ENGINEERING CHEMISTRY

FIRST SEMESTER

UNIT – I

Molecular Mass, Equivalent Mass, Acids and Bases and Chemical Bonding

1.1 MOLECULAR MASS 4 Hrs

Molecule- Molecular formula- Molecular Mass- Mole- Definition-Simple calculations- Avogadro's Hypothesis- Application- Relationship between Molecular Mass and Vapour Density. Gram Molecular Volume-Definition- Avogadro's Number-Definition- Simple Problems.

1.2 EQUIVALENT MASS 2 Hrs

Equivalent Mass & Gram Equivalent Mass- Definition- Determination of Equivalent Mass by Oxide Method (Direct Method)- Simple Problems.

1.3 ACIDS AND BASES 5 Hrs

Theories of Acids and bases-Arrhenius Theory - Lowry- Bronsted Theory - Lewis theory - Advantages of Lewis theory. Definition of pH & pOH. Numerical problems – Indicators - Definition –Acid-Base concept of Indicators (Basic ideas) - Buffer solution- definition-types and examples. Application of pH in industries- Electronic Concept of Oxidation and Reduction- Definition- Example.

1.4 CHEMICAL BONDING 3 Hrs

Definition-Ionic bonding-Formation of NaCl - Covalent bonding-formation of NH_3 – Coordinate bonding- formation of NH_4+ ion - Metallic bonding - Electron sea model.

UNIT-II

SOLUTION, TECHNOLOGY OF WATER AND SOLID STATE

2.1 SOLUTION 4 Hrs

Definition- Methods of Expressing Concentration of a Solution: Molarity, Molality, Normality, Mole fraction, Percentage, Mass- Simple Problems.

2.2 TECHNOLOGY OF WATER 7 Hrs

Sources-depletion of underground water-reasons-rainwater harvesting.

(Basic ideas)-advantages-hard and soft water-carbonate, non - carbonate hardness-methods of expressing hardness-mg/lit, ppm-simple problems-Estimation of total hardness by EDTA method-problems involving total, carbonate, non-carbonate hardness in ppm-softening of hard water ion- Exchange method, Reverse Osmosis method -standards of drinking water-Municipal water supply-purification (sedimentation, filtration and sterilization)-Disadvantages of hard water in boilers -Scale formation, Corrosion of boiler metal, Caustic Embrittlement - Priming and Foaming.

2.3 SOLID STATE 3 Hrs

Structure of Solids- Definition and examples for ionic, Molecular, Covalent and Metallic solids- Unit cell- bcc, fcc and hcp packing of metals –examples and properties reflected by the packing of atoms. (no numerical problems)

UNIT III

COLLOIDS, NANO PARTICLES AND PHOTO CHEMISTRY

3.1 COLLOIDS 5Hrs

Definition- sols-True solution and Colloidal solution- differences-Types-Lyophilic & Lyophobic sols- Differences.- Properties- Tyndall effect, Brownian movement, Electrophoresis, Coagulation – Industrial applications- Smoke Precipitation - Cottrell's method, Purification of water, Cleaning action of soap, tanning of leather and sewage disposal

3.2 NANO PARTICLES 2Hrs

Definition- Area of application - Medicine, Electronics and biomaterials.

3.3 PHOTOCHEMISTRY 7Hrs

Introduction-Important terms- charge transfer, electronic energy migration, emission, Excited state, Frequency, Ground state, Fluorescence, Phosphorescence, Chemiluminescence - photo electric cell- photo emission cell- photo synthesis-general chemical reactions-chlorophyll and accessory pigents - Mechanism of light reactions-Dark reaction-photosynthesis and acid rain.

UNIT - IV

ELECTRO CHEMISTRY, CELL AND BATTERIES

4.1 ELECTRO CHEMISTRY 5Hrs

Electrolytes- Strong and weak electrolytes-Definition- examples. Electrolysis- Definition- Mechanism- Industrial applications of electrolysis –electro-plating -Preparation of surface- factors affecting the stability of the coating - Chrome plating - electro less plating.- Definition- advantages over electroplating- applications.

4.2 CELL 4Hrs

Electro chemical cell- Single electrode potential- Galvanic cell- Formation - Daniel cell. Electrochemical series- Concentration Cell.

4.3 STORAGE BATTERIES 5Hrs

Primary, Secondary and fuel batteries. Primary battery -definition and example - Dry cell- construction and working. Secondary battery – definition- example- Lead acid storage cell -construction and working. Nickel/Cadmium battery – construction and working. Fuel cell- definition example H_2/O_2 fuel cell [green fuel cell] - solar cells.

UNIT V

CORROSION ENGINEERING

5.1 CORROSION 4 Hrs

Definition- types - Theories of corrosion- Galvanic cell Formation theory- Differential aeration theory. - Factors influencing rate of corrosion.

5.2 METHODS OF PREVENTION OF CORROSION 5 Hrs

Control of Environment, Alloying, Surface coating- Metal coating- Electroplating, Galvanization and Tinning- Inorganic coating- Anodizing and Phosphating- Cathodic protection Sacrificial anode and Impressed voltage methods.

5.2 ORGANIC COATING 5 Hrs

Paints-definition- components of paints and their functions- Varnish- Definition-types-Preparation of oil varnish-Difference between paint & varnish-Special paints- Luminescent, heat resistant, fire retardant, Anti-fouling paints - cement paint, aluminium paint & distemper. Dyes-Acid dyes-basic dyes -Mordant dyes -Definition only (No equations)

SECOND SEMESTER

UNIT I

ENVIRONMENTAL CHEMISTRY

1.1 AIR POLLUTION 4 Hrs

Definition- Pollutants (SO2, H2S, HF, CO, Dust) -harmful effects -Acid rain – formation - Harmful effects-Green House effect- causes- Global Warming - Harmful effects - Ozone layer- importance - causes for depletion of Ozone layer (No equations)- effects of Ozone layer depletion -Control of air Pollution.

1.2 WATER POLLUTION 4 Hrs

Causes – (Sewage, effluents, algae microorganisms)- Harmful effects, sewerage - Industrial effluents- harmful effects of heavy metal ions (metals like Lead, Cadmium, Zinc and Copper) – treatment – Eutrophication - Definition and effects – Carcinogenic wastes, pesticides, Insecticides - Health problems.

1.3 SOLID WASTE MANAGEMENT 2 Hrs

Solid wastes-definition-problems-types of wastes- methods of disposal (land fill-incineration) - recycling –advantages of recycling (Basic ideas)

1.4 GREEN CHEMISTRY 1 Hrs

Definition- Goals of green Chemistry (Basic ideas).

UNIT - II

FUELS, ROCKET PROPELLANTS AND COMBUSTION

2.1 FUELS 6 Hrs

Definition-Calorific value- classification, solid fuels-wood-coal -varieties of coal-composition-specific uses-liquid fuels-petroleum-fractional distillation -Fractions and uses, Cracking (concept only). Liquid Hydrogen as fuel- gaseous fuels-preparation and specific uses of producer gas, water gas, biogas-LPG- composition and uses. Advantages of gaseous fuels.

2.2 ROCKET PROPELLANTS 2Hrs

Definition- Essential characteristics- classifications of propellants-brief account of solid & liquid propellants with example.

2.3 COMBUSTION 4Hrs

Combustion of fuels- Definition- combustion calculation by mass (for solid and liquid fuels)- combustion calculation of gaseous fuels-stoichiometric calculations-Volume of air required-excess air- Flue gas-Flue gas analysis- Orsat Apparatus-simple numerical problems.

UNIT III

EXTRACTION OF METALS, POWDER METALLURGY, ALLOYS AND ABRASIVES

3.1 EXTRACTION OF METALS 2Hrs

Extraction of Tungsten and Titanium-uses.

3.2 POWDER METALLURGY 2Hrs

Definition – Metal Powder- Preparation of Metal Powder- Atomisation-Reduction of Metal Oxide-Applications of Powder Metallurgy.

3.3 ALLOYS 4Hrs

Definition- purpose of Alloying- Non- Ferrous alloys - Definition-Composition and uses of – Nickel alloys- Nichrome, Locanel - Copper alloys- Brass - Dutch metal, Cartridge brass, German silver- Bronze-coinage bronze, Gun metal. Aluminium alloys- Duralumin, Magnalumin.

3.3 ABRASIVES 3Hrs

Definition -classification-hardness in moh's scale - Natural abrasives-Diamond, Corundum, Emery, and Garnet. - Synthetic abrasives-Carborundum – Boron carbide manufacture-Properties and uses.

UNIT IV

COMPOSITE MATERIALS, CERAMICS, REFRACTORIES AND LUBRICANTS

4.1 COMPOSITE MATERIALS 3 Hrs

Definition-advantages over metals and polymers-general applications – types - fibre reinforced composites- particulate composites-layered composites.(basic ideas and specific applications)

4.2 CERAMICS 3 Hrs

White pottery- Definition-manufacture of White pottery-uses-glazing - definition -purpose-method-salt glazing.

4.3 REFRACTORIES 3 Hrs

Definition-requirements-classification with examples and uses of fireclay bricks, Alumina bricks and silica bricks.

4.4 LUBRICANTS 2 Hrs

Definition- Characteristics of Lubricants- Types of Lubricants: Solid, Semisolid and liquid Lubricants.

UNIT-V

POLYMERS

5.1 PLASTICS 6 Hrs

Polymerization-types of polymerization-Addition polymerization-formation of polythene-condensation polymerization-formation of phenol formaldehyde-types of plastics-thermoplastics & thermo set plastics-Differences-Mechanical properties-Advantages over traditional materials, (wood &metal)-specific uses of Bakelite, PVC, Nylon & urea formaldehyde resin-reinforced or filled plastics-definitions- advantages-applications-polymers in surgery-biomaterial-definition-Biomedical uses of polyurethane, PVC, polypropylene, polyethylene.

5.2 RUBBER 5 Hrs

Natural rubber-preparation from latex –defects of natural rubber compounding-ingredients & their functions-vulcanization-purpose-synthetic rubber-Buna-S. Thiokol, Neoprene (Preparation & specific uses only-no equation) reclaimed rubber- definition-process-properties-uses.

FIRST SEMESTER

Contents

SECOND SEMESTER

Contents

UNIT – I

MOLECULAR MASS, EQUIVALENT MASS, ACIDS AND BASES AND CHEMICAL BONDING

1.1. MOLECULAR MASS

1.1.1 INTRODUCTION

The universe is made up of matter. The matter is anything that occupies space and has mass or weight. The matter is made up of fundamental particles called elements. To further understand chemistry the basic concepts are essential.

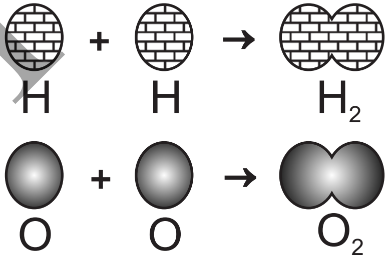
Atom

An Atom is the smallest particle of an element which can take part in chemical reactions. It may or may not be capable of independent existence.

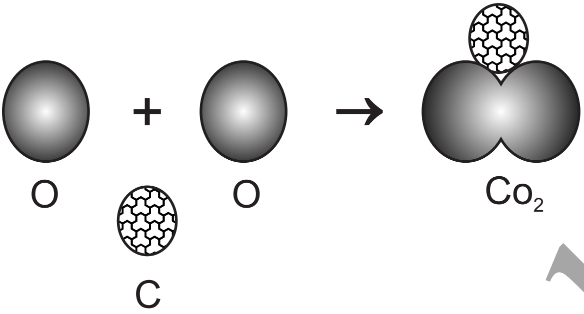
Molecule

A Molecule is defined as the smallest particle of matter (element or compound) which can exist independently. It may be made up of two or more atoms of the same or different elements. For example

Molecules of Chlorine, Oxygen, Nitrogen contain only two atoms.



Molecules of sulphur dioxide, carbon dioxide etc., are built up by more than two atoms and involve the combinations of atoms of different elements. Thus in the molecule of carbon di oxide, one atom of carbon and two atoms of oxygen have united.



1.1.2 Molecular Formula

Molecular formula is the short form of symbolic representation of one molecule of an element or a compound.

Example: Molecular formula of Oxygen is O_2 (element).
Molecular formula of Water is H_2O (compound)

Significance of molecular formula

1. Molecular formula represents one molecule of an element or a compound.
2. It shows the elements present in one molecule.
3. It gives the number of atoms of each element present in one molecule.
4. It helps to calculate the molecular mass.
5. It gives the ratio between the masses of the elements to form the substances.

1.1.3 Molecular Mass

Molecular mass of an element or a compound is the ratio between the mass of one molecule of the element or the compound and the mass of 1/12 part of a carbon Atom.

$$\text{Molecular Mass of an element or a compound} = \frac{\text{Mass of one molecule of an element or a compound}}{\text{1/12 part by mass of a carbon atom}}$$

Calculation of Molecular Mass

Molecular mass can be calculated as the sum of total atomic mass of each element present in one molecule of an element or a compound.

Example

Molecular mass of O_2 = Atomic mass x No of atoms

= 16 x 2 = 32

Molecular mass of NH_3 = (14 x 1) + (1 x 3) = 17

1.1.4 Mole

If the molecular mass is expressed in grams, then it is called gram molecular mass or mole.

$$\text{No of moles} = \frac{\text{Mass in gram}}{\text{Molecular mass}}$$

Example

Molecular mass of O_2 = 32

Gram molecular mass of O_2(or)

1 mole of O_2 = 32 g

Problem: 1

How many moles are represented by 4.4 g. of CO_2?

Atomic mass of Carbon = 12

Atomic mass of Oxygen = 16

Molecular mass of CO_2 = (12 x 1) + (16 x 2)

= 12 + 32 = 44

$$\text{No of moles} = \frac{\text{Mass}}{\text{Molecular mass}}$$

$$\text{Thus, no of moles of } CO_2 = \frac{4.4}{44} = 0.1$$

Problem: 2

How many moles are present in 8.5g of Ammonia?

Atomic mass of Nitrogen = 14

Atomic mass of Hydrogen = 1

Molecular mass of Ammonia (NH3) = (14 x 1) + (1 x 3) = 17

$$\text{No of moles} = \frac{\text{Mass}}{\text{Molecular mass}}$$

$$= \frac{8.5}{17} = 0.5$$

Thus, no. of moles of NH_3 = 0.5

Problem: 3

How many grams of SO_2 are present in 0.4 moles of SO_2?

$$\text{Atomic mass of Sulphur} = 32$$

$$\text{Atomic mass of Oxygen} = 16$$

$$\text{Molecular mass of } SO_2 = (32 \times 1) + (2 \times 16)$$

$$= 64$$

$$\text{Gram molecular mass of } SO_2 = 64g$$

$$1 \text{ mole of } SO_2 = 64g$$

$$\therefore 0.4 \text{ moles} = 64 \times 0.4$$

$$= \mathbf{25.6g.}$$

Problem: 4

What is the mass of 3 gram atoms of Bromine?

1 gram atom of Bromine = 80g

$\therefore$ 3 gram atom of Bromine = 80 x 3 = 240g.

Problem: 5

How many moles of Carbon atoms are present in three moles of C_3H_8?

1 mole of C_3H_8 has 3 moles of carbon

$\therefore$ 3 moles of C_3H_8 will have 9 moles of carbon atoms.

1.1.5 Avogadro's Hypothesis

Avogadro's Hypothesis states that “Equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules”

Applications of Avogadro's Hypothesis

1. It helps in deduction of the relationship between vapour density and molecular mass of gas.
2. Avogadro's Hypothesis helps in determining the relationship between weight and volume of gases.
3. It enables us to calculate the density of a gas.
4. Avogadro's Hypothesis has established the truth about Dalton's atomic theory by making a clear distinction between atoms and molecules.
5. Avogadro's Hypothesis helps in determining the atomicity of gases.
6. It helps in the calculation of molecular mass of hydrocarbons.

1.1.6 Relationship between molecular mass and vapour density

Vapour density

Vapour density of a gas is the ratio between the mass of certain volume of the gas and the mass of the same volume of hydrogen under the same conditions of temperature and pressure.

$$\text{Vapour Density} = \frac{\text{Mass of certain volume of a gas at S.T.P}}{\text{Mass of same volume of hydrogen at S.T.P}}$$

Let there be 'n' molecules in certain volume of a gas

$$\text{Vapour Density} = \frac{\text{Mass of n molecules of a gas}}{\text{Mass of n molecules of hydrogen}}$$

$$\text{Vapour Density} = \frac{\text{Mass of 1 molecule of a gas}}{\text{Mass of 1 molecule of hydrogen}}$$

Let n = 1

Mass of 1 molecule of hydrogen = 2

$$\text{Vapour Density} = \frac{\text{Mass of 1molecule of a gas}}{2}$$

2 x vapour density = Mass of one molecule of a gas

Therefore, Molecular mass = 2 x Vapour Density

1.1.7 Molar volume

Molar volume is the volume occupied by one gram molecular mass or one mole of a gas at S.T.P. Molar volume of the gas at S.T.P is 22.4 litres, i.e. the molar volume is the same for all gases at S.T.P and it is equal to 22.4 litres.

1.1.8 Avogadro's number

According to Avogadro's hypothesis,

I) one molecular mass (i.e. one mole) of every gas occupies 22.4 litres at S.T.P (or N.T.P)

ii) equal volumes of all gases at S.T.P contain equal number of molecules.

Hence it follows that 1 mole of every gas contains the same number of molecules. This number is called the Avogadro's number or Avogadro's Constant. It is denoted by **N**. It has been found to be equal to 6.023×10^{23}. It can be defined as “the no of atoms or molecules present in one mole of an element or a compound respectively”.

Example

One mole of CO_2 = 44g

44 g of CO_2 contains 6.023×10^{23} molecules.

One molar volume of CO_2 = 22.4 litres

22.4 litres of CO_2 contains 6.023×10^{23} molecules

One mole of H_2O = 18g

18 g of H_2O contains 6.023×10^{23} molecules

One mole of Oxygen atom = 16g

16 g of O_2 contains = 6.023×10^{23} atoms

Problem: 1

How many molecules are present in 49g of H_2SO_4 ?

One mole of H_2SO_4 = $(2 \times 1) + (1 \times 32) + (4 \times 16)$

= $2 + 32 + 64 = 98$g

No of molecules in 98g of H_2SO_4 = 6.023×10^{23}

No of molecules in 49g of H_2SO_4 = $\dfrac{6.023 \times 10^{23} \times 49}{98}$

= 3.0115×10^{23}

Problem: 2

Calculate the number of molecules present in 1.12 litres of O_2 at S.T.P?

One molar volume of O_2 at S.T.P = 22.4 litres

No of molecules in 22.4 litres at S.T.P = 6.023×10^{23}

No of molecules in 1.12 litres at S.T.P = $\dfrac{6.023 \times 10^{23} \times 1.12}{22.4}$

= $\mathbf{3.0115 \times 10^{22}}$

Problem: 3

Calculate the mass of an atom of Carbon?

One mole of Carbon atom = 12g

Mass of 6.023×10^{23} atoms of Carbon = 12g

Mass of one atom of Carbon = $\dfrac{12}{6.023 \times 10^{23}}$

= $\mathbf{1.992 \times 10^{-23}}$ **g.**

Problem: 4

What is the mass of a molecule of Ammonia?

One mole of Ammonia (NH_3) = 17g

Mass of 6.023×10^{23} molecules of NH_3 = 17g

Mass of one molecule of NH_3 $= \frac{17}{6.023 \times 10^{23}}$

$= \mathbf{2.882 \times 10^{-23}}$ **g.**

Problem: 5

Calculate the number of atoms present in 64 g of O_2?

One mole of Oxygen atom =` 16g

No of atoms in 16g of O_2 $= 6.023 \times 10^{23}$

No of atoms in 64g of O_2 $= \frac{6.023 \times 10^{23} \times 64}{16}$

$= \mathbf{24.092 \times 10^{23}}$

SUMMARY

In this lesson, the students have learnt some of the details about atom, molecule, concept of molecular mass, Avogadro's hypothesis and Avogadro's number.

Exercise Problems

1. Calculate the molecular mass for the following
   - i) Sulphuric acid (H_2SO_4)
   - ii) Water (H_2O)
   - iii) Potassium permanganate ($KMnO_4$)
   - iv) Carbondioxide (CO_2)
   - v) Sodium carbonate (Na_2CO_3)
2. How many moles are present in the following
   - i) 220 g of carbon di oxide
   - ii) 72 g of water
   - iii) 196g of sulphuric acid
3. Find the mass of the following
   - i) 3 moles of ammonia
   - ii) 2.5 moles of sulphuric acid
   - iii) 1.5 moles of carbondioxide

4. Find the volume occupied by the following
   - i) 16g of oxygen at NTP
   - ii) 44g of carbondioxide at NTP
   - iii) 28g of nitrogen at NTP
5. Find the mass of the follwing
   - i) 1000ml of CO_2 at NTP
   - ii) 2 litres of ammonia NTP
   - iii) 96g of oxygen at NTP
6. How many molecules are present in the following?
   - i) 4g of Nitrogen
   - ii) 16g of Oxygen
   - iii) 32g of Methane
7. What is the mass of the following?
   - i) One molecule of CO_2
   - ii) One molecule of H_2O
8. Which one is heavier in the following at NTP?
   - i) 1 litre of CO_2 (or) 2 litres of NH_3
   - ii) 3 moles of H_2O (or) 1 mole of H_2SO_4

QUESTIONS

Part- A

1. Define molecular mass of a substance.
2. Define mole
3. What is molecular formula?
4. State Avogadro's hypothesis.
5. What is known as vapour density?
6. Define gram molecular volume.
7. Define Avogadro's number.

Part – B

1. What are the applications of Avogadro's hypothesis?
2. Derive the relationship between vapour density and molecular mass.

TEST YOUR UNDERSTANDING

Calculate the molecular mass of Washing soda ($Na_2CO_3.10H_2O$) and Blue vitriol ($CuSO_4.5H_2O$)

1.2. EQUIVALENT MASS

1.2.1 Introduction:-

Elements combine among themselves in a definite ratio by mass to form compounds. The term equivalent mass expresses the combining capacity of an element or a compound in terms of mass with reference to some standard.

Consider the formation of hydrogen chloride.

$$H + Cl \rightarrow HCl$$

Atomic mass 1.008 35.45.

Here the mass of chlorine combining with 1.008 g of hydrogen is 35.45g.

Consider the formation of water

$$2H + O \rightarrow H_2O.$$

2 x 1.008 16

Here the mass of oxygen combining with 1.008g of hydrogen is 8g.

In the above two cases 35.45g of chlorine and 8g of oxygen are equivalent as they combine with the same mass of H_2 i.e., 1.008g.

Expressed without units, the numbers 35.45 and 8 are the equivalent masses of chlorine & oxygen respectively. So, 1.008 parts by mass of hydrogen is taken as a standard. Certain metals which do not combine with hydrogen displace it from dilute acids. Then the equivalent mass is the number of parts by mass of the metal which displaces 1.008 parts by mass of hydrogen.

Many metals do not either combine with hydrogen or displace hydrogen from acids. But almost all elements combine with oxygen and chlorine. Hence 8 parts by mass of oxygen and 35.45 parts by mass of chlorine are also chosen as standards.

1.2.2 Definition

Equivalent Mass of an element is the number of parts by mass of the element which combines with or displaces 1.008 parts by mass of hydrogen or 8 parts by mass of oxygen or 35.45 parts by mass of chlorine or one equivalent mass of any other element.

When the equivalent mass of sodium is 23, it means that 23 parts by mass of sodium combines with or displaces 1.008 parts by mass of H_2 or 8 parts by mass of O_2 or 35.45 parts by mass of Cl_2.

Relationship between Atomic Mass and Equivalent Mass

$$\text{Equivalent Mass} = \frac{\text{Atomic Mass}}{\text{Valency}}$$

1.2.3 Gram Equivalent Mass:

Equivalent mass is mere a number. When equivalent mass is expressed in grams, it is called gram equivalent mass or gram equivalent.

Example:

Equivalent mass of oxygen = 8
Gram Equivalent mass of oxygen = 8g.
In other words, 1 gram equivalent of oxygen = 8g
Therefore 3 grams equivalents of oxygen = 8 x 3 = 24g.

$$\therefore \text{No of gram equivalents} = \frac{\text{Mass}}{\text{Equivalent Mass}}$$

Problem 1:

How many gram equivalent mass are present in 36g of Magnesium?

Equivalent mass of Mg = 12.
Gram equivalent mass of Mg = 12g.
(i.e) 12g of Mg = 1 gram equivalent mass
$\therefore$ 36 g of Mg = 36/12 = 3 gram equivalents mass.

1.2.4 Determination of Equivalent mass

The equivalent mass of an element could be determined by displacement methods and combination methods. The following are the methods to determine the equivalent mass.

1. Hydrogen displacement method.
2. Oxide method.
3. Chloride method.
4. Metal displacement method.
5. Electrolysis method.

Oxide Method

There are two methods to determine the equivalent mass of substances by oxide method. They are direct oxidation and indirect oxidation methods. In these methods, a metal is converted into its oxide either directly or indirectly. The process of conversion of metal to its oxide is called "oxidation".

Direct Oxide Method

Principle:

A known mass of the metal is directly converted to its oxide by heating in air. From the mass of oxide formed, the mass of metal which combines with 8 parts by mass of oxygen is calculated and it gives the equivalent mass of the metal. This method is useful to determine the equivalent mass of elements like Magnesium and Calcium.

Procedure:

i) A clean dry crucible with lid is weighed (W_1g).

ii) A piece of the metal is placed in the crucible and weighed again (W_2g).

iii) The lid is kept slightly open and the crucible is heated.

iv) The metal burns to form the oxide.

v) When the metal is completely burnt, the crucible is allowed to cool to the room temperature.

vi) A drop of water is added and once again heated strongly.

vii) The crucible is allowed to cool in a dessicator and weighed. The heating and cooling are repeated until a constant mass (W_3g) is obtained.

Calculation

Mass of the empty crucible = W_1g.

Mass of the crucible + metal = W_2g.

Mass of the crucible + metal oxide = W_3g .

Mass of the metal = $(W_2 - W_1)$ g.

Mass of the oxygen combined = $(W_3 - W_2)$ g

$(W_3 - W_2)$ g of oxygen combines with = $(W_2 - W_1)$ g of metal.

8 g of oxygen combines with = $\dfrac{(W_2 - W_1)}{(W_3 - W_2)} \times 8$

Thus, equivalent mass of the metal, **E** $= \dfrac{(W_2 - W_1)}{(W_3 - W_2)} \times 8$

$$\text{Equivalent mass of metal} = \frac{\text{Mass of metal}}{\text{Mass of oxygen}} \times \text{Equivalent mass of oxygen}$$

PROBLEMS

Problem - 1

Calculate the number of gram equivalent of oxygen in 48 g of oxygen.

Mass of oxygen = 48g

Equivalent mass of oxygen = 8

$$\text{No. of gram equivalents of oxygen} = \frac{\text{mass}}{\text{Equivalent mass}} = \frac{48}{8} = 6$$

No. of gram equivalents of oxygen = 6

Problem - 2

What is the mass of 3 gram equivalents of chlorine ?

No of gram equivalents of chlorine = 3

Equivalent mass of chlorine = 35.45

Mass of 3 gram equivalents of chlorine = No of g equivalents x Equivalent mass

= 3 x 35.45

= 106.35.

Mass of 3 gram equivalents of chlorine = 106.35g.

Problem - 3

0.48 g of a metal was converted into its oxide by oxidation. The weight of metal oxide formed was 0.80g. Calculate the equivalent mass of the metal?

Weight of the metal oxide = 0.80g

Weight of metal = 0.48g

Weight of oxygen = (0.80 - 0.48) =0.32g

$$\text{Equivalent mass of metal} = \frac{\text{Mass of metal}}{\text{Mass of oxygen}} \times \text{Eq. mass of } O_2$$

$$= \frac{0.48}{0.32} \times 8 = 12$$

Equivalent mass of metal = 12.

Problem - 4

A metal oxide contains 17 % of oxygen. Find the equivalent mass of the metal?

Let the mass of metal oxide = 100g

Mass of oxygen = 17 g

Mass of metal = 83 g

$$\text{Equivalent mass of metal} = \frac{\text{Mass of metal}}{\text{Mass of oxygen}} \times 8$$

$$= \frac{83}{17} \times 8 = 39.06$$

Equivalent mass of metal = 39.06

SUMMARY

The students have learnt the concept of equivalent mass and the determination of equivalent mass of elements.

QUESTIONS

Part –A

1. Define equivalent mass of an element?
2. Define gram equivalent mass.
3. Calculate the number of gram equivalents of HCl in 80 g of it. (Eq.mass of HCl is 36.5).

Part –B

1. How is equivalent mass of a metal determined by oxide method?
2. When 1.986 g of a metal was oxidised 2.47 g of its oxide was obtained. Calculate the equivalent mass of the metal.
3. A metal oxide contains 63% of the metal. Find the equivalent mass of the metal?
4. 6g of the oxide of an element left 4.545g of the element on reduction. What is the equivalent mass of that element?
5. One gram of tin on treating with conc. HNO_3 and on heating gave 1.27 g of tin oxide. Calculate the equivalent mass of tin.

TEST YOUR UNDERSTANDING

Try to know the purpose of adding a drop of water to the metal oxide during the oxidation process.

1.3. ACIDS AND BASES

1.3.1 Introduction

Depending upon the ions produced in the solution, the substances are classified into acids and bases. The acidic and basic nature of matter is more essential to study the chemical reactions.

1.3.2 Acids

An acid is defined as a substance that gives hydrogen ions (H^+) in

$$HCl \rightleftarrows H^+ + Cl^-$$

$$HNO_3 \rightleftarrows H^+ + NO_3$$

aqueous solution.

Example

1.3.3 Bases

$$NaOH \rightleftarrows Na^+ + OH^-$$

$$KOH \rightleftarrows K^+ + OH$$

A base is defined as a substance that gives hydroxyl ions (OH^-) in aqueous solution.

Example

1.3.4 Theories Of Acids and Bases

The acidic and basic nature of substances can be easily explained by the following theories

1. Arrhenius theory
2. Lowry-Bronsted theory
3. Lewis theory.

$$HCl \rightleftarrows H^+ + Cl^-$$

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

(1) Arrhenious Theory (1827)

According to this theory, an acid is a substance that gives hydrogen ions in aqueous solution.

$$NaOH \rightleftarrows Na^+ + OH^-$$

$$Ca(OH)_2 \rightleftarrows Ca^{2+} + 2OH^-$$

A Base is a substance that gives hydroxyl ions in aqueous solution.

Strength of an acid (or) base depends upon the extent to give H^+ (or) OH^- during ionization.

Limitations

1. It is valid only in aqueous solution.
2. It is difficult to explain the basic properties of non-hydroxyl compounds like NH_3 and Na_2CO_3.

(2) Lowry-Bronsted Theory (1923) (Protonic concept)

An Acid is a substance which donates proton (H^+) to any other substance. Hence, it is a proton donor.

A Base is substance which accepts proton (H^+) from any other substance. Hence, it is a proton acceptor.

$$\begin{tikzcd}
\text{ACID} \arrow[r, shift left] \arrow[d] & H^+ + B^- \arrow[l, shift left] \arrow[d] \\
\text{Proton donor} & \text{Proton acceptor}
\end{tikzcd}$$

Drawbacks

1. It explains the acidic and basic characters of a substance only if a solvent like water is present.
2. It does not explain the neutralization of acidic oxides (CO_2,SO_2) by basic oxides (CaO, BaO) because there are no H^+ ions.

(3) Lewis Theory (G.N.LEWIS – 1923) (Electronic concept)

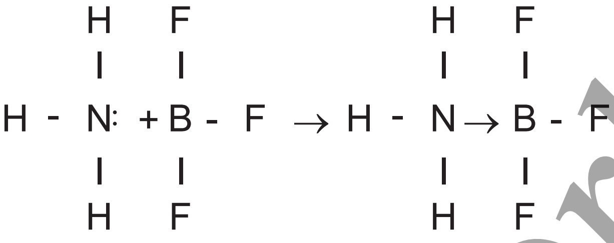
Lewis concept is known as electronic concept because it involves electron pair transfer during base formation.

According to this theory, an acid is s substance that accepts a pair of electrons. So, acid is an **electron pair acceptor**.

A base is a substance that donates a pair of electrons. So, base is an electron$^-$ **pair donor**.

$$H^+ + :\ddot{\underset{\cdot\cdot}{O}}-H^- \rightleftharpoons H\quad \ddot{\underset{\cdot\cdot}{O}}-H$$

ACID BASE



$$H-\underset{H}{\overset{H}{N}}: + \underset{F}{\overset{F}{B}}-F \rightarrow H-\underset{H}{\overset{H}{N}}\rightarrow\underset{F}{\overset{F}{B}}-F$$

BASE ACID

Here, OH^- and NH_3 donate pair of electrons. So, they are bases. H^+ and BF_3 accepts a pair of electrons. So, they are acids.

Advantages

1. It explains the acid base reactions by way of electron transfer.
2. It gives an idea about the acidic character of substances that do not contain hydrogen. The acidic nature of the following substances like BF_3, $FeCl_3$, $AlCl_3$ can be explained by this concept.
3. The neutralization of acidic oxides and basic oxides can also be explained by this concept.

$CaO: + SO_2 \rightarrow CaSO_3$
Acid Base

4. The concept can be easily understood.

1.3.5 Concept of pH and pOH (S.P.L Sorenson)

pH is a convenient way of expressing acidity or the concentration of H^+ in solution. It helps to avoid the use of large of negative power of10.

$$pH = -\log_{10}[H^+] = \log_{10}\frac{1}{[H^+]}$$

$$[H^+] = 10^{-pH}$$

Higher the concentration of H^+, lower will be the value of pH.

Definition

pH is defined as the negative logarithm to the base 10 of the hydrogen ion concentration $[H^+]$ in a solution.

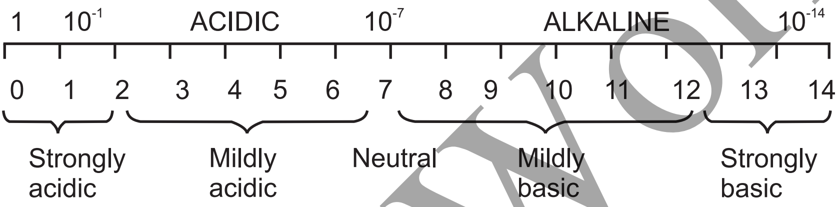
$$pH = -\log_{10}[H^+].$$

Similarly,

pOH is defined as the negative logarithm to the base 10 of the hydroxyl ion concentration $[OH^-]$ in a solution.

$$pOH = -\log_{10}[OH^-]$$

pH Scale



In a neutral aqueous solution

$[H^+].[OH^-] = 10^{-14}$ g ions/litre

Then,

$\log[H^+] + \log[OH^-] = \log 10^{-14} = -14.$

$-\log[H^+] - \log[OH^-] = 14.$

So,

$$pH + pOH = 14$$

Ionic product of water

The product of $[H^+]$ and $[OH^-]$ is known as ionic product of water. The value is 1×10^{-14}.

$K_W = [H^+].[OH^-]$

$= 1 \times 10^{-7} \times 1 \times 10^{-7}$

$= 1 \times 10^{-14}$ g ions/litre

Points to be remembered

1. For pure water, pH and pOH -value is 7
2. The sum of pH and pOH is equal to 14

   pH + pOH = 14.

3. Ionic product of water is 1×10^{-14}.
4. pH = < 7 Acid

   pH = 7 Neutral

   pH = >7 Base

PROBLEMS

1. Calculate the pH of a solution whose hydrogen ion concentration is 4.6×10^{-4} g- ions/litre.

$[H^+] = 4.6 \times 10^{-4}$ g ions/litre

$pH = -\log_{10}[H^+]$

$= -\log_{10}[4.6 \times 10^{-4}]$

$pH = 3.3373$

2. Calculate the pH of 0.003M HCl solution.

The hydrogen ion concentration is 0.003 M

$pH = -\log_{10}[H^+]$

$= -\log_{10}[1 \times 10^{-3}]$

$pH = 3.$

3. Calculate the hydrogen ion concentration of a solution whose pH is 4.45.

$pH = 4.45$

$pH = -\log_{10}[H^+]$

$4.45 = -\log_{10}[H^+]$

$\log_{10}[H^+] = -4.45$

$[H^+]$ = Antilog of -4.45

$[H^+] = 3.548 \times 10^{-5}$ gram ions/litre

4. If the pH of a solution is 5.25, calculate the hydrogen ion concentration of the solution.

$pH = 5.25$

$pH = -\log_{10}[H^+]$

$5.25 = -\log_{10}[H^+]$

$\log[H^+] = -5.25$

$[H^+)$ = antilog of -5.25

$= 5.623 \times 10^{-6}$ g ions/litre.

5. Calculate the pH of 0.1 M NaOH solution.

0.1 M NaOH means

= 0.1g ions/litre.

pOH = $-\log_{10}[0H^-]$

= $-\log_{10}[0.1]$

= $-\log_{10}[1 \times 10^{-1}]$

= $-[-1]$

pOH of NaOH = 1.

pH + pOH = 14

pH + 1 = 14

pH = 14 – 1 = 13

1.3.5 Indicators

An indicator is a substance which has one colour in acid solution and a different colour in alkaline solution.

Example:

Phenolphthalein
Methyl Orange
Methyl Red

Indicators are used in titrations to determine the end point. During the acid-base titration, if certain pH is reached, the indicator changes its colour.

Indicator	**Colour Change**			**pH Range**
Phenolphthalein	Colourless (Acid)	to	Pink (Base)	8 - 9.5
Litmus	Red (Acid)	to	Blue (Base)	5.5 – 7.5
Methyl Orange	Red (Acid)	to	Yellow (Base)	4.5 – 6.5
Methyl Red	Pink (Acid)	to	Yellow (Base)	3.5 – 4.5
Phenol Red	Yellow (Acid)	to	Red (Base)	6.8 – 8.4

It is very clear from the study of the above table that phenolphthalein becomes colourless when pH is 8. This indicates that the solutions is acidic. Methyl orange shows a yellow alkali colour when pH is 4.5. This indicates that the solution is acidic. Therefore, selection of indicators is more important for acid-base titrations. It depends upon the nature of acid and the base involved in the titrations.

1.3.7 Buffer solution

Maintaining of pH is more important in many industries. For that purpose ,buffer solution is needed. Buffer solution is one which maintains a constant pH even when small amount of acid or alkali are added to the solution.

Buffer solution is classified into two types.

1. Acidic buffer
2. Basic buffer

Acidic buffer is obtained by mixing a weak acid with a salt of the same weak acid .It maintains the pH between 0 and 7

Example : Mixture of acetic acid and sodium acetate

CH_3COOH	+	CH_3COONa
Acetic acid		sodium acetate

Basic buffer is obtained by mixing a weak base with a salt of the same weak base. It maintains the pH between 7and 14.

Example: Mixture of ammonium hydroxide and ammonium chloride

NH_4OH	+	NH_4Cl
Ammonium Hydroxide		Ammonium chloride.

1.3.8 Industrial Applications of pH

Maintenance of pH is more important in many industries to get good yield and the quality. pH plays a vital role in industries.

1. Textile Industry:

In textile industry, the pH of dye has to be maintained otherwise dyeing will not be uniform and permanent.

2. Sugar Industry:

The pH of the sugarcane juice should be maintained at 7. Otherwise crystallization of sugar will not be better .The quality and yield will be poor.

3. Leather Industry:

The pH of solution for Tanning purpose should be maintained between 2.5 to 3.5. If not, the hides will putrify.

4. The pH of liquid chlorine is more effective in the pH range of 5 to 6.5 in water treatment.
5. The pH of the soil should be maintained for plants to grow and to get better yield.
6. The pH of human blood is 7.2. If not, it causes coagulation of blood which leads to death.
7. The pH of a gastric juice is 1.4 to 2. Otherwise it may cause vomiting and stomach disorder.
8. Here are the industries where pH plays a vital role: Paper industry, Alcohol industry, Medicine and Chemical industry, Food production industry etc.

1.3.9 Electronic concept of Oxidation and Reduction

By electronic concept, the oxidation and reduction can be explained as below.

Oxidation

Oxidation is a process that involves removal of electrons.

Example

$$Na \xrightarrow{-1e^-} Na^+$$

$$K \xrightarrow{-1e^-} K^+$$

$$H \xrightarrow{-1e^-} H^+$$

Here Na, K and H are oxidised into Na^+, K^+ and H^+ respectively.

Reduction

Reduction is a process that involves addition of electrons.

Example

$$Cl \xrightarrow{+1e^-} Cl^-$$

$$F \xrightarrow{+1e^-} F^-$$

$$Br \xrightarrow{+1e^-} Br^-$$

Here Cl, F and Br are reduced into Cl^-, F^- and Br^- respectively.

SUMMARY

In this chapter, Students have understood the acidic and basic nature of substances based on their electronic configuration which is a fundamental property. Students have also learnt the importance of pH in various fields.

QUESTIONS

Part-A

1. What is Arrhenius theory of acids and bases?
2. What is Lowry- Bronsted theory of acids and bases?
3. What is Lewis theory of acids and bases?
4. Define pH?
5. Define pOH?
6. What is ionic product of water?
7. What is an Indicator?
8. What is a Buffer solution?
9. Give any two examples for indicators?

Part-B

1. Explain the Lowry- Bronsted theory of acids and bases with a suitable example.
2. Explain the Lewis concept of acids and bases with examples.Mention its advantages also.
3. Define pH. Calculate the pH of a solution whose Hydrogen ion concentration is 1×10^{-6} gramions / litre.
4. Write a note on indicators.
5. Write a note on applications of pH in industries.
6. Explain oxidation and reduction by electronic concept.

PROBLEMS

1. The hydrogen ion concentration of a solution is 2×10^{-4} gramions/litre Calculate the pH of the solution.
2. The hydroxyl ion concentration of a solution is 1×10^{-9} gram ion/litre. Calculate the pH of the solution.
3. The pH of a solution is 4.28.Calculate the hydrogen ion concentration of the solution.

4. The pH of a solution is 11.5. Calculate the hydrogen ion concentration of the solution.

TEST YOUR UNDERSTANDING

Try to apply the Lewis theory and explain the following compounds as acid or base.

$AlCl_{3}$, $ZnCl_2$

1.4. CHEMICAL BONDING

1.4.1 Introduction

When two atoms in a molecule strongly tend to remain together, they are said to be in chemical bonding with each other. In other words, it is said that a chemical bond has been established between the two atoms.

Definition

"A chemical bond may be defined as an attractive force which holds together the constituent atoms in a molecule"

According to Kossel and G.N.Lewis (1916) who put forward the octet theory of valency, assumed that all atoms have a tendency to acquire a stable grouping of 2 or 8 valence electrons as the elements in the zero group (Noble gases). Thus it may be concluded that it is the tendency of the atoms to acquire a stable configuration or to complete their outermost orbit which is the cause of the chemical combination between them.

1.4.2 Types of Bonding

(I) Ionic bond (or) Electrovalent bond or Polar bond
(ii) Covalent bond or Non-Polar bond
(iii) Co-ordinate covalent bond or Dative bond
(iv) Metallic bond.

(1) Ionic bond

This type of bond is formed as a result of the complete transfer of one or more electrons from one atom to other.

This bond is generally present in inorganic compounds

Example : Formation of Sodium Chloride

Explanation:

The atomic number of sodium is 11.

The electronic configuration is $1s^2, 2s^2, 2p^6, 3s^1$(2,8,1).

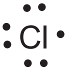
The electron dot formula is Na•

Sodium has only one electron in its outermost orbital.

The atomic number of chlorine is 17.

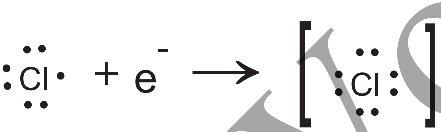
The electronic configuration is $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$ (2,8,7)

The electron dot formula is

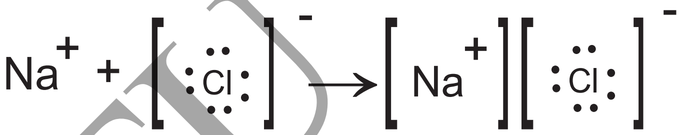


Sodium has one electron in excess of the stable Neon configuration (2,8). While chlorine is one electron short of the stable Argon configuration (2,8,8).

$$\dot{\mathrm{Na}} \longrightarrow \mathrm{Na}^+ + e^-$$



By transferring one electron to chlorine, sodium acquires a unit positive charge. The chlorine atom after gaining one electron acquires a unit negative charge.



These charged ions are held together by electrostatic force of attraction and form a neutral molecule of sodium chloride.

Compounds formed in this way are called electrovalent or ionic compounds and the bond is called Ionic bond or electrovalent bond.

