MODULE-2 Materials for Memory and Display Systems

Q1 What are Memory Devices? Explain the Classification of electronic memory devices with examples

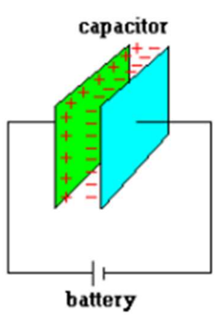
ANS. A memory device is a piece of hardware made of semiconducting materials used to store data.
Example: CD, DVD, USB and external hard disc.
Classification of Memory Devices:

1. Transistor-Type Electronic Memory
2. Capacitor-Type Electronic Memory
3. Resistor-Type Electronic Memory
4. Charge Transfer Effects

1. Transistor-Type Electronic Memory:

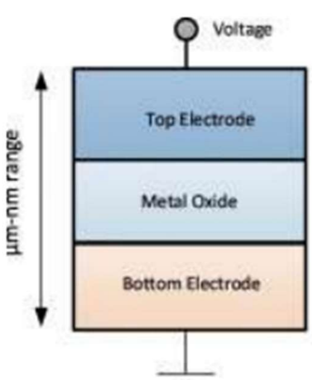
A transistor is a miniature electronic component that can work either as an amplifier or a switch. A computer memory chip consists of billions of transistors, each transistor is working as a switch, which can be switched ON or OFF. Each transistor can be in two different states and store two different numbers, ZERO and ONE. Since chip is made of billions of such transistors and can store billions of Zeros and Ones, and almost every number and letter can be stored.

2. Capacitor-Type Electronic Memory



A capacitor consists of two metal plates which are capable of storing an electric charge. It is like a battery that holds data based on energy.
If the capacitor is charged, it holds the binary numeral,"1" and holds "0' when the cell is discharged.
If the parallel plates of a capacitor are separated by dielectric layer, charges dissipate slowly and memory would be **volatile.**
On the other hand, if the medium between the electrodes is ferroelectric in nature, can maintain permanent electric polarization that can be repeatedly switched between two stable states (bistable) by an external electric field. Thus, memory based on ferroelectric capacitors (FeRAM) is **non-volatile memory.**

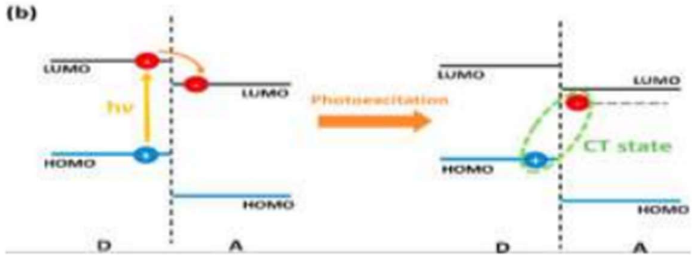
3. Resistor-Type Electronic Memory



Memory devices containing switchable resistive materials are classified as resistor-type memory, or resistive random access memory (RRAM).
Resistor-type electronic memory usually has a simple structure, having a metal-insulator-metal structure generally referred to as MIM structure. The structure comprises of an insulating layer (I) sandwiched between the two metal (M) electrodes and supported on a substrate (glass, silicon wafer, plastic or metal foil).
Initially, the device is under high resistance state or "OFF" and logically "0" state, when resistance changed or under external applied field changes to low resistance state or "ON" logical value "1".

4. Charge Transfer Effects

A charge transfer (CT) complex is defined as an electron donor–acceptor (D–A) complex, characterized by an electronic transition to an excited state in which a partial transfer of charge occurs from the donor moiety to the acceptor moiety. The conductivity of a CT complex is dependent on the ionic binding between the D–A components.



If the donor has intermediate size and ionization potential, it tends to form a weakly ionic salt with the acceptor, which possesses incomplete CT ($0.4 < \delta < 0.7$) and thus is potentially conductive.

Q2 Explain the types of organic memory devices by taking p- type and n-type semiconducting materials.

ANS. Organic electronic memory device uses organic semiconductors and stores data based on different electrical conductivity states (ON and OFF states) in response to an applied electric field.

