoilage, loss of quality, edibility or nutritive value caused or accelerated by microorganisms.

Modern methods of food preservation are:

A. **Freezing:** This is one of the most commonly used processes, commercially and domestically, for preserving a very wide range of foods such as potatoes, as well as prepared foodstuffs that would not require freezing in their normal state.

B. **Freeze-drying:** Water vapour has easier access through the cell structure of any product compared to water-penetrating the product and evaporating from the surface of the product as in case of other drying methods. The gentle escape of water vapour in the freeze-drying process leaves the product close to its original shape, taste, and

colour and there is no loss of aroma or flavor. For example, liquids such as coffee, tea, juices and other extracts, vegetables, segments of fish and meat products. Freeze-drying is a superior preservation method for a variety of food products and food ingredients.

C. **Vacuum-packing:** Stores food in a vacuum environment, usually in an air-tight bag or bottle. The vacuum environment strips bacteria of the oxygen needed for survival, slowing down the rate of spoiling. Vacuum-packing is commonly used for storing nuts to reduce loss of flavor from oxidation.

Inorganic and organic preservatives

Activity 3.19

Reflect for yourself how meat is preserved traditionally at home in our society?

Some inorganic and organic preservatives are available for food preservation. Some examples of inorganic preservatives are sodium chloride (NaCl), nitrate and nitrite salts, sulfites, and sulfur dioxide (SO_2). NaCl lowers water activity and causes plasmolysis by withdrawing water from cells. Nitrites and nitrates are curing agents for meats (hams, bacons, sausages, etc.) to inhibit *carbon. botulinum* under vacuum packaging conditions. Sulfur dioxide (SO_2), sulfites (SO_3), bisulfite (HSO_3), and metabisulfites (S_2O_5) form sulfurous acid in aqueous solutions, which is the antimicrobial agent. Sulfites are widely used in the wine industry to sanitize equipment and reduce competing microorganisms. Wine yeasts are resistant to sulfites. Sulfites are also used in dried fruits and some fruit juices. Sulfites have been used to prevent enzymatic and nonenzymatic browning in some fruits and vegetables (cut potatoes).

? Did you mention examples of organic acids and their salts food preservatives?

A number of organic acids and their salts are used as preservatives. These include lactic acid and lactates, propionic acid and propionates, citric acid, acetic acid, sorbic acid, and sorbates, benzoic acid and benzoates, and methyl and propyl parabens (benzoic acid derivatives).

For example, propionic acid and propionate salts (calcium most common) are active against molds at pH values less than 6. They have limited activity against yeasts and bacteria. They are widely used in baked products and cheeses. Acetic acid is found in vinegar at levels up to 4–5%. It is used in mayonnaise, pickles, and ketchup, primarily as a flavoring agent. Acetic acid is most active against bacteria, but has some yeast and mold activity, though less active than sorbates or propionates.

3.4.8 Manufacturing of Ethanol

Activity 3.20

Reflect for yourself on the following issues.

1. List the most common local alcohol beverages that are produced in most of Ethiopian homes during a holiday?
2. What does fermentation in the absence of oxygen mean?

Ethanol is one of the constituents of all alcoholic beverages. 'Tella', 'Tej', beer, wine, 'Katikalla', ouzo, gin and whisky contain ethanol. There are a number of methods for preparing ethanol using different materials. Since it is the constituent of all alcoholic beverages it is better to describe its industrial preparation.

Industrial preparation of Ethanol

Ethanol is manufactured industrially by:

1. Fermentation of carbohydrates such as sugar: Fermentation is the slow decomposition of carbohydrates such as sucrose, starch and cellulose in the presence of suitable enzyme that results in the formation of ethanol and carbon dioxide.

$$\underset{Sucrose}{C_{12}H_{12}O_{11}} \xrightarrow{Invertase} \underset{Glucose}{C_6H_{12}O_6} + \underset{Fructose}{C_6H_{12}O_6}$$

$$\underset{Glucose}{C_6H_{12}O_6} + H_2O \xrightarrow{Yields} \underset{Ethanol}{2CH_3CH_2OH} + 2CO_2$$

Fermentation can produce an alcoholic beverage whose ethanol content is 12 – 15% only. The alcohol kills the yeast and inhibits its activity when the percentage is higher. To produce beverages of higher ethanol content, distillation of the aqueous solution is required. Most liquor factories in Ethiopia use molasses, a by-product of sugar industries, as a raw material to produce ethanol. In the brewing industry, germinated barley called malt (in Amharic, 'Bikil') is used as the starting material. The whole process taking place in breweries is summarized as follows:

$$\underset{Starch}{2(C_6H_{10}O_5)_n} + nH_2O \xrightarrow{Diastase} \underset{Maltose}{nC_{12}H_{22}O_{11}} \xrightarrow[Maltase]{nH_2O} \underset{Glucose}{2nC_6H_{12}O_6}$$

$$\underset{Glucose}{C_6H_{12}O_6} \xrightarrow{Zymase} \underset{Ethanol}{CH_3CH_2OH} + CO_2$$

2. Catalytic Hydration of Ethene: Most ethanol is manufactured at present by this method. In this process, ethene is treated with steam at 573 K and 60 atm pressures in the presence of phosphoric acid, H_3PO_4, catalyst.

$$\underset{Ethene}{H_2C{=}{=}CH_2}\ (g) + H_2O\ (g) \xrightarrow[573\ k/60\ atm]{H_3PO_4} \underset{Ethanol}{CH_3CH_2OH}\ (g)$$

Experiment 3.3

Dear learner, to have a skill of preparation of ethanol by fermentation perform experiment 3.2. To conduct the experiment, visit a nearby high school and request a teacher who is teaching Grade 12 chemistry to help you in performing or demonstrating the experiment. Note that the experiment should be performed only in the laboratory. If you couldn't find a high school in your area, request your tutor to get support and advices.

Preparation of Ethanol by Fermentation

Objective: To prepare ethanol from sugar.

Materials required: Conical flask, glass rod, distillation flask, condenser, spatula, thermometer, watch glass, Bunsen burner, beaker, stopper and delivery tube.

Chemicals Required: Sugar, ammonium phosphate or ammonium sulphate, yeast, calcium hydroxide.

Procedure:

1. Take 50 mL of distilled water in a conical flask
2. Add 15 g of sugar to it and stir.
3. Add about 1 gram of yeast and a small amount of ammonium phosphate or ammonium sulphate to the solution.
4. Arrange the set-up, as shown below, and let the flask stand for three days at a warm place.

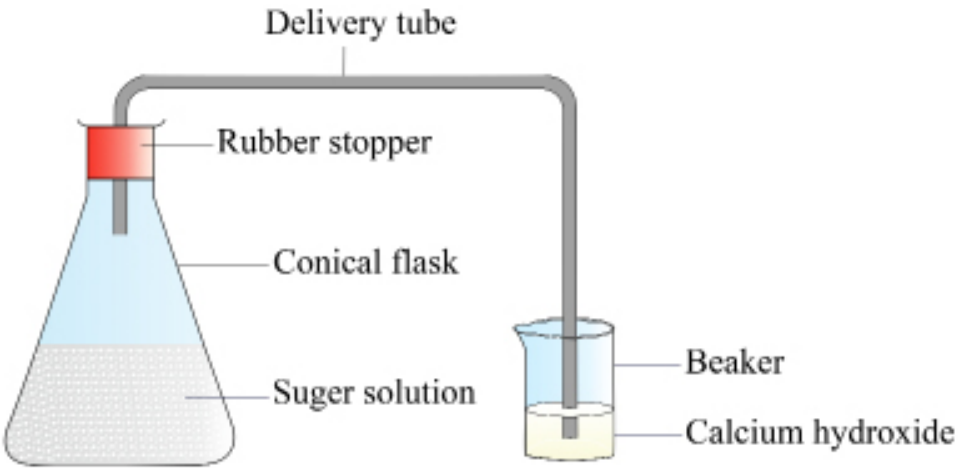


Figure 3.12: The Fermentation of sugar

Observations and analysis:

1. A. What is the purpose of adding yeast to the solution?
   B. Why do we add ammonium phosphate or ammonium sulphate to the sugar solution?
   C. What happened to the calcium hydroxide solution at the end of the first or second day? Which gas is produced?
   D. What is the smell of the solution in the flask after three days?
   E. What happened in the flask containing the sugar solution as it stood for three days?
2. After three days, filter the solution, and arrange the set up as in **Figure 3.13.** Pour 20 mL of the filtrate in to a distilling flask, heat the solution, and collect the liquid in a receiver.

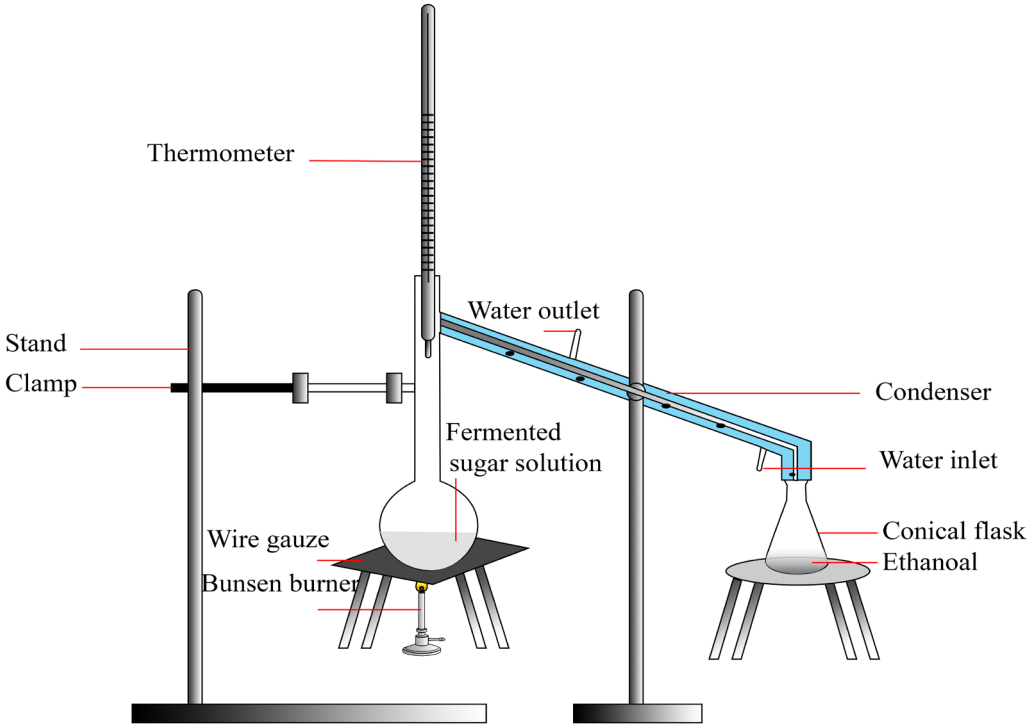


Figure 3.13: Separation of ethanol by distillation

Observations and analysis:

A. Observe the colour and identify the smell of the distillate.
B. Pour a small amount of the distillate on a watch glass, strike a match and bring the flame close to the distillate. Does it catch fire? Write a complete laboratory report on this experiment and submit it to your teacher.

Beer

The raw materials for beer are barley and hops. The first step is to bring the barley to germination, whereby starch is converted into a type of sugar called malt sugar. Heat stops this process and the material is now called malt. After drying and grinding the barley, water is added in the mash tubes. After adding hops and yeast the process of fermentation begins. Then it is stored in tanks for a period of time as required by a type of the product. Later it is pasteurized and carbon dioxide is added under pressure and supplied to consumers. Although the type of beers produced in the world are too many the average beer has alcohol content between 2-6 per cent by volume.

Wine

Although various other fruits can be used, grapes are the most common raw materials for producing wines. Grapes (or tether fruits) are first crushed and then steamed. The liquid that is derived from the crushing process is called must. It then goes to a fermentation takes place. The must then passes to a settling tank where sediment is allowed to settle, and proceeds from there to a filter. The clear liquid is cooled in a refrigerator tank and it is pasteurized as it passes through a flash pasteurizer. It finally goes to a storage tank where it is kept for months or years. The older a wine is kept, the more mature it becomes and usually is considered to have a higher quality fetching higher price. Most wines have an alcohol content varying from 10-16 per cent by volume. **Figure 3.14**, presented a schematic diagram which shows the major steps of Wine beverages.

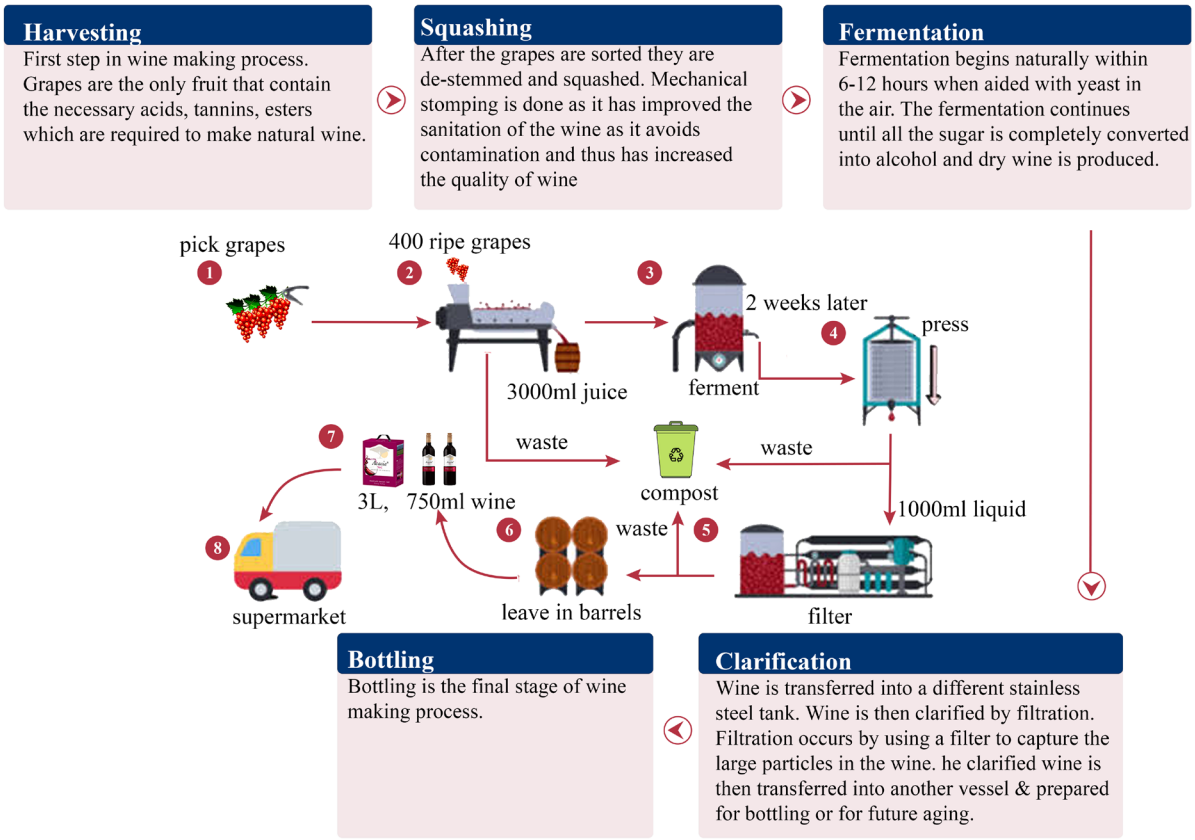


Figure 3.14: Schematic diagram which shows the major steps of Wine beverages

Liquor: Compared with beer and wine liquor contains a higher percentage of pure alcohol. Normally fermentation stops by itself, if the alcohol concentration riches 15 to 17 percent because yeast cells are not able to stay alive in alcohol of higher concentration.

To get drinks with higher concentration of alcohol the alcohol has to be separated from the solution by distillation. Thus liquors (e.g. cognac) are made by distillation of grape wine; rum is produced from sugar cane, and whisky from rye. Different types of liquors have different alcohol concentration. Most of them however range between 30-45 percent of alcohol by volume.

Local Preparation of Ethanol (Araki)

Araki: Araki is the local Ethiopian alcohol which is prepared almost everywhere with certain local differences. In fact, the differences are in the ingredients and not in the process of making it.

First, the barley is made into "Bikel" in the manner as was mentioned in the case of beer. Then with the help of water, the Bikel is mixed with Gesho (Rhamnuspronoides) powder to make starter "Tinses". The starter is left to ferment for about four days. (It may vary from place to place depending upon the local's humidity and temperature). Then the bread is baked from ingredients of Teff, Barley, Wheat, and Sorghum, depending upon their availability and local preferences. The bread is broken down into small pieces, mixed with the already prepared starter and left to stand to ferment for a couple of days (5 to 10 days). After it is fully fermented, a proportional amount of water is added to liquidity the tick dough-like mixture and left for 1 to 2 days for further fermentation. Finally, the liquid mixture is boiled and distilled in the traditional ways as depicted in Figure 3.15. The distillate is called "Araki". While the leftover residue or the un-distilled component is locally called " Atela" and it is usually used to feed cattle.

☞ Araki is the local Ethiopian alcohol which is prepared almost everywhere with certain local differences.

Figure 3.15: Preparation of Local Araki

Project 3.5

Do you know the raw materials that are used and the procedure to be followed to prapare "Tella" or Bordie (depending on your locality) a local non distilled alcohol in most of Ethiopian homes?

3.4.9 Soap and Detergent

Activity 3.21

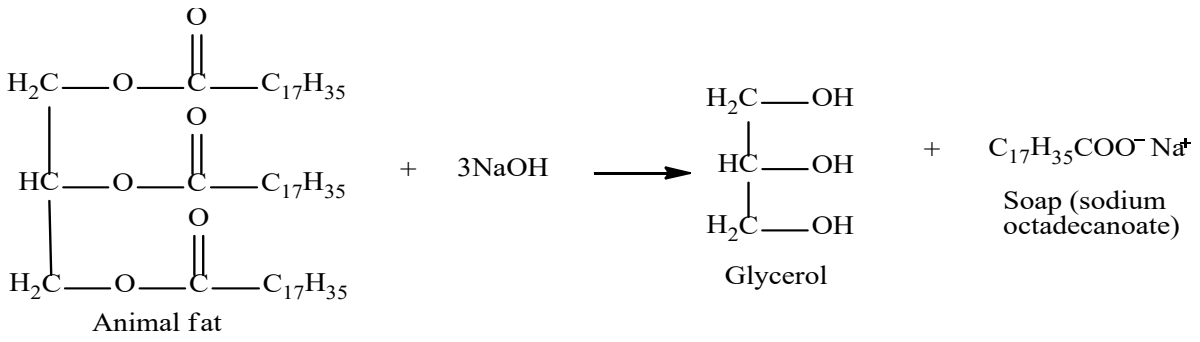
Reflect for yourself on the following issue; do you know any local industry in your surrounding that manufactures soaps? List them and mention the raw materials that are used to manufacture soaps?

Soap

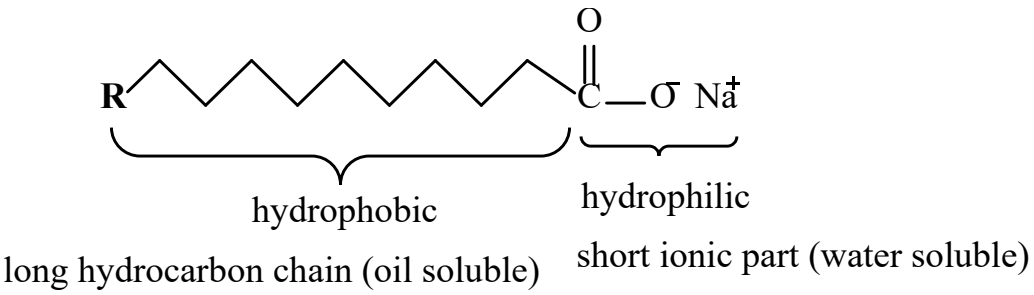
Organic chemicals are used for the synthesis of soaps. For example, animal fat and vegetable oils are used for manufacturing soap. Fats and oils are naturally occurring esters of glycerol and the higher fatty acids. Soaps are substances used to remove dirt. They are also called surfactants or surface active agents. This is because they reduce the surface tension of water and change the surface properties.

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. Soaps are prepared by boiling animal fat or vegetable oil with a base. The reaction that produces soap is called saponification.

Example:



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.



In industry, tallow, lard, cotton seed oil, palm oil, castor oil, olive oil, whale oil and the oil of soybeans are used to prepare ordinary soap. When making hared soaps, the lye is usually caustic soda, but when a soft soap is desired, caustic potash (KOH) and potassium carbonate (K_2CO_3) are used and the glycerin is not salted out.

Industrially soap is produced in four basic steps:

Step 1. Saponification: A mixture of tallow (animal fat) and coconut oil is mixed with sodium hydroxide and heated. The soap produced is the salt of a long chain carboxylic acid.

Step 2. Glycerine removal: Glycerine is more valuable than soap, so most of it is removed. Some is left in the soap to help make it soft and smooth. Soap is not very soluble in salt water, whereas glycerine is, so salt is added to the wet soap causing it to separate out into soap and glycerine in salt water.

Step 3. Soap purification: Any remaining sodium hydroxide is neutralized with a weak acid such as citric acid and two thirds of the remaining water removed.

Step 4. Finishing: Additives such as preservatives, colour and perfume are added and mixed in with the soap and it is shaped into bars for sale.

Figure 3.10 shows a flow chart that showing the soap making process.

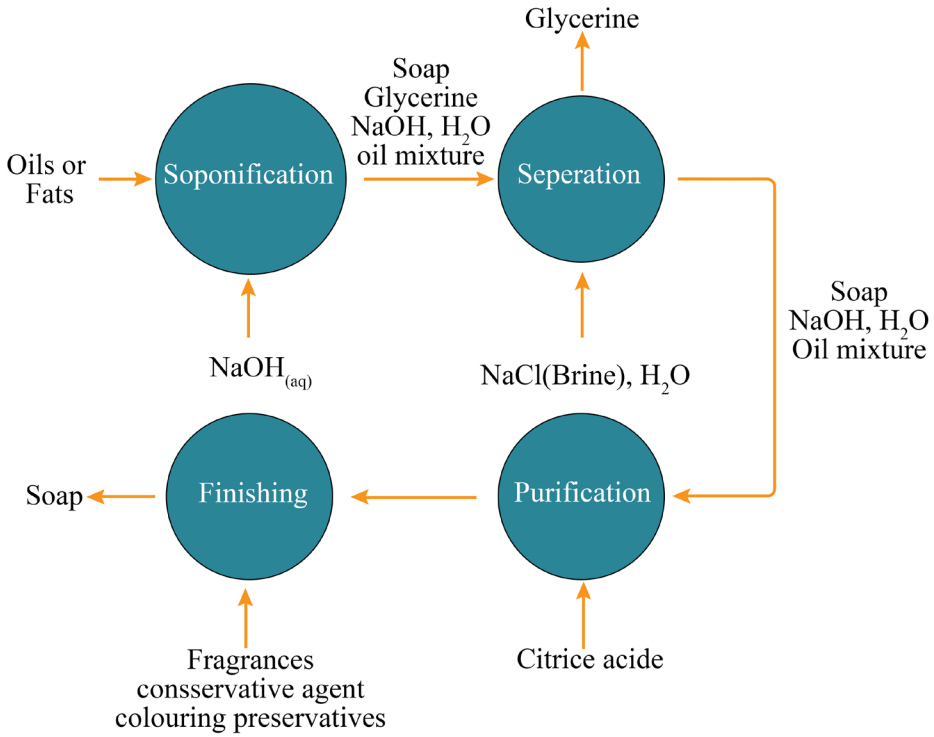


Figure 3.16: Flow chart showing the soap making process.