(2) Covalent bond:

This type of bond is formed by the **mutual sharing** of a pair of electrons between two atoms. The shared electrons are contributed by **both** the atoms. The covalent bond is indicated by a line called 'single bond.(-).'

Example : Formation of Ammonia (NH_3)

Explanation :

The atomic number of Nitrogen is 7.

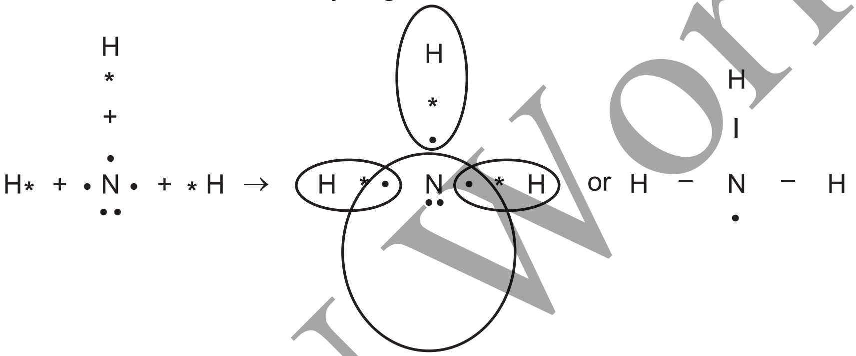
The electronic configuration $1s^2, 2s^2, 2p^3$.

The electron dot formula of Nitrogen is

The atomic number of Hydrogen is 1

The electronic configuration is $1s^1$.

The electron dot formula of hydrogen is



To get stable electronic configuration, Nitrogen shares its three electrons with electrons of 3 Hydrogen atoms.

Thus Ammonia Molecule is formed by 3 covalent bonds.

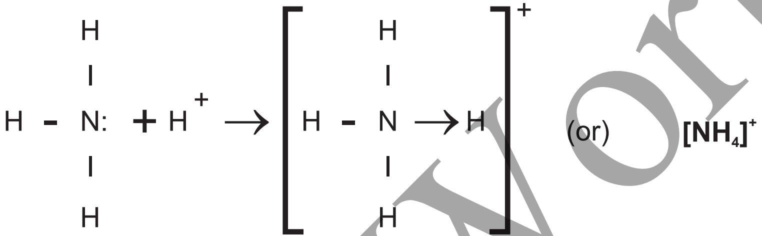
(3) Co-ordinate covalent bond

It is yet another type of linkage by virtue of which atoms acquire a stable configuration. Both transfer as well as sharing of electrons is involved in this mode of bond formation. The “shared pair” of electrons is supplied by one atom only and the other atom simply takes part in sharing. Thus “co-ordinate linkage is one in which the electron pair is contributed by one atom only and the sharing is done by both combining atoms”. The atom which provides the shared pair of electrons (called lone pair) is termed the **donor** and the atom which accepts this pair for the purpose of forming the molecule is called the **acceptor** atom. The co-ordinate linkage is shown by an arrow mark (→). The direction of the arrow points to the acceptor atom.

Example : Formation of Ammonium Ion $[NH_4]^+$

Explanation:

When Ammonia (NH_3) reacts with Hydrogen ion (H^+), Nitrogen of Ammonia donates its unshared lone pair of electrons to Hydrogen ion which needs two electrons to get stable configuration. [Thus the pair of electrons is shared between nitrogen atom & hydrogen ion]. The donor atom which contributes its lone pair becomes positive and the acceptor atom becomes negative. The co-ordinate linkage is also called semi-polar linkage.



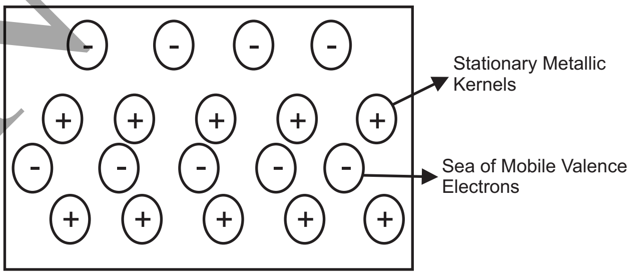
The Ammonium ion is formed as follows.

(4) Metallic Bonding: (Electron Sea Model)

Metallic bond may be defined as the force which binds metal kernels to a number of electrons within its sphere of reference. (The atom without valence electrons is called kernal).

Explanation

In every metal atom there can be a complete free movement of valence electrons in the vacant valence orbits around the nucleus. In other words the valence electrons can move from one kernel to another in the metallic crystal. As a result there may be number of positively charged



Structure of Metallic crystal

kernels in the metallic crystal. Therefore a metal crystal consists of an assembling of positively charged kernels immersed in a sea of mobile valance electrons. The positively charged kernels are stationary. There is considerable electrostatic force of attraction between positively charged kernels and the negatively charged mobile valence electrons. This force of attraction between the metal atom is called metallic bond.

SUMMARY

In this chapter, students have studied the different types of bonding including the nature of bonding in metals.

QUESTIONS

Part—A

1. What are the types of bonding?
2. Define ionic bond.
3. Define covalent bond.
4. Define co-ordinate covalent bond.
5. What is metallic bond?

Part—B

1. Explain electrovalent bond with an example.
2. Explain covalent bond with an example.
3. Explain co-ordinate covalent bond with an example.
4. Explain metallic bond by electron sea model theory.
5. Predict the nature of the bond in the following and give explanation.

   i) NaCl II) NH_3 III) NH_4^+

TEST YOUR UNDERSTANDING

Try to find the type of bonds in CO_2 and SO_4^{2-}

UNIT II

SOLUTIONS, TECHNOLOGY OF WATER AND SOLID STATE

2.1 SOLUTIONS

2.1.1 Introduction

In this chapter we are going to study about true solutions and the different modes of expressing the concentrations of chemical solutions. Study of different units used to measure the concentration of solutions is essential, since in various estimations of chemicals in different fields these concentration units are employed.

Definition

Solution is a homogeneous mixture of solute and solvent whose proportion varies within certain limits.

Solute

Solute is a substance which is present in small quantity in a solution.

Solvent

Solvent is a substance which is present in large quantity in a solution.

Units for measuring concentration of solutions

1. Percentage by mass
2. Normality
3. Molarity
4. Molality
5. Mole-fraction

(1) Percentage by mass

It is defined as the number of grams of solute present in 100grams of solution.

Eg: A 20% solution of NaOH by weight contains 20 parts by mass of NaOH dissolved in 80 parts by mass of water. Generally this unit is used to prepare solutions of approximate concentration.

(2) Normality (N)

Normality is the number of gram equivalents of solute present in1000 ml of solution. Normality is represented by the symbol 'N'

Normal solution (Normality – 1N)

A normal solution contains one-gram equivalent of solute present in one litre of solution.

Decinormal Solution (Normality = 0.1N)

A decinormal solution contains one tenth of a gram equivalent of solute in one litre of solution.

$$\text{Normality } N = \frac{\text{Mass of Solute} \times 1000}{\text{Equivalent mass of solute} \times \text{Volume of solution}}$$

Problem

Calculate the normality of an oxalic acid solution containing 3.2g of oxalic acid in 2 litres of solution.

Mass of oxalic acid = 3.2g
Volume of oxalic acid = 2000ml(2litres)
Equivalent mass of oxalic acid = 63

$$\text{Normality } N = \frac{\text{Mass of Solute} \times 1000}{\text{Equivalent mass of solute} \times \text{Volume of solution}}$$

$$= \frac{3.2 \times 1000}{63 \times 2000}$$

$$= 0.025\text{N}$$

Mole

Mole or gram mole is the molecular mass of a substance expressed in grams.

$$\text{Number of moles} = \frac{\text{Mass of Solute in grams}}{\text{Molecular mass of solute}}$$

(3) Molarity (M)

Molarity is the number of moles of solute present in 1000 ml or one litre of solution.

Molarity is represented by the symbol 'M'.

Molar solution (Molarity =1M)

A Molar solution contains one mole of solute in one litre of solution.

$$\text{Molarity } M = \frac{\text{Mass of Solute} \times 1000}{\text{Molecular mass of solute} \times \text{Volume of solution}}$$

We can also have another formula which relates Molarity and Normality

$$\boxed{\text{MolarityxMolecular mass=NormalityxEquivalent mass.}}$$

Problem

Calculate the molarity of a solution containing 40g of sugar ($C_{12}H_{22}O_{11}$) in 200 ml of solution.

Molecular mass of sugar = 12x12+22x1+16x11=342

Mass of sugar = 40g

Volume of solution = 200ml

$$\text{Molarity } M = \frac{\text{Mass of Solute} \times 1000}{\text{Molecular mass of solute} \times \text{Volume of solution}}$$

$$= \frac{40 \times 1000}{342 \times 200} = 0.5848M$$

Problem

Find the normality of a solution of sulphuric acid whose molarity is equal to 4M.

Molecular mass of sulphuric acid = 98

Equivalent mass of sulphuric acid = 49

Molarity of the solution = 4M

$$\boxed{\text{MolarityxMolecular mass=NormalityxEquivalent mass.}}$$

4x98 = Normalityx49

$$\text{Therefore ,Normality} = \frac{4 \times 98}{49} = 8N$$

(4) Molality (m)

Molality is the number of moles of solute present in 1000g. (or) 1Kg of the solvent.

Molality is represented by the symbol 'm'.

Molal solution (Molality =1m)

A molal solution contains one mole of solute in one Kg of solvent.

$$\text{Molality } m = \frac{\text{Mass Solute} \times 1000}{\text{Molecular mass of solute} \times \text{Mass of solvent}}$$

Problem

Calculate the molality of a solution containing 15g of methanol (CH_3OH) in 300g of solvent.

Molecular mass of methanol = 12+16+4x1=32

Mass of methanol = 15g

Mass of solvent = 300g

$$\text{Molality } m = \frac{\text{Mass Solute} \times 1000}{\text{Molecular mass of solute} \times \text{Mass of solvent}}$$

$$\text{Molality } m = \frac{15 \times 1000}{32 \times 300} = 1.5625 \text{ m}$$

(5)Mole-fraction (X)

Mole-fraction of solvent (X_1)

Mole-fraction of the solvent is the ratio between the number of moles of solvent (n_1) and the total number of moles of solute and solvent ($n_2 + n_1$) present in solution.

$$\text{Mole} - \text{fraction of solvent} = \frac{\text{Number of Moles of solvent}}{\text{Total number of Moles present in solution}}$$

$$= \frac{n_1}{n_1 + n_2}$$

Mole-fraction of solute (X_2)

Mole-fraction of the solute is the ratio between the number of moles of solute (n_2) and the total number of moles of solute and solvent ($n_2 + n_1$) present in solution.

$$\text{Mole} - \text{fraction of solute} = \frac{\text{Number of Moles of solute}}{\text{Total number of Moles present in solution}}$$

$$= \frac{n_2}{n_1 + n_2}$$

Note:

$$\text{Number of moles} = \frac{\text{Mass in gram}}{\text{Molecular Mass}}$$

In any solution, **the sum of mole-fraction of solute and solvent is equal to one**.

$$X_1+X_2=1$$

Problem

Find the number of moles of solute and solvent in a solution containing 9.2g of ethyl alcohol (C_2H_5OH) in 180 g of water.

Molecular mass of ethyl alcohol = 2x12 + 6x1 + 16 =46

Molecular mass of water=18

Number of moles of ethyl alcohol n_2 = Mass / Molecular mass

= 9.2/46 = 0.2

Number moles of water n_1 = 180/18=10

$$\text{Mole}-\text{fraction of solvent} = \frac{\text{Number of Moles of solvent}}{\text{Total number of Moles present in solution}}$$

$$= \frac{n_1}{n_1+n_2}$$

$$= \frac{10}{10+0.2}$$

$$= 0.0196$$

$$\text{Mole}-\text{fraction of solute} = \frac{\text{Number of Moles of solute}}{\text{Total number of Moles present in solution}}$$

$$= \frac{n_2}{n_1+n_2}$$

$$= \frac{0.2}{10+0.2}$$

$$= 0.9804$$

SUMMARY

In this lesson students have learnt the meaning of percentage by mass , Normality , Morality , Molality and Mole-fraction. Problems were worked out to explain the concept.

QUESTIONS

Part – A

1. Define molarity.
2. Define molality
3. Define a molar solution.
4. Define a molal solution.
5. Define mole fraction of solute
6. Define normality.
7. Define deci-normal solution.

Part – B

1. Calculate the Molarity of a solution containing 5.2 g. of calcium bromide ($CaBr_2$) in 200ml.
2. Calculate the Molarity of a solution containing 6.516 g. of sodium chromate (Na_2CrO_4) in 100ml of solution.
3. Calculate the weight of potassium hydroxide (KOH) required to prepare 400ml of 0.082 M solution.
4. Find the mass of urea (Molecular mass = 60) required to prepare a decimolar solution of it, in 250 ml of solution.
5. Calculate the Molality of a solution containing 5.6 g of potassium hydroxide in 250 g of water.
6. Find the mass of sugar required to prepare m/10 solution of it in 300ml of water.
7. Find the Molality of a solution of 2 g of sodium chloride in 450 g of water.
8. 64g of methyl alcohol (CH_3OH) is dissolved in 144g of water. Calculate the mole-fraction of methanol and water.
9. An aqueous solution contains 10% glucose by weight. Find the mole-fraction of both solute and solvent.
10. Find the mole-fraction of both solute and solvent in a solution containing 1.12g of potassium hydroxide in 179.64 g of water.
11. A solution of sodium carbonate contains 1.06 g of Na_2CO_3 dissolved in 100 ml of water. Calculate its concentration in normality.

12. An aqueous solution of potassium permanganate contains 0.316 g of $KMnO_4$ in 200 ml of solution. Calculate its concentration in normality.
13. Find the mass of oxalic acid present in 500 ml of a decinormal solution of oxalic acid.
14. Find the normality of 0.5M sulphuric acid solution.
15. Find the molarity of a 2N solution of sulphuric acid solution.

TEST YOUR UNDERSTANDING

1. A 20% solution of sulphuric acid (by weight) has a density of 1.14g/ml. Calculate molality and molarity of the solution.
2. Find the mole fractions of both solutes and solvent in a solution containing 5% sodium chloride and 5% sodium hypochlorite.

2.2 TECHNOLOGY OF WATER

2.2.1 Introduction

Water is the most essential compound for all living matter on the earth. It plays an important role in human living and industries.

Sources of water

The two important sources of water are (1) surface water and (2) underground water.

Surface water

The water available on the earth's surface is called as surface water. Surface water includes rainwater, river water, lake water and seawater.

Underground water

Underground water includes water present between the rocks in the earth crust, spring water, well water etc.

2.2.2 Depletion of underground water

The decrease in the quantum of underground water is depletion of water. Depletion of water is mainly caused by,

1. Modernization, industrialization and population growth
2. Global warming causing excess evaporation of surface water
3. Deforestation
4. Decrease in rainfall caused by seasonal changes and
5. Effluents from the industries spoiling the ground water source.

To meet out this depletion of ground water sources, it is essential to find alternate plans using water management techniques to recharge the ground water sources. One of the techniques adopted is rainwater harvesting.

2.2.3 Rain water Harvesting

Rainwater harvesting (RWH) is collection of rainwater for useful purposes . The methods employed are

1. Roof top harvesting
2. Open space harvesting

Roof top harvesting

Rainwater is directly used for recharging open wells and bore wells by directing them into it. It can also be stored in sumps or over head tanks and used directly.

Open space Harvesting

Open spaces around the buildings are used for rainwater harvesting as follows

1. With percolation/recharge pits
2. Recharge trenches
3. Recharge wells

The recharge method used depends on the soil condition.

Types of impurities present in water

There are three types of impurities present in water. They are

(i) Suspended and colloidal impurities.

(ii) Dissolved salts.

(iii) Micro - organisms.

2.2.4 Types of water

There are two types of water. They are (i) soft water and (ii) hard water.

(I) Soft water readily gives lather with soap.

(ii) Hard water does not give lather with soap.

2.2.5 Hardness of water

There are two types of hardness in water. They are:

(i) Temporary Hardness: (Carbonate hardness)

It is due to the presence of calcium bicarbonate [$Ca(HCO_3)_2$] and magnesium bicarbonate [$Mg(HCO_3)_2$]. Temporary Hardness can be removed by boiling.

(ii) Permanent Hardness: (Non-Carbonate hardness)

It is due to the presence of chloride and sulphate salts of calcium and magnesium. ($CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$).It cannot be removed by boiling. Hence it is known as permanent hardness.

Disadvantages of a hard water sample

- Hard water cannot be used for drinking purpose.
- It cannot be used for cooking purposes.
- It cannot be used for bathing and washing purposes as it does not give lather with soap.
- Hard water cannot be used in laboratories as it gives unwanted chemical reactions.
- Hard water cannot be used in boilers in steam raising.
- It cannot be used in sugar and paper industries.
- Hard water cannot be used in textile and leather industries.

2.2.6 Degree of Hardness.

Units for measuring hardness

1.mg/litre of $CaCO_3$

2.parts per million of $CaCO_3$

Usually ,the hardness of water is expressed in terms of calcium carbonate equivalents

The formula used to convert the mass of hardness producing salt to mass of $CaCO_3$ equivalents is given below

$$\text{Calcium carbonate equivalents} = \frac{\text{Mass of salt} \times \text{Molecular mass of } CaCO_3}{\text{Molecular mass of salt}}$$

Note Molecular masses of hardness producing salts are given below.

Hardness producing salt	Molecular Mass
$CaSO_4$	136
$MgSO_4$	120
$CaCl_2$	111
$MgCl_2$	95
$Ca(HCO_3)_2$	162
$Mg(HCO_3)_2$	146
$CaCO_3$	100

Problem - 1

A water sample contains 48 mg of $MgSO_4$ per 200ml of water. Calculate the hardness in terms of $CaCO_3$ equivalent in mg/litre of $CaCO_3$.

Mass of $MgSO_4$ = 48mg

Molecular mass of $MgSO_4$ = 120

$$\text{Calcium carbonate equivalents} = \frac{\text{Mass of } MgSO_4 \times \text{Mass of } CaCO_3}{\text{Molecular Mass of } MgSO_4}$$

$$= \frac{48 \times 100}{120} = 40\text{mg}$$

Mass of $CaCO_3$ present in 200 ml of water = 40mg

Therefore, mass of $CaCO_3$ present in 1000ml of water = 200mg

Hardness of water = 200mg/litre of $CaCO_3$

2.2.7 Estimation Of Hardness Of Water - EDTA Method

EDTA method is used to determine the hardness of a sample of water. EDTA refers to Ethylene diamine tetra acetic acid. This method is also called as Modern method.

PRINCIPLE

This is a volumetric method based on the principle of formation of complexes. Ethylene diamine tetraacetic acid (E.D.T.A.) forms colourless complexes with Ca^{2+} and Mg^{2+} ions present in water. Similarly Eriochrome Black-T, another dye, also forms wine red coloured complexes with Ca^{2+} and Mg^{2+} ions. Pure Eriochrome Black-T is blue in colour. At the pH range of 9 to 10, the Eriochrome complexes are less stable when compared to E.D.T.A. complexes. Thus when E.D.T.A. solution is added to Eriochrome-Ca^{2+} or Mg^{2+} complexes it displaces pure Eriochrome to form E.D.T.A-Ca^{2+} or Mg^{2+} complexes. Thus at the end point E.D.T.A. frees the total Eriochrome Black-T to change the colour of the solution from wine red to steel blue.

Eriochrome-Ca^{2+}+E.D.T.A.--------->E.D.T.A-Ca^{2+} + Eriochrome Black-T

WineRed **Steel Blue**

PROCEDURE

The burette is filled with the standard E.D.T.A. solution. A 50-ml pipette is washed with distilled water and rinsed with the sample of hardwater. Exactly 50 ml of hard-water is pipetted out into a conical flask and 5 ml of NH_4Cl - NH_4OH buffer solution is added. A pinch of Eriochrome Black-T indicator is added. The colour of the conical flask solution changes into wine red. The water sample is titrated against the E.D.T.A. solution taken in the burette. The colour changes from wine red to steel blue. This is the end point of the titration. The burette reading is noted. Titrations are repeated until two consecutive values agree. From the volume of E.D.T.A. the hardness of the sample of water is calculated.

Note: In the estimation of hardness of water, a standard data relating the mass of $CaCO_3$ and volume of 0.01M EDTA solution .is given below

$$\boxed{\text{1ml of 0.01M EDTA solution} \equiv \text{1mg of } CaCO_3}$$

CALCULATION

Let,the Volume of water taken =50ml
volume of E.D.T.A. consumed =Vml

1ml of 0.01 M E.D.T.A. ≡ 1 mg of $CaCO_3$

V ml of 0.01 M E.D.T.A.= V mg of $CaCO_3$

V ml of 0.01 M E.D.T.A. ≡ 50 ml of Hard water.

Mass of $CaCO_3$ present in 50 ml of Hard water = V mg

$$\text{Mass of } CaCO_3 \text{ present in 1000ml of Hard water} = \frac{V \times 1000}{50} \text{mg}$$

Mass of $CaCO_3$ present = 20 V mg

HARDNESS OF WATER = 20V mg /litre of $CaCO_3$

Problem-1

A sample of 100 ml of hard water consumes 25 ml of 0.01M EDTA solution. Calculate the hardness of the sample of water.

$$\boxed{\text{1ml of 0.01M EDTA solution} \equiv \text{1mg of } CaCO_3}$$

25ml of 0.01M EDTA solution ≡ 25 mg of $CaCO_3$

25ml of 0.01M EDTA solution ≡ 100 ml of hard water

Mass of $CaCO_3$ present in 100 ml of hard water = 25 mg

Mass of $CaCO_3$ present in 1000ml of hard water = 250mg

Hardness of water = 250mg/litre of $CaCO_3$

To express in ppm

Mass of $CaCO_3$ present in 100 ml of hard water = 25 mg

Mass of $CaCO_3$ present in 100g of hard water = 25×10^{-3}g

= 250g

$$\text{Mass of } CaCO_3 \text{ present in } 10^6 \text{ g of hard water} = \frac{25\times10^{-3}\times10^{6}}{100}\,g$$

Hence, hardness of water = 250 ppm of $CaCO_3$

Problem-2

A sample of 100 ml of water consumed 12.5 ml of 0.01 M EDTA solution. In another titration 100 ml of the same sample, after boiling for half an hour consumed 8.2 ml of the same EDTA solution. Calculate the carbonate and non-carbonate hardness of the sample of water.

Total hardness

12.5ml of 0.01M EDTA solution ≡ 12.5 mg of $CaCO_3$

12.5ml of 0.01M EDTA solution ≡ 100 ml of hard water

Mass of $CaCO_3$ present in 100 ml of hard water = 12.5 mg

Mass of $CaCO_3$ present in 1000ml of hard water = 125mg

Hence, Total hardness of water = 125 mg/litre of $CaCO_3$

Non-carbonate Hardness

8.2ml of 0.01M EDTA solution ≡ 8.2 mg of $CaCO_3$

8.2ml of 0.01M EDTA solution ≡ 100 ml of hard water

Mass of $CaCO_3$ present in 100 ml of hard water = 8.2 mg

Mass of $CaCO_3$ present in 1000ml of hard water = 82 mg

Hence, Non-carbonate hardness of water = 82 mg/litre of $CaCO_3$

Therefore, Carbonate Hardness = Total hardness – Non-carbonate hardness

= (125 – 82) = 43 mg/litre of $CaCO_3$

2.2.8 Methods of softening hard water

(1) Ion exchange method

In this method the hard water is first passed through an acidic resin (RH_2) to remove the cations [Ca^{2+}, Mg^{2+}] and then it is passed through a basic resin [$R'(OH)_2$] to remove the anions. Thus both types of ions are totally removed.

Acidic resin is represented by RH_2.

Basic resin is represented by $R'(OH)_2$.

Softening Process

When the hard water sample is passed through the I-Cylinder (acidic resin) calcium and magnesium ions are replaced by hydrogen ions of the acidic resin.

$$\underset{\textbf{Acidic resin}}{RH_2} + Ca^{2+} \text{----------->} RCa + 2H^+$$

$$\underset{\textbf{Acidic resin}}{RH_2} + Mg^{2+} \text{----------->} RMg + 2H^+$$

When this water is passed through the II-Cylinder (basic resin) chloride, bicarbonate and sulphate ions are replaced by the hydroxide ions of the basic resins.

$$R'(OH)_2 + 2Cl \text{----------->} R'Cl_2 + 2OH^-$$

$$R'(OH)_2 + 2HCO_3^- \text{---------->} R'(HCO_3)_2 + 2OH^-$$

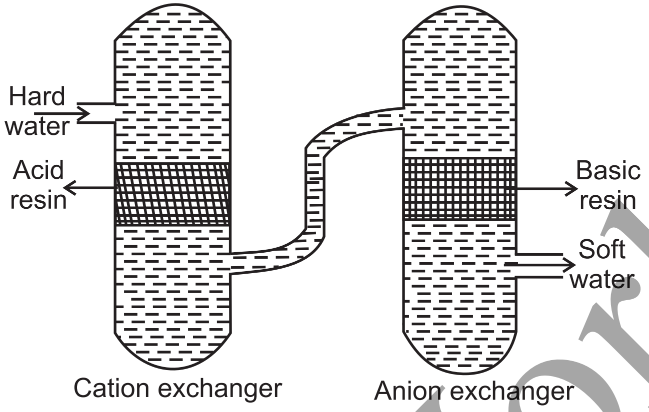
$$R'(OH)_2 + SO_4^{2-} \text{---------->} R'SO_4 + 2OH^-$$

Thus all the ions responsible for hardness are removed from water. The H^+ and OH^- ions combine together to form water.

$$H^+ + OH^- \text{----------->} H_2O$$

The quality of water obtained by this method is equivalent to distilled water.

Diagram



Regeneration of Acid Resin and Basic Resin:

After a long use, the acidic resin can be regenerated by the addition of a strong solution of Hydrochloric acid.

$RCa + 2HCl \text{------------>} RH_2 + CaCl_2$

The basic resin after a long use, can be regenerated by the addition of a strong solution of NaOH.

$R'Cl_2 + 2OH^- \text{------------>} R'(OH)_2 + 2Cl^-$

$R'(HCO_3)_2 + 2OH^- \text{------------>} R'(OH)_2 + 2HCO_3^-$

$R'SO_4 + 2OH^- \text{------------>} R'(OH)_2 + SO_4^{2-}$

Advantages

1) In this method, both types of hardness are removed.
2) The quality of water obtained is equivalent to distilled water.
3) There is no wastage of water

(2) Reverse Osmosis Method

Osmosis

When a semi-permeable membrane separates two solutions of different concentrations, solvent molecules move from dilute side to concentrated side until the two concentrations become equal. This process is called osmosis. The pressure gradient produced due to osmosis is called osmotic pressure.

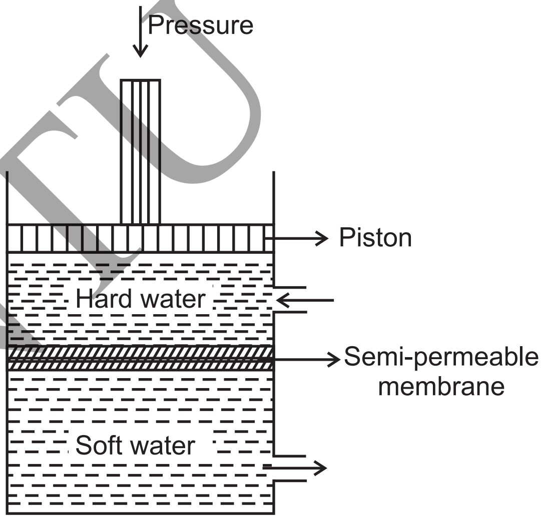
Reverse Osmosis

When a hydrostatic pressure greater than the osmotic pressure is applied on the concentrated side, solvent molecules move from concentrated side to the dilute side across the membrane. This is called reverse osmosis. This principle is used in Reverse Osmosis plants to soften hard water.

Method

- In this method hard water and soft water are taken in two different chambers separated by a semi permeable membrane.
- When a hydrostatic pressure greater than the osmotic pressure is applied on the hard waterside, the water molecules move from hard waterside to soft waterside leaving the impurities on the membrane due to reverse osmosis.
- Thus hard water is converted to soft water by Super filtration or hyper filtration.
- The semi permeable membrane is made of polysulphone or cellulose acetate or polyamide.

Diagram



Advantages

1) In this method ionic, non-ionic, colloidal, and organic particles are removed from water.
2) The semi permeable membrane can be replaced and reused.
3) There is no wastage of water.

2.2.9 Municipal water supply

Water for Drinking purpose (Potable water)

Municipal water is mainly used for drinking purposes and for cleaning, washing and other domestic purposes. The water that is fit for drinking purposes is called potable water

(1)Characteristics of Potable water

1. It should be colourless, odourless and tasteless.
2. It should be free from turbidity and other suspended Impurities.
3. It should be free from germs and bacteria.
4. It should not contain toxic dissolved impurities.
5. It should be moderately soft.
6. It should not be corrosive to the pipe lines.
7. It should not stain clothes.

(2)Standards of drinking water as recommended by WHO

Parameters	WHO standards
pH	6.5 - 9.2
BOD	6
COD	10
Arsenic	0.05ppm
Calcium	100ppm
Cadmium	0.01ppm
Chromium	0.05ppm
Ammonia	0.5ppm
Copper	1.5ppm
Iron	1.0ppm
Lead	0.001ppm
Mercury	0.1ppm
Magnesium	150ppm
Manganese	0.5ppm
Chloride	250ppm
Cyanide	0.05ppm
Nitrate + Nitrite	45ppm

(3)Water quality standards in india

Parameters	Standard
pH	6.3 - 9.2
Total Hardness	600 ppm
Turbidity	25 ppm
Chlorides	1000 ppm
Cyanide	0.05 ppm
Fluoride	1.5 ppm
Nitrate	45 ppm
Sulphate	400 ppm
Manganese	0.5 ppm
Mercury	0.001 ppm
Iron	1 ppm
Copper	1.5 ppm
Cadmiun	0.01 ppm
Chromium	0.05 ppm
Lead	0.15 ppm
Arsenic	0.05 ppm
Zinc	15 ppm
Magnesium	150 ppm

The three stages involved in purifying a water sample for drinking purpose are

1. Sedimentation
2. Filtration
3. Sterilisation

Sedimentation

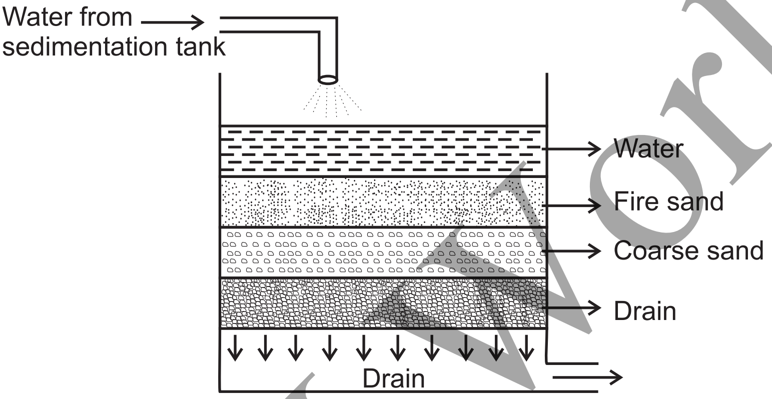
Water from river or lake is taken in the big tank called sedimentation tank. Here the insoluble matter settles down at the bottom of the tank as sediments. In this tank the colloidal impurities are converted into precipitate by adding Alum. The clear water from the top layer is sent to the next tank, called Filtration tank.

Filtration

In filtration tank, the suspended impurities and the microorganisms are removed. In all types of filtration, the filter bed used is constructed as follows.

The filter bed consists of a layer of fine sand, followed by a layer of coarse sand, which is then followed, by a layer of gravel. There is a drain at the bottom to remove the filtered water. The layer of fine sand acts as the filtering unit and the other two beds support the fine sand layer. Generally filtration is done due to the gravitational force. The filtered water is then taken to the sterilization tank.

Diagram



(Note: In industrial areas where large amount of drinking water is required in short period, Pressure filters are used in which water is sent through filter beds using external pressure.)

Sterilization

Sterilization is destroying of bacteria. It is done by Chlorination.

Chlorination

Chlorination is addition of chlorine. Chlorine is added to water in the pH range of 6.5 to 7. When chlorine is added to water, it forms HCl and HOCl. The hypochlorous acid enters into the living cells of bacteria and destroy them.

$H_2O + Cl_2$---------- >HCl + HOCl

Hypochlorous acid

Other sterilizing agents used are chloramines, bleaching powder etc. The advantage of using chloramines is that it does not evaporate out easily and can be carried over to a longer distance along with the water.

Ultra-violet rays can also be used for sterilizing purpose.

2.2.10 Boiler feed water

Water is used in boilers, steam engines etc., to raise steam. When a sample of hard water is used in boiler to prepare steam, the following problems will occur.

1. Scale formation
2. Corrosion of boiler metal
3. Caustic Embrittlement and
4. Priming and foaming.

(1) Boiler scale formation

When hard water is used in boilers to get steam, the impurities that are present in the hard water will settle down on the sides of the boiler. This residue in due course will adhere to the boiler vessel surface in the form of a sludge or scale. This is called as boiler scale. The following calcium salts are responsible for the formation of boiler scale.

$CaSO_4$, $CaCO_3$, $CaSiO_3$, $Ca(OH)_2$, $Mg(OH)_2$, etc.

Disadvantages of Boiler scale

1. The salt deposit formed is a poor conductor of heat. Therefore, fuel is wasted in raising the temperature of the boiler.
2. Due to the increase in the temperature, the plates may melt. This may lead to explosion of boiler.
3. At higher temperature, more oxygen may be absorbed by the boiler metal, which causes corrosion of boiler metal.
4. The sudden spalling of the boiler scale exposes the hot metal suddenly to super-heated steam, which causes corrosion of boiler.

The two types of methods employed to prevent scale formation are,

1. Internal conditioning method
2. External conditioning methods.

1. Internal conditioning methods involve addition of complexing agents like Calgon to boiler feed water. Another method of internal conditioning method is Phosphate conditioning. In this method sodium phosphate is added to boiler feed water which forms non-sticky Calcium

and Magnesium Phosphate which can be removed by blow down operation.

2. In external conditioning methods water is purified either by Zeolite process or by ion-exchange method before being fed into boilers.

(2) Corrosion of Boiler metal

The impurities such as dissolved oxygen, dissolved Carbon di oxide, mineral acids, dissolved salts of calcium and magnesium, organic matter etc.are responsible for the corrosion of boilers.

The dissolved matter undergoes hydrolysis and forms acids. The acid slowly attacks the inner part of the boiler.

The dissolved oxygen attacks iron at high temperature. The CO_2 and H_2O form carbonic acid (H_2CO_3), which slowly attacks the metal.

Prevention of Boiler Corrosion

1. By using proper water treatment procedures.
2. By degasification to remove the dissolved gases like oxygen, CO_2 , etc.,
3. The dissolved CO_2 can be removed by the addition of limewater.
4. Adding calculated amount of base could neutralize the mineral acids.

(3) Caustic Embrittlement:

Sometimes cracks appear inside the boiler parts, particularly at the places, which are under stress. Metal becomes brittle at these places. It is due to the high concentration of caustic soda (NaOH) and a little amount of silica in water. This is called as caustic embrittlement.

Caustic soda is formed by the hydrolysis of Na_2CO_3.

$$Na_2CO_3 + H_2O \text{ ----------> } 2NaOH + CO_2$$

Removal of Na_2CO_3 present in water can prevent caustic embrittlement.

This can be done by the following methods.

1. By adding sulphuric acid.
2. By adding $CaSO_4$ and $CaCl_2$ to boiler water
3. By adding Na_2SO_4.
4. By adding trisodium phosphate.

(4)Foaming and Priming

Foaming

Foaming is nothing but the formation of foam. Bubbles of water will enter the surface of water inside the boilers and results in the formation of foam. Foam comes out of the boiler along with the steam. Hence the steam becomes wet and the heat content of the steam is reduced considerably. This type of wet steam spoils the machine parts where it is used.

The main cause for foaming is the presence of dissolved salts in water. Hence soft water should be used in boilers to avoid foaming.

Priming

Priming is violent and rapid boiling of water inside the boiler. Due to priming the water particles mix up with the steam when it comes out of the boiler. Like foaming, priming also reduces the heat content of the steam and reduces the efficiency of the steam.

Main reasons for Priming

a) Defective design of the boiler.

b) Presence of large quantities of dissolved salts, oily matter, alkaline and suspended matter.

Control

1. Priming can be controlled by proper design of the boiler
2. By uniformly heating the water in the boiler.
3. By using a better sample of water.

Summary

Students have learnt about rain water harvesting, estimation of hardness, methods of softening and bad effects of hard water in boilers.

QUESTIONS

Part – A

1. Define hard and soft water.
2. List the salts that cause Carbonate hardness in a water sample.
3. List the salts that cause Non-carbonate hardness in water.
4. What is rain water harvesting?
5. Mention any two disadvantages of hard water.
6 List any two methods of softening of hard water.

7 What is osmosis?

8. Name the units used to measure the hardness of water.

9. What is ppm?

10. What are boiler scales?

11 Explain corrosion of boiler scale

12. What is caustic embrittlement?

13. How is caustic soda formed in hard water?

14. What is priming?

15. What is foaming?

16. Give any one problem caused by boiler scale.

Part – B

1. List the problems caused by hard water?
2. What is rainwater harvesting? How is it carried out? What are its goals?
3. Explain Ion Exchange method of softening of hard water
4. What is regeneration of Ion-exchange plant? How is it carried out?
6. Explain EDTA method of estimating hardness of a sample of water.
7. Describe the method used in water supply schemes to get potable water
8. What are boiler scales? List the problems caused by boiler scale.
9. Explain caustic embrittlement, priming and foaming in boilers.
10. Calculate the hardness of a sample of water containing 12.5 mg of $CaCO_3$ in 100 ml of water both in mg/litre of $CaCO_3$ and in ppm of $CaCO_3$
11. A sample of water contains 30 mg of $MgSO_4$ in 100 ml of water. Calculate the hardness of the water sample in terms of mg / litre of $CaCO_3$ and in ppm of $CaCO_3$.
12. A water sample contains 204 mg of $CaSO_4$ per litre. Calculate the hardness in terms of $CaCO_3$ equivalent.
13. A sample of water contains 12mg of $MgSO_4$ in 250 ml. Express the hardness in terms of ppm of $CaCO_3$.
14. 100ml of a sample of water consumed 25ml of 0.005M EDTA. Calculate the degree of hardness (i) in mg/l of $CaCO_3$ (ii) in ppm of $CaCO_3$
15. 100ml of a sample of water required 18ml of 0.01M EDTA. 100ml of the

same sample after boiling required 13ml of the same EDTA. Calculate (i) carbonate hardness and (ii) non-carbonate hardness in ppm of $CaCO_3$.

16. 100ml of a sample of water consumed 30ml of 0.01M EDTA. Calculate the hardness in (i) mg/l of $CaCO_3$ (ii) ppm of $CaCO_3$.
17. A sample of water has 15mg of $MgSO_4$ in 500ml. Express the hardness of this sample of water in ppm of $CaCO_3$
18. A sample of 50ml of water when treated with 0.01M EDTA solution consumed 6.2 ml of EDTA. Calculate the hardness of this sample of water in ppm of $CaCO_3$.

TEST YOUR UNDERSTANDING

1. In an EDTA titration 20ml of standard solution of Calcium carbonate containing 2.5mg of $CaCO_3$.in 100ml of distilled water required 25 ml of EDTA solution. When 100ml of a sample of hard water was titrated against the same EDTA solution, it required 33.4ml of EDTA solution. Calculate the hardness of water in mg/litre of $CaCO_3$.
2. A hard water contains 20mg of $CaCl_2$, 15 mg of $MgSO_4$ and 25 mg of NaCl in 100 ml of the sample. Find the volume of 0.01M EDTA solution required in a hardness estimation experiment.

2.3 SOLID STATE

All solids are classified into two types, based on the arrangement of particles present in them.

They are

(1) Crystalline solids &
(2) Amorphous solids.

(1) CRYSTALLINE SOLIDS

In crystalline solids the particles present are arranged in a regular three-dimensional way. A crystalline solid is made up of number of layers in which the particles are arranged regularly in two dimension. These layers are called 'plane surfaces'. In a big crystal a representative unit is again and again repeated. This representative unit is called as 'unit cell'. Therefore a unit cell is the smallest arrangement of a model of a crystal.

When a big crystal is cut with a sharp edged tool, it breaks into two smaller crystals of the same shape. All crystalline solids have sharp melting points.

Generally, when the molten substance is cooled slowly, we get crystalline solids. When the molten substance is cooled slowly, the particles present get sufficient time to arrange themselves in the crystal lattice.

(For eg.) When molten sulphur is cooled slowly, we get needle sulphur and rhombic sulphur.

(2) AMORPHOUS SOLIDS

In amorphous solids the particles are arranged in an irregular manner. Amorphous solids do not have sharp melting point. When the molten substance is cooled suddenly, we get amorphous solids. When the molten substance is cooled suddenly, the particles present in them do not find sufficient time to arrange themselves properly.

(E.g.) When molten sulphur is cooled suddenly by pouring it in ice cold water, we get clay of sulphur.

TYPES OF CRYSTALLINE SOLIDS

Crystalline solids are classified into four types based on the type of particles present in them and the force of attraction operating between these particles.

They are
1. Ionic solids
2. Covalent solids
3. Molecular solids and
4. Metallic solids.

1.IONIC SOLIDS:

In ionic solids the particles present are ions and the force of attraction operating between these particles is 'positive-negative attraction' or 'Electrostatic force of attraction.'

E.g. NaCl, KCl, CsCl etc.

For example in NaCl, the particles present are Na^+ and Cl^- ions and the force of attraction operating between these ions is 'Electrostatic force of attraction'. In NaCl each sodium ion is surrounded by six chloride ions and each chloride ion is surrounded by six sodium ions.

2.COVALENT SOLIDS

In covalent solids all particles are connected to each other by covalent bonds throughout the crystal.

E.g. Diamond, graphite etc.

In diamond each carbon atom is connected to four other carbon atoms by covalent bonds throughout the crystal. Therefore diamond is the hardest substance in the world. In graphite carbon atoms form layers of hexagonal rings (honey comb structure) where each carbon atom is surrounded by three other carbon atoms satisfying three valences of carbon and the fourth valence is satisfied by the loosely bound 'π' electrons between the layers.

3.MOLECULAR SOLIDS

In molecular solids the particles present are molecules and the force attraction operating between these particles is 'Vander wall's force of attraction' or 'dipole-dipole attraction'.

Example: - Dry ice and Ice

Dry ice is solid carbon dioxide. In dry ice the particles present are CO_2 molecules and the force of attraction operating between these particles is 'Vander wall's force of attraction'.

In ice the particles present are H_2O molecules and the force of attraction operating between H_2O molecules is dipole-dipole attraction.

4.METALLIC SOLIDS

All metal crystals are metallic solids. Metals show the following properties.

a. They have high melting point and density.
b. They conduct electricity.
c. On heating they emit electrons. This property is called 'Thermionic emission'.

A new type of bonding called 'metallic bonding' explains all these properties.

TYPE OF PACKING IN METAL CRYSTALS

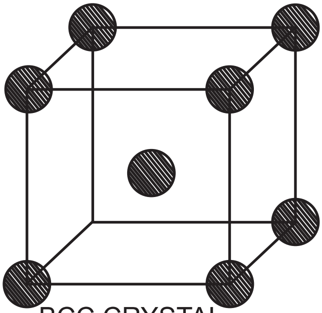
The three type of packing generally present in metal crystals are

(I) Body centered cube (BCC)
(ii) Face centered cube (FCC)
(iii) Hexagonal Close Packing (HCP)

(I) Body Centered Cube (BCC)

This type of packing is present in metals like sodium, potassium etc. The diagram of the unit cell is as follows.

Diagram



BCC CRYSTAL

In the unit cell 8 atoms are placed at 8 corners of a regular cube and one atom is placed at the centre. Therefore the total number of atoms present in a unit cell in BCC packing is calculated as follows.

Number of atoms present in a unit cell = $1 + 8 \times {}^{1}/_{8} = 2$ atoms.

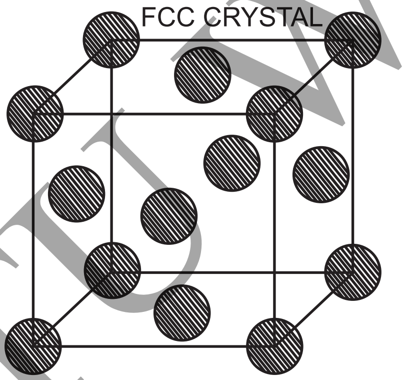
The packing density of the bcc crystal is found to be 68%. In this type of packing the atoms are packed in the least efficient way. Therefore BCC metals are very soft in nature. They can be cut even with a knife. These metals have low melting point and density.

