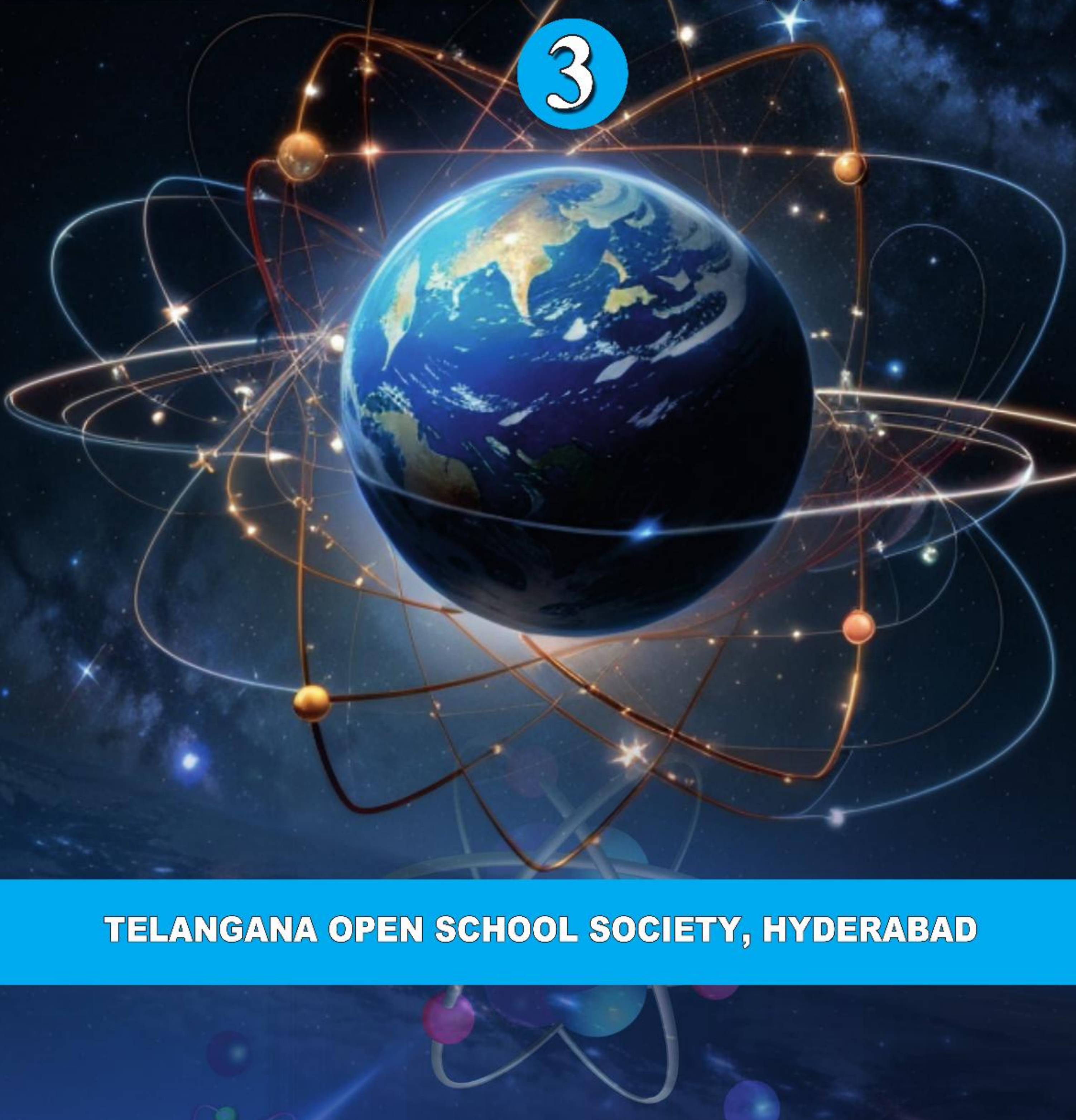
Government of Telangana

313

INTERMEDIATE

CHEMISTRY

3



TELANGANA OPEN SCHOOL SOCIETY, HYDERABAD

313

Intermediate (TOSS) Course
Senior Secondary Course

CHEMISTRY

3

(CORE MODULES)

Telangana Open School Society (TOSS), Hyderabad

SCERT Campus, Opp. to L.B. Stadium, Basheerbagh, Hyderabad-500
001Telangana. Phone: 040-23299568, website; telanganaopenschool.org
E-mail: dirtoshyd@gmail.com

Telangana Open School Society

Print: 2023

No of Copies:

Published by the Director Telangana Open School Society,
Hyderabad with the Copyright Permission of NIOS, NOIDA.

Printed in India

at
For the Director at Telangana Govt. Text Book Press, Mint
Compound, Khairatabad, Hyderabad, Telangana.

SENIOR SECONDARY COURSE
INTERMEDIATE (TOSS) COURSE
CHEMISTRY-ADDITIONAL CURRICULUM

Chief Advisor

Smt. Vakati Karuna, IAS

Secretary to Government,
Department of Education,
Government of Telangana,
Hyderabad

Text Book Printing Council

Smt. A. Sridevasena, IAS

Director of School Education,
Telangana, Hyderabad

Sri. P. V. Srihari

Director, TOSS,
Telangana, Hyderabad

Sri. S. Srinivasa Chary

Director, Textbook Press,
Telangana, Hyderabad

Chief Coordinator

Sri. Marasani Somi Reddy

Joint Director, TOSS,
Telangana, Hyderabad

Coordinators

Sri. B. Venkateswar Rao State Coordinator, TOSS, Telangana, Hyderabad	**Smt. Ganta Sarita** State Coordinator, TOSS, Telangana, Hyderabad

Telangana Open School Society (TOSS), Hyderabad

SCERT Campus, Opp. to L.B. Stadium, Basheerbagh, Hyderabad-500 001Telangana. Phone: 040-23299568, website; telanganaopenschool.org
E-mail: dirtoshyd@gmail.com

SENIOR SECONDARY COURSE
INTERMEDIATE (TOSS) COURSE
CHEMISTRY-ADDITIONAL CURRICULUM
CONTENT DEVELOPMENT TEAM

EDITOR

Dr. Viplav Duth Shukla,
Associate Professor of Chemistry,
Department of Chemistry, Govt City College

WRITERS

Inorganic Chemistry

Dr. Abhijit Kantankar

Assistant Professor,
Department of Chemistry,
Tara Govt College, Sangareddy Dist,

Dr. K. Vani

Assistant Professor,
Department of Chemistry,
Tara Govt College, Sangareddy,

Dr. A. Dayanand

Assistant Professor,
Department of Chemistry,
Govt. City College, Hyderabad

Dr. K. Ashwini

Assistant Professor,
Department of Chemistry,
Telangana Mahila University,

Organic Chemistry

Dr. P. Sarita Rajender

Senior Assistant Professor,
Head, Dept. of Chemistry,
Univ. College of Engineering, O.U.,

Dr. S. Gururaj

Assistant Professor,
Department of Chemistry,
Nizam College, O.U.,

Dr. Viplav Duth Shukla

Associate Professor,
Department of Chemistry,
Govt City College, Hyderabad.

Physical Chemistry

Dr. A. Hari Padmasri

Professor,
Department of Chemistry,
Univ. College of Science, O.U.,

Sri. Busi Anil Kumar

Assistant Professor,
Department of Chemistry,
Govt City College, Hyderabad.

Dr. Eluri Yadaiah

Associate Professor,
Department of Chemistry,
Govt City College, Hyderabad.

Smt. Malathi

Assistant Professor,
Department of Chemistry,
N B Science College, Hyderabad.

General Chemistry

Dr. P. Pallavi

Assistant Professor,
Department of Chemistry,
Nizam College, OU.

Dr. B. Kavita

Assistant Professor,
Department of Chemistry,
Nizam College, OU.

Layout Designing

Dr. S. Gururaj
grsomadi@gmail.com

Cover page designing & Illustrations

Sri. K. Sudhakara Chary
MPUPS, Maripeda, Mulugu

FOREWORD

Dear Learner,

The Department of Education is giving equal importance to non-formal education through Open Distance Learning (ODL) mode of the lines of formal education. This is the first State Open School established in the country in the year 1991 offering courses up to Upper primary Level till 2008. From the academic year 2008-2009 SSC Course was introduced and Intermediate Course from the year 2010-2011. The qualified learners from the Open School are eligible for both higher studies and employment. So far **4,88,853** learners were enrolled in the Open Schools and **2,86,663** learners have successfully completed their courses. The Open School system is providing a second chance of learning for those who could not fulfil their dreams of formal education.

Government of Telangana is keen in providing quality education by supplying study materials along with the text books to enable the learners to take the exam with ease. Highly experienced professionals and subject experts are involved in preparing curriculum and study material based on subject wise blue prints. The study material for the academic year 2023-24 is being printed and supplied to all the learners throughout the state.

Welcome to the Revised Chemistry Course of Telangana Open Schooling System (TOSS) based on the National Institute of Open Schooling and the National Common Core Curriculum. This Course has four volumes I, II and III consist of theory portion and volume IV is a practical manual. The first book is in your hands. This book comprises one lesson of module 1 on Some Basic Concepts of Chemistry, three lessons of Module 2 on Atomic Structure and Chemical Bonding, five lessons of Module 3 on States of Matter, two lessons of Module 4 on Chemical Energetics and five lessons of module 5 on Chemical Dynamics. In Module 1 you will learn about the various units used to calculate the number of atoms, molecules and ions involved in chemical reactions. Module 2 will enlighten you about what lies inside the atoms and the different types of chemical bonds through which atoms combine. Module 3 deals with the various aspects of three states of matter *viz*, solid, liquid and gas. You will also learn about the properties of solutions and colloids. Module 4 deals with chemical reactions accompanied with energy changes and basic concepts like internal energy, enthalpy, entropy and spontaneity. Module 5 highlights on the Characteristics of Chemical Dynamics, catalysis inter conversion of Chemical energy into electrical energy in electrochemistry, electrochemical cells and fuel cell. We hope you will enjoy the course and find it interesting.

WE wish the learners of Open School make best use of the study material to brighten their future opportunities and rise up to the occasion in building Bangaru Telangana.

Wishing you happy chemistry learning ….

With best wishes.....

-WRITERS

HOW TO USE THE STUDY MATERIAL

Your learning material has been developed by a team of chemistry experts in open and distance learning. A consistent format has been developed for self-study. The following points will give you an idea on how to make best use of the print material.

Title is an advance organiser and conveys an idea about the contents of the lesson. *Reflect on it.*

Introduction highlights the contents of the lesson and correlates it with your prior knowledge as well as the natural phenomena in operation in our immediate environment. *Read it thoroughly.*

Objectives relate the contents to your desired achievements after you have learnt the lesson. Remember these.

Content of the lesson has been divided into sections and sub-sections depending on thematic unity of concepts. Read the text carefully and make notes on the side margin of the page. After completing each section, answer intext questions and solve numerical problems yourself. This will give you an opportunity to check your understanding. You should continue reading a section till such time that you gain mastery over it. At some places you will find some text in ***italics and bold***. This indicates that it is important. You must learn them.

Solved Examples will help you to understand the concepts and fix your ideas. In fact, problem solving is an integral part of training in physics. Do them yourself and note the main concept being taught through a particular example.

Activities are simple experiments which you can perform at your home or work placeusing readily available (low cost) materials. These will help you to understand physics by doing. Do them yourself and correlate your findings with your observations.

Intext questions are based on the concepts discussed in every section. Answer these questions yourself in the space given below the question and then check your answers with the model answers given at the end of the lesson. This will help you to judge your progress. If you are not satisfied with the quality and authenticity of your answers, turn the pages back and study the section again.

What have you learnt is essentially summary of the learning points for quick recapitulation. You may like to add more points in this list.

Terminal exercises in the form of short, long and numerical question will help you to develop a perspective of the subject, if you answer these meticulously. Discuss your responses with your peers or counsellors.

Answers to in text questions: These will help you to know how correctly you have answered the intext questions.

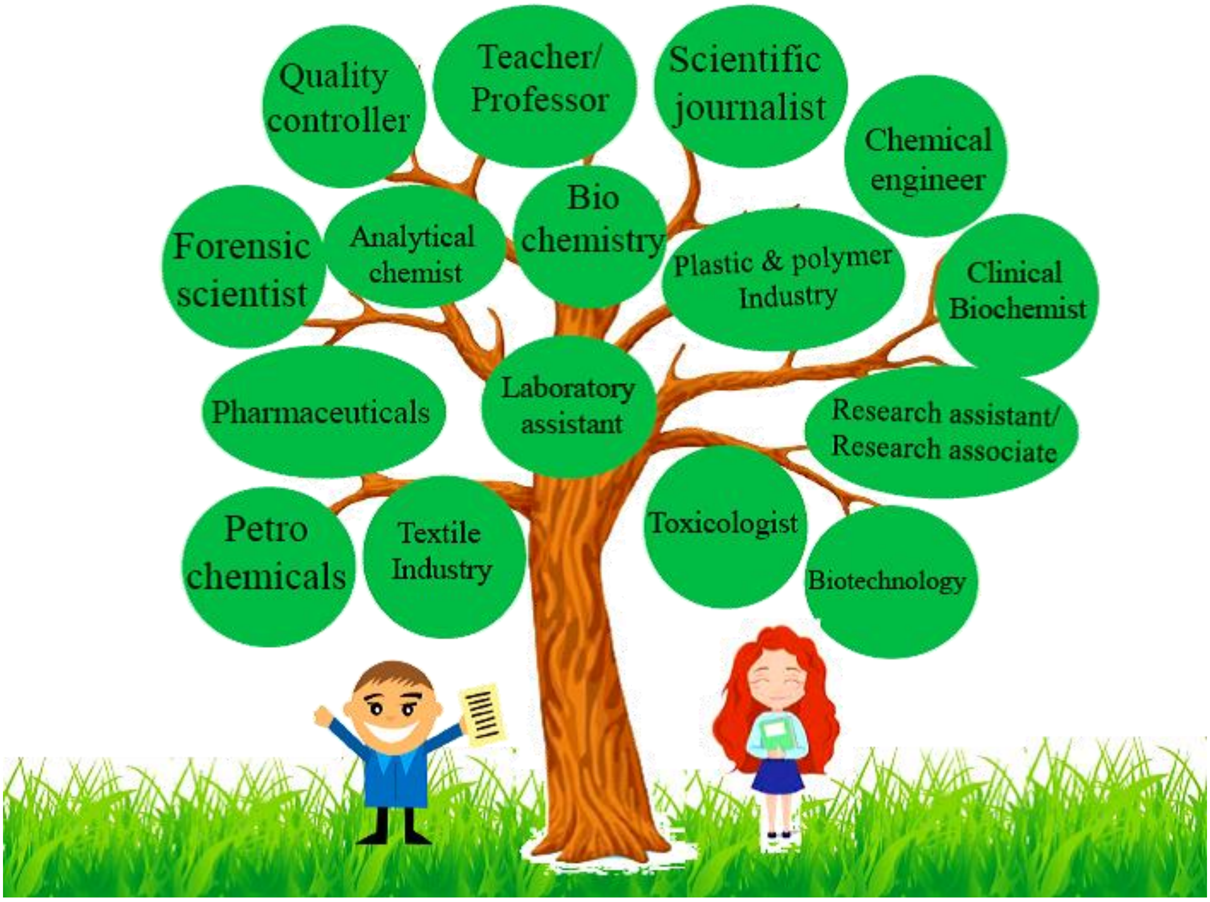
Audio: For understanding difficult or abstract concepts, audio programmes are available on certain content areas. You may listen to these on FM Gyanvani or may buy the CDs from Priced Publication Unit, NIOS.

Video: Video programmes on certain elements related to your subject have been made to clarify certain concepts. You may watch these at your study centre or may purchase these CDs from Priced Publication Unit, NIOS.

www. These are few selected websites that you can access for extended learning. Studying at a distance requires self-motivation, self-discipline and self-regulation. Therefore, you must develop regular study habit. Drawing a daily schedule will help you in this endeavour. You should earmark a well-ventilated and well-lighted space in your home for your study. However, it should not be noisy or distract your concentration from your work.

CAREER OPPORTUNITIES AFTER STUDYING CHEMISTRY

Chemical sciences (Chemistry) offer access to a wide range of careers. Chemistry is the study of substances, their makeup and applications. In fact, it is the study of all materials and is vital to every aspect of our lives. Organic Chemistry, Inorganic Chemistry, Analytical chemistry and Biochemistry are the main branches of chemistry. The career options in chemistry are practically endless! However, employment options depend on how far the education, training and experience taken. A chemistry or biochemistry degree can lead to career paths in professions such as Medicine, pharmacology, agriculture, chemical engineering, forensic science, etc. Some of the important career opportunities after studying chemistry at senior secondary level is as



RATIONALE

According to present scheme of school education at Senior Secondary stage, chemistry emerges out as a separate discipline. It is this stage where major emphasis is to be laid on providing suitable conceptual foundation. The present Senior secondary level Chemistry (313) course at TOSS has now been revised as per the NIOS (National Institute of Open Schooling), Common Core Curriculum developed by COBSE (Council of Boards of School Education) and NCERT (National Council for Educational Research and Training) making it current and need based.

The present chemistry course has been developed basically around the themes: Why do chemical reactions occur? What is the quantitative relationship among reacting constituents in a chemical reaction? How far and how fast will a chemical reaction proceed under a given set of conditions? Can we predict whether a chemical reaction will occur or not? What is the relation between the structure of a chemical substance and its functions/properties? In what way is a chemical reaction relevant for getting new types of substances and materials for daily life and chemical industries? Some interdisciplinary aspects have also been provided to make the course more meaningful and functional.

OBJECTIVES OF THE COURSE

It is expected that a learner will be able to:

Understand the principles, theories and laws of chemistry responsible for various chemical processes/reactions,

- realise the role of chemistry in production of many elements (metals/non-metals) and compounds useful in industries and daily life,
- appreciate the chemical nature of inorganic and organic substances around him/her, choose various vocational, professional and applied courses of his/her choice based on knowledge of chemistry gained.
- Apart from this, the present course also aims at developing the following capacity in the learner:
- perform chemical calculations to know about the chemical reactions and chemical compounds,
- explain chemical reactions, concepts and phenomenon,
- develop awareness about uses and abuses of chemical substances,
- develop skills arranging/setting apparatus, handling apparatus and chemicals properly, and
- analyse and synthesise simple compounds.

SPECIAL FEATURES OF THE COURSE

The academic standard of the present chemistry course in comparable with the chemistry course of any State Education Board or Central Board of Secondary Education. The rationale behind the course is that every lesson has a role to play in understanding the holistic view of chemistry. The present course provides eight modules and a laboratory manual. A student appearing for senior secondary examination is expected to offer all the eight modules and practical.

COURSE STRUCTURE

The Revised Chemistry Course has three parts, I, II and III consist of theory portion and part IV is a practical manual. Part I, II and III of theory portion has eight modules. Part-I consists of five modules namely as: Some basic concepts of chemistry, Atomic Structure and Chemical Bonding, States of matter, Chemical Energetics, and Chemical Dynamics. Part-II consists of three modules namely: Chemistry of Elements and Chemistry of Organic Compounds, Part-III consists of two modules namely: Environmental Chemistry and Chemistry and Industry. Each module is further divided into different lessons.

Overview of the Learning Material

Book - 1

Module - I: Atoms, Molecules and Chemical Arithmetics

01. Mole Concept
02. Chemical Arithmatics

Module - II: Atomic Structure and Chemical Bonding

03. Atomic Structure
04. Periodic Table and Atomic Properties
05. Chemical Bonding

Module - III: State of Matter

06. The Gaseous state
07. The Liquid State
08. The Solid State
09. Solutions
10. Colloids

Module - IV: Chemical Energetics

11.Chemical Thermodynamics
12. Spontaneity of Chemical reactions

Module - V: Chemical Dynamics

13. Chemical Equilibrium
14. Ionic Equilibrium
15. Electro Chemistry
16. Chemical Kinetics
17. Adsorption and Catalysis

Book - 2

Module - VI: Chemistry of Elements

18. Occurance and Extraction of Metals
19. Hydrogen and *s* - block Elements
20. General Characteristics of the *p*-block Elements
21. *p*-block Elements and their Compounds - I
22. *p*-block Elements and their Compounds - II
23. d-block and f-block Elements
24. Coordination Compounds

Module - VII: Chemistry of Organic Compounds

25. Nomenclature and General Principles
26. Hydrocarbons
27. Compounds of Carbon Containing Halogens (Haloalkanes and Haloarenes)
28. Alcohols, Phenols and Ethers
29. Aldehydes, Ketones and CarboxylicAcids
30. Compounds of Carbon Containing Nitrogen
31. Biomlecules

Book - 3

Module VIIIA: Environmental Chemistry

32. Environmental Concerns
33. Air Pollution
34. Water Pollution
35. Heavy Metal Contamination
36. Radioactive Pollution

Module VIIIB: Chemistry and Industry

32. Petrochemicals
33. Polymers
34. Dyes, Paints and Pigments
35. Drugs and Medicines
36. Building Materials

CONTENTS

Module VIIIA

Environmental Chemistry

32. Environmental Concerns

33. Air Pollution

34. Water Pollution

35. Heavy Metal Contamination

36. Radioactive Pollution

Chapter 32

ENVIRONMENTAL CONCERNS

Earth is the only planet which supports life. The earth has just the right kind of conditions of temperature range, air, water, soil for supporting life and is protected from harmful rays from the outer space by the ozone layer. With progressive increase in human population and human activities, the quality of air, water, soil and other natural sources get degraded and become unfit for use by organisms. It causes unwanted effects. In this less on you shall learn about the sources of pollutants and their effects on environment. Thus,the environmental pollution in many ways threaten the existence of many organisms including human being on the earth. Therefore, any threat of degradation or damage to the environment should be a matter of concern.

Objectives

After reading this lesson you will be able to:

- define environment and biosphere;
- differentiate the various environmental segments;
- explain nature of threats to environment;
- define pollutants and its types;
- list sources of pollutants and
- explain the effects of pollutants on environment, organisms and humans in particular.

32.1. Components of Environment

Definition of Environment

Environment can be defined as Biotic and Abiotic surroundings with which living things share or interact. Environment has two (02) components

(i) **Abiotic components** of environment include air, water, soil, energy radiation, etc.

(ii) **Biotic components** of environment are microbes (such as bacteria, algae and fungi), plants, animals etc.,

32.2 Segments of Environment

Environment consists of four (04) segments such as:

(i) Biosphere **(ii) Atmosphere** **(iii) hydrosphere** **(iv) Lithosphere**

(i) Biosphere: The part of earth on which organisms can survive and reproduce is called biosphere. Survival of organisms depend upon a delicate balance between themselves and with the various components of the environment. Any disturbance, damage or adverse change in the quality of environment poses a threat to the survival and well being of organisms.

(ii) Atmosphere: Atmosphere is the only place where free oxygen and water vapour exist. Atmosphere is a thin layer of air (mixture of gases) around the earth which is a great source to all living organisms.

(iii) Hydrosphere: Water plays an important role in the biosphere, without life is impossible. Hydrosphere is the part of earth on which all types of water resources exists, viz., oceans, seas, rivers, lakes, glaciers, icecaps, groundwater, etc.

(iv) Lithosphere: Soil is a part of litho sphere which supports life. Lithosphere is the part of the earth where all types of minerals, metals, organic matters, rocks, soils, etc., exist.

32.3 Threats to Environment

Environment gets damaged due to several reasons. The damage may be in the small area or may affect a much larger area and its effects may be felt all over the globe.

1. The vehicular combustion of fossil fuels (petrol and diesel) releases carbon monoxide (CO), carbon dioxide (CO_2) and sulphur dioxide (SO_2) into the atmosphere. SO_2 combines with water droplets in the atmosphere to form sulphuric acid (H_2SO_4). Sulphuric acid causes acid rain in the atmosphere and damages the environment over a small area.

The environmental effects of acid rain include:

(a) leaching of nutrients from soil and

(b) corrosion of basic material such as limestone and marble.

2. Pesticides, especially DDT (dichlorodiphenyltrichloroethane) and dieldrin used to control mosquitoes and agricultural pests have become serious pollutants of air water and soil. Being long lasting (do not break down to other molecules that is non-biodegradable) under natural conditions. The pesticides remain in the soil and their amount goes on increasing in soil and water with successive applications. Their ill effects damage the environment locally.

3. Various industries like steel, nonferrous metals, fertilizers and petroleum are sources of toxic pollutants like lead (Pb), cadmium (Cd), zinc (Zn), arsenic (As), nickel (Ni) and mercury (Hg). These toxic metals pose a great threat to the local environment.

The industrial waste contains suspended matter, dissolved solids, toxic metals, chemicals, strong acids, alkalies, oils, dyes, etc. These substances deplete the dissolved oxygen of water and impair the biological activities, finally destroying aquatic life.

1. Two instances of environmental hazards due to pollution in our country are quoted below :

   (i) The effluents like SO_2, of Mathura refinery are posing a very serious threat to Taj Mahal.

   (ii) The mishap which took place due to leakage of MIC (methyl-isocyanate) on 2nd December 1984 from factories of Union Carbide at Bhopal killed thousands of people and has affected the health of those exposed to MIC.

2. Chloro flouro carbons (CFCs), used as refrigerants, and various kinds of sprays or sols (eg. perfumes, air freshener, etc.). CFCs cause ozone holes in the ozone layer. Ozone hole refer to depletion of ozone molecules in the ozone layer due to the

reaction of CFCs. The holes in the ozone layer appear elsewhere and not where these chemicals are used.

3. More ultraviolet radiations reach the earth through the ozone holes and the reflected radiations from the earth are absorbed by CO_2 water vapour, etc. The trapped radiations release more and more heat resulting in the phenomenon of Global Warming. This effect is also known as Green House Effect.

Global environment damage affects quality of environment over a much larger area and is not localised to the area where the damage is initiated. Global warming will cause ill effects and are not confined to the area causing the damage. It causes wide range of effects like melting of glaciers, polar caps, rise in water level or sea and flooding of costal plains, etc.

Intext Questions 32.1

1. Define environment.

....

2. What are the two components of environment?

....

3. List three biotic components?

....

4. Name two common toxic metals which pollute water.

....

5. How do CFCs affect the ozone layer?

....

6. What are the different segments of environment

………………………………………...……

7. Define Greenhouse effect.

....

32.4 Environment Pollution

Growth of population forced people to move to their places. They started utilising natural resources such as trees and soil (mud) to build shelters. More waste material started collecting at places at their inhabitation. Humans themselves created conditions for disposal of waste (sanitation). Humans then started industries to manufacture goods for their own comforts. Pesticides and chemical fertilizers were manufactured to grow more food for the growing demand by population. Industries also generated wastes, which ultimately finds, its way to water sources. Pesticides and chemicals were washed into natural water bodies such areas, river, lakes and ponds and affected the aquatic organisms. Such condition where human activities are damaging the environment is termed as pollution.

Pollution refers to *deterioration of natural resources such as air, water and soil because of the action or presence of unwanted substances beyond a certain limit*.

Contamination:

Contaminations refer to the mere presence of undesirable materials to a medium like air, water, soil, etc. making it unfit for a particular use. For example, contamination of air by hazardous exhaust from automobiles. It becomes a pollutant if its concentration exceeds the level which can cause harmful effect.

32.4 Pollutants

Pollutants are the substances in solid, semi solid, liquid, gas or sub molecular particle form which when introduced into the environment in significant amounts cause detrimental (bad) effect on the environment.

The Pollutants may be classified in the following ways (Fig.32.1)

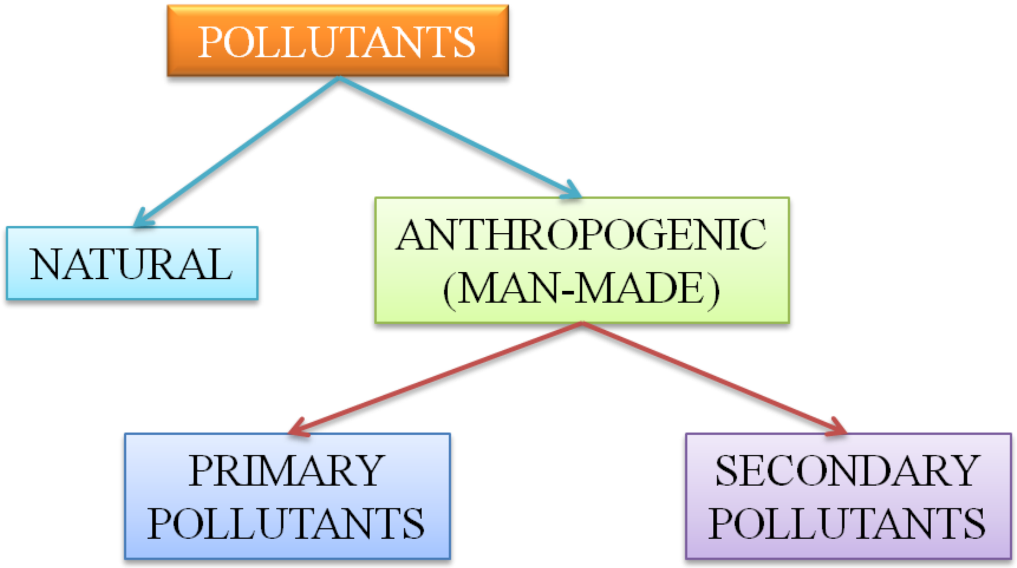


Fig. 32.1: Classification of Pollutants

32.4.1 Natural Pollutants

There can be several natural sources which are the cause of pollution. Some of the mare listed below.

(i) Fires in forests caused when lightning strikes the trees, produces a lot of CO_2 which is released to the atmosphere.

(ii) Soil erosion increases suspended particulate matter and dust in air. These may even enter water bodies as they are washed down by rain or natural water falls.

(iii) Volcanic eruptions also add pollutants like SO_2 and solid particles to the environment.

(iv) Volatile organic compounds from leaves, trees and dead animals naturally enter the atmosphere.

(v) Natural radioactivity and the other natural pollutants have been entering the environment since ages. (But the low level of pollution has rarely endangered lives of organisms).

32.4.2AnthropogenicPollutants

Pollutants added to the environment through human activities are termed anthropogenic pollutants. These are of two kinds.

(i) Primary pollutants: Primary pollutants are added directly in a harmful form to the atmosphere. eg CO_2 and CO from burning of fossil fuel; SO_2 and oxides of nitrogen from vehicular combustion, thermal power stations, etc.

(ii) Secondary pollutants: Secondary pollutants are the products of reaction between the primary pollutants and normal environmental constituents. Thus, SO2 a primary pollutant which reacts with oxygen of air to gives SO_3. Further, SO_3 reacts with water vapour present in the atmosphere and forms H_2SO_4. SO_3 and H_2SO_4 are secondary pollutants. Nitric Oxide (NO), a primary pollutant reacts with oxygen to give NO_2 which is a secondary pollutant.

Intext Questions 32.2

1. Define a pollutant.

....

2. Name two sources of natural pollutants

....

3. Define a secondary pollutant.

....

4. What do you mean by environmental pollution?

....

32.5 Sources of pollutants

Many of the pollutants in our environment have natural as well as human related origins. For example, the natural origin of pollutants includes the release of sulphur dioxide (SO_2) from volcanic eruptions, erosion of soil by wind and water, dissolved minerals carried onto rivers and ocean by surface run off, etc.

The sources of pollutants are also classified:

(i) Stationary and (ii) Mobile sources

Stationary Sources: The pollutants released from a fixed location or a well defined area is known as stationary source. e.g. smokestacks of power plants, smelters, surface mines, etc.

Mobile Sources: The pollutants released from diffused sources or the sources that move from place to place is termed as a mobile source. e.g. automobiles, buses, aircrafts, ships, trains, etc.

The various pollutants of water, their sources and effects are given in Table32.1

Table No. 32.1: Major Air Pollutants their Sources and Effects

Major Pollutants of Air	Some of the Sources	Some of the Effects
SO_2	Vehicular combustion, Irritation to the eyes, acid rain fossil fuel burning	Irritation to the eyes, acid rain premature falling of leaves
CO and CO_2	Vehicular combustion and burning of fuels and hydrocarbons	Global warming, green house effect CO has great affinity for hemoglobin and forms the carboxy haemoglobin
Smoke, fly ash and soot	Thermal power stations	Respiratory diseases
Lead and mercury	Auto exhaust from gasoline, paints, storage batteries, fossil fuel burning	Affects the nervous system and circulatory system causing nerve and brain damage.
CFCs	Refrigerants and aerosol	Kidney damage and ozone depletion.

TableNo.32.2: Major Water Pollutants their Sources and Effects

Major Pollutants of water	Some of the Sources	Some of the Effects
Pesticides and insecticides like DDT, BHC	Improper use in agriculture, mosquito repellants	Toxic to fishes, predatory birds and mammals.
Plastics	Homes and industries	Kills fishes and animals like cows
Chlorine compounds	Water disinfection with chlorine, paper and bleaching powder	Fatal for plankton (organisms floating on the surface of industries water) foul taste and odour, can cause cancer in humans.
Lead	Leaded gasoline, paints etc	Toxic to organisms
Mercury	Natural evaporation and dissolved industrial wastes, fungicides	Highly toxic to humans
Acids	Mine drainage, industrial wastes	Kills organisms
Sediments	Natural erosion, runoff from fertilizer and other factories, mining and construction activities	Reduces ability of water to assimilate oxygen.

The general effects of pollutants are produced due to interactions of pollutants among themselves.

Intext Questions 32.3

1. Mention one bad effect each of SO_2 and CO on humans.

....

2. Name one source of each pollutant lead and CFC.

....

3. Name the two major sources of anthropogenic sources of pollutants in the environment.

....

4. Give two examples of stationary sources of pollution.

....

What You Have Learnt

- Surroundings in which we live is our environment.
- There are two components of environment: physical or a biotic and living organisms or biotic
- Pollutants may be defined as substances added to natural surroundings.
- There are two major sources of pollutants-stationary and mobile.
- Pollutants have adverse effects on environment and living organisms.
- SO_2, CO, CO, smoke, Pb, Hg, CFC, etc. pollute air. Their sources and effects are varied.
- Pollution in simple words in the unhealthy and harmful condition for living organisms and non-living things.
- Pesticides, plastic, detergents, chlorine, mercury, etc. pollute water and endanger life of aquatic organisms.

Terminal questions

1. What is environment?
2. Explain the term anthropogenic pollutants.
3. Write four major pollutants of water, their sources and effects.
4. Differentiate between the Primary and Secondary Pollutants.
5. What are the two sources of pollution? explain

Answers to Intext Questions:

32.1

1. The air, water, earth and living beings in a joint form is called environment.
2. There are two components of environment namely biotic and abiotic.
3. Living organisms such as plants, animals, microbles, etc.
4. Lead and Mercury.
5. Causes holes in the ozone layer.
6. Atmosphere, biosphere, hydrosphere and lithosphere.

32.2

1. Any substance which is present in its excess concentration such as CO, CO_2, SO_2.
2. Volcanic eruptions and run-off from surface mines.
3. Secondary pollutants are the products of reaction between the primary pollutant and the normal environmental constituents.
4. Environmental pollution is the deterioration or unclean objection able conditions in the quality of natural resources such as air, water and soil because of the action or presence of unwanted substances in undesirable concentration.

32.3

1. Irritation to eyes by SO_2 and difficulty in breathing.
2. Lead from exhaust of automobiles running on gasoline (petrol). CFC from refrigerants.
3. Industrial waste and automobile exhaust.
4. Smoke stacks of power plants, run-off from surface mines.

Chapter 33

AIR POLLUTION

Organisms have a close inter-relationship with their immediate environment. Oxygen from air is taken in during respiration and carbon dioxide released into the atmosphere by majority of organisms. The CO_2 is taken up by plants to manufacture food. This harmonious relationship between various organisms and nature has been disrupted by human activities. Intensive agriculture, industrialization, urbanization have degraded our physical resources and as a results oil, water and atmosphere have become highly polluted.

In this lesson we will define atmosphere and mention its constituents, discuss sources of air pollution and damage done to plant and animal life by atmospheric pollutants. We shall also outline measures that can stop further atmospheric pollution.

Objectives

After reading this lesson you will be able to:

- explain the composition of air;
- define air pollution;
- explain respiration, photosynthesis and decay cycle;
- cite examples of major air pollutants;
- recall sources of major air pollutants;
- identify relationship between carbon cycle and oxygen depletion by fossil fuel burning;
- explain nitrogen cycle;
- define green house effect;
- recognize factors causing green house effect;
- explain global warming;
- define ozone layer;
- explain depletion of ozone layer;
- explain acid deposition/acid rain;
- Recognize ill effects of carbon monoxide on hemoglobin and
- List measures for reducing air pollution.

33.1 Composition of Air

Atmosphere is a thin layer of air surrounding the earth. The air becomes thin (less dense) as we go higher up from the surface. Most of the air is present within 50km from the surface of the earth.

The atmosphere has five distinct zones, they are:

1. **Troposphere:** The zone where all weather events occur.
2. **Stratosphere:** This zone consists of water vapour and ozone and temperature
3. **Mesosphere:** This zone contains dense gases and low concentrations of ozone is present and meteors are destroyed in this layer approaching earth
4. **Thermosphere:** is the zone where the gases are present in highly ionized form and here UV and X-rays are absorbed.
5. **Exosphere:** This outermost zone of earth containing satellite orbits

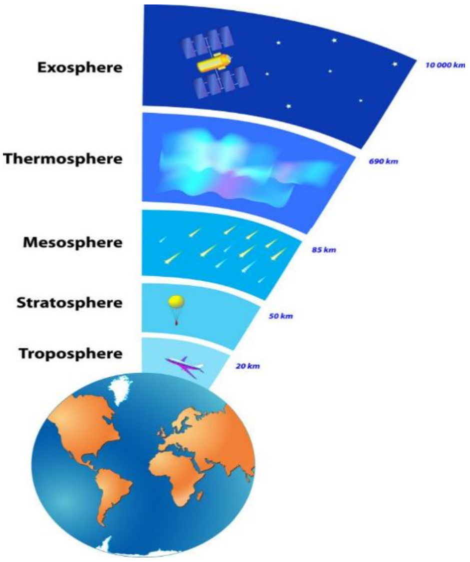


Fig 33.1: zones of atmosphere

The composition of clean, dry and unpolluted air remains almost constant. The composition of air remains constant due to various natural cycles like carbon cycle, nitrogen cycle, etc. in nature. Any disturbance in the cycles has a harmful effect on organisms. Natural atmospheric air is made up of gaseous and non-gaseous constituents.

(a) Gaseous: Nitrogen and oxygen makeup over 98% of volume of air. Other gases are CO2, water vapour and inert gases such as argon, neon, krypton, helium, xenon, radon and ozone are present in traces. These gases based on their available concentrations in the atmosphere are broadly catagorised as major, minor and traces (Table 33.1)

(b)Non-gaseous: Smoke, dust and salt (through evaporation from the sea) are the non-gaseous constituents of air.

Table 33.1 Composition of Atmosphere

Categories	Gas	Formula	Percent By Volume
Major	Nitrogen	N_2	78.9
	Oxygen	O_2	20.94
	Water vapour	H_2O	0.1to5
Minor	Carbondioxide	CO_2	0.035
Trace	Helium	He	0.00052

Methane	CH_4	0.00015
Hydrogen	H_2	0.00005
Sulphurdioxide	SO_2	0.000002
Ammonia	NH_3	0.00001
Carbon monoxide	CO	0.00001
Nitrogen dioxide	NO_2	0.00001
Ozone	O_3	Trace

33.2 Carbon Transfer Pathways - Respiration, Photosynthesis and Decay Cycle

There is a delicate balance between various constituent so fair. Any disturbance in the concentration of the constituents due to pollution will adversely affect the organisms. For example, carbon is actively cycled between inorganic carbon dioxide and various kinds of organic compounds of which organisms are made up of. It moves from inorganic to organic form through the activity of autotrophs (auto; self; trophos: feed). The plants synthesize food through photosynthesis and are the "producers" in the food chain. The process that releases carbon dioxide into the environment is called respiration. Another carbon transfer pathway is decay and decomposition of organic matter brought about by microorganisms.

33.2.1Photosynthesis

Green plants pick up CO_2 from the atmosphere and water from soil. Leaves of green plants contain green pigment chlorophyll - the photosynthetic pigment. Leaves trap solar energy from sun light. Light and the pigment interact and through several steps, starch is synthesized by plants and oxygen is liberated. Oxygen moves into the atmosphere (Fig. 33.2). In fact for the first two billion years after living organisms evolved on the earth, there was no oxygen. Oxygen of the atmosphere resulted from photosynthetic organisms (e.g plants). Plants play a crucial role in supplying the Earth with the precious oxygen essential for the survival of living organisms.