The p-Type Organic Semiconductor Material "Pentacene"

An Organic molecule with π conjugated system and possess holes as major charge carrier is called p-type semiconductor.
Example: Pentacene

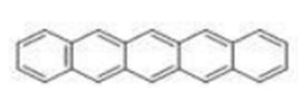
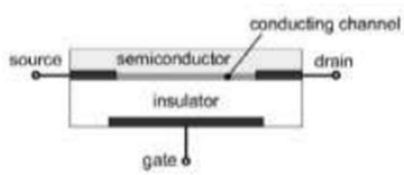
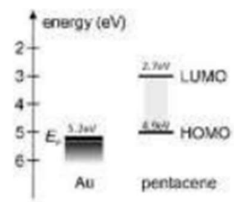


Fig: 2.6 Pentacene

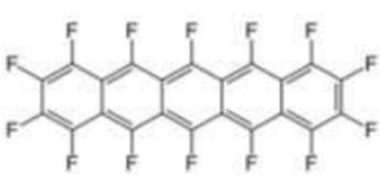




When a positive voltage was applied between gate and source, it was found no flow of electrons to drain due to higher energy gap between the Fermi level of gold (source) and LUMO of Pentacene. On the other hand, when a negative voltage is applied between the drain and source, **holes** are induced at source. This permits a channel of charges (holes) to drain through semiconductor and insulator interface when a secondary voltage is applied. Therefore it called as P-type semiconductor

The n-type organic semiconducting material Perfluoropentacene

An Organic molecule with π conjugated system with electron withdrawing substituent groups and possess electrons as major charge carrier is called n-type semiconductor.



In Pentacene, when hydrogen atoms are substituted by highly electronegative fluorine atoms, it is called Perfluoropentacene and acts as N-type of semiconductor. When a positive voltage is applied between source and drain, **electrons** are induced in the source (gold).This permits the channel of charges to drain through semiconductor-insulator interface as the bandgap between Fermi level of gold (source) LUMO energy of Perfluoropentacene is 1.95ev which is lesser than LUMO energy of Pentacene. Therefore, it is n-type semiconductor.

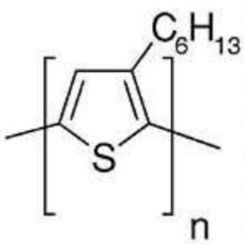
Q3) Write any four properties and applications of light absorbing material - Polythiophenes (P3HT) suitable for optoelectronic devices.

ANS.

Polythiophenes are conjugated polymers, environmentally and thermally stable material. Chemical structure of P3HT Poly (3-hexylthiophene) is a polymer with chemical formula $(C_{10}H_{14}S)_n$. It is a polythiophene with a short alkyl group on each repeat unit. Highly ordered (P3HT) are composed of closely packed, p–p stacked (p–p distance of 0.33 nm).

Properties:

Structure of P3HT



The improved electronic properties yielded for nanostructured P3HT suitable for optoelectronic devices are listed as follows:

1. P3HT is a semiconducting polymer with high stability and exhibits conductivity due to holes therefore considered as p-type semiconductor.
2. Poly-3-hexylthiophene (P3HT) have great capability as light-absorbing materials in organic electronic devices.
3. P3HT has a crystalline structure and good charge-transport properties required for Optoelectronics.
4. P3HT has a direct-allowed optical transition with a fundamental energy gap of 2.14 eV.
5. Fundamental bandgap of P3HT is 490nm visible region, corresponding to $\pi \rightarrow \pi^*$ transition, giving electron-hole pair.

Applications:

1. P3HT-ITO forms a p-n junction permit the charge carriers to move in opposite direction and hence, used in Photovoltaic devices.
2. It can be used as a positive electrode in Lithium batteries.
3. Used in the construction of Organic Solar Cells.
4. Manufacture of smart windows.
5.
6. Used in the fabrication new types of memory devices.

Q4) Write any four properties and applications of Light emitting materials – Poly [9- vinylcarbazole] (PVK)] suitable for optoelectronic devices.

Ans.