(ii) Face centre cube (FCC)

This type of packing is present in metals like copper, silver and gold. The model diagram of the unit cell is as follows.

Diagram

In the unit cell 8 atoms are placed at 8 corners of a regular cube and six atoms are placed at the centre of the six faces. The total number of atoms present in a unit cell of a FCC crystal is calculated as follows.



Number atoms present in a unit cell = $8 \times {}^{1}/_{8} + 6 \times \frac{1}{2}$

$= 1 + 3 = 4.$

The packing density of the FCC crystal is calculated as 74%. Therefore FCC metals are harder than BCC metals. They have high melting point and density. These metals are malleable and ductile.

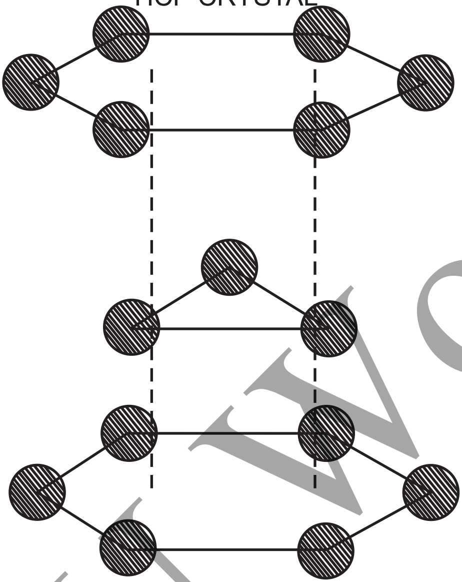
(iii)Hexagonal Close Packing (HCP)

This type of packing is present in metals like Titanium (Ti), Tungsten (W) etc.

The packing diagram can be drawn as follows

Diagram

HCP CRYSTAL



HCP metals are hard and brittle in nature.

QUESTIONS

Part – A

1. What are ionic solids?
2. Name the four types of crystalline solids.
3. What force of attraction is operating between the particles in an ionic solid?
4. Name the hardest substance in the world. Why is it so hard?
5. What is the force of attraction present in ice?
6. Which model of metal crystal explains the properties of metals?
7. What is thermionic emission?
8. What is BCC and FCC packing of metals?
9. Give examples for BCC and FCC metals.

Part – B

1. Explain the four types of crystalline solids.
2. Describe BCC packing in metal crystal with a neat diagram. How this type of packing explains the properties of BCC metals.
3. Explain FCC packing of metal atoms with a neat diagram. How it reflects the properties of FCC metals.
4. What is HCP packing of metals? Explain with a neat diagram with examples.
5. What are ionic and molecular solids? Distinguish between them.

TEST YOUR UNDERSTANDINGS

1. Both ice and dry ice are molecular solids. But ice has got comparatively high melting point. Why?
2. Calculate the packing density of BCC and FCC crystals.

Unit III

COLLOIDS, NANO PARTICLES AND PHOTO CHEMISTRY

3.1 COLLOIDS

3.1.1 Introduction

An aqueous solution of salt or sugar is homogeneous and it contains the solute particles as single molecules or ions. This is called a true solution. The diameter of the dispersed particles ranges from $1A^{\circ}$ to $10A^{\circ}$ [$1A^{\circ} = 10^{-8}$ cm]; whereas in a suspension of sand stirred in water, the diameter of the dispersed particles will be more than $2000A^{\circ}$. The particles which are larger than a molecule and smaller than a suspended particle are said to be colloids and such solutions are called colloidal solution or sol.

Moleculer size < colloids < suspension

($1A^{\circ}$ - $10A^{\circ}$) ($10A^{\circ}$ - $2000A^{\circ}$) (More than $2000A^{\circ}$)

Definition

A colloidal system is made up of two phases. The substance distributed as colloidal particles is called the dispersed phase (analogous to solute) and the phase where the colloidal particles are dispersed is called the dispersion medium (analogous to solvent). A colloidal solution can form eight different types based upon the physical state (solid, liquid, gas) of dispersed phase / dispersion medium. The common example of colloids are milk, curd, cheese, clouds, paint etc. The properties of these colloidal solution are in many ways different from that of true solution.

Table 3.1. Differences between true solution and colloidal solutions

Sl. No.	Property	True Solution	Colloidal Solution
1.	Nature	Homogeneous system	Heterogeneous system
2.	Size	1-10°A	10°A-2000°A
3.	Filterability	Cannot be filtered	can be filtered through animal or starch membrane
4.	Osmotic pressure	High	Low
5.	Scattering of light	It does not scatter light	It scatters light
6.	Brownian movement	Does not exhibit	Does exhibit
7.	Electrophoresis	Does not show	Does show

3.1.2 Types of colloids

Lyophobic colloids

Colloidal solutions in which the dispersed phase has very little affinity for the dispersion medium are termed as lyophobic colloids [Lyo-solvent; phobic-hate]. eg. colloidal solutions of metals and sulphur in water.

Table 3.2 Distinction between lyophilic and lyophobic colloids

Sl. No.	Property	Lyophilic colloids	Lyophobic colloids
1.	Preparation	Easily be prepared	Need some special methods to prepare
2.	Affinity	Solvent attracting	Solvent hating
3.	Coagulation	Coagulation requires large quantity of electrolytes	A small quantity of electrolyte is sufficient

Sl. No.	Property	Lyophilic colloids	Lyophobic colloids
4.	Detection through ultra microscope	Cannot be easily detected	Can be easily detected
5.	Viscosity	Very much different from that of dispersion medium	Almost the same as that of dispersion medium
6.	Surface tension	Very much different from that of dispersion medium	Almost the same as that of dispersion medium
7.	Density	Very much different from that of dispersion medium	Almost the same as that of dispersion medium
8.	Electrophoresis	Particles migrate in either direction	Migrate in a particular direction
9.	Reversibility	The reaction is reversible	Irreversible
10.	Example	Starch solution, Soap solution	Colloidal gold, Colloidal silver

Lyophilic colloids

Colloidal solutions in which the dispersed phase has strong affinity for the dispersion medium are called lyophilic colloids e.g. solution, gum, protein etc..The lyophilic and lyophobic colloids have different characteristics, which is given in Table 3.2.

3.1.3 Properties of colloids

Colloids exhibit certain exclusive properties. They are:

(i) Brownian movement (Mechanical / kinetic property)
(ii) Optical property
(iii) Electrical property

(1) Brownian movement (Mechanical / kinetic property).

When the colloidal particles are seen through an ultramicroscope, it is found that the colloidal particles are found to be in constant zig-zag, chaotic motion.

This was first observed by Brown and so this random movement of colloidal particles is called Brownian movement. This movement is due to the collision of colloidal particles with the molecules of the dispersion medium. The motion becomes more rapid when the temperature of the dispersion medium is high and less viscous.

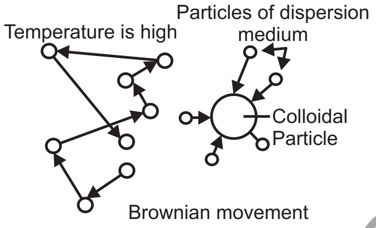


Fig.3.1. Brownian movement

(2) Tyndall effect (Optical property)

When a beam of light is passed through a true solution, and observed at right angles to the direction of the beam, the path of the light is not clear. At the same time, if the beam of light is passed through a colloidal solution, the path of the light is quite distinct due to scattering of light by the colloidal particles. *The phenomenon of scattering of light by the colloidal particles is known as "Tyndall effect".*

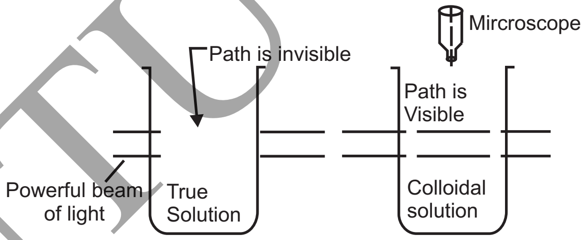


Fig.3.2. Tyndall effect

(3) Electrophoresis (Electrical property)

If an electric potential is applied across two platinum electrodes immersed in a colloidal solution, the colloidal particles move in a particular direction, depending upon the charge of the particles. *Thus the migration of colloidal particles under the influence of electric field is called electrophoresis.*

This phenomenon can be demonstrated by placing a layer of arsenic sulphide solution under two limbs of a U-tube. When current is passed through the limbs, it can be observed that the level of the colloidal solution decreases at one end of the limb and rises on the other end.

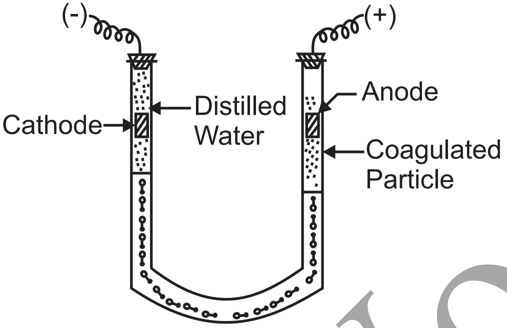


Fig.3.3. Electrophoresis

(4) Coagulation of colloid

The entire colloidal particles are electrically charged; all are positively charged or negatively charged. Therefore every colloidal particle repel each other and remains stable. In order to coagulate a colloid, these charges have to be nullified. This can be done in three ways:

(I) By adding a double salt (electrolyte)
(ii) By introducing an electrode of opposite charge
(iii) By introducing another colloid of opposite charge

After nuetralising the charges, the colloidal particles are brought together and they are large enough to settle down. *Thus the process of precipitating a colloidal solution is called coagulation.*

3.1.4 Industrial applications of colloids

(1)Smoke precipitation (cottrell's method)

Smoke is a colloidal suspension of carbon particles in air. The smoke is first introduced into a chamber and subjected to a very high voltage. The particles get deposited in one of the electrodes and the hot air alone is let out through the chimney.

(2)Purification of drinking water

The suspended impurities of the water cannot be filtered. So it is better to coagulate them. This is done by adding potash alum.

(3)Cleaning action of soap

The dirt particles stick to the cloth or body by the greasy oily substance. It forms an emulsion with soap. The dirt particles get detached from the cloth / body and washed away along with soap with excess of water.

(4)Tanning of leather

Animal hides are colloidal in nature. When a hide, positively charged particles, soaked in tannin, a negatively charged particle, mutual coagulation takes place. This results in hardening of leather. The process is called tanning. Chromium salts are used as tannin.

(5)Disposal of sewage

Sewage dirt particles are electrically charged. So the sewage is allowed to pass through disposal tanks. It is then subjected to high potential. The sewage particles lose the charges and coagulated. Clean water is recycled or used for gardening. Sludge is used as manure.

QUESTIONS

Part-A

1. What is a colloid?
2. Give any two examples for colloid.
3. What are the two types of colloids?
4. Give any two example for lyophilic colloid.
5. Define Tyndall effect.
6. What is called Brownian movement?
7. What is meant by electrophoresis?
8. Define coagulation of colloid.

Part-B

1. Distinguish between true solution and colloidal solution.
2. What are the differences between lyophilic and lyophobic colloids?
3. Write notes on (i) Brownian movement (ii) Tyndall effect.
4. Write notes on (i) Electrophoresis (ii) Coagulation of colloids.
5. Write down any five applications of colloids.

TEST YOUR UNDERSTANDING

1. Why is silver iodide powder is sprinkled over clouds for artificial rain?
2. What is the difference between soap and detergent?

3.2. NANO PARTICLES

3.2.1 Introduction

Nano technology is the study of matter on an atomic and molecular scale. One nanometer (nm) is one billionth or 10^{-9}m. The carbon-carbon bond length is in the range of 0.12-0.15 nm and the DNA double helix has a diameter of 2nm and the bacteria will be around 200nm. So particles of nanometer size are called Nano particles.

3.2.2 Characterization

Materials reduced to nanometer scale show unique characteristics. For instance, opaque substance become transparent (copper); stable materials turn combustible (aluminium); insoluble materials become soluble (gold). Therefore materials on nanoscale find wide applications in the field of medicine, electronics and in all fields of engineering.

3.2.3 Application of Nano particle technology in medicine

The biological and medical research communities have utilized the properties of nano particles for various applications:

Integration of nano materials with biology led to the development of diagnostic devices and drug delivery vehicles.

Diagnostics: Gold nano particles tagged with DNA can be used for the detection of genetic sequence.

Drug Delivery: Drug can be delivered for specific cell using nano particles.

3.2.4 Tissue Engineering

- This may replace todays conventional treatment like organ transplants/artificial inplants.
- Advanced forms in tissue engineering may lead to life extension.
- It can repair damaged tissue.

3.2.5 Application of nanotechnology in electronics

(I) Todays solar cells utilize only 40% of solar energy. Nano technology could help to increase the efficiency of light conversion using nanostructures.

(ii) The efficiency of internal combustion engine is about 30-40%. Nano technology could improve combustion by designing catalysts with maximised surface area.

(iii) Nano porous filters may reduce pollutants.

(iv) The use of batteries with higher energy content is possible with nano materials.

(v) Nano technology has already introduced integrated circuits in nanoscale (50nm) in CPU's and DRAM devices.

(vi) Carbon nano-tubes based cross bar memory called Nano-Ram has been developed.

3.2.6 Biomaterials

- Food and bio processing industry for manufacturing high quality of safe food can be solved using nano technology.
- Bacteria identification and food quality monitoring using bio-sensors are examples of application of nano technology.
- A nano composite coating act as anti microbial agents.
- Natural bone surface is 100nm across; if the artificial bone implant is smooth, the body rejects it; so nano sized finishing of hip and knee would help the body to accept the implant.

QUESTIONS

Part-A

1. What are nano particles?
2. Mention few unique characteristics of nano particles.

Part-B

1. Mention few applications of nano technology in engineering.
2. Explain the applications of biomaterials.
3. How come the nano technology becomes useful in the field of medicine?

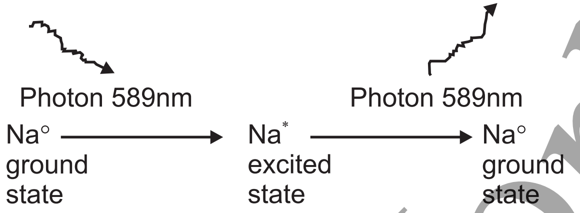
TEST YOUR UNDERSTANDING

1. Imagine few innovative applications of nano technology.
2. What could be the ill effects of nano technology?

3.3 PHOTO CHEMISTRY

3.3.1 Introduction

Photochemistry is the interaction of light and matter. When a sodium atom absorb a photon it goes to an excited state. After a short while, the excited sodium atom emits a photon of 589 nm light and falls back to its ground state. The atom can be excited by a flame, called flame test.



Absorption and emission of photon by sodium atom

3.3.2 Important terms used in Photo chemistry

(1) **Charge transfer / transition:** An electronic transition in which a large fraction of electronic charge is transferred from one region to the other region.

(2) **Electronic energy migration:** The movement of electronic excitation energy from one molecular entity to another.

Ground state: The lowest energy state of a chemical entity (atom)

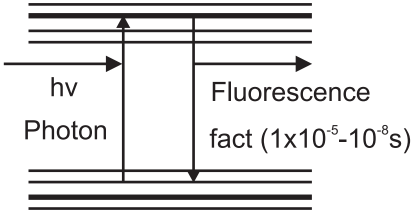
Excited State: A higher energy state of a chemical entity after absorbing energy.

Emission: Deactivation of excited state; transfer of energy from molecular entity to electromagnetic field.

Frequency: (ν or ω) The number of wave periods per unit time.

(3) Fluorescence

When a beam of light is incident on a substance, it emits visible light back; but as and when the incident light is cut off, they stop emitting. This phenomenon is called fluorescence and those substance which emit such light are called fluorescent substances. The other name for fluorescence is “cold light”. This happens due to the absorption of energy by the electron. They move from ground state to higher energy level (excited state).



This is produced in three ways.

i. ***Using electricity:*** When current flows through a medium the moving electrons collide with molecules in the medium. The energy make them excited to emit light e.g. Neon lights, fluorescent light, incandescent bulb.

ii. ***Using ultraviolet light:*** Electricity discharges through a gas (mercury vapour) and causing emission of u.v. light.

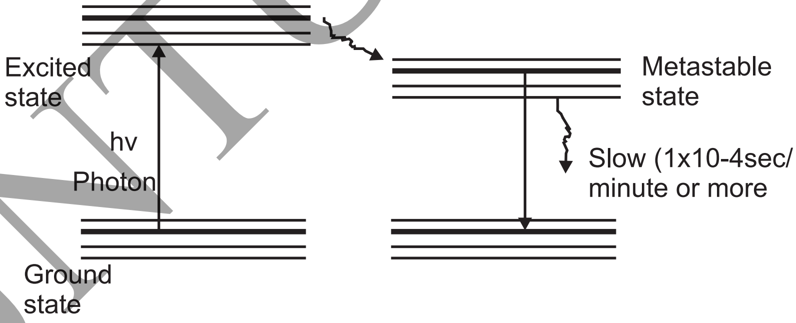
iii. ***Use of heat:*** Burning copper, excite electrons to give green light.

Some fluorescent substances

Fluorine, naphthalene, bibhenyl etc.

(4) Phosphorescence

When light is incident on certain substances, they emit light radiations continuously even after the incident light is cut off. This is called phosphorescence. Those substances are called phosphorescent substances.



A fluorescent paint glows under u.v.lamp, but stops glowing as the lamp is turned off. A phosphorescent paint keeps glowing for a while. Phosphorescent substance have the ability to store up light and release it gradually. Ground state molecules absorb photons and go to excited singlet states. Most of them come back to the ground state causing fluorescence. Few of them come to an intermediate state, called a metastable state by non-radiative process from the metastable state. It comes down to the ground state and slowly give out light. Some of the phosphorescent substances are zinc sulphide, calcium sulphide, etc.

(5) Chemiluminescence

A chemical reaction leading to the expelling light is called chemiluminescence.

$$x + y \longrightarrow [x+y]^{*} \longrightarrow \text{products} + \text{light}$$

A common example of chemiluminescence is the reaction between a fuel and oxidant producing excited products that emit light. Nitrogen monoxide reacts with ozone to produce nitrogen dioxide in an excited state. $[NO_2]^{*}$ returns to lower energy state and emits light.

eg. Sea divers use chemiluminescence for want of light under water.

(6) Photo Electric Cell

A photoelectric cell is a device that is activated by electromagnetic energy in the form of light waves. Light is a form of energy. When light strikes certain chemical substances such as selenium or silicon, its energy causes a push on the electrons.

Based on the nature of photo electric effect there are three types of cells. (i) photo conductive cell (ii) photo emissive cell (iii) photo voltaic cell.

(7) Photo Emissive cell

These cells are very popular for triggering the automatic opening of doors. This type of cell contains a wire, as anode and a semi cylindrical cathode with an emitting surface. These are seated in an evacuated or gas filled bulb. The cathode surface is coated with cesium, potassium or rubidium. As light incident upon cathode, the surface emits electrons. The emitted electrons are attracted to the positive anode as photo current. This is properly designed in a electronic circuit.

(8) Photo synthesis

Photo synthesis is a process by which green plants absorb light energy from sunlight, it then prepares glucose and carbohydrates by the combination of carbondioxide and water. The byproduct of photo synthesis is oxygen which is essential for all living organisms. All atmospheric oxygen has originated only from photo synthesis.

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

General chemical reactions in photo synthesis

Green plants use the energy absorbed in the form of light to make organic compounds from inorganic compounds. The simple form of photosynthesis can be written as

$$CO_2 + H_2O \xrightarrow{\text{Light}} \underset{\text{Carbohydrate}}{[CH_2O]_n} + O_2$$

It was proved that oxygen come only by the photolysis of water molecule. Therefore two molecules of water must be involved to release one oxygen molecule. Therefore,

$$CO_2 + 2H_2O \xrightarrow{\text{Light}} [CH_2O]_n + O_2 + H_2O$$

Chlorophyll and Accessory pigments

A pigment may be defined as a substance that absorbs light. The colour which is not absorbed appears as the colour of the pigment. Chlorophyll absorbs all the wavelength except green.

Mechanism of photosynthesis

Photosynthesis is a two stage process. The first stage called light dependent process is called light reactions. It is followed by light independent process called dark reactions.

(9) Light reactions:

In the light reactions, light strikes chlorophyll-a and excite electrons to a higher energy. In a series of reaction the energy is converted to ATP (Adenosine triphospate) and NADPH (Nicotinamide-Adenine Dinucleotide Hydrogen Phosphate). Water is split in the process releasing oxygen as byproduct of the reaction. During the day time plants make their own food in the form of glucose. It is then stored in the form of starch.

(10) Dark reactions

Carbon fixing reactions are known as dark reactions. The control feature of dark reactions in photo synthesis is the carbon reduction cycle called Calvin Benson cycle. The ATP and NADPH are used to make C-C bonds in the absence of light to form glucose from stored starch.

3.3.3 PHOTO SYNTHESIS AND ACID RAIN

Plants help to remove carbon-di-oxide from the atmosphere and oceans. Plants also produce carbon dioxide during respiration but that is again used for photosynthesis. Plants also convert light energy into chemical energy to form C-C bonds. Animals are carbon-di-oxide producers and obtain their energy from carbohydrates and other products from plant kingdom.

The balance between the carbon dioxide removal by the plants and the carbon dioxide produced by animals is equalised by the formation of carbonates in the oceans.

CO_2 (from animal kingdom) + CO_2 (Plant kingdom) =

CO_2 (taken for photo synthesis) + CO_2(Carbonates in ocean)

The CO_2 from animal kingdom includes CO_2 generated by fossil fuels (coal, petrol, diesel etc.) and industrial outlet. The equation is not balanced due to

(i) Deforestation [Remove less CO_2]

(ii) Industrialisation [Add more CO_2]

This leads to global warming. The increase in CO_2 and other pollutants like NO_2 and SO_2 leads to acid rain.

QUESTIONS

Part-A

1. What is called ground state of an atom?
2. Define excited state of a chemical entity.
3. Give any two example of fluorescent light.
4. Name any two fluorescent substances.
5. What are the three types of photo electric cell?

6. What is coated on the cathodic area of a photo emissive cell?
7. Define photosynthesis.
8. What is the role of chlorophyll- in a green leaf?
9. Mention the disadvantage of deforestation.
10. Define photo chemistry.

Part-B

1. Write notes on (i) flurescence (ii) Phosphorescence.
2. Explain chemi luminescence.
3. Explain the mechanism of photo synthesis.
4. Explain the importance of photosynthesis in preventing acid rain.

TEST YOUR UNDERSTANDING

1. What makes the sky appear blue?
2. Think about a town/city-plan that is free from deforestation.

UNIT IV

ELECTROCHEMISTRY, CELL AND BATTERIES

4.1 ELECTROCHEMISTRY

4.1.1 Introduction

Electrochemistry is a branch of chemistry which deals with the relationship between electrical energy and chemical energy.

Electrochemical reactions find applications in many industries. Electrochemistry broadly discusses about electrical effects on passing electricity through a solution.

Electrolysis comes under this category and finds applications in

I) Metallurgy

ii) Electroplating

iii) Chemical manufacturing processes including medicines.

Chemical effects producing electricity

Electrochemical cells including Dry cells, Daniel cells, Laclanche cells, rechargeable batteries are used in day to day life in torchlight, transistors, wall clocks, automobiles and cell phones.

The basics of electrolysis and its applications in electroplating are discussed in the following sections.

4.1.2 Electrolyte

An electrolyte is a substance, which conducts electricity both in solution and in fused state.

Example: Sodium chloride, hydrochloric acid, copper sulphate solution, etc.

Non-electrolytes

A non-electrolyte is a substance which does not conduct electricity either in solution or in fused state.

Example: Sugar, urea, alcohol, etc.

Strong electrolytes

The electrolytes, which ionize completely in solution, are called strong electrolytes.

Example: Sodium hydroxide, potassium chloride, sodium chloride, etc.

Weak electrolytes

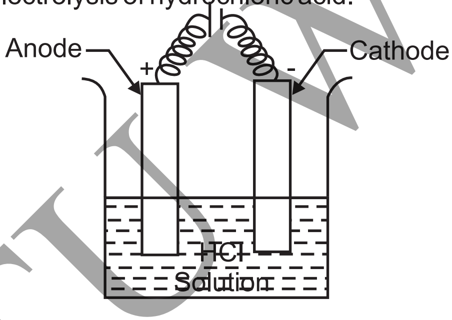
Electrolytes which do not ionize completely in solution are called weak electrolytes.

Example: Acetic acid, oxalic acid, etc.

4.1.3 Electrolysis

Decomposition of a substance by passing electric current is called electrolysis. During electrolysis, electrical energy is converted into chemical energy.

Example: Electrolysis of hydrochloric acid.



4.1.4 Mechanism of electrolysis

Hydrochloric acid contains H^+ ions and Cl^- ions. During electrolysis, H^+ ions move towards the cathode (-ve electrode). So, H^+ ions are called cations. Similarly Cl^- ions move towards the anode (+ve electrode). So, Cl^- ions are called anions.

Anodic reaction:

At the anode, Cl^- ions get oxidized to chlorine atoms by the loss of electrons.

$$Cl \rightarrow Cl + e^- \text{ (oxidation)}$$

$$2Cl \rightarrow Cl_2 \text{ (gas)}$$

Chlorine gas is liberated at the anode.

Cathodic reaction:

At the cathode, H^+ ions get reduced to hydrogen atoms by gain of electrons.

$$H^+ + e^- \rightarrow H \quad \text{(reduction)}$$

$$2H \rightarrow H_2 \text{ (gas)}$$

Hydrogen gas is liberated at the cathode.

Thus, hydrochloric acid decomposes into hydrogen and chlorine.

Electrolysis depends on the following factors:

(i) Nature of electrodes used and (ii) Physical nature of electrolytes used.

4.1.5 Industrial Applications of Electrolysis

Electrolysis is applied in

(i) Electroplating

(ii) Anodization of Aluminium

(iii) Electrolytic refining of metals.

4.1.6 Electroplating

Electroplating is coating of a more noble metal over a less noble metal by electrolysis. Electroplating is done for the following purpose.

(a) To make the surface corrosion resistant.

(b) To improve the surface appearance.

In electroplating,

The metal which is to be electroplated (base metal) is taken as cathode; the metal to be coated on (coat metal) is taken as anode. A salt solution of coat metal is taken as electrolyte.

Example: Chrome plating, silver plating, copper plating, gold plating etc.

4.1.7 Preparation of surface

It is essential to clean the article thoroughly before applying a coating. The cleaning of the article is called as 'preparation of surface'.

- First, a surface is buffed with emery sheet to get a polished (cleaned) surface.

- The surface is then washed with solvents like acetone to remove oil and grease.
- It is then washed with tri-sodium phosphate (TSP) to remove any oil and dirt.
- It is finally dipped in 3N hydrochloric acid for few minutes to remove any oxide impurities.
- In between the above operations, the article is washed with water.
- Finally it is washed thoroughly with demineralised water.

4.1.8 Factors affecting the stability of the coating

The nature, stability and thickness of the coating depends on the following factors:

1. Nature of the electrolyte.
2. Nature of the electrode.
3. Solubility of the electrolyte.
4. Concentration of electrolyte solution.
5. Temperature.
6. Voltage applied (low).
7. Current density (high).
8. Time for which the current is passed.
9. pH of electrolyte solution.

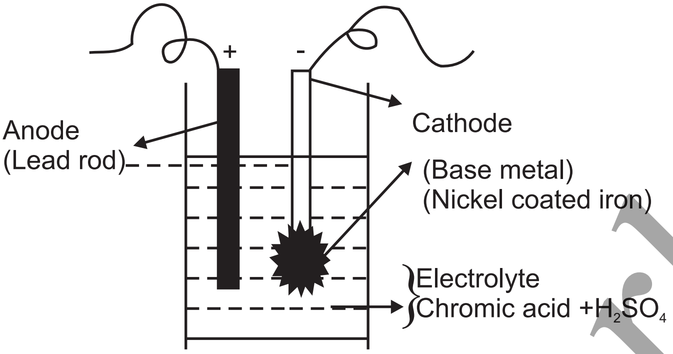
4.1.9 Chrome plating

Coating of chromium over nickel or copper (coated mild steel) is called chrome plating.

Process:

1) The nickel or copper coated iron article (base metal) is placed at the cathode.
2) A lead-antimony rod is used as the anode.
3) A solution of chromic acid and sulphuric acid (100:1) is used as the electrolyte.
4) Temperature of the electrolyte solution is maintained at 40^0C to 50^0C.
5) A current density of 100 – 200 mA/cm^2 is used.
6) Sulphate ions act as catalyst for coating.
7) When electric current is passed, electrolysis takes place and chromium is deposited over the base metal.

A schematic diagram of coating of chromium is given below.



4.1.10 Electroless plating

Electroless plating is a technique of depositing a noble metal (from its salt solution) on a catalytically active surface of a less noble metal by employing a suitable reducing agent without using electrical energy.

The reducing agent causes reduction of metallic ions to metal which gets plated over the catalytically activated surfaces giving a uniform thin coating.

Metal ions + Reducing agent → Metal + Oxidized products

(deposited)

Example: Electroless nickel plating.

Electroless Nickel plating

Procedure:

The pretreated object (example: Stainless steel) is immersed in the plating bath containing $NiCl_2$ and a reducing agent, sodium hypophosphite for the required time. During the process, Ni gets coated over the object.

Anodic reaction:

$H_2PO_2^- + H_2O \rightarrow H_2PO_3^- + 2H^+ + 2e^-$

Cathodic reaction:

$Ni^{2+} + 2e^- \rightarrow Ni$

4.1.11 Advantages of Electroless plating over electroplating

1. No electricity is required for electroless plating.
2. Electroless plating on insulators (like plastics, glass) and semiconductors can be easily carried out.
3. Complicated parts can also be plated uniformly in this method.
4. Electroless coatings possess good mechanical, chemical and magnetic properties.

4.1.12 Applications of Electroless plating

1. Electroless nickel plating is extensively used in electronic appliances.
2. Electroless nickel plating is used in domestic and in automotive fields.
3. Electroless nickel coated polymers are used in decorative and functional applications.
4. Electroless copper and nickel coated plastic cabinets are used in digital as well as electronic instruments.
5. Electroless copper plating is used in manufacture of double sided and multilayered printed circuits boards (PCB).

SUMMARY

In this lesson, types of electrolytes, mechanism of electrolysis, industrial applications of electrolysis, preparation of surface, factors affecting coating, electroplating, electro less plating, its advantages and applications are discussed.

QUESTION

PART - A (1 Mark)

1. What is an electrolyte?
2. Give two examples for strong electrolytes.
3. Give two examples for weak electrolytes.
4. Define strong electrolyte.
5. Define weak electrolyte.
6. Define electrolysis.
7. Give any two industrial applications of electrolysis.
8. What is electroplating?
9. Mention any two factors affecting the stability of coating.

10. What is chrome plating?
11. What is the anode and electrolyte used in chrome plating?
12. What is electroless plating?
13. Give any two advantages of electroless plating over electroplating.
14. Give any two applications of electroless plating.

PART - B (6 Marks)

1. Explain electrolysis with a suitable example.
2. What are the steps involved in preparation of surface?
3. What are the factors affecting the stability of coating?
4. Explain electroplating with an example.
5. Describe chrome plating with a neat diagram.
6. Explain electroless plating with an example.
7. I) What are the advantages of electroless plating over electroplating?
   ii) Give the applications of electroless plating.

4.2 CELL

4.2.1 Introduction

A system in which two electrodes are in contact with an electrolyte is called as cell. There are two types of cells,

I) Electrolytic Cell

ii) Electrochemical cell.

Electrolytic cell is a device which produces chemical change by supplying electric current from outside source. Here, electrical energy is converted into chemical energy.

4.2.2 Electrochemical Cell

Electrochemical cell is a device in which chemical energy from a redox reaction is utilized to get electrical energy. Here, chemical energy is converted into electrical energy.

Example: Daniel cell.

4.2.3 Single electrode potential

The measure of tendency of a metallic electrode to lose or gain electrons when in contact with a solution of its own salt in a half cell of an electrochemical cell is called as single electrode potential.

The tendency of an electrode to lose electrons is called oxidation potential while the tendency of an electrode to gain electrons is called reduction potential.

4.2.4 Galvanic Cell

Galvanic cells are electrochemical cells in which the electrons transferred due to redox reaction, are converted into electrical energy. A galvanic cell consists of two half-cells with each half-cell contains an electrode. The electrode at which oxidation takes place is called anode and the electrode at which reduction occurs is called cathode. The electrons liberated to the electrolyte from the metal leaves the metal ions at anode. The electrons from the solution are accepted by the cathode metal ion to become metal. Galvanic cell is generally represented as follows.

$M_1 / M_1^+ || M_2^+ / M_2$ or M_1 / (Salt of M_1) || M_2 / (Salt of M_2)

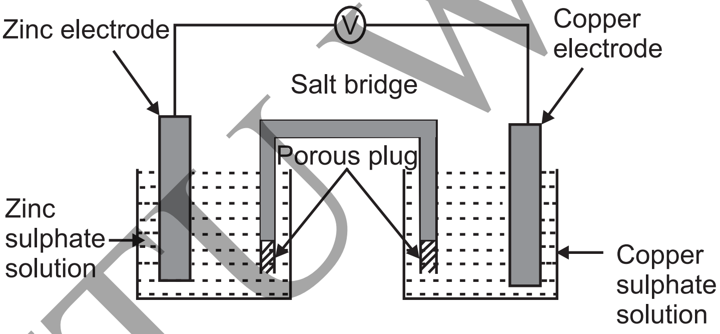
Where, M_1 & M_2 are Anode and Cathode respectively and M_1^+ & M_2^+ are the metal ions in respective electrolyte. The symbol || denotes salt bridge. The above representation of galvanic cell is known as galvanic cell diagram.

Example: The typical example for galvanic cell is Daniel cell.

4.2.5 Daniel Cell

This cell consists of a zinc rod as anode dipped in zinc sulphate solution (electrolyte) in a glass tank and copper rod as cathode dipped in copper sulphate (electrolyte) in another glass tank. Each electrode is known as half cell. The two half cells are inter-connected by a salt bridge and zinc and copper electrodes are connected by a wire through voltmeter. The salt bridge contains saturated solution of KCl in agar-agar gel. The cell diagram of Daniel cell is

$Zn / Zn^{2+} || Cu^{2+} / Cu$ or $Zn / ZnSO_4 || / CuSO_4 ||Cu$



Redox reaction occurs at Daniel cell:

At anode

$Zn \longrightarrow Zn^{2+} + 2e^-$ (Oxidation)

At cathode

$Cu^{2+} + 2e^- \longrightarrow Cu$ (Reduction)

Overall Cell reaction

$Zn + Cu^{2+} \longrightarrow Cu + Zn^{2+}$

4.2.6 Electrochemical series

When various metals as electrodes are arranged in the order of their increasing values of standard reduction potential on the hydrogen scale, then the arrangement is called electrochemical series.

Electrode	Electrode Reaction	Reaction Potential (E^0 Values) Volts
Li^+/Li	$Li + e^- \rightarrow Li$	-3.01
Mg^{2+}/Mg	$Mg^{2+} + 2e^- \rightarrow Mg$	-2.37
Pb^{2+}/Pb	$Pb^{2+} + 2e^- \rightarrow Pb$	-1.12
Zn^{2+}/Zn	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.76
Fe^{2+}/Fe	$Fe^{2+} + 2e^- \rightarrow Fe$	-0.44
Sn^{2+}/Sn	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.13
H^+/H	$H^+ + e^- \rightarrow H$	0.00
Cu^{2+}/Cu	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.34
Ag^+/Ag	$Ag^+ + 2e^- \rightarrow Ag$	+0.80
Au^+/Au	$Au^+ + e^- \rightarrow Au$	+1.50

Electrochemical series

4.2.7 Significance and applications of electrochemical series

1. Calculation of standard EMFof a cell

   Standard electrode potential of any cell can be calculated using this series.

2. Relative ease of oxidation and reduction

   Higher the value of standard reduction potential (+ve value) greater is the tendency to get reduced. Thus, metals on the top having more negative (–ve) values are more easily ionized (oxidized).

3. Displacement of one element by another

   Metals which lie higher in the series can displace those elements which lie below them in the series.

4. Determination of equilibrium constant for the reaction

   The equilibrium constant for the cell can be calculated from the standard electrode potential.

5. Hydrogen displacement behaviour

   Metals having more –ve potential in the series will displace hydrogen from acid solutions.

6. Predicting spontaneity of redox reactions

   Spontaneity of redox reaction can be predicted from the standard electrode potential values of the complete cell reaction.

4.2.8 Concentration cell

The cell which produces electrical energy by transfer of a substance from the solution of higher concentration to the solution of lower concentration is called concentration cell.

This is also an electrochemical cell. The difference in concentration may be brought about by the difference in concentration of the electrodes or electrolytes.

The concentration cells are classified into two types.

I) Electrode concentration cell

ii) Electrolyte concentration cell.

Electrode concentration cell:

Two identical electrodes of different concentrations are dipped in the same electrolytic solution of the electrode metal in a cell is called electrode concentration cell.

Example: Amalgam concentration cells.

Amalgam electrodes are produced by mixing various proportions of lead and mercury. It is represented as,

$$\mathrm{Hg} - \mathrm{Pb}(C_1) / \mathrm{PbSO}_{4(aq)} \,||\, \mathrm{Hg}\text{-}\mathrm{Pb}(C_2)$$

Where, C_1 & C_2 are concentrations of electrolytes

Electrolyte concentration cell:

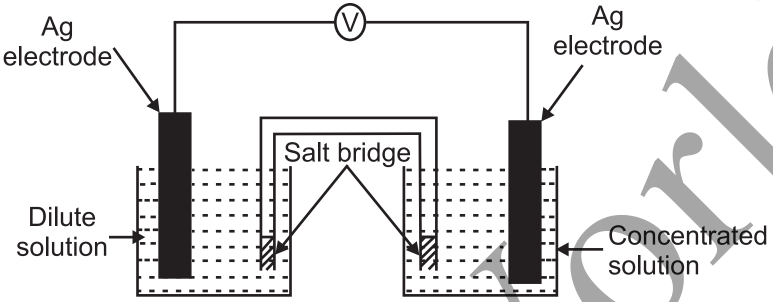
Two identical electrodes of same concentrations are dipped in the electrolytic solutions of different concentration in a cell is called electrolyte concentration cell.

Example: Silver ion concentration cell

The diagram of an electrolytic concentration cell is

$$Ag / Ag^{+}(C_1) \,||\, Ag^{+}(C_2) / Ag \quad (C_2 > C_1)$$

Diluted Concentrated



SUMMARY

In this lesson, electrochemical cells, single electrode potential, galvanic cell, construction and working of Daniel cell, significance and applications of electrochemical series and two types of concentration cells are discussed.

QUESTION

Part - A

1. What is an electrochemical cell?
2. Give two examples for electrochemical cell.
3. Define single electrode potential.
4. What is galvanic cell?
5. Write an example for a galvanic cell.
6. What is Daniel cell?
7. How will you write a short representation of a Daniel cell?
8. Define electrochemical series.
9. Write any two applications of electrochemical series.
10. Define concentration cell.
11. What are the types of concentration cells? Give examples.
12. Give an example for electrode concentration cell.
13. Give an example for electrolyte concentration cell.

Part - B

1. Explain electrochemical cell with example.
2. Explain the construction and working of Daniel cell.
3. Describe a galvanic cell with cell reactions.
4. What are the applications of electrochemical series?
5. Explain the construction and working of a concentration cell with example.

4.3 STORAGE BATTERIES

4.3.1 Introduction

A device that stores chemical energy and releases it as electrical energy is called as battery or storage battery.

A battery is an electrochemical cell which is often connected in series in electrical devices as a source of direct electric current at a constant voltage.

Batteries are classified as follows,

I) Primary battery
ii) Secondary battery
iii) Fuel battery or Flow battery

Primary battery

Primary battery is a cell in which the cell reaction is not reversible. Thus, once the chemical reaction takes place to release the electrical energy, the cell gets exhausted. They are use and throw type.

Example: Dry cell, Laclanche cell etc.

Secondary battery

Secondary battery is a cell in which the cell reaction is reversible. They are rechargeable cells. Once the battery gets exhausted, it can be recharged.

Example: Nickel-Cadmium cell, Lead-acid cell (storage cell), etc.

Fuel battery or Flow battery

Flow battery is an electrochemical cell that converts the chemical reaction into electrical energy. When the reactants are exhausted, new chemicals replace them.

Example: Hydrogen-oxygen cell, Aluminium-air cell, etc.

In Aluminium-air cell, when the cell is exhausted, a new aluminium rod is used and the solution is diluted with more water as the electrochemical reaction involves aluminium and water.

4.3.2 Dry Cell

A cell without fluid component is called as dry cell.

Example: Daniel cell, alkaline battery.

Construction and working:

The anode of the cell is zinc container containing an electrolyte consisting of NH_4Cl, $ZnCl_2$ and MnO_2 to which starch is added to make it thick paste-like so that is less likely to leak. A graphite rod serves as the cathode, which is immersed in the electrolyte in the centre of the cell.

The electrode reactions are given below.

Anodic reaction

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

(Oxidation)

Cathodic reaction

$$2MnO_2\,(s) + H_2O + 2e^- \longrightarrow Mn_2O_3\,(s) + 2OH^-\,(aq)$$

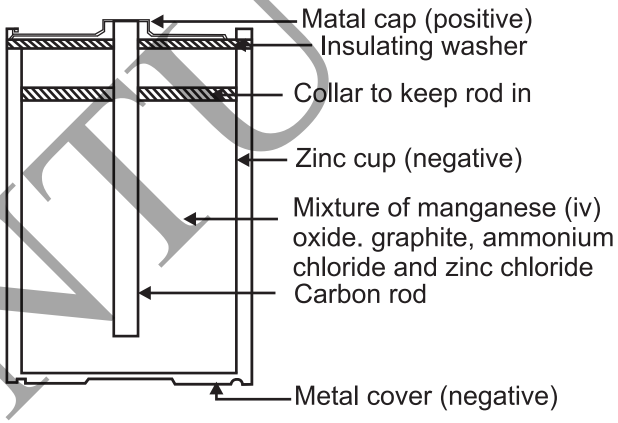
(Reduction)

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

$$2MnO_2\,(s) + 2NH_4^+\,(aq) + Zn^{2+}\,(aq) + 2e^- \longrightarrow [Zn(NH_3)_2]Cl_2\,(s)$$

Overall reaction

$$Zn(s) + 2NH_4^+(aq) + 2Cl^-(aq) + 2MnO_2(s) \longrightarrow Mn_2O_3(s) + [Zn(NH_3)_2]Cl_2(s) + 2H_2O$$



The dry cell is a primary battery, since no reaction is reversible by supplying electricity. Dry cell is very cheap to make. It gives voltage of about 1.5V.

But, it has few demerits: i) When current is drawn rapidly, drop in voltage occurs. ii) Since the electrolyte is acidic, Zn dissolves slowly even if it is not in use.

Uses

Dry cells are used in flash-lights, transistor radios, calculators, etc.

4.3.3 Lead – acid storage cell

The typical example for storage cell is Lead-acid storage cell. It is a secondary battery which can operate as a voltaic cell and as an electrolytic cell. When it acts as a voltaic cell, it supplies electrical energy and becomes run down. When it is recharged, the cell operates as an electrochemical cell.

Construction and Working:

A lead – acid storage cell consists of a number of voltaic cells (3 to 6) connected in series to get 6 to 12 V battery. In each cell, a number of Pb plates used as anodes are connected in parallel and a number of PbO_2 plates used as cathodes are connected in parallel. The plates are separated by insulators like rubber or glass fibre. The entire combinations are immersed in dil.H_2SO_4.

The cell is represented as

$Pb \mid PbSO_4 \parallel H_2SO_4 \mid PbO_2 \mid Pb$

When the lead-acid storage battery operates, the following cell reactions occur.

Anodic reaction:

Lead is oxidized to Pb^{2+} ions, which further combines with SO_4^{2-} forms insoluble $PbSO_4$.

$Pb\,(s) + SO_4^{2-} \longrightarrow PbSO_4\,(s) + 2e^-$

Cathodic reaction:

PbO_2 is reduced to Pb^{2+} ions, which further combines with SO_4^{2-} forms insoluble $PbSO_4$.