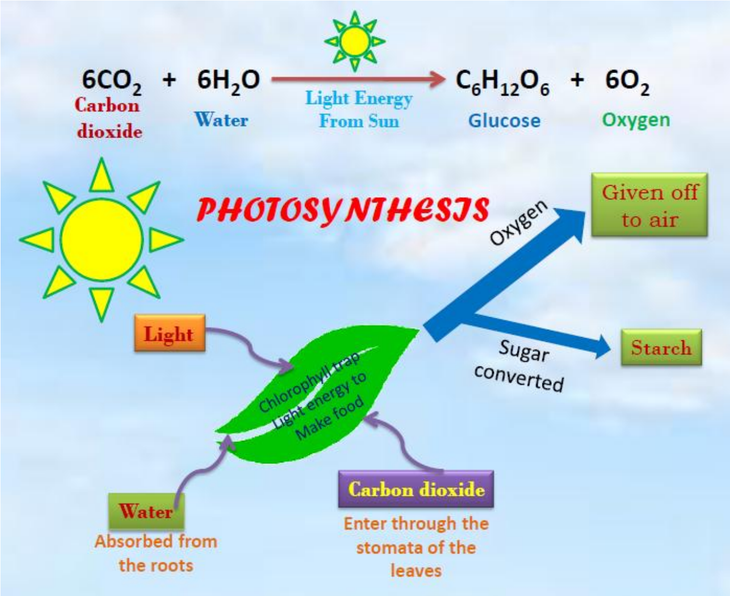


Fig: 33.2: Photosynthesis

33.2.2 Respiration

Respiration is a process of exchange of gases between organisms and atmosphere. Atmosphere is a reservoir of oxygen and organisms take in this oxygen for oxidation of food. Oxidation of food liberates energy. When oxygen reaches the cell of an organism a series of enzyme catalysed reactions take place in which chemical bonds of glucose are broken, energy in the form of ATP (adenosine triphosphate) is liberated and carbon dioxide is released. Carbon dioxide goes back into the atmosphere. (Fig. 33.2) Thus a considerable amount of carbon dioxide is returned to the atmosphere through respiratory activity of organisms.

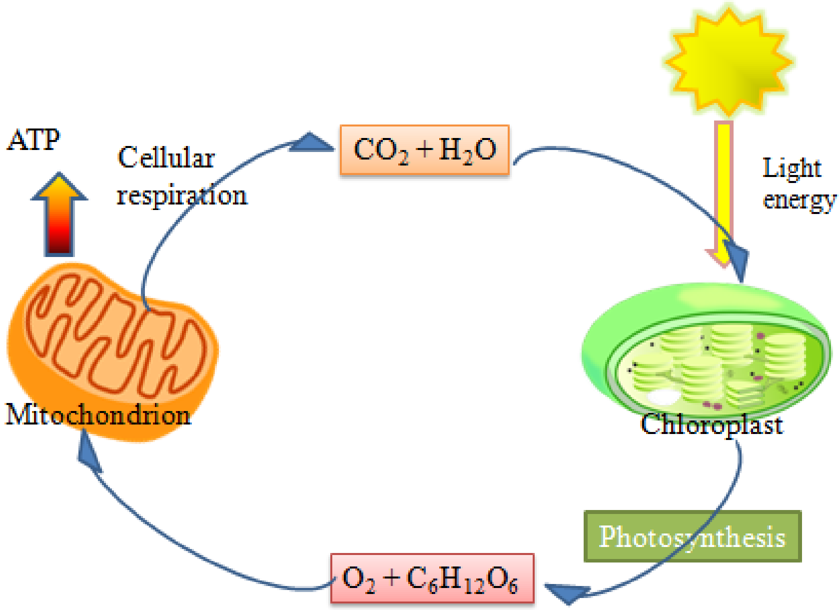


Fig: 33.3: Cellular Respiration

Fig. 33.3 shows cellular respiration in which oxygen oxidises glocose through a series of chemical reactions and an electron transport chain. Energy is released in the form of several molecules of ATP. The CO2 is given out and goes into the atmosphere. Some ATP molecules are also used up in the process and breakup into ADP (adenosine diphosphate and Pi (inorganic phosphate).

33.2.3 Decay of Organic Matter

Microorganisms like bacteria and fungi bring about decay and decomposition of organic matter left after the death of organisms. Due to microbial (by microorganisms) decomposition of partially digested organic matter and dead organisms, CO is liberated and released into atmosphere. Thus the decay cycle also adds CO_2 to the atmosphere.

In swamps, paddy (rice) fields and wetlands, anoxic (lack of oxygen) conditions prevail. Methanogenic bacteria convert low molecular weight fatty acids into methane in these areas.

33.3 Carbon Cycle in Nature

Carbon cycle is the most important biogeochemical gaseous cycle. Also, carbon is returned to the environment as fast as it is removed.

The richest source of carbon is the ocean where carbon exists as carbonate and bicarbonate ions. Carbon enters the atmosphere mainly as a product of aerobic respiration in the form of CO_2. Volcanic eruptions also release carbon from rocks deep in the earth's crust. CO_2 is taken in by plants for photosynthesis during which they use light energy for reducing CO. Plants are, therefore, termed photoautotrophs (photo means light). There are other organisms such as some bacteria which use energy stored in chemical bonds for reducing carbon dioxide to methane. They are termed Chemoautotrophs. Photosynthesis, however, is the most important process through which inorganic carbon is converted into organic from.

When producers and consumers die, decomposers reduce the organic matter of these dead organisms and carbon moves into the soil. Producers, consumers and decomposers add CO_2 to the atmosphere through respiration. Thus a balance in the proportions of O_2 and CO_2 is maintained in nature. (Fig.33.4)

When trees decay, they became fossil fuels and are buried deep in the soil. Carbon in this from remains unavailable till humans deliberately remove it.

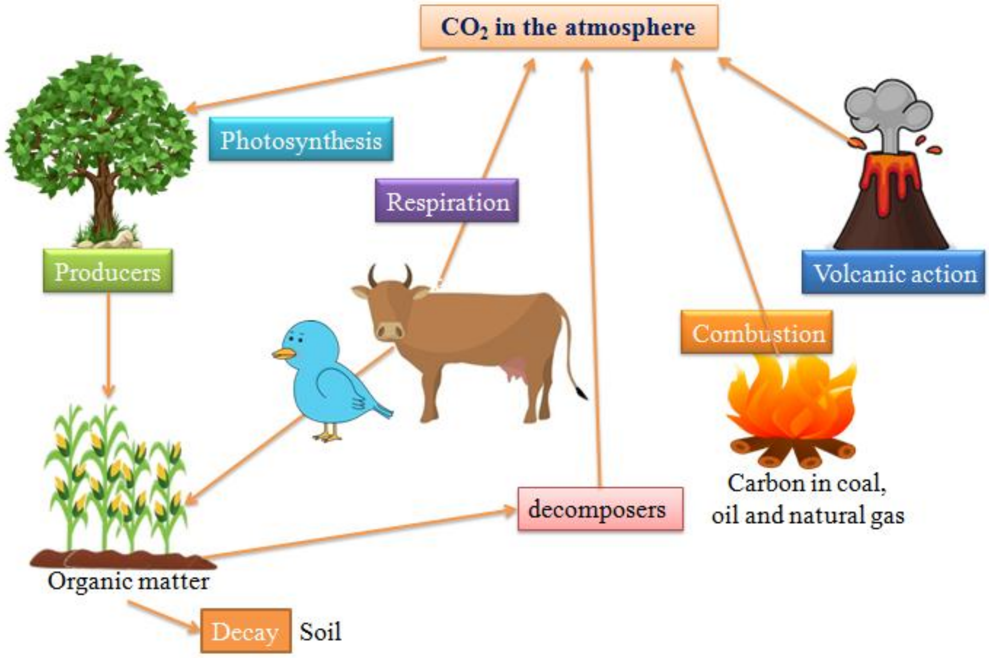


Fig.33.4: The Carbon Cycle in Nature

33.4 The Nitrogen Cycle

Nitrogen and its compounds are essential for the maintenance of life processes in the biosphere. For example, organisms cannot exist without amino acids, peptides, and proteins, all of which are organic molecules containing nitrogen.

Nitrogen is the most abundant gas (about 78% of the atmosphere), however, plants cannot use free nitrogen (N_2) directly. Plants, algae and bacteria take up inorganic nitrogen either as the nitrate ion (NO_3^-) or the ammoniumion NH_4^+ from the environment and use it to build their own protein molecules i.e. organic nitrogen. Organic nitrogen is consumed by animals and human beings to build their bodies.

Nitrogen is a relatively inert element and there are few processes that convert the free nitrogen to available nitrogen compounds. Nitrogen gas in the atmosphere is transformed by lighting of bacterial uptake to nitrates or ammonia. In natural process the nitrogen-fixing bacteria (some blue green bacteria) have a highly specialized ability to "fix" nitrogen i.e. they change it to less mobile, more useful forms by combining it with hydrogen to make ammonia

(NH_3). This is called Nitrogen fixation. In this form the nitrogen is used up by plants and algae. They convert inorganic nitrogen compounds into organic compounds and nitrogen becomes available. Through ecological food chains organic nitrogen enter into other living organisms including humans and animals.

When organisms perish, certain bacteria have the capability to transform the nitrogen-containing organic compounds back into nitrates, ammonia, and eventually into molecular nitrogen (gas). In this way molecular nitrogen is returned back to atmosphere. The process of releasing fixed nitrogen back to molecular nitrogen is known as de-nitrification. The nitrogen cycle is shown in Fig 33.5.

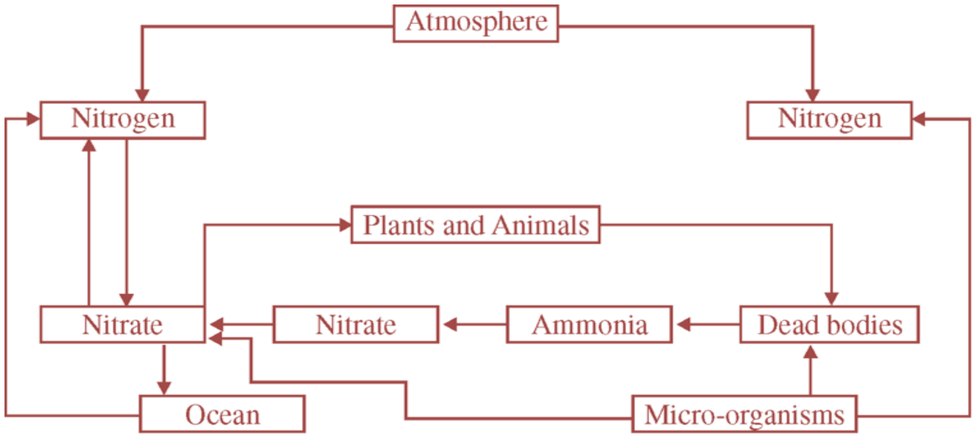


Fig.33.5: *The Nitrogen Cycle*

Intext Questions (33.1-33.4)

1) Which gas is present in maximum amount in the atmosphere?

....

2) Name any two major constituents of air.

....

3) Which organisms are called autotrophs and why?

....

4) Name the food constituent which is broken down during respiration to liberate energy and carbondioxide.

....

5) What is the green photosynthetic pigment present in plants?

....

6) How does carbon get into the environment from dead organic matter?

....

7) Are human’s producers or consumers?

....

8) Name two physical phenomena by which carbon is fixed in the nature.

....

9) Name the atmospheric layer where ozone is mainly available.

....

33.5 AIR POLLUTION

DEFINITION: Air pollution refers to the detrimental alterations to the atmosphere resulting from the introduction of pollutants through human activities, using both physical and chemical methods. CO_2, O_2 and N_2 are balanced in the environment naturally and any imbalance caused, leads to adverse effects. The contaminants or pollutants such as SO_2, NOx, CO and CO_2 are the common gaseous contaminants which cause severe air pollution. Broadly, air pollutants are classified as:

1. Particulate pollutants
2. Liquid droplets
3. Gaseous pollutants

33.5.1 Particulate pollutants

Particulate pollutants can be smoke, dust, mist, pollen, soot, Fly ash, fumes, other combustion byproducts like lead, and agricultural chemicals

- **Smoke:** it is a suspension of gases and particulates which is formed on combustion of organic matter. Example – smoke arises on burning tobacco, wood, oil, fossil fuels and also on cooking. Smoke is the byproduct of burning of organic matter.
- **Dust:** Particulate matter less than 10 microns in size is dust. It reaches lungs, deposits along the respiratory tract and causes asthma or even lung cancer. Dust generated from stone crushers, cement production, and sand activities serves as a few illustrations of particulate pollutants.
- **Soot and Fly ash:** These arise from the chimneys of industries where combustion of fuel and coal. Fly ash is lightweight substance which flies along the gases released by industries. Soot is black substance due to incomplete combustion of coal. They are blown away by wind and mix in air.
- **Fumes:** During sublimation, airborne particles are produced as fumes. Chemical processes such as distillation, boiling cause fumes. These are added to the air.
- **Pollens:** These are produces by flowers and are powdered in nature. They are carried away by wind and are added to air.
- **Agricultural chemicals:** Chemical insecticides, herbicides and other pesticides are added to environment when they are sprayed on plants. Excess usage may cause plants. They are toxic to animals and humans also.
- **Lead:** Lead is most dangerous pollutant as it is added to atmosphere from industries such as Paint, ceramic and pesticide industries, lead storage batteries and recycling of discarded batteries. Major part of lead is added to air through exhaust from

automobiles it is used as an anti- knocking agent in automobile gasoline which contains tetraethyl lead. Lead interferes with development of RBCs and causes anemia. Lead is a cumulative poison and prolonged exposure even in low concentration may damage kidneys and liver.

33.5.2 Hydrocarbons

Hydrocarbons which may be in the form of liquid droplets or gas pollute air. As liquid droplets they are spilled or are added through seepage of oil fields and natural gas leakage.

Example: methane

Methane is emitted in the swamps and paddy fields by methanogenic bacteria. Methane (CH_4) is also generated in stomachs of ruminant animals. Incomplete combustion of fuels release 3,4-benzopyrene which causes lung cancer. Pesticides, paints and solvents also release hydrocarbons. Hydrocarbons are a source of photochemical smog.

33.5.3 Gaseous Pollutants

SO_2, CO_2, nitrogen oxides are commonly added to the air by human activities. An excessive presence of these particulates can lead to severe detrimental impacts on both the physical environment and human health.

SO_2 and H_2S: These are released into atmosphere through processes such as smelting of ores, petroleum refining, combustion of fossil fuels, paper making, in nature through volcanic eruptions and manufacture of H_2SO_4. Plants exposed to SO_2 and H_2S show defoliation (leaves falling off) and reduced growth. In humans, SO_2 pollution causes headache, vomiting, irritation of eye and respiratory passages.

Nitrogen Oxides: An aerobic break down of nitrogenous compounds by bacteria is the natural source of nitrogen oxides. Burning fossil fuel also releases them. Power generators, automobile exhausts, explosives and nitrogenous fertilizer industries and the other anthropogenic sources produce nitrogen oxides.

NOx: causes early dropping off of leaves and fruit sin plants. Nitrogen oxides are one source of photochemical smog, acid deposition and green house effect.

CO2 and CO: Combustion of oil, gas, coal and wood releases CO_2 in the atmosphere. CO is released chiefly from gasoline engines and burning of coal in defective furnaces. Motor vehicles with internal combustion engines emit high levels of CO and hydrocarbons. Excess of CO_2 can cause global warming, CO causes photochemical smog and has a fatal effect when in hailed by humans.

CO poisoning: CO has a high affinity for haemoglobin. It combines with the blood pigment haemoglobin to form carboxy haemoglobin. The normal function of haemoglobin is to carry O_2. But CO_2 combines with haemoglobin about two hundred times faster than O_2. Tissues do not get oxygen and die due to lack of oxygen. Carboxy haemoglobin is dark red in colour, the victims of CO poisoning have dark red lips. Mild CO poisoning causes lung disorders like bronchitis and emphysema. CO from cigarette smoke makes haemoglobin nonfunctional in smokers.

Photo chemical oxidants: Primary pollutants such as nitrogen oxides and hydrocarbons mix in the atmosphere and form secondary pollutants like peroxy acetylnitrate (PAN) and ozone, under the influence of UV radiation from the sun. Both PAN and O_3 form photochemical smog. PAN and O_3 are toxic to plants. In humans they cause irritation of eyes coughing, headachae, dry throat, respiratory problems and haemorrhage.

The various human and natural activities which introduce air pollutants into the atmosphere are summarised in Table **33.2**

Table 33.2: Common air pollutants, their sources and contribution of aural and Anthropogenic Pollution

Air Pollutants	Some Sources	Emission Natural	(% of total) Anthropogenic
Sulphuroxide (SO_x)	Fossil fuel burning, industry, biomass, biomass burning, volcanoes, oceans	50	50
Carbon monixide (CO)	Incomplete combustion, methane oxidation, transportation, biomass, burning, plant metabolism	91	9
Nitrogen Oxide (NO_x)	Fossil fuel burning, lightening, Biomass burning, soil microbes	40	60
Hydrocarbons (HC)	Fossil fules, industrial processes, evaporation of organic solvents, agricultural burning, plant isoprenes, and other biogenics.	84	16
Suspended Particulate Materials(SPM)	Biomass burning, dust, sea salt, biogenic aerosols, gasto particle conversion.	89	11

Intext Questions 33.5

1) What is atmospheric pollution?

....

2) Name two particulate pollutants.

....

3) Name two gaseous pollutants?

....

4) Name one source which causes pollution due to methane.

....

5) Name two air pollutants which form photochemical smog.

....

33.6 Effects of Excessive Atmospheric Pollutants on Nature

Most of pollutants are products of fuel combustion. These pollutants have been released into atmosphere ever since human first started burning wood and coal. Later on, pollutants are being released into air due to increased industrial activity. The nature has not been able to remove all these pollutants because much more pollutants are added than the nature can handle to maintain the balance. Therefore, pollutants have now accumulated in the atmosphere to a proportion whereby atmospheric composition of air has been significantly altered. It is the causes of physical phenomena such as photochemical smog, acid rain, ozone depletion, greenhouse effect and global warming. These are damaging to plants, animals and humans.

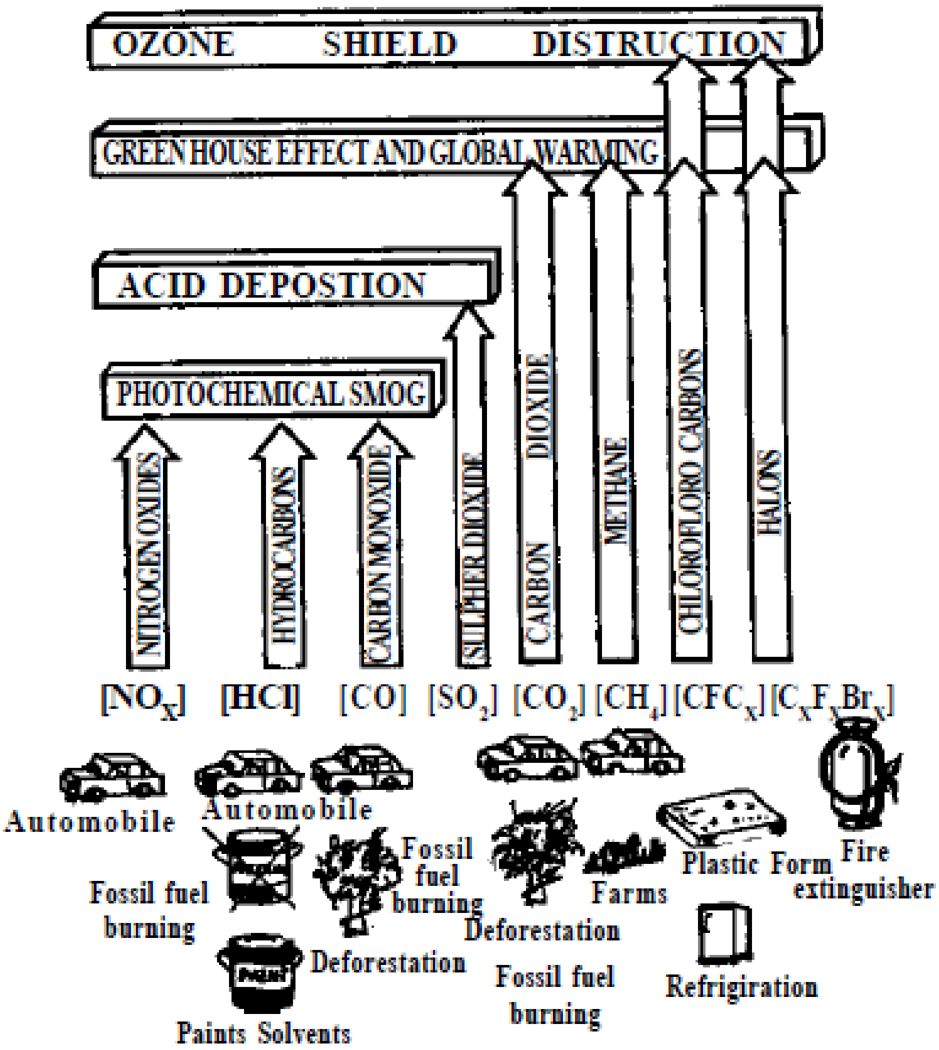


Fig.No.33.6: The major effects of atmospheric pollutants.

1. Photochemical Smog and Temperature Inversion

Pollutants like sulphur dioxide and particulate matter like soot present stagnant air masses, get modified in sunlight and form a sheet called photochemical smog. When sunlight falls on stagnant air under low humid conditions in the presence of pollutants such as SO2 soot, nitrogen oxides and hydrocarbons, photochemical smog is formed.

Smog is a combination of fog, smoke and fumes released by mills and factories, homes and automobiles. Smog stays close to the ground and reduces visibility and causes irritation. Photochemical smog is also called PAN smog due to the formation of peroxy acetyl nitrate or PAN and ozone which are formed from hydrocarbons and nitrogen oxides in the presence of solar radiation. PAN and ozone are called photochemical oxidants. Both of these are toxic irritants to human lungs.

Temperature inversion causes smog to settle and remain near the ground till wind sweeps it away. Normally, warm air rises up into atmosphere. When a layer of cool air at the ground level is held there by an overlying layer of warm stagnant air is called temperature or thermal inversion

Exposure to smog causes respiratory problems, bronchitis, sore throat, cold, headache and irritation to eyes (red shot eyes). Smog also damages crops and reduces crop yield.

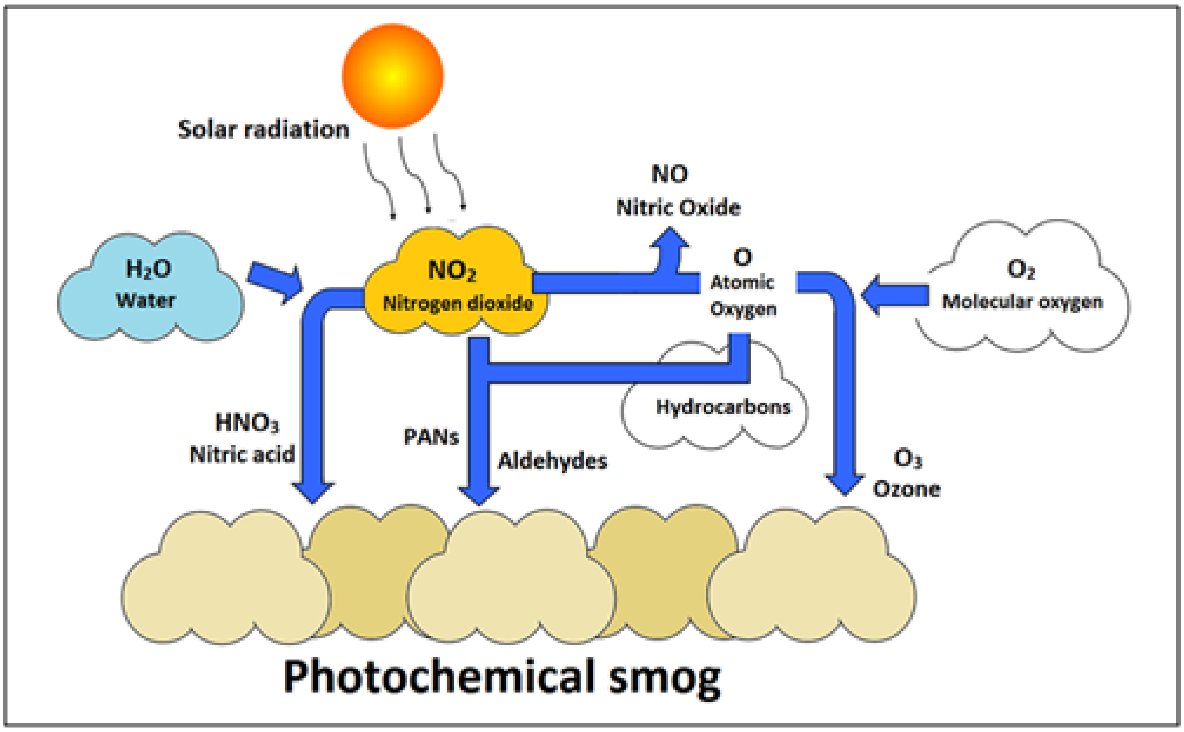


Fig.33.7: Formation of Photochemical Smog

2. Acid Rain

Coal and oil burned by power plants and other industries release SO_2 into air because coal and oil contain small amount of sulphur. Automobile exhausts add SO_2 and nitrogen oxides. They combine with oxygen and water vapour in the atmosphere as per the following photo chemical reactions.

$$2SO2 + O2 + 2H2O \longrightarrow 2H2SO4$$

$$4NO2+O2+2H2O \longrightarrow 4HNO3$$

This reaction in promoted by O_3 in smog. The acids, so formed are washed down from air to earth during rain or snowfall. It is called acid rain or acid snow. The acids react with minerals present in soil to form sulphates and nitrates due to acid rain.

Rain water even in its purest form is slighlty acidic with pH 5.6 due to dissolved CO_2. But areas near coal and oil burning industries and where motor vehicles ply in large numbers, pH goes down to 2 and rain becomes strongly acidic.

Mountain foot hills are the worst affected. There is moisture laden air rises to higher altitudes it condenses to fall as rain or snow, dropping its load of pollutants. In spring. snow melts and adds pollutants to lakes and other water bodies. When the dissolved pollutants drop as rain or snow (wet deposition) it is termed acid precipitation. Deposition of dry gases and salts is dry deposition. Acid rain spreads over areas of several hundred to several thousand kilometers.

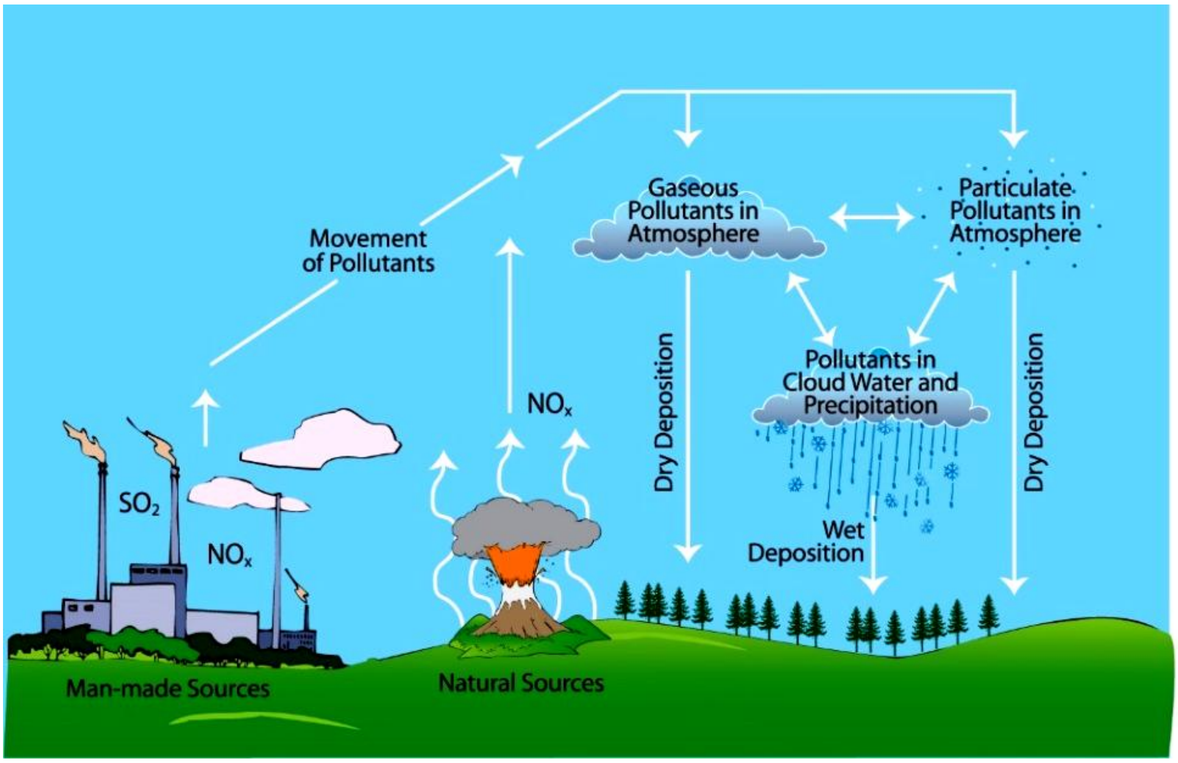


FIG 33.8: Acid rain

Effects of Acid Rain

Some of the effects of acid rain are listed below:

1) Excessive acid concentrations are phytotoxic (toxic to plants). There have been wide spread death of trees in forests due to acid rain.
2) Sea waters are rich in minerals and have great buffering capacity. But buffering capacity of fresh water bodies is low and acid deposits have a toxic effect on the fresh water ecosystems.
3) Mature (capable of reproduction) fish survives in acid rain fed water bodies but fails to reproduce. So there are no young fish in such waters.
4) Exposed surface of buildings, statues get corroded. Lime stone or marble ($CaCO_3$) structures are specially damaged (Fig.32.8).

   The chemical reaction in like

   $$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$
5) The sulphates are leached out by rainwater.
6) Acidic sulphate when present in the atmosphere causes laziness. Acidic mist falling on the ground reduces visibility.

3. Green House Effect and Global Warming

The literal meaning and function of green house is to trap the heat. You must have seen delicate plants being grown in a glass chamber which is comparatively warmer inside than outside. Glass permits solar radiations to come in but restricts the out ward movement of air. The radiations get trapped inside the glass chamber and raises the temperature.

Gases such as CO_2, NO_2, CFCs (chlorofluorocarbons) allows un rays to pass through them but then absorb and reradiate the heat back towards the earth. These are therefore termed as green house gases.

Greenhouse Gases

The common greenhouse gases and their sources of pollution are listed below:

S no	Gases	Sources
1	CO_2	From fossil fuel
2	NO_2	From fertilizer plants, automobile exhaust and animal waste
3	CH_4	From bacterial decomposition, biogas, flooded rice fields
4	CFCs	From Freon, (a refrigerant), aerosol sprays
5	HALONS (halocarbons)	From fire extinguishers.

4. Depletion of ozone layer

Formation of ozone hole:

The second layer of atmosphere around the earth's is Stratosphere (lies 15 km to 50 km above the surface of earth). The energy of the sun splits some molecular O_2 in this layer to give individual (O) atoms which combine with intact molecular oxygen to give O_3. The layer of O_3 forms a shield as it absorbs UV rays and prevent them from striking the earth. Troposphere is the atmospheric layer closest to the earth's surface. Chloroflourocarbons and halons released into the atmosphere by the pollutants have destroyed the ozone shield and an Ozone hole has been detected at the South Pole of Antartic and North Pole of Arctic.

How Ozone shield is depleting?

a) Chlorofluorocarbons (CFCs) are the heat transfer agents used in refrigerators and air conditioners, and foaming agents in foam cups and cartons.

b) Halons or halocarbons are anti fire agents used in fire extinguishers.

The ozone in the stratosphere is being depleted by the presence of mainly cholorofluorocarbons (CFCs) and halogen gas, particularly chlorine. The highly energetic ultra violet radiation splits up the CFCs, releasing chlorine. The released chlorine is responsible for conversion of the ozone into oxygen molecule consequently depletion of ozone layer occurs as per the following equations.

$$Cl^* + O_3 \longrightarrow ClO + O_2$$

$$ClO^* + O^* \longrightarrow Cl^* + O_2$$

It is believed that one molecule of CFC is capable of destroying 1,00,000 ozone molecules in the stratosphere. The area where the ozone is completely destroyed is known as ozone hole. The first ozone hole was observed over Antarctic Ocean.

The important function of ozone layer in the stratosphere is to protect us from dangerous ultra violet (UV) radiations from the sun by absorbing it.

Effects of Ozone Depletion

Ozone layer depletion will allow more UV rays to enter the troposphere and will cause a series of harmful effects such as:

1) Plants and animals living on the surface will start dying.
2) UV radiation will fasten the formation of smog
3) Temperature of the earth will increase leading rise in sea level and flooding of low lying areas.
4) More UV rays will directly fall on the skin of humans causing skin cancer.
5) Leaves of plants will show chlorosis (loss of chlorophyll and yellowing).

33.7 Effects of Air Pollution on Humans

Air is mobile and impact of air pollution on ecosystems is reduced as wind blows away pollutants. But when winds are calm, air pollution becomes not only damaging but life threatening.

The damaging effects of atmospheric pollution have been described along with the account on pollutants. Long term exposure to moderate pollution causes more disease and death. Some adverse effects of air pollution on humans are summarized in table 33.3

Table33.3: Effects of air pollutants on humans

Disease / Discomfort	Caused by
Emphysema. Bronchitis	CO, SO_2, PAN, O_3
Eye irritation, headache	SO_2, PAN, O_3
Silicosis, Asbestosis	Suspended particulate matter like silica, asbestos
Coronary artery disease	Tobacco smoke
Anemia, kidney, liver damage	Pb
Fluorosis, Skin Cancer	Fluorides
Poisoning death	CO

33.8 Control of Air Pollution

The alarming rate at which the atmosphere is being polluted, There is a need of the hour to put a quick check to atmospheric pollution.

Since most of air pollutants are emitted during combustion of fossil fuels, there are two practical approaches for air pollution control which are discussed below:

I) One approach is control undesirable changes in the air we breathe by observing the following precaution:

a) Limiting pollutants into air by using sulphur-free oil and coal, using catalytic convertors in automobiles and avoiding burning of waste material.

b) Taking stringent measures against release of emissions from industries.

II) The other approach is to use sources of energy other than fossil fuels such as wind, water, solar power, etc. Use bicycles and battery powered cars rather than vehicles with internal combustion engines. Service vehicles should use lead free petrol.

Above all, it is necessary to educate the general public. Air pollution should become every human being's concern. Only then will the air become more congenial to healthy living.

Intext Questions 33.5-33.8

1) What is smog?

....

2) Name two photochemical oxidants.

....

3) Name two gases which form acid rain.

....

4) Mention any four green house gases.

....

5) What are the sources of freons and halons in air?

....

6) What effect does acid rain have on marble statues?

....

7) Mention one measure to control air pollution.

....

What You Have Learnt

- Nature's balance has been upset by human activities related to urbanization, industrialization and intensive agriculture.
- Atmosphere is made up of gases of which nitrogen-78%, oxygen-21%, carbon dioxide - 0.1 to 0.3%, inert gases 1%.
- Increase of temperature with altitude is known as positive lapse rate whereas decrease in temperature with increases of altitude is negative lapse rate of temperature.
- Carbon is actively cycled between its inorganic form to organic form through respiration and photothensis. Decay cycle converts organic carbon to inorganic carbon.
- During respiration food is oxidised through a series of enzyme controlled steps in which chemical bonds of glucose are broken down to release energy and CO_2 is liberated.
- In photosynthesis green plants trap solar energy and synthesize starch from CO_2 & H_2O. Oxygen is released into air and after death; the organisms are decomposed by microorganisms. The carbon in organisms moves back to the environment.
- Air pollution is due to
    - i) Particulate matter (soot, dust)
    - ii) Aerosols composed of hydrocarbons
    - iii) Gases like SO, NO are mostly released by burning fossil fuels.

- NO_2 and hydrocarbons are modified by sunlight to form photochemical smog. Smog is a combination of smoke and fog. Automobile exhausts give out NO_2 and hydrocarbons. They form PAN (peroxyacetylnitrate) which along with ozone and SO_2 forms photochemical smog.
- Smog cool sand settles down near the earth and forms a blanket, while warmer air covers it. Thus there is temperature inversion with warm air above and cool air below unlike in the normal conditions.
- SO_2, and NO_2, form acids which drop as H_2SO_4, and HNO_3 on statues and spoil them. This is called acid precipitation. Acid rain kills trees, prevents reproduction in fish and causes poor visibility.
- Green house gases are CO_2, NO_2, CH_4, chlorofluorocarbons and halogens. They trap solar radiation and cause global warming.
- Global warming due to green house effect leads to drought, rise in sea level, lack of rain and water shortage.
- There is a layer of ozone in stratosphere, which protects us from UV radiation by absorbing it.
- Chlorofluorocarbons which are used in refrigerators and foam cups as aerosols and halons used in fire extinguishers, when released into the air cause depletion of ozone shield which protects us from harmful effects of solar radiations. It is feared that ozone depletion will have damaging effects on humans such as causing skin cancer. Complete destruction of ozone layer over an area is termed as ozone hole.
- Air pollution causes respiratory diseases such as emphysema and bronchitis, eye irritation, fluorosis, cancer and may even be fatal.
- Control measures include use of sulphur free oil and coal, use of alternative sources of energy such as wind and solar power, use bicycle and battery powered vehicles, stop burning waste indiscriminately, have stringent measures for release of emissions from industries and above all educate general public and caution them against releasing air pollutants.

Terminal Exercise

1) How are fossil fuels formed in nature?
2) What are the damaging effects of SO_2 and NO_2 on plants and animals?
3) Write a note on carbon monoxide poisoning.
4) What is thermal inversion and how is it caused?
5) Enumerate the various effects of acid rain.
6) What is ozone hole? What are the effects of ozone depletion?
7) Why does sea level rise due to global warming?
8) How do green house gases cause global warming?
9) Mention five disease/discomforts in humans caused by different air pollutants.
10) Enumerate the various measures of control of air pollution.

33.1 - 33.4

Answers to Intext Questions

1. Nitrogen
2. Nitrogen and oxygen
3. Plants; because they synthesize their own food
4. Glucose
5. Chlorophyll
6. Through decay and decomposition
7. Consumers
8. i) volcanic eruption and ii) combustion
9. Stratosphere

33.5

1. Undesirable level of undesirable and harmful substances in the atmosphere
2. Soot, fluoride, Pb dust, NaCl (any two)
3. SO_2, CO, CO_2, NH_3, H_2S (anytwo)
4. methanogenic bacteria, ruminant stomach, fermentation in water logged paddy fields
   (Anyone)
5. PAN and O_3

33.3

1. Fog and smoke
2. O_3 and PAN
3. SO and NO
4. CO_2, NO_2, CH_4, CFC Halogens
5. Refrigerants, fire extinguishers
6. Corrode them
7. Reducing use of fuel which releases air pollutants and use clean renewable fuels.
8. Educate everyone about dangers of pollution.

Chapter 34

WATER POLLUTION

Water is essential for the existence of all life forms. In addition to household uses, water is vital for agriculture, industry, fishery and tourism etc. Increasing population, urbanization and industrialization has led to the decreased availability of water. The quality of water used is also being deteriorated as it is getting more and more polluted. You may be aware of at least some health hazards and harmful effects of water pollution. In this lesson a detailed account of various types, sources and effects of water pollutants is given. Some methods of water pollution control and legislatures involved have also been discussed.

Objectives

After reading this lesson you will be able to:

- list earth's water resources;
- define water pollution and its different parameters;
- list the major types of water pollutants, their sources and effects;
- distinguish between natural and man-made pollutants;
- use the concept of biological oxygen demand (BOD) and account for the changes in a water body;
- state methods for the prevention of water pollution;
- compare primary, secondary and tertiary treatment of sewage and
- know necessary legislative measures for prevention of water pollution in the country.

34.1 Water Resources on Earth

You may be aware that about three fourths of our planet earth's surface is covered by water. However, very little of it is available for consumption. Most (about 97%) of the water on earth is present in the seas and oceans. It is too salty to be of any use for drinking, agriculture and industrial purposes. The remaining 3% is fresh water; 75% of which is locked up in the polar ice caps and in glaciers and quite deep under the earth's surface as underground water.

Which we can use, comes to us from two sources:

i) Surface Water   ii) Ground Water

i) Surface Water:

Rain and snow are good natural resources of fresh water. It is estimated that of all the precipitation (rain water and snow) that falls on the earth, about one-third is absorbed by the plants and another one-third seeps down into the soil and the remaining one third runs off the surface into streams and rivers. This part of precipitation, which runs off to form streams, rivers and lakes, is called the surface water.

