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NOTES OF LESSON – INDEX PAGE

YEAR:	**I**	**SEMESTER:**	**I I**
SUBJECT&SUBJECT CODE:	**40024&ENGINEERING CHEMISTRY-II**	**SCHEME:**	**N SCHEME**

UNIT 1 ELECTRO CHEMISTRY

S.NO	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	**1.1 Electrochemistry-I** Electronic concept of oxidation and reduction – Faradays' laws of electrolysis – simple problems – electrolytes – non electrolytes – electrolysis – definition – Mechanism – Industrial applications of Electrolysis – electroplating – chromoplating.	Chemistry–HigherSecondary–1stand2ndyear,Vol.I&II,TamilNaduTextBookCorporation, 2018. Electrochemistry by Crow	https://youtu.be/I5Rn_iF3L44	Electrochemistry	
2	**1.2 Electrochemical cell** Electrochemical cell – Definition Galvanic cell – Formation of Daniel cell – Electrochemical series – Definition – Significance	Basic inorganic chemistry by Arun Bahl and B. S. Bahl Electrochemistry by Crow	https://youtu.be/I00mXdiMvtA		
3	**–1.3 Energy Sources** Primary Battery – Secondary Battery – Definition and example – Cell – Construction, Working principle and Uses of Lead acid – Storage battery – Lithium ion – battery – Solar Cell – Definition – working principle	Chemistry–HigherSecondary–1stand2ndyear,Vol.I&II,TamilNaduTextBookCorporation, 2018.	https://youtu.be/08N7pph-Y98 https://youtu.be/HhxtfULIO7c		

			https://youtu.be/G5McJw4KkG8		

UNIT 2 CHEMISTRY OF CORROSION AND PREVENTION

S.NO	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	**2.1 Corrosion** Definition – types of corrosion – theories of corrosion – galvanic cell formation theory – differential aeration theory – factors influencing rate of corrosion.	Chemistry–HigherSecondary–1stand2ndyear,Vol.I&II,TamilNaduTextBookCorporation, 2018. A Text Book of Engineering Chemistry – S.S. Dara – S. ChandPublication.	https://youtu.be/SJojrEeQBTI	Corrosion	
2	**2.2 Methods of prevention of corrosion** Galvanization – tinning – anodisation – cathodic protection – sacrificial anode method and impressed voltage method	Chemistry–HigherSecondary–1stand2ndyear,Vol.I&II,TamilNaduTextBookCorporation, 2018	https://youtu.be/L4v-Dk270HI		
3	**2.3 Organic Coatings** Paints- definition – Components of paints – Varnish – Definition –	Chemistry–HigherSecondary–1stand2ndyear,Vol.I&II,Tami	https://youtu.be/ZpD251wcFpc		

	Preparation of oil varnish – differences between paint and varnish – Special Paints – Luminescent paint, fire retardant paints, Aluminium paint and Distemper	lNaduTextBookCorporation, 2018.			

UNIT: 3 FUELS

S.NO	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	Fuel- Definition-Calorific value- Calorie-Liquid fuels- liquid hydrogen- power alcohol- uses- Refining of Petroleum – Fractional distillation- Cracking (Concept only) – Gaseous fuels- Preparation, composition and specific uses of producer gas and water gas- composition and uses of CNG and LPG- advantages of gaseous fuels.		https://youtu.be/PYMWUz7TC3A https://youtu.be/H5JVP8kQYek	Fuel and combustion	
2	Combustion Definition- Combustion calculation by mass (for solid		https://youtu.be/z-CGggAM9Kc https://youtu.be/5mopbuBuX8Q		

	and liquid fuels) – Stiochiometric calculations- Volume of air required – Definition of Flue gas- Flue gas Analysis- Orsat Apparatus- Simple numerical Problems				
3	Rocket Propellants Definition- Characteristics – Classification of propellants- brief idea of solid and liquid propellants. .	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE	https://youtu.be/rf_RmV0il2o		

UNIT: 4 APPLIED CHEMISTRY

S.NO	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	Technology of water-I Sources of water- depletion of underground water- reasons- Rainwater harvesting (Basic ideas) – advantages- hard water and soft water- Hardness of water-carbonate and Non- carbonate hardness-	Basic inorganic chemistry by Arun Bahl and B. S. Bahl	https://youtu.be/i2NCFUEVjFo https://youtu.be/9J1_tuKW7-g	Drinking water purification	

	Methods of expressing hardness- mg/lit and ppm- Simple problems- Disadvantages of hard water- Estimation of total hardness by EDTA method-problems involving total, Carbonate and Non-carbonate hardness in ppm- Disadvantages of using hard water in boilers – Scale formation, Corrosion of boiler, Caustic Embrittlement – Priming and foaming.				
2	– Technology of water 2 Softening of hard water- Ion Exchange method and Reverse Osmosis method –Municipal supply- purification of drinking water-Quality of potable water (WHO standard) – parameters of potable water - pH –TDS- residual chlorine permissible limits- determination of ecoli (preliminary idea)	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE	https://youtu.be/kuxYZb4PKi4 https://youtu.be/c40yPpQG8e0		

UNIT: 5 ENVIRONMENTAL CHEMISTRY

S.NO	TOPIC	REFER TEXT BOOK NAME	VIDEO PRESENTATION	PPT	ANY OTHER
1	Air Pollution Pollution and Air pollution – Definition – Air pollutants (SO2, H2S, HF, CO and Dust) – Sources and Harmful effects – smog and types of smog- Formation of Acid Rain – Harmful effects – Green House Effect – Causes – Global warming – Harmful effects – Ozone Layer – Importance – Causes for Depletion of Ozone Layer (No equations) – Harmful effects of Ozone Layer Depletion – Control of Air Pollution.	BACIC ORGANIC CEMISTRY BY PURI & SHARMA	https://youtu.be/sAKyhfxxr7s https://youtu.be/fephtrPt6wk https://youtu.be/dmgLESI4GGU	Pollution	
2	Water Pollution Causes of Water Pollution – Sewage, Effluents, Algae and Microorganisms – Harmful effects – Definition – Sewage-Sewerage -Disposal – Industrial Effluents – Harmful	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE	https://youtu.be/MEb7nnMLcaA https://youtu.be/UGqZsSuG7ao		

	effects of Effluents – Treatment of Effluents – Eutrophication – Definition and harmful effects.				
3	Solid Waste Management Solid Waste – Definition – Problems – Types of Solid Waste – Methods of disposal – Land fill and Incineration- Recycling – Definition – Examples – Advantages of Recycling (Basic ideas)- Definition – Goals of Green Chemistry (Basic ideas)	A TEXTBOOK OF ENGINEERING CHEMISTRY BY S S DARA ,S S UMARE	https://youtu.be/9KMMwHjJ9R8 https://youtu.be/rAbCMM0WjLI https://youtu.be/PUisOKB6sgA		

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Submitted by IQAC on:	Checked and Approval by IQAC on:

Sign of IQAC coordinator

ENGINEERING CHEMISTRY – II

40024

UNIT 1 ELECTRO CHEMISTRY

1.1 Electrochemistry-I

Electronic concept of oxidation and reduction – Faradays' laws of electrolysis – simple problems – electrolytes – non electrolytes – electrolysis – definition – Mechanism – Industrial applications of Electrolysis – electroplating – chromoplating.

1.2 Electrochemical cell

Electrochemical cell – Definition Galvanic cell – Formation of Daniel cell – Electrochemical series – Definition – Significance

1.3 Energy Sources

Primary Battery – Secondary Battery – Definition and example – Cell – Construction, Working principle and Uses of Lead acid – Storage battery – Lithium ion – battery – Solar Cell – Definition – working principle

1.1 ELECTROCHEMISTRY

INTRODUCTION

Electrochemistry is a branch of chemistry which deals with the relationship between electrical energy and chemical energy. It deals the chemical reactions brought by electric current and chemical reaction producing electrical current.

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

a. Metallurgy
b. Electroplating
c. Chemical manufacturing processes including medicines.

Chemical effects producing electricity

Electrochemical cells including Dry cells, Daniel cells, Leclanche 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.

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 solution, urea solution, alcohol, etc.

Strong electrolytes

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

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

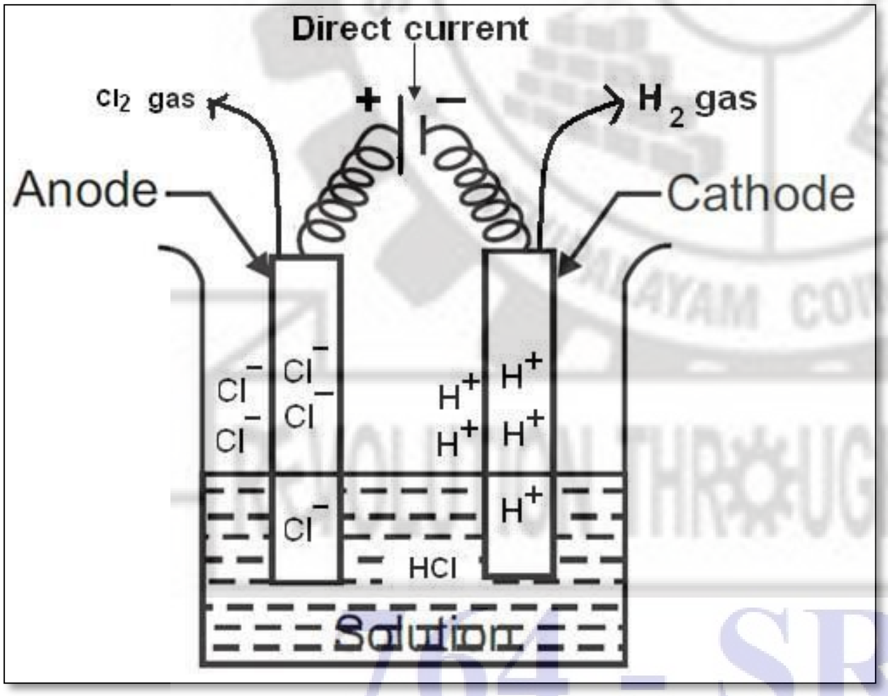
Weak electrolytes

Electrolytes which do not ionize completely in solution are called weak electrolytes. Example: Acetic acid, oxalic acid, etc.

Electrolysis

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

Example: Electrolysis of hydrochloric acid.



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 loss of electrons.

$Cl^- \longrightarrow Cl + e^-$ (oxidation)

$2Cl \longrightarrow Cl_2$ (gas)

Chlorine gas is liberated at the anode.

Cathodic reaction:

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

$H^+ + e^- \longrightarrow H$ (reduction)

$2H \longrightarrow H_2$ (gas)

Hydrogen gas is liberated at the cathode.

Thus, hydrochloric acid decomposes into hydrogen and chlorine.

Electrolysis depends on the following factors:

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

Industrial Applications of Electrolysis

Electrolysis is applied in

- Electroplating
- Anodization of Aluminium
- Electrolytic refining of metals.

Electroplating

Electroplating is the coating of a more noble metal over a less noble metal by electrolysis.

Electroplating is done for the following purpose.

- To make the surface corrosion resistant.
- 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.

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 trisodium 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.

Factors affecting the stability of the coating

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

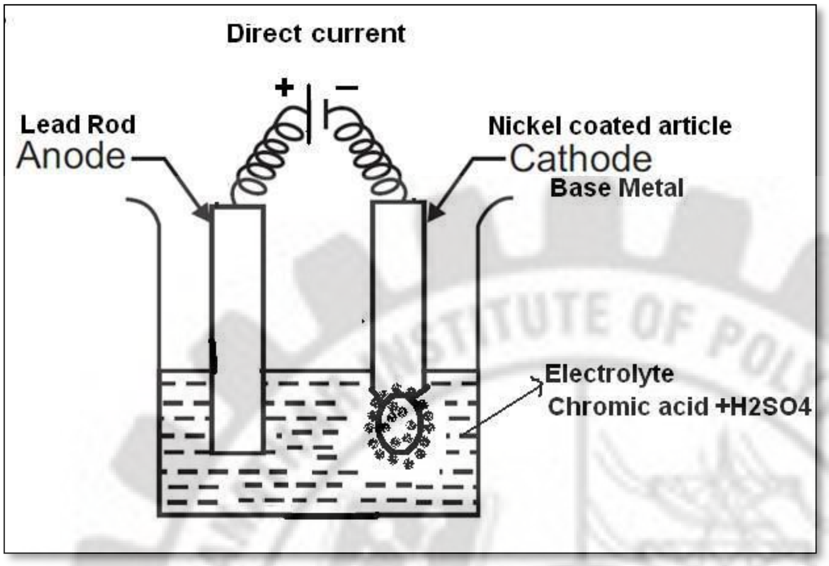
- Nature of the electrolyte.
- Nature of the electrode.
- Solubility of the electrolyte.
- Concentration of the electrolyte.
- Temperature.
- Voltage applied (low).
- Current density (high).
- Time for which the current is passed.
- P^H of the electrolytic solution.

Chrome plating

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

Process:

The nickel or copper coated iron article (base metal) is placed at the cathode.



A lead-antimony rod is used as the anode.

A solution of chromic acid and sulphuric acid (100:1) is used as the electrolyte.

Temperature of the electrolytic solution is maintained at 40^0C to 50^0C.

A current density of 100 – 200 mA/$cm^2$is used.

Sulphate ions act as catalyst for coating.

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 above.

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 and 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.

$$\text{Metal ions + Reducing agent} \longrightarrow \text{Metal + Oxidized products (Deposited)}$$

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:

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

Cathodic reaction:

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

Advantages of Electroless plating over electroplating

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

Applications of Electroless plating

- Electroless nickel plating is extensively used in electronic appliances.
- Electroless nickel plating is used in domestic and in automotive field.
- Electroless nickel coated polymers are used in decorative and functional applications.
- Electroless copper and nickel coated plastic cabinets are used in digital as well as electronic instruments.
- Electroless copper plating is used in the manufacture of double sided and multilayered printed circuit boards (PCB).

Summary

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

QUESTIONS

PART - A

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. What is chrome plating?
8. What is electroplating?
9. What is Electroless plating?

PART – B

1. Give any three industrial applications of electrolysis.
2. Mention any three factors affecting the stability of coating.
3. What is the anode and electrolyte used in chrome plating?
4. Give any three advantages of Electroless plating over electroplating.
5. Give any three applications of Electroless plating.

PART - C

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.

1.2. ELECTROCHEMICAL CELL

INTRODUCTION

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

- Electrolytic Cell
- Electrochemical cell.

Electrolytic cell is a device which produces chemical change when an electrical energy from outside source is supplied. Here, electrical energy is converted into chemical energy.

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.

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 anode leaves the metal ions at anode. The electrons from the solution are accepted by metal ions at the cathode to become metal.

Representation of cell:

Galvanic cell is generally represented as follows.

$$M_1/M_1^{+} \;\|\; {}_2M^{+}/M_2 \text{ or } M_1 / (\text{Salt of } M_1) \;\|\; (\text{Salt of } {}_2M)/M_2$$

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.

Single electrode potential

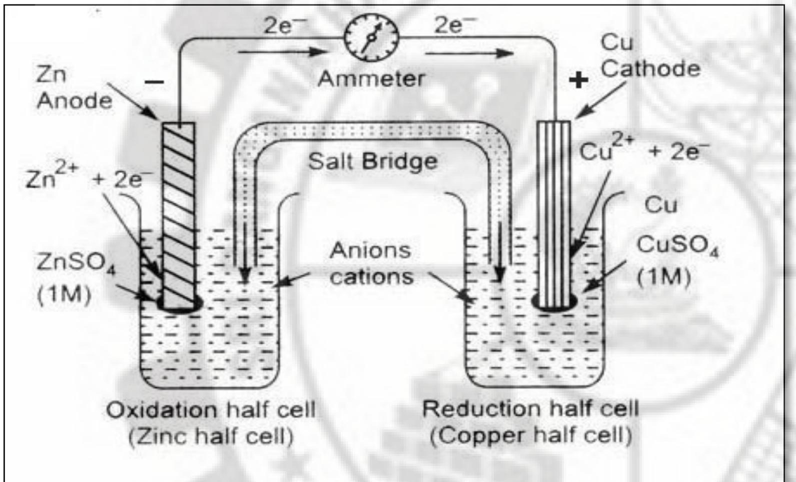
The measure of tendency of a metallic electrode to lose or gain electrons when in contact with a solution of its own salt in a half cell of an electrochemical cell is called as single electrode potential.

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.

Formation of Daniel Cell

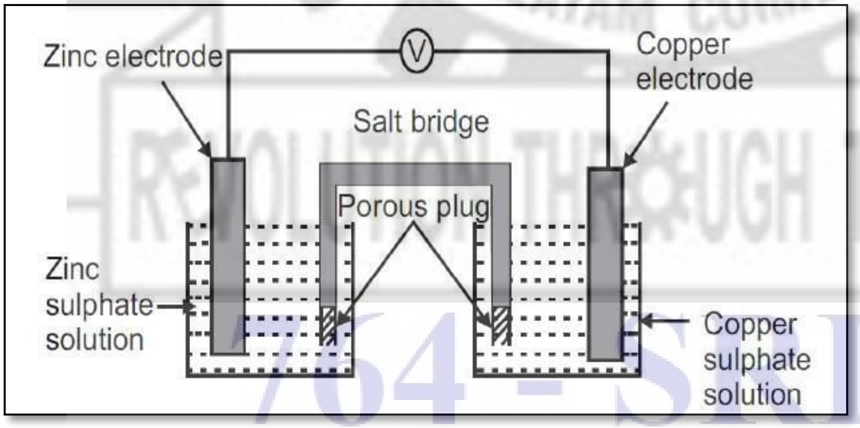
This cell consists of a zinc rod as anode dipped in zinc sulphate solution (electrolyte) in a glass tank and copper rod as cathode dipped in copper sulphate (electrolyte) in another glass tank. Each electrode is known as half cell. The two half cells are interconnected by a salt bridge and zinc and copper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

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



Daniell cell

The other simple diagram of Daniel cell



Redox reaction occurs at the electrodes of the Daniel cell:

At anode

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

At cathode

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

Overall Cell reaction

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

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.