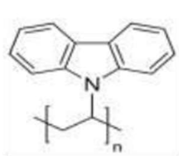


Fig: 2.13 Poly[9-vinylcarbazole] (PVK)]

Poly (N-vinyl carbazole) (PVK) is a polymers and an efficient hole transport material to prepare highly efficient and stable planar heterojunction perovskite solar cells.

Properties of PVK

1. It is a semiconducting polymer and an electron acceptor converts ultra-violet (UV) light into electricity.
2. PVK has a band gap of 3.4 eV, optical absorption edge stating at 350 nm capable of absorbing Ultra-Violet light.
3. The PVK film is hydrophobic, thermally stable with a relatively high glass transition temperature (T_g) of 200 °C
4. The PVK solution also showed good wettability, and provide uniform thin films on glass/ITO substrates.

Applications

1. PVK is used in OLEDs for light harvesting applications.
2. Used in the fabrication of light-emitting diodes and laser printers.
3. Used in the fabrication of organic solar cells when combined with TIO on glass substrate.
4. Used in the fabrication of solar cells when combined with Perovskite materials.
5. PVK-Perovskite junction is used in Light-Emitting Diodes with Enhanced Efficiency and Stability.

Q5) What is OLED? Mention any four properties and applications of OLED.

Ans.

Quantum dot light emitting diodes are a form of light emitting devices consisting of nano-scale crystals that can convert light energy into electrical energy or vice-versa.

Properties of QLED

1. QLEDs are capable of producing highly accurate and vibrant colors due to their use of quantum dots.
2. QLEDs are more energy-efficient than traditional LCD displays because they do not require as much backlighting.
3. QLED displays have high contrast ratios and produce more detailed and lifelike images.
4. QLEDs have a longer lifespan than traditional LCD displays because they do not suffer from the same issues of backlight burnout or color fading over time.

Applications of QLED

1. QLED displays are commonly used in televisions, monitors, smartphones, and other electronic devices.
2. QLEDs can also be used as a source of lighting in various applications, including automotive lighting, street lighting, and architectural lighting.
3. QLEDs can be used in medical imaging applications, such as in MRI machines, to produce high-resolution and accurate images.
4. QLED displays can be used in advertising displays, such as digital billboards and signage, to produce high-quality and eye-catching visuals.

Q6) What is QLED? Mention any four properties and applications of QLED.

ANS.

"OLEDs are thin film devices consisting of a stack of organic layers sandwiched between two electrodes. OLEDs operate by converting electrical current into light via an organic emitter".

Properties of OLED

1. OLEDs are very thin and flexible, which makes them suitable for use in curved or flexible displays.
2. OLEDs have a high contrast ratio, and produce images with vivid and rich colours.
3. OLEDs have a fast response time, resulting in smooth and seamless motion in video content.
4. OLEDs have a wide viewing angle, and image quality is maintained even when viewed from different angles.
5. OLEDs are energy efficient, as they do not require a backlight like traditional LCD displays.

Applications:

1.Consumer Electronics: OLED displays are used in smartphones, TVs, laptops, and other consumer electronics.

2.Automotive: OLED displays are used in the dashboard displays of some high-end cars.

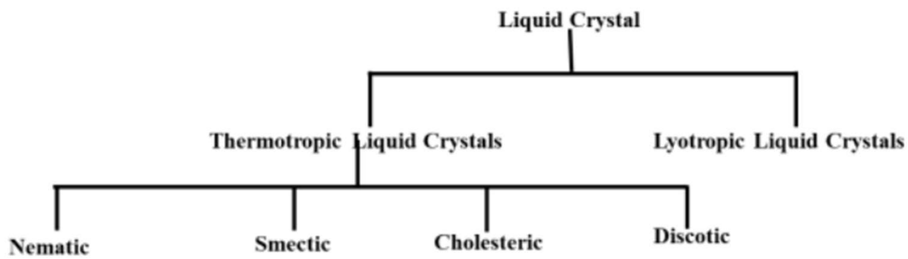
3.Lighting: OLEDs can be used as a source of light for decorative and functional lighting applications.

