Roll No.

Internal Assessment Test 1 – Nov 2025

Sub:	Applied Chemistry for Emerging Electronics and Futuristics Device					Sub Code:	1BCHEE102	Branch: ECE
Date:	05-11-2025	Duration:	90 min's	Max Marks:	50	Sem / Sec:	I / M, N, O & P	OBE

Question no. 1 is COMPULSORY and answer any THREE FULL Questions from the rest.

		MARKS	CO	RBT
1 (a)	Define corrosion. Explain the electrochemical theory of corrosion taking rusting of iron as example.	[7]	CO4	L3
(b)	Define battery. Describe construction and working of Li -ion battery and evaluate its advantages for EV applications (any 4).	[7]	CO1	L3
2 (a)	What are ion selective electrode? Explain construction and working of glass electrode.	[6]	CO4	L2
(b)	Define concentration cell. The EMF of concentration cell, constructed by combining two silver rods immersed in silver nitrate solution is 0.250 V at 25 ºC. If concentration of anodic compartment is 0.002 M, calculate the concentration of cathodic compartment and write the cell reactions.	[6]	CO4	L3
3 (a)	Define corrosion penetration rate (CPR). A thick steel sheet of area 120 inch^2 is exposed to air near the ocean. After 2 years it was found to experience a weight loss of 590 gm due to corrosion. Calculate CPR in mpy and mmy. [Density of the metal is 7.9 gm/cm^3, K(mpy) = 534 and K (mm/y) = 87.6].	[6]	CO4	L3

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(Chief Course Instructor) (HOD)

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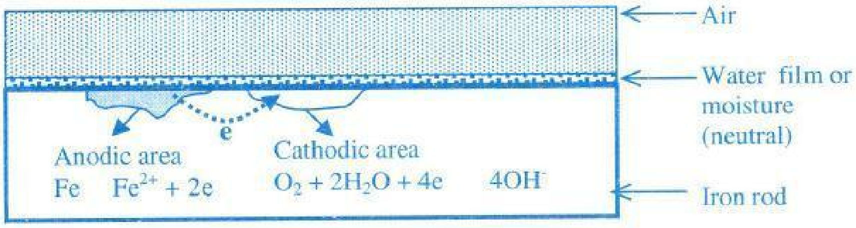
Solutions for IAT-1

1 (a) **Define corrosion. Explain the electrochemical theory of corrosion taking rusting of iron as exampl**

Definition: Metal when exposed to the atmosphere undergoes gradual destruction. Such destruction of metal is known as Corrosion. It's defined as the "destruction of metal or alloys from its surface by the surrounding environment through chemical or electrochemical changes".

Electrochemical theory of corrosion:

According to electrochemical theory, corrosion of the metal take place due to the formation of anodic and cathodic regions on the same metal surface in the presence of a conducting medium. At the anodic region oxidation reaction takes place and the metal gets corroded into ions liberating the electrons. Consequently metals undergo corrosion at the anodic region. At the cathodic region reduction reaction takes place. Metal ions in the cathodic region are unaffected by the cathodic reaction.



The electrons liberated at the anodic region migrate towards the cathodic region constituting corrosion current. The metal ions liberated at the anode and some anions formed at the cathode region diffuse towards each other through the conducting medium and form a corrosion product somewhere between the anode and the cathode. Corrosion of metal continues as long as both the anodic and cathodic reactions take place simultaneously.

Corrosion reactions:

At the anodic region: At anodic region, iron is liberating Fe2+ ions and electrons,

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

At the cathodic region:

The electrons flow from the anodic to cathodic area and at the cathodic region, reduction takes place. Since metal cannot be reduced further, metal atoms at the cathodic region are unaffected by the cathodic reaction. Some constitutions of the corrosion medium take part in the cathodic reaction. There are three possible ways in which the reduction can take place.

If the solution is aerated and almost neutral,

$1/2O_2 + H_2O + 2e^-$ ▼ $2OH^-$

If the solution is deaerated and almost neutral:

$2H_2O + 2e^-$ ▼ $H_2 + 2OH^-$

If the solution is deaerated and acidic:

$2H^+ + 2e^-$ ▼ H_2

If the solution is aerated and acidic:

$1/2O_2 + 2H^+ + 2e^-$ ▼ H_2O

The electrons liberated at the anodic region migrates to the cathodic region. Corrosion of iron produced Fe^{2+} ions and OH^- ions at the anode and cathode sites respectively. These ions diffuse towards each other and produce insoluble

$Fe^{2+}+2OH^{-}$ ▼ $Fe(OH)_2$

In an oxidizing environment, it is oxidized to ferric oxide and the rust is hydrated ferric oxide.