Electrochemical series

Electrode	**Electrode Reaction**	**Reduction potential (E°) Volts**	**Nature**
Li^{+} / Li	$Li^{+} + e^{-} \rightarrow Li$	-3.01	Anode
Mg^{2+} / Mg	$Mg^{2+} + 2e^{-} \rightarrow Mg$	-2.37	Anode
Pb^{2+} / Pb	$Pb^{2+} + 2e^{-} \rightarrow Pb$	-1.12	Anode
Zn^{2+} / Zn	$Zn^{2+} + 2e^{-} \rightarrow Zn$	-0.76	Anode
Fe^{2+} / Fe	$Fe^{2+} + 2e^{-} \rightarrow Fe$	-0.44	Anode
Sn^{2+} / Sn	$Sn^{2+} + 2e^{-} \rightarrow Sn$	-0.13	Anode
H^{+}/H	$H^{+} + e^{-} \rightarrow H$	0.00	Pt – reference
Cu^{2+} / Cu	$Cu^{2+} + 2e^{-} \rightarrow Cu$	+0.34	Cathode
Ag^{+} / Ag	$Ag^{+} + e^{-} \rightarrow Ag$	+0.80	Cathode
Au^{+} / Au	$Au^{+} + e^{-} \rightarrow Au$	+1.50	Cathode

Significance and applications of electrochemical series

Calculation of standard EMFof a cell

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

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).

Displacement of one element by other

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

Determination of equilibrium constant for the reaction

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

Hydrogen displacement behaviour

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

Predicting spontaneity of redox reactions

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

Electrolytic Concentration cell

The cell in which the current is produced by the 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.

- Electrode concentration cell
- Electrolytic concentration cell.

Electrode concentration cell:

Two identical electrodes of different concentrations are dipped in the same electrolytic solution 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,

$Pb (Hg) (C_1) / Pb^{+2} || Pb(Hg) (C_2)$

Where, C_1 & C_2 are concentrations of the electrodes.

Electrolytic concentration cell:

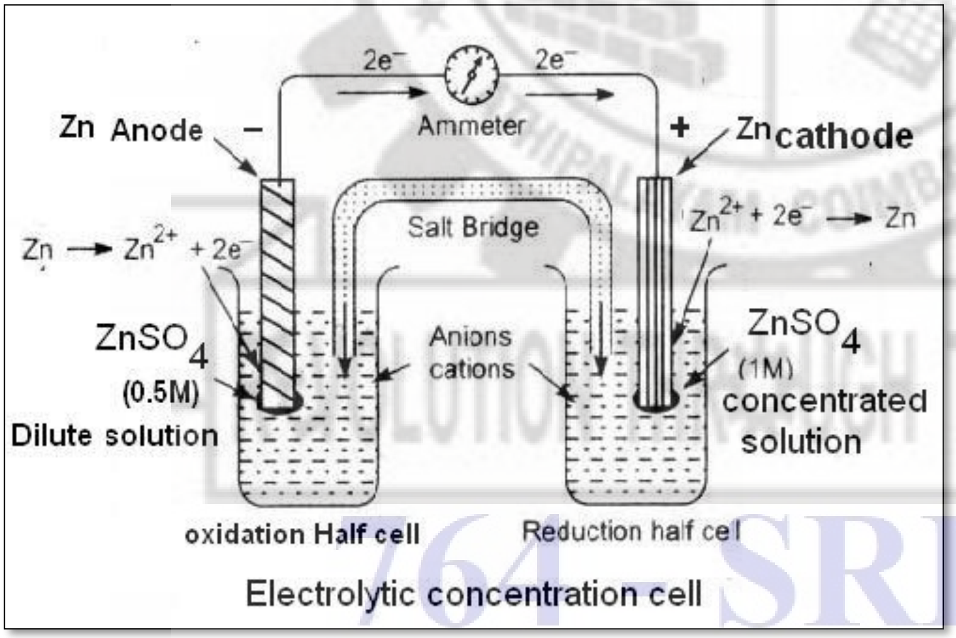
If two identical electrodes of same concentrations are dipped in the electrolytic solutions of different concentration in a cell, then it is called electrolytic concentration cell.

Example: Zinc ion concentration cell

$Zn/ Zn^{+} (C_1)$ |salt bridge| $Zn^{+} (C_2) / Zn$ $(C_2 > C_1)$

Diluted Concentrated

A concentration cell is made up of two half cells. Both the half-cell have the same electrodes and the same electrolytes but with different concentration of electrolytes. In one half cells Zn is placed in its **low concentrated** solutions. In another half-cell the zinc is placed in its **high concentrated** solution. They are connected by a **salt bridge.**
The diagram of an electrolytic concentration cell is



Electrolytic concentration cell

Reaction at anode (Dilute solution)

$Zn \text{-------}\rightarrow Zn^{2+}{}_{(C1)} + 2e^{-}$………….. (1)

The electrons released move to the other electrode.

Reaction at cathode (concentrated solution)

The electrons are taken up by the Zn^{2+} (high conc.)

$Zn^{2+}{}_{(C2)} + 2e^{-} \text{------}\rightarrow Zn$ ……………(2)

The sum of (!) and (2) gives the net reaction.

$Zn^{2+}{}_{(C2)} \text{-------}\rightarrow Zn^{2+}{}_{(C1)}$

This shows that there is no chemical reaction. So the e.m.f developed is only due to the transfer to Zn^{2+} ions from solution of higher concentrations to lower concentrations. The electrolytes of different concentrations try to reach equilibrium by exchange of ions through porous layer. Electrons flow from the anode to cathode producing current when they are externally connected through wire. Hence this cell is called concentration cell.

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.

QUESTIONS

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?

PART-B

1. How will you write a short representation of a Daniel cell?
2. Define electrochemical series.
3. Write any three applications of electrochemical series.
4. Define concentration cell.
5. What are the types of concentration cells? Give examples.
6. Give an example for electrode concentration cell.
7. Give an example for electrolyte concentration cell.

PART - C

1. Explain electrochemical cell with example.
2. Explain the construction and working of Daniel cell
3. Describe the 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.

1.3. ENERGY RESOURCES

INTRODUCTION:

Battery is a device that stores chemical energy and releases it as electrical energy. Hence a device which converts chemical energy into electrical energy is called battery, cell, 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.

A cell contains one anode and one cathode. The emf of a single cell is around 2 volt. A battery contains several anode and cathode. The emf of a battery which contains six anodes and six cathodes is around 12 v.

Definition:

Battery is a device that stores chemical energy and releases it as electrical energy. Hence a device which converts chemical energy into electrical energy is called battery or cell.

Batteries are classified as follows,

- Primary battery
- Secondary battery
- 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, Leclanche 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.

Dry Cell

A cell without fluid component is called as dry cell.

Example: Daniel cell, alkaline battery.

Construction and working of Dry cell:

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, is immersed in the electrolyte in the centre of the cell.

The electrode reactions are given below.

Anodic reaction

$$Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e^{-} \text{ (Oxidation)}$$

$$2MnO_{2\,(s)} + H_2O + 2e^{-} \longrightarrow Mn_2O_{3\,(s)} + 2OH^{-}_{\mathbf{(aq)}} \text{ (Reduction)}$$

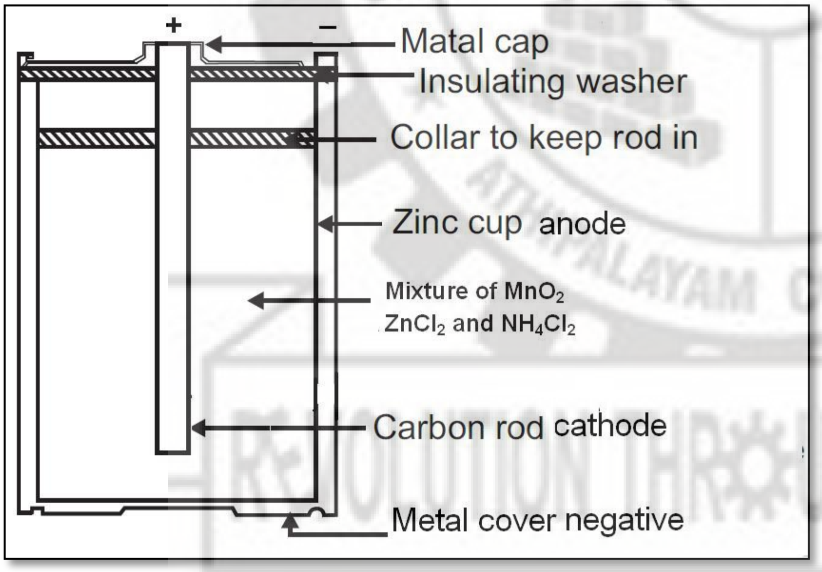
$$NH_4^{+}\,_{\mathbf{(aq)}} + OH^{-} \longrightarrow NH_{3\,\mathbf{(g)}} + H_2O_{\mathbf{(l)}}$$

$$2MnO_{2\,(s)} + 2NH_2^{+}\,_{\mathbf{(aq)}} + Zn^{2+}_{\mathbf{(aq)}} + 2e^{-} \longrightarrow [Zn(NH_3)_2]Cl_{2\,\mathbf{(s)}}$$

Overall reaction

$$Zn_{\mathbf{(s)}} + 2NH_4^{+}\,_{\mathbf{(aq)}} + 2Cl^{-}_{(aq)} + 2MnO_{2\mathbf{(s)}} \longrightarrow Mn_2O_{3\mathbf{(s)}} + [Zn(NH_3)_2]Cl_{2\mathbf{(s)}} + 2H_2O$$

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, clocks 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

Lead – acid storage cell

The typical example for storage cell is Lead-acid storage cell. A secondary battery 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 combination is immersed in 20% dil.H_2SO_4.

The cell is represented as

$$\mathbf{Pb \mid PbSO_4 \parallel H_2SO_4 \parallel PbSO_4 \mid PbO_2 \mid Pb}$$

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

Anodic reaction:

Oxidation reaction takes place at anode. The electrons are released from anode. Hence the anode is called as negative anode and is represented as (-).

Lead is oxidized to Pb^{2+} ions and gives two electron, which further combines with SO_4^{2-} to form insoluble $PbSO_4$.

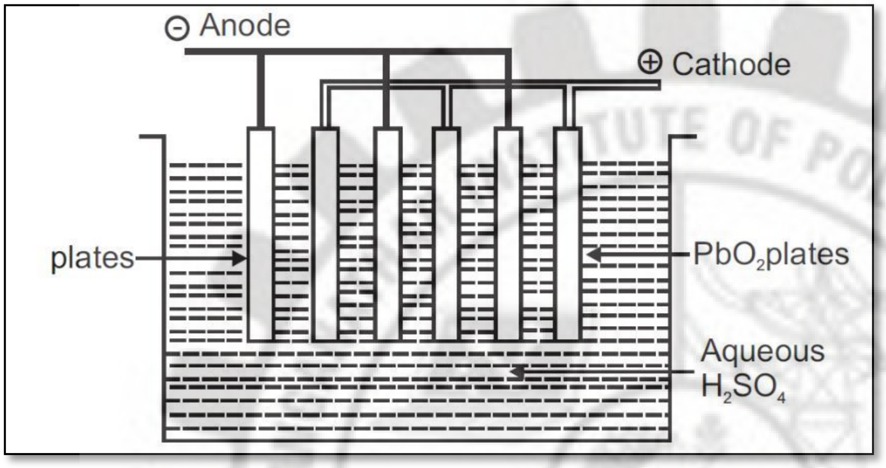
$$Pb\ (s) + SO_4^{2-} \longrightarrow PbSO_4\ (s) + 2e^{-}$$

Cathodic reaction:

Reduction takes place at cathode. Hence the cathode is called as positive cathode and is represented as (+).

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

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



Overall cell reaction during discharging:

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

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 recharged 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, trucks etc.
2. It is used in gas engine ignition, telephone exchanges, power stations hospitals.
3. IT industry, educational institutions, laboratories etc.

Non-conventional Energy Sources

Energy received from the sun is the best example for non-conventional energy resources.

Example: Solar cell

Solar cell

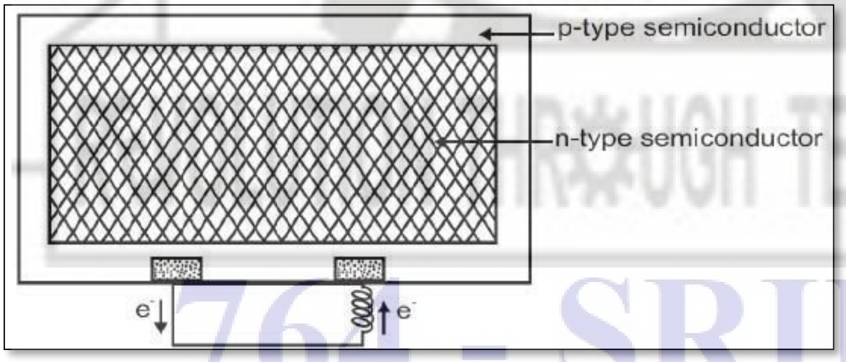
A device which converts the solar energy (energy obtained from the sun) directly into electrical energy is called ‘Solar cell’. This is also called as ‘Photovoltaic cell’.

Principle:

The basic principle involved in the photovoltaic (PV) effect. When sun rays semiconductor devices, potential difference produced. This potential difference causes 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) semiconductor plates. 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, solar cell and their uses are discussed.

QUESTIONS

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.

PART-B

1 What is dry cell? Give an example.
2 Write short representation of lead - acid storage cell.
3 Give any three use of lead – acid battery.
4 What is a solar cell?
5 Give any three applications of solar cells.

PART – C

1 Explain construction and working of dry cell with example.
2 Explain the construction and working of lead – acid battery.
3 Write a note on solar cell.
4 Explain the uses of solar cells.

UNIT 2 CHEMISTRY OF CORROSION AND PREVENTION

2.1 Corrosion

Definition – types of corrosion – theories of corrosion – galvanic cell formation theory – differential aeration theory – factors influencing rate of corrosion.

2.2 Methods of prevention of corrosion

Galvanization – tinning – anodisation – cathodic protection – sacrificial anode method and impressed voltage method

2.3 Organic Coatings

Paints- definition – Components of paints – Varnish – Definition – Preparation of oil varnish – differences between paint and varnish – Special Paints – Luminescent paint, fire retardant paints, Aluminium paint and Distemper

2.1CORROSION

INTRODUCTION

Corrosion is a ‘billion’ dollar thief’. Even though it is a natural phenomenon in which the gases, moisture and other chemicals present in the atmosphere react chemically with metals to convert them into their salts, it results in loss of material and money. We know very well that 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 thereby to the society. The estimate of loss due to corrosion is approximately 2.5 billion dollars per 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 slow and continuous destruction of metal or alloy by the 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 and oxygen.

Definition

Corrosion is defined as the slow and continuous destruction of metal or alloy due to the chemical or electrochemical reaction with its environment.

It may be due to chemical or electrochemical reaction of the metals with the environment.

Example: Rusting of iron.

Causes of corrosion:

Metal occur in nature in two different forms. They are

- Native state
- Combined state.

1. Native state:

The metals occur in native, free, uncombined states or **pure metal are highly stable and non-reactive with the environment.** They do not combine with other elements. They are noble metals exist as such in the earth crust. They have very good corrosion resistance.

Ex. Au, Pt, Ag, Pd, Cu etc,

2. Combined state

Except noble metal, all other metals are reactive and form stable compounds as their oxides, sulphides, chloride and carbonates. They exist in the form of stable compounds called ores or mineral. Ex.FeO_2.ZnO, PbS,$CaCO_3$ etc.,

Except noble metal, the other metals in the pure state are thermodynamically **unstable** as they are considered in excited state ie., higher energy state. Therefore, as soon as the metals are extracted from their ores, the reverse process begins and form stable **metallic compounds**, which are thermodynamically stable, i.e., lower energy state.

Corrosion(oxidation)

Metal (unstable) $\rightleftharpoons$ Metallic Compound (stable)

Higher energy Metallurgy(Reduction) lower energy state

The properties such as electrical conductivity, ductility, malleability etc., are lost due to corrosion.

Types of Corrosion:

Corrosion is of two types.

- Chemical Corrosion or Dry Corrosion
- Electrochemical Corrosion or Wet Corrosion

Chemical Corrosion or Dry Corrosion

The direct chemical action of atmospheric gases like oxygen, halogens, H_2S etc., in a dry environment on metals is known as chemical Corrosion. Due to this, a dry layer of the Corrosion product is formed on the surface of the metal.

Example:

When magnesium is exposed to atmosphere, magnesium oxide is formed over the surface.

$$2Mg+O_2 \longrightarrow 2MgO$$

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 halide on the surface which prevents the further corrosion.

$$2Ag+Cl_2 \longrightarrow 2AgCl$$

On the other hand, stannic chloride formed on tin is volatile and so corrosion is not prevented.

Electro Chemical Corrosion or wet corrosion

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

There are two theories to explain the rusting of iron.

- Galvanic cell formation theory
- Differential aeration theory.

Galvanic cell formation theory Definition

“When a metal with impurities (or two dissimilar metals (Fe and Cu) are in contact with each other) is exposed to atmosphere in presence of an electrolyte or moisture, a mini galvanic cell is formed. The more anodic metal undergoes corrosion. This type of corrosion is known as galvanic corrosion”.**Example: Rusting of iron**

Corrosion is an oxidation process. Oxidation is a process which involves loss of electron. Oxidation takes place at **anode**.

When iron metal with small amount impurities (Cu) is placed in the environment is exposed to the environment (moisture), it undergoes corrosion. Hence it acts as anode and under goes Oxidation. Iron metal loses its two electrons and becomes Fe^{+2}ion. Hence the iron metal undergoes oxidation when it is corroded.

The impurities present in the metal act as **cathode** and undergo reduction. The electron released at anode is absorbed at cathode to form either Hydrogen or water or hydroxide ion depending on the environment. The moisture in the environment behaves like **electrolyte**. **Hence a galvanic cell is formed.**

Rusting of iron is explained as below.