$PbO_2\,(s) + 4H^+ + SO_4^{2-} + 2e^- \longrightarrow PbSO_4\,(s) + 2H_2O$

Overall cell reaction during discharging:

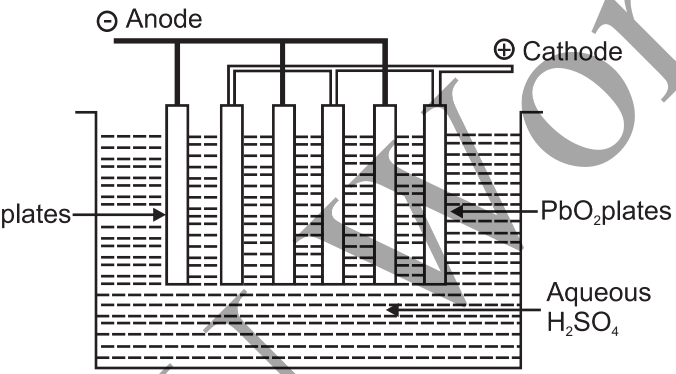
$Pb\,(s) + PbO_2\,(s) + 2H_2SO_4\,(aq) \longrightarrow PbSO_4\,(s) + 2H_2O + \text{Energy}$

From the above cell reactions, it is clear that $PbSO_4$ is precipitated at both the electrodes and the concentration of H_2SO_4 decreases. So, the battery needs recharging.

Overall cell reaction during recharging:

The cell can be charged by passing electric current in the opposite direction. The electrode reaction gets reversed. As a result, Pb is deposited on anode and PbO_2 on the cathode. The concentration of H_2SO_4 also increases.

$$2PbSO_4\,(s) + 2H_2O + \text{Energy} \longrightarrow Pb\,(s) + PbO_2\,(s) + 2H_2SO_4\,(aq)$$



Advantages of Lead – acid batteries:

1. It is made easily.
2. It produces very high current.
3. The self discharging rate is low.
4. It works effectively even at low temperatures.

Uses:

1. Lead – acid batteries are used in cars, buses and trucks etc.
2. It is used in gas engine ignition, telephone exchanges, power stations etc.

4.3.4 Nickel – Cadmium cell

A nickel – cadmium storage cell consists of Cadmium as anode and NiO_2 paste as cathode and KOH as the electrolyte.

The cell is represented as

$Cd \mid Cd(OH)_2 \parallel KOH\ (aq) \mid NiO_2 \mid Ni$

Construction and Working:

When the nickel battery operates, Cd is oxidized to Cd^{2+} ions at anode and the insoluble $Cd(OH)_2$ is formed. NiO_2 is reduced to Ni^{2+} ions which further combines with OH^- ions to form $Ni(OH)_2$. It produces about 1.4 V. The following cell reactions occur.

Anodic reaction:

$$Cd\ (s) + 2OH^- \longrightarrow Cd(OH)_2\ (s) + 2e^-$$

Cathodic reaction:

$$NiO_2\ (s) + 2H_2O + 2e^- \longrightarrow Ni(OH)_2\ (s) + 2OH^-$$

Overall cell reaction during discharging:

$$Cd\ (s) + NiO_2\ (s) + 2H_2O \longrightarrow Cd(OH)_2\ (s) + Ni(OH)_2\ (s) + \text{Energy}$$

From the above cell reactions, it is clear that $Cd(OH)_2$ and $Ni(OH)_2$ are deposited at both the anodes and cathodes respectively. So, this can be reversed by recharging the cell.

Overall cell reaction during recharging:

The cell can be charged by passing electric current in the opposite direction. The electrode reactions get reversed. As a result, Cd is deposited on the anode and NiO_2 on the cathode.

$$Cd(OH)_2\ (s) + Ni(OH)_2\ (s) + \text{Energy} \longrightarrow Cd\ (s) + NiO_2\ (s) + 2H_2O$$

Advantages of Ni-Cd battery:

1. It is portable and rechargeable cell.
2. It has longer life than lead – acid battery.
3. It can be easily packed like dry cell since it is smaller and lighter.

Uses:

1. It is used in calculators.
2. It is used in gas electronics flash units.
3. It is used in transistors, cordless electronic appliances, etc.

4.3.5 H_2-O_2 Fuel cell (Green fuel cell)

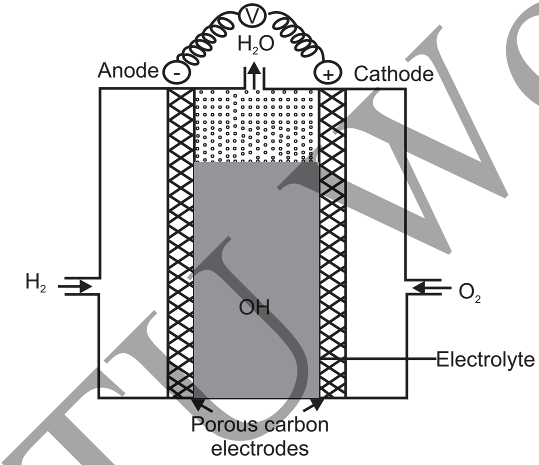
A typical example of pollution free cell is H_2-O_2 fuel cell in which the fuel is hydrogen and the oxidizer is oxygen.

A full cell converts the chemical energy of the fuels directly to electricity. The essential process in a fuel cell is

$$\text{Fuel} + \text{Oxygen} \longrightarrow \text{Oxidation products} + \text{Electricity}$$

Construction and working:

Hydrogen – oxygen fuel cell consists of two porous electrodes made up of compressed carbon coated with small amount of catalysts (Pt, Pd, Ag) and KOH or NaOH solution as the electrolyte.



During working, Hydrogen (the fuel) is bubbled though the anode compartment, where it is oxidized. The oxygen (oxidizer) is bubbled though the cathode compartment, where it is reduced. The following cell reactions occur.

Anodic reaction:

$$2H_2 + 4OH^- \longrightarrow 4H_2O + 4e^-$$

Cathodic reaction:

$$O_2 + 4H_2O + 4e^- \longrightarrow 4OH^-$$

Overall cell reaction:

$$2H_2(g) + O_2(g) \longrightarrow 4H_2O(l)$$

From the above cell reactions, hydrogen molecules are oxidized to water. When a large number of fuel cells are connected in series, it is called fuel battery.

Advantages of fuel cells:

1. Fuel cells are efficient and take less time for operation.
2. No harmful chemicals are produced in fuel cells.

Uses

1. It is used as auxiliary energy source in space vehicles, submarines etc.
2. It is used in producing drinking water for astronauts in the space.

4.3.6 Solar cell

A device which converts the solar energy (energy obtained from the sun) directly into electrical energy is called 'Solar cell'. This is also called as 'Photovoltaic cell'.

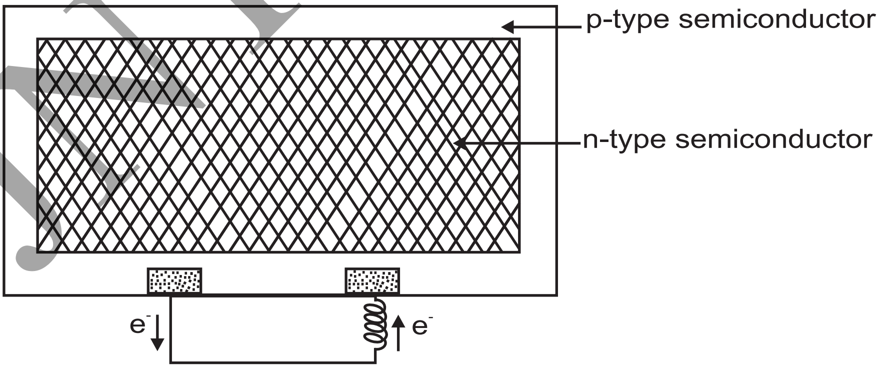
Principle:

The basic principle involved in the solar cells is based on the photovoltaic (PV) effect. When sun rays fall on the two layers of semiconductor devices, potential difference between the two layers is produced. This potential difference causes flow of electrons and thus produces electricity.

Example: Silicon solar cell

Construction:

Solar cell consists of a p-type (such as Si doped with boron) and a n-type (such as Si doped with phosphorous). They are in close contact with each other.



Working:

When the solar rays fall on the top layer of p-type semiconductor, the electrons from the valence band get promoted to the conduction band and cross the p-n junction into n-type semiconductor. Thereby potential difference between two layers is created, which causes flow of electrons (i.e. electric current). The potential difference and hence current increases as more solar rays falls on the surface of the top layer.

Thus, when this p- and n- layers are connected to an external circuit, electrons flow from n-layer to p-layer and hence current is generated.

Applications of solar cells:

1. Solar cells are used in street lights.
2. Water pumps are operated by using solar batteries.
3. They are used in calculators, watches, radios and TVs.
4. They are used for eco-friendly driving vehicles.
5. Silicon Solar cells are used as power source in space crafts and satellites.
6. Solar cells can even be used in remote places and in forests to get electrical energy without affecting the atmosphere.

SUMMARY

In this lesson, various types of batteries, construction, working with cell reactions of storage batteries like, dry cell, lead - acid cell, Ni - Cd cell, H_2 - O_2 fuel cell, solar cell and their uses are discussed.

QUESTION

Part - A

1. Define a storage battery.
2. What is a primary battery? Give example.
3. What is a secondary battery? Give example.
4. Define a fuel cell.
5. What is dry cell? Give an example.
6. Write short representation of lead - acid storage cell.
7. Give any two fuel batteries.
8. What is a green fuel cell? Why is it called so?
9. Give any two use of lead – acid battery.
10. What is a solar cell?
11. Give any two applications of solar cells.

Part - B

1. Explain construction and working of dry cell with example.
2. Explain the construction and working of lead – acid battery.
3. Describe a nickel – cadmium battery with cell reactions.
4. What is green fuel cell? Explain its working.
5. Explain the construction and working of flow battery with example.
6. Write a note on solar cell.
7. Explain the uses of solar cells.

UNIT V

CORROSION ENGINEERING

5.1 CORROSION

5.1.1 Introduction

Corrosion is a 'billion dollar thief'. Even though it is a natural phenomenon in which the gases present in the atmosphere react chemically with metals to convert them into their salts, it results in loss of material and money. Metals have a strong crystalline structure and when they are converted into their salts they lose the metallic strength resulting in the damage to machineries in which they are used. Thus corrosion causes damage to metals and there by to the society. The estimate of loss due to corrosion is approximately 2.5 billion dollars / annum all over the world. Hence it is necessary to understand the mechanism of corrosion. In this lesson we are going to study about the causes and the mechanism of corrosion so that we can find ways to prevent this social enemy.

Corrosion is defined as the deterioration of a metal by chemical or electro chemical reactions with its environment.

Due to corrosion the useful properties of a metal like malleability, ductility, electrical conductivity and also the surface appearance are lost.

The most familiar example of corrosion is rusting of iron when exposed to atmospheric conditions.

Another example is the formation of green film or basic Carbonate [$CuCO_3$+$Cu(OH)_2$] on the surface of copper when exposed to moist air containing CO_2.O_2

5.1.2 Types of Corrosion:

1. Chemical Corrosion or Dry Corrosion
2. Electro chemical Corrosion or Wet Corrosion

(1) Chemical Corrosion or Dry Corrosion

The direct chemical action of atmospheric gases like oxygen, halogen, H_2S etc in a dry environment on metals, a solid filim of the Corrosion produced is formed on the surface of the metal. This is known as chemical Corrosion.

A solid film of the corrosion product is formed on the surface of the metal which protects the metal from further corrosion. If a soluble or volatile corrosion product is formed, then the metal is exposed to further attack. 'For example, chlorine attack silver generating a protective film of silver chloride on the surface.

$$2\,Ag + Cl_2 \rightarrow 2AgCl.$$

(2) Electro Chemical Corrosion or wet corrosion

Wet corrosion occurs due to the electrochemical action of moisture and oxygen on metals. Corrosion of very important metal, iron takes place due to electrochemical attack.

There are two theories proposed to explain rusting of iron.

1) Galvanic cell formation theory

2) Differential aeration theory (concentration cell theory)

5.1.3 Galvanic Cell Formation Theory

- When iron piece with impurity is exposed to atmosphere, a mini galvanic cell is formed.
- Iron with atmosphere forms one electrode.
- Impurity (copper, tin, dirt, etc) with atmosphere forms another electrode.
- **Anodic reaction**

Iron which is more electropositive acts as **anode.** Therefore iron is oxidized to ferrous ions (Fe^{2+} ions) by the removal of electrons. Ferrous ions combine with hydroxide ions to form ferrous hydroxide by atmosphere. Finally ferric hydroxide decomposes to form ferric oxide, which is nothing, but rust.

$$Fe \rightarrow Fe^{2+} 2e^-$$

$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$$

$$Fe(OH)_2 \xrightarrow{[O]} Fe(OH)_3$$

$$Fe(OH)_3 \rightarrow Fe_2O_3 + H_2O$$

- ❖ The electrons released at the anode are absorbed at the cathode to form either hydrogen or water or hydroxide ion depending on the nature of the atmosphere.
- ❖ This completes the formation of the cell, which favours rusting of iron.

Cathodic reaction

Depending on the nature of the atmosphere the following reactions take place at the cathode.

When the atmosphere is acidic and contains no oxygen, hydrogen will be given out.

$2H^+ + 2e^- \rightarrow H_2$

When the atmosphere is acidic and contains more oxygen water will be given out.

$2H^+ + [O] + 2e^- \rightarrow H_2O$

When the atmosphere is basic or neutral and contains no oxygen, OH^- and H_2 will be given out.

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

When the atmosphere is basic or neutral and contains more oxygen OH^- will be given out.

$2H_2O + O_2 + 4e^- \rightarrow 4OH^-$

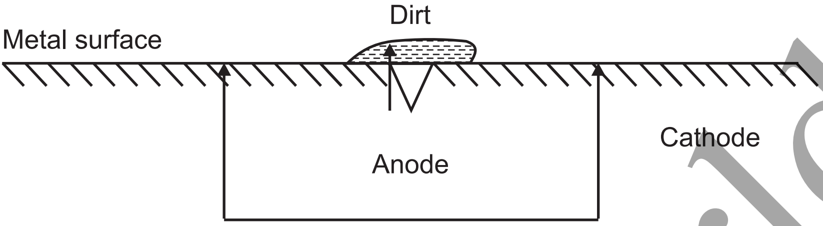
(2) Differential aeration theory or concentration cell formation theory

According to this theory, corrosion occurs due to the development of concentration cell formed by varying concentration of oxygen or any electrolyte on the surface of the metal.

Thus,

The less oxygenated area acts as Anode (gets corroded)

The more oxygenated area acts as the Cathode (Protected from Corrosion)



Reaction

At anode (less oxygenated area)

$Fe \rightarrow Fe^{2+} + 2e^{-}$ (oxidation or corrosion)

At the cathode (more oxygenated area)

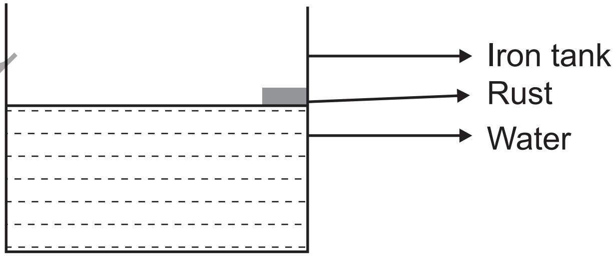
$2H_2o + O_2 + 4e^{-} \rightarrow 4OH^{-}$ (Reduction)

$Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)_2$

$Fe(OH)_2$ is further oxidized to $Fe(OH)_3$. Since the anodic area is small and the cathodic area is large, corrosion is more concentrated at the anode. Thus, a small hole is formed on the surface of the metal. This type of intense local corrosion is called **pitting**.

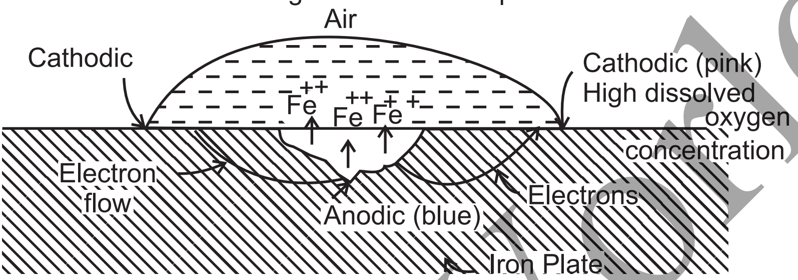
Other examples for differential aeration corrosion are:

1. Corrosion noted on the barbed wire fencing, In a wire fence, the areas where the wires cross are less accessible to air than the rest of the fence and hence corrosion takes place at the wire crossings which are anodic.
2. Corrosion noted in the iron water tanks near the water level water line corrosion.



In iron water tanks , iron portion inside the water is less expose to the oxygen when compared to other portions. Thus a concentration cell is formed and iron rusting takes place at the water level. (the place where the anode and cathode meet). The rust spreads when the water evaporates. This type of corrosion is called water line corrosion.

3. When a drop of water or salt solution is placed over an iron piece corrosion occur at the ridge of the water drop



Areas covered by droplets, having less access of oxygen become anodic with respect to the other areas which are freely exposed to air.

5.1.4 Factors affecting the rate of corrosion

The factors that affect he rate of corrosion are

1) Factors connected with the metal and its surface
2) Factors connected with the atmosphere
3) Factors connected with the corrosion product

Factors connected with the metal:

1) Position of the metal in the E.M.F Series

The type of impurity present in it and its electropositive nature decides the corrosion of a metal. For example when iron has impurities like copper, tin, etc. iron corrodes since iron is more electropositive than metals like copper and tin. On the other hand when iron is coupled with zinc, zinc corrodes since zinc is more electropositive than iron.

2) Purity of the metal.

Generally pure metal does not corrode, as there is no cathode spot available to induce corrosion.

3) Surface of the metal

A rough surface corrodes readily as it collects more dirt and provides more cathode spot for corrosion. A polished surface does not corrode easily.

4) Stress corrosion

Stress in a metal surface is produced by mechanical workings such as quenching, pressing, bending, and riveting, improper heat treatment etc. The portion subjected to more stress acts as anode and other portion act as cathode. This leads to the formation of stress corrosion. Stress corrosion is noted in fabricated articles of certain alloys like high zinc-brasses and nickel brasses.

Caustic embrittlement noted in boilers is a typical example for stress corrosion, which is due the attack of alkali present in water on stressed boiler metal.

5) Anode to cathode area ratio.

When a bigger cathode area covers a smaller anode area, severe corrosion is noted in the anode spot. This is called erosion. It is frequently encountered in piping agitators, condenser tubes etc. where turbulent flow of gases and vapors remove the coated surfaces resulting in differential cells. Removal of surface coatings can also be caused by rubbing or striking activities of solids on the coated surfaces.

6) Physical state of a metal.

The rate of corrosion is influenced by grain size, Orientation of crystals, stress etc.The smaller the grains size of the metal greater the rate of corrosion.

Factors connected with the atmosphere

1) Nature of the atmosphere
2) Temperature of the atmosphere
3) pH of the atmosphere
4) Amount of moisture in the atmosphere
5) Amount of oxygen in the atmosphere
6) Amount of chemical fumes in the atmosphere etc.

Examples

1. Buried pipelines and cables passing from one type of soil to another suffer corrosion due to differential aeration.
2. Lead pipe lines passing through clay and then through sand.
3. Lead pipe line passing through clay get corroded because it is less aerated than sand.

Factors connected with the corrosion product

a. In some causes the corroded product sticks to the surface and absorbs more moisture. This induces further corrosion.

E g Rusting of iron, As rust formed over iron absorbs more moisture, rate of rusting of iron increases

b. In some cases the corroded product acts as the protective coating which prevents further corrosion.

E g Aluminium oxide formed over the surface of aluminium prevents further corrosion and act as a protective coating. This is the basic principle of anodization.

c. In some other cases the corroded product falls out of position exposing the fresh metal surface for further corrosion.

E g Magnesium Oxide formed over the surface of Magnesium falls out of position exposing a fresh surface for further corrosion.

SUMMARY

In this lesson various types of corrosion, theories explaining corrosion and factors influencing corrosion are explained.

QUESTIONS:

Part A

1. What is corrosion?
2. What is dry corrosion?
3. What is wet Corrosion?
4. What type of corrosion takes place in a metal when anode is small and cathode is large. Why ?

Part B

1. Explain the Galvanic cell formation theory.
2. Explain the differential aeration theory with suitable examples.
3. What are the factors affecting the rate of corrosion.

TEST YOUR UNDERSTANDING

1. Why corrosion often takes place under metal washers.
2. Welded joints are better than riveted joints. Why?

5.2 METHODS OF PREVENTION OF CORROSION

5.2.1 Modifying the Environmental Conditions.

The corrosion rate can be reduced by modifying the environment. The environment can be modified by the following:

(a) Deaeration: The presence of increased amounts of oxygen is harmful since it increases the corrosion rate. Deaeration aims at the removal of dissolved oxygen. Disolved oxygen can be removed by deaeration or by adding some chemical substance like Na_2CO_3.

(b) Dehumidification: In this method, moisture from air is removed by lowering the relative humidity of surrounding air. This can be achieved by adding silica gel which can absorb moisture preferentially on its surface.

(c) Inhibitors: In this method, some chemical substance known as inhibitors are added to the corrosive environment in small quantities. These inhibitors substantially reduce the rate of corrosion.

5.2.2 Alloying:

Both corrosion resistance and strength of many metals can be improved by alloying, e-g. Stainless steels containing chromium produce a coherent oxide film which protects the steel from further attack. The other non-corrosive alloys are German silver, Aluminium bronze, Nickel bronze, Duralumin etc

5.2.3 Surface Coating:

Corrosion of metal surfaces is a common phenomenon. To protect a metal surface from corrosion, the contact between the metal and the corrosive environment is to be cut off. This is done by coating the surface of the metal with a continues, non-porous material, insert to the corrosive atmosphere. Such a coating is referred to as surface coating or protective coating. In addition to protective action, such coatings also give a decorative effect and reduce wear and tear.

Objectives of Coating Surfaces

1. To prevent corrosion.
2. To enhance wear and scratch resistance.

3. To increase hardness
4. To insulate electrically
5. To insulate thermally
6. To impart decorative colour.

5.2.4 Metallic Coating:

Surfacing coatings made up of metals are known as metallic coatings. These coatings separate the base metal from the corrosive environment and also function as an effective barrier for the protection of base metals.

The metal which is coated upon is known as the base metal.

The metal applied as coating is referred to as coat metal.

The different methods used for metal coating are.

1. Hot dipping
    - (a) Galvanization
    - (b) Tinning
2. Metal spraying.
3. Cladding.
4. Cementation
    - (a) Sherardizing – Cementation with Zinc powder is called Sherardizing.
    - (b) Chromizing - Cementation with 55% Chromium powder & 45% Alumina is called chromizing
    - (c) Calorizing – Cementaion with Aluminium and Alumina powder is called Calorizing
5. Electroplating or electrodeposition.

1.Hot dipping

In the process of hot dipping, the metal to be coated is dipped in the molten bath of the coating metal. Such hot dip coatings are generally non-uniform. The common examples of hot dip coatings are galvanizing and tinning.

(a) Galvanizing: The process of coating a layer of zinc on iron is called galvanizing. The iron article is first pickled with dilute sulphuric acid to remove traces of rust, dust, etc. at 60-90'c for about 15 -20 minutes. Then this metal is dipped in a molten zinc bath maintained at 430'c.

The surface of the bath is covered with ammonium chloride flux to prevent oxide formation on the surface of molten zinc. The coated base metal is then passed through rollers to correct the thickness of the film.

It is used to protect roofing sheets, wires, pipes, tanks, nails, screws, etc.

(b) Tinning:

The coating of tin on iron is called tin plating or tinning. In tinning, the base metal is first pickled with dilute sulphuric acid to remove surface impurities. Then it is passed through molten tin covered with zinc chloride flux. The tin coated article is passed through a series of rollers immersed in a palm oil bath to remove the excess tin. Tin-coated utensils are used for storing foodstuffs, pickles, oils, etc.

Galvanizing is preferred to tinning because tin is cathodic to iron, whereas zinc is anodic to iron. So, if the protective layer of the tin coating has any cracks, iron will corrode. If the protective layer of the zinc coating has any cracks, iron being cathodic does not get corroded. The corrosion products fill up the cracks, thus preventing corrosion.

5.2.5 Differences between Galvanizing and Tinning.

Galvanising	Tinning
1.A process of covering iron with a thin coat of 'Zinc' to prevent it from rusting.	A process of covering iron with a thin coat of 'tin' to prevent it from corrosion.
2.Zinc protects the iron sacrificially.(Zinc undergo corrosion)	Tin protects the base metal with out undergo any corrosion (non sacrificially)
3.Zinc continuously protects the base metal even if broken at some places.	A break in coating causes rapid corrosion of base metal.
4.Galvanized containers cannot be used for strong acidic food stuffs as Zinc becomes toxic in acidic medium.	Tin is non-toxic in nature of any medium.

5.2.6 Electroplating:

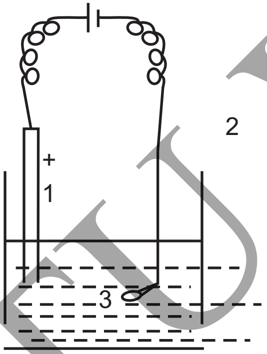
Electroplating is process in which the coat metal is deposited on the base metal by passing a direct current through an electrolytic solution.

Objectives of Electroplating:

a. To increase corrosion resistance.
b. To get better appearance.
c. To get increased hardness.
d. To change the surface properties of metals and non - metals.

Process

In electroplating, the cleaned base metal is made as the cathode and the coat metal is taken as the anode. A solution of the coat metal salt is taken as the electrolyte. The electrodes are connected to a battery and DC current passed. Now electrolysis takes place and the coat metal deposited over the base metal.



1. Silver
2.Copper
3.Silver thiocyanate

The nature of coating depends on 1) the current density 2) time 3) temperature and 4) the concentration of the electrolyte.

For example, to coat silver on copper material, the copper material is taken as the cathode. A silver plate is taken as the anode. Silver thiocyanate solution is the electrolyte. When the electrodes are connected to a DC source of electricity, silver is deposited over the copper material.

The following electrolytes are used for coating other metals.

Copper sulphate – Copper
Nickel sulphate – Nickel
Chromic acid – Chromium

Factors affecting electroplating

The following are the factors affecting electroplating:

1. Cleaning of the article is essential for a strong adherent electroplating.
2. Concentration of the electrolyte is a major factor in electroplating.
3. Low concentration of metal ions will produce uniform coherent metal deposition.
4. Thickness of the deposit should be minimized in order to get a strong adherent coating.
5. Additives such as glue and boric acid should be added to the electrolytic bath to get a strong adherent and smooth coating.
6. The electrolyte selected should be highly soluble and should not undergo any chemical reaction.
7. The pH of the electrolytic bath must be properly maintained to get the deposition effectively.

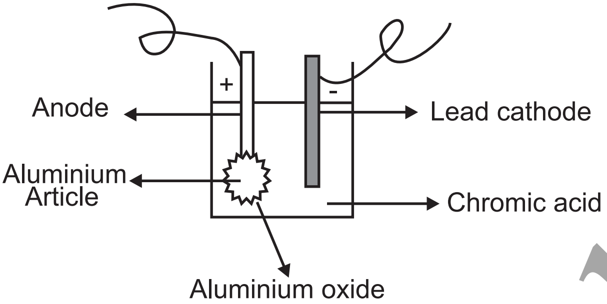
5.2.7 Anodizing:

Anodizing is the process of coating the base metal with an oxide layer of the base metal.

This type of coating is produced on metals like Al, Zn, Mg and their alloys by anodic oxidation process, by passing direct electric current though a bath in which the metal is suspended from anode. Here the base metal behaves as an anode. The electrolytes are sulphonic, chromic, phosphonic, oxalic or boric acid.

Anodised coating have more corrosion resistance due to thicker coating.

'Aluminium oxide coatings" are formed by the oxidation taking place on the aluminium surface at moderate temperatures (35 to 40°c) and moderate current densities. The formed oxide film is initially thin and gain thickness by the continous oxidation of aluminium anode. The surface of oxide film contains pores, which may cause corrosion. The pores can be sealed by exposing to boiling water, when the oxide is converted into monohydrate ($Al_2O_3.H_2O$). This process is called sealing process.



5.2.8 Phosphating:

Phosphate coatings are produced by the reaction between base metal and aqueous solution of phosphoric acid with accelerators (copper salt). Accelerators are used to enhance the rate of the reaction.

Such coatings are applied on iron, steel, zinc, aluminium, cadmium and tin. After the reaction the surface film consists of crystalline zinc iron or manganese iron phosphates.

Phosphate coatings do not prevent corrosion completely, they are principally used as an adherent base primer-coat for paint, lacquers, oils etc.

5.2.9 Cathodic Protection:

The principle involved in cathodic protection is to force the metal behave like a cathode. Since there will not be any anodic area on the metal, corrosion does not occur. There are two types of cathodic protection.

(a) Sacrificial anodic method.
(b) Impressed voltage method.

(a) Sacrificial Anodic Method:

In this technique, a more active metal is connected to the metal structure to be protected so that all the corrosion is concentrated at the more active metal and thus saving the metal structure from corrosion. This method is used for the protection of sea going vessels such as ships and boats. Sheets of zinc or magnesium are hung around the hull of the ship. Zinc and magnesium being anodic to iron get corroded. Since they are sacrificed in the process of saving iron (anode), they are called sacrificial anodes. The corroded sacrificial anode is replaced by a fresh one, when consumed completely.

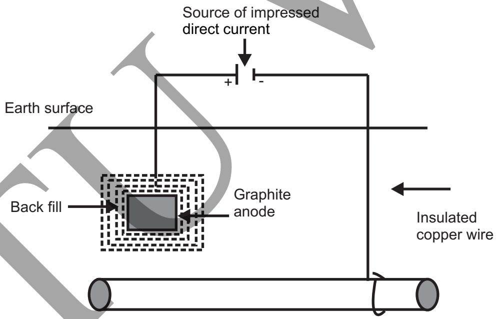
Important applications of sacrificial anodic protection are as follows:

(I) Protection from soil corrosion of underground cables and pipelines.

(ii) Magnesium sheets are inserted into domestic water boilers to prevent the formation of rust.

(b) Impressed voltage Method.

In this method, an impressed current is applied in an opposite direction to nullify the corrosion current and converting the corroding metal from anode to cathode. This can be accomplished by applying sufficient amount of direct current from a battery to an anode buried in the soil and connected to the corroding metal structure which is to be protected. The anode is in a backfill (composed of gypsum) so as to increase the electrical contact with the soil. Since in this method current from an external source in impressed on the system, this is called impressed current method.



Buried pipe made cathode

(protected)

This type of protection is given in the case of buried structures such as tanks and pipelines.

QUESTIONS

Part - A

1. what is galvanization?
2. What is anodizing?
3. What is phosphating?
4. What is a base metal?
5. What is a coat metal?
6. Galvanization is preferred to tinning? Why?
7. What is Sherardizing?

Part - B

1. Differentiate between galvanizing and tinning.
2. What are the factors that affect electroplating?
3. What is anodizing.? How is it carried out?
4. What is tinning?. What are its merits & demerits?
5. Write short notes on cathodic protection.

TEST YOUR UNDERSTANDING

1. Why is moderate current density employed during electroplating?
2. Chromium anode are not used in chromium plating. Give Reason.

5.3 ORGANIC COATINGS

5.3.1 Introduction

Organic coatings include paints and varnishes. In the this lesson we are going to study about paint and its components A little introductions to special paints used also discussed. further we are going to study about varnish, its types and their preparation .A preliminary idea is also given about dyes.

5.3.2 Paint

Paint is a dispersion of a pigment in medium oil (vehicle). When paint is applied on a surface, the medium oil saves the surface from corrosion. The pigment saves the medium oil from the ultra violet light given by the sun.

5.3.3 Components of paints and their functions

The important constituents of paint are as follows.

1. Pigment
2. Drying oil or medium oil or vehicle
3. Thinner
4. Drier
5. Filler or extender
6. Plasticizer
7. Antiskinning agent

1. Pigment:

A pigment is a solid and colour-producing substance in the paint.

Functions:

The following are the functions of the pigment:

(a) A pigment gives opacity and colour to the film.
(b) A pigment gives strength to the film.
(c) It protects the film by reflecting the destructive ultraviolet rays.
(d) It covers the manufacturing defects

2. Drying oil or medium oil or vehicle.

The liquid portion of the which the pigment is dispersed is called a medium or vehicle. E.g. linsed oil, dehydrated castor oil, soyabean oil and fish oil.

Functions:

(a) Vehicles hold the pigment particles together on the surface.

(b) They form the protective film by evaporation or by oxidation and polymerization of the unsaturated constituents of the oil.

(c) Vehicles give better adhesion to the surface.

(d) They impart water repellency, durability and toughness to the film.

4. Thinner:

Thinners are added to paints to reduce the viscosity of the paints so that they can be easily applied to the surface. E.g. turpentine and petroleum sprit.

Functions:

(a) Thinners reduce the viscosity of the paint to render it easy to handle and apply to the surface.

(b) They dissolve the oil, pigments etc. and produce a homogeneous mixture.

(c) Thinners evaporate rapidly and help the drying of the film.

(d) They increase the elasticity of the film.

(e) Thinners increase the penetrating power of the vehicle.

4. Drier:

Driers are used to accelerate the drying of the oil film.

Eg Naphthenates of lead and cobalt, Resonates of lead and cobalt.

Functions:

Driers act as oxygen carrier catalysts which help the absorption of oxygen and catalyze the drying of the oil film by oxidation, polymerization and condensation.

5. Filler or extender:

Fillers are added to reduce the cost and increase the durability of the paint, E.g. talc, Gypsum, mica, asbestos etc.

Functions:

(a) Fillers serve to fill the voids in the film.
(b) They reduce the cracking of the paints.
(c) Fillers increase the durability of the paints.
(d) They reduce the cost of the paint.

6. Plasticizers:

Plasticizers are chemicals added to paints to give elasticity to the film and to prevent cracking of the film, e.g. triphenyl phosphate, tertiary amyl alchol, Tributyl Phthalate.

7. Antiskinning agent:

They are chemicals added to the paint to prevent skinning of the paint, E.g. polyhydroxy phenols.

5.3.4 Varnishes

Varnish is a homogenous colloidal dispersion of natural or synthetic resin in oil or thinner or both. It is used as a protective and decorative coating to surfaces. It provides a hard, transparent, glossy, lustrous and durable film to the coated surface.

There are two types of varnishes

1. Oil Varnish
2. Spirit Varnish

Preparation of oil Varnish

The resin is taken in an aluminium vessel, known as a kettle, and heated The resin melts and the temperature is slowly increased to about 300^{0}C. This process, is known as gum running, Some cracking or depolymerization of the resin takes place and about 25 per cent of the resin is lost in the form of pungent fumes. The required quantity (about 25 per cent of the weight of the resin) of boiled oil or linsed oil along with driers is separately heated to 200 to 220 and is slowly added to the heated resin with constant stirring until thorough combination has taken place. This operation is known as cooking. The kettle is removed from the furnace and allowed to cool, white spirit, which is a thinner is added to varnish when the temperature of the varnish is below the flash point of the thinner with constant stirring during the addition.

The varnish is stored in tanks for some days for maturing. Filtered or packed for marketing.

Preparation of sprit varnish

Sprit varnish is obtained by dissolving a resin in a sprit. E.g. shellac resin dissolved in methylated sprit, a solution of shellac in alcohol, etc.

Resins of trees like Manila, Damar, etc are also used for making varnish.

Difference between paint and varnish

Sl. No	Paint	Varnish
1.	Paint has pigment	There is no pigment in the varnish
2.	It can be applied to both metals & wooden articles	It can be applied only to the wooden articles
3.	It is Opaque	It is transparent

5.3.5 Special paints

In addition to the normal ingredients some special chemicals are incorporated to paints for some specific purposes. They are commonly known as special paints.

1. Luminescent paints

Luminescent paints contains luminophor pigments are used for visibility in the dark. They find application in inks, advertising signboards, road marks, number plates of vehicles, watch dials, etc. The active components in luminous paint are specially prepared phosphorescent materials like CaS, ZnS, etc. They absorb light radiations and emit them in the dark. For colour effect in luminous paints, certain chemicals like copper salts (green), silver salts (blue), cerium and uranium salts (yellow), etc. are used.

2. Heat Resistance paints

When the surfaces are exposed to high temperatures such as in chimneys, exhaust pipes, furnaces, oil stills, etc. Oil paints tend to decompose or get charred, they being organic in nature. Then the surfaces become liable for corrosion. To overcome this problem, a suspension of graphite or lamp black in small amounts of drying oils and more thinners can be used. But more recently, silicone paints are used for heat resistance.

3. Fire-retardant paints

These are paints containing chemicals which are fire-resistant in nature. In other words, they produce gases like CO_2, NH_3 , HCl,HBr on heating which are themselves non-combustible and do not support combustion, there by minimizing the rate of burning or extinguishing the fire.

4. Antifouling paints

Oil paints are liable for attack by living organisms because of the organic content in them. So, in places where living organisms are handled or are present, such paints cannot be used. For use in breweries and biochemical laboratories, the paint is mixed with compounds having fungicidal properties. The active ingredients employed are HgO, Cu_2O, Hg_2Cl_2, DDT, pentachlorophenol, etc.

Such paints are called Antifouling paints.

5. Cement Paint

Cement paint is the coating, which is applied on plastered brickwork, concrete work, etc. The ingredients are

1. White cement (about 70%)
2. Hydrated lime [$Ca(OH)_2$]
3. Pigment (a colouring agent)
4. Very fine sand (an inert filler) and
5. Water- repellent compound

Such paints of different colors are marked in powder form (eg Snowcem, Smocem). The powder is mixed with a suitable quantity of water to get a thin slurry, and applied on surfaces. For good results, a 1.5% to 2% aqueous solution of sodium silicate and Zinc sulphate is applied as primer coat.

6. Aluminium Paint

The base material in aluminium paint is a fine powder of aluminium. The finely ground powder of aluminium is suspended in either spirit varnish or in an oil-varnish depending on the requirement. When paints is applied, the thinner evaporates and oil, if any, undergoes oxidation and polymerization. A bright adhering film of aluminium is obtained on the painted surface.

Advantages of aluminium paint:

1. It possesses a good covering power.
2. It imparts very attractive appearance to the surface.
3. It has fairly good heat-resistance.
4. It has very good electrical resistance
5. The painted film is waterproof.
6. The electrical surface is visible even darkness.
7. Corrosion protection for iron and steel surface is better than all other paints.

7. Distempers

Distempers are water paints. The ingredients of distemper are

1. Whitening agent or chalk powder (the base)
2. Glue or casein (the binder)
3. Colouring pigment and
4. Water (the solvent or thinner).

Advantages

1. Distempers are cheaper than paints and varnishes
2. They can be applied easily on plasters and wall surfaces in the interior of the buildings.
3. They are durable.
4. They give smooth and pleasing finish to walls.
5. They have good covering power.

5.3.6DYES

Dyes are coloured organic compounds capable of colouring various materials and articles.

According to commercial classification of dyes which is based on the application of the dyes are as follows.

1. Direct dyes
2. Basic dyes
3. Mordant dyes etc.

Acid Dyes:

Salts of organic acids are called acid dyes. It donate colour cellulose fibres. They can readily dye only animal fibres.

Eg: Methyl red, Methyl Organe etc.

Basic Dyes.

They are salts of colour bases with hydrochloric acid or Zinc chloride. Basic dyes can dye animal fibres directly and vegetable fibres after the fibres are mordanted with tannin. Basic dyes are mostly used for dyeing silk and cotton.

Eg: Magenta, Para-rosaniline dye, Aniline Yellow.

Mordant or Adjective dyes:

A mordant is any substance, which is fixed to the fibre before dyeing. Commonly used mordants are hydroxides or basic salts of chromium, aluminium or iron. Tannic acid is also used as mordant for basic dyes.

Generally the fabric is dipped in a mordant and then in a solution of dye. The dye coat thus formed is insoluble and does not fade on washing.

E.g. Alizarin and Anthraquinone dyes.

Questions

Part - A

1. Define paint.
2. Give examples for heat resistant paint.
3. What is Varnish?
4. What is the function of the drier in paint?
5. What are Fire-retardant paints?
6. Define Dyes.

Part - B

1. What are the components present in the paint. Explain their functions.
2. How is oil varnish prepared ?
3. Write a short note on special paints.
4. write short notes on Dyes.

TEST YOUR UNDERSTANDING

1. What are toners?
2. What is an enamel?

SEMESTER- I

PRACTICAL- I

VOLUMETRIC ANALYSIS

The method to determine the exact amount of the substance in a given sample is termed as quantitative analysis volumetric analysis is a branch of quantitative analysis involving accurate measurement of volumes of reacting solutions. The volumetric analysis is very much in use due to simplicity rapidity accuracy and wide applicability.

The reacting substances are taken in the form of solutions and made to react. The concentration of one solution is determined using another suitable solution whose concentration is accurately known. A known volume of one solution is measured with a pipette and taken in a conical flask. The other solution is taken in a burette and run into the first solution till the chemical reaction is just complete. The volume of the second solution is read from the burette and the two volumes are compared.

Various terms used in volumetric analysis are given below:

Titration

The process of adding one solution from the burette to another in the conical flask in order to complete the chemical reaction is termed titration.

Endpoint

It is the exact stage at which chemical reaction involved in the titration is just complete

Indicator

It is a substance which will show the end point of the reaction by change of colour. For example phenolphthalein and methyl orange are indicators used in acid alkali titrations. Potassium permanganate itself acts as an indicator in potassium permanganate titrations.

Acidimetry and Alkalimetry Titration:

Acidimentry refers to the titration of alkali with a standard acid and alkalimetry refers to the titration of an acid with a standard alkali.

Permanganimetry Titration:

The titration involving $KMnO_4$ is called permanganimetry titration. In presence of dilute H_2SO_4 $KMnO_4$ oxidizes ferrous sulphate to ferric sulphate and oxidizes oxalic acid to CO_2 and H_2O.

Normality:

The strength of a solution is expressed in terms of normality. Normality is the number gram equivalent mass of solute dissolved in one litre of solution.

Standard solution:

A solution of known strength (Normality) is called a standard solution.

Decinormal Solution:

A solution having the strength (Normality) of 0.1 N is called decinormal solution.

Law of volumetric analysis:

Whenever two Substances react together, they react in the ratio of their equivalent mass. One litre of a normal solution of a substance will react exactly with same volume of a normal solution of another substance. In other words equal volumes of equal normal solutions will exactly react with each other. This result is stated in the form law of volumetric analysis

If V_1 ml of a solution of strength N_1 is required or complete reaction by V_2 ml of the second solution of strength N_2 then

$$V_1N_1=V_2N_2$$

If any three factors (V_1V_2 & N_1) are known, the fourth factor N_2 can be calculated. The following are the important formula used in all volumetric estimations

Mass of solute per litre of the solution = Equivalent mass x Normality

Equivalent mass of some important compounds

Name of the compound	Equulvalent Mass
Hydrochloric acid	36.5
Sulphuric acid	49
Oxalic acid	63
Sodium carbonate	53
Sodium hydroxide	40
Potassium hydroxide	56.1
Potassium permanganate	31.6
Ferrous sulphate	278
Ferrous ammonium sulphate	392
Potassium dichromate	49.04
Copper sulphate	249.54
EDTA (disodium salt)	372

1 ESTIMATION OF SULPHURIC ACID

EX.NO..................

Date.............

Aim

To estimate the amount of Sulphuric acid present in 400 ml of the given solution. You are provided with a standard solution of oxalic acid of normality ....N and an approximately decinormal solution of Sodium hydroxide. (Test solution should be made up to 100 ml)

Principle

The titration is based on the neutralisation reaction between oxalic acid and Sodium hydroxide in titration I and Sulphuric acid and Sodium hydroxide in titration II.

Procedure

Titration I:

Standardisation of Sodium hydroxide

The burette is washed with water, rinsed with distilled water and then with the given oxalic acid.It is filled with same acid up to zero mark. The initial reading of the burette is noted. A 20ml pipette is washed with water,rinsed with distilled water and then with the given Sodium hydroxide solution.20 ml of Sodium hydroxide is pipetted out in to a clean conical flask.Two drops of phenolphthalein indicator is added into the flask.The solution becomes pink in colour. The solution is titrated against oxalic acid taken in the burette.The end point of the titration is the disappearance of pink colour to give colourless solution.The titration is repeated to get the concordant value.From the titre value,the normality of Sodium hydroxide is calculated.

Titration II:

Standardisation of Sulphuric acid

The given Sulphuric acid solution is made upto 100 ml in a 100 ml standard flask.The solution is thoroughly shaken to get a uniformly concentrated solution.The burette is washed with water,rinsed with distilled water and then with the given Sulphuric acid from the standard flask. It is filled with same acid upto zero mark. The initial reading of the burette is noted.Exactly 20 ml of the sodium hydroxide is pipetted out in to a clean conical flask.To this solution two drops of phenolphthalein indicator is added. The solution becomes pink in colour.The solution is titrated against Sulphuric acid taken in the burette.The end point of the titration is the disappearance of pink colour to give colourless solution.The titration is repeated to get the concordant value.From the titre value,the normality of Sulphuric acid and the amount of sulphuric acid present in 400 ml of the given solution is calculated.