Precipitation (rain or snow) that runs-off into streams, rivers and lakes is called surface water. The small fraction of usable surface water is continuously replenished by means of the hydrological cycle, Fig.34.1

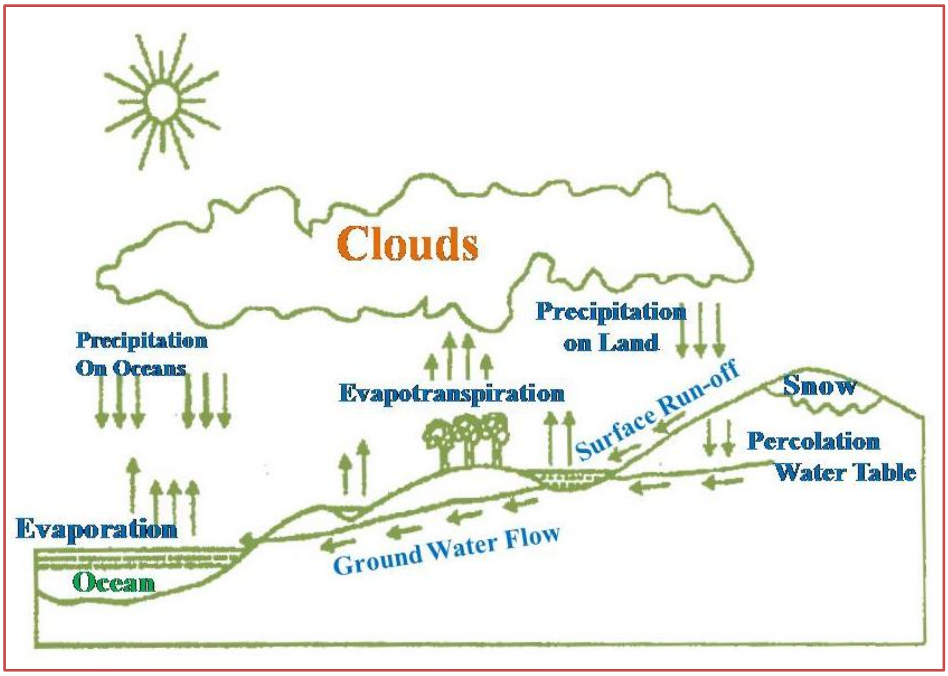


Fig.34.1: A schematically representation of Hydrological Cycle

The hydrological cycle involves evaporation of water from oceans, rivers and other sources to form clouds. The clouds on saturation with water vapours cause precipitation falling back on earth's surface. On surface, the water runs off to rivers and finally to oceans. The water again evaporates and the cycle continues.

Surface water has a natural tendency to clean itself as it contains certain organisms that break down pollutants into harmless substances.

ii) Ground Water:

The part of precipitation that seeps into the ground as a result of gravity and fills the pores between soil particles and rocks under it is called ground water. The water bearing layers of soil and rocks are called aquifers. Ground water is very important for agricultural and industrial purposes. Ground water in the form of wells and springs is often the only source of water supply especially in villages and small towns.

In spite of a good number of water resources, we have shortage of usable water. This is due to increasing population, urbanisation and industrialisation. There is a need to optimise use of water and also conserve surface run-off water by means of rain water harvesting ground water conservation, making use of recycling methods etc.

34.2 Water Pollution-Parameters

A large amount of water is discharged back after domestic and industrial usage. This is contaminated with domestic waste and industrial effluents. When this contamination reaches beyond certain allowed concentrations, it is called pollution and the contaminants are called the pollutants. Water pollution may be defined as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. If the concentration of substances naturally present in water increases then also the water is said to be polluted.

Water pollution may be designed as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. Industrialisation and population explosion are two important factors for water pollution.

Water may be called polluted when the following parameters stated below reach beyond a specified concentration in water.

i) Physical parameters:

Colour, odour, turbidity, taste, temperature and electrical conductivity consitute the physical parameters and are good indicators of contamination.

For instance, colour and turbidity are visible evidences of polluted water while an offensive odour or a bitter and difference than normal taste also makes water unfit for drinking.

ii) Chemical parameters:

These include the amount of carbonates, sulphates, chlorides, flourides, nitrates, and metal ions. These chemicals form the total dissolved solids, present in water.

iii) Biological parameters:

The biological parameters include matter like algae, fungi, viruses, protozoa and bacteria. The life forms present in water are affected to a good extent by the presence of pollutants. The pollutants in water may cause a reduction in the population of both lower and higher plant and animal lives. Thus, the biological parameters give an indirect indication of the amount of pollution in water.

34.3 Water Pollution-Sources

Water pollutants refer to the substances which are capable of making any physical, chemical or biological change in the water body. These have undesirable effect on living organisms. As mentioned earlier, the water used for domestic, agricultural and industrial purposes is discharged with some undesirable impurities in it. This contamination leads to the pollution of water, which is generally called the fresh water pollution. Fresh water pollution may be classified into two (02) types: surface water pollution and ground water pollution.

34.3.1 Surface Water Pollution

When pollutants enter a stream, river or lake these gives rise to surface water pollution. The surface water pollution has a number of sources. These can categorized as:

1. Point and Non-point Sources
2. Natural and Anthropogenic Sources

i) Point and Non-point Sources

The well-defined sources that, emits pollutants or effluents directly into different water bodies of fresh water are called point sources. Domestic and industrial wastage are examples of this type. The point sources of pollution can be effectively checked. On the other hand, the non- point sources of water pollution are scattered or spread over large areas. These types of sources deliver pollutants indirectly through environmental changes and account for majority of the contaminants in streams and lakes. For example, the contaminated water that runs off from agriculture farms, construction sites, abandoned mines, enters streams and lakes. It is quite difficult to control non-point sources.

ii) Natural and Anthropogenic Sources

As mentioned earlier, an increase in the concentration of naturally occuring substances is also termed pollution. The sources of such an increase are called natural sources. Siltation (which includes soil, sand and mineral particles) is one such natural source. It is a common natural phenomenon, which occurs in most water bodies. Indiscriminate deforestation makes soil loose and flood waters bring silt from mountains into streams, rivers and lakes.

On the other hand, the human activities that result into the pollution of water are called anthropogenic or manmade sources of water pollution. For example, domestic (sewage and waste water), industrial and agricultural wastes that goes into the rivers, lakes, streams and seas are anthropogenic sources. Certain materials that are leached from the land by run-off water and enter the various water bodies also belong to this category. The anthropogenic sources of water pollution are shown in Fig.34.2.

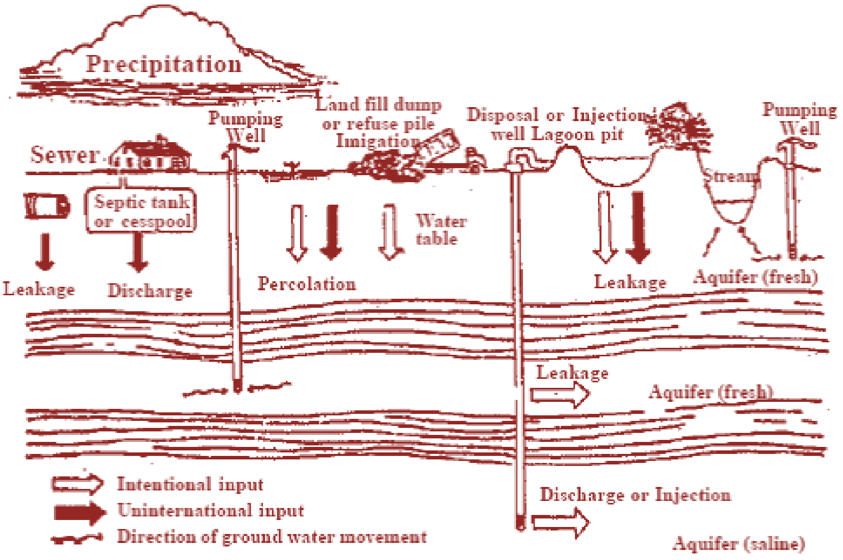


Fig.34.2: Anthropogenic Sources of water pollution

34.3.2 Ground Water Pollution

When the polluted water seeps into the ground, and enters aquifer, it results into ground water pollution. The most of our villages and many townships, ground water is the only source of drinking water. Therefore, pollution of groundwater is a matter of serious concern. Ground water gets polluted in a number of ways. The dumping of raw sewage on soil, seepage pits and septic tanks cause pollution of ground water. Fig.34.3. the porous layers of soil hold back solid particles while the liquid is allowed to pass through. The soluble pollutants are able to mix with the ground water. In addition to these, the excessive use of nitrogenous fertilizers and unchecked release of toxic wastes and even carcionogenic substances by industrial units many result in slow tricking down through the earth's surface and mixing with the ground water. This problem is very serious especially in areas where water table is high (i.e., where water is available near surface of earth).

The ground water can move over large distances by virtue of the large empty space available below the earth's surface. This way if some impurities seep into the ground water at one point, they may be observe data different point far removed from the point of source. In such a case it is difficult to estimate the source of water pollution. However, suspended impurities and bacterial contaminants are removed in the process of seepage by the soil acting as an absorbent and filter, and water acting as a solvent.

Since the movement of groundwater through the porous rock is very slow, pollutants which get mixed the groundwater are not readily diluted. Furthermore, groundwater does not have access to air (in contrast to surface water) therefore, oxidation of pollutants into harmless products in ground water does not occur.

34.4 Water Pollutants

You have read the various sources from where pollutants enter the water bodies. Let us now learn about the various types of pollutant arising out of these sources. These can be broadly put under the following types.

i) Sewage Pollutants (Domestic and Municipal Waste)
ii) Industrial Pollutants
iii) Agricultural Pollutants
iv) Radioactive and Thermal Pollutants

i) Domestic and Municipal Pollutants:

The sewage contains garbage, soaps, detergents, waste food and human excreta and is the single largest sources of water pollution. Pathogenic (disease causing) microogranisms (bacteria, fungi, protozoa, algae) enter the water system through sewage making it infected. Typhoid, chloera, gastroenteritis and dysentery are commonly caused by drinking infected water. Water polluted by sewage may carry certain other bacteria and viruses cannot grow by themselves, but reproduce in the cells of host organisms. They cause a number of diseases, such as, polio, viral hepatitis and may be cancer. They are responsible for deoxygenation of water-bodies which is harmful for aquatic life.

Other ingredients which enter the various water bodies are the plant nutrients, i.e., nitrates and phosphates. They support growth of algae, commonly called **algal bloom** (blue-green species). This process is called **eutrophication** and is discussed in details in the next section.

ii) Industrial Pollutants:

Many industries are located near rivers or fresh water streams. These are responsible for discharging their untreated effluents into rivers like highly toxic heavy metals such as chromium, arsenic, lead, mercury, etc. along with hazardous organic and inorganic wastes (e.g. acids, alkalies, cyanides, chlorides, etc.) River ganges receives wastes from textile, sugar, paper and pulp mills, tanneries, rubber and pesticide industries. Most of these pollutants are resistant to break down by microorganisms (called non biodegradable), therefore damage the growth of crops and the polluted water is unsafe for drinking purposes.

Factories manufacturing plastic, caustic soda and some fungicides and pesticides release mercury (a heavy metal) along with other effluents in nearby water body. Mercury enters the food chain through bacteria, algae, fish and finally into the human body. The toxicity of mercury became evident by the Minamata Bay tragedy in Japan during the period 1953-60. Fish died due to mercury consumption and those who ate fish were affected by mercury poisoning and quite a few died. The milder symptoms of mercury poisoning are depression and irritability but acute toxic effects can cause paralysis, blindness, insanity, birth defects and even death. The high concentration of mercury in water and in fish tissues results from formation of soluble monomethyl mercuryion, (CH_3, Hg) and volatile di methyl mercury [$(CH_3)_2Hg$] by an aerobic bacteria in sediments.

iii) Agricultural Waste:

Manure, fertilizers, pesticides, wastes from farms, slaughter houses, poultry farms, salts and silt are drained as run-off from agricultural lands. The water body receiving large quantities of fertilizers (phosphates and nitrates or manures becomes rich in nutrients which leads to eutrophication and consequent depletion of dissolved oxygen. Consumption of water rich in nitrates is bad for human health especially for small children.

Pesticides (DDT, dieldrin, aldrin, malathion, carbaryl etc.) are used to kill insect and rodent pests. Toxic pesticide residues enter the human body through drinking water or through food chain (biomagnification). These compounds have low solubility in water but are highly soluble in fats. For example, the concentration of DDT in river water may be very low but some fish over a period of time accumulate so much of DDT that they become sun fit for human consumption. The use of pesticides in our country is increasing very rapidly.

Some of these chemicals which are highly toxic become metabolised by animals that graze on fields. Therefore, these poisonous chemicals have been often observed in the human food chain. The presence of these chemicals in humans even in minute amount can cause hormonal imbalance and may lead to cancer.

iv) Physical Pollutants:

Physical pollutants can be of different types. Some of them are discussed below:

(a) Radioactive Wastes: Radio nuclides found in water are radium and potassium-40. These isotopes originate from natural sources due to leaching from minerals. Water bodies are also polluted by accidental leakage of waste material from uranium and thorium mines, nuclear power plants and industries, research laboratories and hospitals which use radioisotopes. Radioactive materials enter human body through water and food, and may be accumulated in blood and certain vital organs. They cause tumours and cancer.

(b)Thermal Sources: Various industries, nuclear power plants and thermal plants require water for cooling and the resultant hot water in often discharged into rivers or lakes. This leads to thermal pollution, causing an ecological imbalance within the aquatic ecosystem. Higher temperature lowers the dissolved oxygen level (which is very essential for marine life) by decreasing the solubility of oxygen in water. Fish and other aquatic organism can get affected by a sudden change in water temperatures.

(c) Sediments: Soil particles carried to streams, lakes or oceans form the sediments. The sediment becomes pollutants due to their substantial volume. Soil erosion defined as the soil carried by flood water from crop land, is responsible for sedimentation. The sediments may damage the water body by introducing a large amount of nutrient matter.

(v) Petroleum Products:

Petroleum products are widely used for fuel, lubrication, plastics manufacturing, etc. and happen to be poisonous in nature. Crude oil and other related products generally get into water by accidental spillage from ships, tankers, pipelines etc. Besides these accidental spills, oil refineries, oil exploration sites and automobile service centers pollute different water bodies. Oil slick which floats on the water surface causes death of marine life and severely affects the ecosystem of the ocean.

Fig 34.3: sources of water pollution (i) industrial effluent (ii) solid wastes (iii) domestic waste

A list of various types of water pollutants, their sources and effects have been summarised in Table 34.1

Table34.1: Types of pollutants, their sources and effects

	Pollutant	Sources of Pollutants	Effects and Significance
1	Pathogens	Sewage, human and animal wastes, natural and urban runoff from land, industrial waste	Depletion of dissolved oxygen in water (foul odour) health effects (out breaks of water borne (diseases)
2	Organic Pollutants ● Oil and grease ● Pesticides and weedicides ● Plastics ● Detergents	Automobile and machine waste, tankers pills, off shore oil leakage Chemicals used for better yield from agriculture Industrial and household waste	Disruption of marine life, aesthetic damage (Toxic effects (harmful for aquatic life), possible genetic defects and cancer; kills fish Eutrophication, aesthetics
3	Inorganic pollutants Fertilizers (phosphates and nitrates)	Agricultural runoff	Algal bloom and eutrophication, nitrates cause methemoglobinemia
4	Acids and alkalies	Mine drainage, industrial wastes, natural and urban runoff water	Kill fresh water organisms, unit for drinking, irrigation and industrial use.
5	Radioactive materials	Natural sources, uranium mining and processing, hospitals and research laboratories using radioisotopes	Cancer and genetic defects

6	Heat	Cooling water for industrial, nuclear and thermal plants	Decreases solubility of oxygen in water, disrupts aquatic ecosystems
7	Sediments	Natural erosion, runoff from agricultural land and construction sites	Affects water quality, reduces fish population

Intext Questions 34.1

1. Define water pollution.

....

2. What do you understand by surface water?

....

3. List any three anthropogenic sources of water pollution?

....

4. List the parameters indicating water pollution.

....

5. Name the element which causes Minamata disease?

....

34.5 Water Pollution and Some Biological Effects

The natural source of water in the form of precipitation or rain is the purest form available in nature. However after reaching the surface and then underground it gets contaminated by a number of pollutants. There are some biological factors also mentioned earlier responsible for spoiling the quality of water. These include the lower plants like algae and bacteria which are the causes of nutrient accumulation in aquatic systems. This nutrient accumulation gives rise to a condition called eutrophication explained below.

34.5.1 Eutrophication

Eutrophication is a process by which a water body slowly becomes rich in plant nutrients such as Nitrates and Phosphates due to soil erosion and run off from the surrounding land. Let us try to understand this phenomenon. A water system like a lake or any reservoir may get a large inflow of organic matter from domestic wastes and run off from the surrounding land. Increasing human population, intensive agriculture and rapid industrial growth have led to an increasing release of domestic waste, agricultural residues, industrial wastes and land run-off into various water bodies. Nutrients are released from organic waste by aerobic (oxygen requiring) bacteria which start decomposing it. Dissolved oxygen is consumed in this process.

As more and more organic matter enters a water body, more is the deoxy genation of the water body and larger is the production of nutrients. These nutrients fertilize an abnormal growth of algae and other large water plants such as duckweed. As more algae grows, aquatic life dies due to Oxygen deficiency in the water body arises (i.e., deoxygenation of the water body). Such a water body is said to be **eutrophied** and theprocess is called **eutrophication**. The word eutrophication is derived from the Greek word which means well nourished as (eu:true, trophos:feeding)

Eutrophication is defined as *a process of release of large amount of nutrients by the action of aerobic bacteria on organic wastes present in a water body naturally or by human activity helping in abnormal growth of algae and causing oxygen deficiency in the water body resulting in death of aquatic life*.

Fig 34.4 : Process of Eutrophication and effect of eutrophication on aquatic life

34.5.2 Biological Oxygen Demand (BOD)

The quality for oxygen used up by microorganisms at 27^0C and in darkness during 3 days in breaking down organic wastes in a water body is called its **biological oxygen demand (BOD).**

It can be explained in the following manner.

You know that there are many organic compounds or waste present in a water body. The microorganisms present in the system act upon this waste using oxygen present in water for their own consumption and growth.

The amount of oxygen required for breakdown of organic waste by microrganisms is defined as **biological oxygen demand (BOD).** The BOD value of an aquatic system depends upon:

- the type and amount of organic waste
- the organisms acting on it
- temperature and pH

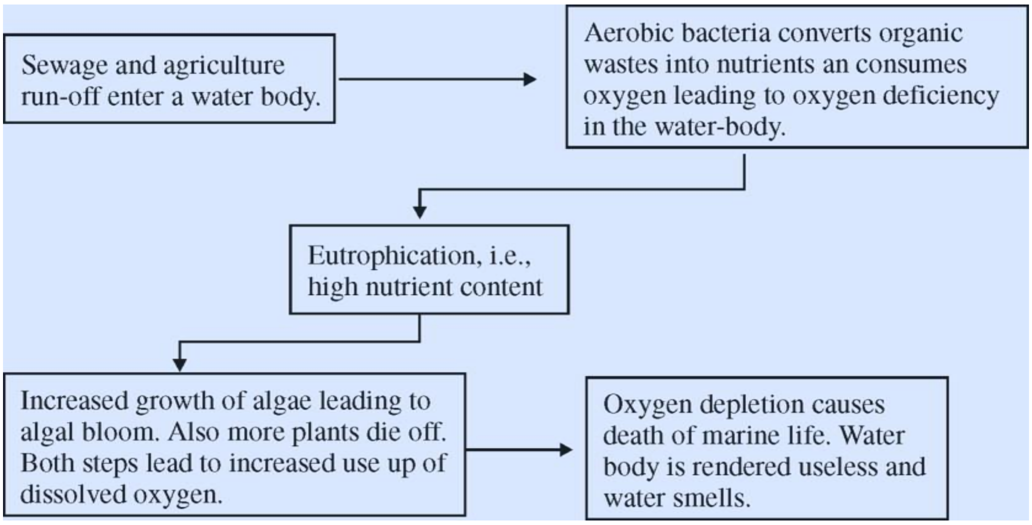
The greater the amount of organic waste in the water body, the greater is the amount of oxygen required to break it down biologically and therefore higher is the BOD value of water. This value is a good measure in evaluating the degree of pollution in a water body. The less polluted water shows comparatively low value of BOD. Its value is used as a criterion for managing water pollution of a water body.

34.5.3 Biomagnification

A variety of toxic chemicals move through food chains. Toxic pesticides may be sprayed for controlling insect pests, fungi, herbs, but they concentrate in the food chain and harm to other (non target) organisms.

For example, DDT was sprayed in the U.S. to control mosquitoes at a concentration expected to be harmless to non target organisms like fish and birds. DDT accumulated in the marshes and planktons. Planktons were eaten by fish and the fish had a higher concentration of DDT in its body. Further, when birds ate the fish, they accumulated still higher concentration.

The increase in concentration of accumulated toxic chemicals as one goes higher in the food chain is termed biomagnification. It has at times threatened the reproduction and survival of carnivores (secondary consumers) who occupy the highest level of the food chain.



34.6 Water Treatment

Waste water generated by house hold activity, industries or garbage landfills is called sewage. Sewage contains solid matters in the form of suspended colloidal and dissolved organic matter, detergent, mineral matter, nutrients and gases. Sewage is one of the major causes of water borne diseases and therefore the treatment of sewage is one of the important tasks. For a long time treatment of municipal waste in the form of sewage involved mainly of the removal of suspended solids, oxygen demanding materials and harmful bacteria. Now the disposal of the solid residue from sewage has been improved by applying municipal treatment processes.

The treatment of this waste water is carried out in the following three stages:

i) Primary treatment ii) Secondary treatment iii) Tertiary treatment

Primary Treatment: When the waste water is be dumped off into a river or flowing steam, the treatment is carried out by sedimentation, coagulation and filtration. This is known as primary treatment. If the water is required for drinking purposes, it has to undergo further treatment called secondary and tertiary treatments. The following steps are performed to do primary treatment of water:

i) Sedimentation: This step is carried out in large tanks specially built for this purpose in sewage treatment plant. The polluted water is allowed to settle so that silt, clay and other matter settle to be bottom and water is slowly allowed to move out. Fine particles do not settle and are thus required to be removed in the next step.

ii) Coagulation: Fine particles and colloidal suspension are combined into large particles by a process called coagulation. This step is carried out by the addition of special chemicals called coagulants (flocculants) such as potash alum. The large particles either settle to the bottom or are moved in the next step.

iii) Filtration: Suspended particles, flocculants, bacteria and other organisms are filtered by passing the water through a bed of sand or finely divided coal or through some fibrous materials. The total impurities collected in these steps are called sludge. It is used as a valuable fertilizer. On compositing (i.e. the action of anaerobic bacteria), it releases sludge gas. It consists mainly of methane gas which is used for cooking purposes.

Secondary or Biological Treatment: The water after primary treatment is not fit for drinking purposes and has to undergo further treatment. This is done through secondary or biological treatment. A commonly used method is to allow polluted water to spread over a large bed of stones and gravel so that the growth of different micro organisms needing nutrients and oxygen is encouraged. Over a period of time a fast moving food chain is setup. For example, bacteria consume organic matter from the polluted water; protozoa live on bacteria. Every form of life, including algae and fungi, contributes to the process of cleaning up the environment. This is called secondary treatment of water. It involves the following processes.

i) Softening: By this treatment undesirable cations of calcium and magnesium are removed from hard waters. Either water is treated with lime and soda ash to precipitate Ca^{2+} ions as carbonates or it is passed through cation exchangers. This makes water soft.

ii) Aeration: In this process, soft water is exposed to air by forcing air through it to add oxygen to water. This encourages bacterial decomposition of organic matter in to harmless products such as carbon dioxide and water. The addition of oxygen reduces carbon dioxide. Sulphide etc. The water is as yet not fit for drinking purposes. The pathogenic and other microorganisms need to be killed. This is done in the next treatment.

Tertiary Treatment: The tertiary treatment is actually disinfecting water. Chlorine is the most commonly used disinfectant used for killing bacteria. However, chlorine also reacts with traces of organic matter present in water and forms undesirable chlorinated hydrocarbons (toxic and potentially carcinogenic). It is therefore desirable to reduce the organic matter in water before passing chlorine gas. Other methods of disinfection such as ultraviolet radiation, ozone gas treatment or reverse osmosis are preferred over chlorine treatment. But these methods are more expensive. Fig. 34.3 gives a clear picture of the process of sewage treatment in total.

In a treatment plant, the waste is passed through a series of screens, chambers and chemical processes to reduce its bulk and toxicity. During primary treatment a large percentage of suspended solids and inorganic material is removed from sewage. The secondary stage reduces organic material by accelerating natural biological processes. Tertiary treatment is done when water is to be reused. Here 99% of solids are removed and various chemical processes are used to ensure that water is free from infecting materials.

Intext Questions 34.2

1. Define eutrophication.

....

2. Why does aquatic life get killed in an eutrophied pond?

....

3. What is the significance of BOD?

....

4. What is biomagnification?

....

5. Mention are the stages of water treatment

……………………………………………………………………………………

34.7 Legislative Measures for Preventing Water Pollution

It is important to utilise a good quality and unpolluted water. The quality criteria may vary depending on the use. Individual efforts do pay in this regard, however, a common policy in the form of legislation is always more effective. The enactment of 'Prevention and Control of Water Pollution Act' in 1974 has helped in the prevention of water pollution. The standards have been prescribed for water pollution under Environment (Protection) Act. 1986. These are given as follows.

- General standards for water pollutants for discharge of effluents in water bodies on land (inland surface water, public sewers, irrigated land and coastal areas)
- Standards specific for each type of industry

- Standards defined for the amount of waste water to be discharged for different industries.
- Standards limiting the amount of a particular pollution on the basis of production capacity of an industrial unit.

The state pollution control boards have also been empowered to grant / renew consent to new/ existing water polluting industries under water 'Prevention and Control of Pollution Act- 1974. 'They have been empowered to shut down any industrial unit which fails to meet the prescribed standards under this Act. The state governments have also been authorized to take harsh measures against defaulting industries.

It becomes imperative to act upon the above - mentioned rules and regulations and also follow measures at individual end to improve the quality of water used for various purposes.

Intext Questions 34.3

1. How is sludge utilized?

………

2. Mention the steps by which polluted water is made fit for drinking purpose?

………

3. Why is chlorination not the most desirable method of disinfecting polluted water?

………

What You Have Learnt

- Water pollution refers to any physical, chemical or biological change that has an undesirable effect on living organisms.
- Sewage, industrial, agricultural pollution and physical pollutants are the various sources of water pollution. These sources may be limited to a point source or spread over large areas (non-point sources).
- Sewage, fertilizers, detergents, toxic wastes released by industries are some of the sources of ground water pollution.
- Phosphatic, and nitrogenous fertilizers cause algal bloom and severe oxygen depletion in water body. This process is eutrophication.
- The quantity of oxygen needed by micro-organisms in degrading organic wastes in a water body is defined in terms of its biological oxygen demand (BOD).
- Biological magnification of toxic materials released into water bodies poses a serious threat to aquatic life and eventually to human life.
- Polluted water may be made useful for human consumption by subjecting it to various treatments.
- Legislative measures have been enacted in our country to restrict the pollution of various water bodies.

Terminal Exercise

1. What are the various types of water pollutants? State their consequences.
2. What are the effects of detergents on fresh water bodies?
3. What are the various sources of ground water pollution?
4. How is the disease 'methaemoglobinaemia' caused?
5. Suggest steps to stopeutrophication of water body.
6. What was Minamata Bay tragedy?
7. Which precaution is necessary before purifying the drinking water through chlorination?

Answers to Intext Questions

34.1

1) Water pollutants refer to the substances which are capable of making any physical, chemical or biological change in the water body.
2) Refertosection34.4
3) Refer to section 34.3.1
4) Refertosection34.1
5) Mercury

34.2

1) Refer to section 34.5.1
2) Refer to section 34.5.1
3) Refer to section 34.5.2
4) Refer to section 34.5.3
5) Refer to section 34.7

34.3

1) As fertilizer.
2) Primary treatment including sedimentation, coagulation, filtration Secondary treatment including softening and aeration and Tertiary treatment involving disinfection of water.
3) Because chlorine reacts with organic matter to produce highly toxic chlorinated hydrocarbons which can cause cancer.

Chapter 35

HEAVY METAL AND RADIOACTIVE POLLUTION

Many metals occur in traces in the earth's crust. Metals like Pb, Hg, Zn, Cd are heavy metals. Some of the heavy metals are beneficial to organisms in traces. But if excessive levels of heavy metals enter environment through human activities, they endanger health and survival of humans and other organisms. You shall learn about toxic effects of a few heavy metals in this lesson.

Objectives

After reading this lesson you will be able to:

- define heavy metal;
- lift the sources of contamination of the environment by heavy metals;
- explain the effects of Pb, Hg, Cd contamination on living organisms and
- list the preventive measures and measures for reduction of heavy metal contamination.

35.1 What is a Heavy Metal?

A heavy metal is one whose density is more than 5g cm^{-3}. Some heavy metals are lead, cadmium, mercury, arsenic selenium, as also iron, copper, manganese, selenium, zinc, etc. All these metals have atomic number greater than 20.

A trace metal is defined as one which occurs in 1000 *ppm* (parts per million or mg/litre) or less in the earth's crust Low concentrations of metal like iron, copper, zinc and some others are essential for organisms. They are called 'trace metals'. On the other hand, metals like lead, mercury, cadmium and some others are toxic to organisms above a certain concentration.

35.2 Sources of Contamination by Heavy Metals

Heavy metals are introduced in to the environment either by natural means or by human activities.

Natural Sources: In nature excessive levels of trace metals may occur by geographical phenomena like volcanic eruptions, weathering of rocks, leaching into rivers, lakes and oceans due to action of water.

Anthropogenic Sources: Following list shows the various human activities through which heavy metals get into the environment.

i) Smelting or processing of ores of metals.
ii) Mining.
iii) Burning of fossil fuels such as coal, petrol, kerosene oil.
iv) Discharging agricultural waste, industrial waste.
v) Discharging domestic waste.
vi) Discharging from auto exhausts.
vii) Using pesticides containing compounds (salts) of heavy metals.

Many toxic inorganic and organic compounds and heavy metals are deposited and buried in the soil by water. Humus, the organic material present in the soil (which also makes the soil look green) has high affinity for heavy metal cations and extract them from water that passes through the soil. Roots of crops and other plants pick up these compounds along with water and pass on to plants and then plants to animals.

In water, particles with adsorbed heavy metals settle to the bottom and then sediments may accumulate over them. But if organisms consume these, then heavy metals enter the food web.

35.3 Heavy Metal Toxicity

Heavy metals like iron, copper and lead have been useful in so many ways. With growth of human population, industrialization, enormous increase in vehicular traffic and use of chemical fertilizers and pesticides, our environment has been contaminated with heavy metals. Heavy metals may also be present in water bodies and underground water in some.

The best example of heavy metal toxicity is the tragic incident in Minamata, a fishing village in Japan. The villagers were suffering from Minamata disease which is due to poisoning of mercury which they acquired by consumption of fish from polluted Minamata Bay. The industrial effluents from a chemical factory owned by the Chisso Corporation, which continued from 1932 to 1968, were sent into the Bay and contaminated the water and mercury was deposited in the fish and indirectly ate by the people.

In our country, several villagers in West Bengal are suffering from sores and ulcers due to arsenic poisoning from drinking water.

Heavy metals cannot be removed rapidly from the environment as they are non-bio-degradable. Thus, heavy metals accumulate in the environment and have harmful effects on organisms causing heavy metal pollution. Some metals which bioaccumulate* and biomagnify** in the food chain, for example, mercury.

**Bioaccumulate organisms have a capacity to neutralize some toxins while others are retained in their tissues known as bioaccumulation.*

*** biomagnify concertation of some toxic metals gradually increase in successive trophic level through food chain. Such biomagnification may make food unsuitable for consumption and thus causes sickness.*

Intext Questions 35.1

1. Name any two toxic heavy metals.

....

2. Define a heavy metal.

....

3. Mention an anthropogenic source of heavy metal pollution.

......……………………………………………………………………………………

4. Which metal causes Minamata disease and in which country it occurred?

....

35.4 Effects of Pb, Hg and Cd Contamination

All trace elements have some toxic effects if ingested for a long enough period or at sufficiently high concentrations. We shall now study the sources of contamination and toxic effects of three heavy metals - lead, mercury and cadmium.

LEAD: Lead is a very severe pollutant.

Occurrence:

0.1% by weight of Pb occurs in the earth's crust in rocks and soil. It occurs naturally in some plants.

Anthropogenic Sources:

Human activities have increased the quantity of lead in the environment. Some such anthropogenic sources are:

i. Soil forms a dumping ground for Pb from mining, smelting, sewage and agricultural sludge;
ii. From vehicle exhausts: Tetra ethyl lead is mixed with petrol for improving efficiency of internal combustion engines of vehicles. Fuel evaporating from fuel tank and carburet or sand unburnt fuel from mopeds and motor bikes release compounds of Pb through automobile exhausts and it accumulates as dust.
iii. Lead is also released from industries and reaches the soil from accumulating as dust. Pb goes into potable (fit for human consumption) water from lead pipes and lead storage tanks. Pipe joints also have Pb in soldering which may be carried along with water flow.
iv. It is released from lead acid batteries.
v. Paints like the yellow lead chromate used for marking roads deteriorate and enter the environment.
vi. Pottery glazers use lead compounds for glazing. This forms a source of Pb contamination.

Toxic effects of Lead:

Lead is a severe toxicant. Some of the toxic effects of lead are discussed below:

i. After getting into human body lead reaches blood and through circulation gets into soft tissues. Lead however ultimately deposits in the bones replacing calcium,
ii. Absorption of lead is higher in children and in people suffering from calcium deficiency.

It can bioaccumulate and remain in the human body for many years. During old age and illnessleadmovesbackfrombonetobloodtoincreaselevelofleadinbloodandbecomes toxic: It may reach the brain and cause brain damage, convulsion and behavioral disorders.

iii. Lead interferes with hemoglobin formation and causes an anemia due to deficiency of hemoglobin. Lack of hemoglobin may further cause kidney and brain damage.

iv. Acute toxicity of lead may be fatal.

MERCURY

Metallic mercury is relatively inert and non toxic. On inhalation it reaches blood and them to central nervous system and causes severe damage.

Occurrence:

Mercury is present in the earth's crust. It also reaches the environment from volcanic gases and evaporation from oceans. Mercury exists as metallic mercury, inorganic salt and organic methyl mercury. Soil bound mercury is converted into dimethyl mercury by the action of anaerobic bacteria. Mercury is also present in traces in fossil fuel and minerals. Plants take up mercury from soil and release it as mercury vapor during transpiration as mercury is volatile.

Anthropogenic Sources:

Mercury has been in the environment for long even earlier than the 20th century. It reaches the environment in the following ways:

- While extracting gold and mercury from the ores.
- Burning of fossil fuels releases mercury vapours into the environment. Coal in India has high mercury content if low grade coal is used in thermal power plants, mercury which has a high vapour pressure and high combustion temperature escapes into the atmosphere and condenses as dust particles.
- Wastes from paper, plastic, caustic soda and chlorine industries release mercury into the environment.
- Mercury compounds, known for their toxicity, are utilized as fungicides or pesticides, and as a result, they can enter the environment.
- Electrical appliances: Mercury is excellent conductor of electricity, so it is used in electric switches, lamps and batteries. Such appliances are potential source for the release of mercury vapours.

Toxic effects of Mercury:

People in Japan suffered from a disease called Minamata disease due to consumption of mercury poisoned fish.

Minamata disease:

In Japan in 1953 mercury poisoning occurred due to consumption of fish which had died of Hg poisoning. Mercury had contaminated the water where it had reached as effluent of a vinyl chloride (ingredient of plastic) factory. Fishermen living in coastal areas of Minamata Bay had eaten the dead fish. They suffered from Minamata disease, whose symptoms were weakened muscles, impaired vision, mental retardation, paralysis and death.

Mercury is non toxic when swallowed but if inhaled in its volatile form it enters brain through bloodstream, causing damage to nervous system. Hence mercury should be handles in a well-ventilated room and cleaned up if spilt. Hg ions have affinity for sulphur and cause harm by attaching to sulphur containing amino acid of proteins. Hg ions also bond with haemoglobin and other blood proteins especially those containing sulphydryl groups.

Most toxic to humans are the organo-mercury compounds especially methyl mercury as it dissolves in fatty tissues and bio-accumulates and bio-magnifies. Microorganisms convert high levels of inorganic mercury into the organic derivatives like dimethyl mercury. Methylmercury compounds are very toxic because of the following reasons:

- These compounds can reach brain and interfere with transmission of nerve impulses.
- These compounds can cause permanent damage to the central nervous system of fetus of pregnant mothers.
- These compounds also cause increased loss of water from kidney and ultimately causes to death.

CADMIUM: Cadmium is highly toxic metal

Occurrence:

The natural sources of cadmium are volcanic activity, spray from oceans and forest fires.

Anthropogenic Sources:

Human activity adds more cadmium to atmosphere than natural sources. Coal mining, non-ferrous metal mining, refineries, coal combustion, burning of refuse (water matter) iron and steel industries and phosphate fertilizers are main sources of cadmium. Tobacco containing cadmium is finely dispersed in air when released with cigarette smoke. Cadmium is chemically very similar to zinc. It also occurs with zinc minerals.

Toxic Effects of Cadmium:

Cadmium is a cumulative poison. It is retained in the body for a long time and causes.

i. hypertension (high blood pressure),
ii. heart ailments
iii. kidney damage
iv. destruction of red blood cells
v. causes abnormal functioning of mitochondrial cells

Cadmium resembles zinc chemically Ca^{2+} and Cd^{2+} share the same charge and have similar sizer. It may therefore replace zinc in enzymes and thus destroy their catalytic activity. In Japan, people got a bone disease "itaiitai" where Ca^{++} of bones was replaced by Cd^{++}.

35.5 Preventive measures of Heavy Metal Toxicity

- Educating people about the ill effects of metals and their toxicity and ask to take preventive steps.
- Industries have been asked to take steps for proper disposal of industrial waste. Special devices have been designed for removal of effluents.
- The government has decided to take penal action against industries which do not install proper devices and dump waste in the rivers or on soil.
- Efforts are underway to gradually phase out the use of leaded petrol. Newly manufactured cars have been designed to use lead-free petrol. Catalytic converters have been designed for using lead free petrol in the old cars.

35.6 Steps for removal of Metal Pollution

It is very difficult to remove metal pollutants as metals are present in a very low concentration; there are however, two ways of designing systems for removal of metal pollution.

i. design process for removal of one metal or
ii. design one process which removes several metals

- For rivers and sediments contaminated by heavy metals; the following have been suggested.
- Place layers of uncontaminated clean soil over contaminated sediments of the metal
- Containing sediment may not get washed away by rivers.
- Treating with $CaCO_3$ which increases pH of the sediment and immobilizes heavy metals.
- Lime stone, gypsum, iron sulphate and activated charcoal can be used as detoxifying.
- Using water plants such as pistia and hydrilla which pickup mercury from water bodies
- and help in reducing mercury-pollution.

Intext Questions 35.2

1. What causes Minamata disease?

....

2. List three sources of lead pollution.

....

3. Name the mercury derivative which is very toxic to human.

....

4. Mention two water plants by which mercury pollution can be reduced?

....

35.7 RADIOACTIVE POLLUTION

Radioactive pollution is contamination of the environment by radioactive elements which undergo ionization emitted harmful radiations.

35.7.1 Sources of radioactive contamination

Natural Sources of Radiation

i) Mining of uranium is the chief natural source of radioactive contamination. The radioisotopes such as uranium and Thorium are present in rocks and while mining they undergo disintegration emitting radiations which are harmful.
ii) Cosmic rays are high energy ionizing electromagnetic radiations that originate from the stars in our galaxy. The cosmic rays cause production of Carbon-14 in all living beings.

iii) Naturally occurring radioisotopes such as radon-222 found in soil in small quantity is and other source of radioactive radiations.

iv) Potassium-40 contributes radioactivity to all potassium containing systems in the soil. Crops grown on such soil contain radioactive elements like carbon-14 and potassium-40. Water gets contaminated with various radio nuclides when it runs through soils and rocks containing radioactive minerals.

We live in an environment of natural radiations that are rarely harmful as the radiation level is quite low. This small level of radioactive radiation which is present everywhere is called the background radiation.

Anthropogenic Sources of Radiation

The following human activities add to the source of radioactive pollution:

i) **Diagnostic medical applications:** Radiations are employed for diagnostic and therapeutic applications. X-rays are used in general radiology and CT scan. Gamma rays are used in treatment of cancer. In all these procedures we are exposed to varying doses of radiations.

ii) **Nuclear Tests:** Nuclear weapons test performed adds a huge amount of radio isotopes to the atmosphere as radioactive dust (also known as radioactive fallout) gets suspended in air at a height of 6 to 7 km above the earth's surface and is dispersed over long distances by winds from the test site. Later through rains these isotopes settle in soil and enter the food chain and finally deposit in living organisms causing health hazards.

India exploded its nuclear device (equivalent to 12 kilotons of Tri Nitro Toluene) in an underground tunnel at a depth of 107 meters in the Thar Desert near Pokharan in 1974. No radioactivity is said to have been released into the surroundings. Again, in May, 1998 India conducted nuclear tests without any fall out of radioactivity into the surroundings.

iii) **Nuclear Reactors:** Radiations may leak from nuclear reactors and other nuclear facilities even when they are operating normally. It is often feared that even with the best design, proper handling and techniques; some radioactivity is routinely released into the air and water.

iv) **Nuclear explosions:** Nuclear explosions are a serious source of radiations hazard. The effects of atomic explosions in Nagasaki and Hiroshima are still not forgotten.

v) **Nuclear Wastes:** When uranium-235 nuclei split in a nuclear reactor, they break into fission products

$$^{235}_{92}\mathrm{U} + \ ^{1}_{0}n \rightarrow \ ^{141}_{56}Ba + \ ^{92}_{36}Kr \ + 3\,^{1}_{0}n \ + energy$$

They are also highly radioactive, since one uranium atom splits into two radioactive products as there is a doubling of the number of radioactive atoms. The wastes of nuclear reactor emit dangerous radiations for thousands and thousands of years. Since it is not possible to destroy these radio nuclides, they must be stored somewhere on this earth in order to ensure least harm to humans.