<u>Anodic reaction (oxidation)</u>

The metal at the anode is oxidised into ferrous ions.

$Fe \longrightarrow Fe^{2+} + 2e^{-}$ (oxidation-loss of electron)

2+ -

$Fe + 2OH \longrightarrow Fe(OH)_2 + Fe(OH)_3 + Fe_2O_3$

Fe^{2+} ions combine with OH^- in the environment forming ferrous hydroxide $Fe(OH)_2$, which under goes further oxidation to give ferric hydroxide $Fe(OH)_3$. the ferric hydroxide undergoes decomposition to give ferric oxide Fe_2O_3(Rust).

Thus rust formed is explained based on the theory of Galvanic cell formation.

<u>Electrolyte</u>

The moisture (H_2O) in the environment act as electrolyte. It dissociates to give H+ and OH^- ions**.**

$H_2O \longrightarrow H^+ + OH^-$

Cathodic reaction (Reduction)

The electrons released at anode are taken up by the H+ ion in the environment.

(i) In acidic medium (reduction-gain of electron)

$2H^+ + 2e^- \longrightarrow H_2 \text{ (gas)} \uparrow$

(ii) In neutral solution with oxygen

$\frac{1}{2} O_2 + H_2O + 2e^- \longrightarrow 2OH^-$

The ferric oxide formed (Fe_2O_3) over iron is called as Rusting of iron.

Examples:

- Corrosion of soldered metal around copper wire.
- Corrosion of steel shaft in bronze bearing.
- Corrosion of steel pipe connected to copper plumbing.

Control

Galvanic corrosion can be avoided by selecting two dissimilar metals which are very close in the electrochemical series.

It can also be avoided by connecting two dissimilar metals through insulating material.

By making cathodic area smaller and anodic area larger.

Differential aeration theory or concentration cell formation theory

According to this theory, when a metal is exposed to varying concentrations of air (oxygen) or an electrolyte, concentration cell is formed. The metallic area which is exposed to less amount of oxygen act as anode undergoes corrosion.

The metallic area which is exposed to greater amount of oxygen act as cathode.

Corrosion of metal occurs due to difference in concentration of air or electrolyte. **Hence this theory is called as Differential aeration theory or concentration cell formation theory.**

Example:

1. Corrosion on wire fence

In an iron fence the point where wires cross is less exposed to oxygen and becomes anode. Therefore corrosion takes place at the point of contact where the wire crosses.

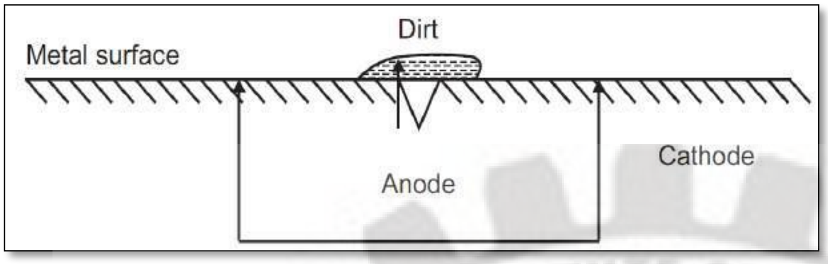
Metal partially immersed in water, the immersed portion is less exposed to oxygen and becomes anode. Therefore corrosion takes place.

Metal area covered by drop of water, sand or dust.

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)-oxidation-loss of electron-corrosion takes place.

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



At cathode (more oxygenated area)

$\frac{1}{2} o_2 + H_2o + 2e^{-} \longrightarrow 2OH^{-}$ (Reduction)

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

Which 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 localized corrosion is called pitting.

Factors influencing the rate of corrosion:

The factors that affect the rate of corrosion are

- Nature of the metal and its surface
- Nature of the atmosphere
- Nature of the corrosion product.

Factors connected with the metal:

1. **The position of the metal in the Electrochemical 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 anodes pot. 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 Nature of the atmosphere

1. Temperature of the atmosphere:

The rate corrosion increases with increase of temperature.

1. PH of the atmosphere :

Lower the P^H greater is the corrosion.

2. Amount of moisture in the atmosphere:

Increase of moisture in the environment increases the rate of corrosion.

3. Amount of oxygen in the atmosphere:

In some cases oxygen enhance the corrosion and in another it passivates the metal.

4. Amount of chemical fumes in the atmosphere:

Industrial fumes like HCl,H_2SO_4 produces electrolytes which are acidic in nature and increases the rate of corrosion.

Examples

Buried pipelines and cables passing from one type of soil to another suffer corrosion due to differential aeration.

Lead pipe line passing through clay get corroded because it is less aerated than sand.

Factors connected with the corrosion product

In some cases the corroded product sticks to the surface and absorbs more moisture. This induces further corrosion. Examples:

a).In 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.

c). Aluminium oxide formed over the surface of aluminium prevents further corrosion and act as a protective coating. This is the basic principle of Anodization.

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

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. Write a note on galvanic cell formation theory.
2. Write a note on differential aeration theory.
3. What are the factors influencing the rate of corrosion?

PART-C

1. Explain the mechanism of Galvanic corrosion.
2. Explain the differential aeration theory with suitable examples.

TEST YOUR UNDERSTANDING

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

2.2 METHODS OF PREVENTION OF CORROSION

INTRODUCTION

Corrosion can be prevented by the following methods:

1. Control of environment
2. Alloying
3. Surface coating
4. Cathodic protection

Control of environment:

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

Deaeration: Removal of dissolved oxygen and other gases in water by mechanical agitation is called deaeration.
The presence of increased amounts of oxygen is harmful since it increases the corrosion rate. Deaeration aims at the removal of dissolved oxygen. Dissolved oxygen can be removed by deaeration or by adding some chemical substance like Na_2SO_3.

Dehumidification: Removal of moisture content present in air is called as dehumidification.
This can be achieved by adding silica gel which can absorb moisture preferentially on its surface.

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.

Alloying:

Both corrosion resistance and strength of many metals can be improved by alloying.eg.Stainless steels containing chromium produce a coherent oxide film which protects the steel from further attack.

Surface Coating:

Surface coating the method of coating of one metal over the other metal (metal to be protected from corrosion). Corrosion of metal surfaces is a common phenomenon. To protect a metal surface from corrosion, the contact between the metal and the corrosive environment (air, moisture. corrosive gases, etc.) is to be cut off. This is done by coating the surface of the metal with a continuous, non-porous material. 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 reduces 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.

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.

a) Hot dipping
b) Galvanization
c) Tinning
d) Metal spraying.
e) Cladding.
f) Cementation
g) Sheardizing – Cementation with Zinc powder is called Sheardizing.
h) Chromizing - Cementation with 55% Chromium powder & 45% Alumina is called Chromizing.
i) Calorizing – Cementaion with Aluminium and Alumina powder is called Calorizing
j) Electroplating or electrodeposition.

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.

Galvanization: The process of coating a layer of zinc over iron is called galvanization. The steel article is first pickled with dilute sulphuric acid to remove traces of rust, dust, etc. at 60-90^{0}C for about 15 -20 minutes. Then this metal is dipped in a molten zinc bath maintained at 430^{0}C.

When zinc is coated over iron, zinc and iron forms a galvanic cell. The electropositive zinc forms the anode and undergoes corrosion. Hence iron is protected from corrosion by sacrificial protection method.

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.

Tinning:

The coating of tin over iron is called tin plating or tinning.

Tinning is done to protect iron, steel and copper from corrosion. It is also called tinplating. Since tin is non-toxic, it is mainly used in food industry for coating food containers. Tin-coated utensils are used for storing foodstuffs, pickles, oils, etc.

Tin is nobler metal (more cathodic) than iron. It is more resistant to atmospheric corrosion. Thus, uniform layer of tin protects iron from corrosion.

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. 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 and is not corroded. The corrosion products fill up the cracks, thus preventing corrosion.

Differences between Galvanizing and Tinning.

Galvanizing	Tinning
1. A process of covering iron or steel with a thin coat of ‘Zinc’ to prevent it from rusting.	A process of covering iron or steel 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 without undergo any corrosion (non sacrifically
3. Zinc continuously protects the base	If any break, in coating causes rapid
metal even if broken at some places.	corrosion of base metal.
4. Galvanized containers cannot be used for storing acidic food stuffs as Zinc becomes toxic in acidic medium.	Tin is non-toxic in nature of any medium.

Electroplating (Refer Electrochemistry)

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

Objectives of Electroplating:

1. To increase corrosion resistance.
2. To get better appearance.
3. To increase the hardness.
4. To change the surface properties of metals and non metals.

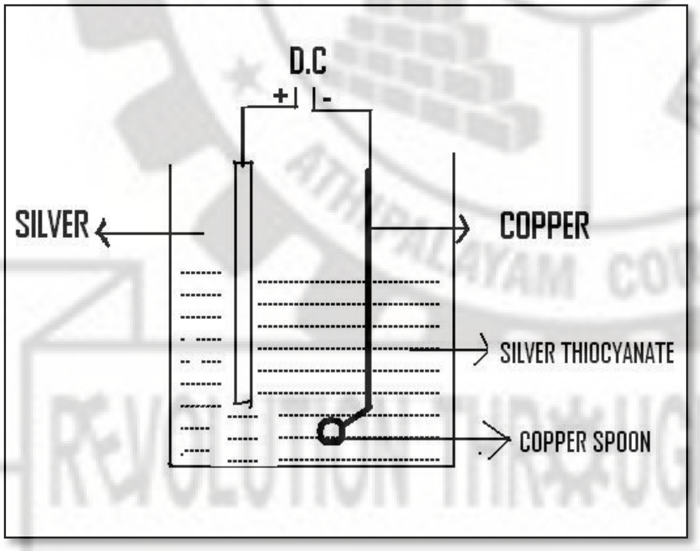
Process

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 the battery and DC current is passed. Now electrolysis takes place and the coat metal is deposited over the base metal.

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

For example, to electroplate a spoon made of copper with silver, the copper spoon 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 spoon.

<u>Electroplating Diagram</u>



The following electrolytes are used for coating other metals.

1. Copper sulphate – Copper
2. Nickel sulphate– Nickel
3. Chromic acid– Chromium

Factors affecting electroplating

The following are the factors affecting electroplating:

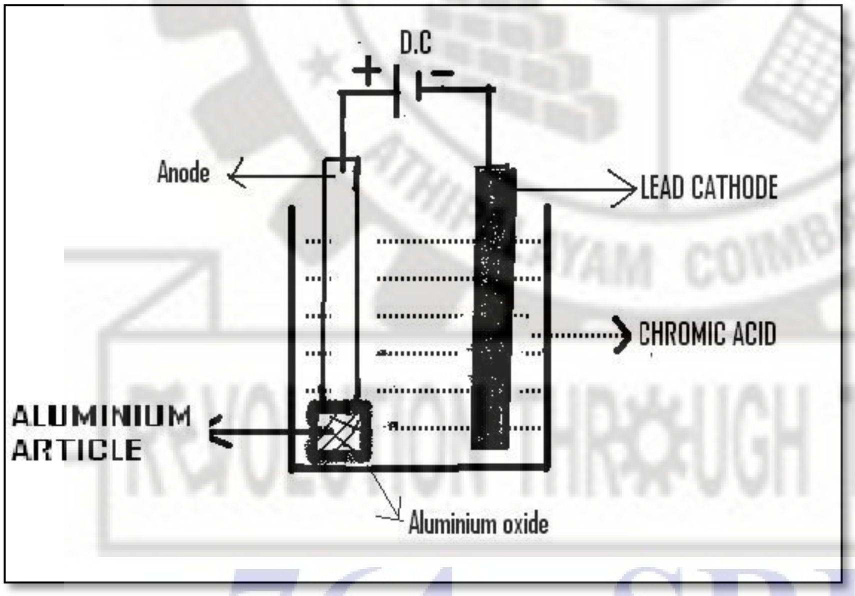
1. Cleaning of the article is essential for a strong adherent electroplating.
2. Concentration of the electrolyte is a major factor in electroplating.
3. Low concentration of metal ions will produce uniform coherent metal deposition.
4. Thickness of the deposit should be minimized in order to get a strong adherent coating.

Additives such as glue and boric acid should be added to the electrolytic bath to get a strong adherent and smooth coating.
The electrolyte selected should be highly soluble and should not undergo any chemical reaction.
The pH of the electrolytic bath must be properly maintained to get the deposition effectively.

INORGANIC COATING

Anodizing:

Anodizing is the process of coating aluminium oxide on the surface of aluminium or its alloy.



This type of coating is produced on non ferrous 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. For anodizing 8% sulphuric acid is used as the electrolyte. Since it is a good oxidising agent, it oxides aluminium (at the anode) into aluminium oxide. The electrolytes are sulphonic, chromic, phosphoric, oxalic or boric acid.

Anodized coatings 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 40^0C) and moderate current densities. The formed oxide film is initially thin and gain thickness by the continuous 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.

The anodized aluminium and its alloy are used in:

1.aircrafts

2.window frames

3.machine parts

4.fancy article and

5.Refrigerator, etc.

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.

Sacrificial anodic protection.

Impressed current cathodic protection.

(a) Sacrificial Anodic Protection:

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:

Protection from soil corrosion of underground cables and pipelines.

Magnesium sheets are inserted into domestic water boilers to prevent the formation of rust.

(b)Impressed current cathodic protection:

In this method, an impresses 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.

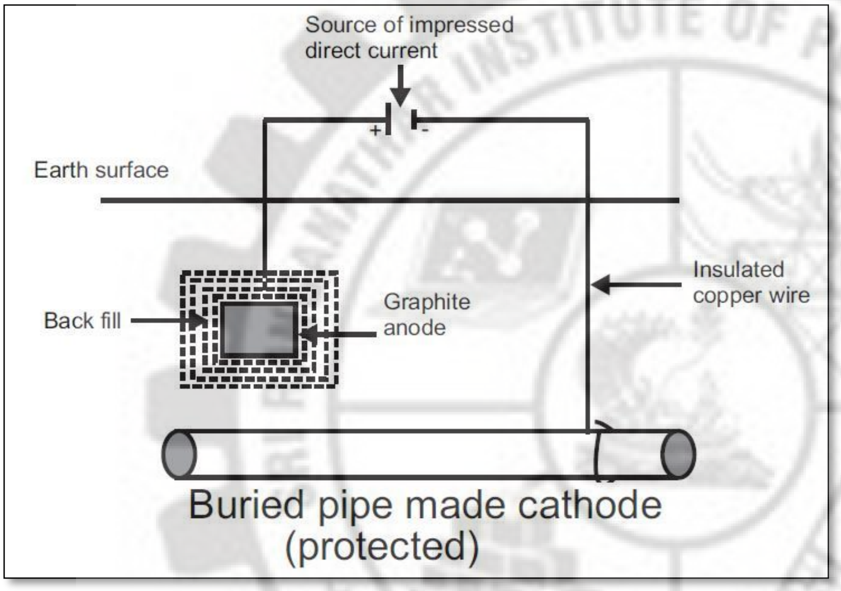


FIGURE: IMPRESSED CATHODIC PROTECTION

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 is impressed on the system, this is called impressed current method

This type of protection is given in the case of buried structures such as tanks and pipelines.

SUMMARY:

In this lesson, prevention of corrosion, Control of environment, Alloying, Surface coatings, Metal coatings, Electroplating, Galvanization and Tinning, Inorganic coating, Anodizing, Cathodic Protection, Sacrificial Anode Method and Impressed Voltage Method are discussed.

Question:

PART -A

1. What is Galvanization?
2. What is anoding?
3. What is base metal?
4. What is coat metal?
5. Galvanizing is preferred to tinning. Why?
6. What is Sherardizing?

PART -B

1. What is a sacrificial anode? How does it function?
2. Differentiate between galvanizing and tinning.
3. What is anodizing? How it is carried out? what are its applications?.
4. What is tinning? What are its merits & demerits?

PART-C

1. Explain the various methods of prevention of corrosion.
2. Explain briefly about cathodic protection
3. Explain briefly about electroplating.

(TEST YOUR UNDERSTANDING)

1. Why is moderate current density employed during electroplating?
2. Chromium anode is not used in chromium plating. Give Reason.

2.3 ORGANIC COATINGS

INTRODUCTION

Organic coating includes paints and varnishes. In this lesson, we are going to study about paint and its components. A little introduction to special paints used is also discussed. Further we are going to study about varnish its types and their preparation.

PAINTS

DEFINITION

Paint is a dispersion of pigment in drying oil.

Paint coating is given to both metallic and wooden articles to protect them from corrosion and to give better surface appearance. Paint covers the manufacturing defects in the articles.

When paint is applied to a metal surface, the thinner evaporates while the drying oil slowly oxidizes forming of pigmented film.

Components of paints and their functions The important constituents of paint are as follows.

1. Pigments
2. Vehicle or drying oils or medium
3. Thinners
4. Driers
5. Fillers or extenders
6. Plasticizers
7. Antiskinning agents

1. Pigment:

A pigment is a solid and colour-producing substance which gives desired colour to the paint.

Example:

- White pigments-- Titanium oxide, Zinc oxide.
- Black pigments -- Graphite, Carbon black.
- Red pigments-- Red Lead, Indian red (Fe_2O_3).

Functions:

The following are the functions of the pigment:

1. A pigment gives opacity and colour to the film.
2. It covers the manufacturing defects.
3. A pigment gives strength to the film.
4. It protects the film by reflecting the destructive ultraviolet rays.

2. Vehicle or drying oils or medium:

The liquid portion in which the pigment is dispersed is called a medium or vehicle.

Example:

Linseed oil, dehydrated castor oil, soybean oil and fish oil.

Functions:

1. Vehicles hold the pigment particles together on the metal surface.
2. They form the protective film by evaporation or by oxidation and polymerization of the unsaturated constituents of the oil.
3. Vehicles give better adhesion to the metal surface.
4. They impart water repellency, durability and toughness to the film.

3. Thinner:

Thinners are added to paints to reduce the viscosity of the paints in order to make it easy to apply on the metal surface.

Example:

Turpentine, kerosene and petroleum sprit.