Result

Normality of Sodium hydroxide =.........................N
Normality of Sulphuric acid =.........................N
Amount of Sulphuric acid present in 400ml of the given solution =.........................g

Titration-I : Sodium hydroxide Vs Oxalic acid

S.No	Volume of sodium hydroxide(ml)	Burette reading (ml)		Volume of oxalic acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of oxalic acid (V_1) =
Normality of oxalic acid (N_1) =
Volume of sodium hydroxide (V_2) = 20 ml
Normality of sodium hydroxide (N_2) = ?
By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_2 = \frac{V_1N_1}{V_2} = \frac{X}{20} = -----N$$

$\therefore$Normality of sodium hydroxide (N_2) = ____________ N

Titration-II : Sulphuric acid Vs Sodium hydroxide

S.No	Volume of sodium hydroxide(ml)	Burette reading (ml)		Volume of sulphuric acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of sulphuric acid (V_1) =

Normality of sulphuric acid (N_1) = ?

Volume of sodium hydroxide (V_2) = 20ml

Normality of sodium hydroxide (N_2) =

By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_1 = \frac{V_2N_2}{V_1} = \frac{\quad \times 20}{\quad} = -----N$$

$\therefore$ Normality of sulphuric acid (N_1)= ______________N

Amount of sulphuric acid present in 400 ml of the given solution =Equivalent mass x Normality of sulphuric acid x 400 / 1000

=49x----------x400/1000

=---------g

SHORT PROCEDURE

Description	Titration I	Titration II
Burette solution	Oxalic acid	Sulphuric acid
Pipette solution	Sodium hydroxide	Sodium hydroxide
Reagents added	....	....
Indicator	Phenolphthalein	Phenolphthalein
End point	Disappearance of pink colour	Disppearance of pink colour
Equivalent mass of sulphuric acid = 49		

2. ESTIMATION OF SODIUM HYDROXIDE

EX.NO..................

Date.............

Aim

To estimate the amount of Sodium hydroxide present in one litre of the given solution.You are provided with a standard solution of Sodium carbonate of normality ....N and an approximately decinormal solution of Sulphuric acid.(Test solution should be made upto 100 ml)

Principle

The titration is based on the neutralisation reaction between Sulphuric acid and Sodium carbonate in titration I and Sulphuric acid and Sodium hydroxide in titration II.

Procedure

Titration I:

Standardisation of Sulphuric acid

The burette is washed with water, rinsed with distilled water and then with the given Sulphuric acid. It is filled with same acid upto zero mark. The initial reading of the burette is noted. A 20ml pipette is washed with water, rinsed with distilled water and then with the given Sodium carbonate solution.20 ml of Sodium carbonate is pipetted out in to a clean conical flask. Two drops of methyl orange indicator is added into the flask.The solution becomes pale yellow in colour. The solution is titrated against Sulphuric acid taken in the burette. The end point of the titration is the change in colour from yellow to permanent pale pink. The titration is repeated to get the concordant value. From the titre value, the normality of Sulphuric acid is calculated.

Titration II:

Standardisation of Sodium hydroxide

The given Sodium hydroxide solution is made upto 100 ml in a 100 ml standard flask. The solution is thoroughly shaken to get a uniformly concentrated solution. A 20 ml pipette is washed with water, rinsed with distilled water and then with the given Sodium hydroxide. Using the rinsed pipette, exactly 20 ml of the made-up solution is transferred into a clean conical flask. To this solution two drops of methyl orange indicator is added. The solution becomes pale yellow in colour. The solution is titrated against Sulphuric acid taken in the burette. The end point of the titration is the change in colour from yellow to permanent pale pink. The titration is repeated to get the concordant value. From the titre value, the normality of Sodium hydroxide is calculated.

Result

(i) Normality of Sulphuric acid =......................N

(ii) Normality of Sodium hydroxide =......................N

(iii) Amount of Sodium hydroxide present in one litre of given solution } =......................g

Titration-I : Sodium carbonate Vs sulphuric acid

S.No	Volume of sodium carbonate(ml)	Burette reading (ml)		Volume of sulphuric acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of sulphuric acid (V_1) =

Normality of sulphuric acid (N_1) = ?

Volume of sodium carbonate (V_2) = 20ml

Normality of sodium carbonate (N_2) =

By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$\therefore$ Normality of sulphuric acid (N_1) = ____________N

$$\therefore N_1 = \frac{V_2N_2}{V_1} = \frac{\quad X20}{\quad} = -----N$$

Titration-II : Sulphuric acid Vs Sodium hydroxide

S.No	Volume of sodium hydroxide(ml)	Burette reading (ml)		Volume of sulphuric acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of sulphuric acid (V_1) =

Normality of sulphuric acid (N_1) =

Volume of sodium hydroxide (V_2) = 20ml

Normality of sodium hydroxide (N_2) = ?

By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_2 = \frac{V_1N_1}{V_2} = \frac{X}{20} = -----N$$

$\therefore$ Normality of Sodium hydroxide (N_2) = ______________ N

Amount of Sodium hydroxide present in One litre of the given solution } = Equivalent mass x Normality of sodium hydroxide

= 40 x ----------

= ---------g

SHORT PROCEDURE

Description	Titration I	Titration II
Burette solution	Sulphuric acid	Sulphuric acid
Pipette solution	Sodium carbonate	Sodium hydroxide
Reagents added	....	....
Indicator	Methyl orange	Methyl orange
End point	Appearance of permanent pink colour	Appearance of permanent pink colour
Equivalent mass of sodium hydroxide=40		

3. COMPARISON OF STRENGTHS OF TWO ACIDS

EX.NO..................

Date.............

Aim

To compare the strengths of two hydrochloric acids solutions in bottles A and B and estimate the amount of hydrochloric acid present in 250 ml of the weaker solution. You are provided with a standard solution of sodium hydroxide of normality ....N.

Principle

The experiment is based on the neutralisation reaction between hydrochloric acid A and Sodium hydroxide in titration I and hydrochloric acid B and Sodium hydroxide in titration II.

Procedure

Titration I:

Standardisation of hydrochloric acid A

The burette is washed with water, rinsed with distilled water and then with the given hydrochloric acid in bottle A. It is filled with same acid upto zero mark. The initial reading of the burette is noted. A 20ml pipette is washed with water, rinsed with distilled water and then with the given Sodium hydroxide solution.20 ml of Sodium hydroxide is pipetted out in to a clean conical flask. Two drops of phenolphthalein indicator is added into the flask. The solution becomes pink in colour. The solution is titrated against hydrochloric acid A taken in the burette. The end point of the titration is the disappearance of pink colour to give colourless solution. The titration is repeated to get the concordant value. From the titre value, the normality of hydrochloric acid A is calculated.

Titration II:

Standardisation of hydrochloric acid B

The burette is washed with water, rinsed with distilled water and then with the given hydrochloric acid in bottle B. It is filled with same acid upto zero mark. The initial reading of the burette is noted.20 ml of standardised Sodium hydroxide is pipetted out in to a clean conical flask. Two drops of phenolphthalein indicator is added into the flask. The solution becomes pink in colour. The solution is titrated against hydrochloric acid B taken in the burette. The end point of the titration is the disappearance of pink colour to give colourless solution. The titration is repeated to get the concordant value. From the titre value, the normality of hydrochloric acid B is calculated

Result

1. Normality of hydrochloric acid A =......................N
2. Normality of hydrochloric acid B =......................N
3. Hydrochloric acid in bottle--------
   is weaker then hydrochloric acid in bottle--------
4. Amount of hydrochloric acid present in 250 ml of the weaker solution } =......................g

Titration-I : Sodium hydroxide Vs Hydrochloric acid A

S.No	Volume of sodium hydroxide(ml)	Burette reading (ml)		Volume of Hydrochlolic acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of hydrochloric acid A (V_1) =

Normality of hydrochloric acid A (N_1) = ?

Volume of sodium hydroxide (V_2) = 20 ml

Normality of sodium hydroxide (N_2) =

By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_1 = \frac{V_2N_2}{V_1} = \frac{\quad X\,20}{\qquad} = -----N$$

∴ Normality of Hydrochloric acid A =........N

Titration-II : Hydrochloric acid B Vs Sodium hydroxide

S.No	Volume of sodium hydroxide(ml)	Burette reading (ml)		Volume of Hydrochlolic acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of hydrochloric acid B (V_1) =

Normality of hydrochloric acid B (N_1) = ?

Volume of sodium hydroxide (V_2) = 20 ml

Normality of sodium hydroxide (N_2) =

By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_1 = \frac{V_2N_2}{V_1} = \frac{\quad X\,20}{\qquad\qquad} = ------N$$

$\therefore$ Normality of Hydrochloric acid B =........N

Hydrochloric acid in bottle.--------
is weaker than hydrochloric acid in bottle--------

Amount of hydrochloric acid present } = Equivalent mass of HCl x
In 250 ml of the weaker solution } Normality of HCl x 250/1000
=..........g

SHORT PROCEDURE

Description	Titration I	Titration II
Burette solution	Hydrochloric acid A	Hydrochloric acid B
Pipette solution	Sodium hydroxide	Sodium hydroxide
Reagents added	....	....
Indicator	Phenolphthalein	Phenolphthalein
End point	Disappearance of pink colour	Disappearance of pink colour
Equivalent mass of hydrochloric acid = 36.5		

4. COMPARISON OF STRENGTHS OF TWO BASES

EX.NO..................

Date.............

Aim

To compare the normalities of Sodium hydroxide solutions supplied in bottles A and B and to estimate the amount of Sodium hydroxide present in 500 ml of the stronger solution. You are provided with a standard solution of Oxalic acid of normality ....N.

Principle

The titration is based on the neutralisation reaction between Oxalic acid and Sodium hydroxide.

Procedure

Titration I:

Standardisation of Sodium hydroxide (A)

The burette is washed with water, rinsed with distilled water and then with the given oxalic acid. It is filled with same acid upto zero mark. The initial reading of the burette is noted. A 20ml pipette is washed with water, ,rinsed with distilled water and then with the given Sodium hydroxide solution in bottle A.20 ml of Sodium hydroxide A is pipetted out in to a clean conical flask. Two drops of phenolphthalein indicator is added into the flask. The solution becomes pink in colour. The solution is titrated against Oxalic acid taken in the burette. The end point of the titration is the disappearance of pink colour to give colourless solution. The titration is repeated to get the concordant value. From the titre value and normality of Oxalic acid. The normality of Sodium hydroxide in bottle A is calculated.

Titration II:

Standardisation of Sodium hydroxide (B)

20 ml of Sodium hydroxide from bottle B is pipette out into a clean conical flask using clean rinsed pipette. To this solution two drops of phenolphthalein indicator is added. The solution becomes pink in colour. The solution is titrated against Oxalic acid taken in the burette. The end point of the titration is the disappearance of pink colour to give colourless solution. The titration is repeated to get the concordant value. From the titre value, the normality of Sodium hydroxide(B) is calculated.

The two normalities are compared and the amount of Sodium hydroxide in 500ml of the stronger solution is calculated.

Result

Normality of Sodium hydroxide in bottleA =....................N
Normality of Sodium hydroxide in bottleB =....................N
Sodium hydroxide in bottle---------------
is stronger then Sodium hydroxide in bottle---------------
Amount of Sodium hydroxide present in
500ml of the stronger solution =-----------------g

Titration-I : Sodium hydroxide (A) vs Oxalic acid

S.No	Volume of sodium hydroxide A (ml)	Burette reading (ml)		Volume of oxalic acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of oxalic acid (V_1) =
Normality of oxalic acid (N_1) =
Volume of sodium hydroxide(A) (V_2) = 20 ml
Normality of sodium hydroxide(A) (N_2) = ?
By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_2 = \frac{V_1 N_1}{V_2} = \frac{X}{20} = -\,-\,-\,-\,-\,-N$$

$\therefore$ Normality of Sodium hydroxide(A) (N_2) = _____________N

Titration-II : Sodium hydroxideB Vs Oxalic acid

S.No	Volume of sodium hydroxide B(ml)	Burette reading (ml)		Volume of oxalic acid(ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of sulphuric acid $(V_1) =$

Normality of sulphuric acid $(N_1) =$

Volume of sodium hydroxide $(V_2) = 20\text{ml}$

Normality of sodium hydroxide $(N_2) = \quad ?$

By the principle of volumetric analysis $V_1N_1 = V_2N_2$

$$\therefore N_2 = \frac{V_1N_1}{V_2} = \frac{X}{20} = -----N$$

Normality of Sodium hydroxide (B) $(N_2) =$ ____________N

Sodium hydroxide in bottle---------------

is stronger then Sodium hydroxide in bottle---------------

$$\left.\begin{array}{l}\text{Amount of Sodium hydroxide present}\\ \text{in 500 ml of the stronger solution}\end{array}\right\} = \begin{array}{l}\text{Equivalent mass x Normality}\\ \text{of sodium hydroxide}\end{array} \times \frac{1}{2}$$

$$= 40\text{ x ----------} \times \frac{1}{2}$$

$$= \text{---------g}$$

SHORT PROCEDURE

Description	Titration I	Titration II
Burette solution	Oxalic acid	Oxalic acid
Pipette solution	Sodium hydroxideA	Sodium hydroxideB
Reagents added	....	....
Indicator	Phenolphthalein	phenolphthalein
End point	Disappearance of pink colour	Disappearance of pink colour
Equivalent mass of sodium hydroxide = 40		

5. ESTIMATION OF MOHR'S SALT

EX.NO..................

Date.............

Aim

To estimate the amount of crystalline ferrous ammonium sulphate present in 100 ml of the given solution. You are provided with a standard solution of crystalline ferrous sulphate of normality ....N and an approximately decinormal solution of potassium permanganate. (Test solution should be made upto 100 ml)

Principle

The titration is based on the oxidation and the reduction reaction. The oxidising agent i.e Potassium permanganate oxidises the reducing agent ferrous sulphate and ferrous ammonium sulphate in acidic medium to ferric sulphate.

Procedure

Titration I:

Standardisation of Potassium permanganate

The burette is washed with water, rinsed with distilled water and then with the given Potassium permanganate solution. It is filled with same solution upto zero mark. The initial reading of the burette is noted. A 20ml pipette is washed with water, rinsed with distilled water and then with the given ferrous sulphate solution.20 ml of ferrous sulphate solution is pipetted out in to a clean conical flask. One test tube full of dilute sulphuric acid (20 ml) is added to it. It is titrated against Potassium permanganate taken in the burette. Potassium permanganate acts as the self indicator. The end point of the titration is the appearance of permanent pale pink colour. The titration is repeated to get the concordant value. From the titre value, the normality of Potassium permanganate solution is calculated.

Titration II:

Standardisation of Mohr's salt (ferrous ammonium sulphate)

The given Mohr's salt solution is made upto 100 ml in a 100 ml standard flask. The solution is thoroughly shaken to get a uniformly concentrated solution. A 20 ml pipette is washed with water, rinsed with distilled water and then with the given Mohr's salt solution .Using the rinsed pipette,exactly 20 ml of the made-up solution is transferred into a clean conical flask. To this solution one test tube full of dilute sulphuric acid (20 ml) is added. The solution is titrated against standardised potassium permanganate taken in the burette. The end point of the titration is the appearance of permanent pale pink colour. The titration is repeated to get the concordant value. From the titre value, the normality of given Mohr's salt solution and the amount of Mohr's salt in 100 ml of the given solution is calculated.

Result

1.Normality of Potassium permanganate =........N
2.Normality of Mohr's salt (ferrous ammonium sulphate) =........N
3.Amount of Mohr's salt present in 100 ml of given solution =.......g

Titration-I : Potassium permanganate Vs Ferrous sulphate

S.No	Volume of Ferrous sulphate (ml)	Burette reading (ml)		Volume of Potassium permanganate (ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of Ferrous sulphate (V_1) = 20 ml
Normality of Ferrous sulphate (N_1) =
Volume of Potassium permanganate (V_2) =
Normality of Potassium permanganate (N_2) = ?
By the principle of volumetric analysis, $V_1N_1 = V_2N_2$
$\therefore$ Normality of Potassium permanganate (N_2)=------------------N

$$\therefore N_2 = \frac{V_1N_1}{V_2} = \frac{\quad X20}{\quad} = -----N$$

Titration-II : Potassium permanganate Vs Mohr's salt

S.No	Volume of FAS (ml)	Burette reading (ml)		Volume of Potassium permanganate (ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of Mohr's salt (V_1) =20 ml

Normality of Mohr's salt (N_1) = ?

Volume of Potassium permanganate (V_2) =

Normality of Potassium permanganate (N_2) =

By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_1 = \frac{V_2N_2}{V_1} = \frac{X}{20} = -----N$$

$\therefore$ Normality of Mohr's salt = ____________N

$$\left.\begin{array}{l}\text{Amount of Mohr's salt present}\\ \text{in 100 ml of the given solution}\end{array}\right\} = \begin{array}{l}\text{equivalent mass x normality}\\ \text{of mohr's salt x 100/1000}\end{array}$$

=---------g

SHORT PROCEDURE

Description	Titration I	Titration II
Burette solution	Potassium permanganate	Potassium permanganate
Pipette solution	Ferrous sulphate	Ferrous ammonium sulphate (mohr's salt)
Reagents added	One test tube of dilute sulphuric acid	One test tube of dilute sulphuric acid
Indicator	self	self
End point	Appearance of pale permanent pink colour	Appearance of pale permanent pink colour
Equivalent mass of Ferrous ammonium sulphate = 392		

6. ESTIMATION OF FERROUS SULPHATE

EX.NO..................

Date.............

Aim

To estimate the amount of crystalline ferrous sulphate present in 500 ml of the given solution. You are provided with a standard solution of crystalline ferrous ammonium sulphate of normality ....N and an approximately decinormal solution of potassium permanganate.

Principle

The titration is based on the oxidation and the reduction reaction. The oxidising agent i.e Potassium permanganate oxidises both ferrous sulphate and ferrous ammonium sulphate in acidic medium to ferric sulphate.

Procedure

Titration I:

Standardisation of Potassium permanganate

The burette is washed with water, rinsed with distilled water and then with the given Potassium permanganate solution. It is filled with same solution upto zero mark. The initial reading of the burette is noted. A 20ml pipette is washed with water, rinsed with distilled water and then with the given ferrous ammonium sulphate solution.20 ml of ferrous ammonium sulphate solution is pipetted out in to a clean conical flask.One test tube full of dilute sulphuric acid is added to it. It is titrated against Potassium permanganate taken in the burette. Potassium permanganate acts as the self indicator. The end point of the titration is the appearance of permanent pale pink colour. The titration is repeated to get the concordant value. From the titre value, the normality of Potassium permanganate solution is calculated.

Titration II:

Standardisation of ferrous sulphate

The given ferrous sulphate solution is made upto 100 ml in a 100 ml standard flask. The solution is thoroughly shaken to get a uniformly concentrated solution. A 20 ml pipette is washed with water, rinsed with distilled water and then with the given ferrous sulphate solution .Using the rinsed pipette, exactly 20 ml of the made-up solution is transferred into a clean conical flask. To this solution one test tube full of dilute sulphuric acid (20 ml) is added. The solution is titrated against standardised potassium permanganate taken in the burette. The end point of the titration is the appearance of permanent pale pink colour. The titration is repeated to get the concordant value. From the titre value,the normality of given ferrous sulphate solution and the amount of ferrous sulphate in 500 ml of the given solution is calculated.

Result

1.Normality of Potassium permanganate =.......................N

2.Normality of ferrous sulphate =.......................N

3.Amount of ferrous sulphate present in 500 ml of given solution=...g

Titration-I : Potassium permanganate Vs Mohr's salt (FAS)

S.No	Volume of FAS (ml)	Burette reading (ml)		Solume of Potassium permanganate (ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of FAS (V_1) =20 ml

Normality of FAS (N_1) =

Volume of Potassium permanganate (V_2) =

Normality of Potassium permanganate (N_2) = ?>

By the principle of volumetric analysis, $V_1N_1 = V_2N_2$

$$\therefore N_2 = \frac{V_1N_1}{V_2} = \frac{\quad X20}{\quad} = -----N$$

$\therefore$ Normality of Potassium permanganate (N_2) =

Titration-II : Potassium permanganate Vs ferrous sulphate

S.No	Volume Ferrous sulphate (ml)	Burette reading (ml)		Solume of Potassium permanganate (ml)	Indicator
		initial	final		

Concordant value=

Calculation:

Volume of ferrous sulphate (V_1) = 20 ml
Normality of ferrous sulphate (N_1) = ?
Volume of Potassium permanganate (V_2) =
Normality of Potassium permanganate (N_2) =
By the principle of volumetric analysis, $V_1N_1 = V_2N_2$
∴ Normality of ferrous sulphate = ____________ N

$$\therefore N_1 = \frac{V_2N_2}{V_1} = \frac{X}{20} = ------N$$

Amount of ferrous sulphate present
in 500 ml of the given solution = Equivalent mass x Normality of ferrous sulphate x 500/1000
= ---------g

SHORT PROCEDURE

Description	Titration I	Titration II
Burettesolution	Potassium permanganate	Potassium permanganate
Pipette solution	Ferrous ammonium sulphate	Ferrous sulphate
Reagents added	One test tube of dilute sulphuric acid	One test tube of dilute sulphuric acid
Indicator	self	self
End point	Appearance of pale permanent pink colour	Appearance of pale permanent pink colour
Equivalent mass of Ferrous sulphate = 278		

7. ESTIMATION OF TOTAL HARDNESSS OF WATER

Ex no……….

Date………….

Aim:

To estimate the total hardness of the given sample of water by EDTA titration.

Principle:

The total harness of water can be determined by titrating a known volume of hard water against EDTA solution using Erriochrome Black - T indicator. The estimation is based on the complexometric titration.

Procedure:

Titration- I

Standarisation of EDTA solution

50 ml of the given calcium chloride solution is pipetted into a clean conical flask. Half a test tube of ammonia buffer solution is added into the conical flask. A pinch of Erriochrome Black - T indicator is added into the conical flask. The solution turns wine red in colour. It is tirated against EDTA solution taken in a clean, rinsed burette. The end point is the change in colour from wine red to steel blue. The tiration is repeated to get concordant values. From the titre values and the molarity of calcium chloride solution, the molarity of EDTA is calculated.

Tiration- II

Standarisation of hard water

50 ml of the given sample of hard water is pipetted into a clean conical flask. Half a test tube of ammonia buffer solution is added into the conical flask. A pinch of Erriochrome Black - T indicator is added into the conical flask. The solution turns wine red in colour. It is tirated against EDTA solution taken in a clean, rinsed burette. The end point is the change in colour from wine red to steel blue. The tiration is repeated to get concordant values. From the titre values, the hardness of the given sample of water is calculated in ppm.

Result:

The total harness of the given sample of water = ……………..... Ppm

Titration-I: Standard calcium chloride solution Vs EDTA

S.No	Volume of Standard calcium chloride sulphate (ml)	Burette reading (ml)		Volume of EDTA (ml)	Indicator
		initial	final		

Concordant value=

Calculation

Volume of standard calcium chloride solution(V_1) = 50 (ml)

Molarity of standard calcium chloride solution(M_1) =0.01 M

Volume of EDTA solution (V_2) = x (ml)

Molarity of EDTA solution (M2) =

By the principle of volumetric analysis, $V_1M_1 = V_2M_2$

$$\therefore M_2 = V_1M_1 / V_2 = \frac{50 \times 0.01}{----}$$

$\therefore$ The molarity of EDTA solution = ...M

Standardised EDTA Vs Hard water sample

S.No	Volume of water sample (ml)	Burette reading (ml)		Volume of EDTA (ml)	Indicator
		initial	final		

Concordant value=

Calculation

Volume of hard water sample($V_{hardwater}$) = 50 (ml)

Volume of EDTA solution (V_{EDTA}) = x (ml)

Molarity of EDTA solution (M_{EDTA}) =

$\therefore$ Total hardness = $V_{EDTA} \times (M_{EDTA} / V_{hardwater}) \times 10^6$

= ppm

SHORT PROCEDURE

Description	Titration I	Titration II
Burette solution	EDTA	EDTA
Pipette solution	Calcium chloride solution	Hard water
Reagents added	Buffer solution	Buffer solution
Indicator	Eriochrome black-T	Eriochrome black-T
End point	Change in colour from wine red to steel blue	Change in colour from wine red to steel blue

8. DETERMINATION OF pH AND CALCULATION OF HYDROGEN ION CONCENTRATION

Ex. No……….

Date……….

Aim:

To find out

1. The pH of given solutions in bottles A,B,C ,D and E
2. To calculate hydrogen ion concentration of the solutions.

Principle:

The pH of the solution can be directly measured using a pH meter. Acids give hydrogen ions in solution. The acidic nature of the solution depends on the hydrogen ion concentration which is expressed as gram ions per litre. The pH of the solution varies with concentration of hydrogen ions.

$$PH = -\log_{10} [H^+]$$

Procedure:

Exactly 50 ml of the given five sample solutions are taken in five 150 ml beakers and labeled as A,B,C,D and E. The pH meter is standardized using a known buffer solution. The electrodes are then washed with distilled water and then immersed in the solution taken in the beaker.

The pH readings are noted. The pH of all the other solutions are to be determined similarly. The electrodes are washed well with distilled water before the electrodes are immersed in next solution. The amount of hydrogen ions present in the solutions are then calculated from the pH.

Result:

The amount of pH and hydrogen ion concentration of the given five sample solutions are

pH and **$[H^+]$CONCENTRATION**

(1) Sample A …………….. g ions / lit
(2) Sample B …………….. g ions / lit
(3) Sample C …………….. g ions / lit
(4) Sample D …………….. g ions / lit
(5) Sample E …………….. g ions / lit

DETERMINATION OF pH AND CALCULATION OF HYDROGEN ION CONCENTRATION

S.No	Sample solution	pH	Hydrogen ion concentration g ions per litre
1	A		
2	B		
3	C		
4	D		
5	E		

Calculations

Sample A

Sample B

Sample C

Sample D

Sample E

MODEL QUESTION PAPER

MODEL: 1

1. Estimate the mass of Sulphuric acid Present in 500 ml of the given solution. You are supplied with a standard solution of oxalic acid of strength 0.098N and an approximately decinormal solution of Sodium hydroxide.

MODEL: 2

2. Calculate the total hardness of the given sample of water. You are given a standard Hard water Solution of 0.01M and an approximately 0.01M EDTA solution.

MODEL: 3

3. Calculate pH of given five samples, using pH meter and Calculate the H^+ ion Concentration of all the samples. (Any two Students only in a batch).

List of Apparatus to be supplied for each student for Board Exam

1.	Burette 50ml	- 1
2.	Pipette 20ml (with safety bulb)	- 1
3.	Conical Flask 250ml	- 1
4.	Funnel	- 1
5.	Porcelain Tile 6x6”	- 1
6.	Burette stand	- 1
7.	Standard flask 100 ml	- 1
8.	Beakers 250 ml	- 1
9.	Wash Bottle	- 1

SEMESTER II

UNIT I

ENVIRONMENTAL CHEMISTRY

1.1. AIR POLLUTION

1.1.1 Introduction

In recent days, everyone speaks about pollution. We are all facing huge risks due to pollution. The air we breathe, the water we drink, and the place where we live and work in may be full of toxic substances. The adverse effects of these pollutants may affect the future generation also.

Pollution may be defined as the excessive discharge or addition of unwanted and undesirable foreign matters into the environment that causes huge damage to human, plants and animal life.

Environment includes air, water and land. The unwanted foreign matters are called pollutants.

1.1.2 Causes of Pollution

The following are the main causes of pollution.

1. Huge increase in population.
2. Rapid Industrialization.
3 Rapid urbanization
4. Uncontrolled exploitation of nature.
5. Radio activity.
6. Volcanic erruptions etc.

To understand the magnitude of pollution problems it may be classified into three as follows:

1. Air pollution
2. Water pollution
3. Land pollution.

1.1.3 Air Pollution

"Excess discharge of unwanted harmful substances into the atmospheric air" is known as Air Pollution. Gaseous pollutants like hydrogen sulphide, sulphur dioxide, carbon monoxide, and Nitrogen dioxide etc., are known as the most important primary air pollutants.

Harmful Effects of Air Pollutants

S.No	Air pollutant	Source	Harmful effects
1	Sulphur dioxide (SO_2)	From petroleum industry, thermal power station, sulphuric acid manufacturing plants.	Causes respiratory disease, eye irritation and throat troubles, damage to agriculture.
2	Hydrogen Sulphide (H_2S)	From industries like petroleum, paper and leather.	Causes eye irritation severe throat pain, headache, corrosion of metals..
3	Hydrogen Fluoride (HF)	Phosphates, fertilizer industry, aluminum industry, brick pottery	Causes irritation, bone, tooth disorders respiratory diseases.
4	Carbon monoxide (CO)	Automobile industry, oil refineries, cigarette smoke, etc.	Causes Headache, visual difficulty, paralysis.
5	Nitrogen dioxide (NO_2)	Combustion of fuels, explosive industry, acid manufacture.	Causes respiratory illness, eye irritation, affects plant growth, smog formation
6	Dust	Cement industry, mines, glass industry, ceramic industry	Causes respiratory diseases, affects lungs, affects agriculture, accelerates corrosion.

1.1.4 Acid Rain

It means that rain water contains more acids. It is due to the dissolved oxides of sulphur and nitrogen. The gases like SO_2 and NO from industries dissolves in water and form respective acids.

$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$2\,SO_2 + O_2 \rightarrow 2SO_3$$
$$SO_3 + H_2O \rightarrow H_2SO_4$$
$$2\,NO_2 + H_2O \rightarrow HNO_3 + HNO_2$$

Harmful effects of Acid Rain

1. Acid rain makes the soil more acidic thereby reduces the fertility of the soil.
2. It affects the growth of crops, plants etc.
3. It affects the survival of fishes and reduces the population of aquatic species.
4. It badly makes damage to buildings, vehicles, structural materials etc.,
5. It affects human being's life system and organs like skin, lungs and hair.
6. It damages the memorable monuments, buildings etc., The famous 'Taj Mahal' is being affected severely.

1.1.5 Green House Effect

The earth surface gets warmed due to the blanketing effect of Pollutants like CO2 present in the atmosphere. It is known as Green house effect.

Several radiations like UV, visible and infra-red from the sun come in contact with the ozone layer. UV radiation is screened by the ozone layer. The visible and infra-red radiation reaches the earth surface and produce heat energy. The pollutants like CO_2 and other gases which form a blanket around the earth prevent the heat energy to escape from the surface of the earth. Hence the earth gets warmed. It is similar to green glass houses where heat radiation cannot escape from that

Gases that cause Green house effect are mainly CO_2, Methane, Water Vapour, and Chloro Fluoro Carbon (CFC). They are called Green house gases.

1.1.6 Global Warming

The increase in the temperature of the earth surface due to the effect of greenhouse gases is termed as Global Warming.

Effects of Global warming

1. Evaporation process of surface water is enhanced very much due to increase in temperature of earth surface which leads to drastic seasonal change.
2. Sea level is increased due to melting of glaciers. Hence low lying land areas will be submerged under sea water.
3. Food production is mainly affected and it leads to draught.
4. It spreads some diseases like malarial fever, Cholera etc.,
5. It causes drastic change in seasons. Hence human beings and animals are mostly affected by climatic change.
6. Natural calamities like Cyclones, Hurricane, Typoons and Tsunami may occur frequently and strongly.

1.1.7 Ozone Layer

One of the best gifts given by the nature is ozone layer. It is present about 20 km above the earth's surface. Oxygen is converted into ozone by photo chemical change as follows.

$$3\,O_2\,(g) \xrightarrow{\text{Radiadion}} 2O_3\,(g)$$

The region in which O_3 density is high is called ozone layer.

Importance of ozone layer

Ozone layer covers the earth surface and prevents the entry of harmful UV radiation. It saves the lives of human beings and animals. If not so, no life is found on the earth.

Causes for depletion of Ozone Layer

For depletion of ozone layer chlorine plays a vital role. Chlorine converts the ozone molecules into oxygen in the presence of UV radiation as follows.

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

$$ClO + O \rightarrow Cl + O_2$$

It is noteworthy that one molecule of chlorine may convert very huge number of molecules of ozone into oxygen. The main source for chlorine is CFC which is released by Aircrafts, Jet planes, Refrigerators, Airconditioners etc., Other gases which cause ozone layer depletion are NO and NO_2.

Effects of Ozone Layer depletion

1. They affect human beings and cause skin disease and eye defects.
2. Due to ozone layer depletion, the harmful UV radiation may enter freely into the earth's surface and affect the lives in earth.
3. They reduce the population of aquatic species.
4. They affect growth of plants and vegetables.
5. They affect the Eco-system very badly.

1.1.8 Control of Air Pollution

"Prevention is better than cure" Similarly it is better to control the air pollutants at its source itself. The following are the steps to be taken to control the air pollution.

1. The exhaust gases from automobiles and vehicles should be minimized by the use of catalyst.
2. Chimneys may be used to reduce the concentration of pollutants at the ground level.
3. Smoke may be removed by cottrell's electrostatic precipitator.
4. Dust Particles can be removed by the use of bag filters and dust separators.
5. Plants take carbon dioxide during photosynthesis and release oxygen to environment. Hence more trees should be planted.
6. Non –polluting fuels can be used for energy production.

Summary:

In this lesson air pollution, acid rain, green house effect, global warming, ozone layer depletion, their causes and harmful effects and methods to control air pollution are discussed.

QUESTIONS

Part-A

1. What are air pollutants?
2. Define air pollution.
3. What is acid resin?
4. What is green house effect?
5. What is global warming?
6. What is the reason for ozone layer depletion?

Part-B

1. Mention the sources of air pollutants and their causes.
2. Give the harmful effects of acid rain.
3. Explain green house effect and give the causes.
3. Give the harmful effects of global warming.
4. Give the importance of ozone layer.
5. What are the causes for depletion of ozone layer?
6. What are the effects of ozone layer depletion?
7. Write a note on control of air pollution.

TEST YOUR UNDERSTANDING

Discuss the various techniques for control of air pollution.

1.2. WATER POLLUTION

1.2.1 Water Pollution

Water is more important for all the living things. Water is essential for the plants to grow. If the water is contaminated with any foreign substance, it is harmful to human beings, plants, animals etc.,

Causes for water pollution

The sources of water pollution are

1. Domestic Sewage
2. Industrial Effluents
3. Algae
4. Micro-organisms

1.2.2 Sewage

Sewage is the liquid wastage of the community which contains human wastes, kitchen wastes and street wastes.

Problems caused by sewage

1. Hydrogen sulphide gas is produced in the sewage due to the decomposition of impurities.
2. Due to corrosive nature, it affects the pipelines.
3. It gives bad odour.
4. It helps bacteria & Viruses to spread over.
5. Inflammable substances if any may cause severe effect and fire accident.

Treatment of Sewage

Removal of sewage by some treatment methods is called “Sewerage”.

1. The floating impurities can be removed by mesh screens.
2. The suspended impurities can be made as precipitate by filtration and coagulation process.
3. Inflammable organic impurities can be removed by oxidation process.
4. By neutralization method, the corrosive acids and bases are removed.
5. The Bacterial impurities can be removed by chlorination.
6. The water left out from the sewage can be treated by purification method. It can be used for other purposes.

1.2.3 Problems caused by Algae

1. Presence of Algae in water produces foul odour and taste to water.
2. They block the pipelines and filters.
3. They affect the aquatic animals due to depletion of oxygen.

Treatment of Algae

1. Using Algicide like Copper Sulphate the growth of algae can be controlled.
2. Using chemicals like bleaching powder, activated carbon and lime the algae can be destroyed.
3. Preventing the sun light to fall on the surface of water controls the growth of algae.

1.2.4 Problems caused by Micro-organism

Micro-organism means Bacteria and viruses. They cause diseases like cholera, Jaundice, Typhoid. They are destroyed using disinfectants like bleaching powder and chlorine.

1.2.5 Industrial Effluents

The water from various industries has harmful chemicals. It is known as Industrial Effluents.

Problems caused by effluents.

1. The effluents from industries of Leather, Textile, Paper etc., may cause severe damages to aquatic animals.
2. The Metals present in the effluent may seriously affect the human organs like kidney, brain etc.,
3. It corrodes the pipe lines due to acidic nature of effluents.
4. The effluents of chemical industries and nuclear power stations may affect the health of human beings and animals.
5. The effluents may enrich the acidic nature of the soil and affect the growth of plants.

Treatment of Effluents

1. Toxic nature of effluents may be removed by chemical methods.
2. The acidic nature of effluents may be removed by neutralisation.

3. The radio active effluents are carefully stored and burried under the ground.
4. The heavy metallic impurities may be removed by special methods.

Harmful effects of some metallic industrial effluents

S.No	Metals	Sources	Harmful effects
1	Lead	From Automobile, Burning of coal, Mining and Lead Smelters	1. Affect liver and kidney 2. Affect fertility and Pregnancy 3. Produce Mental Retardation in Children 4. Produce Gastro-Intestinal damage
2	Cadmium	From Ni - Cd Battaries, Fertilizer Industry, Electro-plating & Welding	1. Damage the Kidney and intestine. 2. Affect Liver, Brain & Throat 3. Produce anaemia and Hypertension
3	Zinc	From Refineries, Metal Plating, Galvanisation and Plumbing	1.Affect Skin 2.Cause Irritation, Vomiting and diarrhea
4	Copper	From Electro-plating process, Jewellery Marking, Bronzemanufactuing and Plumbing	1. Severely affect the digestive system 2. Cause Vomiting & diarrhea 3. Affect lever 4. Produce gastro-Intestinal damage

1.2.6 Eutrophication

The enrichment of nutrients like phosphates, nitrogen compounds from agricultural waste, organic chemical waste in lake water and other water bodies is known as Eutrophication. It enhances the growth of algae. It makes the lake and ponds as water pool of no use.

Harmful effects of eutrophication

1. It enhances the growth of algae in water which leads to depletion of oxygen in water. It affects the aquatic animals badly.
2. It produces bad taste and odour after it decays.
3. It blocks the pipe lines and filters.
4. It admits the growth of bacteria and viruses.It may spread water borne disease which affects human beings.
5. It causes an imbalance in eco-system based on water resources.
6. Population of aquatic animals is reduced.

1.2.7 Carcinogenic wastes

Organic Compounds having high concentration of hydrocarbons which induce cancer, affect DNA and cell growth are known as Carcinogens.

Effects of different carcinogens on human health

Carcinogen	Hazards
Benzene	Lung Cancer, Death
Vinyl chloride	Liver Cancer
Ethylene dichloride	Stomach pain and Liver Cancer

Insecticides, Pesticides:

Pesticides are synthetic chemicals used to kill undesirable organisms like insects. They include insecticides, herbicides and fungicides. The major groups of synthetic insecticides are,

1. Organochlorines (Chlorinated Hydrocarbons)

Example: DDT (Dichloro Diphenyl Trichloroethane), Methoxchlor, Chlordane, Heptachlor etc

2. Organophosphates

Example: Pathion, Malthion

3. Carbamates:

Example: Propxur, Carbaryl

Even after usage, they are very persistant and soluble in lipids causing human health problems.

They are rapidly absorbed through the skin, lungs and gastrointestinal tract, hence very hazardous to those using them. They show a range of symptoms like nausea, vomiting, blurred vision, tremor, confusion, slurred speech, muscle twisting and convulsions.

Summary:

In this lesson water pollutants like sewage industrial effluents, eutrophicatiion, their causes, problems and rectification methods are discussed.

QUESTIONS

Part-A

1. What are water pollutants?
2. What is sewage?
3. What is eutrophication?
4. What are carcinogenic wastes?
5. What are industrial effluents?
6. Define the term eutrophication.
7. What is green chemistry?

Part-B

1. What are the main water pollutants? Give their harmful effects.How are they controlled?
2. What is sewage? What are the problems? How it is disposed?
3. What are effluents? Give their harmful effects. How are they controlled?
4. What are the metallic pollutants in water? Give their harmful effects.

TEST YOUR UNDERSTANDING

Discuss various methods of waste water treatment.

1.3. SOLID WASTE MANAGEMENT

1.3.1 Introduction

Annual Municipal waste in India is about 280 million tones per year and is creating huge problems for this country. Hence there is an urgent need to tackle this problem or to convert the waste into useful products by using appropriate technology.

1.3.2 Definition

Waste is a substance which is left of industries, Kitchen or other wastes which can cause hazard to human health and environment.

1.3.3 Types Of Wastes

Various types of wastes are

1. Commercial garbage includes bricks, cement, sand etc.,
2. Agricultural wastes include herbicides, pesticides and other toxic substances. It also constitute crop residue, animal and poultry wastes.
3. Rural wastes include bagasse, cow dung garbage, rice husk etc.,

   Other wastes include

4. Plastic wastes like plastic toys, cosmetics, food packaging etc.,
5. Medicinal wastes like cotton containing blood, dressing linen, syringes, waste medicines etc., Domestic wastes include food waste, plastics, broken bottle, ceramic materials, metallic containers, paper, cork ,kitchen waste etc.,
6. Huge municipal garbage includes food waste, plastics, metals, paper and paper board and others rubber, textiles etc.
7. Industrial wastes contain lot of chemicals and products of Iron, cadmium, Tin, Lead, Arsenic, Mercury and other radio active materials.

1.3.4 Problems Caused By Wastes

Because of solid wastes environment is affected. Air becomes unclean with foul smell and human health is affected. All ponds are dirty having dissolved oxygen range of 0 – 2 mg/l and contain sulphates, chlorides and other toxic substances beyond permissible limits. The waste water from hand pumps in some village is also impure and even the colour of water is yellow (or) red with foul smell. The wastes generated by hospitals and animal houses cause serious diseases.

Hence these is an urgent need for the management of waste.

Waste management is the collection of wastages and transport, processing, recycling (or) disposal and monitoring of waste materials to reduce their effect on health and environment.

Solid waste management is not fully implemented because of

1. Lack of education and awareness
2. Lack of motivation
3. Resistance to change
4. Non-cooperation from house holds.
5. Lack of knowledge on benefits of segregation.

1.3.5 Role of Private Sector Organisations

The private sector can play an important role in construction, operation, and maintenance of treatment and disposal facility, NGOs can play an important role in:

organizing rag-pickers/waste collectors for door-to-door collection and segregation of waste

creating public awareness for storage of organic and recyclable waste separately at source and handing over the waste to the waste collector.

Rag-pickers could be involved in door-to-door collection of municipal solid waste as well as recyclable waste so that they could get a user fee for collecting waste from the doorstep and derive additional income from sale of recyclables.

1.3.6 Methods of Disposal

(1) Land Fill

In this method, waste is buried underground and covered with earth. Disposing of waste in a land fill involves burying the waste. Landfills were often established in abandoned areas. Poorly designed landfills can create a number of adverse environment impacts such as windblown litter. Another common by product of land fill is gas (Methane & CO_2) which can create odour problems, kill surface vegetation etc.,

Land fill operation

Modern land fill contain a series of three dimensional control cells. The wastes dumped in the appropriate cells can be covered by a layer of soil at the end of each day. Below the wastes dumped in the cell, a double liner system is provided to prevent the leachates from polluting the soil and ground water beneath the site. The upper liner must be flexible-membrane lining made of plastic or rubber. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials.

Landfill operation

(2) Incineration:

Burning of solid wastes such as wood wastes, cloth wastes can be carried out by burning them into charcoal and ash. A number of hazardous wastes incinerators are available.

Organic wastes are disposed by combustion and are converted into residue and gaseous products. This process reduces the volumes of solid wastes to 20 – 30 percent of original volume. Incineration and other high temperature waste treatment described as "thermal treatment" .Incinerators convert wastes into heat, gas, steam and ash.

Incineration plant

(3) Recycling

Recycling is a process of converting used materials (waste) into new products to prevent wastage of potentially useful materials, to reduce the consumption of fresh raw materials, to reduce energy usage, to reduce air pollution (from incineration) and water pollution (from landfilling). This reduces the need for "conventional" waste disposal methods, and there by lower greenhouse gas emissions. Recycling is a key component of modern waste reduction and is the third component of the "Reduce, Reuse, Recycle" waste.

Steel crushed and baled for recycling

Recycling refers to the collection and reuse of waste materials. "Materials for recycling may be collected from general waste and reprocessed into new products."

The most common products recycled include such as copper wire, steel, newspapers, glass bottles, fibre board boxes, PVC etc.,

In the strictest sense, recycling of a material would produce a fresh supply of the same material—for example, used office paper would be converted into new office paper, or used foamed polystyrene converted into new polystyrene. However, this is often difficult or too expensive (compared with producing the same product from raw materials or other sources), so "recycling" of many products or materials involve their reuse in producing different materials

Materials for recycling may be collected separately from general wastes using dedicated bins and collection vehicles.