Plutonium-239 is another nuclear waste. The plutonium-239 isotope is produced as by- product during uranium fission. It is an alpha particle emitter and has a long half-life of 24000 years. Plutonium does not occur naturally on earth. This element is produced either in nuclear reactors or in nuclear weapons programme. The plutonium produced today will have to be taken care of for thousands of years by future generations.

Radon can diffuse through rocks and sills into the atmosphere. Once the radon reaches the atmosphere it can be breathed in. The transformation into lead is very significant because the solid radioactive particles are trapped in the lungs and are acutely harmful.

Fig 35.1: Nuclear power plant in Rajasthan

Accidents in nuclear power plants

Such accidents took place at the "Chernobyl nuclear power plant" in USSR in 1986 and at the "Three Mile Island Power Plant" in USA in 1979. The leakage from the 'Three Mile Island' nuclear reactor has been claimed to be very low with no immediate injuries to workers or people but the leakage at Chernobyl was very heavy causing death to many workers and radiation was spread over large areas spread all over Europe.

Intext Questions 35.3

1. What are ionizing radiations?

....

2. Name any of the two sources of radioactive pollution in nature.

....

3. Name three man-made or anthropogenic sources of radioactive pollution?

....

4. What were the two accidents in the past which led to high radioactive leakage?

....

5. What happens when a neutron strikes uranium-235?

....

35.7.2 Effects of radiation on humans

Exposure to any type of ionizing radiation (α and β particles, γ-rays and X-rays) can prove harmful and even lethal. The two types of effects are:

i) **Genetic disorder:**

In this genes and chromosomes get altered. Its effect may become visible as deformations in the off springs (children or grand children). Alterations or breaks in the genetic material, that is DNA (deoxyribo nucleicacid) the molecule containing genetic information, is called mutation.

ii) non-genetic disorder

In non-genetic effects, the harm is visible immediately in the form of birth defects, burns, some type of leukemia, miscarriages, tumors, cancer of one or more organs and fertility problems.

Fig35.2: Effect of radiation on skin

Table 35.1: Effects of radioactive radiation on living beings

Type of radiation	Effect on the body
α-particles	Generally they cannot penetrate the skin. But if their sources are inside the body, they can cause damage to bones or lungs.
β-particles	Can penetrate the skin but cannot damage the tissues. They can cause damage to skin and eyes (cataract)
γ-radiation	Can easily penetrate the body and pass through it. They cause damage to cell structure.
X-rays	Can travel very far and pass though the body tissues except bones. They can cause damage to the cells.

35.7.3 Preventive measures

The following preventive measures may be adopted to reduce the effects due to both natural and artificial radiations:

- Atomic explosions should not be carried out in the atmosphere.
- In nuclear reactors, closed cycle coolant system may be employed, so that no radiation leakage through coolant can take place.
- Nuclear wastes should always be sealed in double-walled tanks so that no leaks may take place. Useful isotopes generated during fission in the reactors may be recycled in reprocessing plants. A permanent storage space for the wastes in geologically stable underground deep mines should be established it has been suggested that these wastes may be stored till the wastes are reduced to the same radioactivity level as that of a natural uranium mine.
- Production and use of radioisotopes should be minimum and only for every essential use.
- The number of nuclear installations should be minimized so as to limit the emission of radio-pollutants.
- Fission reactions should be minimized.
- In nuclear mines, wet drilling may be used and tailings properly sealed and protected for radiation leakage.
- Industrial wastes contaminated with radio nuclides be disposed off carefully in specially build tanks.
- Working places where radioactive emissions are possible should have high chimneys and good ventilation system.
- In areas where there is a risk of radon leakage from underground. radon concentrations be monitored and protection measures be installed in buildings and homes.

Intext Questions 35.4

1) What are the two effects of radiation?

………………………………………………………………

2) How do radioactive waste management should be done?

....

3) How can we safeguard ourselves from radiation originating from tailings?

....

4) What the dose limit is fixed for the workers of nuclear installations?

....

What You Have Learnt

- Heavy metals occur in earth's crust in traces. Heavy metal is one whose density exceeds $5 gcm^{-3}$.
- A trace metal occurs in 1000 *ppm* or less in the earth's crust.

- In nature, heavy metals accumulate in soil by natural phenomena like volcanic activity, weathering of rocks, actions of wind, water etc.
- The anthropogenic sources for metal pollution are mining, smelting, fossil fuel burning, discharging agricultural, industrial and domestic wastes, auto exhausts etc.
- Heavy metals reach ecosystem from soil and water and enter human sand other organisms through food chain.
- Heavy metals cannot be removed rapidly from environment as they are neither detoxified nor biodegraded. Instead some of them bioaccumulate and biomagnify.
- At the molecular level, metals become toxic as they impair the proper functioning of enzymes by attaching to S-H group of the enzyme or causing conformational changes in them. A heavy metal may displace an essential ion.
- Pb is released from industries or from Pb pipes or leaded petrol. It causes nervous disorders.
- Hg comes into environment from plastic, paper, chlorine industries. Methylmercury :is especially dangerous to humans which they might get through food chains. It causes nerve damage and kidney disorders. In Japan Hg toxicity caused Minamata disease.
- Cadmium is toxic. It enters the environment through coal mining, coal combustion, burning of refuse, fertilizers etc. Cd causes hypertension. In Japan Cd caused a diseased itai-itai.
- Heavy metal toxicity can be prevented by proper disposal of industrial effluents, use of unleaded petrol and educating masses about toxicity of metals. Metals already accumulated can be removed by using aquatic plants which take the mupor by covering contaminated sediments which clean soil.
- Nuclear radiations are emitted in the atmosphere through natural sources and man-made sources.
- Radiations due to natural sources are due to uranium and other radioactive elements which occur in nature and on distintegration may yield other radioactive istotopes. The prominent amongst them is radon-222 gas.
- Radiations can cause mild to very serious effects on the health of human on exposure and may even lead to death. Some ill effects continue to pass on to future generations.
- Various steps have been suggested by which radiation leakage can be minimized.

Terminal Exercise

1) List five human activities which release heavy metals into the environment.
2) How do heavy metals reach the ecosystem?
3) Relate a molecular, mechanism by which a heavy metal becomes toxic.
4) How does cadmium accumulate in the environment? What kind of effect does it have on human body?
5) List five sources of lead pollution. Mention two of its adverse effects.
6) Mention two toxic effects of mercury contamination.

7) Write a note on Minamata disease.
8) Do the cosmic rays act as radioactive pollutant?
9) Which type of radiations are damaging for human health?
10) Define the term 'Background Radiation'?
11) What are the different man-madesources of radiation pollution

Answers to Intext Questions

35.1

1. Any two from Cd, Hg and Pb
2. A heavy mineral is one whose density is greater than 5gcm^{-3}.
3. Anyone from, mining, auto exhaust, paper, plastic, paint factories.
4. Mercury, Japan

35.2

1. Hg 2. Refertosection35.2 3. Methylmercury 4. Pistia, Hydrilla

35.3

1. These are the electromagnetic radiations of short wavelength or charged particles (like and-particles) which can cause ionization of atoms or molecules.
2. Weathering of minerals, cosmic rays from outer space, radioactive elements occurring in nature. (Anytwo)
3. Nuclear waste, nuclear reactors, nuclear accidents.
4. The accident of 'three mile Island' in Middle Town (U.S.A) in 1979 and at Chernobyl nuclear power plant (U.S.S.R) in1986.
5. Uramium-235 splits into two fission products with the production of three neutrons and lot of energy. The slipt products are also radioactive. There action in known as a nuclear fission reaction.

$$ {}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy} $$

35.4

1. Genetic and non-genetic disorders
2. Radioactive waste should be disposed of properly and storing should be done carefully in double walled tanks, storing of this waste should be done till it comes to its natural level of radioactivity.
3. Refer to section36.5
4. Dose limit fixed for workers is 30 mSv.

Chapter 36

NOISE AND SOIL POLLUTION

36.1 Noise Pollution

Any unwanted sound is defined as noise.

Noise is measured in terms of 'decibel' (*db*) - a scale expressing intensity of the sound.

- A very quiet room has a sound level of 20*db*
- cars and household gadgets sound level of 70*db*
- a truck horns produces a noise of 110*db*.

Definition

Noise pollution can be defined as the unwanted noise more than 65*db*.

36.1.1 Sources of Noise pollution

1. **Vehicles:** Heavy traffic due to more number of vehicles causes noise pollution. Unwanted sound of horns during traffic and automobiles sounds cause lot of sound.
2. **Industries:** machinery used in factories produce more noise and sometimes more than our normal level of hearing.
3. **Construction:** nowadays lot of construction of building are taking place, construction area produces noises of the machinery. Mining is also one of the source for noise pollution.
4. **Celebrations:** festival celebrations, wedding functions, processions nowadays use DJ music which was never used in olden days. The sound used is more than our normal level and causes severe problems to people.

36.1.2 Effects of noise pollution

Illness due to stress, breathlessness, high blood pressure, loss of hearing, disturbed sleeps, no proper speech and loss of productivity are the common effects of noise pollution. Noise within the range of 70-80 decibels can lead to feelings of annoyance and irritation. Noise Induced Hearing Loss (NIHL) is the most common health effect.

Standards have now been laid down for different areas. Silence zones are the areas 100 meters around hospitals, courts, schools and other institutions. Honking of vehicle horns, crackers bursting, loud speakers and loud voice of hawkers selling their wares is prohibited. The noise levels have to be kept within 50db. Similar restrictions were made for industries and commercial organizations.

36.1.3 Legislative Measures to Prevent Pollution

The best protection of the environment is not to generate pollutants in the first place. Thus, the legislative measures have been introduced to deal specifically with environmental pollution caused by industries. (Table 36.1) The basic feature of the legislative measures is to empower the Central Government to correct differences of policy making and enforcement in the State through action not specifically permitted under earlier laws.

Table 36.1: Pollution control Legislations in India

Acts	Year
Indian Forest Act	1927
Wild life Protection Act	1972
The water (prevention and control of Pollution) Act	1974
The air (Prevention and control of Pollution) Act.	1981
The Environmental (Protection) Act.	1986
The National Environmental Tribunal Act.	1995

The pollution related laws like the Water Act (1974), Air Act (1981), and the Environmental Protection Act (1995) do not give the right to an individual to move the court under the environment laws for damages caused to them by pollution. The right has been vested only in the agencies of the State Government.

36.1 Intext Questions

1. Define noise pollution.

………

2. What are the common effects of noise pollution

………

3. Give two sources of noise pollution

………

36.2 SOIL POLLUTION

Definition

The change in the composition of soil is due to contamination by pollutants such as toxic metals or due to addition of organic salts in higher concentration than usual levels result in soil pollution.

The various compounds can be added to soil due to microbial activity or decomposition of plants and animals. Through rains, winds also many compounds can be added to soil.

36.2.1 Sources of soil pollution

Two sources through which soil pollution is generated are

1. **Natural sources**

Naturally through rains some contaminants can be deposited in the soils. In some dry ecosystems perchlorate anion can be deposited in soil. Thunderstorm can cause formation of perchlorate ions in the soil containing chlorine and other metal ions

2. **Anthropogenic (man-made) sources**

Man made sources are the main source of contamination in soil. They are:

   1. Usage and pestisides and fertilizers for agricultural development have increased in recent times. More the technology in growing better plants more is the contamination in soil. Lot of pesticides are used so that plants are not damaged and chemical fertilizers are used to improve the quality of the crop. These pesticides which are sprayed on plants remain in soil.
   2. Mining is another soil polluting cause. Mining leads to contamination of soil with heavy metals and radioisotopes.
   3. Another major cause is the industrial waste especially toxic chemical waste that has been disposed into soil. Example iron and steel and aluminium industries produce dust and mud deposit on soil.
   4. Oil spillage is also a way of soil contamination during their transport.
   5. Sewage if not disposed properly can be a part of soil pollution and many toxic metal ions can be deposited in soil.
   6. Non biodegradable plastic are also the cause of soil pollution. Use of plastic bags and not disposing properly contaminate soil.

36.2.3 Effects of soil pollution

1. Plants can be damaged due to excess pesticides and chemicals which are present in soil.
2. Metal contamination may cause harm to the plants
3. Health hazards caused by soil pollutants such as headaches, nausea, cough, skin allergies.
4. The pollutants if entered into food chain through plants cause loss of life for many organisms.

36.2.4 Control of soil pollution

1. Use of non-bridgeable plastics should be banned.
2. Non-biodegradable materials should be recycled and should not be dumped in the soil.
3. Sewage waste treatment should be done and harmful materials should be safely removed.
4. Domestic waste should be collected in bags and should be collected as wet and dry waste so that the wet waste can be dumped in soil and later converted to composite. The dry waste can be recycled; therefore, collection of waste is important and properly done.
5. Industrial waste should be reused without letting out into environment.
6. Polluted soil should be removed and transported to non residential areas.
7. Decontamination can be done using some microbes so that they act on soil.
8. Fungi used to remove metal contamination i.e., mycoremediation.

36.3 Green Chemistry

The strategy to synthesize non hazardous products through processes which do not add up to the pollution of the environment is said to be Green Chemistry.

The process should be able to convert the by-products of the reaction totally to useful things and should not add any of the harmful by product to environment.

Green chemistry is to use safe methods in manufacturing the product which include right from the starting raw materials, processing, packing and distribution and disposal of the product.

The advantage of green chemistry is

- Reduces pollution
- Products are reusable
- Safe environment
- Removal of toxic materials from the products
- Reducing side effects caused by the by products

36.3.1 Principles of Green Chemistry

Twelve basic principles are involved in green chemistry

1. **Prevention of waste**

   Creating waste and trying to dispose waste is a big problem. Therefore, design chemical processes where waste is not produced. This way we can take preventive measures rather than producing waste and thinking how to dispose.

   Most of the drug industries produce more waste than actual product. But if green chemistry principles are applied, we can drastically reduce the waste production.

2. **Atom economy**

   It was introduced by Barry Trost. Atom economy is utilization of all the atoms of starting materials in the formation of product.

   $$\%\,atom\ economy = \frac{Formula\ Weight\ of\ atoms\ utilized}{(Formula\ weight\ of\ all\ reactants} * 100$$

3. **Less Hazardous Chemical Syntheses**

   Synthetic methods used should be less hazardous that is they should produce less harmful materials or at least materials which can be reused, so that no toxic substance can add to atmosphere.

4. **Designing Safer Chemicals**

   Chemicals used in the synthesis of a product should be less toxic and more productive.

5. **Designing safer solvents used**

   Solvent used in the reaction play major role in the reaction. Solvents are used up to 70-80% for the reaction. Therefore, we should employ solvents which can help in more products and at the same time it should not be toxic and should be environmentally friendly.

6. **Design for Energy Efficiency**

   The reactions should be designed in such a way as to minimize the use of energy. The energy released during reactions should not harm the environment. Thus, reactions should be performed at ambient temperatures and pressures

7. **Use of renewable sources**

   Raw materials or feed stocks should be from renewable sources such as plant biomass rather than from fossil fuels.

8. **Reduce usage of derivatives**

   Try to not use derivatives or protecting groups as they require additional solvents and chemicals and generate more waste.

9. **Catalysis**

   Catalysts should be preferred rather than normal stoichiometric reagents. Catalyst increase the efficiency of the reaction and less quantity of it is used compared to normal stoichiometric reagents.

10. **Design for Degradation**

    The reactions should be designed in such a way that the end products should be utilized properly i.e., the product should be degradable completely so that it should not harm the environment.

11. **Real-time analysis for pollution prevention**

    The processes or reactions should be monitored at regular step so that harmful substances be checked and controlled. Thus, analytical methods have to be designed for monitoring.

12. **Inherent safe chemistry for accident prevention**

    The reactions should be safe and environment friendly and minimize explosions, fires and accidents during reactions.

36.3.2 Application of green chemistry in present life

1. **Dry clean-up clothes in eco-friendly way**

   Clothes are dry cleaned using chemical called Perchloroethylene (PERC). This chemical polluted air and also caused cancer.

   Micell Technologies developed Micell, a metal cleaning framework which uses CO_2 and a surfactant for cleaning garments. This technology was developed by Joseph De Simons, Timothy Romark and James.

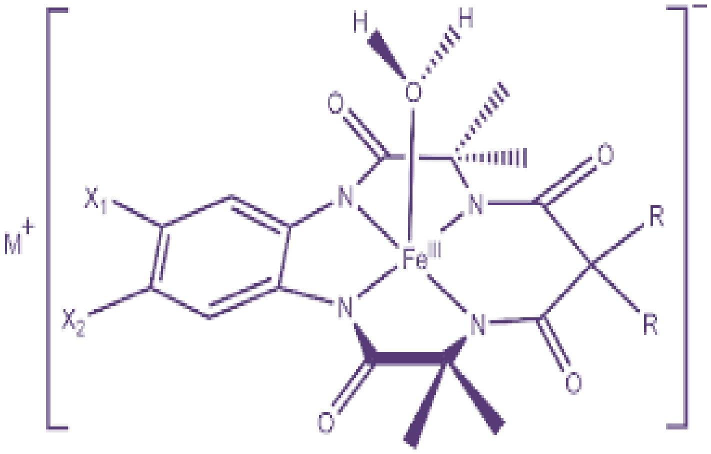
2. **Turbid water clearing**

   Generally, alum i.e., aluminium sulphate is used for clearing turbid water especially in water supply. But it had side effects as skin irritation, dizziness, throat infections, puffy face, allergic reactions and skin ulcer.

   To avoid this harmful effect, the latest discovery is use of tamarind seed kernel powder which is a agricultural waste. Municipal and industrial water are treated with Tamarind seed kernels to clear the turbid water. The advantage of tamarind seed kernel is it’s low cost, perishable and not poisonous.

3. **Bleaching of paper**

   Earlier chlorine gas was used in bleaching of paper where it formed carcinogenic compounds with lignin of paper. Nowadays, hydrogen peroxide is replaced by chlorine gas. Hydrogen peroxide breaks down lignin at faster rate catalysed by TAML (iron–tetraamido macrocyclic ligand) activators. Thus, at low temperatures and less time more lignin is broken down.



Fe- TAML activator

4. In pharmaceutical industry

Ibuprofen is synthesized in 3-step process presently rather than six step process. Drug for high cholesterol, Zocor which was synthesized in multistep method is now prepared faster using enzymes and feedstock. The yew tree bark was used in the synthesis of a chemotherapeutic drug, Taxol. For this large trees were cut down. Now the same drug is prepared by growing tree cells obtained by fermentation vat.

$$CH_2 = CH_2 + O_2 \xrightarrow[\text{Pd(II)/Cu(II)(in water)}]{\text{Catalyst}} CH_3CHO\,(90\%)$$

Terminal Questions

1. Define soil pollution
2. What the sources of soil pollution
3. How can soil pollution be controlled?
4. What is green chemistry?
5. Give the principles underlying green chemistry.
6. What are the applications of green chemistry
7. What is the catalyst used in conversion of ethene to ethanol.

36.1 Answers to Intext questions

1. Noise pollution can be defined as the unwanted noise more than 65db.
2. Refer 36.1.2.
3. REFER 36.1.1

Module VIIIB

Chemistry and Industry

Chapter 32

PETROCHEMICALS

Petrochemicals are the chemicals derived from petroleum. Petrochemicals include a very vast range of chemicals. You would learn about their meaning, classification, production and application. This lesson also deals with soaps and detergents and rockets fuels. Many of them are important byproducts obtained from petrochemicals.

Objectives

After reading this lesson you will be able to:

- define petrochemicals;
- explain different generations of petrochemicals with flow sheet diagram:
- cite various examples of petrochemicals;
- list uses of various petrochemicals,
- write about the status of petrochemicals in India.
- distinguish between soaps and detergents;
- explain types of detergents;
- list advantages and disadvantages of detergents over soaps;
- explain cleaning action of soaps and detergents;
- classify rocket propellants;
- give examples of chemicals used in various classes of rocket propellants and
- write about the status of propellants with reference to Indian Space programs.

32.1 What are Petrochemicals?

The chemicals derived from petroleum are known as petrochemicals. These are used in preparation of polymers, detergents and other plastic materials.

Petroleum is a complex mixture of hydrocarbons formed by the decomposition of fossil remains. It exists as a liquid (crude oil), gas (natural gas) or as solids(oil shales) and is found deep underground or below sea bed.

Petroleum is refined to several useful fractions, which are used as fuel (LPG, petrol, diesel, etc.) or lubricants. About 10% of the petroleum is used to prepare a range of chemicals called petrochemicals, we may define, petrochemicals as a group of chemicals produced directly or indirectly from the hydrocarbons of petroleum or natural gas.

Some gaseous hydrocarbons are also obtained as a byproduct during petroleum refining. These hydrocarbons may contain one to five carbon atoms, for example, methane, ethane, propane, butane, iso-butane, pentane, etc. Methane(CH_4) is also a major hydrocarbon component of natural gas, which occurs in association with petroleum.

Today, the demand of petrochemicals and the materials derived from petrochemicals is so great that we need to deliberately convert higher hydrocarbons to smaller gaseous hydrocarbons by the process of crackling.

The list of petrochemicals is endless. Some important petrochemicals are methyl alcohol, ethyl alcohol, acetaldehyde, acetic acid, acetic anhydride, acetone, benzene, toluene, xylenes, phenol, vinyl chloride, etc. some of these can be used directly or as raw materials for the manufacture of other useful products. These are used to manufacture a vast variety of useful materials like solvents, adhesives, antifreezes, synthetic rubbers, synthetic detergents, rocket fuels, etc. Since every area of human activity makes use of petrochemicals or the materials made from petrochemicals, our life without petrochemicals would be very different and less comfortable.

32.2 Classification of Petrochemicals

Let us try to understand feed- stock, primary and intermediate petrochemicals and the end products in the context of petrochemicals.

Feed-stock

The starting material used for the production of petrochemicals is called feedstock. There are two common feed stocks for the manufacture of petrochemicals; these are :

1. Natural Gas **2. Naphtha and reformed naphtha**

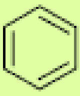
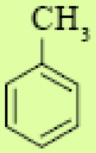
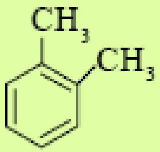
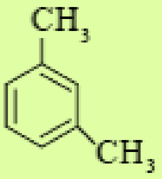
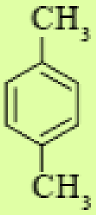
The major hydrocarbon component of natural gas is methane. Naphtha is a fraction obtained during refining of petroleum.

Some countries or industries prefer to use natural gas while some other use naphtha as a starting material (feed stock) for the production of petrochemicals. The choice for the use of natural gas or naphtha as feed stock by a particular country or industry depends upon the availability of a particular feed stock or the availability of technology for the manufacture of petrochemicals.

Primary Petrochemicals

Primary petrochemicals are the molecules obtained from the feed stock and are used to manufacture petrochemical intermediates. Since the feedstock consists of natural gas, naphtha and reformed naphtha, these give different primary petrochemicals. The primary petrochemical obtained from these are compiled in Table 32.1

Table 32.1: Important Primary Petrochemicals from different feed stocks

S.No.	Feed Stock	Primary petrochemicals	Formulae
1.	Natural	Ethene Prepone Ethyne	$CH_2 = CH_2$ $CH_3 – CH = CH_2$ $CH \equiv CH$
2.	Naphtha	Ethene Propene Butadiene	$CH_2 = CH_2$ $CH_3 – CH_2 = CH_2$ $CH_3 = CH_2 – CH = CH_2$
3.	Refomed Naphtha	Benzene	
		Toluene	
		o - xylene	
		m - xylene	
		p - xylene	

Intermediate Petrochemicals and Derivatives

The petrochemicals obtained from primary petrochemicals by chemical reaction are called (secondary) intermediate. These intermediate petrochemicals are further processed to get derivatives of petrochemicals by a chemical reaction or series of reactions to get products for other end uses.

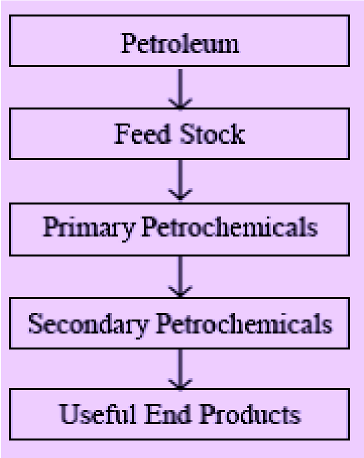


Fig.32.1: Relationship between petroleum, feedstock, primary petrochemicals, secondary (intermediate) petrochemicals and useful end products.

Down Stream Petrochemicals

The petrochemicals obtained from a given feedstock by a series of reaction are called down Stream petrochemicals. Down Stream means that a particular petrochemical comes at a later stage in the sequence of chemicals produced. For example in the following reactions.

$$CH_4 \longrightarrow CH_3Cl \longrightarrow CH_3OH$$

Intext Questions 32.1

1) Define petrochemicals

....

2) What do you understand by the term feed stock with reference to petrochemicals?

....

3) Write names of two feed stocks used in petrochemicals in industry.

....

4) What do you understand by the term downstream petrochemical? Explain with an example.

....

5) Methane is converted into methyl chloride then methyl chloride is converted to methyl alcohol. In this case identify the first generation and second-generation petrochemical.

....

32.3 Petrochemicals from Methane

Methane is the major hydrocarbon component of natural gas. CNG is the compressed natural gas and LNG is the liquefied natural gas. Moreover, methane is also obtained in large quantities as a byproduct of petroleum refining.

The major petrochemicals produced from methane are:

1) Chlorinated products **2) Unsaturated hydrocarbons** **3) Carbon black**
4) Hydrogen **5) Methyl alcohol**

1. Chlorinated products of methane

Methane is chlorinated to get methyl chloride (CH_3Cl), methylene chloride (CH_2Cl_2), chloroform ($CHCl_3$) and carbon tetrachloride (CCl_4).Most of the chlorinated products of methane are used as a solvent.

2. Unsaturated hydrocarbons

Methane is cracked (by pyrolysis) with the help of suitable catalysts to get ethylene, propylene and acetylene. These are used to get other products, which will be discussed later.

3. Carbon black

Methane is converted into carbon black (a form of carbon) by pyrolysis (cracking) and hydrogen is obtained as a byproduct. Carbon black is used a black pigment in manufacture of black printing ink and in rubber tyre industry.

4. Hydrogen

Hydrogen obtained by pyrolysis of methane is used for the manufacture of ammonia gas. Ammonia is used as a raw material for manufacture of urea (a fertilizer), ammonium nitrate and several other products.

5. Methyl alcohol

Methane is converted into methanol (methyl alcohol, CH_3OH) by catalytic oxidation.

$$CH_4 + \quad O_2 \xrightarrow{CATALYST} CH_3OH$$

Methyl alcohol (methanol) is further oxidized to get formaldehyde. Formaldehyde is an important raw material for number of useful products, for example phenol-formaldehyde resins (bakelite). Methyl alcohol is an important industrial solvent.

32.4 Petrochemicals from Ethylene

Ethyne is obtained by pyrolysis of natural gas or from naphtha by cracking. Ethylene is an unsaturated hydrocarbon and has a carbon-carbon double bond. Therefore, ethylene is very reactive and can be converted to a variety of petrochemicals and useful end products.

The major petrochemicals produced from ethylene are:

1) Ethyl alcohol
2) Ethylene oxide
3) Ethylene glycol
4) Dichloroethane
5) Vinyl chloride
6) Poly ethylene
7) Ethyl benzene
8)

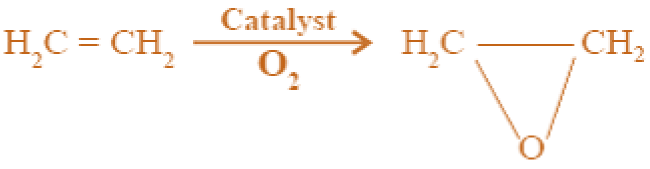
1. Ethyl alcohol

Ethyl alcohol (ethanol) is made by hydration of ethylene. Ethyl alcohol is used as a solvent and a raw material for the manufacture of acetic acid, ethyl acetate and a large number of other useful products.

$$H_2C = CH_2 \xrightarrow{H_2O / H_2SO_4} \underset{\text{(ethanol)}}{CH_3CH_2OH}$$

2. Ethyleneoxide

Ethylene is oxidized to ethylene oxide with air or oxygen in the presence of a catalyst. It is a raw material for the manufacture of ethylene glycol, which is a starting material for the manufacture of polyester.



(ethylene oxide)

3. Ethyleneglycol

Ethyle glycol (1,2-dihydroxyethane) is manufactured by starting with ethylene. There are several methods by which ethylene is converted to ethylene glycol.

Glycolis used as an anti-freeze in automobiles. Ethylene glycolis an important starting material for the manufacture of polyester.

$$H_2C = CH_2 \longrightarrow HO - CH_2 - CH_2 - OH$$

(ethylene glycol)

4. Dichloroethane

Dichloroethane(1,2-dichloroethane) is made from ethylene by the reaction of chlorine. It is used as a starting material for several other raw materials like ethylene glycol, vinyl chloride, etc.

$$H_2C = CH_2 + Cl_2 \longrightarrow Cl - CH_2 - CH_2 - Cl$$

(1, 2 - dichloroethane)

5. Vinylchloride

Vinylchloride is made directly from ethylene or is made from ethylene dichloride.

$$H_2C = CH_2 + Cl_2 \longrightarrow CH_2 = CH - Cl + HCl$$

(vinyl chloride)

$$Cl - CH_2 - CH_2 - Cl_2 \longrightarrow CH_2 = CH - Cl + HCl$$

(vinyl chloride)

6. Polyethylene

On polymerization ethylene gives polyethylene (polyethene), which is an important plastic material.

$$n\ H_2C = CH_2 \longrightarrow - CH_2 - CH_2 [- CH_2 - CH_2 -]_n CH_2 - CH_2 -$$

(ethylene) (polyethylene)

7. Ethylbenzene

Ethylene reacts with benzene in the presence of a suitable catalyst to give ethylbenzene. Ethylbenzene is converted to styrene. Styrene is a raw material for the manufacture of an important plastic material polystryrene.

Ethylbenzene

32.5 Petrochemicals from Propylene

Propylene is obtained pyrolysis of natural gas or by cracking of naphtha. Propylene is an unsaturated hydrocarbon.

The main petrochemicals produced from propylene are:

1. Iso-propyl alcohol
2. Polypropylene
3. Cumene (isopropyl benzene)
4. Glycerol

32.6 PetrochemicalsfromAcetylene

Acetylene (ethyne) is obtained by pyrolysis of natural gas. It is an unsaturated hydrocarbon. It has a carbon-carbon triple bond. It is hughly reactive in nature.

The major petrochemicals produced from acetylene are:

1. Vinylchloride, vinylacetate and acrylonitrile
2. Acetaldehyde

32.7 PetrochemicalsfromButadiene

1,3-Butadiene is obtained from naptha by cracking. It is a diene, that is, it has two carbon-carbon double bonds.

It is a monomer for polybutadine which is used as a substitue for natural rubber. Butadiene and styrene on polymerization give a copolymer called BUNA-S.

32.8 Petrochemicals from Benzene

benzene is obtained from reformed naphtha. Naphtha is subjected to catalytic reforming (also called aromatization). In the process aliphatic hydrocarbons present in naphtha are converted to aromatic hydrocarbons.

Important petrochemical obtained from benzene are:

1. Ethylbenzene and cumene
2. Chlorobenzene
3. Nitrobenzene
4. Cyclohexane
5. Linear alkyl benzenes(LAB)
6. Branched alkylbenzens(BAB)

Intext Questions 32.2

1. Define primary petrochemicals.

....

2. Mention three petrochemicals obtained from natural gas.

....

3. What are the important petrochemicals obtained from propene?

....

4. What are the important petrochemicals obtained from ethyne (acetylene)?

....

5. What are the petrochemicals obtained from benzene?

....

32.9 Soaps and Detergents

Soaps and detergents are widely used as cleaning agents. Chemically soaps and detergents are quite different from each other. The common feature of soaps and detergents is that when dissolved in water the molecules of soap and detergent tend to concentrate at the surface of the solution or at interface. Therefore, the surface tension of the solution in reduced, it causes foaming of the solution.

Soaps and detergents lower the surface tension of the solution. Such substances are called surface-active agents of surfactants.

Soaps and detergents:

1. are used as cleaning agents
2. cause foaming of the solution
3. lower surface tension
4. molecules tend to concentrate near the surface of the solution
5. are the surface-active agents
6. are the surfactants
7. can emulsify grease
8. can remove dirt, etc.

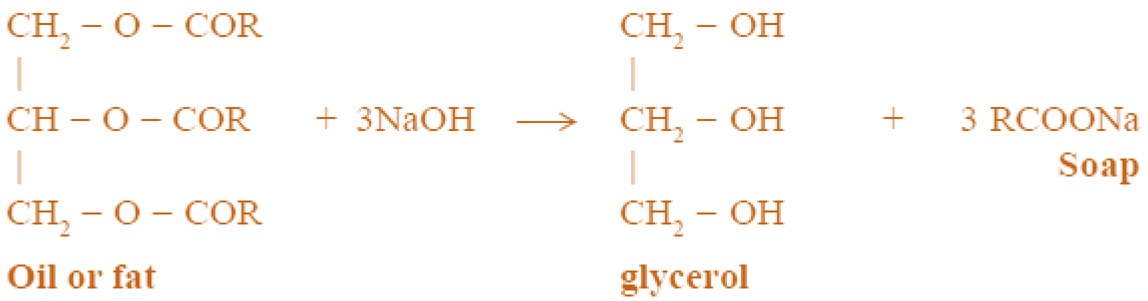
Hydrophilic and Lipophilic Parts

Both soap and detergent molecules have two parts. One part of the molecule is polar (ionic) in nature. Polar nature is due to the presence of groups like carboxylate(-COO) or sulphonate ($-SO_3^-$).The polar group is a hydrophilic group. The hydrophilic group makes soaps and detergents soluble in water. The other part of the soap or detergent molecule is non polar (nonionic) that is lipophilic. The lipophilic (along chain alkyl or a long chain substituted aryl group) makes the molecule oil soluble.

Depending on the nature of the hydrophilic (polar) part in the soap or detergent molecule these are classified as anionic, cationic or non-ionic type. Forexample, soap has acarboxylate anion therefore soap is an ionic type (table8.5.1) Synthetic detergents have sulphonate anion thus they are also classified as anionic type. Anionic types are the most common. However, cationic and non-ionic detergents are also known.

Soaps

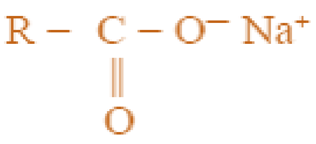
Soaps are the sodium or potassium salts of long chain fatty acids. These fatty acids are present in oil sand fats in the form of glycerides. The glycerides present in oil sand fats are the esters of glycerol and long chain carboxylic acids for example palmitic acid and stearic acid.



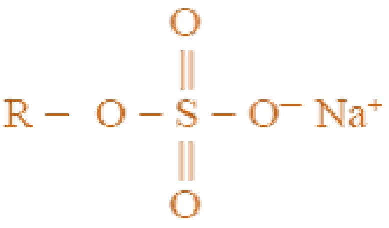
(where R=long chain alkyl group containing 11to17carbon atoms)

Synthetic Detergents

Synthetic detergents are used as cleaning agents much like soaps. Chemically, detergents are sodium salts of long-chain alkyl hydrogen sulphate or sodium salts of long-chain alkyl benzene sulphonicacids. (Remember that soap is a sodiumorpotassium salt of long-chain fatty acid.)



(Soap)



(Detergent)

Detergent molecules are similar to that of soap molecules, that is they have an oil-soluble (lipophilic) long chain of carbon atoms and a polar(hydrophilic) water-soluble part. For example, sodium lauryl sulphate ($C_{12}H_{25}$-O-SO_3Na) has a 12 carbon atom hydrocarbon like alkylchain. The long carbon chain is oil-soluble (lipophilic) part and the sulphate is polar (hydrophilic) part that makes the molecule water-soluble. The water-soluble part is referred to as water-soluble head and the long chain of carbon atoms is referred to a soil-soluble tail.

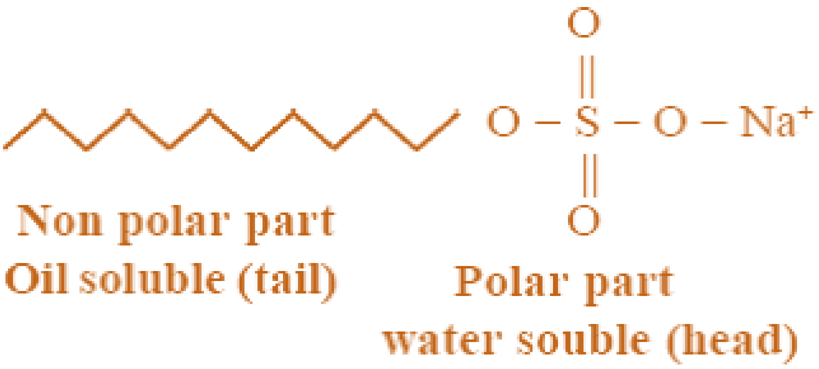
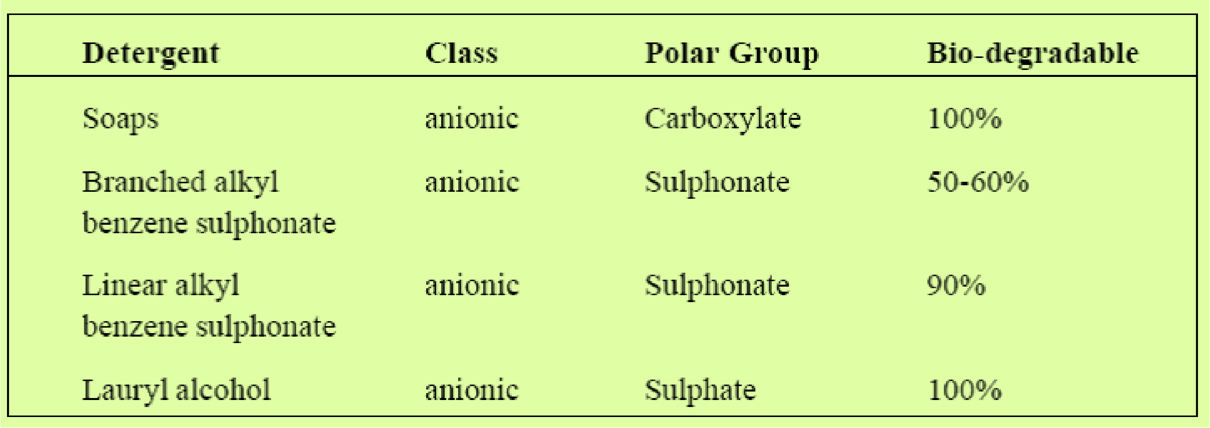


Table 32.2: Bio-degradability and class of soaps and some synthetic detergents



Detergent	Class	Polar Group	Bio-degradable
Soaps	anionic	Carboxylate	100%
Branched alkyl benzene sulphonate	anionic	Sulphonate	50-60%
Linear alkyl benzene sulphonate	anionic	Sulphonate	90%
Lauryl alcohol	anionic	Sulphate	100%

Intext Questions 32.3

1. What is the active component in soaps?

....

2. What are the raw materials used for the manufacture of soaps?

....

3. What is the polar part in a soap molecule?

....

4. What is the polar part (hydrophilic) in a synthetic detergent molecule?

....

5. What is the oil-soluble (lipophilic) part in the soap molecule?

....

32.10 Rocket Fuels

Space rockets are used for launching satellites and for propelling missiles. These rockets work on the same principle as that of fire-work rocket the Newton's third law of motion. However, their design and fuels are more complicated.

Rocket Fuels are different

Fuels used in the rockets are very different from the fuels used in cars, trucks or airplanes. Following are the main differences between the rocket fuels and other conventional fuels.

1. A rocket fuel must occupy small space in the rocket.

- If the fuel occupies a large space, then the rocket will become very big and heavy. It may not be able to attain high velocity to go out high in the space.

2. A rocket must carry enough supply of oxygen (or oxidizing agents) to burn the fuel.

- A space rocket has to pass through areas in space where there is little or no oxygen (air become rarer as we go out in space-away from earth).

Classification of Rocket Propellants

Rocket propellants are classified on the basis of their physical state. The major classes of rocket propellants are:

1. Solid propellants **2. Liquid propellants** **3. Hybrid propellants**

1. Solid Propellants

Solid propellants are the most commonly used rocket propellants. These are also known as solid composite propellants. It is a mixture of a solid fuel and a solid oxidizer.

Polymeric solid substances like polyurethane or polybutadiene are used as fuel. Solid ammonium perchlorate is used as an oxidizer. Finely divided aluminum or magnesium is also added to improve the performance of the propellant.

Double Base propellants

Another type of solid propellant is a double base propellant. It consists of nitroglycerine and nitrocellulose. Both nitro cellulose and nitro glycerine have enough oxygen in their nitro groups to support the combustion of fuel. This do not need any separate oxidizer.