Functions:

1. Thinners reduce the viscosity of the paint to render it easy to handle and apply to the metal surface.
2. They dissolve the oil, pigments etc. and produce a homogeneous mixture.
3. Thinners evaporate rapidly and help the drying of the film.
4. They increase the elasticity of the film.

4.Driers:

Driers are used to speed up the drying process and accelerate the drying of the oil film by oxidation, polymerization and condensation.

Example:

Naphthentates and Resinates of lead, cobalt and manganese.

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. Fillers or extenders:

Fillers are used to increase the volume of the paint and to reduce the cost. It increases the durability of the paint,.

Example:

Asbestos, talc, china clay, calcium sulphate and calcium carbonate.

Functions:

Fillers serve to fill the voids in the film.
They reduce the cracking of the paints.
Fillers increase the durability of the paints.
They reduce the cost of the paint.

6.Plasticizers:

Plasticizers are chemicals added to increase elasticity of the film and to prevent cracking of the film.

Example:

Tertiary amyl alcohol, triphenyl phosphate,triglyceryl phosphate.

7. Antiskinning agents:

They are chemicals added to the paint to prevent skinning of the paint.

Example:

Polyhydroxy phenols, guaiacol, etc.

VARNISHES

Definition

Varnish is a homogenous colloidal dispersion of natural or synthetic resin in oil or spirit medium.

1. If the medium is oil it is known as oil varnishes.
2. If the medium is spirit it is known as spirit varnishes.
3. It is used as a protective and decorative coating to the wooden surfaces. It provides a hard, transparent, glossy appearance and durable film to the coated surface.

There are two main types of varnishes

1. Oil Varnish
2. Spirit Varnish

Preparation of oil Varnish.

Oil varnishes are more difficult to manufacture. Resins that are used in the preparation of oil varnishes are high molecular weight substances and are not easily soluble in oil. The resin is taken in an aluminium vessel and heated over a fire pit or in a small furnace. When resin melts , the temperature is slowly increased to about 300^0C. 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 fumes.

The required quantity (about 25 per cent of the weight of the resin) of boiled oil or linseed oil along with driers is separately heated to 200 to 220^0C and is slowly added to the heated resin with constant stirring until thorough combination has taken place. This operation is known as **cooking**. Over heating must be avoided as it causes discoloration of the varnish.

The kettle is removed from the furnace and allowed to cool, white spirit is then added (which is a petroleum fraction, boiling between 150^0C and 200^0C). It is the most common thinner.

The varnish is stored in tanks for some days for maturing. Foreign matter and particles of resin, which have not dissolved, settle during this period. During maturing, the colour of the varnish also improves and it becomes more homogenous. The varnish is filtered and packed for marketing.

2. SPIRIT VARNISHES

A Spirit varnish is a dispersion of resin in spirit.

Preparation

The resin and spirit are placed in a cylindrical drum. plasticizer and other components are added. The resin is dissolved by agitating the mixture or by rotating the drum. It is then filtered and used. The final product is called spirit 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

Special paints

In addition to the normal ingredients some special chemicals are in corporated to paints for some specific purposes. They are commonly known as special paints.

1. Luminous paints

Luminous paints are visible in the dark. Since it contain luminophor pigments (like CdS, ZnS) that are used for visibility in the dark .They absorb light radiations and emit them in the dark. The active components in luminous paint are specially prepared phosphorescent materials like CdS, ZnS, etc. For colour effect in luminous paints, certain chemicals like copper salts (green), silver salts (blue), cerium and uranium salts (yellow), etc. are added

Uses:

They find application in inks, advertising signboards, road marks, road traffic signs, number plates of vehicles, watch dials, map, chart, etc

.2. Fireretardant paints

The paints which retard the fire are called as fire-retardant.

This paint contains the chemicals PVC, Chlorinated rubber, urea formaldehyde and carbonate pigments which are fire-resistant in nature. These substances at higher temperatures breakdown to give the non-inflammable gases like CO_2,NH_3,HCl and HBr. These gases are non-combustible and do not support combustion. Thus the fire is retarded.

Uses:

Mainly used in defence, industrial, commercial, education and residential complexes

The most frequent source of a fire in any hotel, restaurant or residence. The walls, doors and even kitchen counters should be protected against the spread of fire.

False ceiling, Lift, Equipment Rooms, Aircraft Safe deposit vaults, lockers, Computer Server rooms, Power plants Chemical Plants, Storage Tanks, structures in Sugar Mills, Textile Mills and Floorings.

3. Aluminium Paint

The base material in aluminium paint is a fine powder of aluminium. The ground fine powder of aluminium is suspended in either spirit varnish or an oil-varnish depending on the requirement. When paints are applied, the thinner evaporates and oil, if any, undergoes oxidation and polymerization. A bright adhering film of aluminium is obtained on the painted surface.

Uses:

Wooden and metallic article for interior and exterior decoration.

Advantages of aluminium paint:

It possesses a good covering power.
It imparts very attractive appearance to the surface.
It has fairly good heat-resistance.
It has very good electrical resistance
The painted film is waterproof.
The electrical surface is visible even darkness.

Corrosion protection for iron and steel surface is better than all other paints.

3. Distempers

Distempers are water paints. They contain chalk powder, glue and pigment dissolved in water. They are very cheap and can be easily applied on walls. They are durable and give pleasing finish to walls. The ingredients of distemper are

Whiting agent or chalk powder (the base)
Glue or casein (the binder)
Colouring pigment and
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.

SUMMARY:

In this lesson the organic coating like Paint, Components of Paints and their functions, Varnish Preparation of Oil Varnish, Differences between Paint and Varnish, Special Paints, Luminescent Paints, Fire retardant Paints, Aluminium Paints and Distemper are discussed.

QUESTIONS:

PART -A

1. Define paint.
2. What is Varnish?
3. What is distemper?

PART-B

Write a short note on luminous paints.
Write a note on Aluminium paints.
Explain about Fire retardant paint.
What are the differences between paint and varnish?

PART-C

What are the components present in the paint. Explain their functions.
How is oil varnish preferred?
Explain briefly about special paints.

Test your understanding

(Not for exam purpose)

1.What are toners?

UNIT III
FUELS

3.1Fuels

Fuel- Definition-Calorific value- Calorie-Liquid fuels- liquid hydrogen- power alcohol- uses- Refining of Petroleum – Fractional distillation- Cracking (Concept only) – Gaseous fuels- Preparation, composition and specific uses of producer gas and water gas- composition and uses of CNG and LPG- advantages of gaseous fuels.

3.2Combustion

Definition- Combustion calculation by mass (for solid and liquid fuels) – Stiochiometric calculations- Volume of air required – Definition of Flue gas- Flue gas Analysis- Orsat Apparatus- Simple numerical Problems

3.3Rocket Propellants

Definition- Characteristics – Classification of propellants- brief idea of solid and liquid propellants.

3.1 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. Hence, the carbon compounds have been used as the main source of heat energy.

Fuel

A fuel is a substance, which on proper burning gives large amount of heat energy on combustion. It is used for domestic and industrial purposes. They contain carbon as a main constituent.

Fossil fuel

The main sources of fuels are coal and petroleum oils available in earth’s crust and they are called fossil fuels.

The other sources of fuels are

- Radioactive elements and
- Sunlight

Calorific value of a fuel

Calorific value of a fuel is the total quantity of heat liberated when a unit mass or volume of the fuel is completely burnt.

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° Centigrade (1 kcal = 1000 calories)

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

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 permitted to escape.

Net Calorific Value = Gross calorific value – Latent heat of water vapour formed.

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.

Sl. No.	State of fuel	Natural	Artificial
1	Solid	Wood, peat, lignite, coal	Wood charcoal, coke
2	Liquid	Crude petroleum	Kerosene, petrol, diesel, alcohol
3	Gaseous	Natural gas	Water gas, producer gas, biogas, coal gas, LPG

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_2 = 6%; O_2 = 43% and ash = 1%. The calorific value of dried wood is 3500 to 4500 kcal/kg. It burns with a long and non-smoky flame. It is used as a domestic fuel.

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 calorific 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_2 = 6%; O_2 = 35% and ash = 2.5%. The calorific value of peat is 5400 kcal/kg. It is a low-grade fuel due to high water content.

Uses

1. It is used as fertilizer.
2. It is used as packing material.

2. Lignite

Lignite is immature form of coal. It contains 20-60% moisture. Air- dried lignite contains C = 60-70% and O_2 = 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 production.
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_2 = 10%; H_2 = 5% and N_2 = 2%. Its calorific value is 8500 kcal/kg.

Uses

1. It is used in metallurgy.
2. It is used in steam production.
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_2 = 3%; H_2 = 3% and N_2 = 0.7%. It burns without smoke. Its calorific value is 8700 kcal/kg.

Uses:

1. It is used for steam production 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.

Liquid fuels

Petroleum

Petroleum (Crude oil) is a 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 carried out 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.

bRefining of petroleum – Process

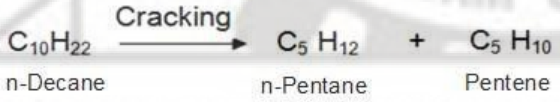
The crude oil is treated with copper oxide to remove sulphur impurities. Then it is repeatedly washed with sulphuric acid to remove basic impurities. It is then washed with sodium hydroxide to remove acidic impurities. Then it is subjected to fractional distillation and various fractions are collected. The various fractions obtained and their uses are given in the table below.

<u>Products of fractional distillation of petroleum and their uses:</u>

SL. 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°Cto 250°C	Used as illuminant and fuel
5	Diesel oil or gas oil	250°C to 320°C	Used as fuel for diesel engine
6	Heavy oil or lubricating oil	320°Cto 400°C	Used for lubrication, cosmetics and in medicines
7	Residue or asphalt or pitch	Above 400°C	Used for road making and water proofing of roofs

Cracking

Cracking is a process by which the hydrocarbons 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.



a. Liquid hydrogen as a fuel

Hydrogen is a colourless and odourless gas composed of diatomic molecules. It holds greater role as fuel in future.

Liquid hydrogen 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 and CO_2 causing environmental pollution. Hence, hydrogen as a fuel has more advantages than any other fossil fuels.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

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 liquefied below its temperature of 33.1K. It is a colourless, odourless liquid below 20.2 K. When allowed to expand, it gets heated up above 22 K.

Gaseous fuels

Examples: Producer gas, water gas, CNG and LPG

Producer gas

Producer gas is a mixture of carbon monoxide and nitrogen. It also contains traces of hydrogen and carbon dioxide.

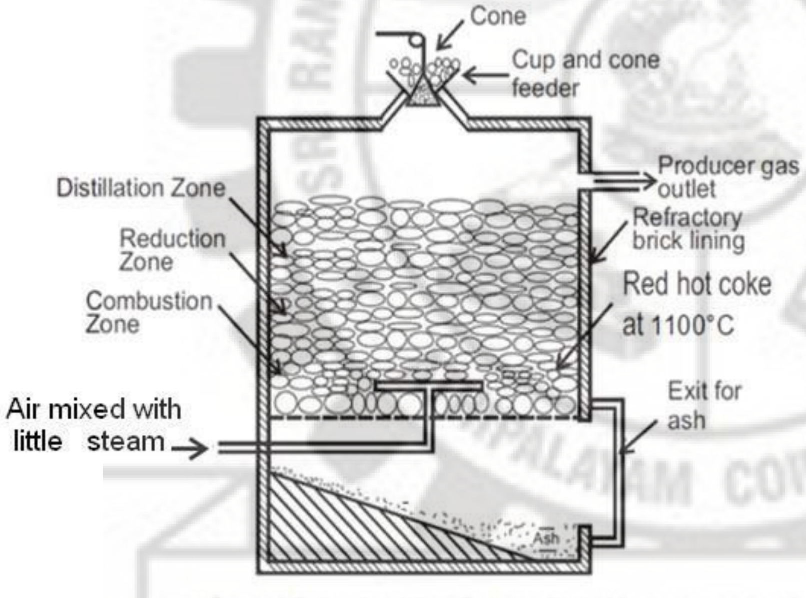
The average composition of producer gas is CO = 22-30%; H_2 = 8-12%; N_2 = 52-55% and CO_2 = 3%.Its calorific value is about 1300 kcal/m^3.

Preparation

Producer gas is prepared by passing air over a red hot coke at about 1100°C in a reactor called gas producer.

$$C + O_2 \longrightarrow CO_2$$

$$CO_2 + C \longrightarrow 2CO$$



Producer gas production

The reactor consists of a steel vessel lined inside with refractory bricks. At the top, it is provided with cup and cone arrangement and an exit for producer gas. At the bottom, it has an inlet for passing air. There is an exit for the ash at the base.

Uses

1. It is used as a fuel in the extraction of metal.
2. It is used in the manufacture of glass.
3. It is used as a reducing agent in metallurgy.

Water gas

Water gas is a mixture of carbon monoxide and hydrogen. It also contains traces of carbon dioxide and nitrogen.

The average composition of water gas is CO = 41%; H_2 = 51%; N_2 = 4% and CO_2 = 4%. Its calorific value is 2800 kcal/m^3.

Preparation

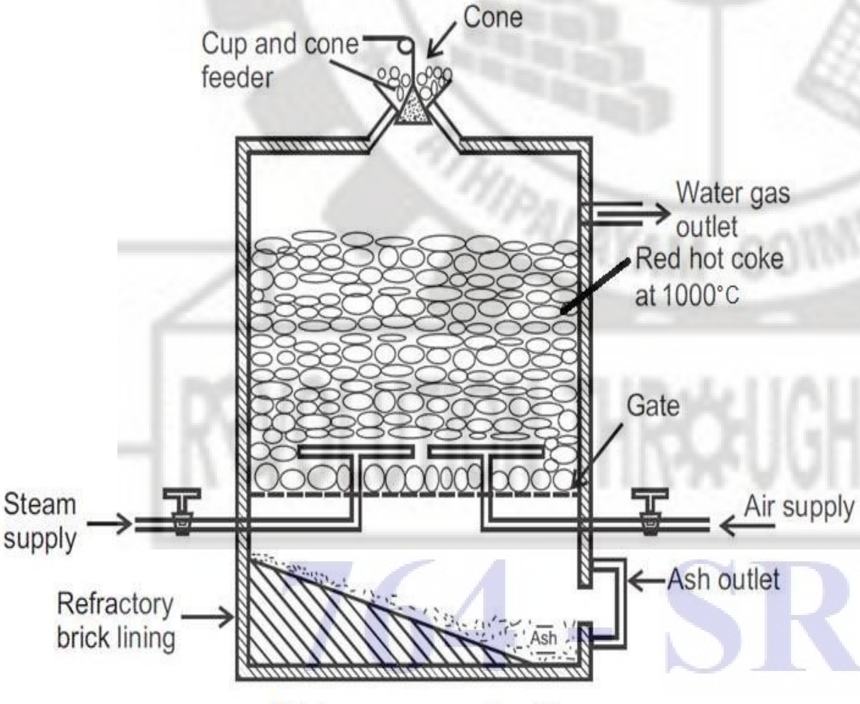
Water gas is prepared by passing steam and little air alternatively over a red hot coke at about 1000°C in a reactor. It is an endothermic reaction. So the temperature of the system decreases.

$$\underset{\text{(Coke)}}{C} + \underset{\text{(Steam)}}{H_2O} \longrightarrow CO + H_2 \text{ (Endothermic reaction)}$$

But, the reaction between carbon and air is exothermic and raises the temperature to about 1000°C

$$C + O_2 \longrightarrow CO_2 \text{ (Exothermic reaction)}$$

Thus, the steam and air are sent in alternatively to maintain the temperature at about 1000°C.



Water gas production

The reactor consists of a steel vessel lined inside with refractory bricks. At the top, it has cup and cone feeder and an exit for water gas. 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 in ceramic industries.

CNG (Compressed natural gas)

CNG is a good alternative fossil fuel. It mainly contains methane.
CNG is made by compressing natural gas which is found in oil deposits landfills and waste water treatment plants to less than 1% of its volume, it occupies at standard atmospheric pressure.
It is stored and distributed in hard containers at a pressure of 2900-3600 psi.

Advantages

1. It is cheaper than petrol or diesel.
2. It emits fewer pollutants like CO_2, CO, etc. In New Delhi, it is used as a fuel for entire city bus fleet, taxis and three wheelers.
3. It is safer than other fuels. In the event of a spill, it disperses quickly in air because, it lighter than air.

LPG (Liquefied petroleum gas)

1. It is a mixture of propane and butane.
2. It is stored in steel cylinder under high pressure.
3. When the cylinder is opened, it comes out in the form of gas.
4. Commercially, it is supplied under various trade names.
5. Its calorific value is 27,800 kcal/m^3.

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.

Relative advantages of solid, liquid and gaseous fuels

Sl. No.	Property	Solid fuel	Liquid fuel	Gaseous fuel
1	Calorific value	Low	Greater than solid fuel and less than gaseous fuel	Very high
2	Smoke production	High	Low	Nil
3	Ash formation	Ash produced	Very low	Nil
4	Storage	Large space needed	Less space needed	Minimum space needed

5	Transportation	More labour involved	Much less labour involved	Transported easily through pipelines
6	Ignition	Difficult	Easy	Very easy
7	Flame control	Difficult	Easy	Very easy

Summary

In this lesson, different types of fuels, their composition and uses are discussed. The manufacture, composition and uses of producer gas, water gas and some details about CNG and LPG are also discussed.

QUESTIONS PART – A

1. Define fuel.
2. Define fossil fuel.
3. Define calorific value of a fuel.
4. How are fuels classified?
5. Give two examples for solid fuels.
6. Give two examples for liquid fuels.
7. Give two examples for gaseous fuels.
8. What are the varieties of coal?
9. What is petroleum?
10. What is meant by cracking?
11. What is producer gas?
12. Give the composition of producer gas.
13. What is water gas?
14. Give the composition of water gas.
15. What are the components present in CNG?
16. Mention the uses of CNG.
17. What are the components present in LPG?
18. Mention the uses of LPG.

PART – B

1. What is refining of petroleum?
2. Write a note on liquid hydrogen as fuel.
3. Give the composition and uses of producer gas.
4. Give the composition and uses of water gas.
5. Give the composition and uses of CNG.