Experiment 3.4

Dear learner, to have a skill of soap preparation from animal fat or vegetable oil. perform experiment 3.4. To conduct the experiment, visit a nearby high school and request a teacher who is teaching Grade 12 chemistry to help you in performing or demonstrating the experiment. Note that the experiment should be performed only in the laboratory. If you couldn't find a high school in your area, request your tutor to get support and advices.

Preparation of soap

Objective: to prepare soap from animal fat or vegetable oil.

Materials required: Measuring cylinder, beaker, glass rod, Bunsen burner, filter paper, funnel, conical flask, and test tube

Procedure:

1. Measure 3 mL vegetable oil or 3 g animal fat and place it in a 100 mL beaker;
2. add 3 mL of ethanol and 3 mL of 5M NaOH.
3. Stir the mixture vigorously with a glass rod and gently heat over a flame for 15 minutes or until it turns in to a paste.
4. When the paste begins to form, stir very carefully to prevent frothing. After all the paste has formed, set the beaker on the bench to cool.
5. Add about 15 mL of saturated NaCl solution to the paste mixture and stir thoroughly. This process is called salting out the soap.
   Filter off the soap mixture by suction filtration and wash the collected soap precipitate with 15 mL of ice water.

Observations and analysis:

A. Why do we add ethanol during the preparation?
B. What is the purpose of adding saturated NaCl solution to the paste mixture? Write a lboratory report and present to the class

Detergents

These cleaning agents are often called, soap less soaps because they lather well, they are very different from ordinary soaps in their chemical composition. Long open-chain alcohols and alkyl benzene sulphonic acid can be used for the production of detergents. 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.

The advantage of detergents is that they lather well with both soft and hard water and even with water that contains common salt or acids. They are more soluble than soap in water, form stable emulsions with grease and do not form a scum with hard water because their calcium and magnesium salts are soluble

One example of detergents is sodium lauryl sulfate, $C_{12}H_{25} - O - SO_2 - ONa$. It is prepared first by reacting dodecyl (lauryl) alcohol with sulphuric acid followed by reaction with sodium hydroxide. The reaction equation is:

$$\underset{\text{Dodecyl alcohol (lauryl alcohol)}}{C_{12}H_{25}-OH} + \underbrace{HO-SO_2-OH}_{H_2SO_4} \longrightarrow \underset{\text{Lauryl hydrogen sulphate}}{C_{12}H_{25}-O-SO_2-OH} + H_2O$$

$$C_{12}H_{25}-O-SO_2-OH + NaOH \longrightarrow \underset{\text{Sodium lauryl sulphate}}{C_{12}H_{25}-O-SO_2-ONa} + H_2O$$

Dry Cleaning

The qualities of some clothes decrease when they are washed with water using ordinary soap. In order to avoid this, other chemicals are used for washing purposes that remove dirt in the same manner as soaps. Dry cleaning refers to the use of different chemicals that are capable of dissolving grease and other dirt stains in a similar manner as soaps without the use of water. The most commonly used chemicals in dry cleaning are organic chemicals such as tetra chloromethane, CCl_4; tetra chloroethylene, $Cl_2C = CCl_2$; benzene and gasoline.

For example, Silk will turn yellow if it is treated with strong soap during laundering. 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.

Project 3.5

Currently, soap is prepared in a small scale (in the cottage industry) in most of the Ethiopian cities and has become a means of income generating. Do you know the raw materials that are used and the procedure to be followed to prepare the soap in such a cottage industry? Please visit the nearby cottage industry and submit a report to your tutor.

Experiment 3.5

Dear learner, to investigate the Chemical Properties of Soap and Detergent perform experiment 3.5. To conduct the experiment, visit a nearby high school and request a teacher who is teaching Grade 12 chemistry to help you in performing or demonstrating the experiment. Note that the experiment should be performed only in the laboratory. If you couldn't find a high school in your area, request your tutor to get support and advices.

Title: Investigating the Chemical Properties of Soap and Detergent

Objective: Describe the chemical properties of soap.

Materials Required: Four 150 ml of beaker, cold water

Chemicals Required: ordinary soap and 3 gram detergent that available in the commercial market

Procedure

Weigh 3 g of ordinary soap and 3 gram detergent that available in the market. Add 3 gram of the soap in the solution (3 mL distilled water + 5 drops 3% magnesium chloride solution) in 150 ml of beaker labeled soap then add 100 ml of water. Do the same thing for 3 gram of detergent in a 150 of beaker labeled as detergent. Stir both beakers. Observe in which beaker leather is well formed.

Observation and Analysis

Based on your observation in procedure 3, which reagent (soap or detergent) lathered well with hard water? Why?

Please do this experiment during the toutorial session in the near by high school. If this is not possible since the chemical and the materials for this experiment are easily accessible ; your can do it for your self.

√ CHECKLIST-3.4

Please put a (√) in the box for the tasks you can perform or concepts you understand

- Can you list the three types of glass and explain how they manufactured? ☐
- Can you describe the steps to be followed in glass production? ☐
- Can you list examples of products of ceramics? ☐
- Can you describe the steps to be included in manufacturing of ceramics? ☐
- Can you list the available raw material in Ethiopia for cement production? ☐
- Can you describe briefly the manufacturing process of cement? ☐
- Can you explain how setting of cement formed? ☐
- Can you describe briefly the steps of sugar manufacturing? ☐
- Can youbdifferentiate the difference between paper and pulp? ☐
- Can you explain briefly the steps involved in paper and pulp manufacturing? ☐
- Can you define what tanning mean ? ☐
- Can you describe briefly the six preparatory stages of leather production? ☐
- Can you describe the major steps of leather production? ☐
- Can you define what food processing and preservation mean? ☐
- Can you describe the difference between the traditional the modern methods of food preservation? ☐
- Can you list examples of organic and inorganic food preservative? ☐
- Can you describe the two methods of industrial preparation of Ethanol? ☐
- Can you explain the methods of preparation of ethanol (Araki)? ☐
- Can you list the organic chemicals that are used for the synthesis of soaps? ☐
- Can you explain the difference between soaps, detergents and dry detergents clearly? ☐
- Can you outline the flow chart that showing the soap making process? ☐
- Can you investigate and describe the chemical properties of soap and detergent? ☐

Self-Test-Exercise 3.4

Give Short answer for the following questions

1. Predict the type of glass produced if potassium carbonate is used instead of sodium
2. To produce glass industrially, two types of furnaces are used, what are the two types of furnaces, and what type of glass is produced in each type
3. Explain the difference between chemical and mechanical pulping.
4. How does natural tanning differ from mineral tanning?
5. Describe the modern methods of food preservation.
6. Explain the reason why the paper quality produced in industries differs.
7. What are the common chemicals that are used for mineral tanning?
8. What is the mechanism that makes food be preserved for a long time without spoiling?
9. How does the traditional way of preparation of Araki differ from industrially prepared liquor (Gin)?
10. Explain the difference between hard soap that is used for cleaning our clothes and soft soap that is used for our body hygiene.
11. How do soap and detergent act on dirt particles during cleaning?
12. Describe how detergent is more effective in hard water than soap. And show the mechanism of action by reaction equation that takes place during the cleaning action.

Unit Summary

- Before 19 th century, chemistry and chemical technology were devoted to satisfying the needs of everyday life however the methods of production used were manual and small scale.
- In the 19th century as a result of Industrial revolution the chemical industries began to develop at a very high rate. The demands for goods produced through chemical processes increased.
- Ethiopia, as developing country, will find chemistry and chemical technology very important components of economic growth and development.
- Industrial chemistry as the branch of chemistry which applies physical and chemical procedures towards the transformation of natural raw materials and their derivatives to products those are of benefit to humanity.
- The resources that can be replenished through rapid natural cycles are known as renewable resource. Examples: plants, (crops and forests), and animals
- The resources that cannot be replenished through natural processes are known as non-renewable resource. Examples: fossil fuels and, minerals.
- Ammonia is an important compound, essential to man for a variety of diverse uses. It is used as a fertilizer, cleaning agent, antimicrobial agent, etc. the process that used to manufactured ammonia in industries are called **Haber - Bosch process**
- Nitric Acid is a highly corrosive mineral acid. And it is a strong oxidizing agent and it is produced industrially from ammonia by the three-step **Ostwald process.**
- The largest percentage of nitric acid is used to synthesize ammonium nitrate, a water soluble fertilizer. Large quantities are also used to make plastics, drugs, and explosives such as trinitrotoluene (TNT) and nitro glycerin.
- $H_2SO_4$the largest volume chemical produced in the world and rate of consumption of this acid is considered as a measure of a country's industrialization.

- Most of the sulphuric produced in the world is manufactured industrially by the contact Process which involves four major steps. Sulfuric is used in the production of fertilizers, detergents, plastics, paints, explosives, as electrolyte in car batteries and as a catalyst in the manufacture of many chemicals.
- DAP has the advantage of having both nitrogen and phosphorus, which are essential for plant growth.
- The most common forms of nitrogen fertilizer include anhydrous ammonia, urea, and urea-ammonium nitrate (UAN) solutions.
- **Urea** is a solid fertilizer with high N content (46%) that can be easily applied to many types of crops and turf. It is manufactured by reacting CO_2 with NH_3 .
- Pesticides belong to a category of chemicals used worldwide to prevent or control pests, diseases, weeds and other plant pathogens in an effort to reduce or eliminate yield losses and maintain high product quality. Examples of common pesticides oregano-chlorine, oregano-phosphate and carbamates.
- A herbicide is a chemical used to kill or otherwise manage certain species of plants considered to be pests. Examples: chlorophenoxy acids such as 2,4-D and 2,4,5-T; triazines such as atrazine, hexazinone, and simazine.
- Sodium carbonate (washing soda) is a white crystalline solid. It exists as a decahydrate (Na_2CO_3. $10H_2O$) compound. Sodium carbonate is manufactured by Solvay process in industrial scale and has industrial and domestic uses.
- NaOH has been manufactured at large scale for many years from readily obtainable raw materials i.e. Rock salt "NaCl" sodium chloride & water "H_2O.
- 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.

- The chemical/manufacturing industry in Ethiopia produces basic chemicals based on local raw materials and currently there are a total of 153 chemical and chemical-related product manufacturers according to CSA's raw data for the year 2014.
- Glass is an amorphous or non-crystalline solid material and is such a popular material in our homes because it has all kinds of really useful properties. Almost all glass contains silica as the main component.
- **Soda-lime glass** is ordinary glass which is a mixture of sodium silicate and calcium silicate.
- Traditional ceramics, such as porcelain, tiles and pottery are formed from minerals such as clay, talc and feldspar whereas industrial ceramics, however, are formed from extremely pure powders of specialty chemicals, such as silicon carbide, alumina, barium titanate, and titanium carbide.
- Ethiopia has a huge amount of reserve of raw materials for the production of cement. The major raw materials for the production of cement are limestone, clay, silica sand, gypsum, and pumice.
- Sugar is mainly manufactured from a raw material sugar cane with 8 stage industrial process starting from collecting the Harvest of sugar cane to for grinding to the last stage separation and packaging
- Paper is a mixture made from rags and wood pulp glued together with some additions, bleached and dried.
- Tanning is a process of converting raw animal hides and skin to leather, using tannin. Leather is a durable and flexible material created by the tanning of animal hides and skin.
- Food preservation usually involves preventing the growth of bacteria, fungi and other microorganisms, as well as reducing the oxidation of fats, which causes rancidity.
- The most common modern methods of food preservation are freezing, vacuum-packing and Freeze-drying
- The alcohol, which is the constituent of beverages, is known as ethyl alcohol or ethanol.

- The preparation of ethyl alcohol is atypical chemical process. It can be done from sugar by bacteria, without air (oxygen).

$$C_6H_{12}O_6 \xrightarrow[\text{bacteria}]{zymase} 2C_2H_5OH + CO_2$$

- The common alcoholic beverages in Ethiopia Beer, liquor(Araki), Wine, Tej and Tella
- There are many kinds of soap available on the market, but the methods used in making them are similar. It is expressed in the equation: Long chain fatty acids (Fat) + NaOH (Lye) → Soap + Glycerin represents the changes in practically all soap making. The soap making process is called saponification.

Self-Assessment Exercise for Unit One

Part I. Write True if the statement is true and false if the statement is false

1. In early stage of industrial chemistry, the methods of production used were manual and small-scale.
2. The largest percentage of nitric acid is used to synthesize ammonium nitrate, a water soluble fertilizer.
3. H_2SO_4 is a leading economic indicator of the strength of many industrialized nations.
4. Diammonium monohydrogen phosphate (DAP) is a white crystalline compound that is insoluble in water
5. In Ethiopia's manufacturing/chemical industry is still at a nascent stage.
6. The present day paper is not completely different from the old papyrus which was used centuries ago.

Part II: Choose the best answer for the following questions among the given alternatives

1. What type of catalyst used in the contact process?
   A. V_2O_5 C. Pd
   B. Fe D. Pt

2. What is $H_2S_2O_7$?
   A. Concentrated sulfuric acid C. Oleum
   B. Sulfur trioxide D. Hydrogen sulfate

3. Which one of the following is the use of sulfuric acid?
   A. In the manufacture of detergents and fertilizers
   B. As food preservative
   C. As a battery acid
   D. As a bleach
   E. E. A and C

4. In the Contact process, what happens to the equilibrium when the pressure is increased?
   A. Shifts to the left C. Shifts to the right
   B. No change in equilibrium D. None

5. What is the name of manufacturing process of sulfuric acid?
   A. Contact C. Haber
   B. frasch D. Ostwald

6. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
   The equation above refers to the 2nd stage of Contact Process. What are the optimum conditions to favour the yield of sulfur trioxide?
   A. Low pressure D. High temperature
   B. High pressure E. b&c
   C. Low temperature

7.

8. Process in which sodium carbonate manufactured is called

   A. calcination
   B. metallurgy
   C. Solvay process
   D. carbonation

9. Pick out the wrong statement?

   A. High early strength cement are made from materials having high silica to lime ratio
   B. The function of gypsum in cement is to enhance its initial setting rate
   C. Acid resistant cements are known as silicate cement
   D. Major component of greyish Portland cement is tricalcium silicate

10. Among the following compounds which one is recycled in Solvay process during the production of Na_2CO_3

    A. NaCl
    B. CO_2
    C. NH_3
    D. $CaCO_3$
    E. b and c

11. The last step of the Solvay process is

    A. preparation of ammonical brine
    B. carbonation
    C. preparation of carbon dioxide and slaked lime
    D. recovery of ammonia

12. The third step of the Solvay process is

    A. preparation of ammonical brine
    B. carbonation
    C. filtration
    D. calcination

13. One of the following is the most common nitrogen based fertilizers
    A. Anhydrous ammonia
    B. Urea
    C. urea-ammonium nitrate (UAN) solutions
    D. all

14. One of the following is the most important chemical groups of herbicides?
    A. Chlorophenoxy acids such as 2, 4-D
    B. organic phosphorus chemicals such as glyphosate;
    C. amides such as alachlor and metolachlor
    D. all of the above

15. Basic chemicals or manufacturing product produced in Ethiopia from the local raw materials available
    A. Sugar
    B. cement
    C. soaps and detergent
    D. caustic soda
    E. All of the above

16. The product obtained by combining a material rich in lime, CaO with other materials such as clay, which contains silica, SiO2, along with oxides of aluminium, iron and magnesium is:
    A. Glass
    B. Cement
    C. Steel
    D. Fertilizer

17. Which of the following is not a specific characteristic of chemical industries:
    A. using naturally available raw materials
    B. providing transport services to customers
    C. involving chemical reactions
    D. consuming energy

18. Which of the following is a non-renewable resource?
    A. soil
    B. petroleum
    C. water
    D. plants

19. In the tanning process, the purpose of putting the skin into slaked lime solution is to:
    A. facilitate the removal of unwanted flesh
    B. dehydrate the skin
    C. facilitate the removal of hair
    D. Soften the skin
20. The stage in which the shredded sugarcane travels on the conveyor belt through a series of heavy-duty rollers, which extract juice from the pulp in sugar manufacturing is called..
    A. Juicing
    B. Collecting the Harvest
    C. Cleansing and Grinding
    D. Clarifying
21. Preservation usually involves preventing .....
    A. The growth of bacteria
    B. The growth of fungi and other microorganisms,
    C. Reducing the oxidation of fats, which causes rancidity?
    D. All of the above
22. ---------- is a component to make soft soap along with the vegetable oil or animal fat
    A. Caustic soda
    B. Caustic potash (KOH)
    C. K_2CO_3
    D. b and c

Part III: Give Short Answer for the following Questions

1. Give a reason why among the essential aspects of industrial chemistry, the chemical industry is the prominent one?
2. Write the chemical equation which shows the three major steps of NH_3 production.
3. List the common uses of H_2SO_4.
4. What is the basic difference in the composition of glass and cement?
5. What is ceramics?
6. Write the main chemical equations involved in the production of cement.
7. Describe the refinery processes involved in sugar production
8. Write the key reaction during the Solvay process? And please describe how solid $NaHCO_3$ is formed.
9. What is the positive aspect of the application of pesticides?
10. Describe the process of production of the most local alcoholic beverages in Ethiopia.

Feed Back to Activities of Unit 1

Activity 3.1

List of chemical products manufactured in Ethiopia

1. Cement 2. Ammonium sulphate 3. Sulphuric acid 4. Glass 5. Steel

Activity 3.2

1. Since fossil fuel that include petroleum, natural gas and coal is non- renewable resources cannot be replenished
2. 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

Activity 3.3

Ammonia is highly soluble in water because it has hydrogen bond which is polar in nature and water is also polar in nature due to hydrogen bond.

Activity 3.4

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.

Activity 3.5

1. 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.

2. 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.

Activity 3.6

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".

Activity 3.7

- 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

Activity3.8

1. The common pesticides that are most frequently used by Ethiopian farmers; organochlorines, organophosphates, carbamates , pyrethroids and biological
2. The common herbcides: 2,4-D and 2,4,5-T;Atrazine, hexazinone, and simazine; Butylate; Alachlor and metolachlor and Glyphosate

Activity 3.9

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 material i.e. sodium bicarbonate and sodium carbonate that is used for glass production is produced with Solvay process

Activity 3.10

The use of Cl_2 gas which is produced during the manufacturing of sodium hydroxide from brine is:

- treat drinking water and swimming pool water by killing bacteria in
- 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)

Activity 3.11

1. Glass is an amorphous or non-crystalline solid material. Most common glasses are mixtures of two or more silicates.

2. a. The **ordinary glass** used for making window pans, bottles, and dishes is called soda lime glass

   b. **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

   c. Borosilicate glass is commonly known as Pyrex. It is manufactured usingboron (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 tube

3. Glass is manufactured in Ethiopia in Addis Glass factory located in Addis Abeba.

Activity 3.12

1. Pottery is one form of ceramic. "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.

2. 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.

Activity 3.13

1. Some cement factories are found in Ethiopia. These factories are located in rural areas closer to places where they get raw materials.
2. The reason that most cement factories are located in rural areas of Ethiopia where raw materials are available is that it is easy to transport the products than to transport the raw materials which demands high cost time and energy.

Activity 3.14

1. Foods and drinks that sugar is an ingredient are; ice cream, candy, pastries, cookies, soda, fruit juices and canned fruit and the raw materials used for sugar production
2. 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.

Activity 3.15

1. The idea that wasting of paper is equivalent to cutting trees. It also helps them realize the importance of proper management of paper.
2. The quality of paper depends on the method used for its production. Give emphasis that wood pulp can be manufactured from soft woods and hard woods. Mention some examples of soft and hard woods.

Activity 3.16

1. leather products are replaced by synthetic products because it is relatively expensive
2. 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.

Activity 3.17

1. Keeping food at cool place hinders the growth of micro-organisms which spoil food.

Activity 3.18

1. The traditional method of food preservation includes salting, pickling, sugaring, smoking, drying and canning.

Activity 3.19

1. 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.

Activity 3.20

1. 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
2. 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.

Activity 3.21

1. 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.

Answer Key for Self-test Exercise for unit Three

Self-Test Exercise 3.1

Part I. Multiple choice

1. C 2. D 3.D 4.E

Part II. Short Answer

1. Chemical industry is an institution involved in the production of chemical product.
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,
   - 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.
   - consume relatively large quantities of energy during the manufacturing process,

Self-Test Exercise 3.2

Short Answer

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. The types of manufacturing industries based on the raw material used for production.
   A. Chemical industries use natural raw materials (resources)
      For example sugar industries use sugar cane to manufacture sugar.
   B. Chemical industries use products from other industries to manufacture their products
4. Examples of natural resources that obtained from the hydrosphere:
   - Sea water is a good source of sodium chloride, magnesium and bromine

Self-Test Exercise Three

1. $N_2 + 3H_2 \rightarrow 2NH_3$
2. 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.
3. 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.

4. 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

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

Step 3: Dissolution of NO_2 with water

$$3NO_2(g)+H_2O(l) \rightarrow 2HNO_3(aq)+NO$$

$$NO\ is\ recycled.$$

5. It is mainly used for preparing fertilizers, explosives, and plastics.

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

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

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

$$NH_2COONH_4 + (NH_2)_2 + CO + H_2O\ (urea + water)$$

7. 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:

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

8. Step 1: Reaction of ammonia with H_3PO_4

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

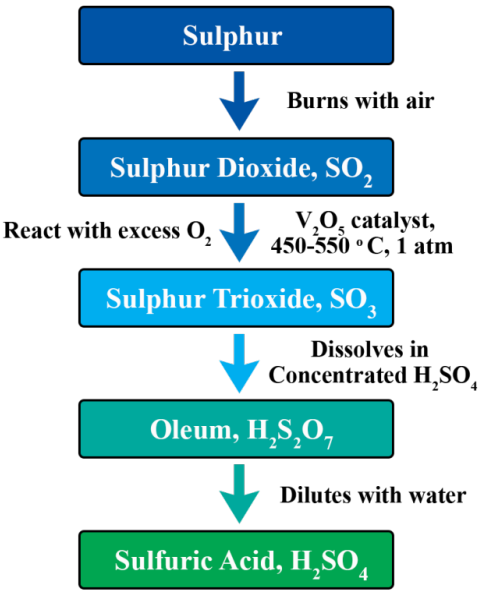
Step 2: Recycling monoammonium phosphate

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

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.