Solid propellants on ignition can be made to burn at a predetermined rate. The problem with solid propellants is that once ignited they will continue to burn and it is not possible to stop ignition or to change the rate of ignition.

2. Liquid Propellants

Liquid propellants use a combination of a liquid fuel and a liquid oxidizer.

Liquid propellants, in general, give a higher thrust than solid propellants. Switching on and off the flow of the propellant can control thrust. Controlling the rate of flow of the fuel can also control the thrust.

Liquid propellants are of two types. These are:

a) Bi-liquid propellants **b) Mono-propellants**

(a) Bi-Liquid Propellants

Bi-liquid propellants contain a liquid fuel and a liquid oxidizer. The liquid fuel and liquid oxidizer are kept in separate tanks. These are taken to the ignition chamber through separate pipeline. If liquid oxygen is used as an oxidizer and liquid hydrogen is used as a fuel then the very low temperatures are to be maintained. Therefore, special engines are used to pump them through the pipes. The engines, which can work at extremely low temperatures, are known as cryogenic engines. Very few countries have the capability to manufacture cryogenic engines.

The most commonly used liquid fuels are kerosene, alcohol, hydrazines, liquid hydrogen, etc. The commonly used oxidizers are liquid oxygen, nitric acid, nitrogen tetraoxide (N_2O_4).

(b) Mono-Propellants

Mono-propellants contain a single chemical compound. On decomposition or ignition these producea large volume of gases.

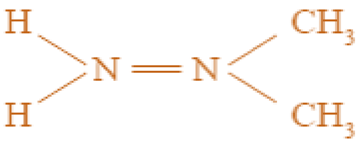
Hydrazine (N_2H_4) can be used as a mono-propellant. Hydrazine on catalytic decomposition produces nitrogen and hydrogen gas. Some other examples of monopropellant are nitro methane, methylenenitrate, hydrogen peroxide, etc.

3. Hybrid Propellants

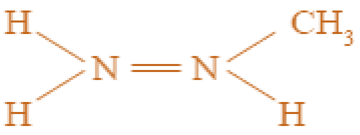
Hybrid propellants are those, which have a solid fuel and a liquid oxidizer. For example, a mixture of acrylic rubber is used as fuel and liquid nitrogen tetraoxide (N_2O_4) as an oxidizer. Propellants used in Various Rockets

Different fuels have been used in different space programs. Some rockets may use different fuels in the different stages of ignition. In India SLV-3 (Space Launch Vehicle) and ASLV (Augmented Space Launch Vehicle) rockets have used composite solid propellants.

The PSVL (Polar Satellite Launch Vehicle) used solid propellants in the first and the third stages. In the second stage liquid propellant nitrogen tetraoxide (N_2O_4) as oxidizer and unsymmetrical dimethyl hydrazine (UDMH) as a fuel is used. In the fourth stage N_2O_4 and monomethyl hydrazine (MMH) is used as a fuel. India is one of the six nations, which have PSLV capability. The other five nations are the US, Russia, China, France and Japan.



Unsymmetrical
dimethyl hydrazine
UDMH



mono methyl hydrazine
MMH

Intext Questions 32.4

1. Which of the Newton's laws of motion governs the motion of rockets?

....

2. Why are rocket fuels different from the fuels used in automobiles?

....

3. What are the main classes of rocket propellants?

....

4. Name one oxidiser used in ballistic missiles.

....

What you have learnt:

- Definition of petrochemicals
- Different generations of petrochemicals with flow sheet diagram
- Different examples of petrochemicals

- Learnt the uses of various petrochemicals
- Known the status of petrochemicals in India
- Difference between soaps and detergents
- Lipophilic and hydrophilic parts of soap and detergent molecules
- Advantages and disadvantages of detergents over soaps
- Classification of rocket propellants
- Chemical composition of various classes of rocket propellants
- Different propellants used in India Space programs.

Terminal Exercise

1. What is the major hydrocarbon component present in the natural gas?
2. What are the common feed stocks used in the manufacture of various petrochemicals?
3. "Alkenes (olefins), benzene, toluene and xylenes are the primary petrochemicals. "Is this statement true or false?
4. What are the major uses of the carbon black?
5. What are the major chemicals manufactured from methyl alcohol?
6. How is ethylalcohol manufactured from ethylene?
7. How is vinylchloride manufactured from ethylene?
8. What is the name of the polymer obtained from polymerization of styrene?
9. Write the name for the dicarboxylic acid obtained by oxidation of para-xylene?
10. Name a primary petrochemical obtained from reformed naphtha, which is used for the manufacture of synthetic detergents?
11. Why are the fuels used in rockets different from the fuels used in homes?
12. What is a double-base rocket propellent?
13. What are cryogenic engines?

Answers to Intext Questions

32.1

1. Petrochemicals are the chemicals obtained directly or indirectly from petroleum or its fraction.
2. Starting material used for the production of petrochemicals is called feed stock.
3. Natural gas and naphtha
4. Downstream petrochemical means a petrochemical which is formed at a later stage in the sequence (order) of the chemicals produced.
5. Methyl chloride is the first generation petrochemical and methyl alcohol in the second generation petrochemical.

32.2

1. Primary petrochemicals are the petrochemicals which are directly obtained from the feedstock.

2. Methyl alcohol, methyl chloride, carbon black.
3. Isopropyl alcohol, polypropylene, cumene and glycerol.
4. Vinyl chloride, vinyl acetate, acrylonitrile and acetaldehyde.
5. Ethyl benzene, chloro benzene, nitrobenzene, cyclo hexane, linear alkyl benzene(LAB) and branched alkyl benzene(BAB)

32.3

1. Sodium or potassium salt of higher fatty acid.
2. Sodium or potassium hydroxide and oils and fats.
3. Carboxylate anion
4. Sulphonate anion.
5. Long normal alkyl chain.
6. False.

32.4

1) The third law of motion.
2) Rockets need to carry their own supply of oxygen and should be light and occupy less volume.
3) Solid, liquid and hybrid propellent.
4) Nitrogen tetraoxide

Chapter 33

POLYMERS

Today polymers have influenced our life style to the extent that it would not be wrong to say that we are in polymer age. Now-a-days polymers find wide range of uses starting from common household utensils, automobiles, clothes, furniture, etc., to space-aircraft and biomedical and surgical components.

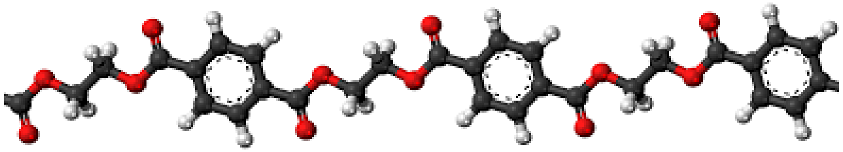
Polymeric materials are light weight but can possess excellent mechanical properties and can be easily processed by different methods. In this lesson you would learn more about polymers, their types and some important-synthetic and natural polymers. In the next lesson you would learn about the colouring materials like dyes, paints and pigments.

Objectives

After reading this lesson you will be able to:

- define the terms like monomers, polymer, homopolymer, copolymer and polymerization;
- classify polymers on the basis of their source, molecular forces and method of preparation;
- list the monomers of the polymers like natural and synthetic rubber;
- list the monomer of the polymer like polythene, polystyrene, Buna-S, PMMA, PVC, teflon, polyester, Nylon66 and Nylon6;
- define biodegradable polymers and
- cite examples of some biopolymers.

33.1 What are Polymers



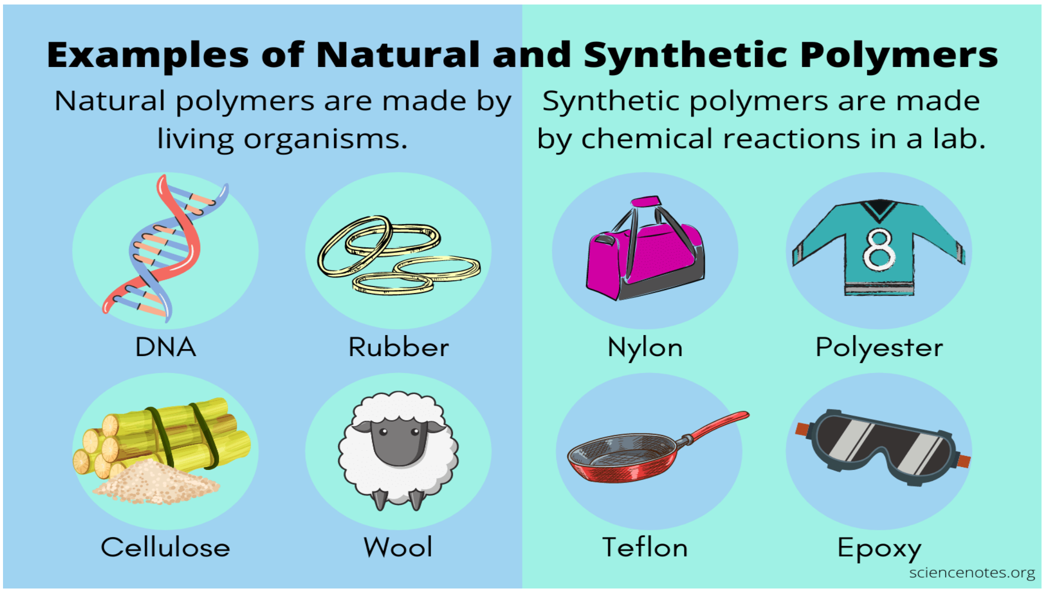
Polymers are large molecules formed by intermolecular linkage between same or different types of smaller molecules called monomers. If a large number of monomers (A) are linked together then the polymerisre presented as $(–A_n–)$ – $(–A–A–A–A–A)_n–$ is a polymer of the monomer of (A). For example, polyethene. $–(–CH–CH–)_n–$ is a polymer of ethene.

Polymer is a high molecular mass molecule formed by linking up of two or more small molecules called monomers.

Monomers are the small molecule which are capable of linking amongst themselves to form big molecules called polymers.

In some polymers more than one type of monomers combine with each other to give the polymer. For example, a polymer may be obtained from two monomers (A) and (B) viz,

$$-A-B-A-B- \qquad \text{or} \qquad -(-A-B-)_n-$$



33.2 Types of Polymers

Depending upon the nature of the repeating sturctural units (monomers), polymers are divided into two broad categories viz., homopolymers and copolymers.

(a) Homopolymer

A polymer formed from only kind of monomers is called homopolymer. Polyethene $-(-CH-CH-)_n-$ is an example of homopolymer.

(b) Copolymer

A polymer formed from more than one kind of monomer units is called copolymer or mixed polymer. For example, Buna-S rubber which is formed from 1,3-butadiene ($CH_2=CH-CH=CH_2$) and styrene ($C_6H_5\ CH=CH_2$) is an example of copolymer

.

33.3 Polymerization

The process by which the monomers get linked up is called polymerization. Polymerization is represented as:

$$M + M \longrightarrow M-M \longrightarrow M-(-M-)_n-M$$

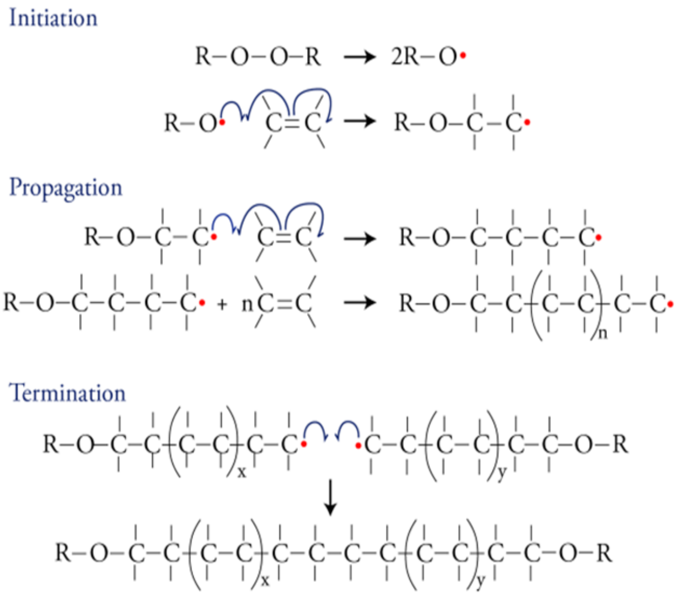
Monomers dimer polymer

33.3 Types of Polymerization

Depending upon the mode of reaction, polymerisation is classified as:

a) Addition polymerization **b) Condensation polymerization**

a) Addition Polymerization: This process involves the addition of monomer units to form a growing chain by reaction mechanism. It is for this reason that the process is also known as chain growth polymerization.

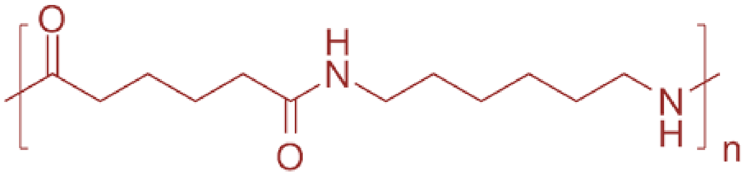


Initiation: Addition polymerization is achieved by adding a catalyst (known as initiator), which provides some reactive species like free radicals.

Chain propagation: These free radicals (R) then attack the unsaturated monomer and form a new free radical which goes on successively adding monomers and thus grows the chain

Chain termination: The final termination of the two growing chains leads to a polymer.

Example : Nylon66, a polymer of polyamides



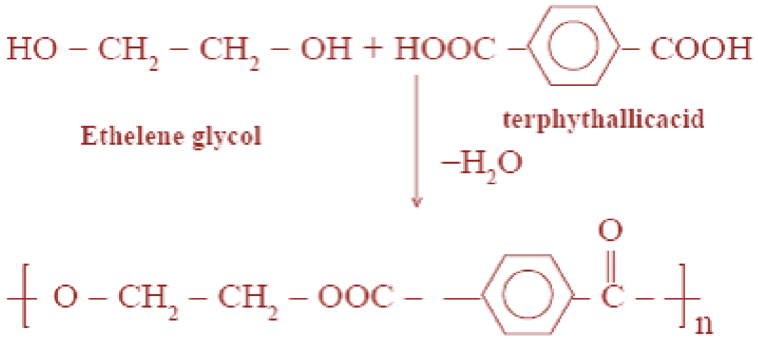
Nylon threads

b) Condensation Polymerization:

In this, the monomers combine with the elimination of a small molecule like H_2O, ROH or NH_3, etc. The reaction is called (step growth) condensation polymerization and the product formed is called condensation polymer.

The process involves the elimination of by product molecules; therefore, the molecular mass of the polymer is not the integral multiple of the monomer units.

For example polyester or Terylene is a condensation polymer of ethylene glycol and terphthallic acid.



Poly (ethylene terphthalate) or (Terylene)

Terylene fabric

These two processes of making polymers have several characteristics which distinguish them from each other. These are shown in (Table 33.1).

Table 33.1: Some differences between addition polymerization and condensation polymerization

Addition Polymerization	Condensation polymerization (Polycondensation)
1. Involves unsaturated monomer like ethylene, vinyl chloride, styrene etc.	1. Involves substances with at least 2 functional groups like ethylene glycol (2-OH groups), adipic acid (2-COOH groups).
2. Fast addition of monomers	2. Step-wise slow addition.
3. At any instant, only monomer and polymers are present.	3. No monomer Mixtures of dimers, tri mers and tetra mers etc. are present
4. Initiator is necessary to catalyse the polymerization.	4. Catalyst is not necessary.
5. No small molecules are eliminated.	5. Small molecules like H_2O, HCl
6. Polymers made are, for example, polyethene, poly propylene, polybutadiene, poly vinylchloride.	6. Polymer made are, for example, terylene, nylon, Formaldehyde - resins, silicones.

Intext Questions 33.1

1. Define the terms:

i) Polymer ii)Monomer

....

2. Write one example of each of:

i) Addition polymerization ii) Condensation polymerization

....

3. Differentiate between homopolymers and copolymers.

....

4. Write monomers of Terylene and Nylon-66.

....

33.4 Classification of Polymers

The polymers can be classified in a number of ways. Some of these are discussed below for a systematic investigation of their properties and uses.

(a) Classification of Polymers on the Basis of Origin.

On the basis of origin, polymers are classified as:

1. Natural Polymer **2. Synthetic Polymers**

1. Natural Polymers:

The polymers obtained from nature (plants and animals) are called natural polymers. Starch, cellulose, natural rubber, proteins, etc. are some examples.

2. Synthetic Polymers:

The polymers which are prepared in the laboratories are called synthetic polymers. These are also called man-made polymers. Polyethene, PVC nylon, Teflon, bakelite, terylene, synthetic rubber, etc. are common examples.

(b) Classification of Polymers on the Basis of structure

On the basis of structure of polymers, these can be classified as:

1. Linear polymers **2. Branched chain polymers**

3. Cross-linked polymers.

1. Linear polymers:

These are polymers in which monomeric units are linked together to from linear chains. These linear polymers are well packed (Fig. 33.1) and therefore, have high densities, high tensile (pulling) strength and high melting points. For example, polyethelene, nylons and polyesters and examples of linear polymers.

2. Branched chain polymers :

These are polymers in which the monomers are joined to form long chain with side chains or branches of different lengths (Fig. 33.2). These branched chains polymers are irregularly packed and therefore, they have lower tensile strength and metling points than linear polymers. For example, low density polythene, glycogen, starch, etc.

3. Cross-linked polymers :

These are polymers in which long polymer chain are cross-linked together to form a three dimensional network. These polymers are hard, rigid and brittle because of the network structure. (Fig. 33.3) backlite, melamine and formaldehyde resin are some examples of this type.

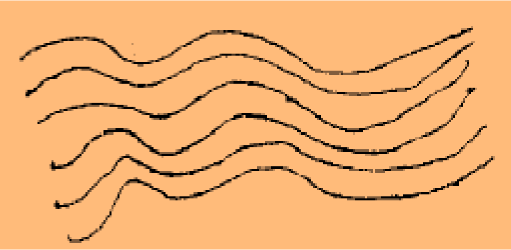


Fig. 33.1: Linear Polymers

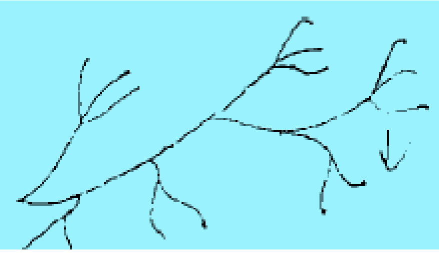


Fig. 33.2: Branched Chain Polymers

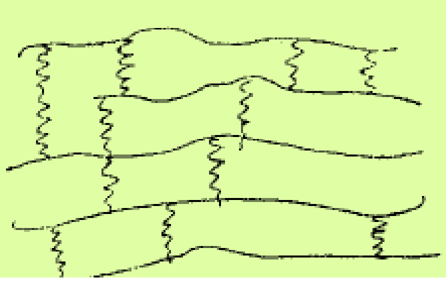


Fig. 33.3: Cross Linked Polymers

c) Classification of Polymers on the Basis of Molecular Forces

Depending upon the intermolecular forces between monomer molecules, the polymers have been classified into four types.

1. Elastomer **2.Fibers** **3. Thermoplastics** **4. Thermosetting**

1. Elastomers:

In case of elastomers the polymer chains are held together by weak vander waals forces. Due to weak forces, the polymers can be easily stretched on applying small stress and they regain their original shape when the stress is removed. This is due to the presence of few - 'cross links' between the chains, which help the polymer to retract to its original position after the force is removed, as in vulcanized rubber. The most important example of elastomer is natural rubber

2. Fibres :

These are the polymers which have strong intermolecular forces between the chains. These forces are either hydrogen bonds or dipole-dipole interactions. Because of the strong forces, the chains are closely packed, giving them high tensile strength and less elasticity. These polymers can be drawn into long, thin and thread like fibres and therefore can be woven in to fabrics. The common examples are nylon-66, dacron, silk, etc.

3. Thermoplastics:

These are linear polymers with very few cross linkages or no cross linkages at all. The polymeric chains are held by weak vander waal forces and slide over one another. Due to lack of cross linkages these polymers soften on heating and harden or rigid on cooling. Thus they can be molded to any shape. Polythene, PVC, polystyrene are addition type thermoplastics and Terylene, nylonare condensation type thermoplastics.

Plasticizers:

Certain plastics donot soften much on heating. These can be easily softened by the addition of some organic compounds which are called plasticizers. For example, poly vinyl chloride (PVC) is very stiff and hard but is made soft by adding di-n-butyl phthalate (a plasticizer). Some other common plasticizers are dialkyl phthalates and cresyl phthalate.

4. Thermo setting polymers:

Usually thermo setting polymer can be heated only once when it permanently sets into a solid which cannot be re-melted and re-moulded. Thermo setting polymers are produced from relatively low molecular mass semi fluid polymers (called polymers) which on heating develop extensive cross-linking by themselves or by adding some cross-linking agents and become in fusible and insoluble hard mass. The cross-links hold the molecules in place so that heating does not allow them to move freely. Therefore, a thermo setting plasticis cross-linked and is permanently rigid. The common example are bakelite, melamine, formaldehyde resin, etc.

Some important differences in the properties of thermo setting and thermo plastic polymers are summerized in Table 32.2

Table 33.2: Distinction between Thermoplastic and Thermosetting polymers

Thermoplastic	Thermosetting polymers
1. Linear polymers.	1. Cross-linked polymers.
2. Weak vander Waals inter molecular forces and thus soften/melt on heating.	2. Chemical cross-linking make them infusible materials. Do not melt on heating.
3. Molten polymer can be moulded in desired shape. it can be remoulded by heating again	3. Cross-linking is usually developed at the time of harden irreversibly.
4. Examples are polystyrene, PVC, SBR, Teflon, PMMA terylene.	4. Examples are Glyptals, epoxy polymers, formaldehyde resins.

Intext Questions 33.2

1. Define natural and synthetic polymers with examples?

....

2. What are cross linked polymers? Give on example of this type.

....

3. How do thermoplastic differ from thermosetting polymers?

....

4. Arrange the following polymers in the increasing order of the intermolecular forces. Also classify them as addition and condensation polymers. Nylon-66, Buna-S, Polyethene.

....

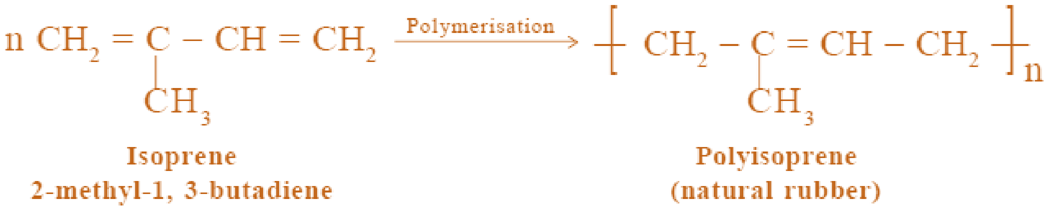
33.5 Some Commercially Important Polymers

Polydienes

These polymers are obtained when an unsaturated hydrocarbon with two double bonds or when a diene (2 double bond compound) is polymerized with a substituted alkene (you have studied in lesson 32 that these alkenes and dienes are petrochemicals). The polymers belonging to this class are rubbers or elastomer. They can be natural or artificial. Consequently, we have natural rubber and synthetic rubber.

1) Natural Rubber:

It is a polymer of unsaturated hydocarbon, 2-methyl-1,3-butadiene also called isoprene. It is obtained from the latex of rubber trees found in tropical and semi-tropical countries such as India (southern part), Indonesia, Malaysia, Ceylon, South America, etc. The latex contains about 25-40% of ruuber hydrocarbons dispersed in water along with stabilizer proteins and some fatty acids. It is a natural polymer and possess remarkable elasticity. It undergoes long range reversible extension under relatively small applied force. This elasticity makes it valuable for a variety of uses.



$$n\,CH_2=\underset{\displaystyle CH_3}{\underset{|}{C}}-CH=CH_2 \xrightarrow{\text{Polymerisation}} \left[CH_2-\underset{\displaystyle CH_3}{\underset{|}{C}}=CH-CH_2 \right]_n$$

In natural rubber 10,000 to 20,000 isoprene units are linked together.

Vulcanization of Rubber:

The wide applications of rubber are due to its property called elasticity and that is why rubber is said to be an elastoplastic or elastomer. Accidentally, in 1893, Charles Good years discovered that addition of sulphur to hot rubber cause changes that improve its physical properties in a spectacular manner. This process is called vulcanization. It is carried out by heating crude rubber in presence of sulphur or dipping it in solution of S_2Cl_2 in CS_2.

vulcanization depends upon:

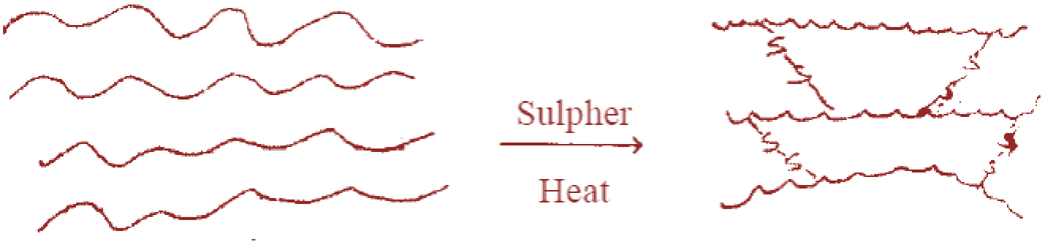
i) The amount of Sulphur used:

by increasing the amount of sulphur rubber can be hardened

ii) Temperature

iii) Duration of heating.

Crude rubber is intimately mixed with about 3% ground sulphur, an accelerator and activator and then heated to about 150°C (for tyres it is 150°C). Vulcanization is a progressive reaction and is allowed to a definite stage. The detailed mode of vulcanization process may be difficult to visualize, but probale structure of vulcanized rubber is depicted below (Fig.33.4)



Natural rubber Vulcanized rubber

Fig. 33.4 : Process of vulcanization of rubber

Table 33.3 : Comparison of some properties of natural rubber and vulcanized rubber :

	Natural Rubber		Vulcanised rubber
1	Natural rubber is soft and sticky	1	Vulcanized rubber is hard and non-sticky.
2	It has low tensile strength.	2	It has high tensile strength.
3	It has low elasticity.	3	It has high elasticity.
4.	It can be used over a narrow range of temperature (from 100to 600^oC)	4.	It can of be used over a wide range of temperature (-400 to 1000^o C)
5	It has low wear and tear resistance	5	It has high wear and tear resistance.
6.	It is soluble in solvents like ether, carbon tetrachloride, petrol, etc.	6.	It is insoluble in most of the common solvents.

2) Synthetic Rubbers:

Synthetic high polymers possessing similar physical properties as that of natural rubber are called synthetic rubber. Synthetic rubber is an improvement over natural rubber, especially with respect to its resistance to oils, gas, solvents, etc.

Attempts to find a synthetic substitute for natural rubber began very early. Faraday, in 1826 concluded that natural rubber was a hydrocarbon (C_5H_8 or $C_{10}H_{16}$). Greville William (1860), obtained isoprene, a liquid from rubber. He considered rubber as a polymer of isoprene. Fritz Hofmann (1909), synthesized rubber first of all by the polymerization of 2, 3-dimethyl butadiene.

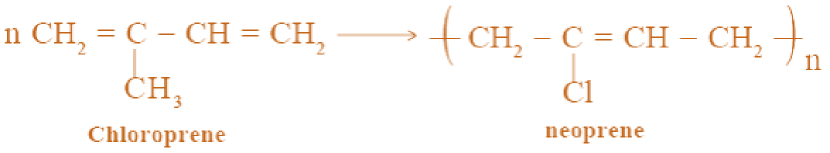
Synthetic rubber has been produced by the polymerization of large number of conjugated dienes resemblingtoisoprene.TheBunaRubber(polymersofbutadiene)waspreparedbyGermans by the action of sodium on butadiene and that is why such synthetic rubber is known as "Buna" rubber ("Bu" from butadiene and "na" from the symbol of sodium Na).

Similarly Americans made S.B.R. (styrene butadiene rubber) usually known as G.R.S. Since then the synthetic rubber industry has survived along with the natural rubber production.

Some synthetic rubbers are made by polymerization of only one monomer, for example Neoprene is made by polymerization of chloroprene, while synthetic rubbers like Buna-S, BunaN and Butylrubber etc. are copolymers as these have more than one monomer.

Neoprene:

This synthetic rubber resembles natural rubber in its properties. It is obtained by polymerization of chloroprene.



$$n\,CH_2=\underset{\displaystyle CH_3}{C}-CH=CH_2 \longrightarrow \left(CH_2-\underset{\displaystyle Cl}{C}=CH-CH_2 \right)_n$$

Chloroprene is obtained by the reaction of HCl with vinylacetylene.

$$CH_2=CH-C\equiv CH+HCl \longrightarrow CH_2=CH-\underset{\displaystyle Cl}{C}=CH_2$$

Neoprene swim suits

Neoprene is superior to natural rubber in its stability to aerial oxidation and its resistance to oils, gasoline and other solvents

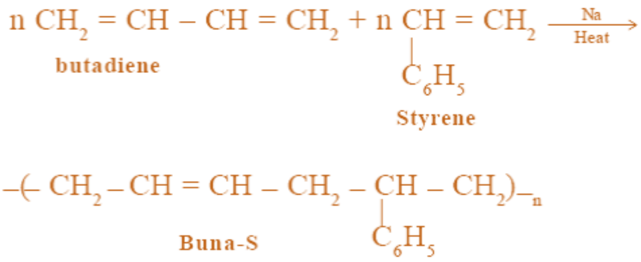
Neoprene is used for

i) making belts, hoses, shoe heals, stoppers, etc. and

ii) manufacture of containers for storing petrol, oil and other solvents.

Buna-S:

It is obtained by polymerization of butadiene and styrene in presence of sodium metal.



$$\underset{\text{butadiene}}{n\,CH_2 = CH - CH = CH_2} + n\,\underset{\underset{\text{Styrene}}{C_6H_5}}{CH} = CH_2 \xrightarrow[\text{Heat}]{Na}$$

$$\underset{\text{Buna-S}}{-\!(CH_2 - CH = CH - CH_2} - \underset{C_6H_5}{CH} - CH_2)\!-_n$$

Slippers made of BUNA S rubber

In Buna-S, **Bu** stand for butadiene, **Na** for sodium and **S** stands for styrene. It is also called S.B.R. (Styrene Butadiene Rubber). It has slightly less tensile strength than natural rubber.

Buna-S is used for:

i) Making automobile tyres **ii) rubber soles, belts and hoses etc.**

Buna-N:

It is obtained by copolymerization of two parts of butadiene and one part of acrylo nitrile in presence of sodium metal. Buna - N is hard and extremely resistant to the swelling action by oils (petrol), solvents and is resistant to heat, etc.

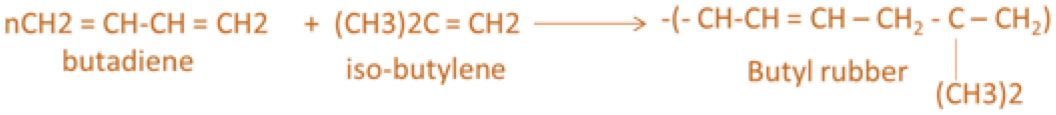
$$nCH_2 = CH - CH = CH_2 + nCH_2 = \overset{\overset{CN}{|}}{CH} \longrightarrow -\!(CH_2-CH = CH-CH_2-CH_2-\overset{\overset{CN}{|}}{CH})_n$$

Uses:

i) It is used for the manufacture of storage tanks for solvents and ii) For making oil seals.

Butyl Rubber:

This is obtained as a result of co-polymerization of butadiene and isobutylene. It is generally carried out in the presence of small quantity of isoprene. The function of isoprene is not exactly known.



$$nCH2 = CH\text{-}CH = CH2 + (CH3)2C = CH2 \longrightarrow -(\text{-}\ CH\text{-}CH = CH - CH_2 - \underset{\underset{(CH3)2}{|}}{C} - CH_2)$$

Butyl rubbers are inert towards acids and alkalies, but have poor resistance towards petroleum products.

Uses:

i) It is used for making inner tubes of tyres and

ii) For making conveyor belts, tank linings and insulation of high voltage wires and cables etc.

Intext Questions 33.3

1. Write the IUPAC names and structures of monomers of the following polymers:

(i) Natural rubber ii) Neoprene

....

2. What is the function of sulphur in the vulcanization of rubber?

....

3. What is Buna-S? How is it synthesized?

....

4. Compare the properties (at least three) of natural rubber and vulcanized rubber?

....

After the detailed discussion of rubbers, we shall now discuss some other commercially important polymers.

33.6 Polyolefins

Poly olefins is a major class of synthetic polymers made by the polymerization of an olefin (alkene) or its suitable derivative. Most of these are obtained from petrochemical industry. Polyethylene, polypropylene, PVC, Teflon, etc. belong to the class of polyolefins. Some important members of this class are discussed here with.

1) Polyethylene or polyethene:

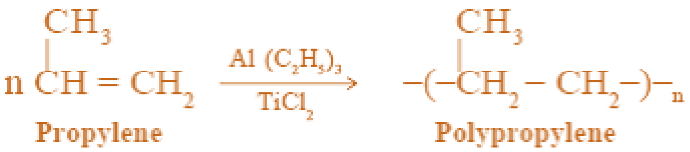
This is formed by polymerization of ethylene ($CH_2 = CH_2$). It is manufactured in large quantities and is the most common polymer which you find almost everywhere. Polyethene is of two types Low Density Polyethene (LDPE) and High Density Polyethene (HDPE) depending upon the nature of has branching in polymer chain and is not compact in polymer molecules. Low density polyethene has branching in polymer chains and is not compact in packing. While high density polyethene has linear chain of molecules which are packed in a more compact fashion (Fig.33.1 and Fig.33.2).

$$\underset{\text{ethylene}}{n\,CH_2 = CH_2} \longrightarrow \underset{\text{polyethylene}}{-(CH_6 - CH_2)-_n}$$

Polyethylene is used for making pipes, insulators, packing films, carry-bags, etc.

2) Polypropylene:

The monomer units are propylene molecules. It is generally manufactured by passing propylene through n-hexane (inert solvent) containing Ziegler-Natta catalyst (a mixture of triethyl aluminium and titaniumchloride)



$$\underset{\text{Propylene}}{n\,\overset{\overset{\large CH_3}{|}}{C}H = CH_2} \xrightarrow[TiCl_2]{Al\,(C_2H_5)_3} \underset{\text{Polypropylene}}{-(-\overset{\overset{\large CH_3}{|}}{C}H_2 - CH_2-)-_n}$$

Polypropylene is harder, stronger and lighter than polyethene. Polypropylene is used for packing of textile material and food, lining of bags, gramophone records, ropes, carpet fibres, etc.

3) Teflon or Poly tetrafluoroethylene (PTFE):

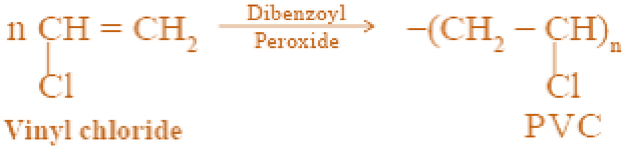
The monomer unit is teraflouroethylene molecule. Teflon is prepared by heating tetrafluoroethylene under pressure in the presence of ammonium peroxo sulphate. [$(NH_4)_2S_2O_8$].

$$\underset{\text{Tetrafluoroethylene}}{n\,CF_2 = CF_2} \xrightarrow[\text{Heat, pressure}]{(NH_4)_2S_2O_8} \underset{\text{Teflon}}{-(-CF_2 - CF_2-)-_n}$$

Teflon is a very tough material and is resistant towards heat, action of acids or bases. It is bad conductor of electricity. Teflon is used for coating utensils to make them non-sticking, making seals and gaskets which can with stand high pressures, insulation for high frequency electrical installations.

4) Polyvinylchloride (PVC):

The monomer units are vinyl chloride molecules. PVC is prepared by heating vinyl chloride in an inert solvent in the presence of dibenzoyl peroxide.

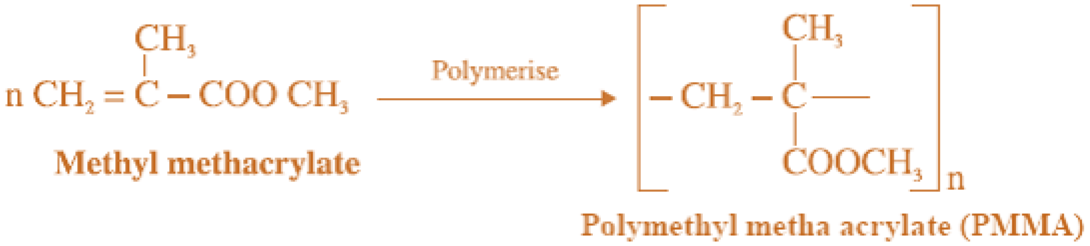


$$\underset{\text{Vinyl chloride}}{n\,\underset{\underset{\large Cl}{|}}{C}H = CH_2} \xrightarrow[\text{Peroxide}]{\text{Dibenzoyl}} \underset{\text{PVC}}{-(CH_2 - \underset{\underset{\large Cl}{|}}{C}H)_n}$$

PVC is a hard horny material. However, it can be made to acquire any degree of pliability by the addition of a plasticizer. It is resistant to chemicals as well as heat. It is used for making raincoats, handbags, toys, house pipes, gramophone records, electrical insulation and floor covering.

5) Polymethyl MethaAcrylate (PMMA):

Its monomer unit is methyl methacrylate



$$n\,CH_2=\overset{\overset{CH_3}{|}}{C}-COO\,CH_3 \xrightarrow{\text{Polymerise}} \left[-CH_2-\overset{\overset{CH_3}{|}}{\underset{\underset{COOCH_3}{|}}{C}}-\right]_n$$

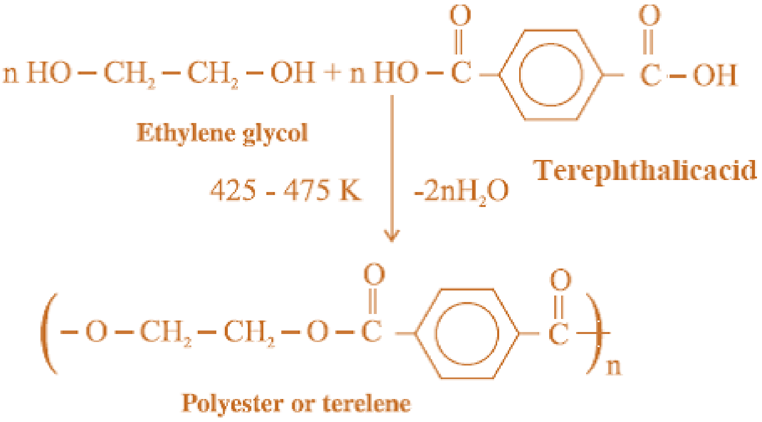
PMMA is a hard and transparent polymer and quite resistant to the effect of heat, light and ageing. It has high optical clarity. It is used in the manufacture of lenses, transparent domes and skylights, dentures, aircraft windows and protective coatings. Its commercial names are Lucite, Plexiglass, Acrylite and Perspex.

33.7 Polyster

Some synthetic polymers have ester group (R-COO-R) in them. These are condensation polymers. The important members of this class are polyster and glyptal resins.

Terelene:

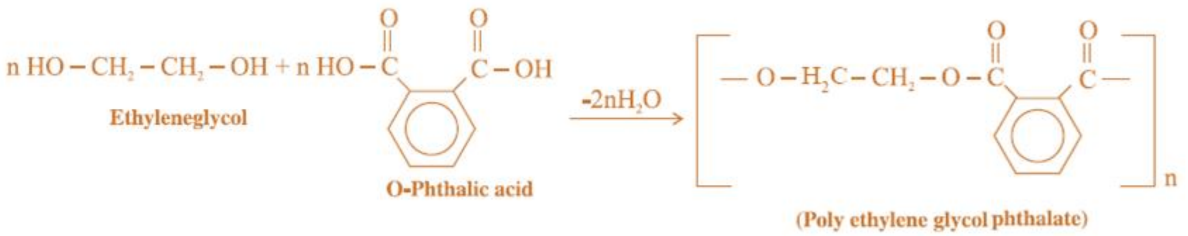
it is a polymer obtained by the condensation reaction between ethyleneglycol and terephthalic acid



Terelene is resistant to the action of most of the common chemicals and biological substances and also to abrasion. It has a low moisture absorbing power. As such it is widely used in making wash and wear fabrics. The polyester textile fibres made from the polymer are marketed under the trade name tereleneor dacron. It is also blended with cotton and wool in clothing. It is also used in seat belt and sails. The polymer is also used in the preparation of films. It is also used in the preparation of films, magnetic recording tapes and for packing food. Dacron (and Teflon) tubes are good substitutes for human blood vessels in heart bypass operation.

Glyptal or Alkyl resin:

Glyptal is a general name of all polymers obtained by condensation of di-basic acids, and polyhydroxy alcohols. The simplest glyptalis (poly etheleneglycol phthalate) which is obtained by a condensation reaction between ethylene glycol and ortho-phthalic acid.