4.Wearables: OLED displays are used in smartwatches and other wearable devices due to their flexibility and low power consumption.

7) Explain the classification of liquid crystals. Mention any four properties and applications of liquid crystals.

ANS.

The liquid crystals are a unique state of matter between solid (crystalline) and liquid (isotropic) phases.



i) **Thermo tropic liquid crystal**

A liquid crystal is said to be thermo tropic if molecular orientation is dependent on the temperature.

Example:

$$\underset{\text{(Solid)}}{p\text{-cholesteryl benzoate}} \xrightarrow{145^\circ C} \underset{\text{(liquid crystal)}}{p\text{-cholesteryl benzoate}}$$

a) **Nematic (or thread-like liquid crystals)** : The molecules move either sideways or up and down. Increase in temperature decreases the degree of orientation.

Example: p-azoxyphenetole

b) **Smectic (or soap-like liquid crystals):** The molecules in smectic crystals are oriented parallel to each other as in the nematic phase but in layers.

Smectic Liquid Crystals
- Smectic A: Molecules are aligned perpendicular to the layer
- Smectic B: Molecules are aligned perpendicular to the layer but tilted

c) **Cholesteric liquid crystals:** Molecules in successive layers are slightly twisted and form helical pattern.

d) **Discotic liquid crystal:** Molecules are arranged in a column arranged with disc like structure.

2) Lyotropic liquid crystals: The orientational behaviour of Lyotropic crystals is a function of concentration and solvent. These molecules are amphiphilic – they have both hydrophilic and hydrophobic ends in their molecules. At low concentrations, molecules are randomly arranged and higher concentration produces a definite pattern heads out and tail in. Soaps and detergents form Lyotropic crystals when they combine with water

Properties of liquid crystals

1. They exhibit optical anisotropy which is defined as the difference between refractive index parallel to the director and refractive index perpendicular to the director.
2. The intermolecular forces are rather weak and can be perturbed by an applied electric field.
3. They interact with an electric field, which causes them to change their orientation slightly.
4. Liquid Crystal can flow like a liquid, due to loss of positional order.

Applications of liquid crystals

1. The liquid crystal layer in LCDs allows for the display of images and text through the use of electrical currents that control the orientation of the crystals.
2. Liquid crystal sensors are used in various applications such as temperature sensing, humidity sensing, and chemical sensing.
3. Liquid crystals are used in various optical devices such as variable optical attenuators, phase shifters, and tunable filters. These devices are used in optical communication systems, spectroscopy, and imaging.
4. Liquid crystals have been used in drug delivery systems, where the drug is encapsulated in the liquid crystal matrix and delivered to specific target cells.

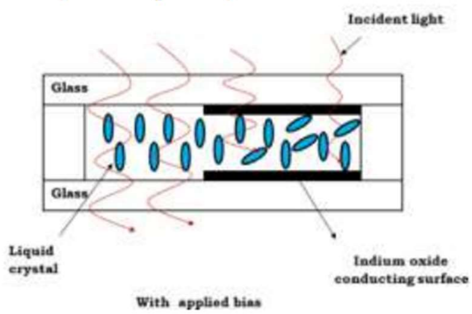
Q8) Discuss the working of Liquid Crystal Display.

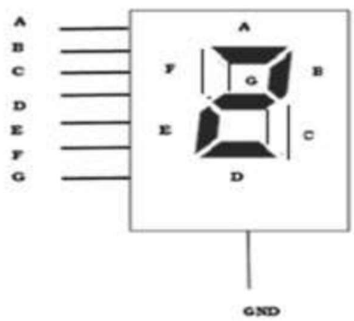
ANS.

Liquid-crystal displays (LCDs) consist of multiple layers. Light produced by a light-emitting diode passes through polarizing filters, color filters, and a liquid-crystal layer to produce an image.

The basic working principle of LCD is blocking of light. When the external light passes from one polarizer to the next polarizer, external supply is given to the liquid crystal, the polarized light aligns itself so that the image is produced in the screen.