9. The major uses of sulphuric acid are for making fertilizers, detergents, plastics & paints.

10. The diagram which shows the four major steps of production of sulphuric acid



11. **Types of pesticides:**

- Insecticides (killing insects)
- Herbicides (killing plants)
- Fungicides (killing fungus)
- Rodenticides (killing rodents, like mice and rats)
- Bactericides (killing bacteria)

Table: Types of herbicides

S.No	Types of herbicide group	Examples of Herbicides
1	Chlorophenoxy acids	2,4-D and 2,4,5-T
2	Triazines	Atrazine, hexazinone, and simazine
3	Organic phosphorus chemicals	Glyphosate
4	Amides	Alachlor and metolachlor
5	Thiocarbamates	Butylate
6	Dinitroanilines	Trifuralin
7	Chloroaliphatics	Dalapon and trichloroacetate
8	Inorganic chemicals	Various arsenicals, cyanates, and chlorates

The raw materials of sodium carbonate manufacturing:

- Brine solution (NaCl)

- Limestone ($CaCO_3$) for CO_2
- Ammonia gas
- Water

12. Burning coke in the Solvay process is required to provides the heat energy to decompose the limestone (an endothermic reaction)
13. a/ Washing soda - Na_2CO_3 b/ Baking soda - $NaHCO_3$ c/ Soda ash - Na_2CO_3
14. 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.

Self-Test Exercise 3.4

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. **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.
3. **Mechanical pulping:** It 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. **Chemical pulping:** Chemical

pulp is produced by combining wood chips and chemicals in large vessels called digesters. Heat and the chemicals break down the lignin which binds the cellulose fibres together without seriously degrading the cellulose fibres. Chemical pulp is manufactured using the Kraft process or the Sulphite Process.

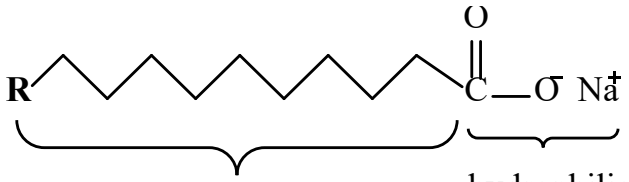
4. **Vegetable or natural tanning:** The skin is placed in a solution of tannin. Tannins occur naturally in the barks and leaves of many plants. The primary barks used in modern times are chestnut, oak, tanoak, hemlock, quebracho, mangrove, wattle (acacia) and myrobalan. Naturally tanned hide is flexible and is used for making shoes, luggage and furniture. **Mineral tanning:** In this process, the skin is placed in solutions of chemicals such as chromium sulphate and other salts of chromium. Chrome tanning is faster than natural (vegetable) tanning and requires only twenty-four hours. The leather is greenish-blue in colour derived from the chromium. This process produces stretchable leather that is used for making garments and handbags.
5. **Freezing:** This is one of the most commonly used processes, commercially and domestically, for preserving a very wide range of foods such as potatoes, as well as prepared foodstuffs that would not require freezing in their normal state.

   Freeze-drying: Water vapour has easier access through the cell structure of any product compared to water-penetrating the product and evaporating from the surface of the product as in case of other drying methods. The gentle escape of water vapour in the freeze-drying process leaves the product close to its original shape, taste, and colour and there is no loss of aroma or flavour. For example, liquids such as coffee, tea, juices and other extracts, vegetables, segments of fish and meat products. Freeze-drying is a superior preservation method for a variety of food products and food ingredients.

   Vacuum-packing: Stores food in a vacuum environment, usually in an air-tight bag or bottle. The vacuum environment strips bacteria of the oxygen needed for survival, slowing down the rate of spoiling. Vacuum-packing is commonly used for storing nuts to reduce loss of flavour from

oxidation.

6. Due to 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.
7. Chromium sulphate and other salts of chromium
8. By preventing the growth of bacteria, fungi and other microorganisms, as well as reducing the oxidation of fats which causes rancidity.
9. 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.
10. 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.
11. 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-C_6 H_4 SO_3 Na, 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 -C_6H_4 groups.

12. 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.

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

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.

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

Answer Key for Self- Assessment Exercise of unit Three

Part I. True or False Items

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

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. 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

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.

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

Upper Part of the Kiln

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

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.

6. 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.

7. 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:

$$CaCO_3 \rightarrow CaO + CO_2$$

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$NaCl + 2CO_2 + 2NH_3 + 2H_2O \rightarrow 2NaHCO_3 + 2NH_4C$$

$$2NaHCO_3 \rightarrow \mathbf{Na_2CO_3} + H_2O + CO_2$$

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

The overall reaction:

$$CaCO_3 + 2NaCl \rightarrow \mathbf{Na_2CO_3} + CaCl_2$$

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 page 199 and 200.

Answer key for Experiments Observation and Analysis

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 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.

Experiment 3.3

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.

Experiment 3.4

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 3.5

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

Because, 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.

UNIT 4

POLYMER

Introduction

Dear learner, from grade 10 unit three, you have learned about chemical reaction and stoichiometry i.e., types of chemical reaction and, hydrocarbons and their nature. You have also discussed in unit six. Detail examples in hydrocarbons and their natural sources as well as some natural sources of hydrocarbons such as ethylene, propylene are important building blocks (monomers) for the polymer polyethylene and polypropylene were discussed. These issues give you information you need for this unit on polymer.

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 organized in three sections. The first section introduces about polymers. It tries to explain the meaning of polymer.

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

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

Unit Outcomes

At the end of this unit, you 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 & 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/monomer, 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 & uses of plastics, rubbers, carbohydrates & proteins;
- list the applications of the different types of polymers
- describe the process of addition & condensation polymerization;

Unit Content

UNIT 4: POLYMER

The Required Study Time **3 weeks**

If you set an average of one hour per day, you will be able to complete unit two by the end of the assigned week. Try to do all the learning activities. And compare your answers with the ones provided at the end of the Module.

If you do not get a particular exercise right in the first attempt, you should not get discouraged, but instead, go back and attempt it over and over again. If you still do not get it right after several attempts, then you should seek help from your friend or even your tutor.

Unit Learning Strategies

The suggested methodology for this unit is active learning methods such as individual study (self-study) and if you have access for internet, you can it. Each section in the unit begins with activity. Please reflect to the questions based on the given activities and check the feedback whether you are correct or incorrect by referring different sources. The activity enables you to remember what you have learned in previous module or unit. Please rate the check list that are given at the end of each section and evaluate your-self. Then check the answer of each self-test which is attached n at the end of the module. If you did not achieve the minimum required level for each self- test exercise, please reread the section again by taking additional study hours. Finally, try to do the self-assessment and the assignment given at the end of the unit that assesses the unit learning outcomes. This enables you to evaluate yourself whether you have achieved or not the minimum required competence level that expected to score for the unit.

Section 4.1: Introduction to Polymer

Dear Learner in this section you will study the basic concepts of introduction to polymer beginning from how the word polymer is derived to its meaningful definition. It also emphasis that this term applies to giant molecules built up of large numbers of interconnected repeating units. You will also learn definition of monomers and then you end up with examples of monomers and polymers.

Objective

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

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

Activity 4.1

Please observe the following materials. Then set criteria and categorize them.

- the textile fibre of your clothes
- your hair and skin
- the wood from which your desk is made up of
- the glass of the window

Polymer

What is a polymer?

The word polymer is derived from the Greek words 'poly' meaning many and 'meros' meaning part. It follows that this term applies to giant molecules built up of large numbers of interconnected repeating units. A polymer is a large chainlike molecule built up from many repeating smaller molecules.

A polymer is generally comprised of more than 100 monomers; structures with lower numbers of monomers are known as oligomers. These polymers or oligomers may be linear, slightly branched, or highly interconnected. In the branched case the structure develops into a large three-dimensional network. With few exceptions, the repeat unit in the polymer usually corresponds to the monomer from which the polymer was made. The size of a polymer molecule may be defined either by its mass or by the number of repeat units in the molecule. This latter indicator of size is called the degree of polymerisation, DP. The relative molar mass of the polymer is thus the product of the relative molar mass of the repeat unit

and the DP. Examples of polymers are:

polyethylene, wood (cellulose), protein, and etc.

Monomers

The small molecules used as the basic building blocks for polymers are known as *monomers. Mono* means *one*.

Example monomers are:

- glucose($C_6H_{12}O_6$) a monomer for cellulose (wood)
- ethylene a monomer for Polyethylene
- amino acid ($NH_2CH(R)(COOH)$) a monomer for protein,

√ CHECKLIST - 4.1

Please put a (√) in the box for the tasks you can perform or the concepts you understand

- Can you define the term polymer? ☐
- Can you define clearly what monomer means? ☐
- Can you list examples of polymer? ☐
- Can you list examples of monomer? ☐

Self-Test Exercise 4.1

Give Short Answer for the following Questions

1. Define the term polymer?
2. Define clearly what monomer means?
3. List at least three examples of polymer?
4. List at least three examples of monomer?

Section 4.2: Polymerization Reactions

Dear learner, in this section you will study the basic concepts on the two major types of polymerization reaction processes that are applied for the preparation of polymers. It begins with addition polymerization. Then it describes the steps of addition polymerization with examples. You will also learn about the second type of polymerization reaction i.e., condensation polymerization. Then you end up with examples of condensation polymerization reactions.

At the end of this section, you 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

Activity 4.2

Please look the following questions and reflect your responses.

1. Long chains are made up of linkage of small metal rings (or other shapes). Use the analogy of making chains to propose formation of large molecules.
2. Suggest another analogy for the formation of polymers.

The chemical change by which monomer units combine to form a polymer is known as **polymerization reaction.** The essential feature of a monomer is to have two or more functional groups (polyfunctionality).

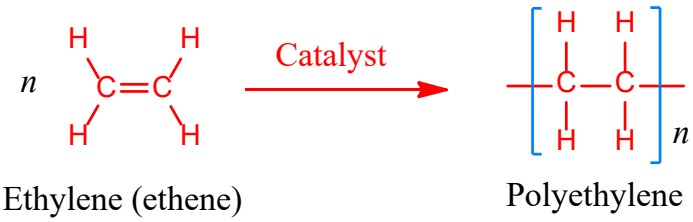
This gives each monomer the capacity to form chemical bonds to at least two other monomer molecules.

Bifunctional monomers can form only linear, chainlike polymers. Monomers with higher functionality yield cross-linked, network polymeric products.

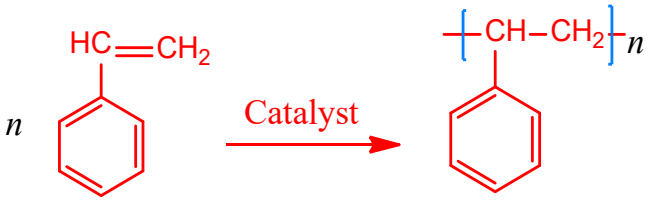
4.2.1 Addition Polymerization

Addition polymerization is a reaction in which a chain reaction adds new monomer units to the growing polymer molecule one at a time. This type of polymerization is also known as **chain-growth polymerization.**

This type of polymerisation reaction occurs by those involving unsaturated monomers. For example, the addition polymerization of many ethylene molecules yields polyethylene and that of styrene molecules gives polystyrene.



Ethylene (ethene) Polyethylene



Styrene Polystyrene

Note that the molecular formula of a polymer is *n* times that of the monomer and upon polymerization, the double bond is converted to a single bond. When monomers with triple bonds are used it is converted to double bonds.

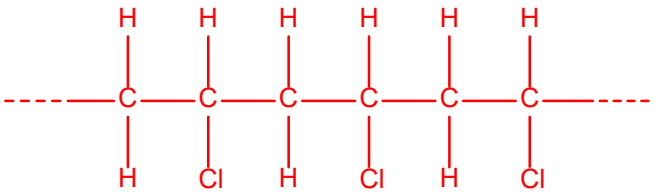
? Is it possible to identifiy the number of monomer for a given polymer?

Note also that: If a polymer is given, you can identify the monomer unit that is repeated in it.

If the mass of the polymer is known, the number of the monomer molecules is determined by dividing the mass of the polymer by the molar mass of the monomer.

Example:

The addition polymer polyvinyl chloride (PVC) has the structure

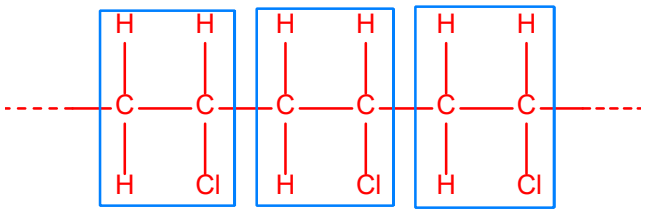


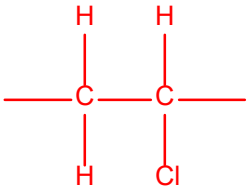
A) Draw the structure of the monomer from which PVC is made

B) How many monomer units are in a PVC polymer that has a molar mass of 1.33×10^5 g/mole

Solution

✌◑We need to find the repeating unit from which this polymer chain is constructed



The repeating unit  and the monomer has carbon-carbon double bond.

B) If the PVC had a molar mass of 1.33×10^5 g/mol, how many monomer units (n) are there?

Given: Molecular mass of CH_2=CHCl (Venyl chloride) is 63.5g/mol

Mass of the PVC 1.33×10^5 g/mol

Required: The number (n) of CH_2=CHCl

Relation:

$$\text{Number of monomer units (n)} = \frac{\text{Molar mass of the polymer}}{\text{Molar mass of the monomer}}$$

$$= \frac{1.33 \times 10^5 \text{ g/mol}}{62.5 \text{ g/mol}}$$

=2128 vinyl chloride molecules

4.2.2 Steps of addition polymerization

The addition polymerization process takes place in three distinct steps.

1. **Chain initiation step**: it is a time when the polymerization process is started by means of a reactive initiator molecule. The initiator molecules can be a free radical, a cation or anion. These reactive centres react readily with other monomers without eliminating the active centre.
2. **Chain propagation** step: It is the period when a monomer adds to the growing chain, with the free radical, cation or anioin transferring to the chain end. High molar mass polymers are formed right from the beginning of the reaction.
3. **Chain termination step**: This is the step when the polymerization is stopped since chain reactions do not continue indefinitely. The radical, cation, or anion is "neutralized" stopping the chain propagation.

A polymerization reaction initiated by free radicals is called **a free radical polymerization.** The free-radical route to chain polymerisation is the most important step in polymerization reaction.

A polymerization reaction initiated by a cation is called **a cationic polymerization.** A polymerization reaction initiated by an anion is called **an anionic polymerization.**

Example of a free radical polymerization:

1. **Chain initiation:**

The free radical on the initiator fragment, shown: as Ra•, attacks the covalent π bond in the monomer, leaving a free radical on the monomer

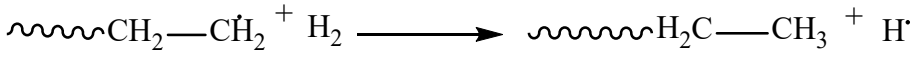
2. **Chain propagation**

3. Chain termination

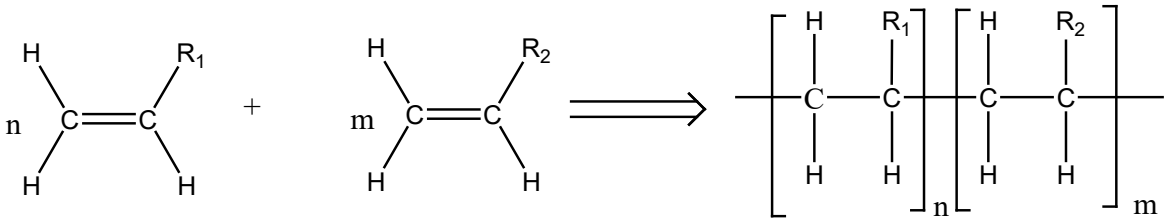
Termination is achieved in two possible processes.

a) A free radical is destroyed by the combination reaction when two chains link as

b) chain transfer may occur to continue polymerization of another chain



Polymers include polyethylene, polyvinyl chloride, acrylics, polystyrene, and polyoxymethylene (acetal) are made by addition polymerization.

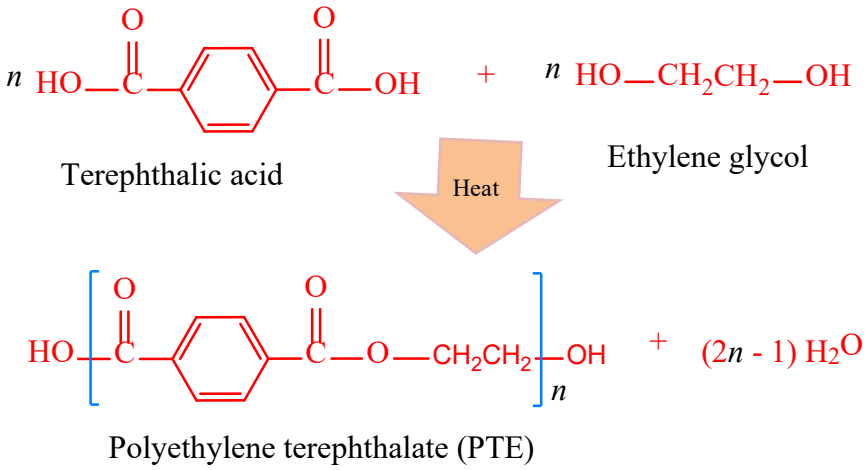


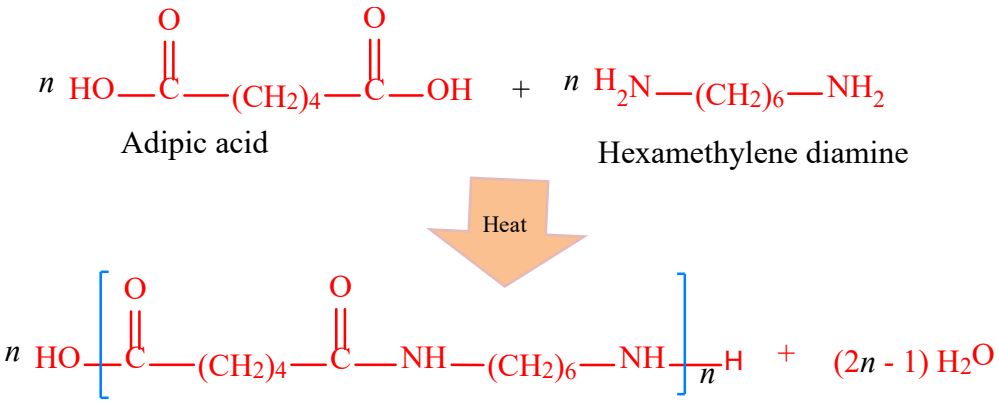
4.2.3 Condensation polymerization

Condensation polymerization involves the combination of monomer molecules, with the release of simple molecules like water or methanol as by product. These products are normally referred to as **condensate.** This polymerization is also known as **step growth polymerization.** In order to produce a condensation polymer, the monomers involved two or more functional groups. Typically, such reactions take place between reactive components, such as dibasic acids with diamines to give polyamides, or dibasic acids with diols to form polyesters. Proteins, starch and cellulose are examples of natural condensation polymers. Whereas, Polyester (Polyethylene terephthalate or Dacron) and the polyamide Nylon 66 represented below, are two examples of synthetic condensation polymers.

They 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.

Dacron is a copolymer and is formed when equimolar amounts of 1, 4-benzene dicarboxylic acid (terephthalic acid) and 1, 2-ethanediol (ethylene glycol) react.



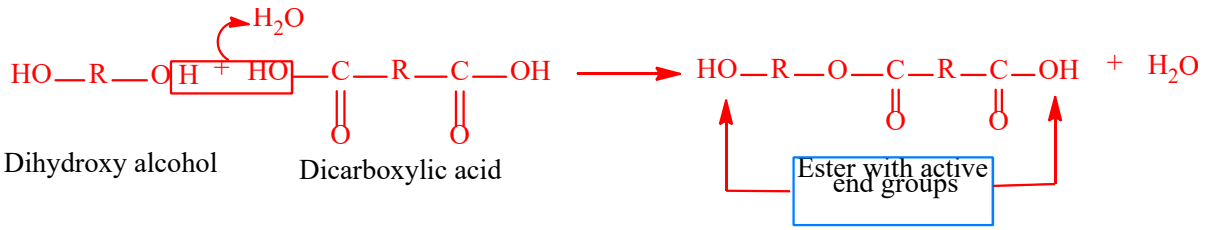


Nylon 66 (the numbers indicate there are six carbon atoms each in hexamethylene diamine and adipic acid)

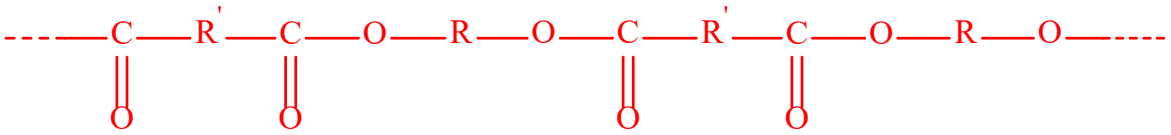
Dacron is a strong and impact resistant. It is colourless and has high transparency. It is mainly used for synthetic fibers. Mixing with various amounts of cotton gives fabrics that are durable, easily dyed and crease-resistant. It is also used for making bottles and packaging materials.

Uses of nylon include making parachutes, ropes, clothes, stockings, hair combs, and rugs. They are also used to reinforce automobiles tires.

Consider the reaction between an alcohol with two –OH groups, HO–R –OH, and a dicarboxylic acid, HOOC–R–COOH as represented below. In this case the ester formed still has a reactive group at both ends of the molecule.