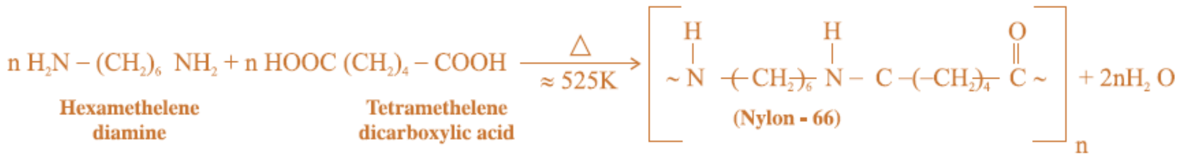
Glyptal resins are three dimensional cross-linked polymers. Poly (ethylene glycolphthalate) dissolves in suitable solvents and the solution on evaporation leaves a tough and non-flexible film. Thus, it is used in adherent paints and lacquers.

33.8 Polyamide

Poly amides are the polymers having amide group (R-CO-NH-) in them. the important poly amide is Nylon-66 which is a synthetic polymer. In nature also the polymer have amide linkages in their molecules.

Nylon-66:

It is a polymer of adipic acid (tetra methelene dicarboxylic acid) and hexamethelene diamine.



$$\underset{\text{Hexamethelene diamine}}{n\,H_2N-(CH_2)_6\;NH_2} + \underset{\text{Tetramethelene dicarboxylic acid}}{n\,HOOC\,(CH_2)_4-COOH} \xrightarrow[\approx 525K]{\Delta} \left[\sim \overset{H}{\overset{|}{N}} -\!\!\left(CH_2\right)_6\!\!- \overset{H}{\overset{|}{N}} - C -\!\!\left(CH_2\right)_4\!\!- \overset{O}{\overset{\|}{C}} \sim \right]_n + 2nH_2O$$

(Nylon - 66)

Nylon-66 (read as nylon-six-six) can be cast in to a sheet or fibres by spining devices. Nylon fibres have high tensile strength. They are tough and resistant to abrasion. They are also somewhat elastic in nature.

Nylon finds use in making bristles and brushes, carpets, and fabrics in textile industry, elastic hosiery in the form of crinkled nylon.

Molecular weight of polymers

The molecular mass of a polymer does not remain constant.

The molecular weight of a polymer is expressed in terms of average value. The molecular weight of polymer is expressed in terms of number – average molecular weight (Mn) and weight–average molecular weight (Mw).

Number–average molecular weight (Mn):

The ratio between total mass of the particles to the number of particles present in it is called the number-average molecular weight.

The number-average molecular weight depends on the number of molecules present in it.

Let the number of particles in a polymer with mass M1 each be N1 and mass M2 each be N2 and with mass Mi each be Ni.

Then the total mass of the polymer sample = $[N_1M_1 + N_2\,M_2 + ... + Ni\;Mi] = \sum_{n=1}^{\infty} NiMi$

Total no. of particles in the polymer are [$N_1 + N_2 + \ldots\ldots Ni$] = $\sum_{n=1}^{\infty} Ni$

Number average molecular weight (Mn) of the polymer = $\frac{\text{Total of the particles}}{\text{Number of particles}}$

$$= \frac{N_1M_1 + N_2M_2 + \ldots\ldots\ldots\ldots + N_1M_1}{N_1 + N_2 + \ldots\ldots\ldots\ldots\ldots + N_1)} = \frac{\sum_{n_1=1}^{\infty} N_iM_i}{\sum_{n_1=1}^{\infty} N_i}$$

The number–average molecular weight can be determined chemically by end-group analysis method or physically by the use of any colligative property.

Weight average molecular weight (Mw):

Molecular weight of each particle is multiplied by the contribution of the species to the total weight of the sample. The sum of the products of each species present in sample is known as weight–average molecular weight of the polymer.

Let the number of particles with mass M1 each be N1, Mass M2 each be N2 and with mass Mi each be Ni. Then

Total weight of all the particles in the polymer = $\sum_{ni=1}^{\infty} NiMi$

Weight of N1 particles with M1 Mass = N1M1

The fraction of the total mass = $\frac{N_1M_1}{\sum_{n=1}^{\infty} NiMi}$

Multiplying the molecular weight of the species (M1) with this fraction we get $(M_1)\left[\frac{N_1M_1}{\sum_{n=1}^{\infty} N_iM_i}\right]$

Similarly for other species it can be worked out sum of the products of molecular weight and the fraction of the total weight = $\frac{\sum_{ni=1}^{\infty}(N_iM_i^2)}{\sum_{ni=1}^{\infty}(N_iM_i)}$

The weight average molecular weight of the polymer $\overline{(Mw)} = \frac{\sum_{ni=1}^{\infty}(N_iM_i^2)}{\sum_{ni=1}^{\infty}(N_iM_i)}$

There are no units for molecular weights and Ni is merely a number.

The ratio of weight-average molecular weight (Mw) and the number-average molecular weight

(Mn) is called poly dispersity index (PDI).

Problem :

Calculate the average molecular mass of a polymer sample in which 20% molecules have a molecular mass of 20,000; 50% have 30,000 and the rest have 50,000.

$$(\overline{M_n}) = \frac{N_1M_1 + N_2M_2 + N_3M_3}{N_1 + N_2 + N_3}$$

$$= \frac{20x20,000 + 50x30,000 + 30x50,000}{20 + 50 + 30} = \frac{34x10^5}{100} = 34x10^3$$

$$= \frac{20x20,000 + 50x30,000 + 30x50,000}{20 + 50 + 30} = \frac{34x10^5}{100} = 34x10^3$$

$$= \frac{20x(20,000)^2 + 50x(30,000)^2 + 30x(50,000)^2}{20x20,000 + 50x30,000 + 30x50,000}$$

$$= \frac{8x10^9 + 45x10^9 + 75x10^9}{4x10^5 + 10x10^5 + 15x10^5} = \frac{128x10^9}{34x10^5} = 37,647.0$$

Intext Questions 33.4

1. What does PMMA represent?

....

2. Write the names of monomers of terylene?

....

3. How is nylon-66 synthesised?

....

4. Write questions for the synthesis of the following polymers:
    i) Glyptal ii) Teflon

....

5. When poly dispersity index(PDI) value of polymer is equal to one?

....

In this section we shall discuss about Biopolymers. (Natural Polymers)

33.9 Biopolymers

Many polymers which are present in plants and animals such as poly sacchrides(starch, cellulose), proteins and nucleic acids etc. which control various life processes in plants and animals are called biopolymers.

i) Starch:

It is polymer of glucose. It is a chief food reserve of plants.

ii) Cellulose:

It is also a polymer of glucose. It is a chief structural material of the plants. Both starch and cellulose are made by plants from glucose produces during photosynthesis.

iii) Proteins:

These are polymers of amino acids. They have generally 20 to 1000 amino acids joined together in a highly organized arrangement. These are building blocks of animals and constitute an essential part of our food.

iv) Nucleicacids:

These are polymers of various nucleotides. For example, RNA and DNA are common nucleotides. These bio polymers are very essential for our life.

33.10 Environmental Problems and Biodegradable Polymers

In this section we shall discuss those polymers which will not cause any environmental pollution. With the increasing use of polymers, the problem of disposal of waste of these products is posing alarming curse. Since most of the synthetic polymers are in the form of plastics, it is frequently used in abundance in the form of packing material and throw away bags. Since ordinary polymers do not degrade naturally by light, oxygen, water or micro organisms, there is a serious problem of their disposal. The environmental problems caused by careless use of non-biodegradable polymers can be reduced by proper disposal of these materials and reusing them and remoulding them for other uses. Another way is to collect them and depolymerize them back to monomers. Though it has a limited application.

Another option is to produce biodegradable polymers which can be broken in to small segments by enzyme-catalysed reactions. The required enzymes are produced by micro-organism. It is a known fact that the carbon-carbon bonds of chain growth polymers are inert to enzyme catalysed reactions, and hence they are non-biodegradable. To make such polymers biodegradable we have to insert certain bonds in the chains so that these can be easily broken by the enzymes. When such polymers are buried as waste, microorganisms present in the soil can degrade the polymer, so that they do not cause any serious effects on the environment.

One of the best methods of making a polymer biodegradable is by inserting hydrolysable ester group into the polymer.

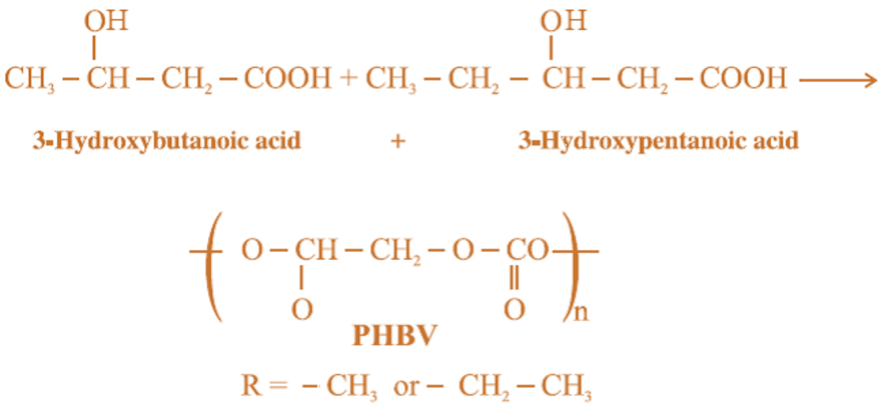
33.11 Some Biodegradable Polymers

A large number of bio degradable polymers are now available and more being added to the list. However, these are expensive, therefore, these find use in special situations where cost factor can be ignored. In future, as their cost reduces these will find greater use in daily life and will replace non-bio-degradable polymers.

Some important biodegradable polymers are PHBV, PGA, PLA and PCL.

(PHBV) Poly-Hydroxybutyrate-co-β-Hydroxyvalerte:

PHBV is a copolymer of 3-hydroxy butanoic acid, and (3-hydroxypentanoicacid), in which, the monomer units are connected by ester linkages.



$$CH_3-\underset{}{\overset{OH}{\overset{|}{C}H}}-CH_2-COOH + CH_3-CH_2-\overset{OH}{\overset{|}{C}H}-CH_2-COOH \longrightarrow$$

3-Hydroxybutanoic acid + 3-Hydroxypentanoic acid

$$\left(O-\underset{O}{\underset{|}{C}H}-CH_2-O-\underset{O}{\underset{\|}{C}O} \right)_n$$

PHBV

$$R = -CH_3 \text{ or } -CH_2-CH_3$$

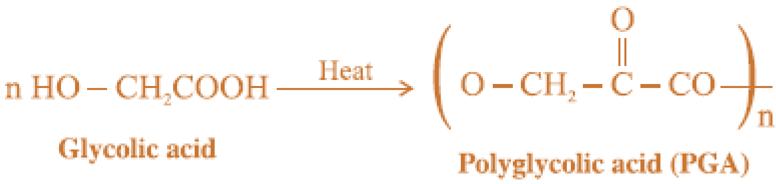
The properties of PHBV vary according to the ratio of both the acids. 3-Hydroxy butanoic acid provides stiffness and 3-hydroxypentanoic acid imparts flexibility to the copolymer.

i) PHBV is used in orthopaedic devices and

ii) In controlled drug release. The drug putin PHBV capsule is released after this polymer is degraded by enzymatic action. It can also be degraded by bacterial action.

PGA:

Polyglycolic acid is obtained by the chain polymerization of dimer of glycolic acid, $HO\text{-}CH_2COOH$.

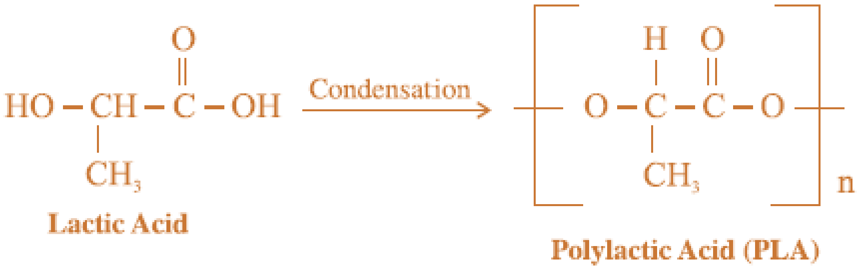


$$n\ HO-CH_2COOH \xrightarrow{Heat} \left(O-CH_2-\overset{O}{\overset{\|}{C}}-CO \right)_n$$

Glycolic acid **Polyglycolic acid (PGA)**

PLA:

Polyactic acid is obtained by polymerization of the dinner of lactic acid ($HO\text{-}CH(CH_3)\ COOH$) or by microbiological synthesis of lactic acid followed by the polycondensation and removal of water by evaporation.



$$HO-\underset{CH_3}{\underset{|}{C}H}-\overset{O}{\overset{\|}{C}}-OH \xrightarrow{Condensation} \left[O-\overset{H}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-\overset{O}{\overset{\|}{C}}-O \right]_n$$

Lactic Acid **Polylactic Acid (PLA)**

PCL:

Poly(E-caprolactone) is obtained by chain polymerization of the lactone of 6-hydroxy hexanoic acid.

$$\left(-O-(CH_2)_5-\overset{O}{\overset{\|}{C}}-O \right)_n \xrightarrow{Polymerisation} \text{PCL Poly (E-caprolactone)}$$

Most of the biodegradable polymers find use in stiching wounds and cuts.

1. In medical goods such as surgical sutures.
2. In agriculture materials such as films, seed coatings.
3. In food wrappers, personal hygiene products, etc.

Intext Questions 33.4

1. What is PHBV?

....

2. Give two examples of biopolymers?

....

3. Define biodegradable polymers? Give three examples?

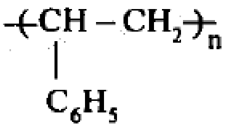
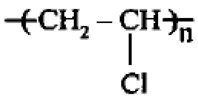
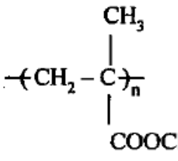
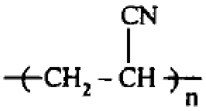
....

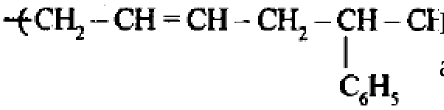
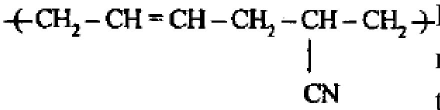
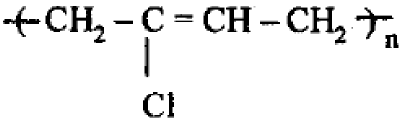
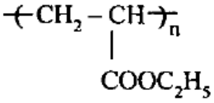
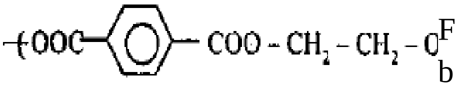
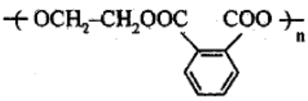
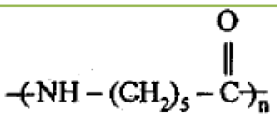
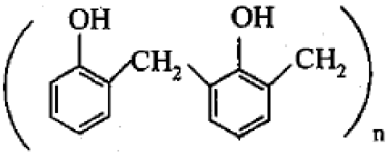
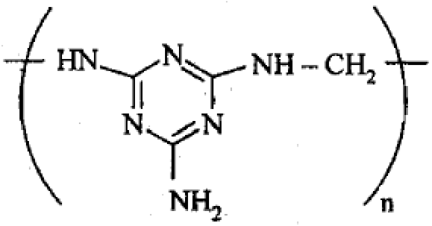
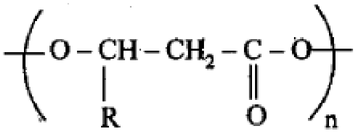
4. Which polymer is used for post-operative stitches?

....

In the following Table 33.4 we shall now give a brief account of the various commercially important polymers along with their structures and uses.

Table 33.4 important polymers along with their structures and uses.

S. No	Name of Polymer	Structure	Uses
1	Polythene	$-\!\left(CH_2 - CH_2\right)\!-_n$	As Insulator, anticorrosive, packing material, household and laboratory wares.
2	Polystyrene	 $-\!\left(\underset{C_6H_5}{\underset{\vert}{CH}} - CH_2\right)\!-_n$	As Insulator, wrapping material, manufacture of toys and household articles
3	Polyvinylchloride (PVC)	 $-\!\left(CH_2 - \underset{Cl}{\underset{\vert}{CH}}\right)\!-_n$	In manufacture of raincoats, hand bags, vinyl flooring and leather clothes
4	Polytetrafluoro ethylene (PTFE) or Teflon	$-\!\left(CF_2 - CF_2\right)\!-_n$	As lubrican t, insulator and making cooking wares.
5	Polymethyl metha acrylate (PMMA) or Flexi glass	 $-\!\left(CH_2 - \overset{CH_3}{\overset{\vert}{\underset{COOCH_3}{\underset{\vert}{C}}}}\right)\!-_n$	As substitute of glass and making decorative materials.
6	Polyacrylonitrile (Orlon)	 $-\!\left(CH_2 - \overset{CN}{\overset{\vert}{CH}}\right)\!-_n$	In making synthetic fibres and synthetic wool.

7	Styrene butadiene rubber (SBR or (BuNa-S)	 $-\!(CH_2-CH=CH-CH_2-\underset{C_6H_5}{\underset{\vert}{CH}}-C$	In making automobile tyres and footwear.
8	Nitrile rubber (BuNa-N)	 $-\!(CH_2-CH=CH-CH_2-\underset{CN}{\underset{\vert}{CH}}-CH_2-)\!-$	In making oil seals manufacture of hoses and tank linings.
9	Neoprene	 $-\!(CH_2-\underset{Cl}{\underset{\vert}{C}}=CH-CH_2-)\!-_n$	As insulator, making conveyor belts and printing rollers
10	Poly ethyl acrylate	 $-\!(CH_2-\underset{COOC_2H_5}{\underset{\vert}{CH}}-)\!-_n$	In making films, hose pipes and furnishing fabrics
11	Terylene (Dacron)		For making fibres, safety belts, tyre cords, tents, etc.
12	Glyptal		As binding material in preparation of mixed plastics and paints.
13	Nylon-6	 $-\!(NH-(CH_2)_5-\overset{\overset{O}{\Vert}}{C}-)\!-_n$	In making fibres, plastics, tyre cords and ropes.
14	Nylon-66	$-\!(NH-(CH_2)_6-NHCO\,(CH_2)_4\,CO-)$	In making brushes synthetic fibres, parachutes, ropes and carpets
15	Bakelite		For making gears, protective coating and electrical fittings.
16	Urea formaldehyde resin	$-\!(NH-CO-NH-CH_2-)\!-_n$	For making unbreakable cups and laminated sheets.
17	Melamine formaldehyde resin		For making plastic crockery un breakable cups and plates
18	Poly-β-hydroxy butyrate-co-β-hydroxy valerate (PHBV)	 $-\!\left(O-\underset{R}{\underset{\vert}{CH}}-CH_2-\underset{O}{\underset{\Vert}{C}}-O\right)\!-_n$ $R=CH_3,-C_2H_5$	As packaging, orthopaedic devices and in controlled durg release.

What You Have Learnt

- Polymers, the high molecular mass macro sized molecules consisting of repeating units of monomers of synthetic or natural origin.
- Synthetic polymers are classified with respect to their composition, mode of polymerization and nature of molecular forces.
- Polymerization is classified into two categories (i) addition polymerization (ii) condensation polymerization.
- Addition polymers are formed by addition of large number of monomers without the elimination of any smaller molecules.
- Condensation polymers are formed by elimination of smaller molecules such as H_2O, NH_3 etc.
- Natural rubber is a linear polymer of isoprene, and is vulcanized by heating with sulphur, which forms cross link between different chains.
- Vulcanized rubber has much improved physical properties.
- Synthetic rubbers are usually obtained by copolymerization of alkene and 1,3-butadiene derivatives.
- Synthetic polymers due to their inertness to degradation have created environmental problems
- Since biopolymers degrade enzymatically, synthetic biodegradable polymers having functional groups such as ester, amide etc. have potential use as sutures, implants, drug release materials, are developed as alternatives. For example, PHBV, PLA, etc. constitute such materials.

Terminal Exercise

1) Explain the difference between chain growth and step growth polymerization.
2) Define the terms thermosetting and thermo-plastics. Give one example of each.
3) What is a copolymer. Give one example.
4) Differentiate between addition polymer and condensation polymer with the help of one example each?
5) What are elastomers? Give the chemical equation for the preparation of Buna-S.
6) Write the information asked for the following polymers:
   i) Neoprene : Materials required for preparation
   ii) PVC : monomer units.
   iii) Synthetic rubber : monomer units
7) What is vulcanization of rubber? What are the advantages of vulcanized rubber?
8) Give examples of two plasticizers.
9) How are polymers classified into different categories on the basis of intermolecular forces? Give on example of a polymer of each of these categories.
10) What are biodegradable polymers? Give three examples.
11) Write the names and structures of monomers of the following polymers :

a)Polystyrene b)Teflon c)PMMA
d)PVC e)PHBV f)Polypropylene

12) How will you prepare the following? Give chemical reaction only:
a)PVC b)Nylon-66 c)PMMA

Answers to Intext Questions

33.1

1.

i) Polymer is a gaint chain like molecule obtained by inter-molecular combinations of similar or different types of smaller molecules.

ii) Monomers are the low molecular mass simple molecules capable of forming inter-molecular linkage to give gaint molecules called polymers.

2.

i) Polyethene ii) Terelene

3.

i) Hompolymers are polymers made of single monomer units, for example, polythene, polystyrene, or polybutadiene.

ii) A copolymer is one which is formed by the co-polymerisation of two monomers. For example, Buna (orSBR, styrene-butadiene rubber)

4.

i) Ethelene glycol and terephthallic acid ii)Hexa methelene diamine and adipicacid.

33.2

1.

i) Natural polymers are found in nature, (in animals and plants) e.g. proteins and nucleic acids.

ii) Synthetic polymers are man-made. e.g. Nylon, polyesters and rubbers.

2. The polymers in which the linear polymer chains are cross linked to form a three-dimensional network structure are called cross-linked polymers. The common example of this type of polymer is bake lite.

3. Thermoplastics differ from thermosetting plastics in terms of mode of linkage and intermolecular forces. Thermoplastic polymer can be moulded in desired shape but thermosetting polymers set to shape on heating and cannot be moulded.

4. Polyethene < Buna-S < Nylon-66

Nylon-66: Condnesation Polymer

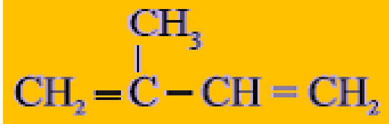
Buna-S:Addition Polymer

Polyethene : Addition polymer

33.3

1\.

i) Monomer of natural rubber

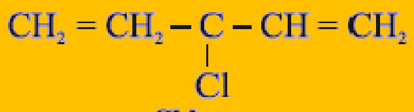


$$CH_2=\overset{\overset{\displaystyle CH_3}{|}}{C}-CH=CH_2$$

Isoprene

2-methylbuta-1,3-diene

ii) Monomer of Neoprene



$$CH_2=CH_2-\underset{\underset{\displaystyle Cl}{|}}{C}-CH=CH_2$$

Chloroprene

2-Chlorobuta - 1,3-diene

2\. Suplhur makes the rubber more elastic, more ductile, less plastic and non-sticky.

3\. Buna-S is obtained by co-polymerization of butadiene and styrene in presence of sodium metal. Bu stand for butadiene, na for sodium and s stand for styrene, It is also called S.B.R.

4\.

i) Natural rubber is soft and sticky, but vulcanised rubber is hard and non-sticky.

ii) Natural rubber has less tensile strength while vulcanised rubber has high tensile strength.

iii) Natural rubber is soluable in solvents like ether, carbontetra cloride, petrol etc. whereas vulcanised rubber is insoluble in all common solvents.

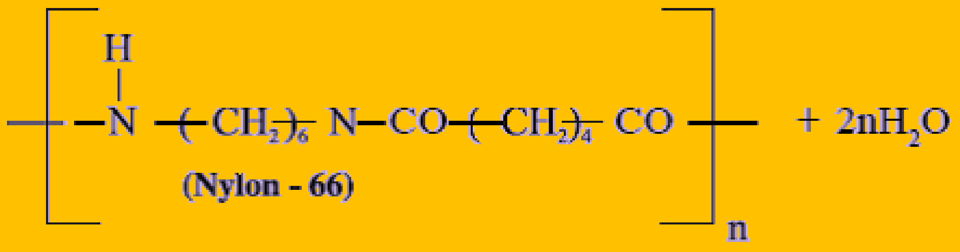
33.4

1\. Polymethylmethacrylate(PMMA)

2\. Ethelene glycol and terphthalic acid.

3\. Nylon-6, 6 is synthesised by the polymerisation of two monomer units adipicacid and hexamethelene diamine.

$$nH_2N\left(CH_2\right)_6NH_2 + n\ HOOC\left(CH_2\right)_4COOH \xrightarrow[525K]{\Delta}$$

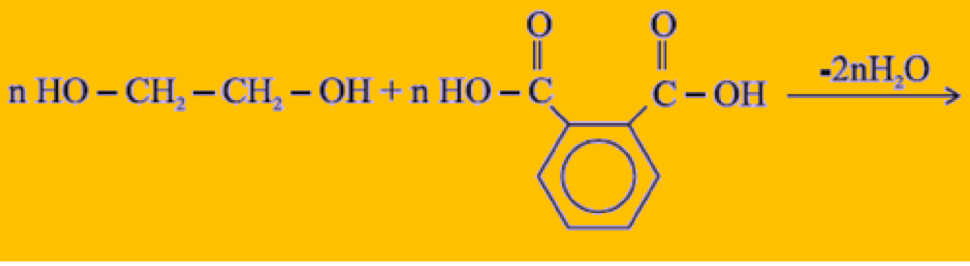


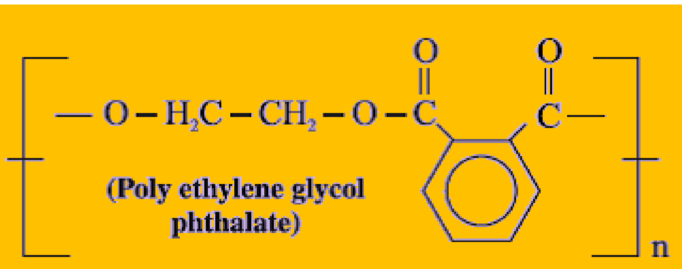
$$\left[-\overset{\overset{\displaystyle H}{|}}{N}-\left(CH_2\right)_6-N-CO-\left(CH_2\right)_4-CO-\right]_n + 2nH_2O$$

(Nylon - 66)

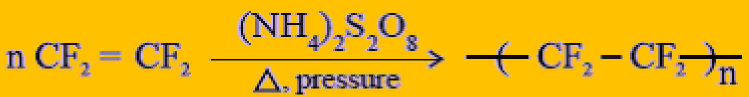
4\.

i) Glyptal





ii) Teflon



$$n\,CF_2 = CF_2 \xrightarrow[\Delta,\ \text{pressure}]{(NH_4)_2S_2O_8} -\!\!\left(CF_2 - CF_2 \right)\!\!-_n$$

5. The PDI Value of a polymer is one. When it built by one type of monomer

$$\textbf{PDI} = \;=\frac{\overline{M}_w}{\overline{M}_N}=\frac{\dfrac{N_1M_1}{N_1}}{\dfrac{N_1M_2{}^2}{N_1M^1}}=1$$

33.5

1. PHBV is copolymer of 3-Hydroxy butanoic acid and 3-hydroxypentanoic acid. It is used in marking capsules. It is biodegradable in nature.
2. Nucleic Acids, proteins.
3. Polymers, which are degraded by microorganisations are called biodegradable polymers. For example, PHBV, Polyglycolic acid, Polylactic acid, etc.
4. Polyglycolic acid (PGA) and poly Lactic Acid (PLA).

Chapter 34

DYES, PAINTS AND PIGMENTS

In this lesson we shall take-up another broad area of chemical industry viz; dyes, paints and pigments. These are organic or inorganic substances which find applications in imparting color fabrics, leather, buildings, furniture and other objects. Psychologists attach special significance to the choice of colours by a person and to his/her state of mind.

Objectives

After reading this lesson you will be able to:

- define dyes, paints and pigments;
- write formula or composition of dyes, paints and pigments;
- explain the process of dyeing and classify various dyes;
- differentiate among dyes, paints and pigments;
- classify paints and pigments;
- list various examples of dyes: Indigo, methylorange, aniline yellow, alizarin and malachite green and etc. and
- list uses of various dyes, paints and pigments

34.1 Dyes

In the early times the colouring materials were extracted from natural sources like plants and insects. Now a day’s thousand of such substances are synthesised in factories on a large scale.

Dyes are the organic compounds that are used to impart colour to textiles, foodstuffs, silk, wool and other objects. Dyes are capable of getting fixed to the fabrics/objects permanently and are resistant to the action of water, soap, light, acid, and alkalies.

Every colored compound cannot be used as dye. A good dye must have most of the following properties.

1) It must have a suitable colour.
2) It must be able to fix itself or capable of being fixed to the fabric from the solution.
3) When fixed, it must be fast resistant to the action of light, water, soap, detergents, etc. during washing or to the organic solvents during dry cleaning.

34.1.1 Why do dyes or dyed articles appear to have a characteristic colour?

If a molecule absorb slight in the visible region (400 nm to 730 nm) corresponding to green colour, then it will appear violet, which is the complementary colour of green. Similarly, if a dye absorbs blue colour, it will appear yellow which is the complementary colour of blue. Thus, the dyes impart colour to fabric by aborbing the complementary colour.

34.1.2 Constitution of Dyes

The colour of a compound is due to the presence of certain groups containing multiple bonds. These groups which impart colour to a compound are called chromophores. Some examples of chromophoresare:

$-NO_2$ (nitro), -N=O (nitroso), -N=N- (azo), quinonoid structures, etc.

At the same time, there are certain groups which they are not chromophores themselves but they deepen the colour when present with colouredcompounds. The groups which deepen the colour of a coloured compound are called auxochromes. Some examples of common auxochromes are:

$-OH_2$, $-NH_2$, -NHR, $-NR_2$, -Cl, -COOH, etc.

34.1.3 Classification of Dyes

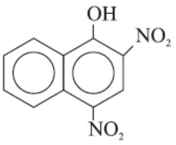
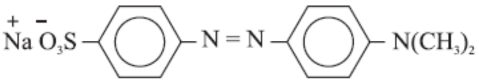
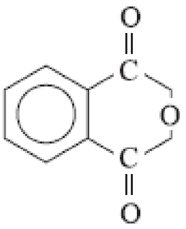
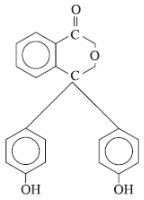
A large number of dyes are used for various purposes. These are classified on the basis of their

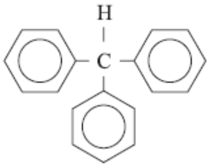
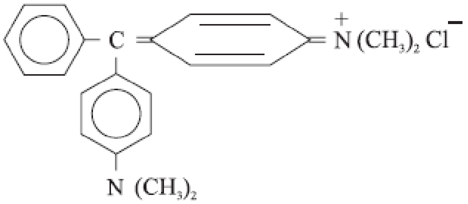
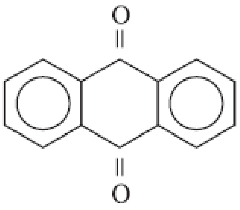
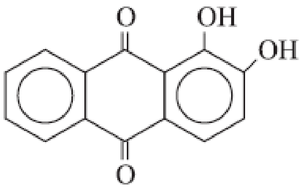
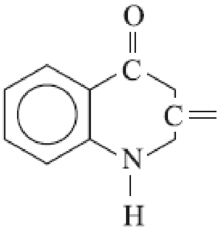
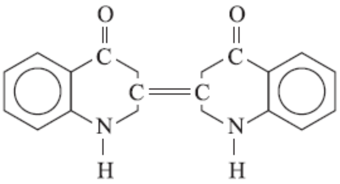
i) constitution **ii) application**

i) Classification based on constitution:

Depending upon the characteristic structural units, the dyes, are classified as given in Table34.1:

Table: 34.1: Classification of some dyes on the basis of their constitution

Dye type	Characteristic structural unit	Typical examples
1) Nitro dyes	$-NO_2$	 **Maritus Yellow** **(2,4-dinitro-1-naphthol)**
2) Azo dyes	$-N=N-$	 Methyl orange
3) Phthalein dyes		 Phenolphthalein

4) Triphenyl methane		 Malachite green
5) Anthraquinone		 Alizarine (ruby red)
6) Indigoid		 **Indigo**

Intext Questions 34.1

1) Which is the structural unit of Methyl orange?

....

2) What is the wavelength range of visible region of spectrum?

....

3) What are complementary colours?

....

4) How is the sturcture of dye related to its colour?

....

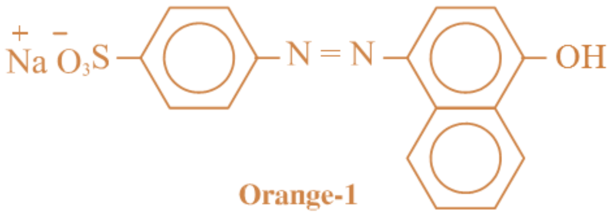
ii) Classification of Dyes on the basis of their applications.

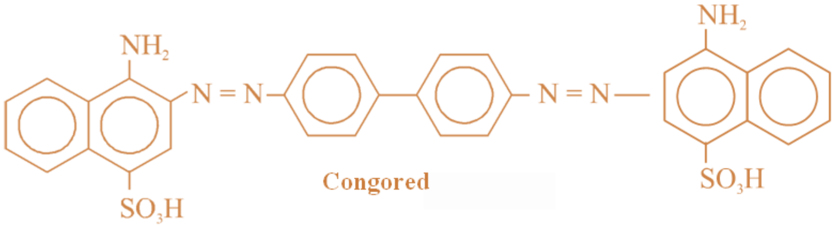
Dyes are classified into the following types on the basis of their application.

i) Acid dyes
ii) Basic dyes
iii) Direct dyes
iv) Disperse dyes
v) Fiber reactive dyes
vi) Vat dyes
vii) Insoluble azo dyes
viii) Mordant dyes

i) Acid Dyes

These are azo dyes used in the form of their sodium salt of sulphonic acid $(-SO_3H)_3$ carboxylic acid (-COOH) or phenol. The dye can be applied to wool, silk and nylon. These do not have much affinity for cotton and therefore, cannot be used to dye OH. The common examples of an acid dye are orange-I and congo red.


Orange-1


Congored

ii) Basic Dyes

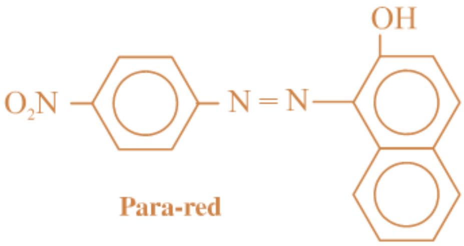
These dyes contain basic groups like (-NH$_2$) group of (-NR$_2$) group therefore these are called basic dyes. These dyes attack the anionic sites present on the fabrics and get attached to them. These are used to dye modified nylons, polyester, wool, cotton, leather, paper, etc. Aniline yellow, malachite green and crystal violet are the basic dyes.

iii) Direct Dyes

As the name suggest these dyes can be directly applied to the fabrics from their aqueous solution. The direct dyes attach to the fibre by means of hydrogen bonding. These are very effective for dying cotton, wool and rayon. Martius yellow (Table 34.1) and congo red are the common examples of direct dyes.

vi) Azo dyes or Ingrain dyes

These dyes are very important because over 60% of the dyes used are azo dyes or ingrain dyes. The fabric to be dyed is soaked in an alkaline solution of phenol or naphthol and is then treated with a solution of diazotized amine. These are used for cotton, silk, polyester and nylon. The colour is not very fast because the interaction is only on the surface. For example, para- redisanin grain dye.


Para-red

v) Disperse Dyes

These dyes are usually applied in the form of a dispersion of finely divided dye. The dyes are dispersed in a soap solution in the presence of phenol, cresol to benzoic acid. These are used for nylon, polyster and polyacrylonitrile. Some common examples of disperse dyes are cell it on fast pink Band cell it on fast blueB

(vi) Reactive dyes

These dyes attach to the fibre themselves by irreversible chemical reactions. These dyes induce fast colour on the fibres which is retained for a longer time. These dyes are used to dye fibres like cotton, wool or silk. Dyes which are derivatives of 2,4 dichloro - 1,3,5 - triazine are important examples of fibre reactive dyes.

(vii)Vat dyes

Vat dyes are the well-known dyes they are insoluble in water and hence cannot be used directly for dying. Therefore, they are reduced to a colourless soluble form (leuco) in large wooden vats with are ducing agent such as an alkaline solution of sodium hydrogen sulphite. Under these conditions, the leuco form develops affinity for the cellulose fibre. Then the fabric is exposed to air which oxidises the leuco (colourless) form to coloured form. Therefore, these dyes are mainly used to dye cotton fibres. Indigo is an important example of this type F (Table34.1).

(viii) Mordant Dyes

These dyes require an additional substance (generally a metal ion) for fixing to the fibre. These are used mainly for dyeing wool. The method involves the precipitation of certain mordant material (binding agent)on the fabrics which then combines with the dye to form an insoluble coloured complex called lake. For acid dyes, metal ions are used as mordants but for basic dyes, tannic acid is used as them or dant.

For example, alizarin is a mordant dye (Table34.1).

It gives a rose red colour with Al^{3+} and a blue colour with Ba^{2+}, a brownish red colour with chromium (Cr^{3+}) and a black voilet with iron mordant.

Intext Questions 34.2

1. How are mordant dyes applied to fabrics?

....

2. Give an example of a Vat dye.

....

3. Distinguish between acidic and basic dyes?

....

4. Why do azodyes not impart fast colours to fabrics?

....

Now we shall discuss about pigments.

34.2 Pigments

Pigments are various organic and inorganic insoluble substances, which are widely used as surface coatings. They are also employed in the ink, plastic, rubber, ceramic, paper and linoleum industries to impart colour. The pigment industry is usually regarded as associated with paints, but in fact it is a separate industry. A large number of pigments are mined or manufactured for the commercial preparation of paints. About 45 year back, white lead [$2Pb\ CO_3 + Pb\ (OH)_2$], Zincoxide (ZnO) and lithopone ($ZnS + BaSO_4$) were the principal white pigments in use while the colou red pigments consisted of Prussian blue, lead chromates, various iron oxides and a few lake colours. Composition, properties and uses of various Pigments will be discussed in the next section.

34.2.1ClassificationofPigments

Pigments are broadly classified into two types:

1.White Pigments **2.Coloured Pigments**

White pigments are of various types. Their composition, properties and applications are summerised in Table 34.2:

Table 34.2: Composition, properties and uses of some white pigments

S. No.	Name of pigment	Composition	Characteristic	Application or Uses
1	White lead $2PbCO_3.Pb(OH)_2$	$PbCO_3$ =68.9% $Pb(OH)_2$ =31.1%	1.Easily applied 2.high covering power 3.Toxic in nature 4.Yellow badly on exposure to atmosphere 5.Soluble in alkali and paints	In manufacture of paints.
2	Sublimed white Lead (Basic sulphate)	$PbSO_4$ =75% PbO = 20% ZnO = 5%	1.High specific gravity and refractive index. 2. Slow chalking out of the film producing a rouch surface.	In manufacture of paints
3	Zinceoxide (ZnO)	ZnO = 100%	1.Brilliantly white having excellent texture 2.Causes no discoloration even in contact with CO_2 gas. 3.More durable in Combination with white lead	1.It is opaque to UV light and thus protects from uv 2.Chalkingcan be prevented.
4	Lithopone ($ZnS+BaSO_4$)	ZnS=28-30% BaSO4 =72-70%	1. Extremely fine and cheap pigment. 2. Good hiding power 3. Not as durable as white lead and zinc oxide	1.Widely used for cold water paints. 2.Traffic paints. 3.In floor covering and oil cloth industry
5	Titanium dioxide $(TiO)_2$	TiFeO3 and TiO2 Iliminite + rutile	1.High opacity and hiding power 2.High Oil absorbing capacity 3.Spreading power is almost double than that of white lead. 4.No tendency of chalking	1. In paints 2. In Paper and textiles. 3. In other industries.

Blue Pigments

The most widely used blue pigment is ultramarine blue. There are three varieties of ultramarine namely blue, white and green. The comparative study of blue pigments is given in Table 34.3:

Table34.3: Composition, Properties and uses of some blue pigments

S. No.	Name of Pigment	Composition	Characteristic Properties	Application/ Uses
1	Ultra marine Blue	White - $Na_5Al_3Si_3SO_{12}$ Green-$Na_5Al_3Si_3S_2O_{12}$ Blue- $Na_5Al_3Si_2S_3O_{12}$	1.Silicate skeleton have a potential influence on the colour. 2.Colour in due to the fact that is present in the form of poly sulphide	1. Bluring in laundering to neutralize the yellowish tone in cotton and linen fabrics.
2	Cobalt Blues	Co_3O_4 - 30 – 35 % Al_2O_3 - 65-70 %	1. Very expensive and are not used in paints for ordinary purposes	1. In manufacture of blue paints 2. In making inks 3. In marking carbon papers and carbon ribbons

Red Pigments

Red pigments are one of the oldest-pigments. These are primarily used for inhibiting rusting of iron and steel structures. Different types of red pigments are summerised in Table 34.4

Table 34.4: Composition, properties and uses of Red Pigments

S. No.	Name of Pigment	Composition	Characteristic Properties	Application/ Uses
1.	Red Lead (Pb_3O_4)	$Pb_3O_4 + PbO$	1. Bright-red powder with high specific gravity 2.Excellent covering power. 3.Inhibitscorrosion	1. For primary coat on structural steel. 2.Inimparting red colour to the glass for making bangles.
2.	Synthetic Iron	Fe_3O_4	1.Has dark brilliant colour 2.High covering power and tinting strength	1. Widely used in domestic paints, enamels, floors and paints.