The indium oxide conducting surface is a transparent layer which is placed on both the sides of the sealed thick layer of liquid crystal. When no external bias is applied the molecular arrangement is not disturbed.





When the external bias is applied the molecular arrangement is disturbed and that area looks dark and the other area looks clear. In the segment arrangement, the conducting segment looks dark and the other segment looks clear. To display number 2 the segments A,B,G,E,D are energized.

The LCD can display images in colour by using filters that absorb different colours of light. First, a white light-emitting diode shines light toward the front of the display, generating each pixel. The pixels actually consist of three sub pixels, one for each color—red, blue, and green. These sub pixels are made up of a liquid-crystal layer and the appropriate color filter sandwiched between two polarizing light filters. Transistor arrays switch the structural states of the liquid crystals to control whether or not a sub pixel gets lit up, which in turn produces all the colors in an image.

MODULE-3

Q1) What is reference electrode? Describe the construction and working of calomel electrode.

ANS. **Reference electrodes**

"Reference electrodes are the electrodes whose electrode potential value is known with reference to those, the electrode potential of any electrode can be measured". Are called reference electrodes.

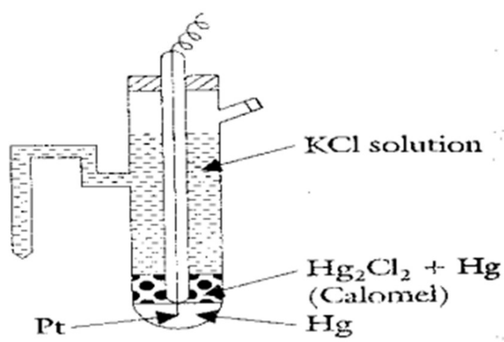
It can act both as an anode or cathode depending upon the nature of other electrode.

It can be classified into two types

1) **Primary Reference electrodes:** Ex- Standard Hydrogen Electrode
2) **Secondary Reference electrode**: Ex- Calomel electrode and Ag/AgCl electrode

Construction and working of Saturated Calomel electrode (SCE)

1. Calomel electrode is a metal-metal salt Ion electrode.
2. It consists of mercury, Mercurous Chloride and a solution of KCl. Mercury is placed at the bottom of a glass tube.
3. A paste of mercury and Mercurous chloride is placed above the mercury. The space above the paste is filled with a KCl solution of known concentration.
4. A platinum wire is kept immersed into the mercury to obtain electrical contact.



Calomel electrode can be represented as, **Hg | Hg_2Cl_2 | Cl^-.**

The calomel electrode can act as anode or cathode depending on the nature of the other electrode of the cell.

When it is Anode:- $2\,Hg + 2Cl^- \longrightarrow Hg_2Cl_2 + 2e^-$

When it is Cathode:- $Hg_2Cl_2 + 2e^- \longrightarrow 2\,Hg + 2Cl^-$

The net cell reversible electrode reaction is

$$Hg_2Cl_2\,(s) + 2e^- \rightleftharpoons 2\,Hg + 2Cl^-$$

Electrode potential, $E = E^0 - \frac{0.0591}{n}.\log[Cl^-]^2$

$$E = E^0 - \frac{0.0591}{2}.2\log[Cl^-] \qquad \text{Where n=2}$$

$$E = E^0 - 0.0591.\log[Cl^-] \quad \text{at 298K}$$

Therefore electrode potential of calomel electrode is depending upon the concentration of KCl. The electrode is reversible with chloride ions. The potential of the calomel electrode depends on the concentration of the KCl.

For saturated KCl, the potential is 0.241V;

For 1M KCl , 0.280V;

For 0.1M KCl, 0.334V.

Q2) What is concentration cell? A concentration cell is constructed by immersing two Silver electrodes in 0.05M and 1.0M Silver nitrite solutions at 298 K. Write the cell representation, cell reactions and calculate the emf of the cell.

ANS.

Concentration cell: A concentration cell is an electrochemical cell in which the electrode material and the solution in both the electrodes are composed of the same substances but only the concentration of the two solutions is different.