The general structure of the polyester can be represented as



Section of the polyester

√ CHECKLIST - 4.2

Please put a (√) in the box for the tasks you can perform or the concepts you understand

- Can you list the two types of polymerization reaction? ☐
- Can you define clearly addition polymerization means? ☐
- Can you describe the steps of addition polymerization reaction? ☐
- Can you list examples of addition polymerization reaction? ☐
- Can you define clearly what condensation polymerization means? ☐
- Can you list examples of addition polymerization reaction? ☐
- Can you list the uses of nylon? ☐

Self-Test Exercise 4.2

Give Short Answer for the following Questions

1. List the types of polymerization reactions.
2. Define each of the types of polymerization reactions.
3. Determine the monomers used to prepare
   a. $-[OC-C_6H_4-COO-(CH_2)_2-O]-_n$
   b. $-[NH-CH_2-CO-N-CH_2-CO]-_n$
4. Decide the type of polymerization reaction taking place between the monomers $H_2NCH_2(CH_2)_4CH_2NH_2$ $COClCH_2(CH_2)_6CH_2COCl$. Write the structure of the polymer.
5. Consider a polymer made from tetrachloroethylene.
   a. Draw a portion of the polymer chain.
   b. What is the molar mass of the polymer if it contains 3.2×10^3 tetrachloroethylene?
   c. Calculate the percentage of C and Cl in the polymer?

Section 4.3: Classification of Polymers

Dear Learner, from the previous two sections you have learned that the term polymer refers to a large molecule made up of many small constituent units of an identical structure known as monomers. Whereas, in this section you will learn concepts like polymers can occur naturally or be created artificially in a lab. So, it is obvious that polymers can be classified in various ways due to their large number, diverse behavior, and ability to be found naturally or synthetically.

So, in this section you will learn the different ways of classification of polymers; the type of monomer in which the polymer is built whether it is identical or different, on the nature of the chemical reactions employed in the polymerisation and whether they are naturally occurring or made by man (synthetic).

Objective

At the end of this section, you 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

4.3.1 Homopolymer versus Copolymer

Activity 4.3

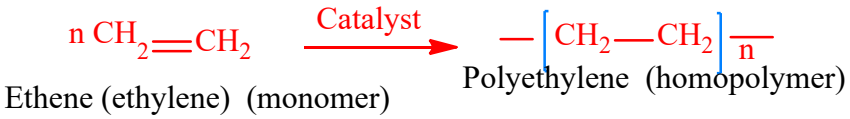
Please reflect on the difference between the different types of polymers and the causes for their difference.

There are a number of methods of classifying polymers. A few of the methods of polymers classification are listed below.

A polymer might be made from identical or different types of monomers. This could be used to classify polymers as *homopolymers or copolymers*.

Homopolymers

Homopolymers are those made from one type of monomer. For example, polyethylene is synthesized by the polymerization of one type monomer, ethene (ethylene).

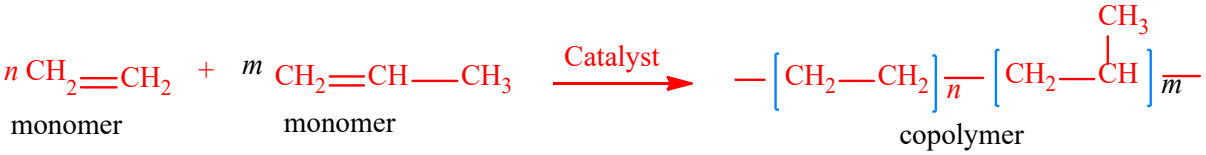


Copolymers

Activity 4.4

please reflect on the challenges to identify when different types of monomers are used to synthesize a polymer with specific properties such as melting point, density etc.

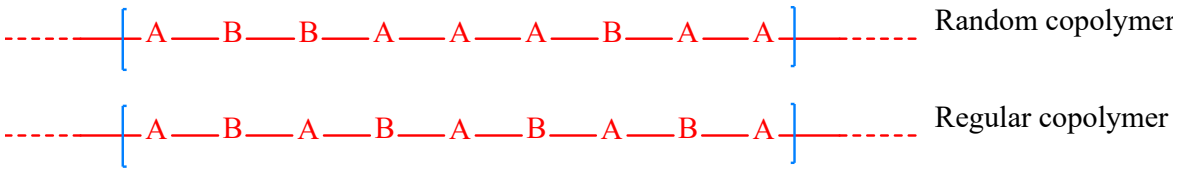
Copolymers are those prepared by polymerizing more than one kind of monomer unit. For instance, ethene ($H_2C=CH_2$) and propene ($H_2C=CH–CH_3$) can be copolymerized to produce a polymer that has two kinds of repeating units:



Copolymers are classified as random or regular, based on the way the monomers are arranged along the polymer chain.

Random polymers contain repeating units arranged in a random fashion.

Regular polymers contain a sequence of monomers in regular alternating repeating units.



Random and Regular copolymers (Where, **A** and **B** represent monomer units).

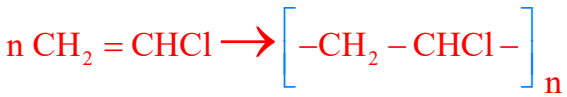
4.3.2 Addition versus condensation polymers

How addition and condensation polymerization does take place?

Another classification system of polymers is based on the nature of the chemical reactions employed in the polymerisation. Here the two major groups are the *condensation* and the *addition* polymers.

Condensation polymers are those prepared from monomers where reaction is accompanied by the loss of a small molecule, usually of water, for example polyesters which are formed by the condensation shown in the reaction:

By contrast, **addition polymers** are those formed by the addition reaction of an unsaturated monomer, such as takes place in the polymerisation of vinyl chloride:



4.3.3 Natural versus synthetic

What is the difference between natural and synthetic polymers?

Furthermore, polymers can be classified based on naturally occurring or made by man (synthetic).

Natural polymers

Activity 4.5

Look at the following questions, and reflect on the following points

1. The similarity/or difference between starch and cellulose
2. The properties of natural rubber
3. Similarity between wood and cotton.
4. The nature of your genetic material and present your answer to the class.

Natural polymers occur in nature and can be extracted, and often referred to as *biopolymers*. Common natural polymers include:

1. Carbohydrates
   a. monosaccaharides eg. glucose, fructose, galctose and ribose
   b. disaccahrides eg. succrose, lactose and maltose

   Figure 4.1 (a) and (b) shows the structure of glucose and sucrose respectively

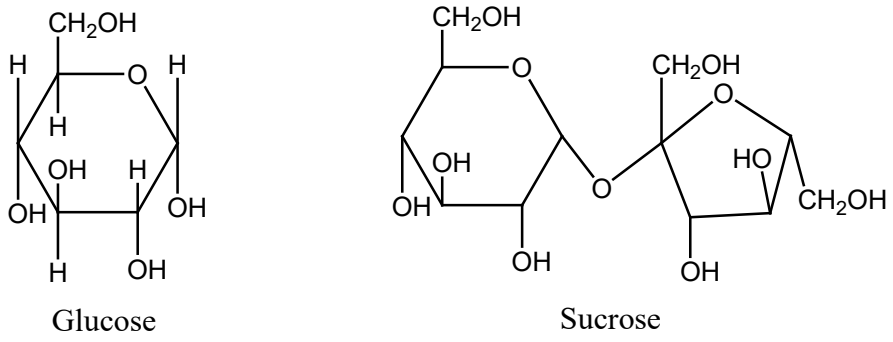
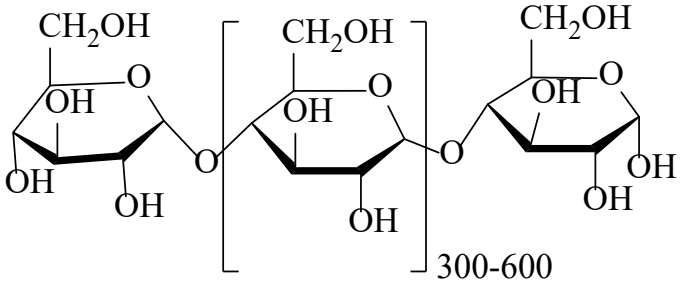


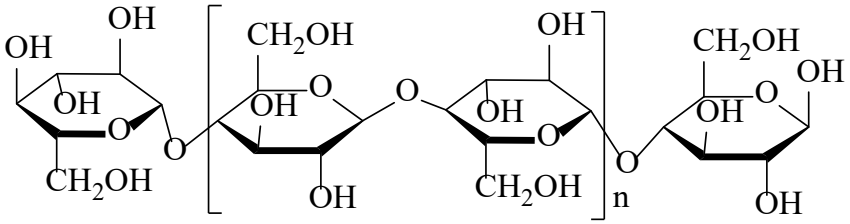
Figure 4.1 (a,b) Structure of monoshaccaride (glucose) and disaccharide (sucrose) respectively

2. Macromolecules such as polysaccharides (*e.g.*, starches, cellulose, gums, *etc.*), proteins (*e.g.*, enzymes), fibbers (*e.g.*, wool, silk, cotton), polyisoprenes (*e.g.*, natural rubber), and nucleic acids (*e.g.*, RNA, DNA)

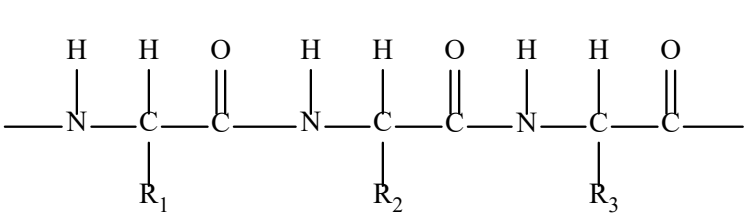
(Figure 4.2).



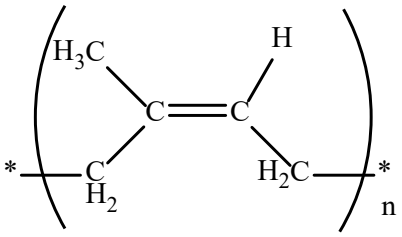
Starch



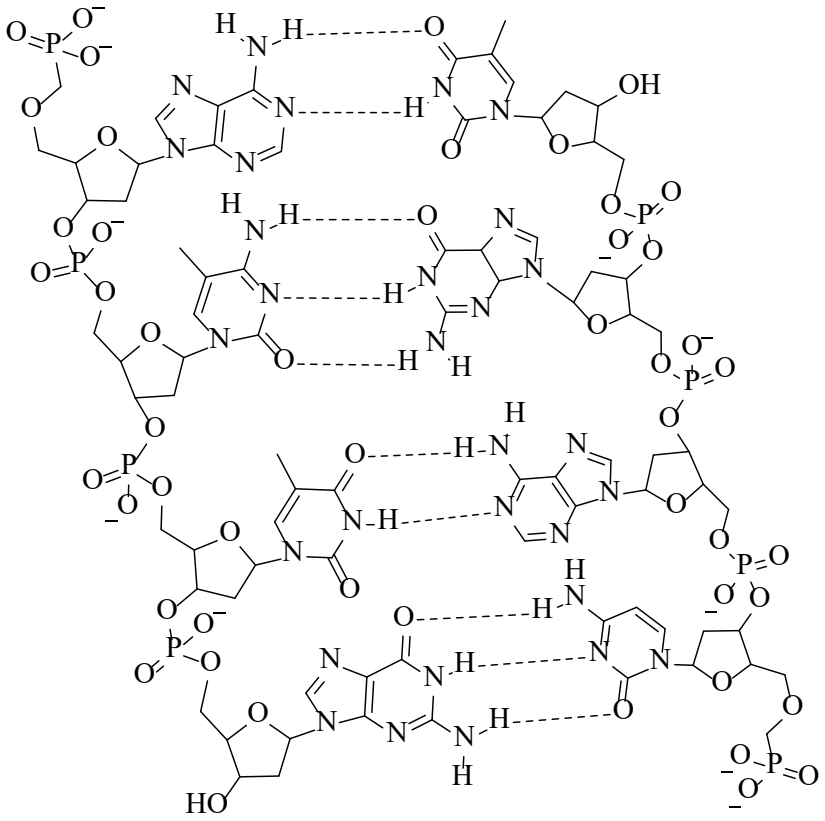
Cellulose (cotton, wood etc)



Protein (Skin, hair, muscles etc.)



Natural rubber



A portion of Deoxyribose nucleic acid (DNA)

Figures 4.2 Some macromolecules natural polymers

Synthetic polymers

Activity 4.6

Collect as many synthetic/artificial or manmade materials around you. Classify them as polymers and non-polymers. Please give a reason for your classification for yourself.

Synthetic polymers are those which are human-made polymers. Synthetic polymers are sometimes referred as "plastics", of which the well-known ones is polyethylene (Figure 4.3). It has no taste or odour and is lightweight, nontoxic and relatively cheap.

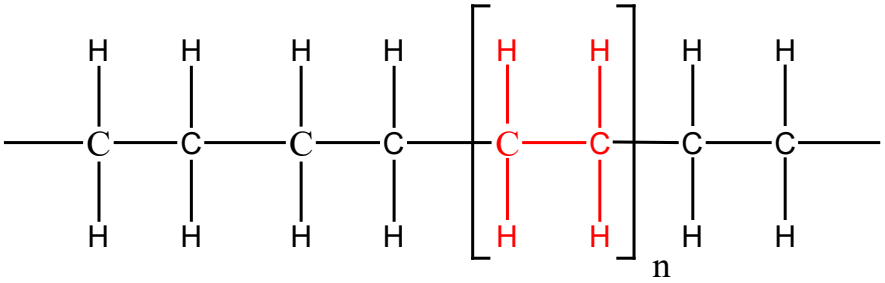


Figure 4.3: Structure of polyethylene (polyethene)

Some of its primarily uses are in making squeeze bottles, plastic wrapping, garment bags, trash bags and electrical insulation (Figure 4.4).

Polyethylene trash bags Squeeze bottle (Wash bottle) Polyethylene tube

Figure 4.4 Some polyethylene materials

Polypropylene

The monomer of polypropylene is propylene (propene) (CH_2=$CHCH_3$). It is produced by the addition polymerization of propylene.

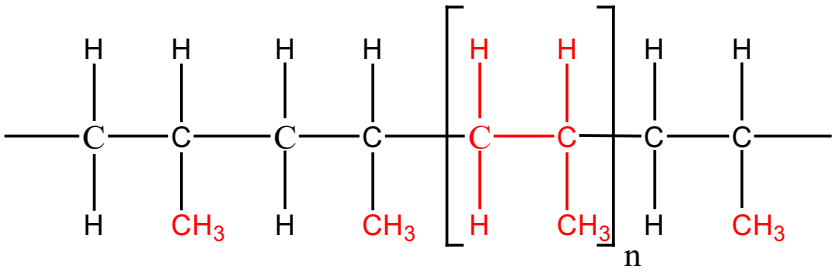


Figure 4.5 Structure of polypropylene

Polypropylene is stronger than polyethylene. It is used for making food containers that can safely be washed in a dishwasher. It can also be used for making ropes; fishing nets, carpets, and bottles (Figure 4.6).

Polypropylene rope Polypropylene carpet Polypropylene bottles

Figure 4.6 Some polypropylene products

Polyvinyl Chloride (PVC)

Polyvinyl chloride is the third most widely produced plastic, after polyethylene and polypropylene. It is prepared by the polymerization of vinyl chloride.

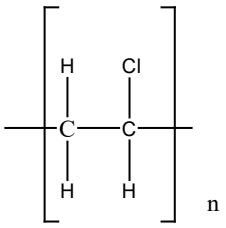


Figure 4.7 Structure of polyvinyl chloride

It is commonly used for making pipes, leather-like materials, shoes, raincoats, aprons, wallpaper, floor tile, and phonograph records.

PVC pipes PVC floor tile PVC raincoat

Figure 4.8 Some polyvinyl chloride products.

Polymethyl methacrylate (Perspex)

Polymethyl methacrylate, PMMA, is sold under the trade name Lucite or plexiglass. It is prepared by the polymerization of methyl methacrylate (CH_2=C(CH_3) $COOCH_3$.

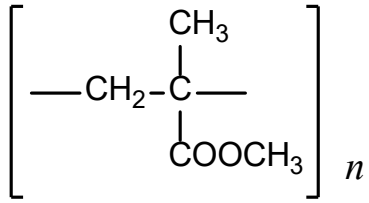


Figure 4.9 Structure of Polymethyl methacrylate

PMMA is a lightweight glass-like polymer used as a glass substitute for example, in airplane windows and streetlights.

Polytetrafluoroethylene, PTFE, Teflon

Teflon is prepared by the addition polymerization of tetrafluoroethylene (CF_2=CF_2). Teflon has good resistance to chemical attack, and it can be used at any temperature between –73 °C and 260 °C with no effect on its properties.

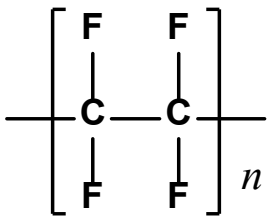


Figure 4.10 Structure of Polytetrafluoroethylene (PTFE)

It also has a very low coefficient of friction, which makes it waxy or slippery to touch. As a result, it is particularly suited to applications in food preparation. For example, bread dough does not stick to a Teflon-coated surface. Teflon is used for coating cooking utensils and for making electrical insulation **(Figure 4.11).**

Teflon coated dish Teflon tape

Figure 4.11: Some Teflon materials

One way of classification of polymers is to adopt the approach of using their response to thermal treatment and to divide them into thermoplastics and thermosets.

Thermoplastic polymers

Activity 4.7

Please, collect samples of various polymers (your collection may include: PVC, nylon, polyester, hair, cellulose etc), and heat them one by one with a flame. Observe the impact of heat upon them. Based on your observation, Classify the materials as thermosetting and thermoplastics.

Thermoplastic polymers are those which melt when heated and resolidify when cooled. They are comprised of essentially linear or lightly branched polymer molecules. They can be remelted or reprocessed (recycled). Examples of thermoplastics include: polyethylene, polypropylene, polyvinyl chloride, teflon, polymethyl methacrylate, nylon and polyester (Dacron), polystyrene (Rubber), and polyamide.

Thermoset polymers

Thermoset polymers are those which do not melt when heated, but at sufficiently high temperatures, decompose irreversibly. They are substantially cross-linked materials, consisting of an extensive three dimensional network of covalent chemical bonding. They exhibit resistance to heat, corrosion, and mechanical stress. Thermoset materials are no-recyclable.

Examples of thermoset polymers include: Bakelite, cyanate esters, epoxy resin, fibber glass (a fibber-reinforced thermoset), polyester resin, Polyurethane, Silicone resin, Vinyl esters, Vulcanized rubber.

√ CHECKLIST - 4.3

Please put a (√) in the box for the tasks you can perform or the concepts you understand

- Can you list the two classes of polymers based on the nature of monomers in which the polymer made. ☐
- Can you give examples of copolymer and homopolymer? ☐
- Can you list the two types of polymerization reaction? ☐
- Can you define clearly addition polymerization? ☐
- Can you give examples of addition polymerization reaction? ☐
- Can you define clearly condensation polymerization? ☐
- Can you give examples of condensation polymerization reaction? ☐
- Can you define clearly natural polymers? ☐
- Can you give examples of natural polymers? ☐
- Can you define clearly synthetic polymers? ☐
- Can you give examples of synthetic polymers? ☐
- Can you define thermoplastic polymers? ☐
- Can you give examples of thermoplastic polymers? ☐
- Can you define thermoset polymers? ☐
- Can you give examples of thermoset polymers? ☐

Self-Test Exercise 4.3

I. Give short and precise answer for the following Questions

1. Define each of the following terms:
   - A. monomer
   - B. polymer
   - C. homopolymer
   - D. copolymer
   - E. natural polymer
   - F. synthetic polymer (order)
2. What are some of the polymers that you encounter every day? Describe their physical properties.
3. Why do different polymers have different properties?
4. Which of the materials listed below may not be made of polymers? leather, computer keyboard, automobile body, cup, rubber, meat, mirror, plastic chairs
5. Classify each of the following polymers as natural or synthetic
   - A. Wool
   - B. Dacron
   - C. Insulin
   - D. Teflon
   - E. Cellulose (order)
   - F. Polyvinyl chloride
   - G. Bakelite
   - H. Glycogen
   - I . DNA
6. Explain the difference between thermoplastics and thermosetting polymers, using examples.

Unit Summary

- A polymer is a large molecule built up from numerous smaller molecules. These large molecules may be linear, slightly branched, or highly interconnected.
- The small molecules used as the basic building blocks for these large molecules are known as *monomers*.
- The size of a polymer molecule may be defined either by its mass or by the number of repeat units in the molecule.
- There are a number of methods of classifying polymers. These include
  - based on whether they are naturally occurring or made by man (synthetic).
  - using the types of monomers used to make the polymer to classify as *homopolymers* or *copolymers*.

- their response to thermal treatment and to divide them into thermoplastics and thermosets
- based on the nature of the chemical reactions employed in the polymerisation and to divide into *condensation* and addition polymers.

- Each of the following polymers is made by addition polymerization.
  - Polyethylene
  - Polypropylene
  - Polyvinyl chloride (PVC)
  - Polymethyl methacrylate (PMMA) ‹
  - Teflon
  - Polystyrene
  - Natural rubber
- Polymers that are synthesized by condensation polymerization are. ‹
  - Nylons
  - Polyesters
  - Bakelite
  - Carbohydrates, and
  - Proteins
- Thermoplastics soften on heating and can be molded into different shapes, and the process of heating and cooling can be repeated several times, but once thermosetting plastics are solidified they cannot be softened or remolded on heating.
- The uses of polymers include
  - in biology: the construction of structures, energy generation, physiological processing.
  - synthetic fibbers
  - building materials
  - cooking utensils
  - ropes, carets, bottles, etc.