Green Pigments

There are of two types of commonly used green pigments. Their properties, composition and uses are given in Table 34.5:

Table 34.5: Composition, properties and uses of Some Green Pigments

S. No.	Name of Pigment	Composition	Properties	Application/ Uses
1.	Chrome Green	Cr_2O_3	1. High Power of oil absorption 2. It has disadvantages such as lack of brilliancy and opacity	As green pigments
2.	Chromium oxide or Guignet's Green	$[Cr_2O(OH)_4]$	1.have high covering power 2. High corrosion inhibition capacity	1. As Paint for metal surface. 2. As fast non-fading green for washable distempers

Black Pigments

Black pigments have good tinting strength as well as high hiding power. The common varieties are discussed in Table 34.6:

Table 34.6: Some Black Pigments

S. No.	Name of Pigment	Composition	Properties	Application/ Uses
1.	Natural Black Oxide	Fe_2O_3 - 94-50%	Oil absorption power is 10 - 15 kg of linseed oil per 100 kg of pigment.	In making paints for priming metal
2.	Precipitated Black Iron Oxide		High hiding Power	In cement emulsions and water paints
3.	Carbon Black/ Furnace Black		1. Increases life of paints 2. Good tinting strength. 3.Not affected by light acids and alkalies.	Used in making water proof paints.
4.	Lamps Black		1.Good tinting strength 2.Resistant to high temperature	In making black pigments

Yellow Pigments

The common yellow pigments are summerised in Table 34.7:

Table 34.7: Some Black Pigments

S. No.	Name of Pigment	Composition	Properties	Application/ Uses
1.	Ochre	Naturally occurring yellow Fe_2O_3	Fast to light and inert to chemical action	In paint industry
2.	Chrome yellow		1.Great opacity 2.High brilliance 3.High hiding power 4.High tinting strength	In making yellow paints

Toners

Insoluble organic dyes are known as toners and can be used as pigments. They are quite durable and can have high colouring power. For example, para red, Hansa Yellow G (lemon yellow), Hansa yellow 10G (Primrose yellow), toluidine toner, etc. are the various dyes that have been used as toners in pigment industry.

Metallic Powders as Pigments

The powdered form of some metals as well as some alloys are used as pigments. For example, finely powdered aluminium and bronze have been used as pigments in lacquers. Pigments containing finely powdered zinc have been used for protective coatings on iron and steel to protect them from atmospheric corrosion.

Intext Questions 34.3

1) List the green pigments, their composition and uses.

……………………………………………………………………………………………………

2) Write names of some blue pigments.

……………………………………………………………………………………………………

3) Which pigment is used to inhibit corrosion of iron and steel objects?

……………………………………………………………………………………………………

4) Write the composition of white lead.

……………………………………………………………………………………………………

5) Which property of zinc oxide protects the vehicles?

……………………………………………………………………………………………………

34.3 What are Paints?

Paints are table mechanical mixtures of one or more pigments. The main function of the pigments is to impart the desired colour and to protect the paint film from penetrating radiation, such as U.V. rays. The pigments and the extenders are suspended in drying oils called vehicle. The vehicle or drying oil is a film forming material, to which other ingredients are added in varying amounts. The paint is applied on a metal or wood surface to give it a protective coating. Driers promote the process of film formation and hardening. Thinners maintain the uniformity of the film by reducing viscosity of the blend.

The important varieties of paints are emulsion paints, latex paints, metallic paints, epoxide resin paints, oil paints, water paints or distempers, etc.

34.3.1 Constituents of Paints

The main constituents of paints are pigments, oil (vehicle) and some of the materials to impart various desirable properties.

1) Pigments

Pigments are the organic or inorganic insoluble substances which are widely used in surface coatings. They protect the film by reflecting the destructive ultraviolet light, to strengthen the film.

The important pigments used for making paints are:

i) **White** : White lead, Titaniumdioxide, Zincoxide
ii) **Red** : Redlead, Ironoxides, Cadmiumreds
iii) **Blue** : Cobaltblue, Ironblues, etc.
iv) **Green** : Chromiumoxide, chrome green
v) **Black** : Carbon black, Lampblack, Furnace black, etc.
vi) **Metallics** : Copper power, Zinc dust, Aluminium, etc.
vii) **Metal Protective pigments** : Red lead, blue lead, zinc and basic lead, etc.

2) Extenders or fillers

The extenders or fillers are the low cost materials. These are added to the paints in order to decrease the cost of the paint. These supplement the pigment in increasing the covering and weathering power of the film. Talc, china clay, gypsum, silica, barite, glass flakes, asbestos and anhydrite, etc. are used as fillers in paints.

3) Film forming materials

The vehicle or film forming materials serve dual purpose in the surface coating formulations. These are usually called drying and semi-drying oils, depending on the degree of unsaturation. Linseed oil, soya bean oil, tung oil, castor oil, varnishes, casein, fish oil, etc. are used as vehicles or drying oils.

4) Driers

Certain driers (which are oxygen carriers) have also been used in the paints, in order to accelerate the drying of the film through oxidation and polymerization. Earlier, PbO was used as a drier, but the Modern driers are Co, Mn, Pb, Zn, resinoleate, linoleate and naphthenates, etc.

5) Thinners or Diluents

Another ingredient, of paint is thinner. It is added to the paints to dissolve film forming materials and to dilute concentrated paints for better handling. After adding thinner, the paitns maybe applied more easily on the surface by brushing, spraying or dipping.

Mineral spirits and solvents namely turpentine, maintains the fluidity of the freshly applied film for reasonable period of time.

6) Anti-skinning Agent

Certain anti-skinning agents are also added to the paints in order to prevent gelling and skinning of the finished product before application of the paints by brushing, spraying or dipping. Polyhydroxy phenols are usually employed as anti-skinning agents.

7) Plasticizers

Plasticizers are added to the paints to provide elasticity to the film and thus prevent cracking of the paint. Chemically, plasticizers are mostly esters. Triphenyl Phosphate, dibutylphthalate and castoroil etc. are used as Plasticizers.

8) Resins:

Varnishes are used as natural or synthetic resins. Examples of natural resins are copal or resin, while that of synthetic resins are Urea formaldehyde, acrylate, vinyl or silicone resins.

9) Binders

Binders act to fix the paint on the coated surface and provide tough, tenacious and glossy film on the painted surface.

10) Other Compounds

Water based paints also require dispersing agents (*e.g.* Casein), antifoam agents, (*e.g.* pine oil) and preservative (*e.g.* chlorophenol).

34.3.2 Paint Removers

The substances or materials which are used to remove various surface coatings or paints are called paint removers. Paint removers are either flammable or non-flammable.

Flammable paint removers may be liquid removers, semi paste remover and paste removers. The common solvents used for the purpose are alcohols such as methanol, ethanol or propanol. Hydrocarbons (benzene, toluene or xylene), acetone and ethyl acetate are also used as paint removers.

34.3.3 Special Applications of Paints

In addition to provide a thin protective layer, paints are also used for other applications some of the special uses are discussed below:

a) Paints are extensively used as acid resisting coats.
b) Oil bound water paints or distempers are widely used for interior decoration of walls.
c) Coal tar products dissolved in mineral spirits have been used as protective coating soft pipes under the name bituminous paints.
d) Bottom of ships are protected by antifouling paints which are prepared by mixing iron oxide, mercuric oxide and copper resinate dispersed in tung oil.
e) A paint with damp resisting properties is prepared by mixing paraffin wax, rosin, bitumen and guttaparcha disperse dintung oil.

Intext Questions 34.4

1. Which constituent of paint is used to decrease the cost of the paint?

....

2. List antifouling agents used to prepare marine paints?

………

3. Write three properties of emulsion paints.

………

4. How can we apply paints on the surfaces?

………

What You Have Learnt

- Dyes are coloured compounds used in imparting colour to the textiles, food stuffs, slik, wool and other objects.
- A dye is a coloured organic compound which can absorb light in the visible region of the electromagnetic spectrum (400 nm to700 nm). The part of the light which is reflected back gives the colour of the dye i.e. complementary to the colour absorbed.
- Dyes are classified on the basis of their structures and on the method of applications.
- Pigments are various organic and inorganic insoluble substances, which are widely used in surface coatings.
- Titanium dioxide is one of the most important white pigments. Carbon black, graphite and lamp back are the chief black pigments, chromium oxide (Cr_2O_3) and Guignet's green are green pigments, Chrome yellow, strontium chromate and barium chromate are yellow pigments.
- Insoluble organic dyes are known as toners and can be used as pigments. They are quite durable and have high colouring power.
- Some powdered form of metals as well as alloys have also been used as pigments.
- Finely powdered zinc has been used for protective coating on iron and steel.
- Paints are stable mechanical mixtures of one or more pigments, extenders fillers, driers, thinners or diluents, lacquers, plasticizers, resins and binders.
- A good quality paint should have good colour, high hiding power and also have proper pigment volume concentration range (PVC). For exterior house paint the PVC range shouldbe28-36%.
- Varnishes differ from paints in that they have no pigments and in varnishes apart or whole of the oil is substituted by resin.

Terminal Exercise

1. Give structure and name of a direct dye.
2. Classify dyes on the basis of their structural units.
3. Give a scheme or preparation of phenolphthalein. How does it behave under

(a)acidic (b)alkaline conditions?

4. What are mordant dyes? What type of binding forces exist between the dye and the mordant?

5. Write preparation, properties and uses of the following pigments.
   i) Zincoxdie ii)Lithopone

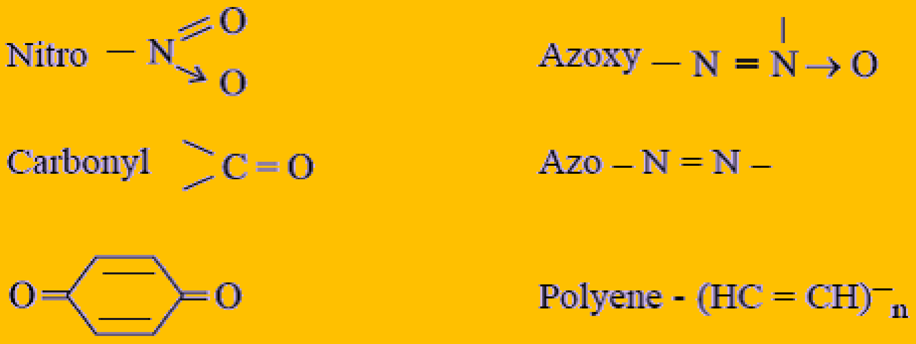
6. Describe various components of paints and their significance.

7. List requirements of good paints.

Answers to Intext Questions

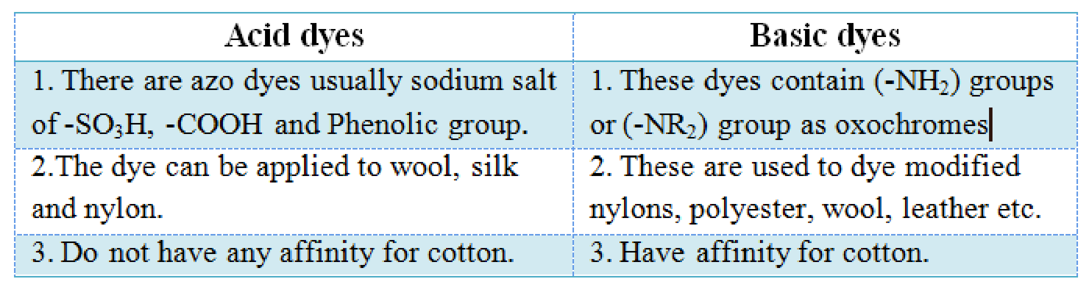
34.1

1. - N=N - group
2. The range of visible region of spectrum is [400 nm to 750 nm]
3. A dye is an organic compound which can absorb light in the visible region of the electromagnetic spectrum (400 nm to 750 nm). The part of the light which is reflected back gives the colour of the dye i.e. complementary to the colour absorbed.
4. The structure of a dye is related to its colour due to the presence of certain unsaturated groups (the groups with multiple bonds)



34.2

1. Mordant dyes are used mainly for dyeing of wool. The method involves the precipitation of certian substances (mordant material) on the fabrics which then combine with the dye to from an insoluble coloured compled called lake depending on the kind of mordant used (material designed to bind dye).
2. Indigo
3. Difference between Acid dyes and Basic dyes



Acid dyes	Basic dyes
1. There are azo dyes usually sodium salt of -SO_3H, -COOH and Phenolic group.	1. These dyes contain (-NH_2) groups or (-NR_2) group as oxochromes
2.The dye can be applied to wool, silk and nylon.	2. These are used to dye modified nylons, polyester, wool, leather etc.
3. Do not have any affinity for cotton.	3. Have affinity for cotton.

4. Because the interaction is only on the surface. The colour goes out on washing.

34.3

1. Green pigments are: a) Chrome green b) Chromium oxide

a) Chrome green – It is chromium oxide (Cr_2O_3) and has high power of oil absorption. It is used as green pigment, known as Chrome green.

b) Chromium oxide – It is also called as Guignet's Green. It is a hydrated chromium oxide [$Cr_2O(OH)_4$]. It is used as paint for metal surfaces and as a fast non-fading green for washable distempers.

2.

i) Ultramarine Blue ii) Cobalt Blue and IronBlue

3. Red Lead

4. Lead carbonate, 60.2 - 68.9% and lead oxide, 31 - 39.9%

5. It is opaque to white light.

34.4

1. Extenders or fillers.

2. Zincoxide, resin (Shellac), driers (Mnlineolate), vehicle (Coal-tar), diluent (pine-oil)

3.

i) Highly durable ii) Impermeable to dirt iii) resistant to washing

4.

i) Hand-painting or brushing ii) Spraying iii) dipping
iv) Roller coating v) Tumbling

Chapter 35

DRUGS AND MEDICINES

In an attempt to conquer pain and disease, a large number of synthetic chemicals have been discovered. The chemicals used as medicines are known as pharmaceuticals. Today pharmaceutical industry has grown to be one of the biggest industries in the world.

In this lesson we will try to introduce you to the area of drugs and medicines. In the process we would attempt to differentiate between drugs and medicines (though commonly used interchangeably). You will also learn about classification of medicines and other important aspects of drugs and medicines.

Objectives

After reading this lesson you will be able to:

- define drugs and medicines;
- differentiate between drugs and medicines;
- classify medicines on the basis of their action (use);
- cite examples and effects of analgesics, antipyretic, antiseptics, disinfectants, antacids, anti-malarials, anaesthetics, antimicrobials (sulphadrugs and antibiotics), anti-fertility drugs, etc.
- differentiate between analgesics and antipyretics;
- differentiate between antiseptics and disinfectants;
- explain habit forming and non-habit forming durgs;
- differentiate between broad spectrum and narrow spectrum antibiotic;
- differentiate between local and general anaesthetics;
- describe self-medication and
- alternate systems of medicine.

35.1 What are Drugs and Medicines?

When we fall ill we take some tablets, pills, injections or apply some ointments to get well. All these are collectively known as medicines. Sometime we may use some parts of plants or some preparations made from herbs, minerals, animals, etc. All these substances used for the treatment or prevention of diseases, can also be called medicines. Medicines contain a single chemical or a number of chemicals in different amounts to have the desired effect.

The mode of action of the chemicals of medicine is quite varied and complicated. In many a cases mode of action may not be fully known to us, but we continue to use them as they are useful to us.

Early man used several plants or parts of plants to cure diseases, without knowing of the chemical components, responsible for it. For example bark of willow tree was used for relieving pain (asanalgesic). Later, it was found that its bark contained 2-hydroxybenzoic acid, which is closely related to acetyl salicylic acid (also known as aspirin). Parts of a plant Rauwolfia serpentina (Hindi name, sarpagandha) have been used in Ayurvedic drugs for the treatment of hypertension (high blood pressure). Later on it was discovered that a compound called reserpine was responsible for reducing blood pressure. Thus reserpine became the first modern medicine to control blood pressure.

In most of the cases nature led to the discovery of modern medicine. Thousands of chemists all over the world are constantly searching for better, efficient, cheaper and safer medicines.

As mentioned earlier the term drugs and medicines are used interchangeably, but there is a difference between the two. Further, the effects of the chemical compounds present in a medicine and their side effects have been properly and extensively studied. The medicines are approved by the relevant governmental authorities like Drug Controller of India.

The term drug is also used for substances, which are habit forming and are often abused, for example, narcotics like cocaine, morphine, heroine, marijuana, etc.

Intext Questions 35.1

1. Write a definition of medicines.

....

2. Most of the chemicals used in medicines are poisonous. Is this statement true or false?

....

3. What are pharmaceuticals?

....

4. Name the compound which is present in the plants arpagandha and is responsible for reducing blood pressure.

....

35.2 Classification of Medicines

You may be familiar with some of the common medicines used for relieving pain, reducing fever or for treating common cold, etc. The number of medicines is very large therefore medicines are classified according to their action or use. Table 35.1 provides a list of some important classes of medicines. The terms like analgesics, antibiotics, antiseptics, etc. are common household words. Let us try to understand the meaning of this classification in a little more details.

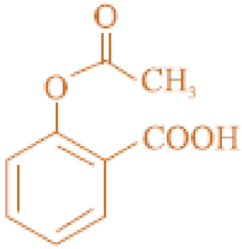
Table 35.1: Some Important Classes of Medicines and their Action

S. No.	Class	Action or Usage
1.	Antipyretics	Reduce body temperature
2.	Analgesics	Reduce pain
3.	Antimalarials	Used for treatment of malaria
4.	Germicides	Kill germs
5.	Antiseptics	Kill germs (can be safely used on living tissue)
6.	Disinfectant	Kill germs (cannot be used on living tissue)
7.	Antacids	Reduce acidity in stomach
8.	Anaesthetics	Loss of sensation
9.	Antimicrobials, Salpha durgs and Antibiotics	Kill microorganisms
10.	Tranquilizers and hypnotics	Reduce anxiety and bring calmness
11.	Birth Control Medicines (Contraceptives)	Birth control

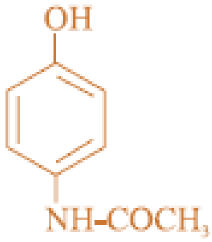
1. Antipyretics

Antipyretics are the substances which are used to reduce body temperature or to control fever. The word antipyretic is derived from pyro which means fire (means hot) anti means against. Thus antipyretic means it counter acts heat (high body temperature).

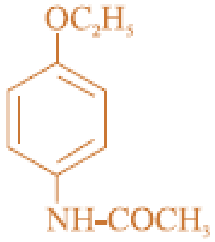
Aspirin, paracetamol and phenacetin ate commonly used antipyretics. You get them in the marked with different trade names like crocin, anacin, disprin, etc.



Aspirin



Paracetamol



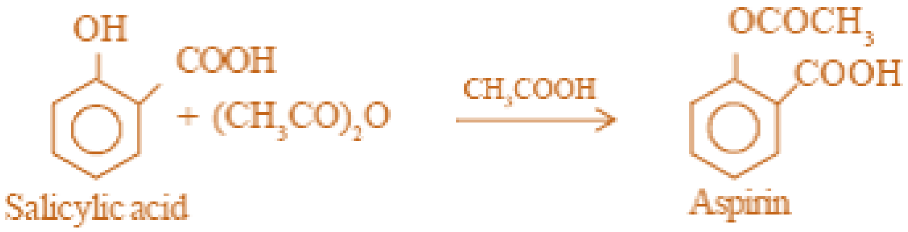
Phenacetin

Aspirin is the most popular antipyretic in use. It gets hydrolyzed in stomach and salicylic acid is released. Overdose and using it over a long time may cause side effects. It may cause bleeding in the stomach wall and even ulcers. Therefore, over dose and prolonged use should be avoided. However, calcium and sodium salts of aspirin are more soluble in water and are less harmful than aspirin.

Aspirin (Acetyl Salicylic acid):

Preparation:

Acetylation of salicylic acid with acetic anhydride gives aspirin.



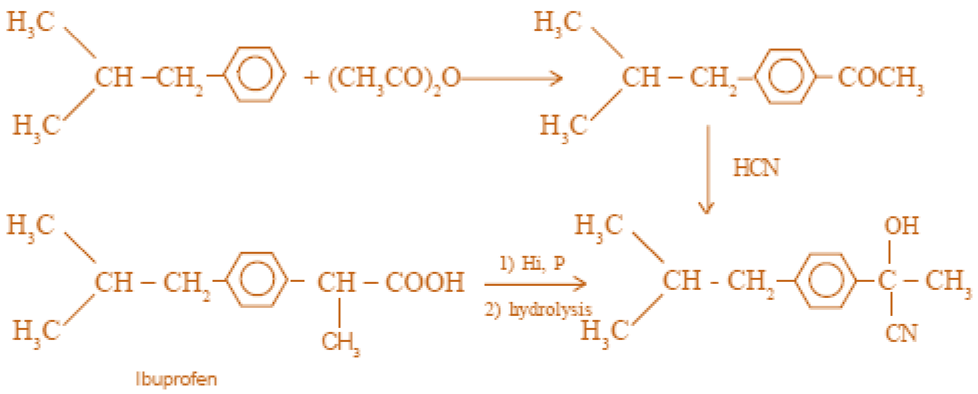
Aspirin is used as anti-inflammatory, analgesic and antipyretic. It is recommended for heart patients to reduce heart attacks.

Over usage of aspirin causes vomiting, abdominal pain, rashes on the skin etc.

Ibuprofen:

Preparation:

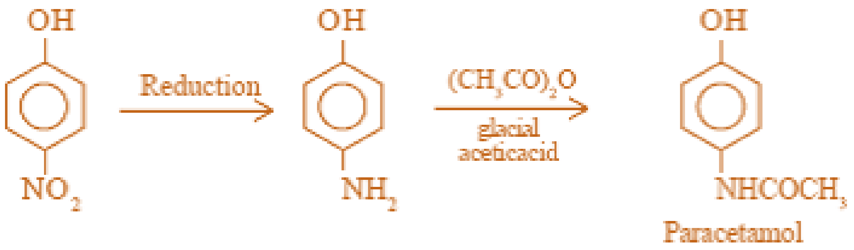
Iso butyl benzene on acetylation gives P-iso butylaceto – phenone which on treatment with HCN gives cyano hydrins. Cyano hydrins on treatment with HI and Red Phosphorus undergo reduction which on further hydrolysis gives Ibuprofen.



Ibuprofen in small doses is used as an anti-inflammatory, anti-pyretic and analgesic drug. On long term usage of this drug results in ulcers, liver damage

Paracetamol (N-acetyl P-aminophenol)

Preparation:



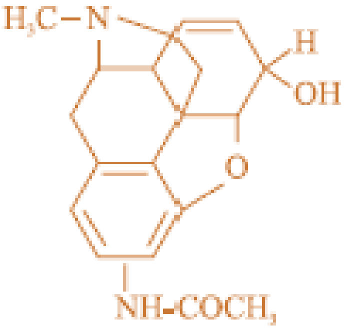
P-nitrophenol is first reduced to p-amino phenol. P-amino phenol is acetylated with glacial acetic acid and acetic anhydride and paracetamol is formed.

It is used as antipyretic and antiinflammatory drug. On long term usage of this drug causes dermatitis and anemia.

2. Analgesics

Analgesics are the substances that reduce pain which may be due to swelling of tissues, injury, inflammation or some other disorders. Analgesics are of two types, namely narcotic & non-narcotic.

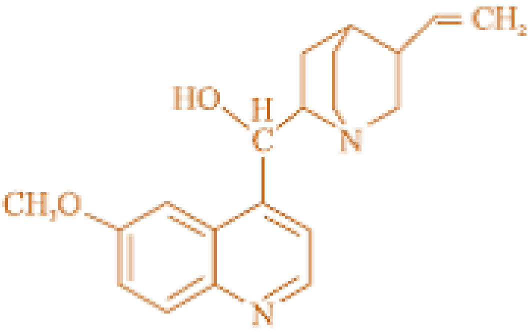
Narcotic analgesics are the ones which induce sleep and thus help to reduce the feeling of pain alkaloids present in opium, *viz*, morphine, codeine, etc. are common examples of narcotics. In higher doses these may cause unconsciousness. These are habit-forming and cause addiction. Due to addiction a person wants to have it regularly and in larger amounts. Such a person feels upset and uncomfortable if he does not get it. Narcotic analgesics do not induce sleep and are not habit forming. A common example of this type of narcotics is morphine.



Morphine

3. Antimalarials

Antimalarials medicines are used to treat malaria. Quinine and chloroquine are widely used antimalarials. Quinineisone of the earliest drugs, which was first obtained from the bark of a plant (cinchona) and later on synthesized in laboratories.



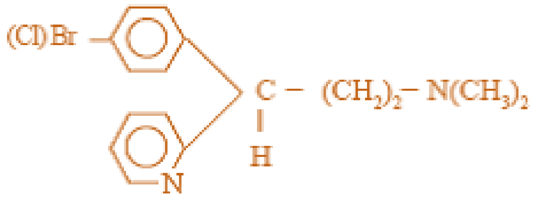
Quinine

4. Antihistamines

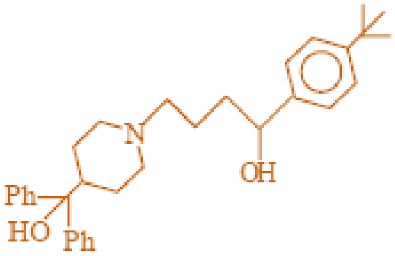
The drugs that interfere with the natural action of histamine by binding sites of receptor are called antihistamines.

Generally histamine stimulates the secretion of acid in the stomach and it is also responsible for the nasal Congestion and allergy related to house dust, pollen etc. Ranitidine (Zintac) is used to prevent the interaction of histamine in the stomach wall.

Antihistamines do not effect the secretion of acid in the stomach. Eg:-Dimetap and terfenadine (Sardane) are the antihistamines.



Bromo or chloro pheniramine



Terfenadine (sardane)

Antihistamines have side effects like drowsiness, impaired alertness, regarded ability to perform work etc.

Intext Questions 35.2

1. Give two examples of antipyretics.

....

2. Give one example of narcotic type analgesic.

....

3. What is the difference between an antiseptic and disinfectant?

....

4. What are antacids? Name two chemicals commonly used as antacids.

....

5. What is the difference between local anaesthetic and general anaesthatic.

....

6. Define antibiotics. Give one example of an antibiotic.

....

7. Write down the chemical names of Aspirin and paracetamol.

....

5. Germicides, Disinfectant and Antiseptic

Germicides are the chemicals, which prevent growth of germs (micro organisms). Germicides are classified as antiseptic and disinfectant. Both kill microorganisms but the difference lies in the way we use them.

Antiseptics kill microorganisms and are safe to beused on living beings (tissues). Antiseptics are used on wounds, cuts or skin abrations. These are used to dress wounds, etc. For example, iodoform (CHI_3), tincture of iodine, ethyl alcohol, a 0.2 percent aqueous solution of phenol and boric acid (H_3BO_3) are common antiseptics.

Some dyes have the ability to kill microorganisms. These days were the earliest compounds to be used as antiseptics. Examples are acriflavine (a yellow coloured dye), mercurochrome (a red coloured dye), methylene blue (a blue coloured dye). These dyes are still in use as antiseptics.

Iodine is a powerful antiseptic. it is used a tincture of iodine. Tincture of iodine is 2 to 3 percent solution of iodine dissolved in ethyl alcohol. Iodoform is a yellow coloured solid, which is used an antiseptic.

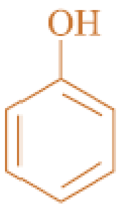
Disinfectant skill germs (micro organisms) but are used on non-living substances like surgical instruments, floors, bathrooms, lavatories, etc. Disinfectants are harsh and are not safe to be used on living beings as disinfectants can damage living tissues.

Chlorine is a powerful oxidizing agent. It is used for disinfecting water. A concentration of 0.2 to 0.4 ppm (parts per million) is enough to kill microorganisms present in water.

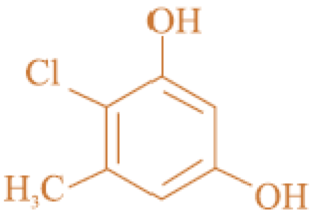
Low concentration of sulphur dioxide is used to kill microorganisms in jams, jellies and squashes. Thus it acts as a food preservative. Sulphur dioxide is used of fumigation in rooms, Operation theaters etc to sterilize them bleaching powder ($CaOCl_2$), Chlorine (Cl_2) Mercuric Chloride ($HgCl_2$), Sodium Hypochlorite (NaClO), SulphurDioxide (SO2) etc. are other examples of disinfectants.

Is Phenol Antiseptic or Disinfectant?

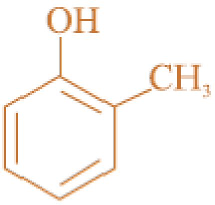
It is interesting to note that 0.2 percent aqueous solution of phenol is used as antiseptic by making. It is safe to be used on living tissues in low concentrations (less than 0.2 percent). If concentration of phenol is high then it can damage tissues. Therefore, at higher concentration (1 percent or more) phenol is used as disinfectant.



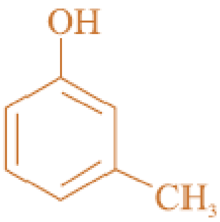
Phenol



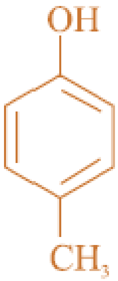
Chloro-xylenol



***O*-cresol**



***m*-cresol**



***p*-Cresol**

Most antiseptics and disinfectants are powerful poisons (Table 35.2) They are able to kill microorganisms as they interfere with their metabolism. While some others are able to kill microorganisms because of their powerful oxidizing or reducing nature (Table 35.2)

Table 35.2: Nature of some important Antiseptics and Disinfectants

Poisons	Oxidising agents	Reducing agents
Dyes Acriflavine (a yellow dye) Gentian Violet Mercurochrome Methylene blue	Bleaching powder Chlorine Hydrogen peroxide Iodine Tincture of Iodine	Sulphur dioxdie
Phenols Phenol Cresols Resorcinol Chloroxylenol	Todoform Pottasium permanganate Sodium hypochlorite	
Others Formaldehyde Boric acid Mercuric chloride Silver nitrate		

6. Antacids

Antacids are the medicines which neutralize the excess acid present in the stomach. Stomach juice contains hydrochloric acid (HCl). This acid helps the process of digestion of food. Due to illness or anxiety or some other reasons more acid is produced in the stomach. The stomach juice becomes more acidic than necessary. This causes problems in digestion, bleeding in the lining of stomach or even ulcers. Some medicines are used to neutrialise the excess acid and correct the pH of the stomach fluid.

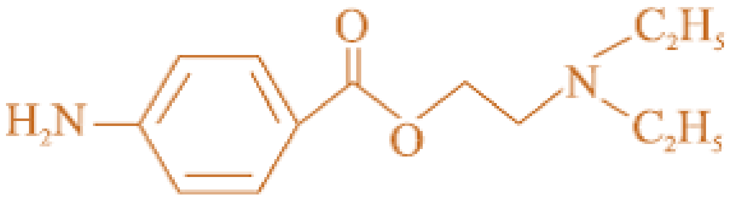
For example, sodium bicarbonate ($NaHCO_3$) or a suspension of magnesium hydroxide is used to neutralize excess of acid present in the stomach. Milk of magnesia contain magnesium hydroxide 'ENO fruit salt' contains sodium bicarbonate which helps to neutralise excess acidity in the stomach juice. Medicine like digene, gelusil, used as an antacid contain magnesium hydroxide.

7) Anesthetics

Anesthetics are substances, which cause loss of sensation over a small area (local) or loss of sensation of the whole body. There are two types of anesthetics namely, local and general.

Local Anesthetics

Local anesthetics produce numbness or loss of sensation of pain, overa small area. Cocaine, procaine and xylocaine are used as local anesthetic. These are useful for minor operations.



Procaine

General Anesthetics

General anesthetics cause unconsciousness and hence loss sensation of pain in the whole body.

General anesthetics are used for carrying out major surgical operations. Some of the general anesthetics are gases like nitrous oxide (also known as laughing gas). Some are low boiling ethers like diethyl ether, divinyl ether, etc. These are given to the patient by inhalation. On inhaling, these are absorbed through the lungs and make the person unconscious. Anesthetics have made surgical operations less risky and less painful.

Some anesthetics are given orally (by mouth), or by injections. Morphine and pathedine (these are the alkaloids obtained from opium) are given injections or through oral route.

8. Antimicrobials

Many diseases are caused due to infection in the body by certain microorganisms (bacteria, fungus or viruses). Some examples of diseases caused by microbes are dysentry, pneumonia, typhoid, urinary tract infection, etc.

Antimicrobials are the chemicals, which are used to kill microorganisms (which has infected to body) without causing much damage to the body of the patient.

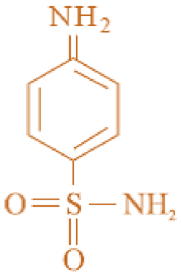
Thus an antimicrobial is a chemical, which is capable of curing diseases caused by various microbes.

An ideal antimicrobial should kill disease - causing microbe and should not have any harmful effect on the patient. In fact may not be any such antimicrobial which is totally safe and without any side effect.

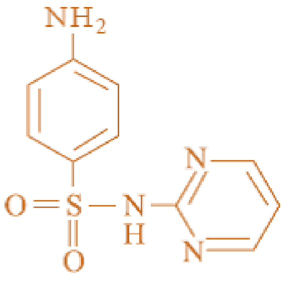
The most common antimicrobials available are the sulhpa drugs and antibiotics.

9. Sulpha Drugs

Sulpha drugs are a group of drugs, derived from sulphanilamide. All the sulpha drugs are synthesized in laboratories. Some of them have been very useful in treating diseases caused by a variety of bacteria. Some of the important sulpha drugs are sulphacetamide, sulphadiazine and sulphaguanidine, etc.



Sulphanilamide



Sulphadiazine

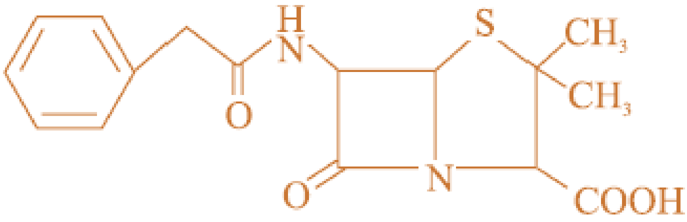
Sulpha drugs have been used for the treatment of pneumonia, sore throat, etc. These are less powerful than antibiotics. Therefore, now a day these have become less popular.

10. Antibiotics

Antibiotics are the metabolic products produced by some microorganisms (mould or fungi). They inhibit growth and even kill disease causing microorganisms (like bacteria, fungi, etc) by inhibiting their life processes. Therefore they are referred to as antibiotics (anti means against and biotic means life).

Penicillin was the first antibiotic to be discovered. Alexander Fleming isolated penicillin in 1929 from a mould Pencillium notatum. Penicillin has been used for the treating diseases caused by several bacteria. It has been effectively used from treatment of pneumonia, bronchitis, sore throat, abscesses, etc.

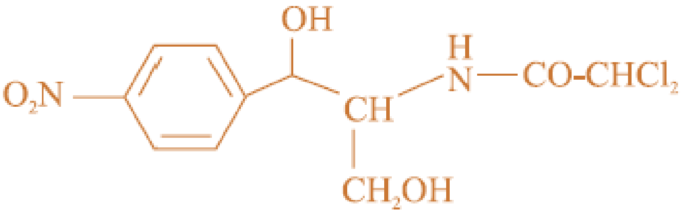
Later on attempts have been made to improve the quality of penicillin. It has led to the discovery of different varieties of penicillin. For example, PenicillinG (also known as benzylpencillin), penicillinF, penicillinK are the more common varieties of penicillin.



Penicillin G (benzyl penicillin

Ampicillin and amoxicillin are the semi-synthetic modifications of penicillin. In this case the metabolic product of mould is obtained and then some reactions are carried out to bring the desired changes in the antibiotic molecule to get ampicillin or amoxicillin.

Attempts are being made to discover better and better antibiotics. This search for finding better antibiotics is a never-ending process. Now a large number of antibiotics are available. Some examples are streptomycin and chloromycetin (chloroamphenicol) and tetracycline.



Chloroamphenicol

Streptomycin is used for the treatment of tuberculosis (TB). Chloromycetin is used for the treatment of typhoid. Tetracycline is used for the treatment of several diseases.

Broad-spectrum antibiotics are those antibiotics, which kill a wide range of disease-causing microorganisms.

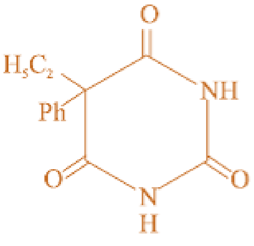
Broad-spectrum antibiotics can be used for treatment of several diseases. For example, streptomycin, tetracycline and chloroamphenicol are broad-spectrum antibiotics. Narrow spectrum antibiotics are effective in the treatment of a few diseases.

11. Allergic Reactions of Antibiotics

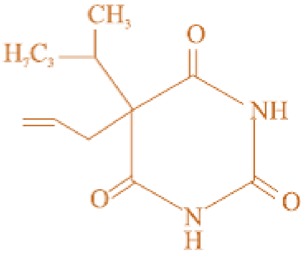
Some people may show allergic reactions to some antibiotics. These reactions may be mild like rashes appearing on the skin or may be very serious and can even be fatal. You might have observed that a doctor gives a small dose of antibiotic by injection and then waits for some time to watch if there is any unwanted reaction. If there is no adverse (bad) reaction, then only the doctor gives the full dose of the antibiotic.

12. Tranquilizers and Hypnotics

Tranquilizers and hypnotics are used to reduce anxiety, and they also make a person calm. Sleeping pills are made up of these compounds. Most of them are habit-forming. Their indiscriminate and over use should be avoided. Otherwise it may lead to addiction and many other complications.

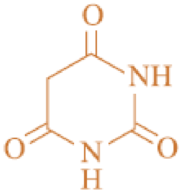


Luminal

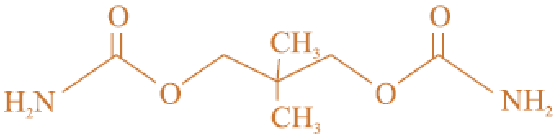


Seconal

Luminal, seconal and equanil are the most commonly used transquilizers. Barbituric acid and some other compounds related to barbituric acid are used in making sleeping pills.



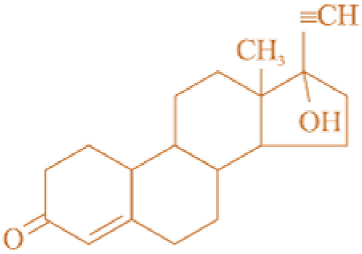
Barbituric acid



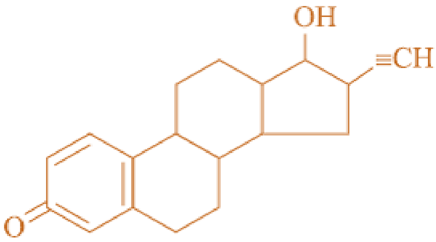
Equanil

13. Fertility Control Medicines

It is a concern of everyone to control human population. Medicines are available which help prevent pregnancy. The medicines, which help prevent pregnancy, are known as contraceptives. These are generally in the form of tablets and are to be taken regularly by females. Chemicals like norethindrone and mestranol are used as contraceptives (birth control pills). Chemically these are similar to female sex hormones.



Norethindron



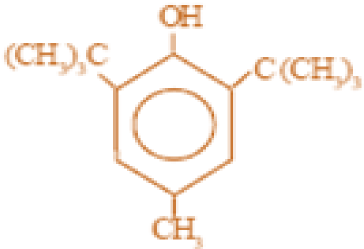
Mestranol

The birth control pills may have some side effects in some cases. Therefore, the birth control its should be used under the guidance of some expert.

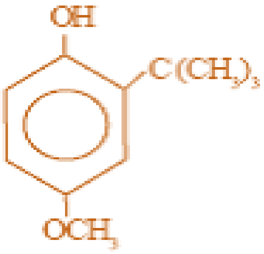
35.3 Food Preservatives:

The chemicals added to food for preservation are called food preservatives. They may be sweeteners, antioxidants, emulsifies, dyes etc. they do not have nutritive value.

Now-a-days antioxidants are preferably used. They retard the action of oxygen on food and preserve it. Two important antioxidants generally used are (BHT) butylatedhydroxyl tolerance and (BHA) butylated hydroxylanisole.



(BHT)



(BHA)

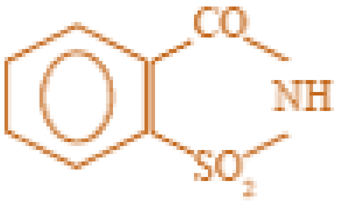
Sometimes they are mixed with citric acid or ascorbic acid to have more synergetic effect. SO_2 and SO_3^{2-} are used as preservatives for sugar, syrup, wine, beer etc.