Advantages of Recycling

1. It helps in the conservation of natural resources.
2 It protects environment of the area.
3. It protects our health.
4. It makes the air clean and free from foul smell.
5. It reduces the pollution of water bodies.
6. It helps the society to know how to reuse things instead of throwing them and polluting atmosphere.

Recycling Technology on Conversion of Various Wastes

1. Conversion of waste into solid fuel.
2. Composting garbage into manure
3. Conversion of bio mass into compost.
4. Conversion of jute wastes into paper.
5. Conversion of waste vegetables into bio fertilizer.

Summary:

In this lesson various types of solid wastes their problems and need for the management and methods of management are discussed.

QUESTIONS

Part – A

1. Define one problem of garbage.
2. What is incineration
3. What is Recycling

Part - B

1. What are the problems of solid wastes?
2. Describe recycling process with its advantages.
3. What are the types of wastes? Explain their problems.
4. Write a note on Land fill and incineration methods.

TEST YOUR UNDERSTANINGS

1. Think of a project how electricity can be produced from garbage.
2. Think of a project how manure can be produced from garbage.

1.4. GREEN CHEMISTRY

1.4.1 Introduction

The chemical industries produce a large number of products that make invaluable contribution in our daily life. It improves the quality of lives and comforts. During the manufacture of such products, the chemical industry releases enormous quantities of environmentally harmful wastes. It results in pollution. Hence, chemistry in particular, has lost some of its glamour in the public eye. One of the most attractive concepts for pollution prevention is Green chemistry.

1.4.2 Green chemistry

It is defined as the design of environment friendly products and process to minimize or remove hazardous substances. Natural process are 'green' while synthetic process are often 'grey'. Cleaner process and cleaner synthesis will certainly contribute to better environmental protection.

1.4.3 Goals of Green Chemistry

Some guidelines may be given while designing the products and determining the processes to achieve the Green chemistry goals.

1. To prevent the formation of waste material before it is formed.
2. To convert almost all the materials used in the process into the final product.
3. To design some synthetic methodologies that does not give toxic chemicals.
4. To avoid the usage of auxiliary substances (solvents) wherever possible.
5. To ensure the conduction of synthetic methods at ambient temperature and pressure.
6. To reduce the formation of by-products which are harmful.
7. To make use of renewable materials as raw materials during the process.
8. To perform the process in a safe and controlled way.
9. To reduce the quantity of highly hazardous chemicals during the process.

Summary:

In this lesson green chemistry and its goal have been discussed.

QUESTIONS

Part-A

1. What is green chemistry?

Part-B

1. What are the goals of green chemistry?

UNIT-II

FUELS, ROCKET PROPELLANTS AND COMBUSTION

2.1 FUELS

2.1.1 Introduction

In this present age of rapid industrial development the power requirement is increasing day-by-day. Heat energy is the main source of power . Burning of carbon, an exothermic reaction, produces heat energy. So the carbon compounds have been used as the main source of heat energy. The primary or main sources of fuels are wood, coal and petroleum. They are available in the earth's crust and are called fossil fuels.

2.1.2 Definition:

A fuel is a substance, which on proper burning gives large amount of heat used for domestic and industrial purposes. They contain carbon as a main constituent.

The main sources of fuels are coal and petroleum oils available in earth crust and they are called Fossil fuels. The other sources of fuels are

(i) radioactive elements and

(ii) The Sun

2.1.3 Calorific value of fuels

Calorific value of a fuel is the total quantity of heat liberated when a unit mass or volume of the fuel is completely burnt.

(1) Unit of Heat:

Heat energy is measured in terms of calorie or kilocalorie

Calorie is the quantity of heat required to raise the temperature of 1 gram of water through 1^0C

1kcal=1000 Calories

(2) Gross calorific Value

Gross calorific value of a fuel is defined as the total quantity of heat liberated when a unit mass of the fuel is completely burnt and the combustion products are cooled to room temperature

Gross calorific value = Heat of reaction + Latent heat of steam produced + sensible heat obtained by cooling the combustion products to room temperature.

(3) Net Calorific Value

The net calorific value of a fuel is the actual amount of heat available when unit mass of the fuel is completely burnt and combustion products are allowed to cool.

Net Calorific value = gross calorific value – (Latent heat of steam+ sensible heat on cooling of the products of combustion)

2.1.4 Classification of fuels

Fuels are classified into natural or primary fuels and artificial or secondary fuels. Each type is further subdivided into solid, liquid and gaseous fuels.

	State of Fuel	Natural	Artificial
1.	Solid	Wood, peat, lignite and coal	Wood charcoal and coke
2.	Liquid	Crude petroleum	Kerosene, Petrol, diesel and alcohol
3.	Gaseous	natural gas	Water gas, producer gas, biogas, coal gas, LPG

2.1.5 SOLID FUELS:

Wood:

It is a low – grade fuel. Freshly cut wood contains 25-50% moisture. Moisture may be reduced to 25% on air-drying. The composition of moisture free wood is C= 55%; H=6%; O=43% ash=1%. The calorific value of dried wood is 3500 to 4500 kcal/kg. It burns with long and non-smoky flame. It is used as a domestic fuel.

Varieties of Coal:

Coal is a natural fuel formed by the slow carbonization of vegetable matter buried under the earth some thousands of years ago. It is classified into four kinds based on the carbon content and the caloriffc value.

1. Peat
2. Lignite
3. Bituminous Coal
4. Anthracite Coal

(1) Peat:

It is the first stage of formation of coal from wood. It is brown, fibrous jelly-like mass. It contains 80-90% moisture. The composition of peat is C=57%; H=6%; O=35% Ash=2.5%. The calorific value of peat is 5400kcal/kg. It is a low –grade fuel due to high water content. It is used as a fertilizer and packing material.

(2) Lignite:

Lignite is immature form of coal. It contains 20-60% moisture. Air –dried Lignite contains C=60-70% O=20%. It burns with a long smoky flame. The calorific value of lignite is 6500-7100 kcal/kg.

Uses:

1.It is used as a domestic fuel.

2.It is used as a boiler fuel for steam raising.

3.It is used in the manufacture of producer gas.

(3) Bituminous Coal:

It is a high quality fuel. Its moisture content is 4%. Its composition is C=83%. O=10%, H=5% and N=2%. Its calorific value is 8500 kcal/kg.

Uses:

1. It is used in metallurgy.
2. It is used in steam raising.
3. It is used for making coal gas.
4. It is also used for domestic heating.

(4) Anthracite Coal:

It is the superior form of coal. it contains C=92-98%, O=3%, H=3% and N=0.7%. It burns without smoke. It's calorific value is 8700 \kcal/kg

Uses:

1. It is used for steam raising and house hold purposes.
2. It is used for direct burning in boilers and in metallurgy.
3. It is used in thermal power plant.
4. It is used in coal tar distillation.
5. It is used in glass furnaces.

2.1.6 Liquid Fuels:

Petroleum is the naturally available liquid fuel. It is a dark greenish-brown viscous oil found deep in earth's crust. It is composed of various hydrocarbons with small amount of other organic compounds as impurities.

Refining of Petroleum:

The process of purification and separation of various fractions present in petroleum by fractional distillation is called refining of petroleum. Refining is done in oil refineries.

Fractional Distillation:

It is the process of separation of various components of a liquid mixture based on the difference in their boiling points by repeated evaporation and condensation.

Refining of Petroleum Process:

The Crude oil is treated with copper oxide to remove sulphur impurities. Then it is repeatedly washed with sulphuric acid to remove basic impurities. It is then washed with sodium hydroxide to remove acidic impurities. Then it is subjected to Fractional Distillation and various fractions are collected.

Products of Petroleum distillation and their uses

S.No	Fractions	Temperature	Uses
1.	Gases	Below 30°C	Used as industrial and domestic Fuel
2.	Petroleum ether	30°C to 80°C	Used as a solvent
3.	Gasoline or Petrol	40°C to 180° C	Used as a solvent fuel and in dry cleaning
4.	Kerosene Oil	180° C-250°C	Used as illuminant and fuel

S.No	Fractions	Temperature	Uses
5.	Diesel Oil or Gas Oil	250°C-320°C	Diesel engine fuel
6.	Heavy Oil or Lubricating Oil	320°C-400°C	For lubrication, cosmetics and in medicines
7.	Residue or Asphalt or Pitch	above 400°C	Road making and water proofing of roofs.

2.1.7 Cracking

Definition: Cracking is a process by which the hydro carbons of high molecular mass are decomposed into hydrocarbons of low molecular mass by heating in the presence or absence of a catalyst . Generally Aluminum silicates are used as catalyst.

Example

$$\begin{array}{ccc} C_{10}H_{22} & & C_5H_{12} + C_5H_{10} \\ \text{decane} & \xrightarrow{\text{cracking}} & (\text{n-pentane} + \text{Pentene}) \\ \text{B.Pt:}174^{\circ}\text{C} & & \text{B.Pt:}36^{\circ}\text{C} \end{array}$$

Gas oil and Kerosene contain hydrocarbons of high molecular mass and boiling. They are unsuitable as fuel in automobiles. Hence they are decomposed into hydrocarbons of low molecular mass and low boiling point.

2.1.8 Liquid Hydrogen as a fuel:

Hydrogen as a fuel:

Hydrogen is a colourless and odourless gas composed of diatomic molecules. It holds greater role as a fuel in future.

Liquid Hydrogen H_2 is a favourable rocket fuel. On combustion it produces more heat per gram than any other fuel. Further it produces only water on combustion whereas the fossil fuels produce gases like SO_2, NO_2 & CO_2 causing environmental pollution. Therefore Hydrogen as a fuel have more advantage than any other fossil fuels.

Hydrogen is not a primary fuel. It is obtained from other sources of energy. It can be obtained directly from water by decomposing with some energy source. Solar photovoltaic collectors are used to decompose water by electrolysis.

Hydrogen can be liquified below the temperature of 33.1°K. It is a colourless odourless liquid below 20.2°k. When allowed to expand it gets heated up above 22°K.

2.1.9 Gaseous Fuels

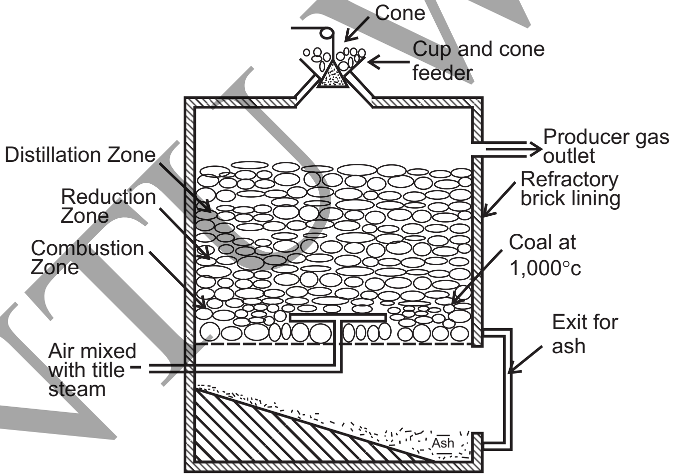
(1) Producer Gas

Producer gas is a mixture of carbon monoxide and nitrogen. it also contains traces of hydrogen and carbondioxide.

Composition

The average composition of producer gas is CO=22 to 30% H_2=8-12% N_2=52-55% and CO_2=3%

It's calorific value is about 1300 kcals/m^3



Gas Producer

It is prepared by passing air over a red hot coke at about 1100°C in a reactor called gas producer.

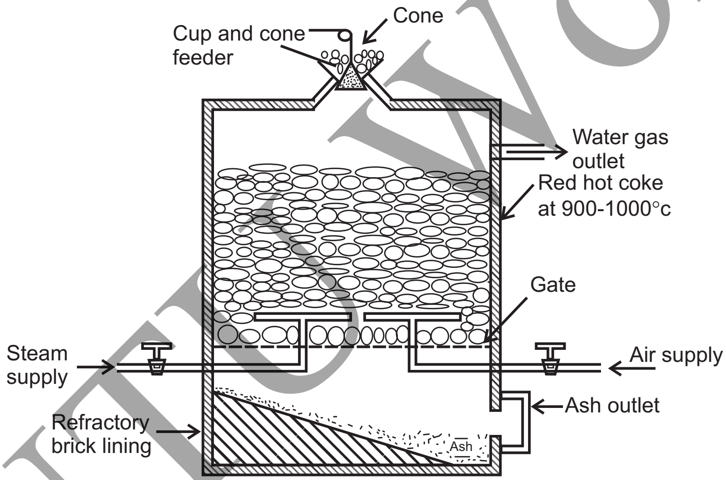
The reactor consists of a steel vessel lined inside with refractory bricks. It is provided with cup and cone arrangement at the top and side opening for producer gas exit. At the bottom it has inlets for passing air. There is an exit for the ash at the base.

Uses:

1. It is cheap and clean.
2. It is used as a fuel in the extraction of metal.
3. It is used in the manufacture of glass.
4. It is used as a reducing agent in metallurgy.

(2) Water Gas

Water gas is a mixture of carbon monoxide and Hydrogen. It also contains traces of carbondioxide and nitrogen.The average composition of water gas is CO=41% H_2=51%, N_2=4%, CO_2=4%. It's calorific value is 2800kcal/m^3



Water gas production

It is prepared by passing alternatively steam and air through red hot coke at about 1000°C in a reactor. It is an endothermic reaction. So the temperature of the system falls.

$$C+H_2O \rightarrow CO+H_2 - \text{Endothermic}$$

But the reaction between carbon and air is exothermic and raises the temperature to 1000°

$$C+O_2 \rightarrow CO_2 - \text{Exothermic}$$

Thus the steam and air are sent in alternatively to maintain the temperature at 1000°c

The reactor consists of a steel vessel lined inside with refractory bricks. It has cup and cone feeder at the top and an opening near the top for water gas exit. At the base inlet pipes for steam and air are provided. At the bottom out let for ash is also available

Uses:

1. It is used as a source of hydrogen gas.
2. It is used as an illuminating gas.
3. It is used as a fuel.

(3) Biogas

Preparation: Biogas is produced by the action of bacteria on biological matter like cow dung in the absence of free oxygen.

Example : Gobar Gas

The average composition of Gobar gas is CH_4=55% H_2=7.4%, CO_2=35% N_2=2.6% and traces of H_2S. The calorific value of gobar gas is 1200Kcal/m^3.

Uses:

1. It is mainly used as a domestic fuel.
2. It is also used as an illuminant.

(4) LPG:

1. LPG is the Liquefied Petroleum Gas.
2. It is a mixture of propane and butane.
3. It is a stored in steel cylinder under high pressure.
4. When the cylinder is opened it comes out in the form of gas.
5. Commercially it is supplied as Indane or Burshane.

Uses:

1. It is mainly used as a domestic fuel.
2. It is used as a fuel in diesel engines.
3. It is used as a motor fuel and in tractors also.

(5) Advantages of Gaseous Fuels:

1. They have high calorific value.
2. They are transported easily through pipelines.

3. They do not produce ash.
4. They can be easily ignited.
5. They require minimum storage place.
6. They produce no smoke.
7. Flame can be controlled easily.
8. They can be made oxidizing flame, reducing flame etc by controlling air supply.This gives more advantage in metallurgy.
9. They produce high temperatures.
10. They can be directly used in internal combustion engines.

2.1.10 Relative advantages of Solid, Liquid and Gaseous Fuels.

S.No	Property	Solid Fuel	Liquid Fuel	Gaseous Fuel
1.	Calorific Value	Low	Greater than solid and less than gaseous fuel	Very high
2.	Smoke production	High	Low	Nil
3.	Ash formation	Ash Produced	Nil	Nil
4.	Storage	Large spaces needed	Less space needed	Minimum space needed
5.	Transportation	More labour involved	Much less labour involved	Transported through pipelines
6.	Igniting	Difficult	Easy	Much easy
7.	Flame control	Difficult	Easy	Very easy

Summary:

In this lesson different types of fuels, their composition and uses have been discussed .The manufacture, composition and uses of water gas and producer gas and some details about bio-gas and LPG have also been discussed.

QUESTIONS

Part-A

1. Define the terms
   (i) Fuel (ii) Carfic value (iii) calorie
2. How are fuels classified?
3. Define gross calorific value.
4. Define net calorific value.
5. What is meant by cracking?
6. What is LPG? give its uses.
7. What are the gases present in LPG?
8. Give the composition and uses of gobar gas.
9. Give the composition and uses of
   (i) Producer gas (ii) water gas
10. What are the varieties of coal.?

Part- B

1. Write a note on solid fuels.
2. Describe refining of petroleum.
3. Describe the manufacturer of producer gas. Give its composition and uses.
4. Describe the manufacture of water gas. Give its composition and uses.
5. Write short notes on (i) LPG (ii) Bio-gas
6. Write a note on liquid hydrogen as a fuel.
7. What are the advantages of gaseous fuels?
8. Give the relative advantages of Solid, liquid and gaseous fuels.

TEST YOUR UNDERSTANDING

Describe how the house hold waste can be utilised to produce gaseous fuels.

2.2. ROCKET PROPELLANTS

2.2.1 Definition

Fuels which burn quickly and give a very large volume of gases to propel a rocket are called rocket fuels or propellants. They are either high oxygen-containing fuels or a mixture of a fuel and an oxidant.

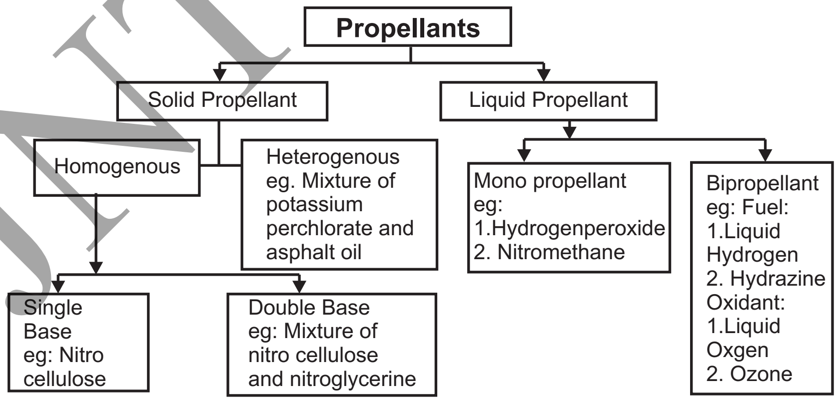
The propellant reacts quickly producing a very large volume of gases at a temperature of 3000°C and a pressure of 300kg/cm^2. The gases exit through a small opening called nozzle at super sonic velocity. This act of pushing the gas backwards produces equal force acting in the opposite direction which moves the rocket forward.

Rockets are used for putting space capsule into orbit and hurling explosives.

2.2.2 Characteristics of a good propellant:

1. It should have high specific impulse and produce gases of low molecular mass.
2. It should have high density.
3. It should burn at a slow and steady rate.
4. It should have high stability.
5. It should have high flame temperature.
6. It should produce large volume of gases.
7. The gases produced should not be toxic or corrosive.
8. It should not leave solid residue after ignition.

2.2.3 Classification of propellants:



2.2.4 Solid Propellants

Solid propellants are divided into two types as

(i) Homogenous solid propellant
(ii) Heterogeneous solid propellant

Homogenous Solid Propellant:

A solid propellant or a mixture of propellants mixed in colloidal state is called a homogenous propellant. It may be in either single base or double base.

When a single propellant is used it is called a single base propellant.

Example: Nitro-cellulose

A solid propellant containing two materials mixed in colloidal state is called a double base propellant.

Example

1. Mixture of nitrocellulose and nitroglycerine.
2. Mixture of nitrocellulose and Nitroglycerine with diethyl phthalate (solvent Plasticizer) and diphenylamine (Stabilizer)

This gives propellant gives a flame temperature of 2700°C and volume of gases produced is 1500 times the original volume of fuel.

Heterogeneous or Composite Solid Propellant:

Definition: In heterogeneous propellant the oxidant is uniformly dispersed in fuel.

Example

1. Potassium perchlorate and asphalt oil
2. Ammonium perchlorate and resin binder

2.2.5 Liquid Propellants:

It is further classified into (i) mono propellant and (ii) bipropellant

Monopropellant:

A mono propellant has the oxidant and fuel in the same molecule or both in same solution

Example : Hydrogen peroxide, nitromethane, ethylene oxide, hydrazine, propylnitrate and mixture of methanol and hydrogen peroxide.

Bipropellant:

In this type fuel and oxidant are kept separately and injected separately into the combustion chamber

Example for fuels:	Liquid hydrogen Hydrazine, Ethylalcohol Aniline and Kerosene Oil
Example for oxidants :	Liquid oxygen, ozone Hydrogen peroxide Fuming nitric acid and Liquid Fluorine

Liquid propellants are more versatile. The engine which use them can be checked and calibrated easily. But liquid propellant is delicate and cannot withstand rough handling

2.2.6 Comparison of Solid and Liquid Propellants

S.No	Solid Propellants	Liquid Propellants
1.	They have low specific impulse.	They have high specific impulse.
2.	They are easily, safely stored, handled and transported.	They have problem in storing, handling and transporting.
3.	The engine using these propellants are of simple design.	The engine using these propellants are delicate and require careful handling.
4.	They are more economical.	They are less economical.
5.	Checking and calibration of engines are difficult.	Checking and calibration of engines are easy.

Summary:

In this lesson rocket propellants, their types and applications are discussed.

QUESTONS

Part- A

1. Define Propellant.
2. How are Propellants classified ?
3. Give two examples for solid propellants.
4. Give two examples for liquid propellants.

Part- B

1. What are the characteristics of Propellants?
2. Write a note on solid propellants.
3. Write a note on liquid propellants.
4. Explain the classification of propellants with examples.

TEST YOUR UNDERSTANDING

Why the molecular masses of propellants must be low?

2.3. COMBUSTION

2.3.1 Introduction

Combustion is an exothermic chemical reaction accompanied by heat and light. To ensure complete combustion., substance should be brought to its ignition temperature. For example combustion of carbon and oxygen

$$C + O_2 \rightarrow CO_{2(g)} + 97\text{kcal}$$

The gaseous products of combustion are mainly CO, CO_2, N_2, SO_2, O_2, H_2O which are known as flue gases. The main elements present in most of the fuels are C, H, O and S.

2.3.2 Calculation of Air Qualities:

Substances always combine in definite proportions which are determined by the molecular masses of the substances involved and the products formed.

Stoichiometric (or) Minimum quantity of air for complete combustion of solid and liquid fuels

1. Combustion of Carbon

$$\begin{array}{ccccc} C_{(s)} & + O_{2_{(g)}} & \rightarrow & CO_{2(g)} \\ 12 & 32 & & 44 \end{array}$$

12 kg of carbon requires oxygen for complete combustion=32 kg

∴ Given carbon in the fuel requires oxygen
for complete combustion

= 32/12xC ...(1)

2. Combustion of Hydrogen

$$\begin{array}{ccccc} 2H_{2_{(g)}} & + O_{2_{(g)}} & \rightarrow & 2H_2O(\ell) \\ 4 & 32 & & 36 \end{array}$$

4 kg of hydrogen requires 32 kg of oxygen for combustion

∴ H kg of hydrogen in the fuel requires 32/4 x H kg of oxygen.

From the total amount of hydrogen, some of it is present in the combined form (i.e. as H_2O). Since, the combined hydrogen is non-combustible substance, it does not take part in combustion.

The rest of hydrogen only takes part in the combustion reaction.

Hence oxygen required for

$$\text{combustion of hydrogen} = \frac{32}{4} x (H - O/8)$$

$$= 8(H - \frac{O}{8}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

3. Combustion of Sulphur:

$$\underset{32}{S(s)} + \underset{32}{O_2(g)} \rightarrow \underset{64}{SO_2(g)}$$

32 kg of sulphur requires 32 kg of oxygen.

The given sulphur in the fuel requires $\frac{32}{32}$ x S kg of oxygen. .... (3)

On combining the above three equations we get the theoretical oxygen required for combustion of C, H and S.

$$= \frac{32}{12} x\, C + 8(H - \frac{O}{8}) + S$$

Air contains 23% by mass of oxygen and 21% by volume of oxygen.

∴ Minimum mass of oxygen is calculated on the basis of complete combustion.

Minimum mass of oxygen required = Theoretical O_2 required - O_2 present in fuel.

Minimum mass of oxygen required for combustion of 1 kg of fuel

$$= \frac{100}{23} \times \left[\frac{32}{12} \times C + 8\left(H - \frac{O}{8}\right) + S\right] kg$$

Minimum volume of air required for combustion

$$= \frac{100}{21}\ x \left[\frac{32}{12}\ x\ C + 8\left(H - \frac{O}{8}\right) + S\right] m^3$$

2.3.4 Examples

Example:1

A fuel contains 90% carbon 3.5% hydrogen, 3% Oxygen , 0.5% Sulphur.

Determine stoichiometric mass of air required to completely burn 1 kg of this fuel.

Given

C = 0.9 kg
H = 0.035kg
O = 0.03 kg
S = 0.005 kg

Mass of air required for complete combustion

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } C + 8\left(H - \frac{O}{8} \right) + S \right] \text{kg}$$

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } 0.9 + 8\left(0.035 - \frac{0.03}{8} \right) + 0.005 \right]$$

$$= 11.543 \text{ kg.}$$

Example:2

Calculate the minimum volume of air used for complete combustion of a fuel having the composition by mass.

$C = 92\%$ $H = 4\%$ $O_2 = 2\%$ ash = 2%.

C = 0.92kg
H2 = 0.04kg
O2 = 0.02 kg
S = 0

Minimum volume of air required for combustion

$$= \frac{100}{21} \text{ x } \left[\frac{32}{12} \text{ x } 0.92 + 8\left(0.04 - \frac{0.02}{8} \right) + S \right]$$

$$= \frac{100}{21} \times \left[\frac{32}{12} \times 0.92 + \left(0.04 - \frac{0.02}{8} \right) + 0 \right]$$

$$= 13.11 \text{ m}^3$$

Example:3

The gravimetric analysis of coal is as follows

$C = 84\%$ $H_2 = 10\%$ $O_2 = 4\%$ $N_2 = 2\%$.

Calculate theoretical air required for complete combustion.

Given $C = 84\%$ $H_2 = 10\%$ $O_2 = 4\%$ $N_2 = 2\%$

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } C + 8\left(H - \frac{O}{8}\right) + S\right] \text{kg}$$

$$\text{Air required } = \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } 0.84 + 8\left(0.1 - \frac{0.04}{8}\right) + 0\right]$$

$$= 13.0434 \text{ kg}$$

Example:4

Calculate the amount of air by mass required for complete combustion of 2kg of coke assuming 100% carbon

$$\text{Mass of } O_2 \text{required for combustion of 2kg of coal } =$$

$$2 \text{ x } \frac{32}{12} = 5.33 \text{ kg}$$

$$\text{Mass of Air required } = \frac{100}{23} \text{ x } 5.33$$

$$= 23.2 \text{ kg.}$$

Example:5

A sample petrol on analysis gave $C = 85\%$

$H_2 = 15\%$

Calculate weight of air required for complete combustion of 1 kg of petrol.

Given $C = 0.85\text{kg}$

$H_2 = 0.15 \text{ kg}$

Weight of air required for complete combustion of 1 kg of Petrol

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } C + 8 \left(H - \frac{O}{8} \right) + S \right] \text{kg}$$

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } 0.85 + 8 \left(H - \frac{0.}{8} \right) + S \right]$$

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } 0.85 + 8 \text{ x } 0.15 \right]$$

$$= \frac{100}{23} \text{ x } [2.2666 + 1.2]$$

$$= \frac{100}{23} \text{ x } [3.4666]$$

$$= \frac{346.66}{23}$$

$$= 15.0721 \text{ kg}$$

2.3.5 Excess Air

During combustion, there is an incomplete combustion, when stoichiometric air is supplied. In practice ,excess amount of air is supplied to get complete combustion. To avoid cooling effect, about 25% to 50% of preheated air is supplied .

Total mass of air / kg of fuel = Stoichiometric mass of air + Excess mass of air

Example6:

Calculate the mass of air to be supplied for the combustion of a fuel containing 75% carbon, 8% hydrogen, 3% oxygen if 40% excess air is supplied.

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } C + 8 \left(H - \frac{O}{8} \right) + S \right] \text{kg}$$

Minimum stoichiometric air required $= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } C + 8 \left(H - \frac{O}{8} \right) + S \right] \text{kg}$

$C = 0.75$ kg

$H = 0.08$kg

$O = 0.03$ kg

Excess air = 40%

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } 0.75 + 8\left(0.08 - \frac{0.03}{8}\right) + O \right]$$

$$= 11.3478 \text{ kg}$$

Excess air = 11.3478 x 40% = 4.5391 kg

Total mass of air = 11.3478+405391=15.8869 kg.

Example:7

The percentage composition of a coal is C = 90% H_2 = 4%, O_2= 3% N = 3% S = 0.5%. Calculate the minimum mass of air required for combustion.

Solution:

C = 0.9 kg O_2= 0.03 kg

H_2= 0.04 kg S = 0.005 kg

$$= \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } C + 8\left(H - \frac{O}{8}\right) + S \right] \text{kg}$$

$$\text{Weight of air required} = \frac{100}{23} \text{ x } \left[\frac{32}{12} \text{ x } 0.9 + 8\left(0.04 - \frac{0.03}{8}\right) + 0.005 \right]$$

$$= \frac{100}{23} \text{ x} 2.695$$

$$= 11.72 \text{ kg}$$

Combustion of Gaseous Fuels

The quantity of air required for the combustion of flue gases is calculated mainly based on the balanced combustion equation.

(1) Combustion of Carbon Monoxide:

$$2CO + O_2 \rightarrow 2CO_2$$

2 vol 1vol 2 vol

Oxygen required for burning CO = ½ x CO m^3

carbon dioxide formed from carbon monoxide = $^2/_2$ CO m^3

(2) Combustion of Hydrogen

Oxygen required for burning hydrogen = ½ H_2m^3

$$2H_2 + O_2 \rightarrow 2H_2O$$

$$2\text{ vol} \quad 1\text{ vol} \quad 2\text{ vol}$$

(3) Combustion of Methane:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$1\text{vol} \quad 2\text{vol} \quad 1\text{vol} \quad 2\text{vol}$$

Oxygen required for burning methane = 2/1 $CH_4\ m^3$

Carbon dioxide formed from burning methane = 1/1 CH_4m^3

Stoichiometric or minimum air required for complete combustion of gaseous fuels

1 m^3 of H_2 needs 0.5 H_2m^3 of O_2

1m^3 of CO needs 0.5 CO m^3 of O_2

1 m^3 of CH_4 needs 2 $CH_4\ m^3$ of O_2

If in 1 m^3 of fuel hydrogen is H_2m^3, carbon monoxide is CO m^3 and methane is CH_4m^3.

Oxygen required = $0.5 H_2 + 0.5 CO + 2CH_4 - O_2m^3$.

Since air contains 21% of oxygen by volume, the minimum volume of air required for complete combustion (or)

Example:8

$$\text{Stoichiometric volume of air} = \frac{100}{21}\ (0.5\ (H_2 + CO)\ +\ 2CH_4\text{-}O_2)m^3$$

Determine the volume of air needed for complete combustion of one cubic meter of producer gas having the following composition by volume.

Hydrogen = 30% CO = 12% CH_4 = 5%

Nitrogen = 50%

The combustion equations are

$$\begin{array}{lll} H_2 + \frac{1}{2}O_2 & \rightarrow & H_2O \\ 1\text{vol} \quad 0.5\text{vol} & & 1\text{vol} \end{array}$$

$$\begin{array}{lll} CO + \frac{1}{2}O_2 & \rightarrow & CO_2 \\ 1\text{ vol} \quad 0.5\text{ vol} & & 1\text{ vol} \end{array}$$

$$\begin{array}{lll} CH_4 + 2O_2 & \rightarrow & CO_2 + 2H_2O \\ 1\text{ vol} \quad 2\text{ vol} & & 1\text{ vol} \quad 2\text{ vol} \end{array}$$

Volume of oxygen needed for complete combustion of 1m^3 of gas

$$= \frac{100}{21}\left[0.5\,(H_2 + CO) + 2CH_4 - O_2\right]$$

$$= \frac{100}{21}[0.3 \text{ x } 0.5 + 0.12 \text{ x } .5 + 0.05 \text{ x } 2]$$

$$= \frac{100}{21}[0.15 + 0.06 + 0.1]$$

$$= \frac{100}{21} \text{ x } 0.31$$

$$= 1.4761 \text{ m}^3$$

2.3.6 Flue Gas Analysis - Experiment

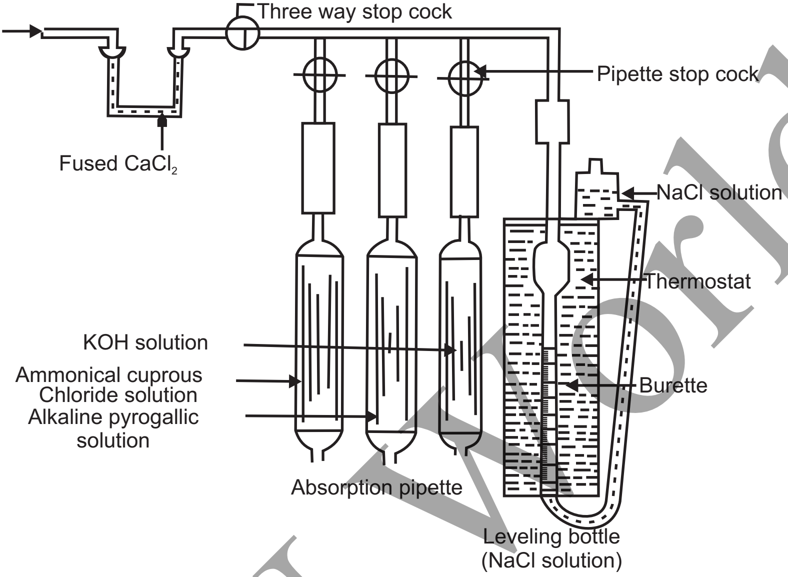
Flue gas is a mixture of gases produced from the products of combustion of a fuel. Its major constituents are CO, CO_2, O_2 and N_2.

The efficiency of combustion can be understood by qualitative analysis of flue gas. Usually excess oxygen in the flue gas suggests that excess of air is supplied for combustion. More carbon monoxide content suggests, incomplete combustion process. Based on flue gas analysis, improvement in the design of internal combustion engines, combustion chamber, furnace etc can be done.

Orsat's apparatus

Mainly the flue gases CO, CO_2, O_2 are quantitatively analysed by Orsat's apparatus.

The apparatus consists of a burette surrounded by water maintaining constant temperature. One end of burette is connected to a leveling bottle through a rubber tube. The leveling bottle contains saturated NaCl solution which do not absorb any flue gases. By raising and lowering of the leveling bottle, the volume of gases present in it are made to overflow and have close contact with three absorption pipette solutions.



Orsat's gas analysis apparatus

The absorption pipette have solution for absorption of CO_2, O_2 and CO respectively .First pipette is filled upto the mark with standard KOH solution to absorb CO_2. The second pipette is filled with standard alkaline pyrogallol solution. This solution can absorb CO_2 and O_2. The third pipette is filled with standard ammonical Cuprous chloride. This absorbs CO_2, O_2, and CO. Hence it is necessary to pass the flue gas first through standard KOH solution and then through standard pyrogallol solution and finally through std. ammoniacal $CuCl_2$ solution.

To flush out the air in the apparatus, the three way stop cock is opened to the flue gas supply after closing the entries of absorption pipettes. By lowering the leveling bottle, the flue gas is admitted in the burette and the three way stop cock is opened to the flue gas supply after closing the absorption pipettes. Now the leveling bottle is raised and the gas - air mixture is pushed out into the atmosphere. The procedure is repeated until the pure flue gas occupies the apparatus. Then adjust the leveling bottle and exactly permit 100 ml. of the flue gas as noted in the burette and close the three way stop cock completely. First the stopper of the first absorption pipette having KOH solution is opened and the flue gas in the burette is forced into pipette solution by raising the leveling bottle. By repeatedly raising and lowering the leveling bottle, the gas is brought into intimate contact with the pipette KOH solution which absorbs the CO_2 gas completely. Then the residual gases are taken into the burette and the levels of the KOH solution is made to stand in fixed mark. By adjusting the leveling bottle, the volume of residual gases after the removal of CO_2 by the absorption pipette is measured in the burette. The decrease in volume gives the volume of CO_2 in 100 ml. (%) of the sample flue gas. The same procedure is then repeated with the alkaline pyrogallol solution. After the absorption of O_2 in the absorption pipette, the pipette level is fixed and entry closed. After that the burette reading is noted by leveling with the leveling bottle. The further decrease in volume gives the volume of oxygen in the 100 ml (%) of the sample flue gas.

Finally the third absorption pipette is opened and by adjusting the leveling bottle up and down the remaining flue gas in it forced to pass through the ammoniacal cuprous chloride solution of the absorption pipette. This is done to have through absorption of the remaining CO gas in the absorption pipette. After this, the level of pipette is made fixed and entry closed. The residual gas finally present in the burette is then measured by using the leveling bottle. The decrease in value from the last noted value gives the volume of carbon monoxide present in 100 ml (%) of the sample flue gas.

The percentage of Nitrogen is obtained by the difference.

Example :9

A fuel contains 45% of H_2,40%, CO,12% CH_4 and 3% O_2 by volume. Determine volume of air required to burn 1 m^3 of this fuel.

Given H_2 = 45% = 0.45

CO = 40% = 0.4

CH_4 = 12% =.12

O_2 = 3% = 0.3

$$\text{Minimum volume of air required} = \frac{100}{21}\,(0.5\left[H_2 + CO) + 2CH_4\text{-}O_2\right]$$

$$= \frac{100}{21}\,(0.5\,(H_2 + CO) + 2CH_4\text{-}O_2)$$

$$= \frac{100}{21}(0.5\,(0.45 + 0.4) + 2(0.12)\text{-}0.03)$$

$$= 3.023\ m^3 air$$

Example :10

Volumetric analysis of producer gas supplied to a engine is H_2=20%.

CH_4 = 3% CO = 22% CO_2 = 8% N_2 = 47%

Excess air supplied is 50%. Estimate the volume of air required for combustion of 1m^3 of gas.

H_2 = 20% = 0.2

CO = 22% = 0.22

CH_4= 3% = 0.03

$$\frac{100}{21}\left[0.5\,(H_2 + CO) + 2CH_4\text{-}O_2\right]$$

$$\text{Minimum air required} = \frac{100}{21}\left[0.5\,(H_2 + CO) + 2(CH_4)\text{-}O_2\right]$$

$$= \frac{100}{21}\left[0.5\,(H_2 + CO) + 2(CH_4)\text{-}O_2\right]$$

$$= \frac{100}{21}\left[(0.5\,(0.2 + 0.22) + 2(0.03)\right]$$

$$= 1.286\ m^3$$

Excess air = 50% of 1.286 = 0.643 m^3

= 1.286 + 0.643 = 1.929 m3

Summary:

In this lesson stoichiometric air required for complete combustion of solid, liquid and gaseous fules are explained.

flue gas analysis by Orsat apparatus is explained. Worked examples are given for understanding.

QUESTIONS

Part - A

1. What energy conversion takes place when a fuel is burnt?
2. What is a flue gas?
3. More CO in flue gas suggests what?
4. Excess Oxygen in flue gas suggests what?

Part – B

1. What are flue gases?

   How are they analysed by orsat apparatus?

2. A gaseous fuel has the following composition by volume.

   H_2 = 15% CO 30% CH_4 3% CO_2 5% O_2 = 2%

   remaining Nitrogen. Calculate volume of air needed for complete combustion of 100 m^3 of fuel.

3. A gaseous fuel has following composition by volume.

   Methane 5% Hydrogen 20% CO 25%
   CO_2 6% rest Nitrogen.

   If 20% Excess air is used for combustion, calculate volume of air supplied per m^3 of fuel.

4. A sample of coal was found to have the following composition.

   C = 75%   H = 5.2%

   O = 12.1% N = 3.2% and ash 4.5%.

   Calculate (i) minimum amount of air by mass necessary for complete combustion of 1 kg of coal.

   ii. mass of air required if 40% excess air is supplied.

5. A fuel is found to contain

   C 90% H = 6% S 2.5%

   O = 1% ash 0.2%

   Calculate the amount of air required for complete combustion.

   i. If 1 kg of fuel is used

   ii. If 25% excess air is used for combustion calculate the mass of air required.

TEST YOUR UNDERSTANDINGS

How to distinguish between complete and incomplete combustion of coal.

1. How can you analyse the masses of CO_2 and H_2O produced during combustion of a fuel?
2. Why a good fuel must have low ash content?

UNIT – III

EXTRACTION OF METAL , POWDER METALLURGY, ALLOYS AND ABRASIVES

3.1. EXTRACTION OF METALS

3.1.1 Introduction

Metallurgy deals with extraction of a metal in its pure form from its ore. The stages involved in extracting a metal from its ore are

1. Crushing and grinding of ore
2. Concentration of ore by Physical methods
3. Conversion of concentrated ore into its oxide by chemical reactions
4. Conversion of metal oxide into metal by reduction and
5. Purification of metal by suitable method.

In this lesson we are going to study the metallurgy of two important metals namely Titanium (Ti) and Tungsten (W) which are mainly used to prepare hard steel varieties.

31.2 Titanium (Ti)

(1) The main ores of Titanium are

1. Rutile – TiO_2
2. Ilmenite –$FeTiO_3$

(2) Extraction

Stage I: The ores of Titanium (Rutile and Ilmenite) is converted into titanium tetra chloride ($TiCl_4$) by heating them at 900ºC with carbon in a current of Chlorine.

$$TiO_2 + C + Cl_2 \xrightarrow{900^0 c} TiCl_4 + CO_2$$

Stage II: The vapours of $TiCl_4$ are collected and condensed to get $TiCl_4$ liquid. $TiCl_4$ liquid, which boils at 136ºC, is purified by distillation.

Stage III: $TiCl_4$ is then reduced with sodium metal in argon atmosphere to get titanium.

$$TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$$

The metal thus obtained is washed with 3% nitric acid to remove impurities.

Stage IV: Finally the metal is purified by Van Arkel method. In this method impure Titanium is heated with iodine vapours to get Titanium tetra iodide vapours. These vapours are taken to a different chamber and passed over a heated tungsten wire at 140ºC. TiI_4 decomposes to give pure Titanium.

$$Ti + I_2 \longrightarrow TiI_4$$

$$TiI_4 \xrightarrow{140°C} Ti + I_2$$

(3) Conversion Of Ilmenite Ore Into Titanium Oxide

The ilmenite ore is treated with concentrated sulphuric acid to get a mixture of Titanium suphate and ferrous sulphate. This mixture is digested with excess of water. Iron goes into solution as ferrous sulphate. Titanium sulphate undergoes hydrolysis to form titanium hydroxide precipitate.

$TiO(OH)_2$ on heating gives titanium oxide..

$$Ti\,(SO_4)_2 + 3\,H_2O \longrightarrow TiO(OH)_2 \downarrow$$

(4) Properties

$$TiO(OH)_2 \longrightarrow TiO_2$$

Titanium is a shining white metal. It has low density and high melting point. It is a good conductor of heat and electricity.

(5) Uses

1. Titanium has better corrosion resistance and is much lighter in mass when compare to stainless steel. It is therefore used in aircrafts, gas turbine engines, marine equipments etc.
2. It is also used for hardening steel.
3. TiO_2 is used as a semi-precious artificial gem. It is the ninth most abundant element present in the earth crust.

3.1.3 TUNGSTEN (W)

(1) Ores of Tungsten are

1. Wolframite – (Fe, Mn) WO_4
2. Scheelite - Ca WO_4
3. Tungstenite – WS_2
4. Solzite - Pb WO_4
5. Cuproscheelite -Cu WO_4

(2) Extraction

1. The finely powdered ore of tungsten is concentrated by electromagnetic separation to remove non-magnetic gangue (earthly impurities).

2. The concentrated ore is fused with Sodium carbonate in oxidizing atmosphere. Tungsten forms sodium tungstate.

$$4FeWO_4 + 4Na_2CO_3 + O_2 \longrightarrow 2Fe_2O_3 + 4Na_2WO_4 + 4CO_2$$

$$2MnWO_4 + 4Na_2CO_3 + O_2 \longrightarrow 2MnO_2 + 4Na_2WO_4 + 4CO_2$$

3. The fused mass is extracted with water. The solution of sodium tungstate is concentrated to get the crystals. The crystals are filtered out. Sodium tungstate crystals are again dissolved in minimum quantity of water and acidified with HCl acid. Hydrated tungstic acid WO3.xH2O precipitates out.

$$Na_2WO_4 + 2HCl \longrightarrow 2NaCl + H_2WO_4$$

4. Tungstic acid thus obtained is ignited strongly to remove water. The formed WO_3 is reduced with hydrogen to get tungsten.

$$H_2WO_4 \longrightarrow WO_3 + H_2O\downarrow$$

$$WO_3 + 3H_2 \xrightarrow{1470K} W + 3H_2O$$

5. Tungsten thus obtained is purified by converting it into vapours of tungsten hexa chloride and the vapours when passed over a heated tungsten wire give pure tungsten.