Self-Assessment Exercise for Unit Two

Part I: Choose the best answer for the following questions among the given alternatives

1. Which of the following statement is incorrect about polymers?
   A. they are macromolecules made from smaller units.
   B. they can be prepared by either condensation or addition polymerization.
   C. most condensation polymers are homopolymers.
   D. disposing synthetic polymers999 can pollute the environment.
2. The process by which monomer units combine to form polymers, is:
   A. condensation
   B. thermoplastic
   C. thermosetting
   D. evaporation
3. What is the molar mass of a polyethylene sample, [— CH_2 —CH_2—] n, when n = 4600? (Atomic mass, H = 1 and C = 12).
   A. 1.288 ×103 g/mol
   B. 1.288 × 105 g/mol
   C. 1.196 × 103 g/mol
   D. 1.196 × 104 g/mol
4. Which one of the following is not formed by addition polymerization? a polyethylene c teflon b polyvinyl chloride d Dacron
5. Which one of the following polymer-monomer pairs is incorrectly matched?
   A. Teflon-propylene
   B. PVC-chloroethene
   C. Plexiglass-methyl methacrylate
   D. Bakelite-phenol and formaldehyde
6. Which one of the following is not a synthetic polymer?
   A. nylon
   B. cotton
   C. teflon
   D. dacron
7. Polyethylene is not used for making:
   A. squeeze bottles
   B. trash bags
   C. electrical insulation
   D. airplane windows
8. Dacron is made by the polymerization of _____ and _____.
   A. terephthalic acid, ethylene
   B. adipic acid, ethylene glycol
   C. terephthalic acid, ethylene glycol
   D. adipic acid, hexamethylene diamine

9. Which one of the following is a thermosetting plastic?
   A. polyethylene
   B. polypropylene
   C. dacron
   D. bakelite
10. Which of the following structures represents the monomer of -[-CH_2 -CH =CH-CH_2-]$_n$- ?
   A. $CH_3CH=CHCH_3$
   B. $CH_2=CH—CH=CH_2$
   C. $CH_2=CH—CH_2—CH_3$
   D. none of the above
11. A disaccharide made from two glucose units that are linked by a-1,4 glycosidic bond is:
   A. cellulose
   B. maltose
   C. lactose
   D. sucrose
12. Which one of the following disaccharide is prepared from two different monosaccharide units?
   A. Cellulose
   B. Maltose
   C. Lactose
   D. Fructos

Part II: Give Short Answer for the following Questions

1. Define each of the following terms and give an example for each:
   A. Monomer
   B. Polymer
   C. Carbohydrate
   D. Amino acid
2. Classify each of the following polymers as natural or synthetic.
   A. Polyethylene
   B. Polypropylene
   C. Cellulose
   D. Dacron
   E. Deoxyribonucleic acid
   F. Polytetrafluoroethylene
   G. Polystyrene
   H. Nylons
   I. Cotton
   J. Polyvinyl chloride
3. Classify each polymer in Question 2 as an addition polymer or a condensation polymer.
4. What functional groups are involved in the addition and condensation polymerization processes?
5. Mention major uses of each of the following synthetic polymers.
   A. Polypropylene
   B. Polyvinyl chloride
   C. Teflon
   D. Polystyrene
   E. Bakelite
   F. Nylon
6. Why are olefins (alkenes) good monomers for polymerization reactions?
7. How does the molecular-level structure of these polymers (polymers made of olefin monomers) influence their physical properties?

8. Besides the extent of branching, can you think of any other structural parameters that might lead to the differences in physical properties?
9. What kind of structural changes accompany bond-breaking and bond-forming in olefin polymerization?
10. Draw the structure of the copolymer of:
    HO–CH_2CH_2–OH and HOOC–CH_2CH_2–COOH.
11. What is the role of a catalyst?
12. Does ethylene polymerize under mild conditions in the absence of a catalyst (initiator)?

Feedback to Activities in Unit 2

Activity 4.1

1. The textile fibre of your clothes and the glass of the window are categorized as synthetic polymers whereas your hair and skin and the wood from which your desk is made up of are catogprized as natural polymer

Activity 4.2

1. Among the analogy they have knew, the following the following are the relevant one: Just as the chain is formed by the linkage of simple rings, the large molecules are formed by Chemical reaction between simple molecules
2. Train forgoes, …

Activity 4.3

1. **Homopolymer versus co-polymer:** Homopolymers are those made from one type of monomer whereas Copolymers are those prepared by polymerizing more than one kind of monomer unit.

   Condensation versus Addition polymers: Condensation polymers are those prepared from monomers where reaction is accompanied by the loss of a small molecule, usually of water whereas addition polymers are those formed by the addition reaction of an unsaturated monomer.

Natural versus synthetic polymers: Natural polymers occur in nature and can be extracted, and often referred to as *biopolymers* whereas Synthetic polymers are those which are human-made polymers. Synthetic polymers are sometimes referred as "plastics", of which the well-known ones is polyethylene.

Thermoplastic versus thermoset: Thermoplastic polymers are those which melt when heated and resolidify when cooled Whereas Thermoset polymers are those which do not melt when heated, but at sufficiently high temperatures, decompose irreversibly.

Activity 4.4

1. The challenges that arise when different types of monomers are used to synthesize a polymer:

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

Activity 4.5

1. By taking as an example starch and cellulose :

   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 **has 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.

1. The major properties of natural rubbers are:

   - Abrasion Resistance: Excellent.
   - Tear Resistance: Excellent.

- Solvent Resistance: Poor.
- Oil Resistance: Poor.
- Aging Weather/Sunlight: Poor.

2. Both wood and cotton contains a natural polymer i.e. cellulose. **Wood** contains natural polymers such as lignin, cellulose, and various hemi-celluloses but has very different properties from the synthetic polymers with which it is most often combined. **Cotton** is a polymer which is made up of cellulose. Cellulose is a carbohydrate which is also a polymer of repeated chains of glucose.
3. 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.

Activity 4.6

1. 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.

Activity 4.7

1. Nylon and polyethylene are thermoplastic polymers which melt when heated and solidify when cooled.

Answer Key for Self-test Exercise for Unit Four

Self-Test Exercise 4.1

1. The word polymer is derived from the Greek words 'poly' meaning many and 'meros' meaning part. It follows that this term applies to giant molecules built up of large numbers of interconnected repeating units.
2. The small molecules used as the basic building blocks for polymers are known as *monomers*
3. Examples of polymers are: polyethylene, wood (cellulose), protein, etc.
4. Example monomers are:
   - glucose($C_6H_{12}O_6$) a monomer for cellulose (wood)
   - ethylene a monomer for Polyethylene
   - amino acid ($NH_2CH(R)(COOH)$) a monomer for protein,

Self-Test Exercise 4.2

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. **Condensation polymerization** involves the combination of monomer molecules, with the release of simple molecules like water or methanol as by product.
3. a. $HOOCC_6H_5OOH$ and $HO(CH_2)_2OH$

   b. H_2NCH_2COOH
4. Condensation

   $-[HNCH_2(CH_2)_4CH_2NH\ COCH_2(CH_2)_6CH_2CO]-n$
5. a. $-[CCl_2-CCl_2]-_n$

   b. 530, 656

   c. % C=14.49; %Cl= 85.51

Self-Test Exercise 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 ate 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.

Answer Key for Self-Assessment Exercises of unit 4

Part I: Multiple Choices

1. C	2. D	3. B	4. D	5. A	6. B
7. D	8. C	9. D	10. B	11. B	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
   c. Natural polymer
   d. Synthetic polymer
   e. Natural polymer
   f. Synthetic polymer
   b. Synthetic polymer
   g. Synthetic polymer
   h. Synthetic polymer
   i. Natural Polymer
   j. Synthetic polymer

3. a. Addition polymer
   c. condensation polymer
   d. condensation
   e. condensation
   f. Addition
   b. Addition polymer
   g. Addition
   h. condensation
   i. condensation
   j. 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 n (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-CH_2CH_2-OOC-CH_2-CH_2-CO] $_n$-OH
11. A catalyst reduces the energy of activation for a reaction by providing an lternative 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.

UNIT 5

INTRODUCTION TO ENVIRONMENTAL CHEMISTRY

Introduction

Dear learner, from grade 12 unit three, you have learned about industrial chemistry which deals about natural resources and manufacturing of valuable products from natural resources such as nitrogen-based fertilizers, agro chemicals like pesticides and herbicides which have negative impact on the environment. So, some background in environmental chemistry should be part of the content of chemistry subject of every chemistry student. The ecologically illiterate chemist can be a very dangerous species. Chemists must be aware of the possible effects of their products and processes might have an impact on the environment. Furthermore, any serious attempt to solve environmental problems must involve the extensive use of chemicals and chemical processes.

This unit of the module mainly emphasizes on introducing the relationship between chemistry and environment.

The unit also describes the basic concepts in relation to chemistry of the atmosphere, freshwaters, oceans and soils, as well as the ways in which pollutants behave in these media (exemplified by case studies based upon topical environmental problems). It also examines the transfer of pollutants between different environmental compartments, the method of reducing environmental pollution, the ecological and human health effects of chemical pollution.

The unit is presented into four sections. The first section of this unit 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 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 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 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 industry.

Unit Outcomes

At the end of this unit, you 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 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

Unit Content

UNIT 5: INTRODUCTION TO ENVIRONMENTAL CHEMISTRY

The Required Study Time 4 weeks

If you set an average of one hour per day, you will be able to complete unit three by the end of the assigned week. Try to do all the learning activities. And compare your answers with the ones provided at the end of the Module.

If you do not get a particular exercise right in the first attempt, you should not get discouraged, but instead, go back and attempt it over and over again. If you still do not get it right after several attempts, then you should seek help from your friend or even your tutor.

Unit Learning Strategies

The suggested methodology for this unit is active learning methods such as individual study (self-study) and if you have access for internet use also visual based learning. Each section begins with activity. Please reflect on the given activities questions and check the feedback you gave whether you are correct or incorrect by referring different sources. The activity enables you to remember what you have learned in previous module or unit. Please rate the check list that are given at the end of and evaluate your-self by doing the self-test exercises given at the end of each section. Then check the answer of the self-test for each section which is attached at the end of the module in case if you did not achieve the minimum required level for each section of self- test exercise, please study the section again by taking additional study hours. Finally try to do the self-assessment and the assignment given at the end of the unit that assesses the unit learning outcomes. This enables you to evaluate yourself whether you have achieved or not the minimum required level that expected to score for the unit.

Section 5.1: Introduction

Dear Learner, in this section you will study the basic concepts related to introducing environmental chemistry for beginners that are important to understand environmental chemistry as a whole. It gives information how it deals with the origins, transport, reactions, effects and fates of chemical species in the water, air, terrestrial and living environments by taking a single pollutant species. You also learn about components of the environment, natural cycles in the environment and then end up with studying fundamental concepts that are used to explain environmental chemistry.

Objective

At the end of this section, you 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 component of the environment
- explain how the important reaction take place in each component of the environment
- describe the cycle of hydrological, carbon, nitrogen, oxygen, sulfur and phosphorus
- explain how the cycle of hydrological, carbon, nitrogen, oxygen, sulfur and phosphorus occurred in the environment

Acivity 5.1

Please look at and reflect on the following questions

1. "What do you" understand from the term Environmental Chemistry?
2. Take CO_2 as an example of a typical pollutant, and describe its interaction with ecosystem and eventually its fate in the environment.

Environmental chemistry is 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 thereon.

A common pollutant species is used to illustrate the definition of environmental chemistry. Sulfur in coal is oxidized to sulfur dioxide gas, which is then released into the atmosphere. Sulfur dioxide gas can be oxidized to sulfur trioxide and eventually converted to sulfuric acid in the atmospheric, then fall back to earth as acid rain, affect a receptor like plants, and end up in a "sink" like a body of water or soil. Figure 5.1 shows a simplified schematic diagram that shown fate of pollutant species in the environment.

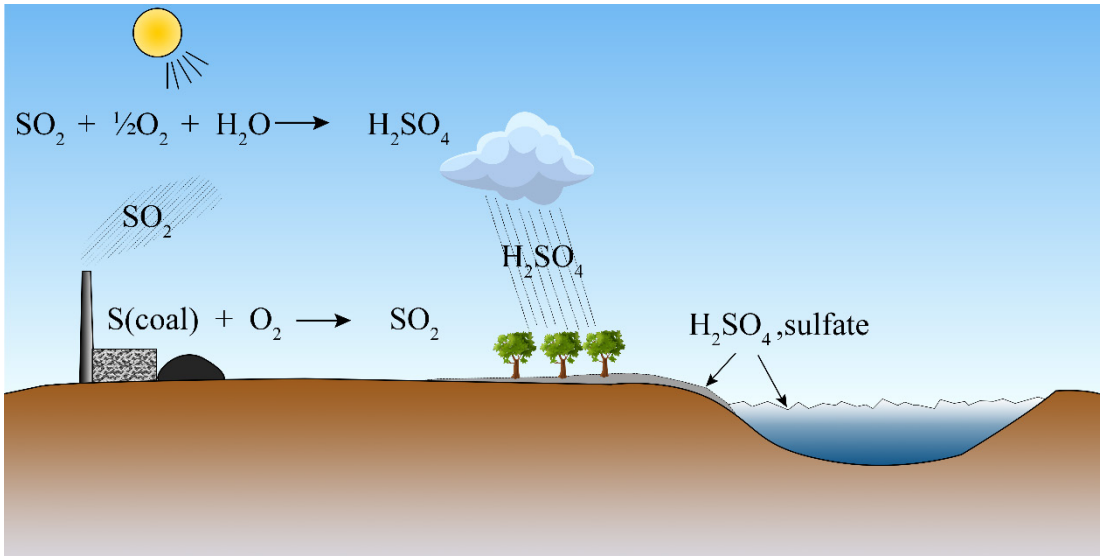


Figure 5.1 Simplified schematic diagram that shown fate of pollutant species in the environment.

5.1.1 Components of the Environment

? What portion of the environment's component is included in the hydrosphere?

The environment consists of various compartments, including: atmosphere, hydrosphere, lithosphere and biosphere. Figure 5.2 shows the four components of the environment.

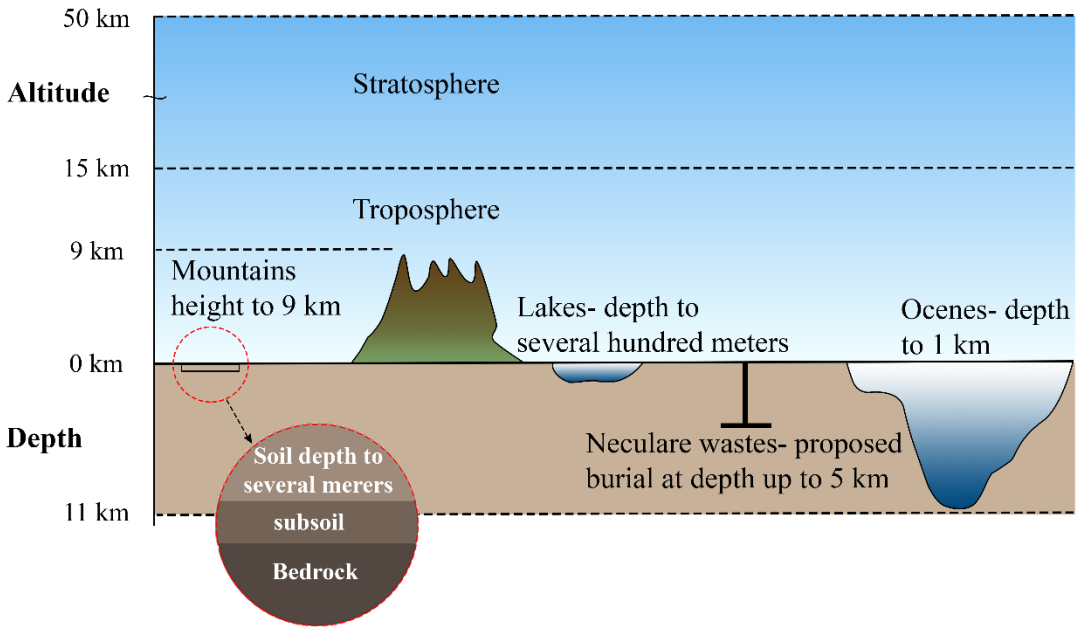


Figure 5.2 Components of the environment (atmosphere, hydrosphere, litho-sphere & Biosphere)

Atmosphere

One of the main components of Earth's interdependent physical systems is the atmosphere. An atmosphere is the layers of gases surrounding a planet or other celestial body. Earth's atmosphere is composed of about 78% nitrogen, 21% oxygen, and one percent other gases.

In general, the atmosphere provides many benefits to earth's living organism including human being: such as protective blanket of gas surrounding the earth (0 – 50 km), absorbs infrared (IR) radiation emitted by the sun and re-emitted from the earth, controls temperature of the earth, allows transmission of significant amounts of radiation from near UV (300 nm) to near IR (2500 nm) and blocks transmission of damaging UV radiation.

For example, the following important reactions occurred in the atmosphere:

I. Nitric oxide is oxidized by oxygen to nitrogen dioxide in the presence of ultraviolet light.

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

SO_2, SO_3 and NO_2 react with rainwater and form sulphurous acid (H_2SO_3), sulphuric acid (H_2SO_4) and nitric acid (HNO_3), respectively and cause acid rain.

II. Chlorofluorocarbons are used as refrigerants, solvents and plastic foam-blowing agents. When entering the atmosphere, they penetrate into the upper layers and interact with ultraviolet radiation as follows.

$$CF_2Cl_2 + UV \rightarrow CF_2Cl^{\cdot} + Cl^{\cdot}$$

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

$$Cl^{\cdot} + O_3 \rightarrow ClO^{\cdot} + O_2$$

Hydrosphere

"The hydrosphere is the combined mass of water found on, under, and above the surface of the earth". The hydrosphere 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. Only ~1% of global water supply is fresh water. Whereas, the greatest source of water on the planet is the ocean, which constitutes all salt water and at the same time, is the greatest source of water vapor. In the ocean, there are at least 77 important elements such as sodium and chlorine, magnesium and bromine, which are commercially exploited from seawater.

Some examples of chemical reaction in hydrosphere:

I. Ammonia (NH_3)/ammonium (NH_4^+) that discharged from agriculture, aquaculture, industry and urban area into large water bodies result in toxicity to fish or aquatic ecosystem.

- For example, the biological oxidation of NH_4^+ to nitrite and then nitrate is a key part of the complex nitrogen cycle and a fundamental process in aquatic environments, having a profound influence on ecosystem stability and functionality.

Nitrate (NO_3^-)/Nitrite (NO_2^-) that discharged from agriculture, industry, aquaculture and sewage into water bodies result in accelerating aquatic plant growth leading to eutrophication.

- For example, the organic form of nitrogen, ammonia, has been converted into an inorganic form of nitrogen, nitrate that plants can use. The chemical equation:

  $$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$$

  The equation shows the entire nitrification process.

Lithosphere

The lithosphere consists of earth's crust and upper mantle in which the crust part is the Earth's outer skin that is accessible to humans being. This part of the earth i.e., the crust consists of rocks and soil (most important part to humans and the environment). Some examples of important reaction in the lithosphere are:

II. Different bacteria (mainly autotrophic, i.e., not dependent on organic material for their carbon supply) can affect oxidation or reductions of minerals.

$$2FeCO_3 + \frac{1}{2}O_2 + 3H_2O \xrightarrow{Ferrobacilha} 2Fe(OH)_3 + 2CO_2$$

III. Chemical weathering of rocks:

$$Fe_2O_3 + 3H_2O \rightarrow Fe_2O_3 \cdot 3H_2O$$ (Hydration of rocks)

Biosphere

It refers to the realm of living organisms and their interactions with the environment (i.e. other compartments). This compartment divided into smaller units called **ecosystems.** Each ecosystem contains dynamic interrelationships between living forms and their physical environment. These interrelations manifest as natural cycles, such as hydrologic, oxygen, nitrogen, phosphorous and sulfur. The natural cycles operate in a balanced manner providing a continuous circulation of essential constituents. Examples of some important reaction in the biosphere:

I. Photosynthesis:

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

II. Respiration:

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{Yields} 6CO_2 + 6H_2O + Heat\ energy$$

5.1.2 Natural Cycles in the Environment

Acivity 5.2

Please look at and reflect on the following questions

1. In the oxygen cycle, what is the role of photosynthesis from the environment perspective?
2. What is the nitrogen cycle and why it is Key to Life?

Within the environment, natural cycles serve to continuously circulate constituents essential to life and other processes on earth. Among the common natural cycles: hydrologic cycle, oxygen cycle, nitrogen cycle, phosphorous cycle, sulfur cycle and carbon cycle are the important ones.

The Hydrologic Cycle

Hydrologic cycle is arguably the most important natural cycle. In this 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.

Photosynthesis is the process by which plants use sunlight, water, and carbon dioxide to produce oxygen and energy in the form of sugar.