PART – C

1. Write a note on solid fuels.
2. Explain the fractional distillation of petroleum.

3. Describe the manufacture of producer gas. List its uses.
4. Describe the manufacture of water gas. List its uses.
5. Write a note on CNG.
6. Write a note on LPG.
7. Compare the relative advantages of solid, liquid and gaseous fuels.

TEST YOUR UNDERSTANDING

Think of how household waste can be utilized to produce gaseous fuel.

3.2 COMBUSTION

INTRODUCTION

Combustion is an exothermic chemical reaction accompanied by heat and light. To ensure complete combustion, substance should be brought to its ignition temperature. Most of the combustible substances are enriched with carbon, hydrogen and sulphur. During combustion they undergo thermal decomposition and oxidation to give products like CO_2,H_2O and SO_2 etc.

Hence for an efficient combustion it is essential that the fuel must contact with sufficient quantity of air. The air contains oxygen which is used for combustion. But the non-combustible constituents like N_2,CO_2,and H_2O do not take any oxygen from air.

Incomplete combustion occurs only when there is too little air or oxygen is supplied. During incomplete combustion the carbon monoxide is formed instead of CO_2.

Ignition temperature:

The minimum temperature at which a fuel catches fire and burns is called ignition temperature.

Definition:

The chemical reaction of a fuel with oxygen(oxidising agent) which produces heat and light energy is called combustion of a fuel.

Example: Combustion of carbon

$$C + O_2 \longrightarrow CO_{2(g)} + 97 \text{ kcal}$$

The gaseous products of combustion are mainly CO, CO_2, N_2, SO_2, O_2 and H_2O which are known as flue gases. The main elements present in most of the fuels are carbon (C), hydrogen (H), oxygen (O) and sulphur (S).

Air contains 23% by mass of oxygen and 21% by volume of oxygen.

Combustion calculation by mass (for solids and liquids):

Stochiometric or minimum quantity of air required for the complete combustion of solid and liquid fuels

Substances always combine in definite proportions which are determined by the molecular masses of the substances involved and the products formed.

1. Combustion of Carbon

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

12 32 44

12 kg of carbon requires32 kg of oxygen for complete combustion

$$\therefore \left.\begin{array}{l}\text{The given carbon in the fuel requires}\\ \text{oxygen for complete combustion}\end{array}\right\} = \frac{32}{12} \times C \text{ kg}$$

$$\therefore \left.\begin{array}{l}\text{For } C \text{ Kg carbon in the fuel requires}\\ \text{oxygen for complete combustion}\end{array}\right\} = \frac{8}{3} \times C \text{ kg} \quad \text{———} \quad (1)$$

1. Combustion of Hydrogen

$$2\,H_{2(g)} + O_{2(g)} \longrightarrow 2\,H_2O_{(l)}$$

$$4 \qquad 32 \qquad\qquad 36$$

4 kg of hydrogen requires 32 kg of oxygen for complete combustion

$$\therefore \left.\begin{array}{l}\text{The given hydrogen in the fuel requires}\\ \text{oxygen for complete combustion}\end{array}\right\} = \frac{32}{4} \times H \text{ kg}$$

$$\therefore \left.\begin{array}{l}\text{For } H \text{ Kg of hydrogen in the fuel requires}\\ \text{oxygen for complete combustion}\end{array}\right\} = 8 \times H \text{ kg}$$

$$= 8\,H \text{ Kg} \longrightarrow 2$$

Combined hydrogen in fuel present as moisture (H_2O) does not undergo combustion. The rest of hydrogen only takes part in the combustion reaction.

2. Combustion of Sulphur

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

$$32 \qquad 32 \qquad\qquad 64$$

32 kg of sulphur requires 32 kg of oxygen for complete combustion

$$\therefore \left.\begin{array}{l}\text{The given sulphur in the fuel requires}\\ \text{oxygen for complete combustion}\end{array}\right\} = \frac{32}{32} \times S \text{ kg} \quad \text{———} \quad (3)$$

$$= S \text{ kg}$$

On combining the above three equations,

Let us assume that 1 Kg of fuel contains' C' Kg of carbon, H Kg of hydrogen and S Kg of sulphur. Then the total mass of oxygen required for the complete combustion of 1 Kg of fuel is given below:

$$\left.\begin{array}{l}\text{The theoretical oxygen required for}\\ \text{combustion of 1 Kg of fuel}\end{array}\right\} = \frac{8}{3} \times C + 8H + S \text{ Kg}$$

'C'=Wt. of carbon;H=Wt.of hydrogen;S=Wt.of sulphur

☐ Minimum mass of oxygen is calculated on the basis of complete combustion. **Note. If the fuel already has some amount of oxygen, then that amount of oxygen has to be deducted from the total mass**

Minimum mass of oxygen required = Theoretical O_2 required – O_2 present in fuel

$$\left.\begin{array}{c}\text{ie.,The total mass of oxygen}\\ \text{required per Kg of fuel}\end{array}\right\} = \left[\frac{8}{3} \times C + 8H + S\right] - O_2$$

$$(\text{'}O_2\text{'} = \text{Mass of oxygen})$$

<u>Mass percentage of oxygen</u>

The mass percentage of oxygen in air=23%

23% of Oxygen is supplied by 100 % Mass of air supply That

is to supply 23 Kg of oxygen = 100 kg of air required

$$\text{Hence, one kg of oxygen is supplied by} = \frac{100}{23}\ \text{kg of air}$$

Hence the mass of air that is required for combustion of 1 Kg of fuel is

$$\begin{array}{l}\text{Minimum mass of air required}\\ \text{for combustion of 1 kg of fuel}\end{array} = \left[\left[\frac{8}{3} \times C + 8H + S\right] - O_2\right] \times \frac{100}{23}\ \text{Kg}$$

Where C, H, O and S are the respective masses of carbon, hydrogen, oxygen and sulphur present in 1 kg of the fuel.

Examples:

Example 1

A fuel contains 90% carbon, 3.5% hydrogen, 3% oxygen and 0.5% sulphur Determine stoichiometric mass of air required to completely burn 1 kg of this fuel.

C = 90% = 0.9 kg

H = 3.5% = 0.035 kg

O = 03% = 0.03 kg

S = 0.5% = 0.005 kg

1. Combustion of carbon

$$\therefore \left.\begin{array}{l}\text{For C Kg carbon in the fuel requires} \\ \text{oxygen for complete combustion}\end{array}\right\} = \frac{8}{3} \times C \text{ kg}$$

For 0.9 kg of C requires oxygen for complete combustion

$$= \frac{8}{3} \times 0.9$$

$$= 2.4 \text{ kg}$$

2. Combustion of hydrogen

$$\therefore \left.\begin{array}{l}\text{For H Kg of hydrogen in the fuel requires} \\ \text{oxygen for complete combustion}\end{array}\right\} = 8XH \text{ kg}$$

 0.035 kg of hydrogen requires oxygen for complete combustion

$$= 8H$$

$$= 8 \times 0.35 = 0.28 \text{ kg}$$

3. Combustion of Sulphur

$$\therefore \left.\begin{array}{l}\text{The given sulphur in the fuel requires} \\ \text{oxygen for complete combustion}\end{array}\right\} = \frac{32}{32} \times S \text{ kg}$$

$$= S \text{ kg}$$

 0.005 kg of sulphur requires oxygen for complete combustion $= \frac{32}{32} \times 0.005$

$$= 0.005 \text{ kg}$$

Minimum mass of oxygen required for complete combustion of 1 kg of the fuel (Theoretical O_2 required) $\Big\}$ = 2.4 + 0.28 + 0.005

= 2.685 kg

Minimum mass of oxygen required = Theoretical O_2 required – O_2 present in fuel

= 2.685 – 0.03

= 2.655 kg

Minimum mass of air required for complete combustion of 1 kg of the fuel $\Big\}$ $= \frac{100}{23} \times 2.655$

= 11.54kg

Example 2:

Calculate the minimum mass of air required for complete combustion of 1 kg of a fuel having the composition C = 92%, H_2 = 4%, O_2 = 2% and ash = 2% by weight.

C = 92% = 0.92 kg

H_2 = 04% = 0.04 kg

O_2 = 02% = 0.02 kg

1. Combustion of carbon

∴ **For C Kg** carbon in the fuel requires oxygen for complete combustion $\Big\}$ $= \frac{8}{3}$ x C kg

∴ 0.92 kg of C requires oxygen for complete combustion = = $\frac{8}{3}$ x C kg

$= \frac{8}{3} \times 0.92$ kg

= 2.45 kg

2. Combustion of hydrogen

∴ **For H Kg of** hydrogen in the fuel requires oxygen for complete combustion $\Big\}$ = 8XH kg

For 0.04 kg of hydrogen requires oxygen for complete combustion

=8x0.04
=0.32

= 0.32 kg

Minimum mass of oxygen required for complete combustion of 1 kg of the fuel (Theoretical O_2 required) $\Big\}$ = 2.45 + 0.32

$= 2.77$ kg

Minimum mass of oxygen required = Theoretical O_2 required – O_2 present in fuel

$= 2.77 – 0.02$

$= 2.75$ kg

$$\left.\begin{array}{l}\text{Minimum mass of air required for}\\ \text{complete combustion of 1 kg of the fuel}\end{array}\right\} = \frac{100}{23} \times 2.75$$

$= 11.96$kg

Example 3:

Calculate the minimum amount of air by mass required for complete combustion of 2 kg of coke assuming 100% carbon.

$$\therefore \left.\begin{array}{l}\text{For C Kg carbon in the fuel requires}\\ \text{oxygen for complete combustion}\end{array}\right\} = \frac{8}{3} \times C \text{ kg}$$

Mass of O_2 required for combustion of 2 kg of coke $= \frac{8}{3} \times 2$ kg

$= 5.33$ kg

$$\left.\begin{array}{l}\text{Minimum mass of air required for}\\ \text{combustion of 2 kg of coke}\end{array}\right\} = \frac{100}{23} \times 5.33$$

$= 23.17$ kg

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% preheated air is supplied.

Total mass of air/kg of fuel = Stoichiometric mass of air + Excess mass of air

Let the theoretical minimum air supplied = Y Kg

Let the Air supplied in excess is = 50%

Excess air supplied = $\frac{150}{100}$

$$\left.\begin{array}{l}\textbf{Then the actual amount of air supplied}\\ \textbf{per Kg of the fuel including the excess}\\ \textbf{air}\end{array}\right\} = Y \times \left\{\frac{100+50}{100}\right\}$$

$$\left.\begin{array}{l}\text{Minimum mass of air required for}\\ \text{complete combustion of 1 kg of the fuel}\end{array}\right\} = Y \times \frac{150}{100}$$

$= Y \times$ **1.5 Kg of air**

Example 4

Calculate the mass of air to be supplied for the combustion of 1 kg of a fuel containing 75% carbon, 8% hydrogen and 3% oxygen, if 40% excess air is supplied.

C = 75% = 0.75 kg

H = 8% = 0.08 kg

O = 3% = 0.03 kg

1. Combustion of carbon

$\therefore$ For C Kg carbon in the fuel requires oxygen for complete combustion $\left.\right\} = \frac{8}{3} \times C$ kg

□0.75 kg of C requires oxygen for complete combustion

$$= \frac{8}{3} \times 0.75 \text{ kg}$$

2. Combustion of hydrogen

$\therefore$ For H Kg of hydrogen in the fuel requires oxygen for complete combustion $\left.\right\} = 8 X H$ kg

0.08 kg of hydrogen requires oxygen for complete combustion

$= 8H$

$= 8 x .08$

$= 0.64$ kg

Minimum mass of oxygen required for complete combustion of 1 kg of the fuel (Theoretical O_2 required) $\left.\right\} = 2 + 0.64$

$= 2.64$ kg

Minimum mass of oxygen required = Theoretical O_2 required – O_2 present in fuel

$= 2.64 – 0.03$

$= 2.61$ kg

Minimum mass of air required for complete combustion of 1 kg of the fuel $\left.\right\} = \frac{100}{23} \times 2.61$

$= 11.35$kg

Excess air supplied = 40%

Minimum mass of air required for complete combustion of 1 kg of the fuel $\left.\right\} = 11.35 \times \frac{140}{100}$

$= 15.89$ kg

Combustion calculation by volume(for gaseous fuels):

Stochiometric or minimum volume of air required for the complete combustion of 1 m^3 gaseous fuels

The volume of air required for the combustion of gaseous fuels is calculated mainly based on the balanced combustion equation.

1. Combustion of carbon monoxide

$2CO + O_2 \longrightarrow 2CO_2$

2 vol 1 vol 1vol

$2m^3$ of CO needs $1m^3$ of oxygen Therefore;

1 m^3 of CO needs 0.5 m^3 of O_2 for combustion

2. Combustion of hydrogen

$2H_2 + O_2 \longrightarrow 2H_2O$

2 vol 1 vol 1vol

$2m^3$ of Hydrogen needs $1m^3$ of oxygen Hence;

1 m^3 of H_2 needs 0.5 m^3 of O_2 for combustion

3. Combustion of methane

$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O$

1 vol 2 vol 1 vol 2 vol

1 m^3 of CH_4 needs 2 m^3 of O_2 for combustion

4. Combustion of ethane

$2C_2H_6 + 7O_2 \longrightarrow 4\,CO_2 + 6\,H_2O$

2 vol 7 vol 4 vol 6 vol

$2m^3$ of ethane needs 7 m^3 of oxygen

Hence;

1 m^3 of C_2H_6 needs 3.5 m^3 of O_2 for combustion

5. Combustion of ethylene

$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$

1 m^3 of C_2H_4 needs $3m^3$ of O_2 for combustion Calculation of minimum volume of air required:

The minimum volume lf air required is calculated by multiplying the oxygen required by 100/21 since the percentage volume of air is 21%.

Example 1

Determine the volume of air needed for complete combustion of one cubic meter of producer gas having the following composition by volume.

H_2 = 30%, CO = 12%, CH_4 = 5% and N_2 = 50%.

H_2 = 30% = 0.3 m^3

CO = 12% = 0.12 m^3

CH_4 = 05% = 0.05 m^3

1. Combustion of hydrogen

–

1 m^3 of H_2 needs 0.5 m^3 of O_2 for combustion

□0.3 m^3 of H_2 requires oxygen for complete combustion = $\frac{0.5}{1}$ x 0.3

= 0.15 m^3

2. Combustion of carbon monoxide

1 m^3 of CO needs 0.5 m^3 of O_2 for combustion

□0.12 m^3 of CO requires oxygen for complete combustion = $\frac{0.5}{1}$ x 0.12

= 0.06 m^3

3. Combustion of methane

1 m^3 of CH_4 needs 2 m^3 of O_2 for combustion

0.05 m^3 of CH_4 requires oxygen for complete combustion = $\frac{2}{1}$ x 0.05

= 0.1 m^3

$$\left.\begin{array}{l}\text{Volume of oxygen needed for}\\ \text{complete combustion of 1m}^3\text{ of gas}\end{array}\right\} = 0.15 + 0.06 + 0.1$$

= 0.31 m^3

$$\left.\begin{array}{l}\text{Minimum volume of air required}\\ \text{for combustion of 1 m}^3\text{ of gas}\end{array}\right\} = \frac{100}{21} \times 0.31$$

= 1.48 m

Example 2

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.

H_2 = 45% = 0.45 m^3

CO = 40% = 0.4 m^3

CH_4 = 12% = 0.12 m^3

O_2 = 03% = 0.03 m^3

1. Combustion of hydrogen

1 m^3 of H_2 needs 0.5 m^3 of O_2 for combustion

Hence;

□0.45 m^3 of H_2 requires oxygen for complete combustion = $\frac{0.5}{1} \times 0.45$

= 0.225 m^3

2. Combustion of carbon monoxide

1 m^3 of CO needs 0.5 m^3 of O_2 for combustion

□0.4 m^3 of CO requires oxygen for complete combustion = $\frac{0.5}{1} \times 0.4$

= 0.20 m^3

3. Combustion of methane

1 m^3 of CH_4 needs 2 m^3 of O_2 for combustion

□0.12 m^3 of CH_4 requires oxygen for complete combustion = $\frac{2}{1} \times 0.12$

= 0.24 m^3

$$\left.\begin{array}{l}\text{Volume of oxygen needed for}\\ \text{complete combustion of } 1m^3 \text{ of gas}\\ (\text{Theoretical } O_2 \text{ required})\end{array}\right\} = 0.225 + 0.20 + 0.24$$

= 0.665 m^3 O_2

Minimum volume of oxygen required = Theoretical O_2 required - O_2 present in fuel.

= 0.665 – 0.03

$= 0.635\ m^3$

$$\left.\begin{array}{l}\text{Minimum volume of air required for}\\ \text{combustion of 1 } m^3 \text{ of gas}\end{array}\right\} = \frac{100}{21} \times 0.635$$

$= 3.023\ m^3$ of air

Example 3

Volumetric analysis of producer gas supplied to a engine is, H_2 = 20%, CO = 22%, CH_4 = 3%, CO_2 = 8% and N_2 = 47%

Excess air supplied is 50%. Estimate the volume of air required for combustion of 1 m^3 of gas.