(3) Properties

Tungsten is a hard silvery white metal. It is as heavy as gold. It has highest melting point (8650k). Its wire is very hard and has high tensile strength. It is resistant to acids.

(4) uses

1. The chief minerals of Tungsten present about 10^{-4} % in the lithosphere.
2. Tungsten is mainly used for preparing special type of steels. It is also used for making filaments of electric bulbs, pinpoints, strings for musical instruments etc.,
3. Steel containing 14-22% tungsten and 3-5% Chromium forms a high-speed tool steel material, since it retains its hardness even at very high temperature. It is also used as anti cathode in X-ray tubes.
4. Tungsten is also used for making surgical instruments, spark coils, gramophone needles, Voltage regulators, telegraphic keys, contact points etc.,Tungsten carbide is used to prepare very hard alloys.
5. Sodium tungstate is used for making fireproof fabrics. It is also used as a mordant in dyeing.
6. WO_3 is used as yellow pigment.

Summary:

In this lesson extraction of titanium and tungsten and their properties and uses are discussed.

QUESTIONS

Part – A

1. Name the ores of Titanium.
2. List the uses of Titanium
3. Name the ore of Tungsten
4. List the uses of Tungsten.
5. How is tungsten ore concentrated?
6. How is Titanium tetra chloride prepared from titanium ore?
7. How is $TiCl_4$ reduced to get titanium?
8. How is tungsten obtained from tungstic acid?

Part – B

1. Explain how tungsten is obtained from its ore in pure form.
2. Explain the extraction of Titanium from its ore.
3. Describe Van Arkel method of purification of Titanium.

TEST YOUR UNDERSTANDINGS

1. What are the alloys prepared using titanium?
2. What are the alloys prepared using tungsten?

3.2. POWDER METALLURGY

3.2.1 Introduction

Generally metal components are prepared by pouring molten metal in the mould castings. In Foundry shops the metal castings are made by this traditional method. Powder metallurgy is a new technique in which moulds are made using compressed metal powders. Even though this method is more expensive as it involves preparation of metal powder, it has many advantages over the traditional method. In this chapter we are going to study about the methods used to prepare metal powders and also special advantages derived in different industries when this method is used.

3.2.2 Powder Metallurgy

Powder Metallurgy is an art of making objects by heating compressed metal powder. By this method even complicated structures can be moulded easily.

Articles can be made by using

1. Single metal powder
2. Mixture of metal powders
3. Mixture of metal and non-metal powders.

Production of Metal Powder

1) Reduction Method:

Reduction of the salt solution using reducing agents can produce metal powder. For example powder copper can be prepared by reducing the copper sulphate solution using zinc metal.

$$CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$$

Powders of metals like copper, silver etc., can be prepared by metal displacement method.

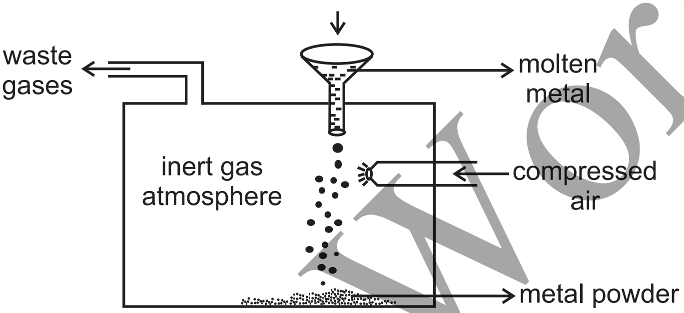
Metal can be obtained by reducing the metal oxide using carbon monoxide or hydrogen. Metal thus obtained can be crushed to get metal powder. Powder copper can be obtained by reducing copper oxide using hydrogen.

$$Cu_2O + H_2 \longrightarrow 2Cu + H_2O$$

Powders of metals like Iron, Tungsten, Nickel, Copper can be prepared by this method.

2) Atomization Method

A molten metal is forced through an orifice. A compressed stream of air is passed over the metal. The liquid metal is broken and sprayed into minute droplets. The droplets are cooled and condensed to get metal powder. To avoid oxidation of metal powder, inert gas is used instead of air. Powders of low melting metals metals like Zinc, Lead and Tin are produced by this method.



3.2.3 Applications Of Powder Metallurgy

- This technology is successfully employed to make compact complicated geometrical shapes.
- Used for making metal bearings embedded with graphite powder.
- Even dense ductile sheets of highly brittle metals like Tungsten and Molybdenum can be produced by this method.
- Wear resisting cutting tools with Cobalt and Nickel metal powder and Carbides of Tungsten and Molybdenum can be produced by this method.
- This method is used to make special electrical contacts containing a current and heat conducting metal mixture.
- This method is used to prepare filaments for bulbs. (Tungsten filament)
- Used to make diamond impregnated cutting tools.
- Used to prepare magnetic materials.

Summary:

In this lesson importance of powder metallury and methods of production of metal powder are discussed.

QUESTIONS

Part – A

1. What is powder metallurgy?
2. Name any two methods of preparing metal powder.
3. How is powder metallurgy method better than conventional method to get a mould?
4. Give an example for a metal displacement reaction.

Part – B

1. Explain any two methods of preparing metal powder.
2. What are the special advantages of powder metallurgy method in the preparation of moulds?

TEST YOUR UNDERSTANDING

1. What are the electrical components prepared by powder metallurgy?

3.3. ALLOYS

3.3.1 Introduction

Definition: Alloys are metallic mass obtained by the intimate mixing of two or more metals. Generally alloys are prepared by fusing together the different ingredients (metals) in a furnace. By alloying metals we get new characters developed in metals.

3.3.2 Advantages of Alloying a Metal

By alloying the metal their physical properties can be improved.

1. Metals are made as good corrosion resistant materials. eg. Stainless steel.
2. The abrasion resistance and tensile strength of the metal can be improved.
3. The machinability of the metal can be improved.
4. The hardness of the metal can be increased.
5. Some metals can be made magnetic in nature by suitably alloying them eg. Alnico alloy
6. Melting point of the metal can be decreased by alloying them. e.g. Fuse wire
7. Malleability and ductility of the metals can be changed by alloying them.
8. The colour and metallic luster can be improved by alloying the metal.

3.3.3 Types Of Alloys

Alloys are classified into two types.

They are 1) Ferrous alloys and 2) Non-ferrous alloys.

Ferrous alloys are alloys containing Iron. E.g. Stainless Steel

Non-ferrous alloys are alloys not containing Iron. E.g. Brass, Bronze etc.

3.3.4 Non-Ferrous Alloys

Alloys not containing iron are called Non-ferrous alloys.

(1) Copper Alloys

Brass:

Brass is an alloy of Copper and Zinc. It is mainly used for making household articles and vessels.

Types of Brass:

Dutch metal:

It contains 80% copper and 20% Zinc. It has golden yellow colour. It is suitable for all drawing and forming operations. Used for making cheap jewellery, musical instruments, battery cap, flexible hoses, tube, nameplates etc.

German silver:

It contains 50% Copper, 30% Nickel and 20% Zinc. It has very high corrosion resistance. Used for making coins, ornaments and decorative materials.

Cartridge Brass:

It contains 70% copper and 30% Zinc. It has high tensile strength and ductility. It is used for making condenser tubes, brass sheets etc.

Bronze:

Bronze is an alloy of Copper and Tin.

Types of Bronze

Gun Metal:

It contains 88% Copper, 10% Tin and 2% Zinc. It is very strong and tough. It can even withstand explosion. It is mainly used for making bearings, coins, and hydraulic fittings and in foundry works.

Coinage Bronze or common bronze

It contains 89 to 92% copper and 11 to 8% tin. It is soft, ductile and durable. It is used in pumps, valves, wires, flanges, utensils, coins and statues.

(2) Nickel alloys

Nichrome:

It contains 60% Nickel, 12% chromium, 2% Manganese, 26% iron. It is a chemical and heat resistant material. It has a very high melting point and high electrical resistance. It is used in making resistance coils, heating elements in stoves, electric irons, and toasters.

Locanel:

It contains approximately 80% Nickel, 14% chromium and 6% iron. It is very ductile in nature. It is a good corrosion-resistant material. It retains its hardness even at 400ºC. It is used for springs even at elevated temperature conditions. It is used in exhaust manifolds, aircraft engines etc.

(3) Aluminium Alloys

Duralumin:

It is an alloy of Aluminium containing 95% Aluminium, 4% Copper, 0.5% Magnesium and 0.5% Manganese. It is light, tough, highly ductile, easily cast able, good conductor of heat and electricity and corrosion resistant. It can be easily worked and possesses high machinability. It is used in building aircraft. It is used for automobile and locomotive parts. It is also used for making surgical instruments, cables, fluorescent-tube caps etc.

Magnalumin

It contains 70-90% aluminium, 30 –10% magnesium. It is quite strong, tough and lighter than aluminium. It possesses mechanical properties similar to that of brass. It is used for making airplane parts and scientific instruments.

NON-FERROUS ALLOYS

Name of the alloy	Composition	Properties and uses
COPPER ALLOYS		
Brass	Copper and Zinc	It is mainly used for making household articles and vessels.
Dutch Metal	80% Copper, 20% Zinc	Used for making cheap jewellery, musical instruments, battery cap, flexible hoses, tube, nameplates etc.
German silver:	It contains 50% Copper, 30%Nickel and 20% Zinc.	Used for making coins, ornaments and decorative materials.
Cartridge Brass:	70% copper and 30% Zinc.	It is used for making condenser tubes, brass sheets etc.

Name of the alloy	Composition	Properties and uses
Bronze:	Copper and Tin.	It is mainly used for making bearings, coins, and hydraulic fittings and in foundry works.
Gun Metal:	88% Copper, 10% Tin and 2% Zinc.	It is mainly used for making bearings, coins, and hydraulic fittings and in foundry works.
Coinage Bronze or common bronze	89 to 92% copper and 11 to 8% tin.	It is used in pumps, valves, wires, flanges, utensils, coins and statues.
NICKEL ALLOYS		
Nichrome	60% Nickel, 12% Chromium, 2% Manganese, 26% iron.	It is used in making resistance coils, heating elements in stoves, electric irons, water heater and toasters.
Ioconel	80% Nickel, 14% chromium and 6% iron.	It is used for making springs used at elevated temperature conditions. It is used in exhaust manifolds, aircraft engines etc.
ALUMINIUM ALLOYS		
Duralumin:	95% Aluminium, 4% Copper, 0.5% Magnesium and 0.5% Manganese.	Used for building aircrafts. It is used for automobile and locomotive parts. It is also used for making surgical instruments, cables, fluorescent-tube caps etc.
Magnalumin	70-90% Aluminium, 30 -10% Magnesium	It is used for making airplane parts and scientific instruments.

Summary:

In this lesson the importance of alloying, composition and uses of copper alloys, nickel alloys and alluminium alloys are discussed.

Questions

Part – A

1. What are alloys?
2. What are the two types of alloys?
3. What are ferrous alloys? Give example.
4. What are non-ferrous alloys? Give example.
5. What is brass?
6. What is bronze?
7. Give the composition and uses of duralumin.
8. What is Nichrome alloy? Give its uses

Part – B

1. What are the special advantages achieved by alloying metals?
2. Give the composition and uses of any two types of brass.
3. Name two nickel alloys. Give their composition and uses.
4. Give the composition and uses of the following alloys
   (i) German silver (ii) Duralumin.
5. List the composition and uses of aluminum alloys.
6. Give the composition and uses of Gun metal and coinage bronze.

TEST YOUR UNDERSTANDING

1. What are the alloys used in aircraft parts?

3.4 ABRASIVES

3.4.1 Introduction

'Abrasives are hard substances used for cutting, grinding and polishing surfaces.'

We have observed different hard and soft substances used for the above said processes in day to day life.

- Hard silicon carbide discs used in workshops in shaping machines.
- Emery sheets used to clean the metal surfaces before painting them
- Discs used for sharpening knives and other cutting tools.
- Fine metal powders used for mosaic polishing.

Such substances used for cutting, grinding and polishing purposes are called abrasives. They find lot of application in day to day life and in industries. The main property of abrasive materials is their hardness.

3.4.2 Hardness of Abrasives

Hardness is the main property of an abrasive. It is defined as the capacity of an abrasive to grind another substance. Harder the abrasive better will be its capacity to grind other substances. Hardness of abrasives is measured in a scale called Moh's scale. In Moh's scale, the hardness of Diamond, which is the hardest among all substances, is taken as 10. The hardness of the softest substance, talc is taken as one. Therefore the hardness of other substances in Moh's scale lies in between 1 and 10.

HARDNESS OF ABRASIVE MATERIALS

Material	Hardness (Moh's scale)
Talc	1
Gypsum	2
Calcite	3
Fluorite	4
Appatite	5
Feldspar	6
Quartz	7
Topaz	8
Corundum	9
Diamond (C)	10

Generally hardness of abrasives is measured by piercing a needle through it using some pressure. Hardness is measured in terms of the distance pierced by the needle in the abrasive material and comparing the same with a standard substance of known hardness.

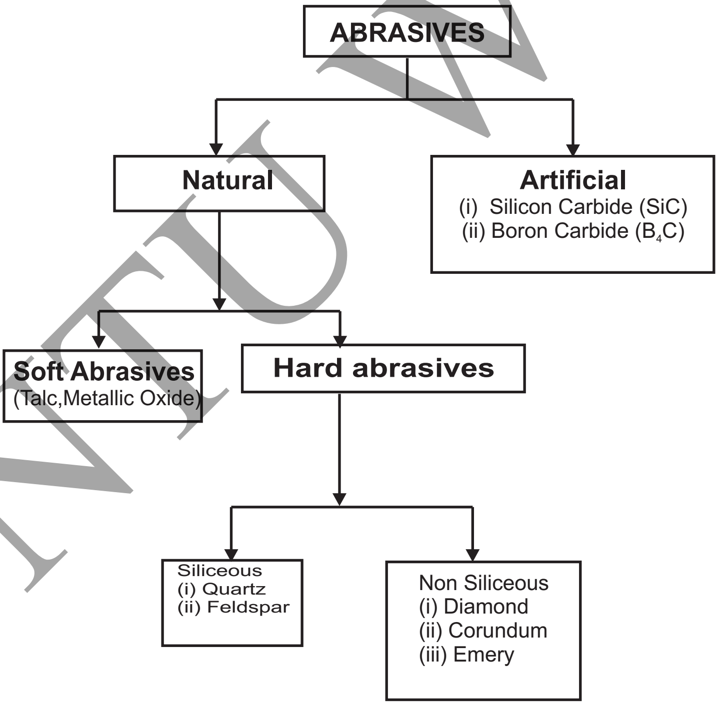
The other important property of an abrasive is toughness. Abrasive material should be brittle so that it can function effectively. The other important character of an abrasive is its ability to withstand high temperature.(Refractoriness)

3.4.3 Classification:

Abrasives are classified as natural and artificial abrasives.

They are further classified as follows

CLASSIFICATION



3.4.4 IMPORTANT NATURAL ABRASIVES

(1) DIAMOND

- It is the hardest substance in the world.
- It is the purest form of carbon.
- It is a natural hard non-siliceous abrasive.
- Its hardness in Moh's scale is 10.

In diamond each carbon atom is connected to four other carbon atoms by covalent bonds throughout the crystal. This explains the extreme hardness of diamond. It is used for cutting, grinding and polishing purposes. It is mainly used in rock drilling.

(2) CORUNDUM

- It is a natural hard non-siliceous abrasive.
- It is fused aluminium oxide.
- It is obtained by fusing the ore of aluminium called Bauxite.
- It is mainly used in grinding wheels.
- It is specially used for grinding paper pulp.
- Its hardness in Moh's scale is 9.

(3) EMERY

- It is a mixture of corundum (Al_2O_3) and magnetite (Fe_3O_4).
- The presence of magnetite decreases the hardness of corundum.
- It is mainly used for scratching and rubbing surfaces.
- It is also a natural hard non-siliceous abrasive.
- Its hardness in Moh's scale is 7 to 9.

(4) GARNET

- Garnets are tri-silicates of alumina, magnesia and ferrous oxide.
- They are natural hard siliceous abrasives.
- In Moh's scale their hardness is 6.5.
- They are not as hard as emery.
- They are mainly used for making abrasive cloth and paper.

3.4.5 ARTIFICIAL ABRASIVE

(1)Silicon carbide (SiC):

It is also called as Carborundum. In hardness, it is almost equivalent to diamond.

Preparation:

Silicon Carbide is prepared by fusing a mixture of Silica (sand) and Carbon (coke) with some salt and sawdust in an electric arc furnace at 2500°C.

$$SiO_2 + 3C \xrightarrow{2500^0 C} SiC + 2CO$$

Salt and saw dust is added to infuse air into the product so that it can be broken into pieces easily. The product obtained is first washed with strong acid followed by strong base to remove basic and acidic impurities Finally it is washed with water.

Silicon Carbide is chemically inert. It is also a good refractory material. It is used for making grinding wheels, which are used to grind glass, granite, carbides, rubber, chilled iron, etc.

(2) BORON CARBIDE

It is harder than silicon carbide. It is also called as NORBIDE. It is obtained by heating Coke with Boron Oxide (B_2O_3) at 2500°C in electric arc furnace.

$$2B_2O_3 + 7C \xrightarrow{2500^0 C} B_4C + 6CO \uparrow$$

It is chemically inert and used for cutting steel, tungsten carbide and other hard materials.

SUMMARY:

In this lesson hardness of abrasives, classification and their applications are discussed.

QUESTIONS

Part – A

1. What are abrasives?
2. Why is carbon the hardest material in the world?
3. What are the main uses of emery?
4. What is carborundum?
5. What is the commercial name of Boron Carbide?

Part – B

1. Give the chemical nature, hardness and uses of the following natural abrasives

(a) Diamond (b) Corundum and (c) Garnet.

2. How is silicon carbide prepared? Give its properties and uses.
3. Write short notes of hardness of abrasive.
4. What are abrasives? How are they classified?

TEST YOUR UNDERSTANDINGS

1. What is grit or grain size of an abrasive material? How it helps to select abrasives for specific jobs?
2. What is mesh number? Explain.

UNIT - IV

COMPOSITE MATERIALS, CERAMICS, REFRACTORIES AND LUBRICANTS

4.1. COMPOSITE MATERIALS

4.1.1. Introduction

Each class of basic engineering materials like metals, high polymers and ceramics has its own outstanding and distinct characteristics as well as laminates. However very stringent requirements of super sonic aircraft, gas turbines, high temperature reactors have forced to develop a new class of materials called "composites".

The composite materials are generally made by placing the dissimilar materials together in such a manner that they work as a single mechanical unit. The properties of new materials so produced are different in kind and scale from those of any constituents. Thus it has became possible to incorporate or alter properties, more than that, introduce a combination of properties like high strength and stiffness at elevated temperatures.

Metals for instance loose their strength at elevated temperatures. High polymeric materials in general can withstand still lower temperatures. Ceramics due to their brittleness are unsatisfactory structural materials. This led to the exploration of combination of metals and polymers with ceramics resulting in composites having required properties seem to be hope for the future.

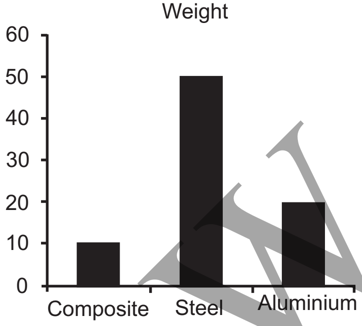
4.1.2. Defintion

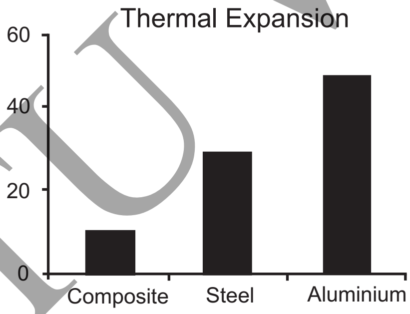
A composite material is a material system consisting of a mixture of two (or) more micro constituents which are mutually insoluble differing in form and composition and forming distinct phases.

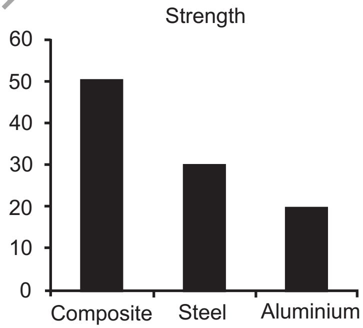
Thus using composites it is possible to have such combination of properties like high strength and stiffness, corrosion resistance, and ability to withstand extreme high temperature conditions.

For eg. Wood (a composite of cellulose fibres and lignin cementing materials), rain proof cloth (cloth impregnated with water proof material) and bone (a composite of soft callogen and brittle and hard material apatite).

Comparison of properties of composites with steel and Aluminium.







4.1.3 Advantageous Properties of the composites over metals, polymers and ceramics

The important advantages of composites over the common bulk materials are as follows:

1. Higher specific strength.
2. Lower specific gravity.
3. Higher specific stiffness.
4. Lower electrical conductivity.
5. Better corrosion and oxidation resistance.
6. Can be fabricated easily.
7. They are tough having good impact and thermal shock resistance.

4.1.4 Constituents of Composites

Two essential constituents of composites are

1. Matrix Phase is the continuous body constituent which encloses the composite and give it its bulk form. Matrix phase may be metal, ceramics (or) polymers.

Composites using these matrix are known as metal matrix composites (MMC).

Ceramic Matrix Composites (CMC)
Polymer Matrix Composites (PMC)

Functions of Matrix Phase

It binds the dispersed phase together acts as a medium to transmit and distribute an externally applied load to the dispersed phase.

It protects the dispersed phase from chemical action and keep in proper position and orientation during application of loads prevents propagation of brittle cracks due to its plasticity and softness.

Dispersed Phase is the structural constituent which determines the internal structure of composite. Important dispersed phases of composites are

I. Fibre ii. Particulates

4.1.5. Types of Composites

(1) Fibre reinforced composites involve 3 components namely filament, a polymer matrix and a bonding agent.

The fibre reinforced composites posses superior properties like higher yield strength, fatigue life. The fibres prevent slip and crack propogation and inhibit it, there by increasing mechanical properties.

Some types of fibre reinforced composites are described below:

a. **Glass fibre** - reinforced polymer composites employ glass fibres for improving the characteristics of especially polymeric matrices containing nylons, polyesters etc. These composites posses lower densities higher tensile strengths and impact resistance and resistance to corrosion and chemicals.

   Applications: Automobile parts, storage tanks transportation industries, plastic pipes etc.,

b. **Carbon fibre - reinforced polymer** composites are employed in situations requiring excellent resistance to corrosion, lighter density retention of properties even at high temperatures.
   Applications : Structural components of aircraft, sport materials.

c. **Alumina and / (or) carbon fibre** reinforced metal composites have improved specific strength, stiffness, abrasion resistance and dimensional stability.

Applications: (i) Matrix - Aluminum alloy reinforced with Al_2O_3 or carbon fibre used in components of automobile engines

(ii) Matrix - Ni and Co based alloy reinforcement with Al_2O_3 (or) tungsten used in components of turbine engines.

(2) **Particulate composites** are made by dispersing particles of varying size and shape of one materials in a matrix of another material.

Ceramic bonded with metals called cermets are refractory material these are metal carbides dispersed in alloys are used as cutting tools for hardened steel.

Cermets are three types

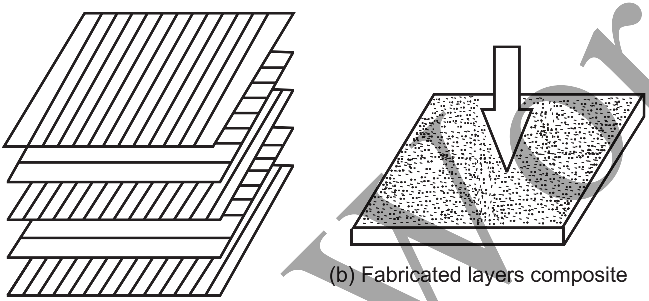
a. Carbide based cermets: WC (carbide) and Co (matrix) cermet is quite hard used in wire-drawing dies, valves etc.

b. Oxide based cermets such as Al_2O_3 dispersed in Cr matrix. It has good thermal shock resistance.

c. CrC (Carbide) and Co (Matrix) cermet has resistance to abrasion and corrosion, used in valves spray nozzles, pump parts etc.

(3) **Layered composites** are extensively employed. for example

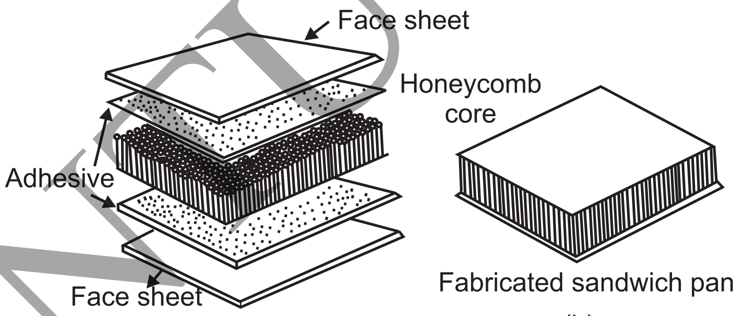
Plywood (laminated composite of thin layers of wood with alternative layers glued together so that grain of each layer is at right angles of its neighbour).



(b) Fabricated layers composite

(a) stacking of successive oriented fiber-rainforced layers

Successive stacking of oriented fiber-reinforced layers for producing a laminar composite



Fabricated sandwich panel

(b)

(a)

Stainless steel vessels with copper clad bottom stainless steel bonding on both sides of copper case etc. Properties of these composites depends on constituents and geometrical design. Layered composites posses high strength in both directions of reinforcement but shear strength is comparatively low.

Another type of layered composite is **sandwich panel** which consists of two strong outer sheets and intervening layer of less dense material. These 3 layers are joined by an adhesive.

Sandwich panels find application in fabrication of aircrafts wings, ship structure parts, building roofs, floors, walls etc.

1.1.6. Application of composite materials:

Glass fibre reinforced plastics have a broad applications in construction industry, electrical industry, transportation, consumer goods, and sports.

Even automobile tyres can be considered as a composite material, in that the rubber matrix and textile reinforcing fibres are independent and either of them functions because of the other in a tyre. Asbestos reinforced phenolic resins are used in automotive brake lining but because of carcinogenic properties of asbestos fibres they are replaced by fluorinated fibres.

Aeronautical applications like components of air craft, helicopters etc.,

Fabrication of roofs and floors, furniture

Communication antennae, electronic circuit boards, sport goods, furniture and turbine engines, valves , pump parts spray nozzles etc. They are also extensively used in automobile industries,marine applications like propellers, spars, ship parts.

Summary:

In this lesson advantages of composite materials, their types and application are discussed.

QUESTIONS

Part – A

1. Give an example of layered composite.
2. Give one applications of sandwich panel

Part – B

1. Write a note on advantage of composite materials over metals and ceramics.
2. Write a note on layered composite.
3. Write a note on fibre reinforced composite.
4. Write a note on particulate composite.
5. What are the applications of composite materials?

4.2. CERAMICS

4.2.1. Introduction

Ceramics find wide application in engineering, medical and domestic usage. Ceramics are increasingly used in motor parts; E.g. ceramic disc brakes, ceramic balls replace ball bearings. Ceramic engine does not require cooling system. They withstand heat upto 3300°C. One of the main application of ceramics is white pottery.

4.2.2. Definition

Ceramics are inorganic non-metallic materials that are processed at high temperatures, and subsequent cooling. E.g. ceramic wash basin, ceramic tiles etc.

4.2.3. White Pottery

Whiteware products consist of refractory body and glossy coating. They are white ceramic materials that are white in colour.

The raw materials used for manufacture of white pottery, are given below.

1. China Clay
2. Feldspar ($KAlSiO_2$)
3. Flint(SiO_2)

Whitewares are prepared with a refractory material and then glazed with glazing materials.

MANUFACTURE OF WHITE POTTERY

Step-I

Preparation of body ware

The raw materials Kaoline [$Al\ (OH)_4\ SiO_5$] and Feldspar are made into fine powder and mixed with water to form a cream.

The excess of water is removed by filtration. The article is prepared from the paste either by hand moulding or by using potters wheel.

It is dried and then fired in a 'biscuit' oven to get porousware called 'Bisque'.

Step- II

Glaze

In order to make the porous ware into watertight article, it is covered with glaze by melting it over the surface of the body.

The constituents of glaze material are quartz, feldspar, little boric acid and little lead oxide.

Glaze material mixture is finely ground and then mixed with water to form a slip or slurry.

The bisque is dipped in the glaze slurry and fired again at high temperature until the glaze materials melt to form a smooth glossy surface.

The glaze used should have the same coefficient of expansion of the bisque.

Step-III

Decoration

The article is decorated with paints before glazing or it is decorated with coloured glass after glazing.

Uses of White ware

They are used for the preparation of

1. Spark plugs
2. Electrical Insulators
3. Lab equipments
4. Crucibles, dishes etc

4.2.4. GLAZING

A glaze is a fine powder consisting of glass forming materials like lead silicates, borosilicates etc. They are colourless glazing and colour glazing mixtures. Colourless glazing is done with glass forming materials like lead silicate and borosilicate. Colour glazing is done by mixing coloured metal pigments with glass forming materials.

Eg: Iron oxide for red and brown
Copper oxide for green
Cobalt oxide for blue

Purpose of Glazing

1. To get decorative effect.
2. To make the surface impervious to liquids.
3. To improve appearance of the article.
4. To increase the durability of ceramic material.
5. To get a smooth glossy appearance.
6. To protect the surface from atmospheric action.

Methods of glazing

There are two methods of glazing

1. Salt glazing
2. Liquid glazing

Salt glazing

In salt glazing, common salt (sodium chloride) is used for getting glossy films over earthenware. The process consists of throwing NaCl into furnace, when the article is in red-hot condition.

At high temperature, NaCl melts and reacts with silica of the article to form a glossy and impervious film of 'Sodium Silicate'.

Liquid glazing

This is a superior method. In this method fine powder of glaze mixture and required amount of pigments are mixed with water to form a colloidal solution. It is called as 'glaze-slip'.

The article to be glazed is burnt at a low temperature in a kiln. It is then dipped suddenly in a 'glaze-slip'. The glaze material enters the pores in the article.

Now the article is fired in the kiln at a higher temperature so that the glaze material fuses and forms a thin glossy film over the article.

Care is taken to see that the article does not come in contact with fire since dust or carbon soot may discolour the glossy film coat.

SUMMARY

In this lesson, various steps involved in the manufacture and uses of ceramics are explained. Glazing, purpose of glazing and methods of glazing are also explained.

QUESTIONS

Part-A

1. What are ceramics?
1. What are the raw materials used to manufacture white pottery?
2. What is glazing?
3. Write the uses of white pottery.
4. Explain salt glazing.
5. Write any two purpose of glazing

Part -B

1. Explain the manufacture of white pottery.
2. Write a note on glazing.
3. What are the purposes of glazing?

TEST YOUR UNDERSTANDING

1. What are the engineering applications of ceramics?

4.3. REFRACTORIES

4.3.1. Introduction

Refractory has very high-density upto 2300 kg/m^3 and specific heat 1000 J/kg K. Refractories find wide application in linings of the furnaces, tanks, converters, kilns, crucibles, ladles etc. employed for the manufacture of metals, cement, glass, steel, ceramics, paper, etc.

4.3.2. Definition:

Refractories are materials, which can withstand high temperatures. They are resistant to heat and corrosive action of gases, metallic liquids and slags.

4.3.3. Requirements of a good refractory:

1. Refractoriness: It is the ability to withstand very high temperature without deformation during operation.

2. Strength or Refractoriness under load (RUL): They must possess high mechanical strength even at very high temperature and bear maximum possible load without breakage.

3. Thermal expansion: A good refractory should have low thermal expansion under normal conditions.

4. Thermal conductivity: In general a good refractory must have low thermal conductivity to reduce heat losses by radiation. But when heat is to be supplied from outside the refractory must possess good conductivity.

5. Porosity: A good refractory should have low porosity. In porous refractory the molten metal and slag enters and weaken the structure. But porosity helps in thermal shock-resistance of refractories.

6. Thermal spalling: It is breaking, cracking, peeling off or fracturing of the refractory under high temperature. A good refractory must have low thermal spalling.

7. Chemical composition: A good refractory must be chemically inert with charge and slag.

4.3.4. Classification:

The refractories are classified into three types based on the chemical properties.

1. Acid refractories
2. Basic refractories
3. Neutral refractories

Types of refractories	Example	Uses
1. Acid refractories called RO_2 group	1.Zirconia (ZrO_2) 2.Silica (SiO_2)	Used in furnaces where the charge and slag are acidic in nature
2. Basic refractories called RO group	1.Magnesia (MgO) 2.Dolomite	Used in furnaces where the charge and slag are basic in nature
3. Neutral refractories called R_2O group	1. Chromite (Cr_2O_3) 2. Alumina (Al_2O_3)	Used in furnaces where the charge and slag are acidic or basic in nature

4.3.5. Uses of a few refractory bricks:

a.* Silica bricks*: It contain 90 to 95% silica and about 2% lime

1. The silica bricks are used in open hearth furnaces, electric furnaces and glass furnaces.
2. They are also used in coke-ovens and gas retort settings.
3. They are also used in lining of acid converters.

b.* Fire clay bricks*: It contains major portion of alumina and silica and small percentage of K_2O, Fe O, CuO and MgO.

1. They are used in blast furnaces and open hearth furnaces.
2. They are also used in stoves, crucibles, furnaces, kilns, regenerators and charging doors.

c.* Alumina bricks*: It contains more percentage of $Al_2 O_3$

1. They are used in vertical shaft kilns for burning lime.
2. They are used in linings of rotary kiln in cement manufacture.
3. They are also used in brass melting reverberatories, lead-dressing reverberatory furnaces, aluminium melting furnaces and in oil fired furnaces.

SUMMARY:

In this lesson the different types of refractories, properties and their uses are discussed.

QUESTIONS

Part - A

1. What are the most important characteristics of a refractory?
2. Give an example for acid refractory
3. Give the type of refractory used in acidic conditions.
4. Give an example for Basic and neutral refractory.
5. What are refractories?
6. Mention any two refractories and give their uses.
7. Mention the uses of fire clay.
8. Mention any two requirements of a good refractory.

Part - B

1. What are refractories? How are they classified? Give an example for each.
2. What are the requirements of a good refractory?
3. Mention any three refractories and give their specific uses.

TEST YOUR UNDERSTANDING

Surf the net for various types of furnaces.

4.4. LUBRICANTS

4.4.1. INTRODUCTION

Whenever a Machine works, its moving, sliding or rolling parts rub against each other with the result a friction is developed. Friction causes a lot of wear and tear of the concerned surfaces. Further due to friction, large amount of energy are dissipated in the form of heat and thus causes loss in the efficiency of a machine. More over the heat produced due to friction causes damage to the moving part.

The above ill effects can be minimized by applying a thin layer of certain substances known as lubricant in between the moving parts. Thus "Lubricants may be defined as the Substance which reduces the friction between the two moving surfaces".

The process of applying the Lubricant in between the two moving or sliding surfaces is called as Lubrication.

4.4.2. Characteristics of Lubricants:

1. It should have a high viscosity index.
2. It should have flash and fire points higher than the operating temperature of the machine.
3. It should have high oiliness.
4. The cloud and pour points of a good lubricant should always be lower than the operating temperature of the machine.
5. The volatility of the lubricating oil should be low.
6. It should deposit least amount of carbon during use.
7. It should possess a higher resistance towards oxidation and corrosion.
8. It should have good detergent quality.

4.4.3. Classification of Lubricants:

Lubricants may be broadly classified as follows

(1) Solid Lubricants
  (a) Graphite
  (b) Molybdenum disulphide
  (c) Talc
  (d) Mica.

(2) Semi – solid Lubricants
    (a) Greases
    (b) Vaseline's

(3) Liquid Lubricants
    (a) Vegetable oils – eg: palm oil & castor oil
    (b) Animal oils - eg: Whale oil & lard oil
    (c) Mineral oils – eg: petroleum fractions.
    (d) Blended oils or compounded oils – Eg: Mineral oils with various additives to induce desired properties.
    (e) Synthetic oils – eg: Silicones.

4.4.4. Solid Lubricants

The most widely used solid Lubricants are Graphite and Molybdenum disulphide.

Solid Lubricants are used in the following areas.
    (a) For heavy machinery working as a crude job at very high loads.
    (b) When the operating temperature or load is very high.
    (c) Where a liquid or semisolid lubricant film cannot be maintained.

(1)Graphite:

Graphite has a layered structure of carbon atoms. The carbon atoms are joined together by strong covalent bonds. The adjacent layers are held together by the weak Vander walls force. Thus they forms a net work of hexagons.

Graphite is soapy to touch, non-inflammable and not oxidized in air below 375° c.

When it is incorporated as lubricant between uneven surfaces, it makes the surface more even, Further the particles slide easily over each other as the surfaces of the machinery are in motion.

Graphite can be used as a dry powder or as a colloidal dispersion.

A dispersion of graphite in water is called aqua dag and that in oil is called oil dag.

Uses

It is used as a lubricant in IC engines, air compressors, lathes, food stuff industry, railway-track joints, general machine job works, etc.

(2)Molybdenum Sulphide

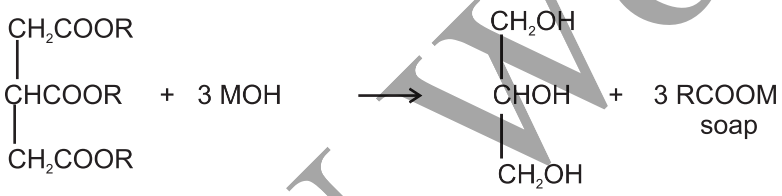
Fine powder of molybdenum sulphide is used as lubricant. It has capacity to withstand very high temperature and stable in air upto 500°C. Hence it is used as lubricant in high - speed machines.

4.4.5. Semi – Solid Lubricants:

E.g.:- Greases and Vaseline's.

Grease is a semi solid lubricant obtained by thickening of a lubricating oil by the addition of a metallic soap. The thickener is usually a sodium, calcium, lithium or aluminium soap.

Greases are manufactured by saponification of fats with alkali followed by adding a hot lubricant oil under severe agitation. Their properties depend on both the base used for saponification and the fatty acid present in the oil.



$$\begin{array}{l} CH_2COOR \\ | \\ CHCOOR \\ | \\ CH_2COOR \end{array} + 3\,MOH \longrightarrow \begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + \underset{\text{soap}}{3\,RCOOM}$$

4.4.6. Liquid Lubricants

Vegetable Oils

They are commonly used lubricants. Eg: Castor oil, coconut oil etc. They are classified as drying and semi-drying oils. They are easily oxidized by atmosphere.

Animal Oils

They are oils of animal origin. They are mainly animal fats.

Eg: Tallow oil, Whale oil, Lard oil etc. They are very costly. Hence they find little use as lubricants. They are also easily oxidized by atmosphere.

Petroleum Products

Hydrocarbons with higher molecular mass obtained by the Fractional Distillation of Petroleum are used as lubricants. They are obtained from the paraffin residue. Eg: Paraffin oil, Lubricating oil etc.

Blended Oils

They are mixtures of vegetable oils and Petroleum products. They show improved properties. Different oils are suitably mixed depending on the requirement. They are synthetic lubricants.

Summary:

In this lesson purpose of lubrication, properties and types of lubricants are discussed.

Questions:

Part A

1. What is Lubricant?
2. What is grease?
3. Give two examples for solid lubricants.

Part B

1. What are the Characteristics of the lubricants?
2. Write a short note on solid lubricants.
3. What are the classification of lubricants? Give an example each.
4. Write a note on liquid lubricants.

TEST YOUR UNDERSTANDING

1. What types of lubricants are used for transformers.?
2. Why does graphite act as a good lubricant on the surface of the motion?

UNIT V

POLYMERS

5.1 PLASTICS

5.1.1 Introduction

The name plastics or plastic materials in general is given to organic materials of high molecular mass, which can be moulded into any desired form when subjected to heat and pressure in presence of catalysts.

Polymer resin is the basic binding material, which forms the major part of a plastic. In recent years plastics have attained greater importance in every walk of life due to their unique properties.

Now, plastics substitute all engineering materials like wood, metal, glass etc because of their special advantages over other conventional materials.

5.1.2 Definition

Plastics are products of polymers. Polymers are resins which can be moulded into different shapes by using heat and pressure.

5.1.3 Polymerisation

Polymerisation is the process of converting small organic molecules into high molecular weight molecules either by addition or by condensation reaction. The small molecules are called monomers and the products are called polymers.

There are two types of polymerisation.

1. Addition polymerisation
2. Condensation polymerisation.

5.1.3 Addition Polymerisation

These types of polymers are formed by simple addition reaction between small molecules containing double or triple bonds.

Example: Ethylene polymerizes to form polyethylene or polythene.

$$nCH_2=CH_2 \longrightarrow -(-CH_2-CH_2-)n-$$

Ethylene Polyethylene

Other examples: Polyvinyl chloride (PVC), Polystyrene, etc.

5.1.4 Condensation Polymerisation

These types of polymers are formed by reaction between small molecules with elimination of molecules like H_2O, H_2S, NH_3, etc.

Example: Formation of Phenol-formaldehyde resin. It is formed by the reaction between phenol and formaldehyde.

$$C_6H_5OH + HCHO \longrightarrow -(-\overset{\overset{OH}{|}}{C_6H_4}-CH_2-)_n-$$

Phenol Formaldehyde Phenol-formaldehyde

Other examples: Urea-formaldehyde resin, Nylon 6:6 etc.

5.1.5 Types of Plastics

Plastics are classified into two types:

1. Thermoplastics and
2. Thermosetting plastics.

Thermoplastics:

They are the resins which soften on heating and set on cooling. Therefore, they can be remoulded any number of times and used.

Example: Polythene, PVC, Nylon, etc.

Thermosetting plastics:

They are the resins which set on heating and cannot be resoftened. Hence, their scrap cannot be reused.

Examples: Phenol-formaldehyde resin (Bakelite), urea-formaldehyde resin, etc.

5.1.6 Differences between thermoplastics and thermosetting plastics

The differences between two types of plastics arise mainly due to the difference in their chemical structure.

Property	Thermoplastics	Thermosetting plastics
Action of heat	They soften on heating and set on cooling every time	They set on heating and cannot be resoftened.
Type of bonding between adjacent polymer chains	The polymer chains are held together by weak force called Van der Waal's force of attraction.	The polymers chains are linked by strong chemical bonds. (covalent bonds)
Solubility	They are soluble in organic solvents.	They are insoluble in organic solvents.
Expansion due to heating	They expand very much on heating.	Their expansion is only marginal due to heat.
Type of polymerisation	They are formed by addition polymerization	They are formed by condensation polymerization
Type of moulding	They are processed by injection moulding.	They are processed by compression moulding.
Scrap recovery	Scarp can be reused.	Scarp cannot be reused.
Example	Polythene, PVC, Nylon	Bakelite, Plaskon

5.1.7 Mechanical properties of Plastics

1. Creep or Cold flow:

Creep is a time dependent continuous deformation of plastics under load. Plastics undergo deformation when a load is applied continuously. Creep is due to the displacement of molecules in a polymer structure. Because of this property plastics cannot be used as load bearing materials.

2. Strength to weight ratio:

Plastics have good strength when compared to their lightweight. Therefore, they replace lightweight metals like magnesium, aluminium in many fields.

3. Impact strength:

When subjected to suddenly applied load or stress, plastics undergo rupture at a particular load or stress. Impact strength of plastics is measured by tests in which a pendulum is allowed to attack the specimen. Plastics have better impact strength when compared to glass. Hence, they are replacing glasses in many places.

4. Tear resistance:

The resistance to tearing is an important property when plastic films are used as packing material. It is measured by using a falling pendulum with a striking edge. Plastics have poor tear resistance.

5. Thermal stability:

Plastics either degrade or soften at high temperatures. Hence, they can not be used at high temperatures.

6. Hardness:

Hardness is defined as the resistance of the plastics to penetration, scratching etc. Hardness of plastics can be determined by penetration tests. Thermosetting plastics are hard in nature when compared to thermoplastics.

7. Softening temperature:

Softening temperature refers to the particular temperature at which a plastic changes from elastic stage to fluid stage. This can be measured by penetration test. The temperature below which a polymer is hard and above which it is soft is known as 'Glass transition temperature (Tg)'.