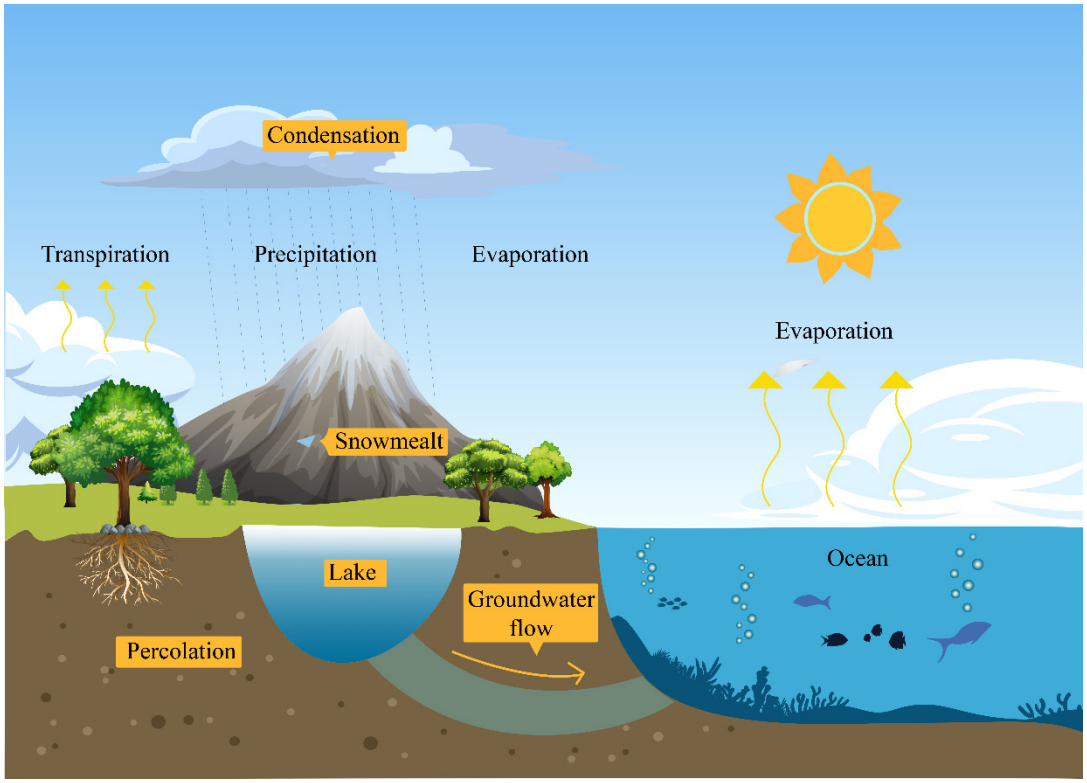


Figure 5.3 The hydrological cycle (water cycle)

The Oxygen Cycle

The oxygen cycle is the important cycle in the environment. Important to atmospheric chemistry, geochemical transformation and life processes. The following reactions show the importance of the oxygen cycle in the environment. For:

- Energy production

$$CH_4 + 2O_2 \xrightarrow{Yields} CO_2 + 2H_2O + Heat\ energy$$

- Degradation of organic material (taking example of glucose)

$$CH_2O + O_2 \xrightarrow{Yields} CO_2 + H_2O$$

- Weathering of minerals

$$4FeO + O_2 \xrightarrow{Yields} 2FeO_3$$

- Photosynthesis

$$CO_2 + H_2O \xrightarrow{Yields} CH_2O + O_2$$

- Sun screen (O_3)

$$'O' + O_2 \xrightarrow{Yields} O_3$$

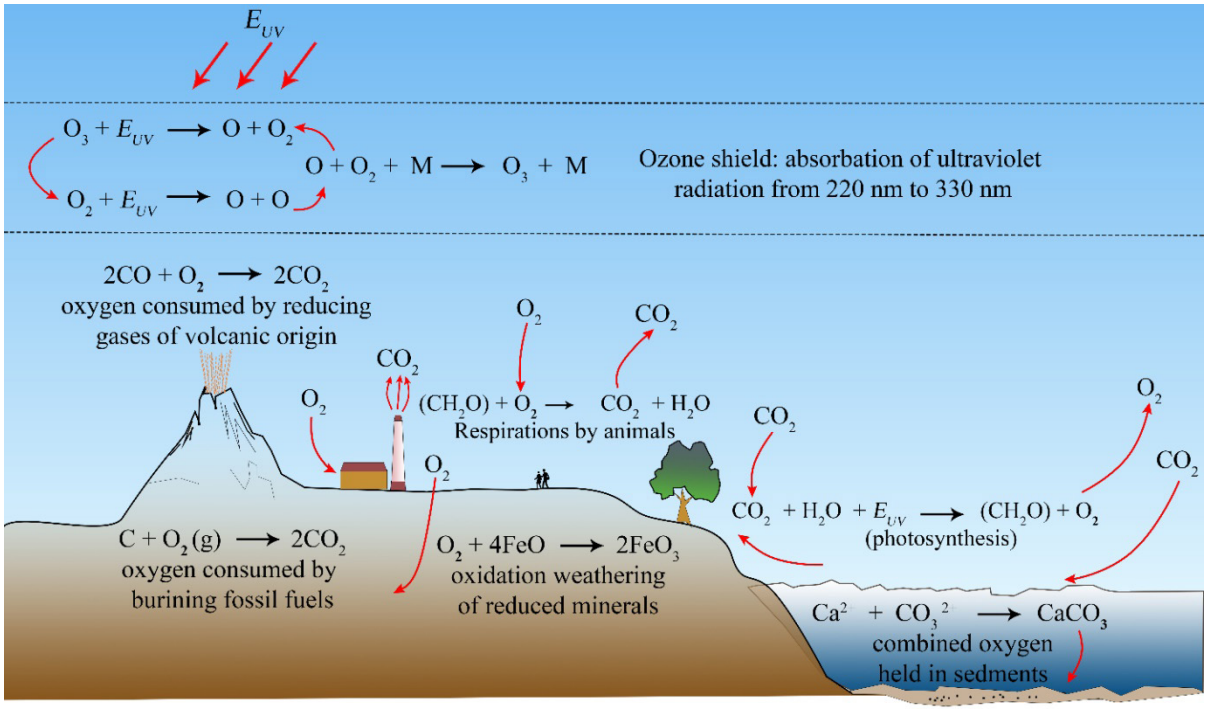


Figure 5.4 The oxygen cycle

The Nitrogen Cycle

The nitrogen cycle is arguably the second most important cycle, after the carbon cycle, to living organisms. Nitrogen is essential to plant growth, and therefore is a significant contributor to the human food chain, but its presence in the environment is strongly influenced by anthropogenic activities. The following are the important reaction of nitrogen cycle in the environment:

- Fixation by bacteria and algae:

$$2N_2 + 3CH_2O + 3H_2O + 4H^+ \xrightarrow{yields} 3CO_2 + 4NH_4^+$$

- Nitrification by nitrosomas and nitrobacteria:

$$2O_2 + 3NH_4^+ \xrightarrow{Yields} NO_3^- + 2H^+ + H_2O$$

- Nitrate reduction by microbial action:

$$2NO_3^- + CH_2O \xrightarrow{Yields} 2NO_2^- + H_2O + CO_2$$

$$2NO_2^- + 3(CH_2O) + 4H^+ \xrightarrow{Yields} 2NH_4^+ + H_2O + 3CO_2$$

- Denitrification returns N to the atmosphere:

$$2NO_3^- + 5(CH_2O) + 4H^+ \xrightarrow{Yields} 2N_2 + 7H_2O + 5CO_2$$

- Perturbed by anthropogenic activity:

$$N_2 + O_2 + \ldots \xrightarrow{Yields} (combustion)\, NO_X + \ldots$$

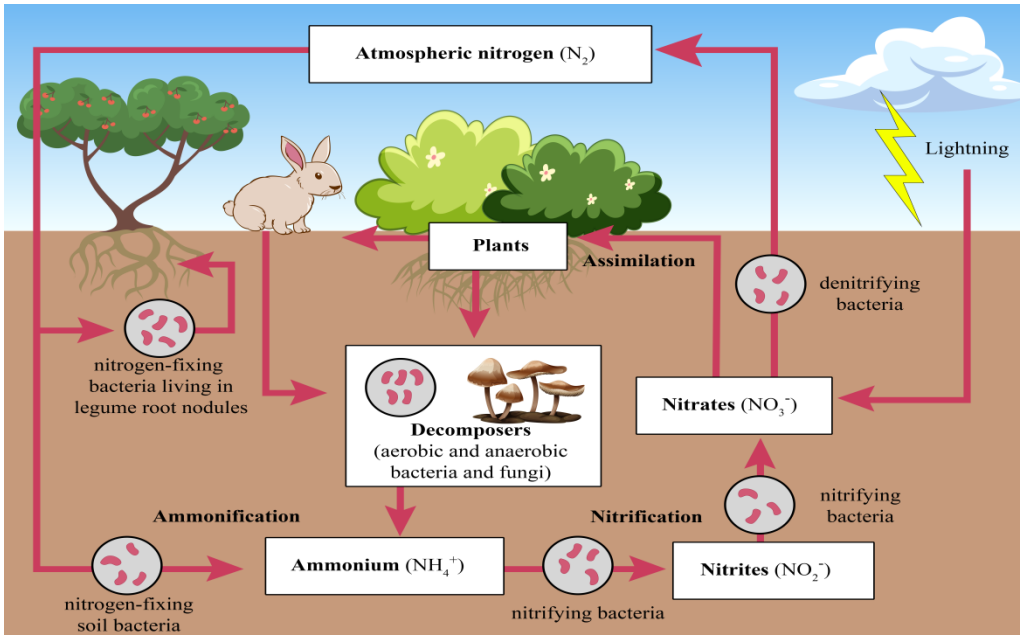


Figure 5.5 The Nitrogen cycle

The Phosphorous cycle

The phosphorus cycle is responsible for increasing the availability of phosphorus in the soil for plant growth and soil fertility. Understanding the mechanism of the phosphorus cycle helps to understand the physiology of different microorganisms involved in the process.

1. Central to many processes, including
   a) Cell division involving production of DNA and RNA
   b) Growth/maintenance of animal bones and teeth
2. Sources include
   a) Inorganic phosphorous, such as soluble $H_2PO_4^-$, $HPO_4^{-2}$and insoluble $Ca_5(OH)(PO_4)_3$ and $Fe_3(PO_4)_2 \bullet 8H_2O$
   b) Terrestrial plants convert inorganic phosphate salts to organic phosphate
3. Animals obtain phosphate by eating plants
4. Upon death, phosphorus is returned to soil
5. Soil microorganisms convert returned phosphate into soluble inorganic phosphate (mineralization)
6. In water, phosphors solubility is controlled by availability of Fe and Al (under acidic conditions) and Ca (under basic conditions

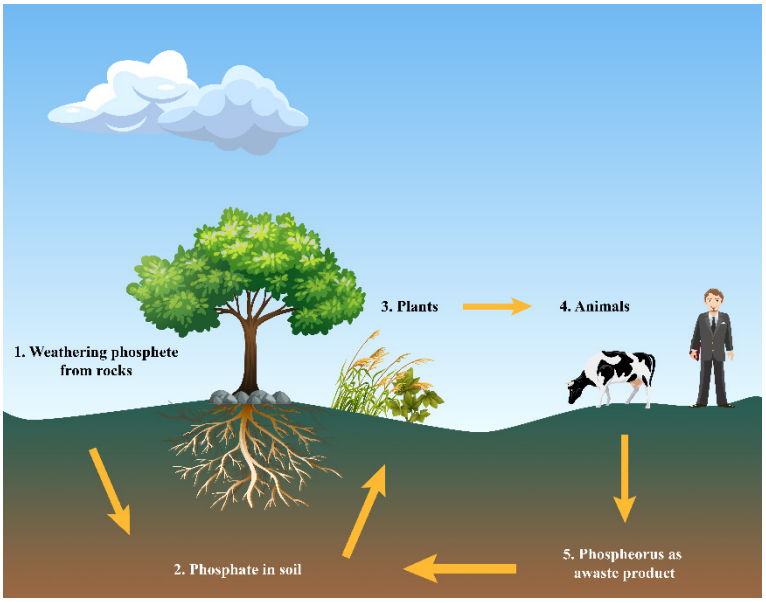


Figure 5.6 The phosphorus Cycle

The Sulphur Cycle

The sulphur cycle is essential as it balances the concentration of sulfur in different reservoirs so as to make the Earth a hospitable place for life. Sulfur cycle show the circulation of sulphur in various forms through nature. Sulphur occurs in all living matter as a component of certain amino acids. It is abundant in the soil in proteins and, through a series of microbial transformations, ends up as sulfates usable by plants. The following are importance of sulphur cycle in the environment.

- Atmospheric oxidation produces higher charge states
- In hydrosphere and soil, S is present in many inorganic and organic forms with oxidation states from -2 to +6
- Most common forms of S include
  - Sulfate (SO_4^{2-}), produced via a variety of pathways (e.g., bacterial):
    $2H_2S + 4O_2 \rightarrow 4H^+ + 2SO_4^{2-}$
  - Sulfide (S^{2-}), produced by reduction of sulfate in organic rich reducing aqueous environments:
    $SO_4^{2-} + 2CH_2O + H^+ \rightarrow H_2S + 2H_2O + 2CO_2$

The Carbon Cycle

The Earth's atmosphere contains 0.035% carbon dioxide (CO2), and the biological environment depends upon plants to convert carbon dioxide into sugars, proteins and fats.

As shown in Figure 5.7, green plants convert atmospheric carbon dioxide and water into glucose and oxygen in a process called photosynthesis.

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g); \triangle H = +2803\ kJ\ mol^{-1}$$

Photosynthesis is an endothermic reaction. Solar energy from the sun provides the necessary energy for the above reaction to proceed.

Animals (including humans) eat plants, or eat other animals that have eaten plants, and incorporate the plants' carbon atoms into their cells.

Carbon returns to the physical environment in a number of ways. Both plants and animals respire, and they release carbon dioxide during respiration.

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l); \triangle H = -2803\ kJ\ mol^{-1}$$

Respiration is an exothermic reaction, releasing 2803 kJ/mol of energy.

The process of decomposition of organic matter also releases carbon dioxide back into the atmosphere.

Over a very long period of time, dead organisms under high pressure and in the absence of air can be converted into fossil fuels such as **coal, oil and gas.** Human's combust these fossil fuels as energy sources which releases carbon dioxide back into the atmosphere. The complete combustion of coal, oil, or natural gas results in the formation of carbon dioxide gas:

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

The combustion of fossil fuels is exothermic, and therefore, releases energy in the form of heat.

According to law of conservation of mass, the total number of carbon atoms (in the atmosphere) is always constant; but there is a growing concern over the amount of carbon that exists as carbon dioxide, because

carbon dioxide is a greenhouse gas and is a major contributor to global warming.

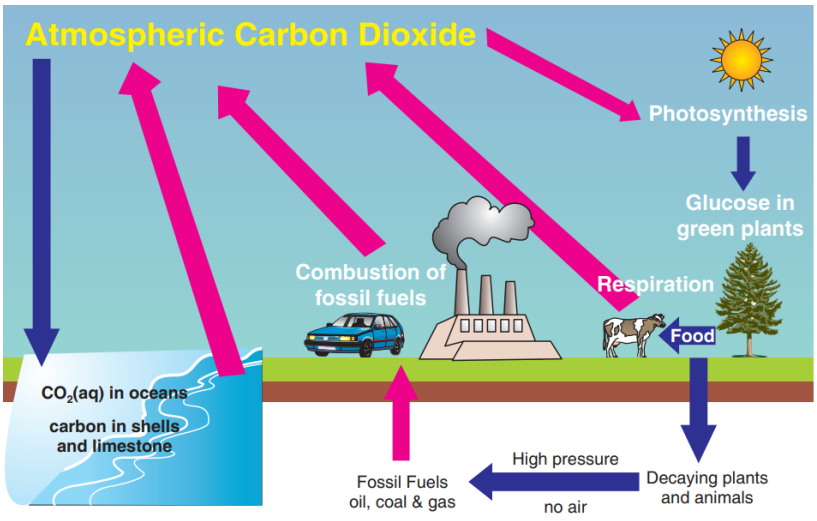


Figure 5.7 Carbon cycle

5.1.3 Concepts Related to Environmental Chemistry

Acivity 5.3

What is the relationship between pollutant and Environmental pollution? And what criteria should be considered to level the environment is polluted? Reflect on this concept.

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.

Contaminant: - A substance that does not occur in nature, but it is introduced into the environment through human activity. A contaminant is called a pollutant when it exerts detrimental effects on human health receptor. Examples include bodies of water, humans, trees, animals and fish.

Sink: - The medium that interacts and retains pollutants or converts them chemically

Dissolved Oxygen (DO): - Oxygen dissolved in water. It is vital for aquatic life. The optimum levels of DO in good quality water are 4 – 8 mg L^{-1}. Whereas water with levels < 4 mg L^{-1} is considered polluted and unfit for human or animal consumption.

Biological Oxygen Demand (BOD): - Indicates 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.

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

√ CHECKLIST 5.1

Please put (√) in the box for the tasks you can perform or the concepts you understand

- Can you define environmental chemistry? ☐
- Can you list the four components of the environment? ☐
- Can you describe briefly the four components of the environment? ☐
- Can you describe the hydrological, oxygen, nitrogen, carbon, pho phorus and sulphur cycles in the environment? ☐
- Can you write the important chemical reactions takes place the h drological, oxygen, nitrogen, carbon, phosphorus and sulphur cycles in the environment? ☐
- Can you define the following terms: ☐
  - Pollutant: ☐
  - Contaminant: ☐
  - Sink ☐
  - Dissolved Oxygen (DO ☐
  - Threshold Limit Value (TLV) and ☐
  - Biological Oxygen Demand (BOD) ☐

Self-Test Exercise 5.1

Give Short Answer for the following questions

1. What part of environment does the hydrosphere components include? Give examples.
2. In oxygen cycle the two important reactions are degradation of organic material and photosynthesis could express these two important reactions in terms of chemical equation.
3. Write the equation that express Nitrogen fixation by bacteria and algae?
4. Define pollutant and give examples of pollutants.
5. What is Threshold Limit Value (TLV)?

Section 5.2: Environmental Pollution

Dear Learner, in this section you will learn about environmental pollution which is the major problem of the globe at present. It examines the transfer of pollutants between different environmental compartments. It will discuss types of pollution, pollutants of air, water and land, the impact of pollutions i.e., the ecological and human health effects of chemical pollution and its cause, finally it ends up the methods of reducing pollution.

Objective

At the end of this section, you 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 and
- recommend method of preventing pollution caused by over use of fertilizers

Acivity 5.4

Look at the following questions and reflect your opinion

1. Ethiopia's 2015 Climate Commitment Sets a High Bar for National Climate Action. What was this climate commitment to be taken by Ethiopia?
2. The Copenhagen summit was a popular international climate change summit. What was the role played by Ethiopia? What were the major issues of the summit?
3. Mention any activity in your area to bring awareness of air pollution and global warming.

Dear learner, did you know about pollution before this lesson?

Pollution is any discharge of a solid, liquid or gaseous substance or radiation (energy) into an environment that causes unwanted changes. Pollution causes short-term or long-term harm that affects the earth's ecological balance and lowers the quality of life in the environment. A pollutant is any substance that changes air, water or any other natural resource in a way that impairs the use of the resource. Pollutants are discharged into the environment as a result of natural events (like a volcanic eruption) and as a result of human activities (such as the operation of chemical industries, agriculture, etc.). Pollutants can be classified by the type of pollution they cause: air pollution, water pollution, and land pollution.

Pollution is any discharge of a solid, liquid or gaseous substance or radiation (energy) into an environment that causes unwanted changes.

A pollutant is any substance that changes air, water or any other natural resource in a way that impairs the use of the resource

5.2.1 Air Pollution

Acivity 5.5

1. Based on the situation of your locality, please reflect on the following issues.
   a) Explore some human activities which contribute to air pollution.
   b) How do these activities contribute to air pollution?
   c) What solutions do you recommend to overcome these Problems?
   d) What could be your contribution to reduce air pollutions?
2. Give your suggestions on the statement, 'Air pollution anywhere is a potential threat elsewhere.

Dear learner, how does air polluted?

Atmosphere is considered as solution. Several different gases make up our atmosphere (Table 5.2.1). Because N_2 (g) is a molecule present in greatest amount in the atmosphere, N_2 is the "solvent" in our atmospheric "solution". The solute present in largest amount is O_2 (g), but certainly there are many others.

Table 5.2.1 Gases Present in atmosphere

Name	Percent by volume
Nitrogen	78%
Oxygen	20.95 %
Argon	0.93%
Gaseous water	0 .08 %
Carbon dioxide	0.04% and increasing

Air pollution is caused by the presence of contaminant gaseous substances in the air that affect the lives of plants and animals on earth. Some common air pollutants are sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, hydrocarbons, particulates, chlorofluorocarbons (CFCs), and lead compounds.

Sulphur dioxide (SO_2):- This enters the atmospheric air from the combustion of coal and petroleum, and during extraction of metals from their sulphide ores. It causes coughing, chest pains and shortness of breath. It is thought to be a cause for bronchitis and lung diseases. It slowly oxidizes to SO_3 by reacting with the oxygen in the air.

Oxides of nitrogen: - These can be formed in the atmosphere by natural processes like **thunderstorms.** Combustion of fossil fuel containing nitrogen compounds as impurities and exhaust gases from furnaces and engines increase the amount of nitric oxide, NO, and nitrogen dioxide, NO_2, in the atmosphere. Nitric oxide, NO, catalyzes the decomposition of ozone in the upper layer of the atmosphere to oxygen, thus decreasing the ozone layer:

$$2O_3(g) \xrightarrow{NO} 3O_2(g)$$

Nitric oxide is oxidized by oxygen to nitrogen dioxide in the presence of ultraviolet light:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

SO_2, SO_3 and NO_2 react with rainwater and form sulphurous acid (H_2SO_3), sulphuric acid (H_2SO_4) and nitric acid (HNO_3), respectively and cause acid rain. Acid rain accelerates corrosion and the deterioration of metals, buildings, statues and also causes tree defoliation, release of heavy metal ions from soil into water courses and drop in the pH of water in rivers and lakes.

Hydrocarbons and ozone are responsible for photochemical smog. It is characterized by a reddish-brown haze containing substances irritating to the eye, nose, and lungs, and causes extensive damage to vegetation. Considerable amounts of hydrocarbons are released into the atmosphere by the evaporation of gasoline as un burnt hydrocarbons in auto exhaust. These substances react with ozone to give compounds that contribute to the oxidizing nature of photochemical smog.

Carbon monoxide:- Most of the carbon monoxide escapes into the atmosphere due to the incomplete combustion of fuel. Prolonged exposure to carbon monoxide impairs vision, produces headaches, and exerts strain on the heart. It also reduces the oxygen-carrying capacity of the blood by reacting with hemoglobin.

Particulates: - Dust storms, forest fires, volcanic eruptions and human activities such as mining and burning coal and oil increase the amount of solid particles in the air. Industrial areas contain particles of limestone, fertilizers, coal, stones, cement and silica. These particulates irritate the lungs and deleteriously affect breathing.

Chlorofluorocarbons (CFCs): - Chlorofluorocarbons are used as refrigerants, solvents and plastic foam-blowing agents. When entering the atmosphere, they penetrate into the upper layers and interact with ultraviolet radiation as follows:

$$CF_2Cl_2 \xrightarrow{UV} CF_2Cl\bullet + Cl\bullet$$

The free chlorine, Cl, reacts with ozone to form chlorine monoxide and oxygen:

$$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$$

These reactions result in the conversion of ozone to molecular oxygen and contribute to depletion of the ozone layer. This situation in the upper atmosphere allows dangerous ultraviolet radiation to reach the earth's surface. This radiation causes skin cancer in human beings.

Volatile Organic Compounds (VOCs):- These are compounds that can easily become gas or vapor. They are mostly released from the burning of gasoline, wood, natural gas, and coal. Other sources of VOCs include thinners and paints, cigarettes, solvents, wood preservatives, air fresheners, furnishings, copy machines and printers, cleaners, pesticides, and disinfectants.

PCBs (polychlorinated biphenyls):- These are organic chlorine compounds that were at one point extensively used as coolant fluids and dielectric in electrical gadgets, in heat transfer fluids, and in carbonless copy papers.

Excess carbon dioxide: - The combustion of coal and petroleum to generate electricity, move our vehicles, heat our homes and supply power to our industrial machinery causes a significant increase in the concentration of carbon dioxide in the atmosphere. Combustion of these fuels releases about 20 billion tonnes of CO_2 annually. The increase in the concentration of CO_2 in the atmosphere has resulted in a rise in the average global temperature, owing to the greenhouse effect. Carbon dioxide and water vapour absorb infrared radiation, re-radiated from the earth, behaving like the glass in a greenhouse. Since CO_2 and water vapor absorb heat they are called green-house gases. Due to the absorption of heat by the greenhouse gases in the atmosphere, the overall effect is global warming (an increase in the average temperature of our planet). This rise in global temperature causes melting of polar ice and thus additional water flowing into the oceans. This situation, in turn, results in the rising of the levels of seas and oceans, flooding of coastlines and lowland areas, which can submerge these areas.

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.

What are the potential air pollutants in and around your home?

Methods of Reducing Air Pollution

Acivity 5.6

Answer the following questions

1. Name the major air pollutants.
2. What methods do you recommend to reduce air pollution which is different from the methods listed below?

The following are some of the ways to reduce 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
- Implement Afforestation
- Avoid using of products with chemicals
- Avoid usage of crackers

5.2.2 Water Pollution

Acivity 5.7

1. In your community,

   a) What are the major sources of drinking water?

   b) What are the principal sources of contamination of surface water and ground water?

   c) What could be done to reduce these problems? Please reflect on the above issues?