$H_2 = 20\% = 0.2\ m^3$

$CO = 22\% = 0.22\ m^3$

$CH_4 = 3\% = 0.03\ m^3$

1. Combustion of hydrogen

–

1 m^3 of H_2 needs 0.5 m^3 of O_2 for combustion

□0.2 m^3 of H_2 requires oxygen for complete combustion = $\frac{0.5}{1} \times 0.2$

$= 0.1\ m^3$

2. Combustion of carbon monoxide

1 m^3 of CO needs 0.5 m^3 of O_2 for combustion

□0.22m^3 of CO requires oxygen for complete combustion = $\frac{0.5}{1} \times 0.22$

$= 0.11\ m^3$

3. Combustion of methane

1 m^3 of CH_4 needs 2 m^3 of O_2 for combustion

□0.03 m^3 of CH_4 requires oxygen for complete combustion = $\frac{2}{1} \times 0.03$

$= 0.06\ m^3$

$$\left.\begin{array}{l}\text{Volume of oxygen needed for}\\ \text{complete combustion of } 1m^3 \text{ of gas}\end{array}\right\} = 0.1 + 0.11 + 0.06$$

$$= 0.27\ m^3$$

$$\left.\begin{array}{l}\text{Minimum volume of air required}\\ \text{for combustion of } 1\ m^3 \text{ of gas}\end{array}\right\} = \frac{100}{21} \times 0.27$$

$$= 1.28\ m^3$$

Excess air supplied = 50%

$$\therefore \left.\begin{array}{l}\text{Minimum volume of air required}\\ \text{for combustion of } 1\ m^3 \text{ of gas}\end{array}\right\} = 1.28 \times \frac{150}{100}$$

$$= 1.92\ m^3$$

Problem:4

A gas has the following % composition by volume CH_4=4%, CO=22%.H_2=14%.CO_2=6% N_2=52% and O_2=3%.

H_2 = 14% = 0.14 m^3

CO = 22% = 0.22 m^3

CH_4 = 4% = 0.04 m^3

1. Combustion of hydrogen

1 m^3 of H_2 needs 0.5 m^3 of O_2 for combustion

☐0.2 m^3 of H_2 requires oxygen for complete combustion

$$= \frac{0.5}{1} \times 0.14$$

$= 0.700\ m^3$

2. Combustion of carbon monoxide

1 m^3 of CO needs 0.5 m^3 of O_2 for combustion

☐0.22m^3 of CO requires oxygen for complete combustion $= \frac{0.5}{1} \times 0.22$

3. Combustion of methane

1 m^3 of CH_4 needs 2 m^3 of O_2 for combustion

□0.03 m^3 of CH_4 requires oxygen for complete combustion

$$= \frac{2}{1} \times 0.04$$

$$=0.08$$

$$= 0.08\ m^3$$

$$\left.\begin{array}{l}\text{Volume of oxygen needed for}\\ \text{complete combustion of } 1 m^3 \text{ of gas}\end{array}\right\} = 0.07 + 0.11 + 0.08$$

$$= 0.26\ m^3$$

Oxygen already in the fuel =0.24

Total volume of oxygen required for the complete combustion is=0.26-0.02

=0.24 m^3

$$\left.\begin{array}{l}\text{Minimum volume of air required}\\ \text{for combustion of 1 } m^3 \text{ of gas}\end{array}\right\} = 0.24 \times \frac{100}{21}$$

$$= 1.148\ m^3 \text{ AIR}$$

Flue gas

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 quantitative 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.

Flue gas analysis by Orsat's apparatus

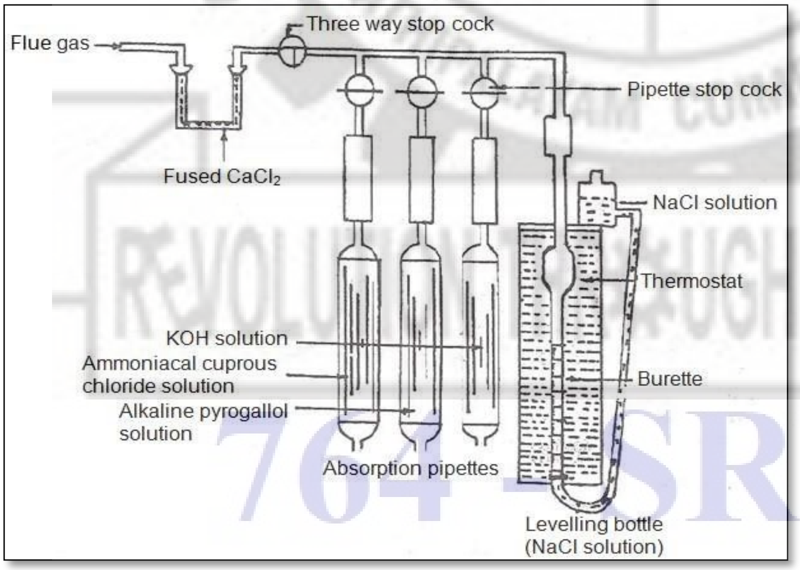
Mainly, the flue gases CO, CO_2 and O_2 are quantitatively analysed by Orsat's apparatus.

The apparatus consists of a graduated burette (100 ml) surrounded by water, for maintaining constant temperature. One end of burette is connected to a levelling bottle through a rubber tube. The levelling bottles contain saturated NaCl solution which does not absorb any flue gases. By raising and lowering the levelling bottle, the volume of gases present in it are made to overflow and have close contact with three absorption pipette solutions.

The absorption pipettes have solution for absorption of CO_2, O_2 and CO respectively. The 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 absorbs CO_2 and O_2. The third pipette is filled with standard ammoniacal cuprous chloride. This solution 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 alkaline pyrogallol solution and finally through standard ammoniacal $CuCl_2$ solution.

To flush out the air in the apparatus, the three way stop clock is opened to the flue gas supply after closing the entries of absorption pipettes. By lowering the levelling bottle, the flue gas is admitted in the burette and the three way stop clock is opened to the flue gas supply after closing the absorption pipettes. Now, the levelling 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 levelling bottle and exactly permit 100 ml of the flue gas as noted in the burette and close the three way stop clock 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 levelling bottle. By repeatedly raising and lowering the levelling 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 levelling 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 levelling with the levelling bottle. The further decrease in volume gives the volume of O_2 in 100 ml.of the flue gas.



Finally, the third absorption pipette is opened and by adjusting the levelling bottle up and down, the remaining flue gas is forced to pass through the ammoniacal cuprous chloride solution of the absorption pipette. This is done to have complete 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 levelling bottle. The decrease in value from the last noted value gives the volume of CO present in 100 ml. of the flue gas.

The percentage of nitrogen is obtained by the difference.

Summary

In this lesson, combustion, combustion calculations and flue gas analysis are discussed.

QUESTIONS

PART – A

1. Define combustion.
2. Write the complete equation for the combustion of methane present in a fuel.
3. What is flue gas?

PART – B

1. Mention the use of flue gas analysis.
2. Name the reagents used for the absorption of CO_2, O_2 and CO in flue gas analysis.

PART – C

1. Explain flue gas analysis by Orsat apparatus.
2. Calculate the mass of oxygen required for the combustion of 1 kg of a carbon, hydrogen and sulphur.
3. A sample of hydrocarbon contains 18.18% hydrogen and 81.82% of carbon by weight. Find the mass of air required for the complete combustion of 1 kg of the fuel.
4. A sample of coal was found to have the following composition.
   C = 75%, H_2 = 5.2%, O_2 = 12.1%, N_2 = 3.2% and ash = 4.5% by mass.
   i. Calculate the amount of air required for complete combustion of 1 kg of coal.
   ii. Calculate the amount of air required for complete combustion of 1 kg of coal if 40% excess air is used.
5. A fuel is found to contain C = 90%, H = 6%, S = 2.5%, O_2 = 1% and ash = 0.2% by mass.
   i. Calculate the amount of air required for complete combustion of 1 kg of fuel.

i. Calculate the amount of air required for complete combustion of 1 kg of fuel if 25% excess air is used.

6. A gaseous fuel has the following composition by volume. H_2 = 15%, CO = 30%, CH_4 = 3%, CO_2= 5%, O_2 = 2% and remaining N_2.Calculate the volume of air needed for complete combustion of 1 m^3 of fuel.
7. The composition of gaseous fuel is Carbon monoxide = 22%, Hydrogen = 14%, Methane = 4%, Carbon dioxide = 6%, Nitrogen = 52% and Oxygen = 2% by volume. Calculate the volume of air required for the combustion of 1 m^3 of the fuel.
8. A gaseous fuel has following composition by volume. Methane = 5%, Hydrogen = 20%, CO = 25%, CO_2 = 6% and the rest nitrogen. If 20% excess air is used for combustion, calculate the volume of air supplied per m^3 of fuel.
9. A fuel contains 45% H_2, 40% CO, 12% CH_4 and 3% O_2 by volume. Excess air supplied is 50%. Determine the volume of air required to burn 1 m^3 of the fuel.

TEST YOUR UNDERSTANDING

1. How to distinguish between complete and incomplete combustion of coal.
2. How can you analyse the masses of CO_2 and H_2O produced during combustion of a fuel?
3. Why a good fuel must have low ash content?

Unit 4

APPLIED CHEMISTRY

Technology of water-I

Sources of water- depletion of underground water- reasons-Rainwater harvesting (Basic ideas) – advantages- hard water and soft water- Hardness of water-carbonate and Non- carbonate hardness- Methods of expressing hardness- mg/lit and ppm- Simple problems- Disadvantages of hard water- Estimation of total hardness by EDTA method-problems involving total, Carbonate and Non-carbonate hardness in ppm- Disadvantages of using hard water in boilers – Scale formation, Corrosion of boiler, Caustic Embrittlement – Priming and foaming

Technology of water 2

Softening of hard water- Ion Exchange method and Reverse Osmosis method –Municipal supply- purification of drinking water-Quality of potable water (WHO standard) – parameters of potable water - pH –TDS- residual chlorine permissible limits- determination of ecoli (preliminary idea)

4.1 TECHNOLOGY OF WATER

INTRODUCTION

Water is the most essential compound for all living matter on the earth.

It plays an important role in human living, industrial and agricultural purposes.

So there is no life in the earth without water.

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.

Reason for Depletion of underground water

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

Modernization, industrialization and population growth

Global warming causing excess evaporation of surfacewater

Deforestation

Decrease in rainfall caused by seasonal changes and
Effluents from the industries spoiling the ground watersource.

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.

Rain water Harvesting

Rainwater harvesting (RWH) is a technique of capturing and storing of rainwater (tanks, slums, lake) for useful purposes and recharging the excess water into the ground.

The methods employed are

- Roof top harvesting
- 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 overhead tanks and used directly.

Open space Harvesting

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

With percolation/recharge pits
Recharge trenches
Recharge wells

The recharge method used depends on the soil condition.

Advantages of rain water harvesting

- RHW increases the ground water level.
- It avoids the depletion of underground water.
- Soil erosion is prevented.
- It also prevents flooding in urban areas during rainy season.
- It ensures the availability of water for our future generation.

Types of impurities present in water

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

- Suspended and colloidal impurities.
- Dissolved salts.
- Microorganisms.

Types of water

There are two types of water.

They are (i) soft water and (ii) hard water.

Soft water readily gives lather with soap.
Hard water does not give lather with soap.

Hardness of water

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

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.

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

It is due to the presence of chloride and sulphate salts of calcium and Magnesium. ($CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$).Hence it is called as permanent hard water.

Methods of expressing the Hardness.

The hardness of water can be expressed by any one of the following two methods.

Units for measuring hardness

mg/litre of $CaCO_3$

It is the number of mg $CaCO_3$ of present in one litre of water or mg/lit

part per million of $CaCO_3$

It is the number of parts by weight of $CaCO_3$ present in million parts of water or ppm.

1mg / litre = 1 ppm

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 the mass of $CaCO_3$ equivalent is given below.

$$\left.\begin{array}{l}\text{Calcium}\\ \\ \text{Carbonate}\\ \text{Equivalents}\end{array}\right\} = \frac{\text{Mass of salt x Molecular mass of } CaCO_3}{\text{Molecular mass of salt}}$$

To prove the relation between mg/litre and ppm

Let us consider a water sample whose hardness is ‘x’ mg/litre of $CaCO_3$.

Therefore, Mass of $CaCO_3$ present in 1000ml of water =Y mg i.e. Mass of $CaCO_3$ present in 1000g of water = Y 10^{3}g

Therefore,

Mass of $CaCO_3$ present in 10^6g of water = Y 10^{3}g 10^{6}

= Yx1000g.

Hence hardness of water is = Y ppm.

Therefore, 1 mg / litre = 1 ppm. Hence it is proved.

Even though $CaCO_3$ is not a hardness producing salt and is insoluble in water, it is used as the standard to express the hardness of water. Since the hardness producing salts are present in traces, mass of $CaCO_3$ equivalent to hardness producing salt is calculated to express the hardness of a water sample.

The formula used to convert the mass of hardness producing salt to mass of $CaCO_3$ is given as follows.

One molecular mass of one molecular mass of

Hardness producing salt $CaCO_3$

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

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 $CaCO_3$.

One molecular mass of $MgSO_4$ = one molecular mass of $CaCO_3$

i.e. 120 mass of Mg SO_4 = 100 mass of $CaCO_3$

Therefore mass of 48mg of $MgSO_4 = \frac{48 \times 100}{120}$ = 40mg of $CaCO_3$

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 $CaCO_3$

Disadvantages of a hard water sample

Hard water cannot be used for drinking, as it does not quench thirst. 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.

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

Modern method.

PRINCIPLE:

This is a volumetric method based on the principle of formation of complexes. Ethylene diamine tetra acetic acid (E.D.T.A.) forms colorless 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

Wine Red **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 hard-water. 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 already established formula is used. This gives a standard data relating the mass of $CaCO_3$ and volume of 0.01M EDTA solution. The formula is

1ml of 0.01M EDTA solution ≡ 1mg of $CaCO_3$

HARD WATER Vs EDTA

Sl. No.	Volume of Hard water	Burette Reading		Volume of EDTA (ml)	Indicator
		Initial	Final		
1	20	0			Eriochrome Black-T
2	20	0			
3	20	0			

CALCULATION:

Let V ml be the volume of E.D.T.A. Hard water.

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

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

50 ml of Hard water contains V mg of $CaCO_3$

Therefore Weight of $CaCO_3$ present
In 1000 ml of Hard water

$$\frac{V \times 1000}{50} \text{ mg}$$

20 V mg

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

(Note: In the estimation of hardness, 0.01M EDTA solution is prepared by dissolving 3.72 g of Disodium salt of EDTA in 1000 ml of distilled water.

NH_3 - NH_4Cl buffer solution is prepared by dissolving 67.5 g of ammonium chloride (AR) in 200ml of water and by adding 570ml of Liquor ammonia (AR) with specific gravity 0.92 and the total volume is made up to one litre.)

Worked out Example

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

Formula

1ml of 0.01M EDTA solution ≡ 1mg of $CaCO_3$

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

By titration, 25ml of 0.01M EDTA solution ≡100 ml of hard water
Therefore

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

Mass of $CaCO_3$ present in 1000ml of hard water = 250mg Hence hardness of water = 250mg/litre of $CaCO_3$

To give 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
Therefore

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

= 250g

Hence hardness of water = 250 ppm of $CaCO_3$

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.

(NOTE: In the given problem, volume of EDTA consumed in the first titration is equivalent to total hardness of water which includes both carbonate and

non-carbonate hardness. But the volume of EDTA consumed by the water after boiling is equivalent to non-carbonate hardness as carbonate hardness in water can be removed by boiling water.)

Total hardness

1ml of 0.01M EDTA solution ≡ 1mg of $CaCO_3$
Therefore,

12.5ml of 0.01M EDTA solution ≡ 12.5 mg of $CaCO_3$
By titration,

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

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

Therefore 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

1ml of 0.01M EDTA solution ≡ 1mg of $CaCO_3$

Therefore,

8.2ml of 0.01M EDTA solution ≡ 8.2 mg of $CaCO_3$
By titration,

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

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

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

$$(125 - 82) = 43 \text{ mg/litre of } CaCO_3$$

SOFTENING OF HARD WATER

The method of converting the hard water into soft water is called softening of hard water. Two important methods of softening the hard water are

1. Ion-Exchange method

2. Reverse Osmosis method.

Ion Exchange method

(Demineralization Method or de-ionization method)

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

Acid resin is represented by RH_2.

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

Softening Process:

When the hard water sample is passed through the acid resin, calcium and magnesium ions are removed.

$2RH + Ca^{2+}$ ---------- R_2Ca + $2H^{+}$

Acidic resin

$2RH + Mg^{2+}$ ---------- R_2Mg + $2H^{+}$

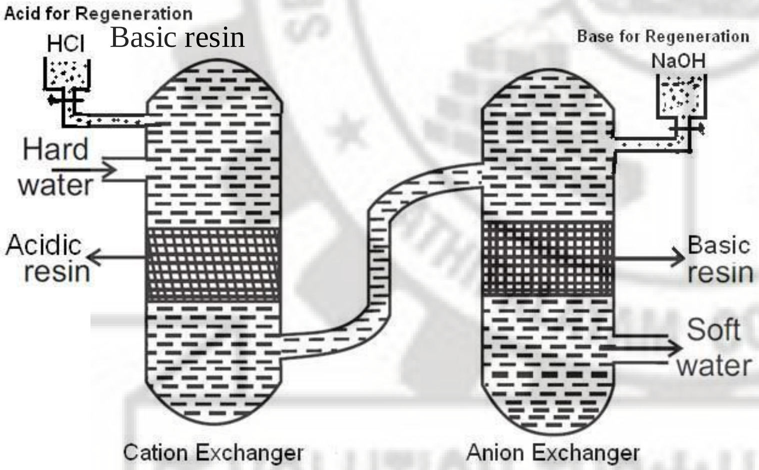
Acidic resin

When this water is passed through the base resin, chloride, bicarbonate and sulphate ions are removed.

$R'OH + Cl^{--}$ ---------- $R'Cl$ + OH^{-}

$2R'OH + SO_4^{2-}$ ---------- R'_2SO_4 + $2\,OH^{-}$

Basic resin



ION-EXCHANGE METHOD

Thus both types of ions are removed from water. The H^+ and OH^- ions combine together to form water.

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

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

Regeneration of Acidic Resin and Basic Resin:

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

$R_2Ca + 2HCl$ ----------- $2RH + CaCl_2$

The basic resin after a long use can be regenerated by washing it with a strong solution of NaOH.

$R'Cl + NaOH$ ----------- $R'OH + NaCl$

$R'_2SO_4 + 2NaOH$ ---------- $2R'OH + Na_2SO_4$

Advantages

In this method, both types of hardness are removed.

The quality of water obtained is equivalent to distilled water.

There is no wastage of water.