8. Optical properties:

Some of the plastics are transparent like glass. Hence they can be substituted for glass in optical instruments.

9. Electrical properties:

Plastics are good insulators as they are poor conductors of electricity. Therefore, they are mainly used for electrical insulation purposes.

5.1.8 Advantages of plastics over other traditional materials (like wood, metals, glass etc)

1. Plastics are available in attractive colours.
2. They do not undergo corrosion.
3. They are not affected by insects.
4. They are light in weight.
5. They are cheap.
6. They can be moulded into any shape easily.
7. They are chemically inert.
8. They have good abrasion resistance.
9. They are good insulators of heat and electricity.

5.1.9 Specific uses of some plastics

Bakelite (Phenol-formaldehyde):

1. It is used for making TV cabinets, housing laminates, telephone components, decorative articles, bearings, electrical goods, etc.
2. It is also used as an excellent adhesive.

P.V.C (Polyvinyl chloride):

1. P.V.C is mainly used as an insulating material.
2. It is used for making table clothes, rain coats, toys, tool handles, radio components, etc.
3. It is used for making pipes, hoses, etc.
4. It is used for making helmets, refrigerator components, etc.
5. It is used in making cycle and automobile parts.

Nylon (Nylon 6:6):

1. It is mainly used as fibre in textile industry.
2. It is used for making ropes, household articles, etc.
3. It is used for making machine components such as gears, bearings, etc.

Urea-formaldehyde (Beetle ware):

1. It is used as cation exchanger in water treatment.
2. It is used in paper industry.
3. It is used to prepare insulation tapes.
4. It is used for lamination purposes.
5. It is used for making radio cabinets, switches, buttons, cups, plates etc.

5.1.10 Reinforced or filled plastics

Physical and mechanical properties of plastics are improved by compounding of them with suitable materials. These materials are called fillers and main types of fillers used are silicate materials. Such type of polymers which are reinforced with fillers are called 'Reinforced or Filled Plastics'.

Most commonly used fillers are:

Wood flour, Saw dust, Ground cork, Asbestos, Marble flour, China clay, Paper pulp, Corn husk, Mica, Pumice powder, Carbon, Cotton fibres, Boron fibres, Graphite, Silicon carbide, Silicon nitride, Alumina, Glass fibres, Metallic oxides like ZnO, PbO etc, and Metallic powders like Al, Cu, Pb, etc.

5.1.11 Advantages of filled plastics

Fillers modify properties of basic polymer. They improve thermal stability, mechanical strength, hardness, desired finish and water resistance.

Specific fillers are added to give special characters.

For example,

1. Fillers like carborundum, quartz and mica are added to improve hardness of polymers.
2. Fillers like asbestos is added to give heat and corrosion resistance to polymers.
3. Fillers like barium sulphate makes the polymers resisting X-rays.

   The percentage of fillers used can be up to 50%.

5.1.12 Applications of filled plastics

1. Addition of carbon block about 40% increases tensile strength of natural rubber which is used in automobile tyres.
2. Addition of china clay increases the electrical insulation property of PVC.
3. Fibrous fillers like wood flour, short length synthetic fibres, cotton floc, etc. are added to thermosetting plastics like phenol-formaldehyde resin, melamine-urea resin to improve the impact resistance.
4. In textiles for making shutters filled polymer is used with nylon as polymer.
5. In electrical and electronic industries, filled polymers are used for making exhaust fans, computer tapes, insulators, wire and cable insulation, switch gear parts, spools etc.(using polypropylene, PET, nylon and SAN as base polymers).
6. In consumer goods like doors, windows, hinges, chairs, camera housing, etc (Polypropylene, ABS are used as base polymers).
7. In defence for making nose cones, pistol grips and riffle bullets, filled polymers like polystyrene, nylon, etc are used.

8. They are used in automobiles for making door handles and engine cooling fans.

5.1.13 Polymers in Medicine and Surgery

Biomaterials:

Biomaterials are the materials that can be implanted in the body to provide special prosthetic functions or in diagnostic, surgical and therapeutic applications without causing adverse effect on blood and other tissues. Use of polymers as biomaterials is increasing day by day since many polymers having diverse properties are more similar to the body. Their appeal and acceptability is mainly due to their versatility and the fact that they are tailor-made or modified at will suit specific body functions.

Polymers used for medical application should be biocompatible. It should possess the following characteristics.

1. It should have purity and reproducibility.
2. It should have optimum physical and chemical properties.
3. It should be fabricated into any desired shape without being degraded.
4. It should be sterilized easily.
5. Biopolymers that come in contact with blood and tissues should not damage cellular elements of blood, enzymes and protein.
6. They should not produce toxic and allergic reactions.
7. They should not deplete electrolytes present in the body.

Biomedical uses of polymers:

The mostly used polymers in medical applications are silicone rubber and polyurethane. Polymers used in specific medical applications in medicine are given below.

S.No	Polymer	Applications
1	Polyurethane	Heart valves, blood filters, artificial hearts, vascular tubes, etc.
2	Polyvinyl chloride (PVC)	Disposable syringes, etc.
3	Polypropylene	Heart valves, blood filters, etc.
4	Polyethylene	Disposable syringes, etc.

Summary

In this lesson, plastics, types of polymerisation, mechanical properties, industrial and biomedical applications of polymers and filled plastics are discussed.

QUESTIONS

Part – A

1. What are plastics? How are they classified?
2. Name the two types of polymerisation.
3. Define polymerization.
4. Give an example for addition polymer.
5. Give an example for condensation polymer.
6. What is creep?
7. Mention any two mechanical properties of plastics.
8. What are thermoplastics?
9. What is a thermosetting plastic?
10. Give the uses of Bakelite?
11. Give the uses of urea-formaldehyde resin.
12. Give the preparation of phenol-formaldehyde resin.
13. Give the uses of nylon
14. Give the uses of PVC.
15. What is a reinforced plastic?
16. What are biomaterials?
17. Give any two biomedical uses of polyethylene.
18. Give any two polymers used in surgery.

Part – B

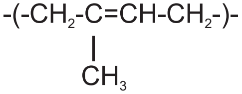
1. Explain addition polymerisation with example.
2. Explain condensation polymerisation with example.
3. Give the differences between addition and condensation polymerisation.

4. State the differences between thermoplastics and thermosetting plastics.
5. Explain the mechanical properties of plastics.
6. What are the advantages of plastics over the traditional materials?
7. What are reinforced plastics? Give their applications.
8. What are biomaterials? Give their uses.

5.2. RUBBER

5.2.1 Introduction

Rubber is a natural elastic polymer of isoprene. It is obtained from the milk of rubber called 'Latex'. The structure of natural rubber is as follows.



$$-(-CH_2-\underset{\underset{CH_3}{|}}{C}=CH-CH_2-)-$$

5.2.2 Preparation of Natural Rubber from Latex

1. Latex is rubber milk containing about 30 to 45% of rubber.
2. The rubber milk is diluted with water and allowed to stand for sometime.
3. The clear liquid from the top is treated with acetic acid or formic acid to precipitate rubber.
4. The precipitated rubber is collected and passed through rollers to get sheets of rubber.
5. Rubber sheets are finally dried by smoking. This rubber is called 'Smoked rubber'.
6. During the coagulation of rubber milk with acetic or formic acid, retardants like sodium bisulphite ($NaHSO_3$) are added to prevent oxidation of rubber. This is called 'Creep rubber'.

5.2.3 Defects of natural rubber

The natural rubber obtained from latex cannot be used in industries because it has some defects.

1. It becomes soft and sticky during summer.
2. It become hard and brittle during winter.
3. It swells up in oils.
4. It flows plastically due to prolonged stress.
5. Chemicals easily affect natural rubber.

5.2.4 Compounding of rubber

Natural rubber is compounded with some substances to get quality rubber.

1. Reinforcing agents or Hardeners

   They are compounded with natural rubber to get hard rubber.

   Example: Carbon powder, Zinc oxide, etc.

2. Softeners

   They are compounded with natural rubber to get soft spongy rubber.

   Example: vegetable oils, Stearic acid, paraffin oil etc.

3. Anti-Oxidants

   They are added to prevent aerial oxidation of rubber.

   Example: β-naphthol.

4. Vulcanization

Vulcanization is compounding of rubber with sulphur. By vulcanization, we get rubber of different hardness.

5. Colouring matter

   They are added to give different colour to rubber.

Example: Metallic oxides

Zinc oxide – White
Lead chromate – Yellow
Chromium oxide – Green
Carbon black – Black

6. Accelarators

   They are added to speed up the vulcanization reaction of rubber.

   Example: Lime-magnesia, White lead, etc.

7. Fillers

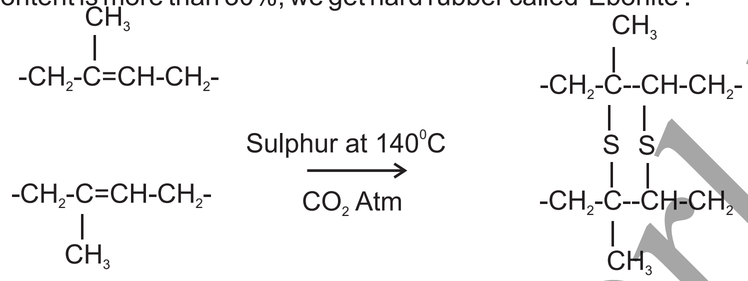
Fillers are added to i) reduce the cost, ii) increase the bulk and iii) introduce new characters.

Example: Textile wastes, Asbestos, Mica, Gypsum, Talc, etc.

5.2.5 Vulcanization of rubber

- Vulcanization is compounding of rubber with sulphur.
- Vulcanization is done by heating rubber with sulphur at 140° C in CO_2 atmosphere.

- Sulphur adds to the double bonds present in rubber to provide cross links between the polymer chains.
- 2 to 4% Sulphur addition gives soft elastic rubber. When sulphur content is more than 30%, we get hard rubber called 'Ebonite'.



Properties of Vulcanized Rubber

1. Vulcanized rubber has very little electrical and thermal conductivity. Hence, it is mainly used for electrical insulation purposes.
2. It has high elasticity and tensile strength.
3. Corrosive chemicals and oils do not affect it.
4. It is also not affected by atmosphere.

5.2.5 Synthetic rubber

1. Buna-S

Buna-S is obtained by co-polymerization of butadiene and styrene in the presence of sodium catalyst. It is also called as Styrene rubber or GRS rubber.

It can be vulcanized like natural rubber. It is mainly used in the manufacture of tyres. It is used as electrical insulator. It is used in making floor tiles, gaskets and footwear components, etc.

2. Thiokol

It is obtained by the polymerisation of ethylene-di-chloride with sodium polysulphide. It does not have the properties of rubber. It can withstand cold but not heat.

It is unaffected by petrol, oil, etc. So, it is mainly used for making hose pipes, lining tanks, etc.

3. Neoprene

It is obtained by polymerisation of chloroprene.

It is used for making hoses, gaskets, sponges, conveyor belts, adhesives etc. It is also used for making hose pipes and tubes for carrying corrosive oils and gases.

5.2.6 Reclaimed rubber

Rubber obtained from waste rubber articles such as worn out tyres, tubes, gaskets, hoses, foot wears, etc, is called reclaimed rubber.

The process of reclamation of rubber is carried out as follows.

1. The waste is cut into small pieces and powdered by using a 'cracker'.
2. Then iron impurities, if any present, is removed by using electromagnetic separator.
3. The purified waste is digested with caustic soda solution at 200°C under pressure for 8 to 15 hours in 'steam jacked autoclaves'. This process hydrolyses the fibres present in the waste rubber.
4. After the removal of fibres, reclaiming agents like petroleum or coal tar based oils and softeners are added.
5. Sulphur gets removed as sodium sulphide and rubber gets devulcanised.
6. The rubber is thoroughly washed with water spray and dried in hot air driers.
7. Finally, the reclaimed rubber is mixed with small portions of reinforcing agents like clay, carbon block etc.

5.2.7 Properties of Reclaimed Rubber

1. Reclaimed rubber has less tensile strength, low elasticity and possesses very low wear resistance when compared to natural rubber.
2. However, it is much cheaper and has uniform composition.
3. It has better aging property.
4. It is quite easy for fabrication.

5.2.8 Uses

Reclaimed rubber is used for the manufacture of tyres, tubes, automobile floor mats, belts, hoses, battery containers, mountings, shoes, etc.

Summary

In this lesson, extraction of natural rubber from Latex, defects of natural rubber, compounding of rubber, vulcanization, different synthetic rubbers, their preparation and uses, special rubbers like Neoprene, Thiokol etc. and reclaimed rubber are discussed.

QUESTIONS

Part – A

1. What is milk of rubber called? Name the chemical used for coagulation.
2. Name any two fillers used in compounding of rubber.
3. Name any two ingredients used in compounding of rubber.
4. What are the defects of natural rubber?
5. How is Thiokol prepared?
6. Give the uses of Neoprene.
7. Give the uses of Buna-S.
8. What is reclaimed rubber?
9. Give two uses of reclaimed rubber.
10. Give any two properties of reclaimed rubber.

Part – B

1. Explain how the natural rubber is obtained from latex.
2. What is compounding of rubber? Explain.
3. What is vulcanization of rubber? Explain.
4. Give the preparation and uses of any three synthetic rubbers.
5. What are reclaimed rubber? Explain the process of reclamation of rubber.

SECOND SEMESTER

MODEL QUESTION PAPER I

Time: 3 hours Maximum Marks:75

PART-A

I. Answer any Fifteen Questions: 15x1=15 marks

All Questions carry equal marks

1. Define Pollution.
2. What is Sewage?
3. Give two examples of greenhouse gases.
4. Give two Harmful effects of Lead pollution.
5. Give two uses of silica bricks.
6. What are the components present in LPG gas?
7. What is flue gas?
8. What are Propellants?
9. What is producer gas?
10. Mention the ore of Tungsten.
11. Mention the methods of metallic powder.
12. What are alloys?
13. What are abrasives?
14. What is called Bisque?
15. What are refractories?
16. What are the types of composite materials?
17. Give two examples of solid lubricants.
18. What are the types of polymers?
19. Mention any two uses of PVC.
20. What is Vulcanization?

PART- B

II. Answer any TWO Sub-divisions in each of the following Questions:

5x12=60

All Questions carry equal marks

1. a) What is global warming? List its harmful effects.

   b) Define Green Chemistry. Give the goals of green Chemistry.

   c) Explain how solid wastes are recycled for use.

2. a) Explain fractional distillation of petroleum.

   b) How is water gas manufactured?

   c) A fuel contains 40% H_2 45% CO 11% CH_4 and 4% O_2 by volume Determine the volume of air required to burn 1m^3 of the fuel?

3. a) Describe the extraction of Titanium from its ore.

   b) List the advantages of alloying a metal.

   c) Write a note on Natural Abrasives.

4. a) What are the advantages of composite materials over traditional materials?

   b) Describe the manufacture of white pottery.

   c) What are the characteristics of good refractories.

5. a) Distinguish between Addition and condensation polymerization.

   b) What are the Mechanical properties of plastics?

   c) Write notes on syntheticRubber.

MODEL QUESTION PAPER – II

Time: 3 hours **Max. Marks:75**

Part – A

I.Answer any 15 questions **(15 x 1 =15)**

All questions carry equal marks

1. Define air pollution.
2. Mention the name of a pollutant responsible for depleting ozone layer.
3. What is called effluent?
4. Give any two goals of green chemistry.
5. Define Calorific value of a fuel.
6. What is meant by cracking?
7. Give two examples of liquid propellants.
8. Give the composition of water gas.
9. Mention the ores of Titanium.
10. Give the composition of German silver.
11. Define powder metallurgy.
12. Give two examples for synthetic abrasives.
13. Mention two uses of alumina bricks.
14. Give two examples for fibre reinforced composites.
15. Define white pottery.
16. Give two examples for Liquid Lubricants.
17. Define Addition polymerization.
18. What are reinforced plastics?
19. Mention the uses of Thiokol rubber.
20. What is reclaimed rubber?

Part – B

II. Answer any two subdivisions in each of the following questions:

(5 x 12=60)

All Questions carry Equal marks

1. a) What are the main air pollutants? Mention their harmful effects.

   b) Define Eutrophication. What are its harmful effects?

   c) Write the advantages of recycling of solid wastes.

2. a) Write a note on solid fuels.

   b) Give a brief account on Solid Propellants.

   c) A producer gas has the following composition by volume: CH_4=3.5%; CO = 25%; H_2= 10%; CO_2=10.8%; N_2 = 50.7%. Calculate the theoretical quantity of air required for combustion per m^3 of the gas.

3. a) Describe the extraction of Tungsten from its ore. Mention any of its two uses.

   b) What are Alloys? How are they classified? Give Examples.

   c) Explain how Carborundum and Boron Carbide are manufactured. Mention their uses.

4. a) Write a note on particulate composites and layered composites.

   b) Define and explain glazing.

   c) Explain classification of lubricants with examples.

5. a) What are the advantages of plastics over traditional materials?

   b) What are the ingredients added during compounding of rubber? Give their functions.

   c) Write a note on Reclaimed rubber.

SEMESTER - II

PRACTICAL - II

QUALITATIVE ANALYSIS

Simple qualitative analysis involves the identification of the constituents of an inorganic substance or a mixture of substances. The inorganic substances are split-up into two types of charged particles one of which is positively charged and the other is negatively charged. The charged particles are called ions or radicals. The positively charged ions are called cation or basic radical. The negatively charged ion is called anion or acid radical.

In the qualitative analysis of an inorganic substance number of tests are carried out in order to discover the acidic and basic radical present in it. A test is an experiment along with an observation made to show the presence or absence of a certain substance or class of substances. In the test we note the formation or disappearance of

(I) a colour or (ii) a precipitate or (iii) a gas or (iv) an odour

The test may be positive or negative. A positive test is one that gives the result indicated in the procedure and shows the presence of the particular radical. A negative test is one which does not give the indicated results and shows the absence of the particular radical. The substances or solutions added to bring about the reactions are called reagents.

SYSTEMATIC ANALYSIS OF THE GIVEN INORGANIC SIMPLE SALT

A. PRELIMINARY DRY REACTIONS

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
1.	COLOUR The Colour of given salt is noted.	a) Blue or Bluish Green b) White	May be Copper Absence of Copper salts
2.	APPEARANCE The appearance of the given salt is noted	a) Amorphous b) Crystalline	May be carbonate Absence of carbonate

3.(a)	SOLUBILITY IN DILUTE hydrochloric acid A little of the given salt is dissolved in dilute HCl in a test tube	a) Soluble b) Insoluble	Absence of lead May be lead
(b)	SOLUBILITY IN WATER A little of the given salt is dissolved in distilled water in a test tube	a) Insoluble b) Soluble	May be Carbonate Absence of Carbonate
4.	ACTION OF HEAT A little of the given salt is strongly heated in a dry test tube.	a) A white sublimate is formed b) Yellow when hot white when cold c) Orange red when hot yellow when cold d) Reddish brown vapours evolved. e) Blue changes to white f) No characteristic change	May be Ammonium May be Zinc May be lead May be Nitrate May be copper Absence of Ammonium, Zinc, Copper, lead and nitrate
5.	FLAME TEST The paste of the given salt with Conc. HCl is introduced into the non-luminous part of the flame and the colour is noted.	a) Bluish Green coloured flame b) Brick red coloured flame c) Pale green coloured flame d) No characteristics change	May be Copper May be Calcium May be Barium Absence of copper calcium and barium

B. WET REACTIONS

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
6.	ACTION OF Dil.HCl To a pinch of the salt taken in a test tube dilute hydrochloric acid is added	a) A colourless gas with brisk effervescence turning lime water milky is evolved. b) No characteristic gas is evolved	Presence of Carbonate is confirmed Absence of Carbonate
7.	ACTION OF CONC.SULPHURIC ACID To a little of the substance taken in a test tube a few drops of conc. Sulphuric acid is added and warmed.	a) A colourless pungent smelling gas giving dense white fumes with ammonia, is evolved b) Brown vapours c) No characteristic reaction	May be chloride May be nitrate Absence of chloride and nitrate
8.	ACTION OF CONC.H_2SO_4 AND COPPER TURNINGS To a small amount of the given salt conc. H_2SO_4 and copper turnings are added and heated	a) Copious evolution of brown vapours b) No brown vapours	Presence of nitrate Absence of Nitrate
9	ACTION OF CONC. H_2SO_4 AND MnO_2 To a little of the given salt, conc. H_2SO_4 and MnO_2 are added & warmed	a) A greenish yellow gas is evolved b) No characteristic change	Presence of chloride Absence of chloride
10	CHROMYL CHLORIDE TEST To a small amount of the given salt conc. H_2SO_4 and $K_2Cr_2O_7$ are added and warmed	a) Reddish brown vapours giving yellow precipitate with a glass rod dipped in lead acetate solution. b) No characteristic change	Presence of chloride Absence of chloride

C. REACTIONS USING SODIUM CARBONATE EXTRACT

Preparation of Sodium Carbonate Extract:

A mixture of one part of the given salt and three parts of solid sodium carbonate is boiled with distilled water and filtered. The filtrate is called sodium carbonate extract.

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
12	BARIUM CHLORIDE TEST A little of the extract is acidified with dil. HCl and $BaCl_2$ solution is added	a) A white precipitate insoluble in Conc. HCl is obtained b) No characteristic change	Sulphate is confirmed Absence of sulphate
13	LEAD ACETATE TEST A little of the extract is acidified with dil.HNO_3 and lead acetate solution is added	a) A white precipitate is formed b) No characteristic change	Sulphate is confirmed Absence of sulphate
14	SILVER NITRATE TEST A little of the extract is acidified with dil.HNO_3 and $AgNO_3$ solutionis added	a) A curdy white precipitate soluble in NH_4OH is obtained b) No precipitate	Chloride is confirmed Absence of chloride
15	BROWN RING TEST To a little of the extract dil. sulphuric acid is added till the effervescence ceases. To this freshly prepared ferrous sulphate solution is added, then conc. sulphuric acid is added through the sides of the test-tube.	a) Brown ring is formed at the junction of the two liquids b) No Brown ring	Nitrate is confirmed Absence of nitrate

D.IDENTIFICATION OF BASIC RADICALS

Preparation of original solution:

(1) For Nitrate, Chloride and Sulphate:

The given salt is dissolved in distilled water. The solution obtained is known as original solution.

(2) For Carbonate:

The original solution is prepared by dissolving the substance in dilute hydrochloric acid or dilute nitric acid

GROUP SEPERATION

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
1	I GROUP (LEAD) To a little of the original solution dil.HCl is added.	a) A white precipitate is formed b) No precipitate	Presence of I group (lead) Absence of I group
2	II GROUP (COPPER) To a little of the original solution dil.HCl and yellow Ammonium sulphide are added.	a) A black precipitate is formed b) A yellow precipitate is formed b) No precipitate	Presence of II group (copper) Presence of II group (cadmium) Absence of II group
3	III GROUP (ALUMINIUM) To a little of the original solution ammonium chloride and ammonium hydroxide are added.	a) A gelatinous white precipitate is formed b) No precipitate is formed	Presence of III group (aluminium) Absence of III group
4	IV GROUP (ZINC) To a little of the original solution ammonium chloride, ammonium hydroxide and yellow ammonium sulphide solution are added	a) A white precipitate is formed b) No precipitate	Presence of IV group (zinc) Absence of IV group
5	V GROUP (CALCIUM,BARIUM) To a little of the original solution ammonium chloride, ammonium hydroxide and ammonium carbonate are added	a) A white precipitate is formed b) No precipitate	Presence of V group (calcium and barium) Absence of V group
6	VI GROUP (MAGNESIUM) To a little of the original solution ammonium chloride, ammonium hydroxide and disodium hydrogen phosphate solution are added	a) White precipitate is formed b) No Precipitate	Presence of VI group (Magnesium) Absence of VI group
7	VII GROUP (ammonium) To a small amount of the salt sodium hydroxide solution is added and heated	a) A colourless gas giving dense white fumes with a rod dipped in con. HCl is evolved. b) No characteristics reaction	Presence of VII group (ammonium) Absence of VII group

GROUP ANALYSIS AND CONFIRMATORY TESTS FOR BASIC RADICALS

EXPERIMENT	OBSERVATION	INFERENCE
I GROUP ANALYSIS (Lead)		
1. To a little of the original solution potassium chromate solution is added	Yellow precipitate is obtained	May be Lead
2. To a little of the original solution potassium iodide solution is added.	Yellow precipitate is obtained	Presence of Lead
3. The above yellow precipitate is dissolved in hot water and cooled under the tap	Golden yellow spangles are obtained	Lead is confirmed
II GROUP ANALYSIS(Copper) Copper		
1. To a little of the original solution ammonium hydroxide solution is added drop by drop	Pale blue precipitate is obtained	Presence of Copper
2.To the pale blue precipitate excess of ammonium hydroxide is added	The precipitate dissolves in excess to form a deep blue solution	Confirms the presence of copper
3. To a little of the original solution Potassium ferro cyanide solution is added	A chocolate brown precipitate is obtained	Copper is confirmed
III GROUP ANALYSIS (Aluminium)		
1. Sodium hydroxide Test To a little of the original solution sodium hydroxide is added drop by drop to excess.	A white precipitate soluble in excess of sodium hydroxide is obtained.	Presence of Aluminium
2. Blue ash test To a little of a original solution (fairly concentrated solution) few drops of dilute nitric acid and cobalt nitrate solutions are added. A filter paper is soaked in this solution and is burnt in a blue flame.	Blue ash is obtained	Presence of Aluminium is confirmed

EXPERIMENT	OBSERVATION	INFERENCE
IV GROUP ANALYSIS(Zinc)		
1. To a little of the original solution sodium hydroxide is added drop by drop to excess.	A white precipitate soluble in excess of sodium hydroxide is obtained	Presence of Zinc
2. To a little of the original solution Potassium ferro cyanide solution is added .	A white precipitate is obtained	Presence of Zinc
3. Green ash test To a little of the original solution a few drops of dilute nitric acid and cobalt nitrate solutions are added. A filter paper is soaked in this solution and is burnt in a blue flame.	Green ash is obtained	Confirms the presence of Zinc
V GROUP ANALYSIS (Calcium, Barium)		
1. To a little of the original solution dilute sulphuric acid is added	a) A white precipitate is obtained b) No white precipitate	Presence of barium Presence of calcium
2. To a little of the original solution acetic acid and potassium chromate solution are added	a) Yellow precipitate is added b) No yellow precipitate	Presence of barium Presence of calcium
3. If barium is absent to a little of the original solution Ammonium hydroxide and ammonium oxalate solutions are added.	A white precipitate is obtained	Presence of Calcium is confirmed
VI GROUP ANALYSIS (Magnesium)		
1. To a little of the original solution sodium hydroxide is added drop by to excess.	A white precipitate insoluble in excess of sodium hydroxide is obtained	Presence of Magnesium.
2. To a little of iodine solution sodium hydroxide is added until it is decolorized. Then original solution is added.	Colour of iodine is reappeared	Presence of Magnesium
3.To a little of the original solution a few drops of Magnason reagent is added	Blue precipitate is obtained	Presence of Magnesium is confirmed

EXPERIMENT	OBSERVATION	INFERENCE
VII GROUP ANALYSIS (Ammonium) 1.To a little of the original solution sodium hydroxide solution is added and heated	A colourless gas giving dense white fumes with a rod dipped in con. HCl is evolved.	Presence of ammonium
2.Nesslers test To a little of the original solution Nesslers reagent is added	Brown precipitate is obtained	Presence of ammonium is confirmed

MODEL ANALYSIS-AMMONIUM SULPHATE

A.PRELIMINARY DRY REACTIONS

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
1.	COLOUR The Colour of given salt is noted	White	Absence of Copper salts
2.	APPEARANCE The appearance of the given salt is noted	Crystalline	Absence of carbonate
3.	SOLUBILITY IN DILUTE hydrochloric acid A little of the given salt is dissolved in dilute HCl in a test tube	Soluble	Absence of lead
	SOLUBILITY IN WATER A little of the given salt is dissolved in distilled water in a test tube	Soluble	Absence of Carbonate
4.	ACTION OF HEAT A little of the given salt is strongly heated in a dry test tube.	A white sublimate is formed	May be Ammonium
5.	FLAME TEST The paste of the given salt with conc.HCl is introduced into the non-luminous part of the flame and the colour is noted.	No characteristics change	Absence of copper calcium and barium

B. WET REACTIONS

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
6.	ACTION OF Dil. HCl To a pinch of the salt taken in a test tube dilute hydrochloric acid is added	No characteristic gas is evolved	Absence of Carbonate
7.	ACTION OF CONC. SULPHURIC ACID To a little of the substance taken in a test tube a few drops of conc. Sulphuric acid is added and warmed	No characteristic reaction	Absence of chloride and nitrate
8.	ACTION OF CONC.H_2SO_4 AND COPPER TURNINGS To a small amount of the given salt conc. H_2SO_4 and copper turnings are added and heated.	No brown vapours	Absence of Nitrate
9.	ACTIONOF CONC. H_2SO_4 AND MnO_2 To a little of the given salt, conc. H_2SO_4 and MnO_2 are added & warmed	No characteristic change	Absence of chloride
10.	CHROMYL CHLORIDE TEST To a small amount of the given salt conc. H_2SO_4 and $K_2Cr_2O_7$ are added and warmed	No characteristic change	Absence of chloride

C.REACTIONS USING SODIUM CARBONATE EXTRACT

Preparation of Sodium Carbonate Extract:

A mixture of 1part of the given salt and 3parts of solid sodium carbonate is boiled with distilled water and filtered. The filtrate is called sodium carbonate extract.

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
12.	BARIUM CHLORIDE TEST A little of the extract is acidified with dil. HCl and $BaCl_2$ solution is added	A white precipitate insoluble in Conc. HCl is obtained	Sulphate is confirmed

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
13.	LEAD ACETATE TEST A little of the extract is acidified with dil.HNO_3 and lead acetate solution is added	A white precipitate is formed	Sulphate is confirmed
14.	SILVER NITRATE TEST A little of the extract is acidified with dil.HNO_3 and $AgNO_3$ solutionis added	No precipitate	Absence of chloride
15.	BROWN RING TEST To a little of the extract dil.sulphuric acid is added till the effervescence ceases.To this freshly prepared ferrous sulphate solution is added,then conc.sulphuric acid is added through the sides of the test-tube.	No Brown ring	Absence of nitrate

D.IDENTIFICATION OF BASIC RADICALS

Preparation of original solution

The given salt is dissolved in distilled water. The solution obtained is known as original solution.

GROUP SEPERATION

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
1	I GROUP (LEAD) To a little of the original solution dil. HCl is added.	No precipitate	Absence of I group
2	II GROUP (COPPER) To a little of the original solution dil. HCl and yellow Ammonium sulphide are added.	No precipitate	Absence of II group
3	III GROUP (ALUMINIUM) To a little of the original solution ammonium chloride and ammonium hydroxide are added.	No precipitate is formed	Absence of III group

S.NO	EXPERIMENT	OBSERVATION	INFERENCE
4	IV GROUP (ZINC) To a little of the original solution ammonium chloride, ammonium hydroxide and yellow ammonium sulphide solution are added	No precipitate	Absence of IV group
5	V GROUP (CALCIUM, BARIUM) To a little of the original solution ammonium chloride, ammonium hydroxide and ammonium carbonate are added	No precipitate	Absence of V group
6	VI GROUP (MAGNESIUM) To a little of the original solution ammonium chloride, ammonium hydroxide and disodium hydrogen phosphate solution are added	No Precipitate	Absence of VI group
7	VII GROUP (AMMONIUM) To a small amount of the salt sodium hydroxide solution is added and heated	A colourless gas giving dense white fumes with a rod dipped in con. HCl is evolved.	Presence of VII group (ammonium)

E.GROUP ANALYSIS

EXPERIMENT	OBSERVATION	INFERENCE
VII GROUP ANALYSIS (Ammonium) 1. To a little of the original solution sodium hydroxide solution is added and heated	A colourless gas giving dense white fumes with a rod dipped in con. HCl is evolved.	Presence of ammonium
2. Nesslers test To a little of the original solution Nesslers reagent is added	Brown precipitate is obtained	Presence of ammonium is confirmed

F.CONFIRMATORY TEST FOR ACID RADICAL(SULPHATE)

EXPERIMENT	OBSERVATION	INFERENCE
BARIUM CHLORIDE TEST A little of the extract is acidified with dil. HCl and $BaCl_2$ solution is added	A white precipitate insoluble in Conc. HCl is obtained	Sulphate is confirmed

G.CONFIRMATORY TEST FOR BASIC RADICAL(AMMONIUM)

EXPERIMENT	OBSERVATION	INFERENCE
NESSLER'S TEST To a little of the original solution Nessler's reagent is added	Brown precipitate is obtained	Presence of ammonium is confirmed

Result:

Acid Radical : Sulphate

Basic Radical : Ammonium

The given salt : Ammonium Sulphate

ANALYSIS OF EFFLUENTS CONTAINING METAL IONS (LEAD, COPPER, CADMIUM, ZINC)

Identification of Basic radical in effluent

EXPERIMENT	OBSERVATION	INFERENCE
1. To a small portion of a effluent solution dilute hydrochloric acid is added	a) White precipitate b) No precipitate is formed	Presence of Lead Absence of lead
2. To a small portion of a effluent solution dilute hydrochloric acid is added and then hydrogen sulphide gas is passed through the solution	a) Black precipitate b) Yellow precipitate c) No characteristic precipitate	Presence of copper Presence of cadmium Absence of copper and cadmium
3. To a small portion of the effluent solution ammonium chloride and ammonium hydroxide are added. Then hydrogen sulphide gas is passed through the solution	a) White precipitate b) No precipitate is formed	Presence of zinc Absence of zinc

EXPERIMENT	OBSERVATION	INFERENCE
CONFIRMATORY TESTS FOR BASIC RADICAL		
1.LEAD		
1. To a little of the original solution potassium chromate solution is added	Yellow precipitate is obtained	May be Lead
2. To a little of the original solution potassium iodide solution is added.	Yellow precipitate is obtained	Presence of Lead
3. The above yellow precipitate is dissolved in hot water and cooled under the tap	Golden yellow spangles are obtained	Lead is confirmed
2.COPPER		
1. To a little of the original solution ammonium hydroxide solution is added drop by drop	pale blue precipitate is obtained	Presence of Copper
2 .To the pale blue precipitate excess of ammonium hydroxide is added	the precipitate dissolves in excess to form a deep blue solution	Confirms the presence of copper
3. To a little of the original solution Potassium ferro cyanide solution is added	A chocolate brown precipitate is obtained	Copper is confirmed
3.CADMIUM		
1. To a little of the original solution ammonium hydroxide is added drop by drop to excess.	A white precipitate soluble in excess of ammonium hydroxide is obtained	Presence of Cadmium
2. To a little of the original solution ammonium sulphide solution is added.	A yellow precipitate is formed.	Presence of Cadmium
3.To the above yellow precipitate dil. HCL is added and warmed	The yellow precipitate dissolves.	Presence of Cadmium is confirmed
4. ZINC		
1. To a little of the original solution sodium hydroxide is added drop by drop to excess.	A white precipitate soluble in excess of sodium hydroxide is obtained	Presence of Zinc

EXPERIMENT	OBSERVATION	INFERENCE
2. To a little of the original solution Potassium ferro cyanide solution is added.	A white precipitate is obtained	Presence of Zinc
3. Green ash test To a little of the original solution a few drops of dilute nitric acid and cobalt nitrate solutions are added. A filter paper is soaked in this solution and is burnt in a blue flame.	Green ash is obtained	Confirms the presence of Zinc

Harmful effects of metallic effluents

1. **Lead :**It causes mental retardation, kidney and liver damage, gastro-intestinal disorder, nervous disorder, loss of appetite, brain damage abnormalities infertility and pregnancy, decay of teeth and gums, affects mental development of children.
2. **Copper :**It causes dryness and irritation of throat, disorder in liver, headache, tightness in chest and gastro intestinal disorder. It affects blood, bone and teeth. It also causes cancer and tuberculosis. It is toxic to aquatic life.
3. **Cadmium :**It causes kidney damage, gastro intestinal damage, bronchitis, nausea, vomiting, diarrhea, liver damage, disorder of heart, nerves and brain, anaemia and hyper tension.
4. **Zinc :**It causes irritation and damage to mucous membrane, nausea, vomiting, diarrhoea, corrosive effect on skin, dizziness and itching.

MODEL ANALYSIS OF AN EFFLUENT

EXPERIMENT	OBSERVATION	INFERENCE
1. To a small portion of a effluent solution dilute hydrochloric acid is added	White precipitate	Presence of Lead
2. To a small portion of a effluent solution dilute hydrochloric acid is added and then hydrogen sulphide gas is passed through the solution	No characteristic precipitate	Absence of copper and cadmium

EXPERIMENT	OBSERVATION	INFERENCE
3. To a small portion of the effluent solution, ammonium chloride and ammonium hydroxide are added. Then hydrogen sulphide gas is passed through the solution	No precipitate is formed	Absence of zinc
CONFIRMATORY TEST FOR LEAD		
1. To a little of the original solution potassium chromate solution is added	Yellow precipitate is obtained	May be Lead
2. To a little of the original solution potassium iodide solution is added.	Yellow precipitate is obtained	Presence of Lead
3. The above yellow precipitate is dissolved in hot water and cooled under the tap	Golden yellow spangles are obtained	Lead is confirmed

RESULT :

The metallic ion in the given effluent solution is LEAD.

Harmful effects of Lead: It causes mental retardation, kidney and liver damage, gastro- intestinal disorder, nervous disorder, loss of appetite, brain damage, abnormalities in fertility and pregnancy, decay of teeth and gums, affects mental development of children.

MODEL QUESTION PAPER

1. Analyse the given Inorganic Simple Salt and report the acid radical and basic radical present in it. Record your observations. Name the chemical substance.
2. Analyse the given sample of effluent and report the metallic pollutant with procedure and its harmful effects.

Note: All the students are given same Questions and each student is given different Inorganic simple salt and different effluents.

List of Apparatus to be supplied for each student for Board Exam

1. Test tubes	
a. 15 x 1.5mm	- 4
b. 15 x 2.5mm	- 2
2. Test tube stand	- 1
3. Test tube Holder	- 1
4. Test tube cleaning brush	- 1
5. Funnel	- 1
6. Glass Rod	- 1
7. Spatula	- 1
8. Watch Glass	- 1
9. Beakers 250 ml	- 1
10. Wash Bottle	- 1

Along with this Heating facility to be provided

LIST OF EQUIPMENTS

List of equipments needed for a batch of 30 students in Chemistry Laboratory

Non-Consumable Items:

1. Indane gas Connection (DBC)	1 no
2. Exhaust Fan (High capacity)	Sufficient Numbers
3. Fire Extinguisher	1 no
4. First Aid Box (Full set)	2 nos
5. Safety chart	1 no
6. Chemical Balance	1 no
7. Fractional weight box	1 no
8. PH meters	5 nos
9. Working Table with all accessories	8 nos

Glassware and Other Items:

1. Burette 50ml	35 nos
2. Pipette 20ml (with safety bulb)	35 nos
3. Conical Flask 250ml	35 nos
4. Funnel 3” (Polythene)	50 nos
5. Porcelain Tile 6x6”	35 nos
6. Measuring Cylinder	
a.100ml	5 nos
b.500 ml	3 nos
7. Reagent Bottle (White) 250ml	60nos
8. Reagent Bottle (White) 125ml	100 nos
9. Reagent Bottle (Amber) 250ml	80 nos
10. Test tubes	
a.15 x 1.5mm	1000 nos
b.15 x 2.5mm	500 nos
11. Test tube stand	35 nos
12. Test tube holder	35 nos
13. Test tube cleaning brush	35 nos
14. Glass Trough	5 nos
15. Beakers	
a.1000 ml	5 nos
b.500 ml	5 nos

c.250 ml	35 nos
d.100 ml	5nos
16. Glass Rods 15cm	100 nos
17. Watch Glass 3”	35 nos
18. Wash Bottle (Polythene) 1000ml	35 nos
19. Nickel Spatula	10 nos
20. Kipps Apparatus	1 no
21. Burner Nipple	30 nos
22. Bunsen Burner for gas connection	30 nos
23. Wire Gauge with asbestos center	15 nos
24. Plastic Buckets (15 lts)	10 nos
25. Tripod Stand (Iron)	30 nos
26. Filter Paper Round sheets	1000 nos
27. Burette stand	35 nos
28. Standard flask 100 ml	35 nos
29. Pipette 10ml	5 nos.

FIRST AID FOR ACCIDENTS IN CHEMISTRY LABORATORIES

Accident	First Aid Treatment
1. **Fire** **(a)** Inflammable liquids, gases on fire	(I) Pour water carefully, except when sodium, potassium, oil or spirit is on fire. (ii) Throw large quantities of sand if sodium, etc. is on fire. (iii) Throw a mixture of sand and sod, bicarbonate if oil or spirit is on fire. (iv) If any liquid or flask has caught fire, cover the mouth of the vessel with a damp cloth or duster. (v) Cover with a piece of blanket or thick cloth or card-board.
(b) Burning of clothes	Lay the person on the floor, burning parts of cloth upwards and cover with a blanket. Never throw water on the person; otherwise it will cause serious boils on the body.
2. **Cuts**	Remove the visible glass pieces, etc. if any from the affected part. Stop bleeding by one of the following methods (i) By applying pressure at the place of injury. (ii) By washing with alum or $FeCl_3$ solution. (iii) By applying a little spirit or dettol on the skin and cover with a piece of leucoplast.
3. Burns (a) By dry heat (i.e., flame, steam, hot object, etc.)	(i) Avoid handling the affected area as far as possible. Do not break the blisters. For minor burns apply burnol and sarson oil (mustard oil). (ii) Cover the affected part with lint or linen saturated with carron oil (a mixture of linseed oil and lime water in equal amounts) or with cold cream, etc. and bandage tightly.
(b) By corrosive acids	(i) If conc. H_2SO_4 falls on skin, wipe it with cotton. (ii) Wash with plenty of cold water, then with dilute $NaHCO_3$ solution (t in 88) and again with water. If burning persists wipe the skin with cotton wool and apply burnol and sarson oil.
(c) By corrosive alkalis	Wash immediately with excess of water, then with dilute acetic acid or lemon juice and apply burnol or sarson oil dressing.

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(d) By bromine	(i) Wash with petrol or alcohol and then rub glycerin. Finally smear with burnol. (ii) Wash with dil. Na_2CO_3 solution (1:10); then with alcohol and picric acid and apply oil dressing.
(e) By sodium	Remove sticking sodium piece by a forceps. Wash with excess of water. Apply burnol or cover with gauze a=soaked in olive oil.
4. **Eye Injuries**	
(a) By acid	Wash with excess of water, then with 3% $NaHCO_3$ and then with excess of water, forcibly opening the eyes. If necessary, drop castor oil (mobile oil) into the eyes, cover with cotton wool and bandage lightly.
(b) By alkalis	Wash well with 2% boric acid solution; the fest as in (a).
(c) By bromine or chlorine vapour	Wash with dil. $NaHCO_3$ solution and then bring near the eyes a cloth or sponge soaked in alcohol or alcohol +ether mixture. Do not allow the liquid to enter the eyes.
(d) By foreign particles	Wash it by sprinkling water into the eyes. Open the eye carefully and remove the particle by means of cotton wool or clean handkerchief. Wash again with water. Then put a drop olive or castor oil in the eyes and keep closed.
5. **Damage to Clothes**	
(a) By acids	Apply $(NH_4)_2CO_3$ solution or dilute ammonia and wash well with water.
(b) By alkalis	Apply lemon juice or dil, acetic acid, wash well with plenty of water.
6. **Poisoning**	
(a) Strong acid	Give plenty of water. Then give 2 tablespoons of lime water or milk of magnesia.
(b) Caustic alkalis	Give plenty of water. Then give orange or lemon juice.
(c) Salts of heavy metal or copper sulphate	Give milk or white of an egg.
(d) Mercury salts	Immediately give a tablespoon of common salt or zinc sulphate in a tumbler of warm water.

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(e) Arsenic or antimony salt	(i) Drink plenty of warm water and make vomiting. (ii) Give large quantities of freshly precipitated ferric hydroxide (mix equal vols. of $FeCl_3$ and NH_4OH) or magnesium hydroxide or castor oil mixed with milk and white of egg. (iii) Keep the feet and abdomen warm by hot water bottles and blankets.
7. **Inhalation**	
(a) Bromine or chlorine	Inhale alcohol or ammonia vapour.
(b) Carbon monoxide	Fresh air; inhale dilute oxygen.
(c)Nitrous fumes	Plenty of fresh air; inhale steam.
(d) Chloroform	Fresh air; artificial respiration; apply hot and cold douche.
(e) H_2S	Artificial respiration; inhalation of ammonia. Apply warm and cold douches to head.