Cell representation: $Ag(s) \mid AgNO_3\,(0.05\ M) \parallel AgNO_3\,(1\ M) \mid Ag(s)$

At anode: $Ag\ (0.05\ M) \rightarrow Ag^+\ (0.05\ M) + e^-$

At cathode: $Ag^+\ (1\ M) + e^- \rightarrow Ag\ (1\ M)$

Net cell reaction: $Ag\ (0.05\ M) + Ag^+ \rightarrow Ag^+\ (0.05\ M) + Ag$

$$E_{cell} = \frac{0.0591}{n}\log\left(\frac{C_2}{C_1}\right)$$

$$E_{cell} = \frac{0.0591}{n}\log\left(\frac{1}{0.05}\right)$$

$E_{cell} = 0.0768\ V$

Q3) The emf of the cell Cd/CdSO4 (0.0093 M)// CdSO4 (X M)/ Cd is 0.03 V at 298K. Find the value of X.

ANS.

Q4) The emf of the cell Cu/CuSO4 (X M)// CuSO4 (1.0 M)/ Cu is 0.0295 V at 298 K. Find the value of X.

ANS.

Q5) Define corrosion. Explain the electrochemical theory of corrosion by taking Iron as an example.

ANS.

Corrosion is defined as "the destruction and consequent loss of metals or alloys through chemical or electrochemical attack by the surrounding environment".

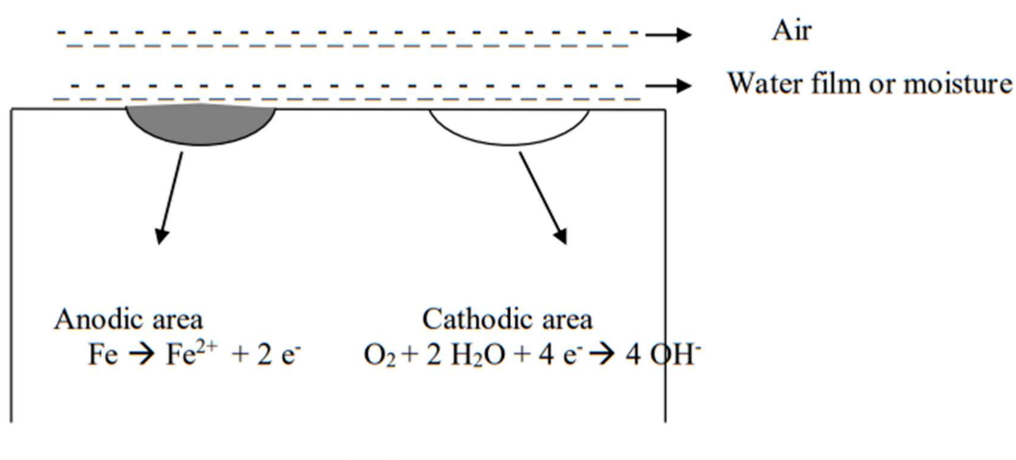
$$\underset{\text{(thermodynamically stable)}}{\text{Ore}} \xrightarrow{\text{Metallurgy}} \underset{\text{(thermodynamically unstable)}}{\text{Metal}} \xrightarrow{\text{Corrosion}} \underset{\text{(thermodynamically stable)}}{\text{Corrosion product}}$$

<u>Electrochemical theory of corrosion:</u>

The corrosion takes place on the basis of electrochemical reactions on the surface of metal in presence of moisture such a type of corrosion is known as wet corrosion.

Electrochemical theory of corrosion can be explained by taking **iron** as an example.

When a metal like iron is exposed to the environment according to electrochemical theory, corrosion of metal takes place due to the formation of **anodic & cathodic regions** on the same metal surface or when the two metals are in contact with each other in a corrosive medium.



Rusting of iron

At anode **oxidation** takes place so that metal is converted into metal ions with the liberation of electrons.

Anodic reaction:

For iron $Fe \longrightarrow Fe^{2+} + 2e^-$

At the cathodic regions, **reduction** takes place since the metal at cathodic region cannot be reduced further, so some constituents of the corrosive medium take part in the cathodic reaction.