$2Fe(OH)_2 + 1/2O_2 + (n-2)H_2O$ ▼ $[Fe_2O_3.nH2O]$

[Rust]

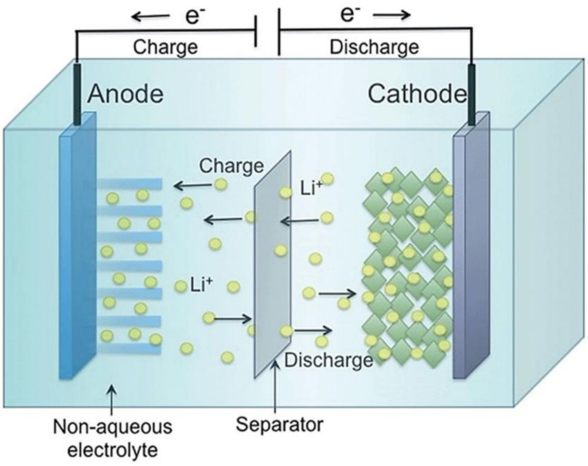
(b) **Define battery. Describe construction and working of Li -ion battery and evaluate its advantages for EV applications (any 4).**

A battery is an electrochemical device that converts chemical energy into electrical energy through redox reactions. It consists of one or more electrochemical cells, each having two electrodes (anode & cathode) and an electrolyte. Batteries are widely used in portable electronics, electric vehicles, renewable energy storage, and military applications.

Lithium-ion batteries are rechargeable secondary batteries widely used in electric vehicles (EVs) due to their high energy density, light weight, and long cycle life. They work on the principle of reversible intercalation/de-intercalation of lithium ions between electrodes during charging and discharging.

2. Construction of a Lithium-Ion Battery

A typical Li-ion cell consists of:



Anode (Negative Electrode): Usually graphite (C_6). Stores lithium ions during charging.

Cathode (Positive Electrode): Made of lithium metal oxides ($LiCoO_2$, $LiFePO_4$, $LiMn_2O_4$, or NMC – $LiNiMnCoO_2$).

Electrolyte: Lithium salt ($LiPF_6$, $LiBF_4$) dissolved in organic solvents (EC, DMC, DEC). Provides ionic conductivity.

Separator: A thin porous polymer film (polyethylene or polypropylene). Prevents electrical contact between electrodes but allows ion flow.

Current Collectors: Copper foil (anode side) and aluminum foil (cathode side).

3. Working Principle of Lithium-Ion Battery (a) Discharging process: Lithium ions move from anode → cathode, releasing stored energy. Electrons flow through external circuit to power devices (e.g., EV motor).

Anode (C): $Li_xC_6 \leftrightarrow xLi^+ + xe^- + C_6$

Cathode ($LiCoO_2$): $Li_{1-x}CoO_2 + xLi^+ + xe^- \leftrightarrow xLiCoO_2$

(b) Charging Process: External power source applies voltage. Lithium ions move from cathode → through electrolyte → to anode and intercalate into graphite layers. Electrons flow through an external circuit to maintain charge balance.

4. Advantages of Lithium-Ion Batteries in EV Applications

1. High Energy Density: Stores more energy per unit weight (150–250 Wh/kg), extending EV driving range.
2. High Power Density: Can deliver high current quickly, enabling fast acceleration.
3. Long Cycle Life: Typically 1000–3000 cycles, supporting years of EV usage.
4. Lightweight & Compact: Much lighter than lead-acid or NiMH batteries, reducing EV weight.
5. Low Self-Discharge: Only ~2–3% per month, making them efficient for long-term use.

2 (a) What are ion selective electrode? Explain construction and working of glass electrode.

These electrodes selectively respond to a specific ion in a solution and potential developed is a function of concentration of that ion in the solution. These electrodes consist of a membrane which is capable of exchanging specific ions with solution with which it is in contact. These are also called as membrane electrodes. Eg. Glass electrode.