The most important food preservative is sodium benzoate. It is metabolized by conversion to hippuric acid and is finally exerted in the urine. Generally dyes are used to color the food. Carotene is safe food color. Some are harmful particularly for children and patients etc. some dyes act as nutritional supplements such as minerals, vitamins, amino acids etc. Except these all others have no nutritional value.

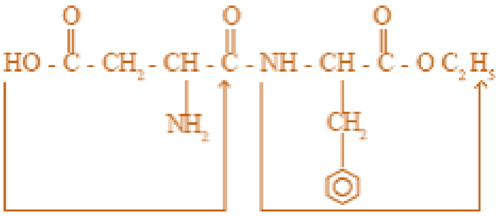
35.4 Artificial sweetening agents:

Sweeteners instead of sucrose which are added to calorie intake are called artificial sweeteners.

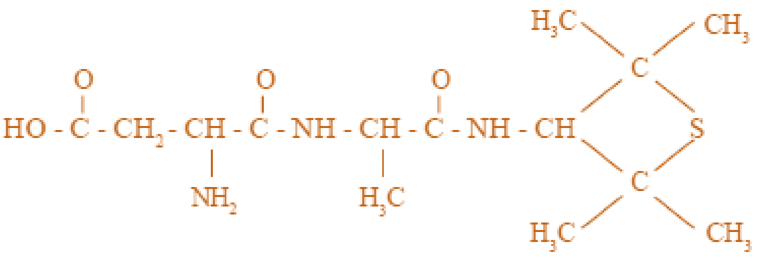
1) Sachhario is 550 times sweeter to cane sugar and is excreted in the urine. It is used for diabetic patients also.



2) Aspartane is 100 times sweeter to sugar. It is mostly used for cold foods and soft drinks because it is unstable at cooking temperature.



3) Alitame is 200 times sweeter to sucrose and more stable than aspartane. It is stable at cooking temperature.



35.5 Hazards of Self Medication

Then medicines are taken by a patient without the advice of a qualified doctor, it is called self-mediation.

Self-medication is very harmful and dangerous practice. One should never try self-medication. Some of the harmful effects are:

1. A medicine, which has worked well for someone, may not be good for you and can even cause some serious harm.
2. You may take a medicine in quantity more than necessary. It may be harmful for you.
3. You may take quantity less than necessary. The disease-causing microorganisms may gain resistance to the medicine and the medicine may become ineffective.

You should avoid self-medication. Without advice of a doctor avoid use of common medicines over prolong periods. Improper use of even most common medicines, which are readily available without a prescription of a doctor, can have harmful effect.

The medicines, which you can buy without a prescription of a doctor, are called over-the- counter medicines. For example cough syrups, crocin, aspirin, etc are over the counter medicines.

The medicines, which you can buy after showing a prescription of a qualified doctor, are known as scheduled drugs. Improper use of scheduled drugs is likely to cause more serious problems. Therefore, their sale is controlled and regulated by the government.

Most of good chemists do not sell scheduled medicines without a proper prescription. Some Irresponsible chemists may sell such medicines without a prescription. It is not a good practice you should not encourage it.

35.6 Alternative Systems of Medicines

Allopathic system of medicine mostly make use of chemicals as medicines. It takes several years of testing and trails on animals and humans, before an allopathic medicine is made available in the market. It's effects, side-effects, efficiency, fixing recommended dose, etc. are extensively studied on scientific lines before it is sold in a market. Governments all over the world create several laws, rules and regulations regarding production, quality control, sale, etc. in the interest of public safety. The allopathic system is popularly known as the western system or the English system of medicine.

In addition to the allopathic system of medicine there are a large number of other systems of medicine which are used in different parts of the world. Some of them are Ayurvedic, Unani, Homeopathic, Chinese, Tibetan, conventional, tribal, traditional, etc. Some of these systems are more popular in a particular part of world. Some are localized to a small area or used by a small group of people. In some cases there may not be any written record about the system of treatment and the knowledge is passed on by word of mouth from generation to generation.

Many of these systems are not popular over a large population. It may be due to lack of proper knowledge of the system or due to lack of adequate study of the alternative systems of medicine. There is an urgent need to extensively study all types of systems so as to make best use of knowledge for the benefit of mankind.

Intext Questions 35.3

1. What is the use of transquilizers and hypnotics?

....

2. Give one example of transquilizer.

....

3. What are contraceptives?

....

4. What are over the counter medicines?

....

What You Have Learnt

- Medicines are the chemicals or mixture of chemicals used for the prevention, cure, treatment, management of diseases and disorders or recovery of patients.
- Medicines are obtained from plants or parts of plants or synthesized in laboratories.
- Medicines may contain only one chemical compound or it may be mixture of several compounds.
- Drugs may be the crude mixtures and the identity of all the chemical components and their amount present in them may not be accurately known.
- Antipyretics are used to reduce body temperature for example aspirin and paracetamol.
- Analgesics reduce body pain for example aspirin and morphine.
- Antiseptics kill microorganisms and are safe to be used on a living tissue while disinfectants are used on in animate objects.
- Aqueous solution (less than 0.2 per cent) of phenol is used as an antiseptic. In higher concentrations phenol is used as a disinfectant.
- Antibiotics are the metabolic products produces by certain microorganisms which can kill some microorganisms. For example penicillin, streptomycin, tetracycline, etc.
- Broad spectrum antibiotics can kill several different microorganisms, therefore, can cure several diseases.
- Local anaesthetics cause numbness, loss of sensation of pain over a small area. General anaesthetics cause loss of sensation of the whole body.
- Self-medication is the use of medicines by patients without proper advice of a qualified doctor. It can be very harmful to the patient.
- In addition to the allopathic system of medicine there are several other alternative systems of medicine in use. Ayurvedic, Unani, Homeopathic, Chinese, Tibetan, conventional, tribal, traditional are some of the examples.

Terminal Exercise

1. How are medicines classified?
2. Who isolated the first antibiotic?
3. Name a medicine, which is used as analgesic as well as antipyretic.
4. What is a non-narcoticanalgesic?

5. Why is 2.0 percent aqueous solution of phenol used as a disinfectant?
6. What do you understand by allergic reactions of antibiotics?
7. What are scheduled drugs?
8. Which medicines can you purchase without the prescription from a doctor?
9. What is self-medication? Describe some of its ill effects.
10. What are the alternate systems of medicine?

Answers to Intext Questions

35.1

1. Medicines are all those substances or formulations which are used for cure, treatment, prevention of diseases or disorders and recovery of a patient.
2. True
3. Pharmaceuticals are the chemicals which are used as medicines.
4. Reserpine

35.2

1. Aspirin and Paracetamol.
2. Morphine.
3. Disinfectants kill germs but can damage living tissues Anticeptics are safe for living tissues and yet kill germs.
4. Medicines used to neutralize excess acid in the stomach. Magnesium hydroxides and sodium carbonate.
5. Local anesthetics cause loss of sensation of pain over a small area while general anesthetics cause loss of consciousness.
6. Metabolic products of certain microorganisms and can kill some other microorganisms.
7. Pencillin is an example of antibiotic.
8. Acetyl salicylic acid, N-acetyl P-amino phenol.

35.3

1. Tranquilizers and hypnotics are used to reduce anxiety and the seal so make a person calm.
2. luminal
3. Contraceptives are the medicines used for prevention of pregnancy.
4. Over-the-counter medicines are those which can be purchased without a prescription from a doctor.

Chapter 36

BUILDING MATERIALS

The prehistoric man took shelter in caves to save himself from the beasts and the fury of nature. Since then, different natural resources have been exploited, in native as well as in the modified forms, along with the synthetic materials to make living more comfortable. Today a large number of materials like, cement, steel, glass, ceramics, stone, timber, paints and varnishes etc. are used for making buildings and other structures that are strong, durable and safe. Chemistry has an important role in the development of these materials, their mode of action and newer applications. In this lesson you will learn about some of the building (or construction) materials in terms of their composition, preparation and applications.

Objectives

After reading this lesson you will be able to:

- define cement;
- list the raw materials used for the manufacture of Portland cement;
- discuss the process of setting of cement;
- describe different types of special cements and their applications;
- describe and differentiate between mortar, concrete and R.C.C;
- define glass;
- list the raw materials used for the manufacture of glass and outline their importance;
- describe the process of manufacture of glass;
- discuss general properties of glass;
- describe different types of glass and their uses;
- define the term, 'Ceramics';
- list different types of clay products
- describe and distinguish between different types of clay products.

36.1Cement

The word cement means' to cohere on unite'. Cement can be identified as an inorganic material which when mixed with water gradually sets to give a hard mass. This is used to join (or cement) together bricks, stones, etc. to create different structures. Cement is in use since antiquity. The Egyptian pyramids and many of the ancient Greek structures were constructed by using some kind of cementing materials.

There are different types of cements like, natural cement, Puzzolana cement, slag cement and Portland cement, etc. These differ in their composition, mode of preparation and applications. We shall discuss about the Portland cement which is currently the most commonly used cement in the construction works. In India manufacture of Portland cement started about a hundred years ago (1904) by South India Industries Ltd. Today, Indian cement industry manufactures over 100 million tones of cement per year.

36.1.1 Manufacture of Portland Cement

Portland cement was invented in 1824 by calcinating (or burning) argillaceous limestone (limestone containing 20-40 % of clay). it was called as Portland cement because the concrete (a mixture of cement and gravel or sand) obtained from it resembled the building stone from Isle of Portland in England. Today many types of Portland cement with different compositions are available for different applications.

a) Raw Materials:

A number of raw materials are required for the manufacture of Portland cement. These can be broadly put into two categories:

i) Calcareous (rich in calcium) material: like limestone ($CaCO_3$), chalk etc. are the principal constituent of cement and need to be used in appropriate amounts. The excess of lime or its deficiency, both reduce the strength of the cement.

ii) Argillaceous material: These are rich in silica and alumina for example, clay (a mixture of Al_2O_3, and SiO_2), shale, slate or volcanic material etc. These impart strength to the cement and affect the setting properties of the cement.

In addition to the above, powdered coal or fuel oil and gypsum ($CaSO_4.2H_2O$) are also used in the manufacture of cement. Addition of gypsum controls the setting time of the cement. The amount of gypsum has to be carefully controlled because if it is present in more than required amounts it causes cracks.

b) Manufacturing process:

To prepare cement the raw materials are mixed in appropriate amounts, crushed to powder and then calcinated (burned or fired) There are two types of manufacturing processes wet process and dry process depending on whether the mixing and grinding of raw materials is done in wet or in dry conditions.

i) Wet process: In this method the raw materials are treated with water (about 35-40% by mass) and then powdered in ball mills. These raw materials can be treated individually or in the form of a mixture. The paste like material so obtained is then sieved and powdered further if necessary. This is then passed through a rotary kiln (Fig. 36.1) for calcinations.

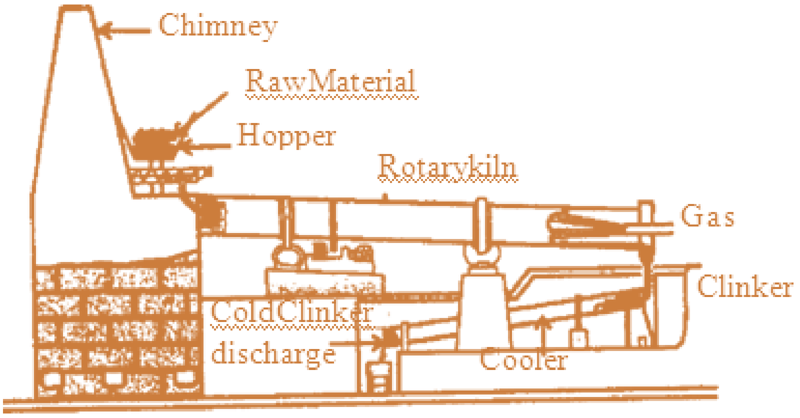


Fig.36.1:Rotary kiln used in the manufacture of cement.

The furnace consists of a slightly inclined long pipe that revolves slowly around its own aixs. The mixture paste is fed into the long pipe through a hopper installed at the top of the pipe. A sit moves down it meets the hot gases going up wards. In the high temperature of the kiln, the raw materials undergo a number of chemical reactions to form many new compounds. The mixture comes out of the kiln in the form of small greenish black or grey coloured hard balls known as clinkers which falls into a second pipe called cooler. These clinkers are then allowed to cool and powdered. To this powder a small amount (2-3%) of gypsum is added and powdered again to obtain cement.

ii) Dry method: in this method the raw materials are mixed and powdered in ball mills. This is then places into rotating panniers whose walls are fitted with water sprays. In the panniers the centrifugal force keeps the material in contact with the wall where it gets somewhat wet and takes the shape of small spheres. These are then passed through the rotary kiln as described above.

c) Composition of cement

The Portland cement contains calcium aluminium silicates. It contains more than one compounds. The approximate percentage of different elements present in Portland cement are expressed as their oxides (Table 36.1).

Table 36.1: Approximate percentage composition of Portland cement

Oxide	Approximate percentage	Average percentage
CaO	60-67	**64**
SiO_2	17-25	**22.5**
Al_2O_3	3-8	**6.5**
Fe_2O_3	0.5-6.0	**2.0**
MgO	0.1-4.0	**2.0**
SO_3	1.0-3.0	**1.5**
K_2O, Na_2O	**0.4-1.3**	**-**

The first four of the oxides listed above, provide the basic compounds while there stare referred to as secondary compounds. The oxides listed above don't exist as such CaO and MgO absorb moisture and CO from the atmosphere to give hydroxides and carbonates.

Chemistry of Portland cement has been well understood. It contains different compounds which are known as Bogue's compounds. They are so named because they were identified by R.H. Bogue. The Bogue's compounds, their chemical formulae, and abbreviations and typical percentages are given in Table 36.2

Table 36.2: Bogue's compounds in Portland cement

Name of the compound	Chemical formula*	Abbreviation	Typical percentage
Tricalcium Silicate	$3CaOSiO_2$	C_3S	54.1
Dicalcium Silicate	$2CaOSiO_2$	C_2S	16.6
Tricalcium Aluminate	$3caOAl_2O_3$	C_3A	10.8
Tetracalcium Aluminoferrate	$4CaO.Al_2O_3Fe_2O_3$	C_4AF	9.1

70.80% of cement is C2S and C3S.

In addition to the four compounds listed in Table 36.2, a number of some other compounds have been discovered in Portland cement but these four compounds are the most important. The amount of these compounds in a sample of cement can vary and determine the properties of cement.

36.1.2 Setting and Hardening of Cement

In contact with water cement sets to a hard mass and this phenomenon is called setting of cement. The setting and hardening of cement is a process that takes a long time. A number of theories have been proposed for the setting of cement and there is a general agreement that it involves two important processes. These are hydration and crystallisation. Hydration is the initial stage when water is mixed with cement. It is followed by crystallization of different compounds.

The mixture of cement and water forms a' cement paste. In this the constituents of cement get hydrated and form gel and crystalline products. Since the solubility of these products in water is low, they cause the paste to get stiffened. (harden) This initial stiffening of the paste is called setting of the cement. The setting process is complete in about 25 hours. The paste then continues to harden over a long period of time. This process is called hardening and involves further gel information and gradual crystallisation of the products of hydration. The process of hardening is almost complete in about a year, however this process continues for over a decade. The two processes are shown diagrammatically in Fig.36.2

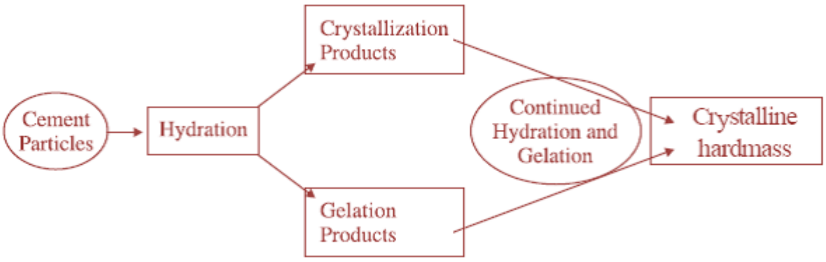


Fig 36.2: Setting of Cement

Different compounds listed in Table 36.2 have different characteristic like rates of hydration, setting time and strength. These 'set' in different time span and contribute to the development of strength of the cement over a long period of time. In terms of chemistry, the first reaction of cement with water is as follows

$$C_3A + 6H_2O \longrightarrow C_3A.\ 6H_2O$$

This reaction proceeds with the evolution of heat. After a few hours of contact with water, the following reaction starts

$$C_3S + H_2O \longrightarrow C_2S + C.H_2O$$

These processes cause the initial setting of the cement. In the second stage, i.e., hardening of cement involves the following reactions.

$$C_3A.\ 6H_2O + C.H_2O + 6H_2O \longrightarrow C_4A\ .13H_2O$$

$$C_3S + n\ H_2O \longrightarrow C_2S.\ n\ H_2O$$

36.1.3 Special Cements

Portland cement also known as normal setting or ordinary cement is widely used for most of the construction activity like construction of buildings, roads, bridges and dams, etc.. However, it is unsuitable for application under corrosive conditions. Such applications require special characteristics in the cement. These have lead to the development of special cements. Some of these are given below:

a) High alumina cement: This is prepared by fusing a mixture of limestone and bauxite (an ore of aluminium containing some impurities of iron oxide, magnesium silicate, etc.) at high temperature. It has high rate of setting and hardening and can achieve full strength in about 24h. It is also known as quick setting cement. It has superior chemical resistance so that it can be used safely, with sea water and waste containing sulphates.

b) White Portland: It is an expensive variety of normal setting Portland cement characterized by the absence of iron compounds. The absence of iron compounds gives it the whiteness. The white cement is expensive because its manufacture requires high purity of the raw materials viz. lime stone and clay. It finds applications in the manufacture of tiles and repairing of marble structures. White Portland cement has an added advantage that is can be mixed with different colouring materials (pigments) to give aesthetic application. Chromium oxide gives it a green coloration, cobalt oxide imparts blue coloration.

c) Sorel cement (magnesium oxychloride cement): This cement was discovered by a French Chemist Sorel and is obtained by the addition of 20% solution of $MgCl_2$ to a finely ground mixture of calcinated magnesite and caustic (NaOH). The main constituent is magnesium oxychloride ($3MgO.MgCl_2.\ 12H_2O$). Sorel cement is used primarily for flooring and is also used in dental fillings.

d) Water proof cement: This is obtained by mixing water proof substance like, calcium or aluminium stearate during grinding while making Portland cement. Sometimes substances like soaps, waxes and bitumen etc. are also used to achieve water repelling properties.

36.1.4 Applications of Cement

Cement is generally not used as such; it is normally mixed with certain fillers or additive like sand, crushes stone, gravel, slag, etc. Depending on the nature of the filler or additive and the composition there are three broad types of mixtures. These are

i) Mortar **ii) Concrete and** **iii) Reinforced Concrete Construction (RCC)**

i) Mortar: It is obtained by adding water to a mixture of cement and sand. The resulting paste is called cement-mortar. Mortar finds applications in binding bricks and stones, etc. and also in plastering the walls.

ii) Concrete: It is formed by making a mixture of cement and fine and coarse inert mineral aggregates like sand, coarse rock, stone, gravel or slag etc. The concrete can be put into any desired shape. Concrete finds applications in making roads, roofs, columns in the building, foundation works etc.

iii) Reinforced Concrete Construction (R.C.C.): Sometimes the constructed structure, say abridge, has to take a lot of load. A plain concrete construction is not appropriate for such an application because concrete has low ability to with stand tension. In such cases, the structure is strengthened (or reinforced) by incorporating a network of iron or steel rods which helps to take up load. This type of construction is called Reinforced Concrete Construction (R.C.C) and is used in the construction of bridges, arches, roofs, girders, floor beams, etc.

Intext Questions 36.1

1. What is Portland cement?

....

2. What are its main raw materials of Portland cement?

....

3. What do you understand by setting of cement?

....

4. List the names of different types of special cements.

....

36.2 Glass

Your are familiar with glass and its common applications. Glass is defined as 'a rigid, amorphous transparent or translucent super cooled liquid'. It means that glass is not a solid but a rigid material that may allow light to pass through. Further, it is amorphous which means that it lacks regular three dimensional internal structure characteristic of crystalline solids. Glass has extremely high viscosity and normally does not set over areas on ably long period of time.

Glass is obtained by the fusion of sand, alkali metal carbonates alkaline earth carbonates and some other additives. We cannot give it a particular chemical formula, however, glass can be roughly represented as $xM^{I}_{2}O$. yM^{II}_{O} . $6SiO_2$ where M^{I} = refers to an alkali metal like Na, K while M^{II}, indicates a bivalent metal like Ca, Pb, etc. Glass is a mixture of silicates of alkali and alkaline earth metals with excess of silica. Some verities of glasses may contain small amount of Al_2O_3, Fe_2O_3, etc. Some common variety of glasses are given in Table 36.3

Table 36.3: Types of Glass

Types of glass	M^{I}	M^{II}	Approximate formula
Soda lime glass or Soda glass	Na	Ca	$Na_2O.CaO.6SiO_2$
Potash lead glass	K	Pb	$K_2O.PbO.6SiO_2$

36.2.1 Manufacture of Glass

A large variety of glasses are known today and these are prepared by varying the composition of the raw materials. The basic raw materials and their role in determining the properties of a glass are briefly out lined below:

a) Raw materials

i) Sand: It is the source of silica. - the major component of glass. The sand used for manufacture of glass. must be almost pure quartz containing about 99.1 - 99.7% SiO_2. The sand particles should be uniform and of moderate size. Larger particles are slow to react while very fine particles cause violent reaction.

ii) Alkali metal compounds: (Na_2CO_3, K_2CO_3, $NaNO_3$, KNO_3, Na_2SO_4). These are the sources of Na_2O (in soda glass) and K_2O (in hard glass).

iii) Alkaline earth compounds: (CaO, $CaCO_3$ and $BaCO_3$). These are provided by lime stone and burnt lime from dolomite ($CaCO_3$, $MgCO_3$). Dolomite also provides MgO which helps in controlling the physical properties of glass. Alkaline Earth compounds contribute towards the high refractive index of glass.

iv) Heavy metal oxides (ZnO, PbO, Pb_2O_4 and Pb_3O_4) Litharge (PbO) or red lead (Pb_3O_4) are used as a source of lead in flint glass or crystal glass. It provides lusture and high refractive index to the glass.

v) Feldspar is a cheap source of Al_2O_3. Feldspars have a general formula $M^1{}_2O.Al_2O_3.6SiO_2$ where MI represents Na or K or both. Therefore, feldspar has an added advantage as it provides Na_2O, K_2O and silica also. Alumina (Al_2O_3) makes glass resistant to sudden changes in temperature.

vi) Borax is amin or component and is a source of boronoxide (B_2O_3) and Na_2O. Borax reduces the coefficient of expansion of glass and increases its fusibility, chemical durability and refinement.

vii) Cullets or pieces of broken glass are generally added to the raw mateial to increase the fusibility of the glass produced from it. In other words it lowers the temperature of fusion so that we can manufacture glass at a lower temperature. The cullets may contribute from 10% to 80% of the raw material and thus provide a good way of utilising the waste glass.

viii) Besides the above mentioned raw materials certain metallic oxides are also added to impart a colour (if desired) to the glass. Some of the principal glass colorants are given in Table 36.4.

Table 36.4: Some common glass colorants

Colorant	Formula	Colour imparted
Oxides of iron	FeO, Fe_2O_3	Light green or bottle green
Cobalt oxide	CoO	Blue
Chromium compounds	Cr_2O_3,K_2CrO_4	Green tending to yellow
Cadmium sulphate	$CdSO_4$	Yellow
Gold powder	Colloidal Au	Shades of ruby

b) Manufacturing Process: The raw materials including the cullets, are powdered in a grinding mill and mixed in proper proportion. This powder is then fused in an open or covered furnace. Certain decolorants like MnO, etc., are added and the heating is continued till the evolution of gases stops. The coloring material is added at this stage and the heating is continued till a homogenous mass is obtained. It is then gradually cooled to a certain degree of plasticity so that it can be handled easily. The glass so obtained is called mother glass. It is then blown or moulded to get the desired shape. The articles are then cooled slowly. This process is called annealing. The finished glass product is then obtained after processes like cleaning, cutting, grinding and polishing, etc.

36.2.2 Properties of Glass

- It is amorphous in nature, having low range of internal order.
- It does not have a sharp melting point. On heating glass gradually becomes softer and softer and eventually starts flowing.
- On cooling, the hot liquid gradually cools to a viscous liquid which can then be transformed in to articles of desired shape.
- It may be transparent or translucent.
- It is quite inert and is not readily affected by ordinary chemicals except hydrogen fluoride and some alkalis.
- It has high compressor strength It lacks ordered internal structure.
- It is an insulator of heat and electricity.

36.2.3 Types of Glasses

Commercially glasses are available in a wide variety. These are used for diverse applications from simple window pane to bullet proof glass. Some types of glasses and their uses are discussed below.

i) Soda glass or soft glass: This is commonly used, low quality, cheap glass. It constitutes about 95% of all the glass manufactured and is prepared by fusing sand (silica), calcium carbonate (lime stone) and soda ash (Na2CO3). The approximate composition in $Na_2O.CaO.6SiO_2$. It contain 70-74% SiO2, 8 to13% CaO and 13-18% Na_2O. About 2% of Al_2O_3 may be present as impurity. It is called soft glass because it soften at a relatively lower temperature. The soda glass also finds application in making eletric bulbs, window panes, bottles, jars, etc.

ii) Lead Glass or flint glass: Is prepared by fusing litharge (PbO), potassium carbonate, soda ash, lime stone and silica in proper proportions. The approximate composition is $K_2O.PbO.6SiO_2$. It contains about 45% silica and variable amounts of lead oxide, Na_2O, K_2O and CaO. High lead-content glasses are used as shields against x-rays and γ-rays. These are used in the buildings in which x-ray and γ-ray scintillation units are installed. These may even be used in nuclear installations to protect from nuclear radiations. Besides, these applications, lead glass finds extensive use in making optical components like lenses, quality table ware (crystal ware), ornamental or artificial jewellery, imitating artificial precious stones and electrical insulations, etc.,

iii) Toughened (or tempered) glass: This is not exactly a type of glass but a kind of treatment done to the glass article before annealing. The hot article is dipped in an hot oil both. The outer layer of the article shrinks and hardens where as the internal layer is in a state of stress or tension. If the surface is broken, it shatters into many pieces. This procedure is called tempering of glass. Such a glass is very strong and tough and can withstand higher mechanical and thermal shock. Such glasses are used in making automatic doors, large showcase. Toughened glass also finds application as wind shields of cars, trucks and aero planes.

iv) Laminated safety glass: It is obtained by pressing or bonding together two or three flat glass sheets having a thin layer of poly vinyl butyral plastic or vinyl acute resin and a bonding material (adhesive) between them. These may be cemented with the help of heat and pressure. The glass becomes tough on cooling and can with stand sudden changes in temperature and process. On breaking, the glass pieces do not fly off i.e. it is shatter proof. Such a glass is an idea material to be used for entrance doors, sliding doors, sky lights, sloped looking windows of tall buildings, etc. These also find application as the wind screens of cars and automobiles. If several layers of glass are condensed together with alternating layer of vinyl resin we can get bullet proof glass.

v) Insulated Glass: It is prepared by entrapping insulting materials like anhydrous (or dry) air between two panes of glass thermally sealed along the perimeter. Such glass modules are used in places where inside of the building is to be protected from the drastic climatic conditions outside. In extreme weather conditions a module containing three panes and two layers of insulation may be used. These modules keep the room cool during summer and warm in winters.

In addition to the above mentioned, a number of other types of glass are known that find applications in making tableware, chemical containers and apparatus, optical lenses, goggles, neonsings, cathode ray tubes and many more.

Intext Questions 36.2

1. List different raw materials used in the manufacture of glass.

....

2. What is the chemical composition of soda glass ?

....

3. What do you understand by tampering of glass?

....

4. Give two examples of substances used as colourants for glass.

....

36.3 Ceramics

The term ceramics originated from the Greek word, keramos meaning 'burntstuff'. It refers to a broad class of chemically inorganic materials that are prepared by high temperature processes or a reused at high temperatures. These are broadly grouped into following classes:

(i) Clay products **(ii) Refractory ceramics**

In this section we shall discuss about clay products.

(i) Clay products

The clay products are sub divided into the following types.

i) Structural clay products: These contain iron oxide as one of the important constituents and are used form a king bricks, terracotta, sewer pipes and tiles, etc.

ii) White wares or white pottery: These are prepared from china clay (or Kaoline) mixed with some fusible silicates. These include products like chinaware, porcelain stoneware and vitreous ware.

iii) Chemical stoneware: These are prepared from refractory clays mixed with crushed stones and pottery, etc. which are then glazed. These are generally quite strong and non-porous products. These find applications in making sanitary fixtures like bathtubs, wash basins, sinks and drainage pipes, etc.

(ii) Refractory ceramics

Refractory ceramics are a subset of ceramic materials that are specifically designed and manufactured to exhibit exceptional resistance to high temperatures, thermal shock, and aggressive chemical environments. These ceramics are used as lining materials in various industrial applications where they come into contact with extreme heat, molten metals, slag, gases, and other challenging conditions.

36.3.1 What is Clay?

Geographically, clays are the products obtained by the disintegration of rocks over long periods of time due to the effects of weather. These consist mainly of aluminium silicates along with other substances like, mica, quartz and sand, etc. some of the common clays and their chemical formulae are:

i)	Beidellite	$Al_2O_3\ 2SiO_2.H_2O$
ii)	Kaolinite	$Al_2O_3\ 2SiO_2.2H_2O$
iii)	Halloysite	$Al_2O_3\ 2SiO_2.3H_2O$

These differ only in terms of the number of water molecules of hydration. Clays have an important property called plasticity because of which on mixing with water these form a plastic like mass which can be easily moulded into desired shape. You would have observed pottery makers turning clays into various shapes. The wet clay has sufficient rigidity so that it does not get deformed on standing.

36.3.2 Structural Clay Products

The structural clay products like bricks and tiles are prepared from common clay containing iron oxide and other impurities.

i) Bricks: These are one of the oldest and extensively used construction material. These are cheap, locally available (other than on hilly areas) and have good strength. The main raw materials used for preparing bricks are clay (alumina) and sand (silica). Small amounts of lime (to reduce shrink age and give strength) and iron oxide (to help in the fusion of the brick particles and for giving colour to the bricks) are also added. Manufacture of bricks involves the following steps:

1. Kneading of clay with water till homogenous
2. Moulding and drying of bricks
3. Baking of dry bricks

Now a days bricks are being prepared from fly ash-the waste product of thermal power stations.

ii) Tiles: These are prepared from better quality clay (free from pebbles, grit and other impurities) and are used in flooring, making pavements and roofs, etc.. Superior quality tiles are used for decorative purposes. Finely ground mixture of glass and pottery are also added to the clay while preparing tiles, this provides strength to the tiles.

36.3.3 White wares and White Pottery

These are clay products having white or pale-cream colour. Whitewares are prepared from china clay, feldspar($K_2O.Al_2O_3$ SiO_2.) and sand or flint (SiO_2). These are used in varying amounts to get different products. The raw materials contain none or negligible amounts of iron oxides.

To prepare whitewares the raw materials are ground to a fine powder and mixed with water. The wet clay is moulded into desired shape, dried, baked and glazed. During glazing the pores of the clay are plugged (closed) so as to make it water proof and shining. Glazing is done in a number of ways depending on requirement. Glazing materials used are glass forming materials like quartz, feldspar, lead and boro-silicates, etc. along with some coloring components. These are mixed with water to form a colloidal solution (called slip-glaze). The ware to be glazed is removed from the furnace and dipped into glaze-slip and continued to bake at high temperature. The glaze material fuses and fills the pores and provides a glossy surface to the ware.

36.3.4 Chemical Stoneware

As the name suggests, the stonewares are quite strong like stone. These are obtained by heating the raw materials at high temperature. A typical stoneware can be prepared by grinding a mixture of clay, kaoline, feldspar and sand. The plastic like mass so obtained is moulded into the desired shape. The shaped articles are dried and heated at about 1273K. These are then salt glazed at 1373K. In salt glazing the hot article is sprinkled with sodium chloride and heated a high temperature. Sodium chloride vapourises and reacts with the ware producing sodium aluminium silicate. This is highly fusible and fills the pores on the surface of the article. This glazing treatment makes the article impermeable to liquids.

The chemical stonewares have low absorption power, high density and chemical resistance. These differ from the whitewares interms of their colour. The stonewares are used in making sanitary fixtures like bathtubs, washbasins, sinks and drainage pipes, etc.

Intext Questions 36.3

1. What are ceramics?

....

2. What are clay products? How are these classified?

....

3. List the raw materials used to prepare white wares.

....

4. List different uses of chemical stone wares.

....

What You Have Learnt

- Cementis an inorganic material which when mixed with water gradually sets to give a hard mass and can be used to join together bricks, stones, etc.
- There are different types of cement that differ in their composition, mode of preparation and applications. Of these, Portland cement is currently the most commonly used cement.
- Portland cement contains a number of oxides which exist as complex compounds like, tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium alumino ferrate, etc. These are called Bogue's compounds.
- Setting of cement involves two important processes hydration and crystallisation. These processes take long period of time.
- Cement is used in combination with a number of additives like sand, coarse rock, stone, gravel or slag, etc. depending on the application. These combinations are called mortar or concrete depending on the additive. A concrete reinforced with steel is called R.C.C.
- Glass is a rigid amorphous transparent or translucent super cooled liquid 'which lacks regular three dimensional internal structure and has extremely high viscosity.
- For manufacturing glass, the raw materials like sand, feldspar, alkali metal and alkaline earth compounds, heavy metal oxides, etc. are mixed in proper proportion, powered, and fused in a furnace.
- Commercial glasses are available in a wide variety. There are used for diverse applications from simple window panes to bullet proof glass etc.
- Ceramics refer to a broad class of chemically inorganic materials that are prepared by high temperature processes or are used at high temperatures and are classified as clay products and refractories.
- Clay consists of a mixture of alumino silicates differing in number of water of crystallisation.
- Clay products are classified into structural clay products (like bricks and tilesetc), White wares and stone wares.

Terminal Exercise

1. Match the following

i) Mixing of water and cement leads to	( )	a. Crystallisation
ii) Second stage of hardening of cement	( )	b. Sorelcement
iii) Cement with good chemical resistance	( )	c. Mortar
iv) Cement used in repairing marble	( )	d. High alumnina Cement
v) Cement used in dental fillings	( )	e. Whitecement

2. Describe the process of manufacture of cement.
3. What are Bogue's compounds and what is their importance.
4. Discuss different applications of cement.
5. What is the composition of white cement? Give some of its applications.
6. Differentiate between **i)** Mortar and concrete **ii)** Concrete and R.C.C.
7. Describe the process of manufacture of glass.
8. List different raw materials used for the manufacture of bricks and indicate their role.
9. What do you understand by the term, 'glazing'? Why are certain clay products glazed?

Answers to Intext Questions

36.1

1. The Portland cement is the most commonly used cement. It contains a number of sliticates like calcium aluminio silicates.

2. Calcareous materials like lime stone and chalk and argillaceous materials like, clay, shale or slate, etc. are the principal constituent of cement. In addition to these, powdered coal or fuel oil and gypsum ($CaSO_4.2H_2O$) are also used.

3. Setting of cement involves two important processes called hydration and crystallisation. These processes take a long time. On mixing water and cement the constituents of the cement get hydrated and form gel and crystalline products. These cause the paste to stiffen and it is called setting of cement.

4. There are different types of cement with special properties. Some of the special cement are: high alumina cement, while Portland, sorel cement and water proof cement.

36.2

1. Sand, Alkali metal compounds, alkaline earth compounds, heavy metal oxides, borax & cullets.
2. Please refer to section 36.2.3
3. Please refer to 36.2.3.
4. oxides of iron and gold powder

36.3

1. Please refer to section 36.3
2. Please refer to section 36.3.1
3. China clay, feldspar and sand
4. Bath tubs, wash basins, sinks & drainage pipes.

The Modern Periodic Table of the Elements

H — Symbol
1 — Atomic Number
1.008 — Atomic Wigight
Hydrogen — Name

( ) = Estimates

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	**H** 1 1.008 Hydrogen																	**He** 2 4.00 Helium
2	**Li** 3 6.94 Lithium	**Be** 4 9.01 Beryllium											**B** 5 10.81 Boron	**C** 6 12.01 Carbon	**N** 7 14.01 Nitrogen	**O** 8 16.00 Oxygen	**F** 9 19.00 Fluorine	**Ne** 10 20.18 Neon
3	**Na** 11 22.99 Sodium	**Mg** 12 24.31 Magnesium											**Al** 13 26.98 Aluminium	**Si** 14 28.09 Silicon	**P** 15 30.97 Phosphorus	**S** 16 32.07 Sulphur	**Cl** 17 35.45 Chlorine	**Ar** 18 39.95 Argon
4	**K** 19 39.10 Potassium	**Ca** 20 40.08 Calcium	**Sc** 21 44.96 Scandium	**Ti** 22 47.88 Titanium	**V** 23 50.94 Vanadium	**Cr** 24 52.00 Chromium	**Mn** 25 54.94 Manganese	**Fe** 26 55.85 Iron	**Co** 27 58.93 Cobalt	**Ni** 28 58.69 Nickel	**Cu** 29 63.55 Copper	**Zn** 30 65.39 Zinc	**Ga** 31 69.72 Gallium	**Ge** 32 72.61 Germanium	**As** 33 74.92 Arsenic	**Se** 34 78.96 Selenium	**Br** 35 79.90 Bromine	**Kr** 36 83.80 Krypton
5	**Rb** 37 85.47 Rubidium	**Sr** 38 87.62 Strontium	**Y** 39 88.91 Yttrium	**Zr** 40 91.22 Zirconium	**Nb** 41 92.91 Niobium	**Mo** 42 95.94 Molybdenum	**Tc** 43 (97.9) Technetium	**Ru** 44 (101.07) Ruthenium	**Rh** 45 (102.91) Rhodium	**Pd** 46 (106.42) Palladium	**Ag** 47 (107.87) Silver	**Cd** 48 (112.41) Cadmium	**In** 49 114.82 Indium	**Sn** 50 118.71 Tin	**Sb** 51 121.76 Antimony	**Te** 52 127.60 Tellurium	**I** 53 126.90 Tellurium	**Xe** 54 131.29 Xenon
6	**Cs** 55 132.91 Cesium	**Ba** 56 137.33 Barium	**La** 57 138.91 Lanthanum	**Hf** 72 178.49 Hafnium	**Ta** 73 180.95 Tantalum	**W** 74 183.85 Tungsten	**Re** 75 186.21 Rhenium	**Os** 76 190.2 Osmium	**Ir** 77 192.22 Iridium	**Pt** 78 195.08 Platinum	**Au** 79 196.97 Gold	**Hg** 80 200.59 Mercury	**Tl** 81 204.38 Thallium	**Pb** 82 207.2 Lead	**Bi** 83 208.98 Bismuth	**Po** 84 (209) Polonium	**At** 85 (210) Astatine	**Rn** 86 (222) Radon
7	**Fr** 87 223.02 Francium	**Ra** 88 226.02 Radium	**Ac** 89 227.03 Actinium	**Rf** 104 (261) Rutherfordium	**Db** 105 (262) Dubnium	**Sg** 106 (263) Seaborgium	**Bh** 107 (262) Bohrium	**Hs** 108 (265) Hassium	**Mt** 109 (266) Meitnerium	**Ds** 110 (269) Darmstadium	**Rg** 111 (272) Roentgenium	**Cn** 112 (277) Copernicium		**Fl** 114 (287) Flerovium		**Lv** 116 (289) Livermorium		Unnamed Discovery 118 Nov.1999
	ALKALI METALS	ALKALI EARTH METALS															HALOGENS	NOBLE GASES

LANTHANIDES	**Ce** 58 140.12 Cerium	**Pr** 59 140.91 Praseodymium	**Nd** 60 144.24 Neodymium	**Pm** 61 (145) Promethium	**Sm** 62 150.36 Samarium	**Eu** 63 152.97 Europium	**Gd** 64 157.25 Gadolinium	**Tb** 65 158.93 Terbium	**Dy** 66 162.50 Dysprosium	**Ho** 67 164.93 Holmium	**Er** 68 167.26 Erbium	**Tm** 69 168.93 Thulium	**Yb** 70 173.04 Ytterbium	**Lu** 71 174.97 Lutetium
ACTINIDES	**Th** 90 232.04 Thorium	**Pa** 91 231.04 Protacinium	**U** 92 238.03 Uranium	**Np** 93 237.05 Neptunium	**Pu** 94 (240) Plutonium	**Am** 95 243.06 Americium	**Cm** 96 (247) Curium	**Bk** 97 (248) Berkelium	**Cf** 98 (251) Californium	**Es** 99 252.08 Einsteinium	**Fm** 100 257.10 Fermium	**Md** 101 (257) Mendelevium	**No** 102 259.10 Nobelium	**Lr** 103 262.11 Lawrencium

Government of Telangana

TELANGANA OPEN SCHOOL SOCIETY, HYDERABAD