Since in the cathodic reaction as the constituents of the corrosion medium are involved, they are more complicated and dependent on the nature of corrosion environment. Most common type of cathodic reaction are

Cathodic reactions:

a. If the medium is neutral or alkaline and in the presence of O_2.

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

b. If the medium is neutral or alkaline in the absence of O_2.

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

c. If the medium is acidic and in the absence of O_2

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

The metal ions (Fe^{2+}) liberated at anode and some anions (OH^-) formed at cathode diffuse towards each other through the conducting medium and form a corrosion product some where between the anode and cathode as

$$2Fe^{2+} + 4OH^- \longrightarrow 2Fe(OH)_2$$

In an oxidizing environment, the insoluble $Fe(OH)_2$ oxidized to ferric oxide

$$4Fe(OH)_2 + O_2 + 2H_2O \longrightarrow 2\,[Fe_2O_3 \,.\, 3H_2O]\text{. Yellow rust}$$

If the concentration of oxygen is limited then Fe $(OH)_2$ is converted into magnetic oxide of Fe and is known as black rust.

$$3Fe(OH)_2 + \tfrac{1}{2}O_2 \longrightarrow \underset{\text{black rust}}{Fe_3O_4.3H_2O.}$$

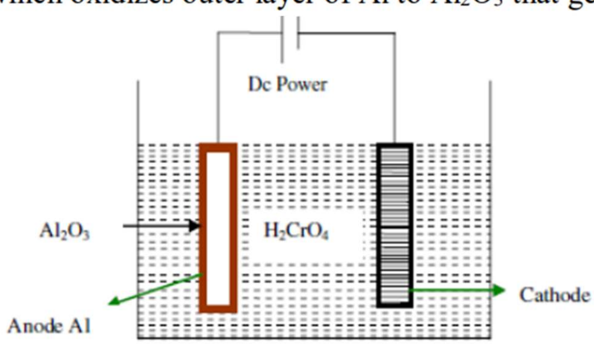
Q6) What is anodizing? Explain the process of Anodizing of Aluminium.

ANS.

Anodizing is the process of oxidation of outer layer of metal to its metal oxide by electrolysis. Oxide layer is formed over the metal itself acts as protective layer.

Anodizing of Aluminium:

In anodizing of aluminum, it is cleaned, degreased and polished and taken as anode in an electrolytic cell. It is immersed in an electrolyte consisting of 5-10% chromic acid. Steel or copper is taken as cathode. Temperature of the bath is maintained at 35^0C. A current density of $100A/m^2$, which oxidizes outer layer of Al to Al_2O_3 that gets deposited over the metal.



Anodized aluminium is exposed to a corrosive environment, the Al_2O_3 layer on the surface acts as a protective coating. Hence corrosion is prevented.

Other metals such as Mg, Ti etc. can also be anodized.

Electrolyte	5-10% of chromic acid
Temperature	35^0c
Thickness of oxide layer	2-8μm

$$\text{At anode:} \quad 4Al + 6H_2O \rightarrow 2Al_2O_3 + 12H^+ + 12e^-$$

$$\text{At cathode:} \ [2H^+ + 2e^- \rightarrow H_2] \times 6$$

$$\text{Net reaction:} \ 4Al + 6H_2O \rightarrow 2Al_2O_3 + 6H_2$$

The oxide film is porous these porous are sealed by dipping it in boiling water. Al_2O_3 gets converted into $Al_2O_3 . H_2O$. This seals the pores.

Application: Anodized articles are used in Tiffin carriers household utensils, window frames etc.

Q7) Explain the galvanization process with neat diagram.