Glass Electrode: Construction and Working

Construction:

The glass electrode consist of glass tube, the bottom of the glass tube is glass bulb made up of very thin glass membrane. The thickness of glass membrane varies from 0.03 mm to 0.1 mm. The membrane is made up of special glass of low melting point and high electrical conductivity. Its composition is SiO_2 – 72%, Na_2O- 22%, CaO- 6%. It can sense H^+ ions up to a pH of about 9. Glass bulb contains 0.1 N HCl (Assume concentration is C_2). An Ag/AgCl electrode (internal reference electrode) is also placed in the solution for electrical contact.

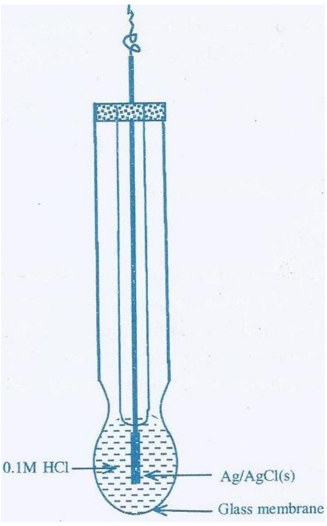


Fig: Glass Electrode

The electrode is represented as,

Ag/AgCl (s)/ 0.1M HCl/ Glass or Glass/0.1M HCl /AgCl(s)/Ag

Working of glass electrode: When the glass electrode is dipped into any solution containing H^+ ions, the Na+ ions of the glass membrane are exchanged for H+ ions of the test solution.

$H^+ + Na^+ GI^- \longrightarrow Na^+ + H^+GI^-$

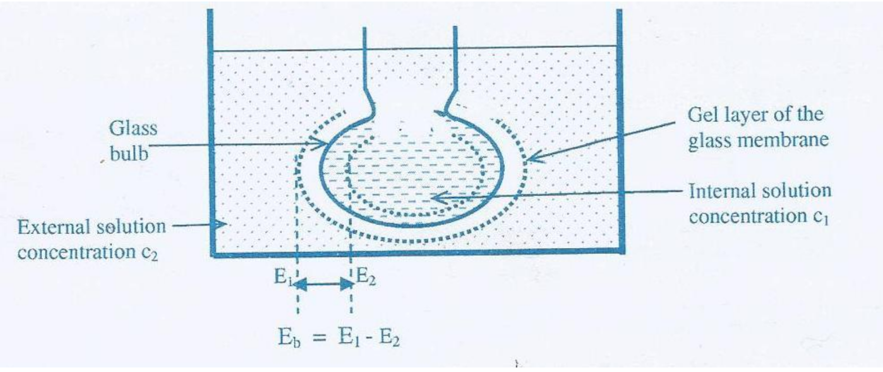


Fig : Boundary Potential

If a thin walled bulb containing an acid is immersed in another solution containing H^+ ions (fig), a potential is developed across the glass membrane. This is called the boundary potential E_b. It is a potential developed across the glass membrane when concentration of the solution inside and outside the glass membrane are different. The E_b is due to the difference in potential (E1-E2) developed across the gel layer of the glass membrane between the two liquid.

Mathematically it is represented as,

$E_b = \mathbf{E_1 - E_2}$

Where, $\mathbf{E_1}$= Potential due to H^+ present in outside solution (Unknown solution)

E_2 = Potential due to H^+ present in inside solution (known solution)

According to Nernst equation

$$E_b = \frac{2.303RT}{nF} \log \frac{C_1}{C2}$$

$$E_b = \frac{0.0591}{n} \log C_1 - \frac{0.0591}{n} \log C_2 \text{..................(1)}$$

Where, C_1 is the concentration of H^+ ions of the solution into which glass membrane is dipped. The concentration of H^+ ion inside the bulb (C_2) is constant i.e. $C_2 = 0.1$ M.

Thus, $E_b = \frac{0.0591}{n} \log C_1 + \mathbf{K}$ **or**

$= \mathbf{K} + \frac{0.0591}{n} \log C_1$

Glass electrode selects only H^+ ions ignoring other ions.

Hence $C_1 = \mathbf{H^+}$

$E_b = \mathbf{K} + 0.0591 \log [\mathbf{H^+}]$

Where, $\log [H^+] = -pH$

$$\boxed{\text{Thus, } E_b = K - 0.0591pH \text{ --------------------(2)}}$$

The combined glass electrode is dipped into acidic solution, then the potential of the glass electrode is given by….