Dear learner, what is water pollution? Water pollution is the degradation of the quality of water brought by the discharge of untreated sewage, industrial and agricultural waste, and oil spillage. In general, water is said to be polluted if it contains matter that affects the health of living things or causes damage to property. 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. Phosphate and nitrate fertilizers washed out of the soil and phosphate detergents from untreated water, enter natural water systems, such as streams, rivers, lakes, and seas. These dissolved minerals are valuable nutrients for plants, and their discharge into the water systems accelerates the growth of surface-water plants, such as algae. As a result, less light reaches the bottom-living plants, which reduces the photosynthesis they need to live, and they die. When these aquatic plants die, they rot under the action of bacteria which multiply greatly and consume the oxygen dissolved in the water at a rate faster than natural aeration or photosynthesis can replenish. Thus, the amount of oxygen in the water decreases. This depletion of oxygen kills aquatic animals like fish. This sequence of events is called eutrophication. Examples of some of the water pollutant and their descriptions: -

Domestic sewage: Domestic sewage is also a major source of plant nutrients, mainly nitrates and phosphates. Excess nitrates and phosphates in water promote the growth of algae, sometimes causing unusually dense and rapid growths known as algal blooms. When the algae die, oxygen dissolved in the water declines because microorganisms use oxygen to digest algae during the process of decomposition.

Solid waste: The improper disposal of solid waste is a major source of water pollution. Solid waste includes garbage, rubbish, electronic waste, trash, and construction and demolition waste, all of which are generated by individual, residential, commercial, institutional, and industrial activities.

Fertilizers: - causes water pollution from excessive amounts of nitrates and phosphate washed out from food and animal waste as well as inorganic fertilizers.

Insecticides (pesticides) and herbicides: Insecticides (pesticides) and herbicides are applied in agriculture may also be washed into lakes, rivers, streams and seas. Some of the insecticides and herbicides do not decompose easily and are persistent in the environment.

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.

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.

5.2.3 Land Pollution

Acivity 5.8

Please attempt on the following questions

1. Explain the causes of land pollution in your environment?
2. What are the three major things you believe elected officials should take to decrease soil erosion in the region you live?
3. What should be your responsibility in solving the land pollution problems?

Dear learner, is land polluted? How? Land pollution is caused by things we put into it. It results from the spillage of oil, leaching of harmful chemicals and heavy metal ions, and dumping of non-biodegradable wastes such as plastics.

Causes of Land Pollution

- Spillages of oil from leaking pipelines.
- Harmful heavy metal ions from buried waste leaching into water systems.
- Leaching of harmful chemicals from corroded metal drums which have been buried underground.
- Dumping of non-biodegradable (do not decompose by the action of bacteria) wastes like plastics which remain unchanged in the soil for decades or hundreds of years. Their accumulation in the soil hinders air and water movement and affects the growth of plants.
- Excessive use of synthetic fertilizers in agricultural activities also contributes towards land pollution.

What are the contributions of commercial inorganic fertilizers to land pollution?

Some of the pollutants that cause land pollution and their description:

Garbage: This is one of the significant land pollution causes. In every household, we will find garbage. Tons and tons of garbage are produced by typical and domestic households annually. When that massive amount gets generated, the disposal of it falls short. Consequently, all this garbage gets dumped onto the land. This land of disposal is known as a landfill.

Plastic: This is one of the most common environmental pollutants and bears one of the greatest impacts. The abundance of plastics in the world even led to the coining of the term "plastic pollution."

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.

Methods of Reducing Land Pollution

Acivity 5.9

Please reflect on the following questions

1. What methods should be practiced to reduce land pollution in Ethiopia?
2. Propose the potential safe methods of disposing non-biodegradable wastes?

When we deal about methods of reducing land pollution, we deal especially with reducing non-biodegradable wastes. This is because non-biodegradable wastes cannot be broken down by decomposers as a result their disposal poses a big problem. Non-biodegradable waste is a major source of soil, air, and water pollution. Besides, it's cited as the primary cause of serious diseases such as cancer. The following are examples of non-biodegradable waste: glass, medical waste, Plastic, man-made synthetic materials, electronic components, cans, nuclear waste, man-made polymer and artificial rubber.

CHECKLIST - 5.2

Please put (√) in the box for the tasks you can perform or the concepts you understand

- Can you explain the term environmental pollution? ☐
- Can you list three types of environmental pollution? ☐
- Can you describe briefly air, water and land pollution? ☐
- Can you list the causes of air, water and land pollution? ☐
- Can you give examples of air, water and land pollution? ☐
- Can you describe the impacts of air, water and land pollution?
- Can you describe the methods of reducing of air, water and land pollution? ☐

Self-Test Exercise 5.2

Give short Answer For the Following Questions

1. Describe the main agents of:
   a. air pollution b. water pollution c. land pollution
2. What are the impacts/effects of:
   a. air pollution b. water pollution c. land pollution
3. What are the main methods of reducing:
   a. air pollution b. water pollution c. land pollution
4. Describe the potential method of preventing pollution caused by over use of fertilizers
5. Are pollutants of land can cause air pollution and water pollution? Take one example and show its interdependence

Section 5.3: Global Warming and Climate Change

Dear Learner, in this section, you will learn the role of several chemical reaction that occur in the atmosphere, as well as direct emissions of some greenhouse gases into the atmosphere which cause to global warming. In general, the relationship between chemistry and climate change will be explored under two headings: global warming and climate change from the standpoint of chemistry, and greenhouse gas chemistry and its impacts on climate change. In short, this section emphasis about global warming and climate change from the perspective of chemistry by prioritizing the greenhouse gases and their effects.

Objective

At the end of this section, you 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

5.3.1 Global Warming and Climate Change

Acivity 5.10

Please look at the following questions and reflect on each.

1. The role of industrial byproducts to global warming.
2. Types of activities which are carried out in your surrounding that contribute to global warming.
3. In recent years in Ethiopia, the green legacy has been practiced in the country. What is the relationship between the green legacy, Global warming and climate change. What other methods used to capture CO_2 from the atmosphere.

Why chemistry is so important in the fight against 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. Data in our hands reveals the existence of a global warming process and urgent actions are needed before dramatic and irreversible (on a human scale) climate changes could take place. The emission of certain substances to the atmosphere produces a greenhouse effect contributing to the global warming. Even if their origin is diverse, many of these emitted gases or substances resulted from:

- Certain type of chemical reaction mainly from combustion of fuel:

$$C_X H_Y + O_2 \rightarrow CO_2 + H_2O + heat\ energy$$

Where X and Y are carbon and hydrogen number of hydrocarbon compound.

- Some of them may be manufactured products like CIFCs, solvents and volatile organic compounds.
- Some of them have a natural origin, as it is the case of methane generated by living organisms, in particular in the oceans.
- In other cases, however, they are associated with human activities. The most well-known is carbon dioxide (CO_2) and its increasing content in the atmosphere is mainly associated with the combustion of fossil fuels.

According to data from the US Department of Energy, global emissions of carbon dioxide resulting from combustion of fossil fuels increased by larger than 10 factor since 1900. A variety of other gases 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.

5.3.2 Chemistry of Greenhouses Gasses and their effects on Climate change

Acivity 5.11

Please reflect on the following questions

1. Mechanism in which the greenhouse gases increase average earth's temperature.
2. Reactions of gases occurred in the atmosphere that contributes for global warming?

Greenhouse Effect

Dear learner, what do you know about greenhouse gas and its effect on the environment?

The greenhouse effect happens when certain gases, which are known as greenhouse gases, accumulate in Earth's atmosphere. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), water vapor (H_2O) and fluorinated gases. These gases warm our planet by absorbing infrared (IR) light radiation that would otherwise escape into space. Without this warming effect (called the greenhouse effect), the average temperature on Earth would be a chilly 255 K (that's -18 °C, or the temperature on an extremely cold winter day). Because these greenhouse gases in our atmosphere absorb IR light, Earth's average temperature is 288 K (that's 15 °C, about the temperature on a slightly cool spring day). Thus, Earth is 33 K warmer than what would be expected if there was no the greenhouse effect.

For example, $CO_{2(g)}$ 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. On the other hand, 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.

The greenhouse effect happens when certain gases, which are known as greenhouse gases, accumulate in Earth's atmosphere. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), water vapor (H_2O) and fluorinated gases.

Contribution of Greenhouses Gases for Global warming

Do you know which greenhouse gases that human produce has the most impact on global warming?

Not all have the same effect, nor do they come from the same sources, and in the same way each lasts for a different time in the atmosphere. Other variables such as the formation of water of anthropogenic origin and black carbon in snow for their lesser effect are excluded. There are five gases of human origin that contribute most – together up to 95% of the total – to the increase in global warming. Here you will discover the source of their emission, the time they spend in the atmosphere and what percentage they contribute to the greenhouse effect in the following table.

Table 5.3.1 Sources, atmospheric life time and percentage of contribution of greenhouse gases

Greenhouse gas	The sources of their emission	Time spent in atmosphere	%stage of contribution to global warming
Greenhouse gas	**The sources of their emission**	**Time spent in atmosphere**	**%stage of contribution to global warming**
Carbon dioxide	Result of processes such as fuel use, deforestation and production of cement and other materials.	80% lasts for 200 years and the other 20% can take up to 30,000 years to disappear	52.92 %
Methane	Generated by activities such as livestock production, agriculture, sewage treatment, natural gas and oil distribution, coal mining, fuel use and is also given off from waste tips	It lasts an average of 12 years in the atmosphere	14.88 %
Halogenated compounds (CFCs)& HCFCs	Results from the production of chemicals by diverse sectors such as refrigeration and air conditioning, electrical and electronic equipment, medicine, metallurgy, and so on	Depending on the type of compound, their duration in the atmosphere varies from a few months to tens of thousands of years	10.78 %

Greenhouse gas	The sources of their emission	Time spent in atmosphere	%stage of contribution to global warming
Tropospheric ozone	This is a product of the reaction between the gases carbon mon-oxide (CO), nitrogen dioxide (NO_2) and VOCs (Volatile Or-ganic Compounds), given off during the burning of fuels	These gases don't last as long in the atmosphere as others, a matter of months at the most.	10.72 %
Nitrous oxide	It comes mainly from the use of fertilizers, fuel use, chemical production and sew-age treatment	Lasts longer in the atmosphere, up to 114 years.	10.70 %

√ CHECKLIST 5.3

Please put (√) in the box for the tasks you can perform or the concepts you understand

- Can you describe the relationship between climate change and Global warming? ☐
- Can you explain the role of chemistry in fight against climate change? ☐
- Can you explain the reason why the emission of certain substances to the atmosphere produces a greenhouse effect that contributing to the global warming? ☐
- Describe how the greenhouse effect happened? ☐
- Can you list the common Greenhouse gases? ☐
- Can you describe the sources, atmospheric life time and percentage of contribution of greenhouse gases? ☐

Self-Test Exercise 5.3

Give short Answer for the following Question

1. Write the general chemical reaction equation that express combustion of fuel and result in increasing of global warming
2. List an example of greenhouse gases that contribute for Global warming from anthropogenic and natural sources
3. Describe the composition of the atmosphere
4. Describe the mechanism how greenhouse gases increase global warming

Section 5.4: Green Chemistry and Cleaner Production

Dear Learner, we know that we are surrounded by a huge variety of materials with a wide range of chemical and physical properties. We are continually developing processes to create products with desired properties. Our ability to manufacture materials provides many conveniences, but also some drawbacks. We are using raw materials at an alarming rate. We are also discarding hazardous chemicals into our landfills or incinerating them and releasing chemicals into our atmosphere. This section deals about principles of green chemistry and cleaner production. It also 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.

At the end of this section, you 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

Acivity 5.12

Attempt the following issues and evaluate your answer.

1. What can you do to "green" your day? How does this suggestion reduce your ecological footprint?
2. Brainstorm the criteria for a "green" product.

What does it mean when you say "Green chemistry and cleaner production"?

Have you seen your surroundings?

Think about all of the different substances that you deal with on a daily basis. Consider your notebook or the materials that help to deliver power to your calculator. How was the cover of your notebook made? What will happen to it when you throw it away? What materials were used to make the batteries or the solar cells in your calculator? What will happen to these materials once they no longer work properly?

We are starting to understand more about the hazards of chemical processes. Industries in many countries are now paying attention to the fuels and raw materials they use and the by-products they release along with their intended products. Sometimes manufacturers simplify processes to fewer steps. This has many benefits, including reducing waste. Processes are burning less fuel, using fewer toxic reactants, and releasing fewer unwanted by-products. Industry is attempting to become "greener."

5.4.1 Principle of Green Chemistry

Acivity 5.13

Attempt and reflect on the following question

1. How does green chemistry differ from cleaning up pollution?
2. Use of renewable feedstock is one of the principles of green chemistry, and can be accomplished by increasing awareness of sustainability in our modern society that led to switch the use of biomass as a feedstock and an energy source. What are other examples of renewable feedstock in your surroundings?

what do you mean by green chemistry?

"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."

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. The result is a process that generates less waste, uses less energy, and is more profitable! The "12" principle of green chemistry which are listed below directly or indirectly involves both modern methods of pollution control mechanism and cleaner production.

"Green chemistry" is a movement to make industries that involve chemicals more environmental friendly and sustainable

Developing a green alternative begins with considering the hazards of the required chemicals as well as their properties

A green chemistry solution may involve using safer chemicals.

The "12" Principles of Green Chemistry

1. 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.

By preventing waste generation, the risks associated with waste storage, transportation, and treatment could be limited. A solid example can be the pulp and paper industry, usage of chlorine compounds in processes produce toxic chlorinated organic waste. Green chemistry developed a method to convert wood pulp into paper using oxygen, water, and polyoxometalate salts while producing only water and carbon dioxide as by-products. Isn't that great?

Simply, "*Less Waste is directly proportional to Less Pollution*".

2. 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. Atom economy can be assessed easily by calculating the number of atoms in the Chemical Reaction. 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.

Assume for a reaction:

$$A+B \rightarrow C+D, where\ 'C'\ is\ the\ desired\ product$$

The Atom Economy can be calculated as,

$$Atom\ economy = \left[\left(Mass\ of\ C\right) / \left(Mass\ of\ C+D\right)\right] * 100$$

For an optimal process, the atom economy should be near or equal to 100%.

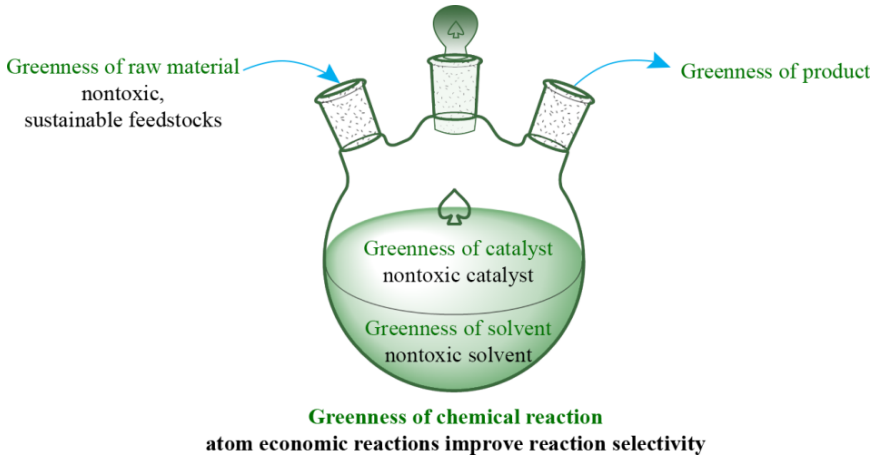


Figure 5.8 simple diagrams which shows atom economic reaction

Atom economy beneficial to promote the atom economy as it helps in: minimizes the waste, and reduces the cost associated with waste management and treatment; simplifies storage and transportation; minimizes potential pollution problems and prevents companies from illegal pursuits and reduces emissions, etc.

3. Less Hazardous Chemical Synthesis

- Wherever practicable, synthetic methods should be designed to use or generate chemicals that pose little or no toxicity to the environment and human health.
- *The goal should be to avoid reactions that give hazardous by-products.*

4. Design of Safer Chemicals

The design of safer chemicals deals with the rendering of chemicals which fulfill their intended purpose and yet are benign and harmless to the ecosystems.

This modification should be reflected up to the molecular level of the chemical's design.

5. Safer Solvent and Auxiliaries

Most of the industries from polymer to pharmaceutical industries and other chemical allied industries use solvents at some point in their manufacturing. In general, the use of solvents should be avoided, but that is not possible in all cases. So we can possibly replace toxic, non-recyclable solvents with safer and innocuous solvents.

6. Design for Energy Efficiency

Recognition of the energy requirements, their impact on the environment and economy, and its minimization to the extent possible will pave way for a greener process. Processes should be carried out at ambient conditions. Some ways in which this can be achieved are well-maintained equipment in plants, recovery of waste heat, and removal of solvents, proper utilization of catalysts, and combined heat and power (CHP).

7. Use of Renewable Feedstock

The increasing awareness of sustainability in our modern society has led to switch to the use of biomass as a feedstock and an energy source.

8. Reduce Derivatives

In this principle, "*the reaction takes place at a particular functional group blocking unnecessary waste generation* "by reducing the process steps with the use of enzymes, catalysts, or solvent, therefore, reducing demand for feedstock and utilities required for down-streaming hence increasing overall economy and efficiency of the process.

For example, the synthesis of the common nonprescription pain medication, ibuprofen, nicely illustrates the success of a green chemistry approach (Figure 5.9). First marketed in the early 1960s, ibuprofen was produced using a six-step synthesis that required 514 g of reactants to generate each mole (206 g) of ibuprofen, an atom economy of 40%. In the 1990s, an alternative process was developed by the BHC Company (now BASF Corporation)

that requires only three steps and has an atom economy of ~80%, nearly twice that of the original process. The BHC process generates significantly less chemical waste; uses less-hazardous and recyclable materials; and provides significant cost-savings to the manufacturer (and, subsequently, the consumer). In recognition of the positive environmental impact of the BHC process, the company received the Environmental Protection Agency's Greener Synthetic Pathways Award in 1997.

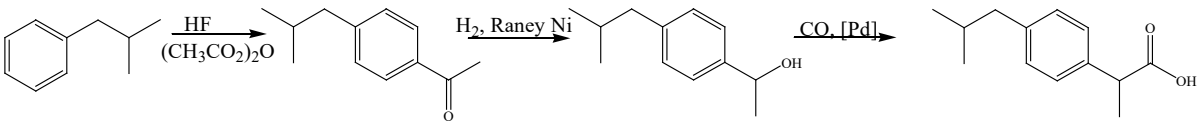


Figure 5.9 The BHC process for synthesizing ibuprofen requires only three steps and exhibits an impressive atom economy.

9. Catalysis

Catalysis is one of the most important pillars of Green Chemistry. "Stoichiometric" technologies are the primary source of waste; on the other hand, "Catalytic Processes" are achieving the goals of environmental protection and economic benefit.

Catalysts provide many benefits from lower energy consumption to increase selectivity of the reaction and allow a decreased use of harmful and toxic chemical agents.

Zeolites, Clays are promising and benign catalysts used in Heterogeneous Catalysis, which can replace the use of harmful catalysts. Enzymes are biocatalysts which are natural substances derived from Biological sources, are renewable and Biodegradable.

Catalysis can help us build a more sustainable world and can play a major role to mitigate the global environmental impacts of unsustainable chemical processes.

10. Design for Degradation

This principle stands for, "Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment". That means during the usage of chemicals it should be stable and do not persist the environment but after usage, it should be degraded into small molecules that are not harmful to the environment and humans.

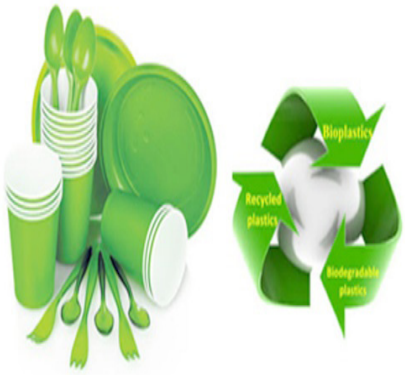


Figure 5.10 Simple illustration of biodegradable product

11. Real-time Analysis for Pollution Prevention

Just like watching the live news telecast i.e., in real-time makes it better to understand and act best according to the situation. Real-time analysis in chemical and allied industries is essential for production, transportation, and especially in the case of pollution prevention. Pollution in the industrial premises could become a potential threat to various probable hazards. The real-time analysis opens the scope of online process control and prevents any possible threats hence increasing overall profit to the industry as well as ensures safety to the environment.

12. Inherently Safer Chemistry for Accident Prevention

It involves choosing a safe or safer chemical to mitigate the chances of occurrence of an accident. It benefits the industry as well as the environment as it acts as a safeguard against calamitous industrial or laboratory accidents. Avoidance of hazard is the key.

5.4.2 Cleaner Production in Chemistry

Acivity 5.14

Do you think that one gram of reactants produces one gram of product/s? If not why? Reflect on the concept.

An ideal chemical reaction should have a number of attributes such as safety, simplicity, selectively, high yield, energy efficiency, use of renewable or recyclable raw materials and reagent and absence of hazardous byproducts or at least minimizing or containing them.

In practice, it is impossible to achieve all these attributes simultaneously. Indeed it is a challenge for chemists and engineers to identify environmentally preferable reaction pathways that optimize the balance of all the desirable attributes.

Goals of Green Chemistry from the perspective of cleaner production

The goals of "green chemistry" from cleaner perspective include the following 7 points: -

1. to reduce adverse environmental impacts by appropriate and innovative choice of materials and their chemical transformation
2. to develop processes based on renewable (plan-based) rather than non-renewable (fossil carbon –derived) raw materials
3. to develop products that are less toxic or which require less toxic raw materials/feedstock's
4. To develop products that degrades more readily /rapidly in the environment than the current products.

5. To reduces the requirement for hazardous or environmentally persistent solvents and extraction in chemical processes
6. To improve energy efficiency by developing low temperature and low pressure processes by using new/improved catalysts
7. To minimize byproducts in chemical transformation through redesign of reactions and reaction sequences. In other words, to achieve better" Atom economy"

$$\% \text{ of atom economy} = \left(\frac{\text{Formula weight of the product}}{\text{sum of formula weights of all the reactants}} \right) * 100$$

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. It is better to see atom economy in detail with illustrative example below:

Atom economy: 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. It is important for sustainable development and for good economic reasons to use reactions with high atom economy. A chemical reaction may give, and often does, more than one product, but of the mixture of products, perhaps only one of them is the desired useful product. The percentage atom economy of a reaction is readily calculated using the balanced equation for the reaction expressed in reacting masses.