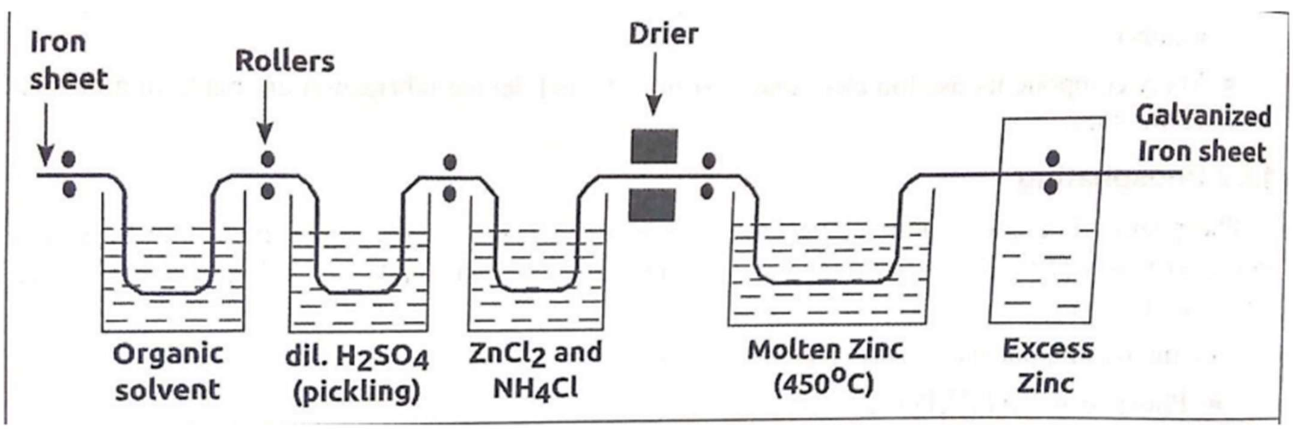
ANS.

Galvanization:

It is a process of coating a base metal (iron) with zinc (Zn) metal. This process usually carried out by hot dipping method.

1. The base metal surface is washed properly with organic solvents to remove any organic matter (like oil, grease etc) on the surface
2. It washed with dil. H_2SO_4 to remove any inorganic matter (like rust).
3. Finally the base metal is well washed with water and air-dried.
4. The base metal then dipped in a bath of molten zinc maintained at 425-430 ^{0}C and covered with a flux of NH_4Cl to prevent the oxidation of molten zinc. Then excess zinc on the surface is removed by passing through a pair of hot rollers so that a proper thin coating is obtained.

Application: Galvanized articles are mainly used in roofing sheets, fencing wire, buckets, bolts nuts, pipes and tubes etc. but galvanized articles are not used for preparing and storing food stuffs. Since zinc dissolves in dilute acids and become toxic.



Q8) Explain the Sacrificial anode method of corrosion control.

ANS.

a. **<u>Sacrificial anode method</u>:** The method involves the use of more active metals as sacrificial anode in contact with specimen (like iron, copper or brass). The active metals like Zn, Mg, Al, and their alloy acts as an auxiliary anode, and undergoes preferential corrosion protecting the metal structure. Here the anode metals are sacrificed to protect the metal, the method is known as sacrificial anode method, exhausted anodes are replaced by new ones as and when required.

Egs: 1. Al, Mg or Zn block connected to a buried oil storage tanks or pipe lines.

Mg bars are connected to ocean going ships

Sacrificial anode methods are simple with low installation cost and do not require power supply.

Q9) What is corrosion penetration rate? Calculate the CPR in both mpy and mmpy for a thick steel sheet of area 100 inch2 which experiences a weight loss of 485g after one year. (Density of steel=7.9g/cm3).

ANS.

Q10) A metal iron plate was found in a vessel containing acidic media, it was estimated that the original area was 20 inch2 that approximately 1.2 kg had corroded. Assuming a corrosion penetration rate of 400mpy for this iron in acidic, calculate time in years, density of iron 7.87g/ cm3 .

ANS.

Q11) Calculate the CPR in both mpy and mmpy for a thick steel sheet of area 120 inch2 which experiences a weight loss of 525g after one year. (Density of steel=7.9g/cm3).

ANS.

Q12) A metal iron plate was found in a vessel containing acidic media, it was estimated that the original area was 35 inch2 that approximately 2.3 kg had corroded. Assuming a corrosion penetration rate of 500 mpy for this iron in acidic, calculate time in years, density of iron 7.87g/ cm3 .

ANS.