Reverse Osmosis Method

Osmosis

When two solutions of different concentrations are separated by a semi-permeable membrane, solvent molecules move from the region of low concentrated side to the region of high 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 high concentration region, solvent molecules move from high concentration region to the low concentration region across the semi permeable membrane. This is called reverse osmosis. This principle is used in Reverse Osmosis plants to soften hard water.

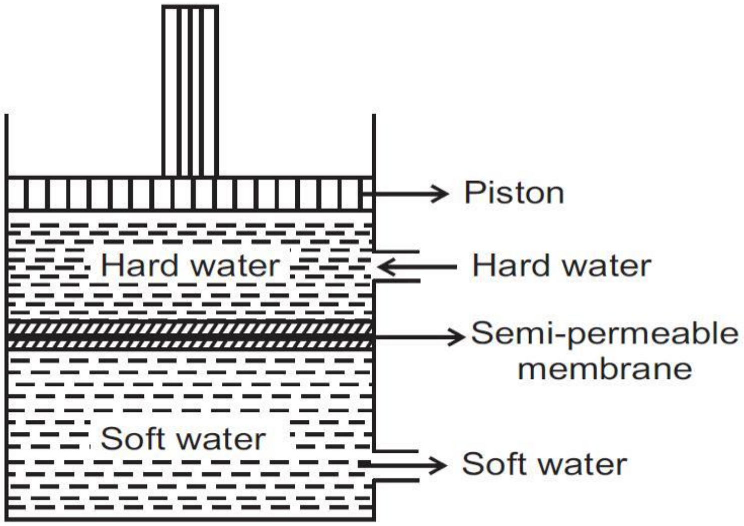
Method

In this method hard water and soft water are taken in two different chambers separated by 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

Diagram



The semi permeable membrane is made of polysulphone or cellulose acetate or polyamide.

Advantages

In this method ionic, non-ionic, colloidal, and organic particles are removed from water.

The semipermeable membrane can be replaced and reused.

There is no wastage of water.

MUNICIPAL WATER SUPPLY

WATER FOR DRINKING PURPOSE (Potable water)

Water used for drinking should be

Colourless and odourless

Free from colloidal and suspended impurities and

Free from microorganisms and bacteria.

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

SEDIMENTATION

FILTRATION

STERILISATION

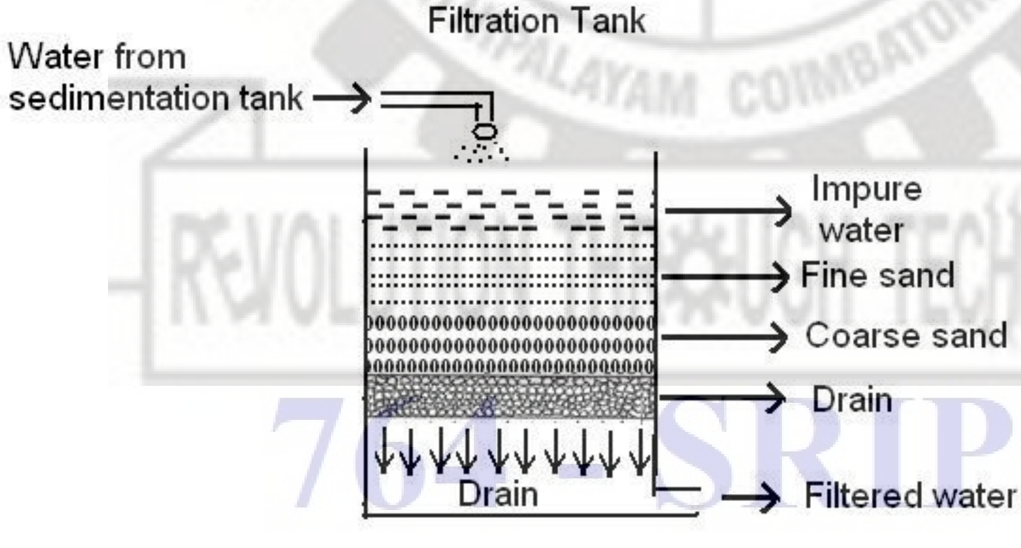
SEDIMENTATION

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 TANK

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 the 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.



(Note: In drinking water supply schemes, generally gravity filters are used. However, 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. In gravity filtration, there are two types namely slow sand filtration and rapid sand filtration. The difference between these two methods is mainly in the recovery of filter beds used.)

STERILIZATION

Sterilization is the process of killing the bacteria. It is done by Chlorination.

Chlorination

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

$$\mathbf{H_2O + Cl_2 \longrightarrow HCl + HOCl} \text{ (Hypochlorous acid)}$$

Other sterilizing agents used apart from chlorine 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.

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.

Scale formation
Corrosion of boiler metal
Caustic Embrittlement and
Priming and foaming.

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

Disadvantages of using hard water Boilers

The salt deposit formed is a poor conductor of heat. Therefore fuel is wasted in raising the temperature of the boiler.

Due to the increase in the temperature, the plates may melt. This may lead to explosion of boiler.

At higher temperature, more oxygen may be absorbed by the boiler metal, which causes corrosion of boiler metal.

The sudden spalling of the boiler scale exposes the hot metal suddenly to super-heated steam, which causes corrosion of boiler.

Methods employed to prevent scale formation are,

Internal conditioning method
External conditioning method.

Internal conditioning methods involve addition of complexing agents like Calgon to boiler feed water. Another method of internal conditioning 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.

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

<u>Corrosion of Boiler metal:</u>

Water containing the following impurities is responsible for the corrosion of boiler metal. The impurities such as dissolved oxygen, dissolved Carbon dioxide, mineral acids, dissolved salts of calcium and magnesium, organic matter etc. are responsible for the corrosion of the 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.,

The dissolved CO_2 can be removed by the addition of limewater.

Adding calculated amount of base could neutralize the mineral acids.

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.

$$Na_2CO_3 + H_2O \longrightarrow 2NaOH + CO_2$$

Removal of Na_2CO_3 present in water can prevent caustic embrittlement.

This can be done by the following methods.

By adding sulphuric acid.

By adding $CaSO_4$ and $CaCl_2$ to boiler water

By adding Na_2SO_4.

By adding trisodium phosphate. etc.

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:

Defective design of the boiler.

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

Control

Priming can be controlled by proper design of the boiler
By uniformly heating the water in the boiler.
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

Define hard and soft waters.

List the salts that cause Carbonate and non-carbonate hardness in a water sample.
What is rain water harvesting?
Mention any two problems caused by using hard water sample.
List any two methods of softening of hard water.
What is osmosis?
What is osmotic pressure?
Explain reverse osmosis.
Name the membranes used in R.O.method of softening of hard water
What is ppm?
What is sedimentation?
What is sterilization of water?
Explain the reaction that takes place when chlorine is added to water.
What are boiler scales?
What is caustic embrittlement?
What is priming?
What is foaming?
Give any one problem caused by boiler scale.

PART – B

List the problems caused by hard water?

What is rainwater harvesting? What are its goals?

PART-C

Explain Ion Exchange method of softening a hard water sample.
What is regeneration of Ion-exchange plant? How is it carried out?
Explain Reverse Osmosis method of softening a hard water sample.
Explain EDTA method of estimating hardness of a sample of water.

Describe the method used in water supply schemes to get potable water.

What are boiler scales? List the problems caused by boiler scale. How to overcome this problem.

Explain caustic embrittlement, priming and foaming in boilers during the production of steam.

4.2 CATALYSIS

INTRODUCTION

Catalyst plays an important role in chemical reaction. Catalytic reagents are better than ordinary reagents. Catalyst mainly used to prevents the environmental pollution. It helps us to achieve the goal of green chemistry.

DEFINITION

A catalyst is a substance which alters the speed of a chemical reaction without itself taking part in the chemical reaction. The process of using a catalyst to alter the speed of a chemical reaction is called as catalysis.

Example,

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$$

Decomposition of potassium chlorate is very slow under normal conditions. When a small amount of manganese dioxide is added the rate of decomposition of potassium chlorate increases. In the above reaction, MnO_2 acts as a catalyst. The reaction is called as catalysis.

TYPES OF CATALYST:

There are two types of catalysts

Positive catalyst

Negative catalyst

1. POSITIVE CATALYST

A catalyst which increases the speed of the reaction is called positive catalyst and the phenomenon is known as positive catalysis. Various examples are given below:

In Decomposition of $KClO_3$, MnO_2 will act as a positive catalyst.

Mno_2

$$2KClO_3 \text{ -----}\rightarrow 2KCl+3O_2$$

Iron is used as a positive catalyst in the synthesis of ammonia by Haber's process.

$Fe_{(S)}$

$$N_{2\,(g)} + 3H_{2\,(g)} \text{ -----------}\rightarrow 2NH_{3(g)}$$

Nitric oxide is used as the catalyst in the lead chamber process

$NO_{2(g)}$

$$SO_{2(g)} + O_{2(g)} \text{ ---------}\rightarrow SO_{3(g)}$$

2. NEGATIVE CATALYST:

A catalyst which decreases the speed of the reaction is called negative catalyst and the phenomenon is known as negative catalysis.

The decomposition of hydrogen peroxide is decreases in the presence of glycerin.

Glycerin

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

Promoters:

Promoter is a substance which increases the activity of the catalyst.

The activity of a catalyst can be increased by addition of a small quantity of a second material. These substances which, though itself not a catalyst, promotes the activity of a catalyst is called a promoter.

Some examples of the promoters are given below.

In the Haber's process for the synthesis of ammonia, traces of molybdenum increase the activity of finely divided iron which acts as a catalyst.

$$N_2 + 3H_2 \xrightarrow[\text{Mo (promoter)}]{\text{Fe (solid)}} 2NH_3$$

CATALYTIC POISONS:

Catalytic poison is a substance which lowers the activity of the catalyst.

A substance which destroys the activity of the catalyst is called a poison and the process is called catalytic poisoning. Some of the examples are:

The iron catalyst used in the synthesis of ammonia in Haber process is poisoned by H_2S.

$$N_2 + 3H_2 \xrightarrow[\text{(Poisoned by } H_2S\text{)}]{\text{Fe (solid)}} 2NH_3$$

Types of catalytic reactions

The process of using a catalyst to alter the speed of a chemical reaction is called as catalysis.

Catalytic reactions are classified into two broad types;

Homogeneous catalysis

Heterogeneous catalysis

HOMOGENEOUS CATALYSIS:

If the catalyst and the reactants are in the same phase, then it is called as homogenous catalysis.

Example:

In the lead chamber process Oxidation of sulphur dioxide into sulphur trioxide with oxygen in the presence of nitric oxide is used as the catalyst

$$SO_{2\,(g)} + O_{2\,(g)} \xrightarrow{NO_{2(g)}} SO_{3(g)}$$

Hydrolysis of methyl acetate is catalyzed by H+ ions furnished by Hydrochloric acid.

$HCl_{(l)}$

$$CH_3\,COO\,CH_{3\,(l)} + H_2O_{(l)} \longrightarrow CH_3COOH + CH_3OH$$

In above two reactions, the catalyst and the reactants are in same phase, hence these reactions are called as homogenous catalysis reactions.

HETEROGENEOUS CATALYSIS:

If the catalyst and the reactants are in the different phase, then it is called as heterogeneous catalysis. Some of the examples of heterogeneous catalysis are given below.

Iron is used as a positive catalyst in the synthesis of ammonia by Haber’s process.

$$N_{2\mathbf{(g)}} + 3H_{2(g)} \xrightarrow{Fe(s)} 2NH_3$$

The reactants are in gaseous phase while the catalyst is in solid phase. Hence this reaction is called as heterogeneous catalysis reaction.

General characteristics of a catalyst:

The following characteristics are generally common to most of the catalytic reactions.

The catalyst remains unchanged in mass and in chemical composition at the end of the reaction. But it may undergo physical change.

Only a small quantity of catalyst is generally needed.

A catalyst cannot initiate a reaction.

The function of a catalyst is only to alter the speed of the reaction which is already occurring at a particular rate.

A catalyst does not alter the position of equilibrium in a reversible reaction.

The catalyst is generally specific in its action.

A catalyst cannot change the nature of the products obtained in a reaction.

A catalyst is efficient only at a particular temperature.

APPLICATIONS OF CATALYST:

In order to increase the yield of products and also to increase the rate of reaction, catalysts are employed for various applications in industries.

They are

1 In the Haber's process for the synthesis of ammonia, traces of molybdenum increase the activity of finely divided iron which acts as a catalyst.

$$N_2 + 3H_2 \xrightarrow[\text{Mo (promoter)}]{\text{Fe (solid)}} 2NH_3$$

In the contact process of preparation of sulphuric acid, platinum is used as a catalyst.

$$2SO_{2\,(g)} + O_{2(g)} \xrightarrow{Pt} 2SO_{3(g)}$$

In the manufacture of ethyl alcohol from sucrose, the enzyme Invertase and zymase are used as catalyst.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

4. In the manufacture of hydrogen chloride from hydrogen and chloride,

activated carbon is used as catalyst.

$$H_2 + Cl_2 \longrightarrow 2HCl$$

5. In the manufacture of methyl alcohol from CO and H_2, zinc oxide is used as

Catalyst.

$$CO + 2H_2 \xrightarrow{ZnO} CH_3OH$$

In the refining of petroleum, phosphoric acid is used as a catalyst.

In the cracking of petroleum fractions, silica is used as a catalyst.

In the hydrogenation of vegetable oil, nickel is used as a catalyst.

Summary

Students learned about the catalyst, catalysis and its application.

QUESTIONS

Part A

Define catalyst.

Define promoters.

What is catalytic poison?

Define the term catalysis.

Name the types of catalysis.

Part B

- What is a catalyst poison? Explain with example
- What is a promoter? Explain with example?
- Explain the heterogeneous catalysis with example

PART C

1. Explain any five industrial applications of catalysts

2.What are catalysis reactions? Explain its types with example?

3.Write any five characteristics of a catalyst?

UNIT- V

ENVIRONMENTAL CHEMISTRY

5.1 Air Pollution

Pollution and Air pollution – Definition – Air pollutants (SO_2, H_2S, HF, CO and Dust) – Sources and Harmful effects – smog and types of smog- Formation of Acid Rain – Harmful effects – Green House Effect – Causes – Global warming – Harmful effects – Ozone Layer – Importance – Causes for Depletion of Ozone Layer (No equations) – Harmful effects of Ozone Layer Depletion – Control of Air Pollution.

5.2 Water Pollution

Causes of Water Pollution – Sewage, Effluents, Algae and Microorganisms – Harmful effects – Definition – Sewage- Sewerage -Disposal – Industrial Effluents – Harmful effects of Effluents – Treatment of Effluents – Eutrophication – Definition and harmful effects.

5.3 Solid Waste Management

Solid Waste – Definition – Problems – Types of Solid Waste – Methods of disposal – Land fill and Incineration- Recycling – Definition – Examples – Advantages of Recycling (Basic ideas)- Definition – Goals of Green Chemistry (Basic ideas)

5.1- AIR POLLUTION

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

Pollution may be defined as the excessive discharge or addition of unwanted and undesirable foreign matters into the environment that causes huge damage to the life and properties of human, plants and animal.

Environment includes air, water and land. The harmful substances that cause damage are called **pollutants**. They are discharged from various industries, automobiles, microorganism, volcanic eruptions, forests and strong winds.

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. Radioactive substances.
6. Volcanic eruptions, etc.

Classification of pollution

To understand the magnitude of pollution problems, it may be classified into three types as follows.

1. Air pollution
2. Water pollution
3. Land pollution

Air pollution

Air Pollution may be defined as the excessive discharge or addition of unwanted and undesirable foreign matters into the atmosphere that causes huge damage to the life and properties of human, plants and animal.

Gaseous pollutants like sulphur dioxide, hydrogen sulphide, hydrogen fluoride, carbon monoxide and dust are the most important primary air pollutants.

Harmful effects of air pollutants

Sl. No.	Air pollutant	Source	Harmful effects
1	Sulphur dioxide (SO_2)	Petroleum industry, thermal power station, sulphuric acid manufacturing plants, etc.	Causes respiratory diseases, eye irritation, throat troubles, damage to agriculture, etc.
2	Hydrogen sulphide (H_2S)	Petroleum industries, paper industries, leather industries, etc.	Causes eye irritation, severe throat pain, headache, corrosion of metals, etc.
3	Hydrogen fluoride (HF)	Fertilizer industry, aluminium industry, etc.	Causes irritation, respiratory diseases, bone disorders, tooth disorders, etc.
4	Carbon monoxide (CO)	Automobile industry, oil refineries, cigarette smoke, etc.	Causes headache, visual difficulty, paralysis, etc.
5	Dust	Cement industry, mines, glass industry, ceramic industry, agricultural industry, etc.	Causes respiratory diseases, affects lungs, accelerates corrosion, etc.

Acid rain

The gases like SO_2 and NO_2 emitted from various industries react with moisture present in the atmosphere to form corresponding acids. It means that rain water contains more acids. The rain water containing the acid is called acid rain. They slowly fall down on the earth as acid rain during snow fall or normal rainfall. This is called as acid rain.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$HCl + H_2O \longrightarrow HCl$$

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$4\,NO_2 + O_2 + 2\,H_2O \longrightarrow 4\,HNO_3$$

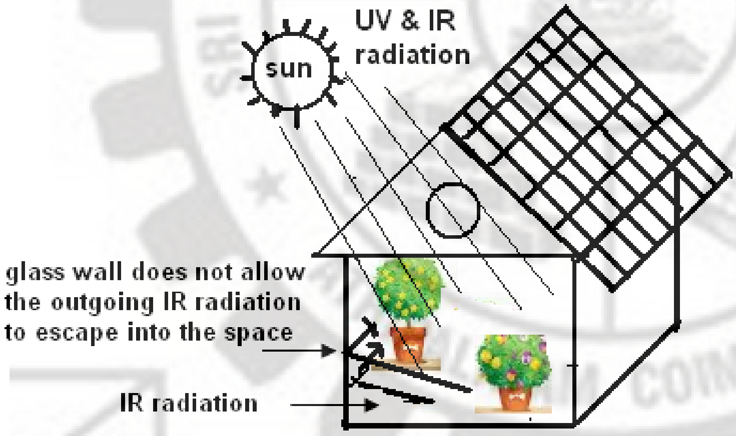
Harmful effects of acid rain

1. Acid rain makes the soil more acidic and 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.
7. It causes corrosion in metal.
8. Acid rain damages automobiles coatings and oil based paints.