The atom economy of a reaction is a theoretical percentage measure of the amount of starting materials that ends up as the 'desired' useful reaction products. It's sometimes referred to as atom utilization.

$$Atom\,economy = 100 * \frac{Mass\,of\ desired\ \ or\,useful\ product}{Total\,mass\,of\ all\,reactants\,or\ products}$$

In atom economy calculations you can say REACTANTS or PRODUCTS because of the law of conservation of mass. The greater the % atom economy of a reaction, the more 'efficient' or 'economic' it is likely to be. Many reactions give more than one product, and not all of them are useful, so it is useful to calculate what % of the products is theoretically useful, and we call this the atom economy of the reaction. The reactions that only give one product, have the maximum atom economy of 100% and these are the most economic reactions e.g. synthesis of ammonia and reacting ethene with water to make ethanol.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \; and \; CH_2 = CH_2 + H_2O \rightarrow CH_3CH_2OH$$

Example of calculation of atom economy:

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

Using the atomic masses of Fe = 56, C = 12, O = 16, we can calculate the atom economy for extracting iron based on the above reaction.

Solution: [(2 x 56) + (3 x 16)] + [3 x (12 + 16)] → [2 x 56] + [3 x (12 + 16 + 16)]

[160 of Fe_2O_3] + [84 of CO] → [112 of Fe] + [132 of CO_2] so there are a total of 112 mass units of the useful/desired product iron, Fe, out of a total mass of reactants or products of 160 + 84 = 112 + 132 = 244. Therefore, the atom economy = 100 x 112 / 244 = **45.9%**

Note: It doesn't matter whether you use the total mass of reactants or the total mass products in the calculations; they are the same due to the law of conservation of mass.

? Why the reaction with one product will always give the highest atom economy?

CHECKLIST 5.4

Please put (√) in the box for the tasks you can perform or the concepts you understand

- Can you describe the relationship between green chemistry and cleaner production? ☐
- Can you explain the 12 principles of green chemistry? ☐
- Can you give examples of chemical reactions that support the principles of green chemistry? ☐
- Can you explain the reason why it is better to prevent waste than to treat or clean up waste after it has been generated? ☐
- Can you describe cleaner production in chemistry mean? ☐
- Can you list the common goals of "green chemistry" from cleaner perspective? ☐
- Can you describe atom economy with illustrative examples? ☐

Self-Test Exercise 5.4

Part I: Multiple choice Questions

1. Which one is the aim of Green chemistry?
   A. Design chemical products and process that maximize profits
   B. Design safer chemical products and processes that reduce or eliminate the use and generation of hazardous substances
   C. Design chemical products and processes that work most efficiently
   D. Utilize non-renewable energy
2. Which of the following is a challenge for green chemists?
   A. Awareness of the benefits of green chemistry
   B. Developing chemicals that are recyclable
   C. Training for cleaning up chemical spills
   D. Knowing when to reduce and eliminate hazardous waste
3. Environmental benefits of green chemistry include?
   A. Fewer raw materials and natural resources used
   B. Cleaner production technologies & reduced emissions
   C. Smaller quantities of hazardous waste to be treated and disposed of
   D. All of the above

Part II: Give Short Answer For the Following Questions

1. Give examples of green chemistry solution that involve safer chemicals.
2. Explain what cleaner production means
3. Calculate the atom economy of the fermentation of sugar to make ethanol ('alcohol')

Unit Summary

- Environmental chemistry encompasses a number of fields of chemistry and chemical processes that take place in soil, water, air, and in living systems.
- Environmental chemistry is the 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 thereon.
- The environment consists of various compartments, including: atmosphere, hydrosphere, lithosphere and biosphere
- Examples of some important reaction in the biosphere:
- Photosynthesis: $6CO_2 + 6H_2O \xrightarrow{sunlight} C_6H_{12}O_6 + 6O_2$ and
- Respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Heat\ energy$
- Pollutant: A substance whose concentration has increased due to human activity, ultimately having detrimental effects on the environment
- Pollution is any discharge of a solid, liquid or gaseous substance or radiation (energy) into an environment that causes unwanted changes.
- Pollutants can be classified by the type of pollution they cause: air pollution, water pollution, and land pollution.
- Air pollution is caused by the presence of contaminant gaseous substances in the air that affect the lives of plants and animals on earth
- Some common air pollutants are sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, hydrocarbons, particulates, chlorofluorocarbons (CFCs), and lead compounds.
- Water pollution is the degradation of the quality of water brought about by the discharge into it of untreated sewage, industrial and agricultural waste, and oil spillage.

- 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
- Land pollution is caused by things we put into it. It results from the spillage of oil, leaching of harmful chemicals and heavy metal ions, and dumping of non-biodegradable wastes such as plastics.
- The emission of certain substances to the atmosphere produces a greenhouse effect contributing to the global warming. The greenhouse effect happens when certain gases, which are known as greenhouse gases, accumulate in Earth's atmosphere.
- Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and fluorinated gases.
- Because N_2 (g) is the compound present in greatest amount in the atmosphere, N_2 is the "solvent" in our atmospheric "solution". The solute present in largest amount is O_2 (g), but certainly there are many others.
- "Green chemistry" is a movement to make industries that involve chemicals more environmentally friendly and sustainable.
- Developing a green alternative begins with considering the hazards of the required chemicals as well as their properties
- A green chemistry solution may involve using safer chemicals.
- One of the principles of green chemistry, chemists should 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.

$$\%\ \text{of atom economy} = \left(\frac{\text{Formula weight of the product}}{\text{sum of formula weights of all the reactants}} \right) * 100$$

- 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)

Self-Assessment Exercise for Unit Three

Part I: True or False Item Questions

1. Green chemistry can provide green technology solutions for a sustainable future
2. Bio-catalysis has become very useful in green chemistry manufacturing
3. Green chemistry is more expensive than traditional chemistry
4. Pollutant is a substance, whose concentration has increased due to natural activity.
5. It is better to prevent waste than to treat or clean up waste after it has been generated is one of the important principles of green chemistry.

Part II: Multiple-Choice Questions

1. Green chemists reduce risk by?
   A. Reducing the hazard inherent in a chemical product or process
   B. Minimizing the use of all chemicals
   C. Inventing technologies that will clean up toxic sites
   D. Developing recycled products

2. The first listed of the 12 Principles of Green Chemistry is?
   A. Prevent waste
   B. Catalysis
   C. Atom economy
   D. Benign solvents

3. Which of the following is the greenest solvent?
   A. Formaldehyde
   B. Benzene
   C. Ethanol
   D. Water

4. Which one of the following is an excellent 'green' solvent as well as a greenhouse gas?
   A. Methanol
   B. CFCs
   C. Carbon monoxide
   D. Carbon Dioxide

5. Benzene, a _____ substance, is an important industrial solvent used in the production of pharmaceuticals, plastics, and dye.
   A. Odorless
   B. Non-flammable
   C. Biodegradable
   D. Carcinogenic

6. The gases that contribute to the greenhouse effect on Earth are, in their order of importance from greatest to smallest

   A. CO_2, H_2O, CH_4
   C. CH_4, CO_2, H_20
   B. H_2O, CO_2, CH_4
   D. H_2O, CH_4, CO_2

7. Which of the following is an example of impact of development activities on the hydrosphere?

   A. Air pollution
   C. Soil erosion
   B. Soil pollution
   D. Water pollution

8. What is the source of carbon monoxide?

   A. incomplete burning of wood
   B. fuels
   C. exhaust fumes of motor vehicles
   D. all of above

9. What is the source of sulfur dioxide?

   A. PowerStation's and industries using fossil fuels
   B. exhaust fumes of motor vehicles
   C. incomplete burning of wood
   D. none of above

10. Which of the following will not cause any atmospheric pollution?

   A. Hydrogen
   C. Carbon dioxide
   B. Sulphur Dioxide
   D. Carbon monoxide

11. Photochemical smog is related to the pollution

   A. Soil
   C. Noise
   B. Water
   D. air

12. The largest reservoir of nitrogen in our planet is:

   A. Ocean
   C. Biosphere
   B. Atmosphere
   D. Fossil fuels

13. Most important contributing pollutant of the soil/land

   A. plastics
   C. detergents
   B. iron junks
   D. glass junks

14. Depletion of ozone layer is due to oxide of
    A. Carbon
    B. phosphorus
    C. nitrogen
    D. None
15. Greenhouse effect is caused
    A. Those gases which absorb the infrared light reflecting from earth
    B. CH_4, SO_2 and NO_2
    C. CO_2 only
    D. None of the above
16. The result of ozone hole is
    A. acid rain
    B. Global warming
    C. the UV radiations the earth
    D. Greenhouse effect
17. Which of the following gases contribute to the global warming?
    A. Carbon monoxide
    B. Sulphur dioxide
    C. carbon dioxide
    D. nitrogen dioxide
18. Which of the Following Greenhouse Gases Is Present in Very High Quantities?
    A. Carbon dioxide
    B. Ethane
    C. Propane
    D. Methane
19. Burning of Fossil Fuels Results In
    A. Increased oxygen level
    B. Decreases greenhouse gases
    C. Increased greenhouse gases
    D. Increased ethane level
20. One of the following is Naturally Occurring Greenhouse Gas?
    A. Nitrous oxide
    B. Methane
    C. Carbon dioxide
    D. Ethane

Based on the following reaction do question number 21.

$$N_2 + O_2 \rightarrow 2NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$NO_2 \rightarrow NO + O$$

$$O + O_2 \rightarrow O_3$$

21. The above reactions describe the chemical process that forms:
    A. Photochemical smog
    B. Industrial smog'
    C. Acid precipitation
    D. Ozone

22. One of the following is not true about the role of catalyst in cleaner production?
    A. allows a decreased use of harmful and toxic chemical agents
    B. enzymes are Biocatalysts are not renewable and Biodegradable
    C. increased selectivity of the reactions
    D. Lower energy consumption

Part III: Short Answer Questions

1. Why it is called the "greenhouse" effect?
2. Do all greenhouse gases have the same effect?
3. Carbon monoxide is more dangerous than carbon dioxide. Why?
4. List the common water, air and soil pollutant
5. Describe the mechanism to reduce, water, air and soil.
6. What is greenhouse effect? Which gas is mainly responsible for global warming?
7. Write at least 1 Green chemistry principle most commonly practiced in your surrounding?

Part IV. Problem

1. Write a brief note about "What does "Green chemistry and cleaner production mean?"
2. Write a brief note on adverse effects of specific metal pollutants.
3. Consider the following three reactions "A", "B" and "C"

   Reaction A: converting ethanol to ethene
   Reaction B: ethene + water → ethanol
   Reaction C: fermentation of sugar to make ethanol ('alcohol')
   Calculate the atom economy of the above reaction A, B and C. Both reaction B and C are gives the same desired product ethanol, which is more environmental friendly? And give your reason?

Written Assignment for Module II contents

Dear learner, you are supposed to work on the following assignment questions after completing Module II. The questions were designed from module 2 contents. Please, attempt to answer all the questions on separate answer sheet and submit it to your tutor for correction as a part of your assessment.

Part I. write true if the stamen is correct and write false if the statement is incorrect

1. Tanning is a process of converting raw animal hides and skin to leather, using tannin
2. The application of pesticides has only positive aspects.
3. Anhydrous, 100% sulfuric acid is a colorless, odorless, heavy, oily liquid.
4. Bakelite, cyanate esters and epoxy resin are examples of thermoplastics polymers
5. Polymers are large molecules that are made from small units called monomers
6. In this general formula of detergent R-C6 H4 SO3 Na the fat-soluble group is –SO3Na and the water-soluble group is –R -C6H4
7. Proteins, starch and cellulose are examples of synthetic condensation polymers
8. A substance that does not occur in nature, but it is introduced into the environment through human activity.
9. Pollution causes only short-term harm that affects the earth's ecological balance and lowers the quality of life in the environment.
10. The greenhouse effect happens when certain gases, which are known as greenhouse gases, accumulate in Earth's atmosphere.

Part II. Choose the best answer for the following questions among the given Alternatives

1. In the Contact process, what happens to the equilibrium when the temperature is increased?

   A. Shifts to the left B. No change in equilibrium

   C. Shifts to the right D. None

2. Which of the following is a renewable natural resource?

   A. minerals B. petroleum

   C. water D. fossil fuel

3. The first step of the Solvay process is

   A. Preparation of ammoniacal brine B. Carbonation

   C. Filtration D. Calcination

4. One of the following is not true about the properties of NaOH

   A. a white translucent crystalline solid with a melting point of 591 k

   B. It is un stable compound

   C. it has a corrosive action on many substances

   D. It dissolves readily in water and moderately soluble in alcohol

5. One of the following is an example of monomer correctly paired with its polymer

   A. Glucose($C_6H_{12}O_6$) a monomer for cellulose (wood)

   B. Ethylene a monomer for Polyethylene

   C. Amino acid ($NH_2CH(R)(COOH)$) a monomer for protein

   D. All of the above

6. One of the following is an example of thermoplastic polymer

   A. Polyvinyl chloride B. Bakelite C. Epoxy resin D. Fibber glass

7. Which one of the following is a natural polymer?

   A. Nylon B. Cotton C. Teflon D. Dacron

8. Which one of the following gases absorb infrared light as a result it is the main contributors to the greenhouse effect.

   A. Water vapor B. CO2 C. CH4 D. all of the above

9. In most freshwater lakes, the algal productivity is limited by the availability of which of the following inorganic ions?

   A. Carbon B. Nitrogen

   C. Phosphorus D. All of the above

10. Which of the following is a greener route to produce ethanal commercially?

    A. Catalytic cracking of ethanol

    B. Oxidation of ethene with an ionic catalyst

    D. Dehydrogenation of ethylene

Part III: Give Short Answer for the following Questions

1. Write the chemical equation which shows the three major steps of NH3 production
2. Describe the refinery processes involved in sugar production
3. Write the key reaction during the Solvay process? And please describe how solid NaHCO3 is formed.
4. Describe the process of production of the most local alcoholic beverages in Ethiopia.
5. Write the structure of the following polymers and also indicate the monomer units involved in the formation of these polymers.

   A. Nylon 66 B. Dacron

6. What makes thermoplastic materials recyclable, whereas thermosetting ones are not.
7. A polymer's structure influences its physical properties. Describe two structural variations that are possible for polypropylene but not for polyethylene
8. How acid rain is formed. Write the reaction that shows formation of acid rain
9. Which principle of green chemistry besst explained in cleaner production?
10. What is atom economy? What implies that the reaction has good atom economy?

Feedback to Activities in Unit 5

Acivity 5.1

1. 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
2. The possible sources of CO_2 i.e. combustion of fuel and show the fate of CO_2 in the atmosphere would be fall back to earth as acid rain by writing the chemical reaction $CO_2(g) + H_2O$ (water vapor) $\rightarrow H_2CO_3$.

Acivity 5.2

1. Since, 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 and
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.

Acivity 5.3

1. The relationship between environmental pollution and pollutant described as: Environmental pollution is defined as the contamination of the environment with unwanted, harmful, and hazardous substances that negatively affect the biological as well as physical atmospheric constituents. So the pollution causing agents are known as pollutants, and different types of pollutants cause different types of environmental pollution.

Acivity 5.4

1. 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.
2. 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
3. Activities in our area that brought awareness of air pollution and global warming are:

Acivity 5.5

1. a)
   - Daily Litter,
   - Agricultural Activities,
   - Vehicular Emissions
   - Residential Heating, Lighting and Cooking
   - Industrial Facilities

   b) For example :
   - **Littering** is another human activity that massively contributes to air pollution. Single-use plastics have become an integral part of our daily lives, and the most commonly littered items are food wrappers and plastic bottles
   - **Vehicular Emissions:** Poor urban planning, which leads to suburban sprawl and the dependency on cars is a major factor in accelerated greenhouse gas emissions, which causes air pollution. Gases emitted from vehicles including trucks, jeeps, cars, trains, aero planes cause an immense amount of pollution.

   c)
   - **Cut down on car journeys:** one great way to start on your journey to lower air pollution is to go car-free
   - **Cut down on your meat and dairy intake:** While the connection between eating meat and air quality may not seem immediately obvious, scientists have found that animal agriculture is actually the largest producer of air pollutants at over 50%. Cattle and dairy farming is responsible for a large number of ammonia emissions, which cause pollution not only in the air but to surface and ground waters.

- **Plant more trees and greenery:** Supporting local garden initiatives (or starting your own) can help improve the long-term air quality in your local neighbourhood. Plants help clean the air around them by consuming CO_2.
- **Avoid burning at home:** Burning solid fuels, such as in open fires and wood-burning stoves has a significant impact on air pollution. Avoid burning leaves and rubbish in your garden too.

d) My contribution should be apply the methods indicated in C to reduce air pollution

2. 'Air pollution anywhere is a potential threat elsewhere mean **air pollution**, release into the atmosphere of various gases, finely divided solids, or finely dispersed liquid aerosols at rates that exceed the natural capacity of the environment to dissipate and dilute or absorb them. These substances may reach concentrations in the air that cause undesirable health, economic, or aesthetic effects from the sources they released to the place far from the sources.

Acivity 5.6

1. There are six major air pollutants that have been designated by the U.S. Environmental Protection Agency (EPA) as "criteria" pollutants—*criteria* meaning that the concentrations of these pollutants in the atmosphere are useful as indicators of overall air quality. These six major air pollutants are:
   - Carbon monoxide (CO),
   - Nitrogen oxides (NO and NO2)
   - Sulfur dioxide (SO2)
   - Ozone (O3)
   - Particulate matter
   - Lead

2. Some of the methods to reduce air pollution are:

- **Cut down on car journeys:** one great way to start on your journey to lower air pollution is to go car-free
- **Cut down on your meat and dairy intake:** While the connection between eating meat and air quality may not seem immediately obvious, scientists have found that animal agriculture is actually the largest producer of air pollutants at over 50%. Cattle and dairy farming is responsible for a large number of ammonia emissions, which cause pollution not only in the air but to surface and ground waters.
- **Plant more trees and greenery:** Supporting local garden initiatives (or starting your own) can help improve the long-term air quality in your local neighbourhood. Plants help clean the air around them by consuming CO_2.
- **Avoid burning at home:** Burning solid fuels, such as in open fires and wood-burning stoves has a significant impact on air pollution. Avoid burning leaves and rubbish in your garden too.

Acivity 5.7

1.

a) Water for public drinking is come from in most case from tap water that comes from surface or ground water. This source of water refers to bodies of water (such as rivers, streams, lakes, reservoirs, springs, and ground water) that provide water to public drinking-water supplies and private wells.

b) The major ground and surface water contaminants:

- Agricultural Chemicals including fertilizers, pesticides and herbicides
- Domestic house hold wastes including Septic Waste
- Landfills
- Hazardous Waste Sites
- Storage Tanks

c) 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

Acivity 5.8

1. Some of the pollutants that cause land pollution in our surroundings:
   - Harmful heavy metal ions from buried waste leaching into water systems.
   - Excessive use of synthetic fertilizers in agricultural activities also contributes towards land pollution.
   - Dumping of non-biodegradable
   - Leaching of harmful chemicals from corroded metal drums which have been buried underground.
2. Some of the methods to reduce soil erosion
   - **Use Soil-friendly Agricultural Practices:** Terraced farming needs to be implemented to make hillside agriculture manageable. Terraces prevent erosion and allow more water to flow to crops. In addition, hillside farm fields need full crop cover to help keep the soil in place. This can be accomplished by intercropping, which means growing two crops together in the same field, such as planting rows of maize or soybean between rows of oil palm trees.
   - **Prevention AND Rehabilitation:** the key to managing and reducing soil erosion is to rehabilitate already-damaged land, stop further degradation and put erosion-preventative measures at the core of land management policy.

3. I will implement the following methods to reducing land pollution
    - Make people aware of the concept of Reduce, Recycle and Re-use
    - 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

Acivity 5.9

1. Methods should be practiced to reduce land pollution in Ethiopia?
    - 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

2. 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.

- 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

Acivity 5.10

1. 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.
2. 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.
3. 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 (CO2) 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.

Acivity 5.11

1. 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.

2. 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.

Acivity 5.12

1. "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?"

2. Industries in many countries are now paying attention to the fuels and raw materials they use and the by-products they release along with their intended products. Sometimes manufacturers simplify processes to fewer steps. This has many benefits, including reducing waste. Processes are burning less fuel, using fewer toxic reactants, and releasing fewer unwanted by-products. Industry is attempting to become "greener."

Acivity 5.13

1. 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
2. 1st one is **prevention** that is 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.

Acivity 5.14

1. Practically it is not possible to attend complete conversion of reactant to products i.e. 1 gram of reactant not completely converted to 1 gram of product. (I.e. percentage yield =100%). In the laboratory, if you are taking a very low amount of samples, then you may achieve 99%. If you are escalating the same reaction to industrial scale, then it is difficult to attain such a high conversion value.

Answer Key for Self-test Exercise for unit Five

Self-Test 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. Degradation of organic material: $CH_2O + O_2 \rightarrow CO_2 + H_2O$

   Photosynthesis: $CO_2 + H_2O \xrightarrow{h\nu} CH_2O + O_2$

3. Nitrogen fixation by bacteria and algae:

$$2N_2 + 3CH_2O + 3H_2O + 4H^+ \rightarrow 3CO_2 + 4NH_4{}^+$$

4. **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
5. **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.

Self-Test Exercise 5.2

1. a/ main causes 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 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.

$SO_3 + H_2O$ vapor$\rightarrow H_2SO_4$ (acid rain) or

$SO_2 + H_2O$ vapor$\rightarrow H_2SO_3$ (acid rain)

5. 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.

Self-Test 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)& 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.

Self-Test Exercise 5.4

Part I. Multiple choice

1. B 2. D 3. D

Part II. Short Answer

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." reactants to products.
3. Atom economy = mass of desired product/ total mass of product * 100

   Atom economy =

   Mass of desrired product i.e, $2C_2H_5OH$ = 92 gram/mole

   Total mass of product = = 180 gram/mole

   Atom economy = (mass of desired product/ total mass of product) * 100

   = (92/180) * 100 = 51.11 %

Answer Key for Self- Assessment Exercise of unit three

Part I. True or False

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

Part II. Multiple choice Questions

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

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 CO2. Because CFC-12 is a large, heavy molecule with many atoms and a CO2 molecule is small and light in comparison, there are fewer molecules of CFC-12 in each ton of CFC-12 emissions than CO2 molecules in each ton of CO2 emissions. Each ton of CFC-12 emissions is about 5,750 times more efficient at trapping heat than each ton of CO2. The comparatively greater amount of CO2 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. **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. 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.

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 ===> ethanol

   Reaction C: fermentation of sugar to make ethanol ('alcohol')

   I. Reaction A (converting ethanol to ethane) 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 = = 46 gram/mole
   Atom economy = (mass of desired product/ total mass of product) * 100 = (28/46) * 100 = **60.87 %**

   II. Reaction B: ethane + water → ethanol

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 = = 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 =

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 = = 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.

References of Module Two

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