Green house effect

The earth surface gets warmed due to the blanketing effect of pollutants like CO_2 present in the atmosphere. It is known as green house effect.

Several radiations like UV, visible and infra-red rays from the sunlight reaches the earth surface and produce heat energy. Some of the heat that is absorbed by the earth’s surface is radiated back into the space. 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 earth. Hence the earth gets warmed. It is similar to green glass houses where heat radiation cannot escape from them.



Green House effect

Gases that cause green house effect are mainly CO_2, methane, water vapour and chloro fluoro carbons (CFC). These gases are called green house gases.

IMPACTS OF GREEN HOUSE EFFECT:

Global warming

The warming up of the earth's surface due to green house effect is termed as global warming. CO_2 and other green house gases present in the atmosphere trap the infrared radiation from the sun and do not allow the radiations to escape. Hence the earth's surface is warming up more and more.

Harmful effects of global warming caused by Green house effect:

1. Evaporation process of surface water is enhanced very much due the increase in temperature of earth's surface which leads to drastic seasonal change. Some region of the world would become dry.
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. The tropical diseases like malarial fever, dengue fever and cholera will spread to the other parts of the world.
5. It causes drastic change in seasons. Hence, human beings and animals are mostly affected by climatic change.
6. Natural calamities like cyclones, hurricane, typhoons and tsunami may occur frequently and strongly.
7. Because of global warming, the normal weather pattern is disrupted. Some parts of the world will face severe water crisis while the other parts will suffer from flooding. Spring arrives earlier in many parts of the world. An early spring may disturb animal migration.
8. Biological productivity also decreases due to global warming.

Ozone layer

One of the gifts given by nature is ozone layer. It is present about 20 km above the earth's surface. It forms a layer of about 3mm thickness called ozone layer. Oxygen is converted into ozone by photochemical change as follows.

$$3\,O_{2\,(g)} \xrightarrow{\text{Radiation}} 2\,O_{3\,(g)}$$

The region in which O_3 density high is called ozone layer.

Importance of ozone layer

1. Ozone layer covers the earth's 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 earth.

2. If the ozone layer is not present in the atmosphere, the harmful UV radiations will enter the earth. This will destroy human and animal life, change the wind pattern, rain fall, climatic change and global temperature.

Causes for depletion of ozone layer

Chlorine plays a vital role in the depletion of ozone layer. Chloro fluoro carbons are released from the supersonic jets, air crafts and jet engines. They get accumulated at high altitude and undergo decomposition in the presence of ultraviolet radiations. Chlorine is the main decomposition product. It reacts with the ozone and converts it into oxygen.

Chlorine converts the ozone molecules into oxygen in the presence of UV radiation as follows.

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

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

It is noteworthy that one atom of chlorine may convert huge number of molecules of ozone into oxygen. The main source for chlorine is CFC which is released by aircrafts, jet planes, refrigerators, air-conditioners, etc. **One atom of chlorine can convert about 10^6 molecules of ozone into oxygen**. The other gases which cause ozone layer depletion are NO and NO_2.

Harmful effects of ozone layer depletion

1. Due to ozone layer depletion, the harmful UV radiation may enter freely into the earth's surface and affect the lives on earth.
2. They affect human beings and cause skin cancer, skin aging, breast cancer, lungs cancer, eye defects and visual defects.
3. They reduce the population of aquatic species.
4. They affect the growth of plants and vegetables.
5. They affect the eco-system very badly.
6. The sea food production also decreases due to the depletion of ozone layer.
7. Depletion of ozone layer causes the change in earth's climate, wind pattern, rainfall and global warming.

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 for controlling air pollution.

1. The exhaust gases from automobiles and vehicles should be minimized by the use of catalyst.
2. Tall 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. The use of coal, wood and traditional fuels should be slowly reduced. Solar energy, tidal power, nuclear power and electricity should be used for domestic and industrial purpose.
6. Acid and chemical fumes are absorbed in water, concentrated and reduced.
7. Growing of trees reduces more pollution as well as the harmful carbon dioxide concentration in the atmosphere. Plants take carbon dioxide during photosynthesis and releases oxygen to environment. Hence, more trees should be planted.

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 the air pollution are discussed.

QUESTIONS

PART – A

1. Define pollution.
2. Define air pollution.
3. Give examples for air pollutants.
4. Mention the harmful effects of SO_2.
5. Mention the harmful effects of H_2S.
6. Mention the harmful effects of HF.
7. Mention the harmful effects of CO.
8. Mention the harmful effects of dust.
9. Give examples for gases causing acid rain.
10. Give two examples for green house gases.
11. What is global warming?
12. Mention the names of pollutants responsible for depletion of ozone layer.

PART – B

1. What is acid rain?
2. Mention the harmful effects of acid rain.
3. What is green house effect?
4. Mention the harmful effects of global warming.
5. What is the importance of ozone layer?
6. Mention the harmful effects of ozone layer depletion.

PART – C

1. What are the major air pollutants? Give their source and harmful effects.
2. What is acid rain? Mention its harmful effects.
3. Write a note on green house effect.

4. What is global warming? List its harmful effects.
5. What are the causes of ozone layer depletion? List the problems caused by ozone layer depletion.
6. Write a note on control of air pollution.

TEST YOUR UNDERSTANDING

Discuss the various techniques employed for the control of air pollution.

5.2 .WATER POLLUTION

INTRODUCTION

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.

Water Pollution

Water Pollution may be defined as the excessive discharge or addition of unwanted and undesirable foreign matters into the water that causes huge damage to the life and properties of human , plants and animal.

Causes of water pollution

The main sources of water pollution are

1. Sewage
2. Effluents
3. Algae and
4. Microorganisms

Sewage

Sewage is the liquid waste of the community which includes human wastes, kitchen wastes and street washings.

Harmful effects of sewage

1. Hydrogen sulphide gas is produced in the sewage due to the decomposition of organic impurities which gives a bad smell.
2. Due to corrosive nature, it affects the pipelines.
3. It helps for the growth of harmful bacteria and viruses and cause many diseases like cholera, janduice, polio etc.
4. Inflammable substances like alcohol and ether may cause severe effects and fire accident.
5. The enrichment of nutrients like nitrates and phosphates in sewage water which causes the growth of aquatic plants which releases the toxic chemicals .This affects the aquatic lives.
6. The solids in it reduce the flow of water and become stagnant.
7. The aquatics like fish die due to lack of oxygen in sewage. The biological oxygen demand is reduced.
8. It also affects the nature and fertility of the soil and affects the food production.

Sewerage(Treatment of sewage):

Removal of sewage by some treatment methods is called sewerage. It involves the following steps.

1. The floating impurities can be removed by mesh screens.
2. The suspended impurities can be removed by filtration and coagulation process using Alum.
3. Inflammable organic impurities can be removed by oxidation process.
4. By neutralization method, the corrosive acids and bases can be removed.
5. The bacterial impurities can be removed by chlorination.
6. The water left out from the sewage can be treated by suitable purification method and can be used for other purposes.
7. By passing oxygen the oxidisable matter is removed.
8. It is treated with lime to remove phosphorous as calcium phosphate.

Effluents

The waste water from various industries containing harmful chemicals. This Industrial waste water is known as effluent.

Harmful effects of effluents

1. It may cause severe damage to aquatic animals.
2. The metals present in the effluent may seriously affect the human organs like kidney, brain, etc.
3. It corrodes the pipelines 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 fertility of the land and growth of plants.
6. The phosphates and nitrates cause Eutrophication.
7. The metallic pollutants like Cu, Pb, Cd present in the effluents affects the health.
8. The organic impurities help the growth of disease causing microorganisms like bacteria, virus and protozoa and produces diseases like cholera, jaundice and typhoid.

Treatment of effluents

1. Toxic nature of effluents may be removed by chemical methods.
2. The acidic nature and basic nature of the effluents may be removed by neutralization.
3. The radioactive effluents are carefully stored and buried under the ground.
4. The heavy metallic impurities may be removed by special methods.

Harmful effects of heavy metal ions present in effluents

Harmful effects of Lead

1. Affects liver and kidney
2. Causes nervous disorder
3. Produce mental retardation in children
4. Produce gastro-intestinal damage
5. Causes loss of appetite

Harmful effects of Copper

1. Severely affect the digestive system
2. Causes vomiting and diarrhea
3. Affects blood, bone and teeth
4. It is toxic to aquatic life
5. Causes cancer and tuberculosis

Harmful effects of Cadmium

1. Causes kidney damage
2. Affects liver
3. Produce anemia and hypertension
4. Produce gastro-intestinal damage
5. Causes vomiting and diarrhea

Harmful effects of Zinc

1. Affects skin
2. Causes vomiting and diarrhea
3. Causes irritation
4. Causes dizziness and itching
5. Causes nausea

Harmful effects of algae

1. Presence of algae in water produces foul odour and bad 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. The growth of algae can be controlled by using algaecide like copper sulphate.
2. The algae can be destroyed by using chemicals like bleaching powder, activated carbon and lime.
3. The growth of algae can also be controlled by preventing the sunlight to fall on the surface of water.

Harmful effects and control of microorganisms (Bacteria and viruses)

1. They cause diseases like cholera, jaundice, typhoid, etc.
2. They are destroyed using disinfectants like bleaching powder and chlorine.

Eutrophication

The ageing of lake and pond by the enrichment of nutrients is called eutrophication.

Causes of Eutrophication

Eutrophication is due to the mixing of sewage water water from agricultural land, domestic detergent wastes, containing nitrogen compounds and phosphates into lake water. It enhances the growth of algae.

Harmful effects of eutrophication

1. It enhances the growth of algae in water which leads to depletion of oxygen in water. Algae release the toxic chemicals. It affects the aquatic animals badly.
2. When the oxygen level falls to zero, the sulphates are reduced to H_2S.
3. It produces bad taste and odour after it decays.
4. It blocks the pipelines and filters.
5. It admits the growth of bacteria and viruses. It may spread water borne disease like dysentery, cholera, Typhoid, yellow fever which affects human beings.
6. It causes an imbalance in eco-system based on water resources.
7. Population of aquatic animals is reduced.

8. Algal toxin accumulated in shell fish are harmful to human system. They produce paralysis, diarrhoea and stomach disorder.

9. Algae and other rooted weeds clog the water filters. They also cause damage to hydroelectric engine.

Summary

In this lesson, water pollutants like sewage, effluents, eutrophication, their causes, problems and rectification methods are discussed.

QUESTIONS

PART – A

1. Give two examples for water pollutants.
2. What is sewage?
3. What is sewerage?
4. What are industrial effluents?
5. Give the problems of lead in water.
6. Give the problems of copper in water.
7. Give the problems of cadmium in water.
8. Give the problems of zinc in water.
9. What is eutrophication?

PART – B

1. Mention any three harmful effects of sewage.
2. Write a note on sewage disposal.
3. Mention the harmful effects of effluents.
4. Mention the harmful effects of algae. How it is controlled?
5. Mention the harmful effects of microorganisms. How it is controlled?
6. Mention any three harmful effects of eutrophication.

PART – C

1. What are the major water pollutants? Give their harmful effects.
2. What is sewage? What are its harmful effects? How it is disposed?
3. What are effluents? Explain the problems and treatment of effluents.
4. Mention the harmful effects of metallic pollutants (lead, copper, cadmium and zinc) in water.
5. Define eutrophication. Mention its harmful effects.

TEST YOUR UNDERSTANDING

Discuss various methods of waste water treatment.

5.3 SOLID WASTE MANAGEMENT

INTRODUCTION

Annual municipal waste in India is about 280 million tons per year and is creating huge problems for the country. Hence there is an urgent need to tackle this problem.

Solid waste

Any substance that is discarded is called waste. The waste may solid, liquid of gaseous substances. The solid waste arises from human and animal activities.

Solid waste is a substance which is left of from industries, kitchen or other waste and thus thrown away. They can cause hazard to human health and environment. Hence, there is an urgent need for the management of solid waste.

Solid waste management is the collection of wastages, transporting, processing, recycling and monitoring of the waste materials to reduce their effect on health and environment.

Types of solid waste

Various types of solid wastes are

Sl. No.	Types	Examples
1	Commercial Garbage	Bricks, cement, sand, etc.,
2	Agricultural waste	Herbicides, pesticides, crop residue, animal and poultry waste, etc.,
3	Rural waste	Bagasse, cow dung garbage, rice husk, etc.,
4	Plastic waste	Plastic toys, cosmetics, food packaging, etc.,
5	Medicinal waste	Cotton containing blood, dressing linen, syringes, waste medicines, etc.,
6	Domestic waste & e-waste	Food waste, plastics,computer,TV, broken bottle, ceramic materials, metallic containers, kitchen waste, etc.,
7	Municipal garbage	Food waste, plastics, metals, paper and paper board, etc.,
8	Industrial waste	Products of iron, cadmium, tin, lead, arsenic, mercury, radioactive materials, etc.,

Problems caused by solid waste

1. Air becomes unclean with foul smell.
2. The biomedical waste causes infectious disease and gives bad smell.
3. Human health is affected.
4. Pollutes the air, land and ground water.
5. Contaminate the environment.

6. Affects the climate.

Hence, there is an urgent need for the management of solid waste. 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 co-operation from house holds
5. Lack of knowledge on benefits of segregation

Role of private sector organizations

The private sector can play an important role in construction, operation and maintenance of treatment and disposal facility. NGO's can also play an important role in,

Organizing rag-pickers/waste collectors for door-to-door collection and segregation of waste.

i. Creating public awareness for storage of organic and recyclable waste separately at source and handing over the waste to 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.

Methods of disposal of solid waste

The waste management concepts includes 1.Reduce 2.Reuse 3.Recyle

The aim of waste management is to extract maximum benefit from the wastes and to reduce the amount of waste. The final disposal of solid wastes can be carried out by the following methods.

1. Land fill

In this method, waste is buried underground and covered with soil. Landfills were often established in abandoned areas.

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 a well flexible membrane lining made of plastic or rubber.

A properly designed and well managed land fill can be a hygienic and relatively inexpensive method of disposing of waste materials.

Poorly designed landfills can create a number of adverse environment impacts such as wind-blown litter. Harmful gases like methane are given off from land fill sites that cause air pollution and contribute to global warming.

2. Incineration

Incineration is a waste treatment process that involves the combustion of solid waste at 1000° C. Waste materials are converted into ash, flue gas and heat. The ash is mostly formed by the inorganic constituents of the waste and gases due to organic waste. The heat generated by incineration can be used to generate electricity.

This process reduces the volumes of solid wastes to 20-30 percent of original volume.

Figure: Incineration plant

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. What are solid wastes? Give examples.
2. What are the two methods employed for disposal of solid waste?
3. What is landfill?
4. What is incineration?

Part- B

1. Write a note on land fill.
2. Write a note on incineration.

PART – C

1. List the different types of solid wastes. Explain their origination.
2. Mention the problems caused by solid waste.

Explain the two methods of disposal of solid waste

TEST YOUR UNDERSTANDING

1. Think of a project – How electricity can be produced from garbage?
2. Think of a project – How manure can be produced from garbage?

5.4 GREEN CHEMISTRY

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.

Green chemistry

Green chemistry is defined as the design of environment friendly products and process to minimize or remove hazardous substances. **The chemistry which is used to prevent pollution is called as Green chemsitry.**

Natural processes are ‘green’ while synthetic processes are often ‘grey’. Cleaner process and cleaner synthesis will certainly contribute to better environmental protection.

Goals of green chemistry

Some guidelines may be given while designing the products and determining the processes to achieve the goals of green chemistry.

1. To prevent the formation of waste material before it is formed.
2. It aims to minimize the global warming.
3. New methods should be developed to convert almost all the reactants used in the process into the final product.
4. To design synthetic methodologies that does not give toxic chemicals.
5. To avoid the usage of auxiliary substances (solvents) wherever possible.
6. To ensure the conduction of synthetic methods at ambient temperature and pressure.
7. To reduce the formation of byproducts which are harmful.
8. To make use of renewable materials as raw materials during the process.
9. To perform the process in a safe and controlled way.
10. To reduce the quantity of highly hazardous chemicals during the process.
11. Using the non-conventional energy like solar and wind energy.
12. The products should be recyclable.

Recycling

Recycling is a process of converting used materials (waste) into new useful and valuable products.

This process is carried out to,

1. prevent wastage of potentially useful materials
2. Reduce the consumption of fresh raw materials
3. Reduce energy usage
4. Reduce air pollution and water pollution

Recycling reduces the need for “conventional” waste disposal methods and there by lower green house gas emissions. Recycling is a key component of modern waste reduction and is the third component of the “Reduce, Reuse, Recycle” waste.

Recycling refers to the collection and reuse of waste materials. Materials for recycling may be collected from general waste and reprocessed into new products.

Examples of recycling

1. Used paper can be converted into new paper.
2. Used foamed polystyrene can be converted into new polystyrene.
3. Used aluminium containers can be converted into new containers.
4. Kitchen scraps can be used to make compost (Compost is an organic material that adds nutrients to soil).
5. Used glass containers can be converted into new glass containers.
6. Metal scraps can be converted into new materials.

Advantages of recycling

1. It helps in the conservation of natural resources.
2. It protects the environment of the area. The recycling is eco-friendly.
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 saves lot of energy.
7. Forests are saved by recycling the waste paper. This minimizes the global warming.

Summary

In this lesson, green chemistry, goals of green chemistry, recycling, examples of recycling and its advantages are discussed.

QUESTIONS

PART – A

1. Define green chemistry.
2. Give any two goals of green chemistry.
3. What is recycling?

PART – B

1. Give any three goals of green chemistry.
2. What is recycling? Give an example.

PART – C

1. Define green chemistry. Give the goals of green chemistry.
2. Explain the advantages of recycling.

TEST YOUR UNDERSTANDING

Think of a project – how different materials can be recycled?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