$E_G = E_b + E_{Ag\text{-}AgCl}$……………………….(3)

From equation 1, theoretically if C1= C2, Eb Should be 0, however it has been observed practically that even when C1 = C2, a small potential is developed which is called as asymmetric potential (E_{asym}). Hence equation 3 can be rewritten as

$E_G = E_b + E_{Ag\text{-}AgCl} + E_{asym}$ ……………………….(4)

Substituting the value of Eb from equation (2) in equation (4)

$E_G = K - 0.0591pH + E_{Ag/AgCl} + E_{assy}$

$\boxed{\mathbf{E_G = E^o_G - 0.0591pH}}$ ………………(5) Where ($E^o_G = K + E_{Ag/AgCl} + E_{assy}$)

The above expression (eq 5) indicate that the potential of glass electrode, E_G varies with the pH of the acidic solution.

Advantages of Glass electrode:

1. It can be used in presence of strong oxidizing /reducing substances and metal ions.
2. It does not get poisoned easily.
3. Equilibrium is easily attained.
4. Portable and compact.

Limitation of glass electrode:

1. It can be used up to pH 13 but becomes sensitive to Na^+ ions above pH 9 resulting in an alkaline error.
2. It does not function satisfactorily in pure alcohol.
3. It has to be handled with care because of glass electrode, and is very fragile.

(b) **Define concentration cell. The EMF of concentration cell, constructed by combining two silver rods immersed in silver nitrate solution is 0.250 V at 25 ^oC. If concentration of anodic compartment is 0.002 M, calculate the concentration of cathodic compartment and write the**

cell reactions.

Definition:

A concentration cell is an electrochemical cell in which both electrodes are the same material and the only difference between the two half-cells is the concentration of the redox species. The cell potential arises from the concentration difference and is given by the Nernst equation.

Given Data:

$E = 0.250$ V (cell EMF at 25 °C)
$T = 25$ °C $= 298.15$ K
Anodic $[Ag^+] = 0.0020$ M
For Ag^+/Ag, $n = 1$

Calculation:

Using the Nernst equation (at 25 °C):

$E = (0.05916/n) \times \log([Ag^+]\text{ cathode} / [Ag^+]\text{anode})$

Substitute values:
$0.250 = 0.05916 \times \log([Ag^+]\text{cathode} / 0.0020)$

$\log([Ag^+]\text{\_cathode} / 0.0020) = 4.2258$
$[Ag^+]\text{ cathode} / 0.0020 = 10\text{^}4.2258 = 1.6820 \times 10^4$

Therefore, $[Ag^+]\text{cathode} = 1.6820 \times 10^4 \times 0.0020 = 33.64$ M
Result: $[Ag^+]\text{\_cathode} \approx 33.6$ M.

(Note: This is a theoretical value and exceeds realistic solubility for $AgNO_3$.)

Cell Reactions:

Anode (oxidation, lower concentration side):
$Ag(s) \rightarrow Ag^+ (0.0020\text{ M}) + e^-$
Cathode (reduction, higher concentration side):
$Ag^+ (33.64\text{ M}) + e^- \rightarrow Ag(s)$
Overall reaction:
$Ag^+ (33.64\text{ M}) \rightarrow Ag^+ (0.0020\text{ M})$

3 (a) Define corrosion penetration rate (CPR). A thick steel sheet of area 120 inch^2 is exposed to air near the ocean. After 2 years it was found to experience a weight loss of 590 gm due to corrosion. Calculate CPR in mpy and mmy. [Density of the metal is 7.9 gm/cm^3, K(mpy) = 534 and K (mm/y) = 87.6].

Definition

Corrosion Penetration Rate (CPR) is the rate at which metal is lost due to corrosion, expressed as a penetration (thickness) per unit time. It is commonly reported in mils per year (mpy) or millimetres per year (mm/y). The CPR can be calculated from mass loss using the formula:

$CPR = (K \times W) / (D \times A \times T)$

where K is a unit-dependent constant (534 for mpy, 87.6 for mm/y), W is weight loss (mg), D is density (g/cm^3), A is exposed area, and T is exposure time (hours).

Given data

Weight loss, $W = 590.000$ g $= 590000$ mg
Density, $D = 7.90$ g/cm^3
Exposed area, $A = 120.00$ in^2 $= 774.192$ cm^2
Exposure time, $T = 2.00$ years $= 17520$ hours
Constants: K(mpy) = 534.0, K(mm/y) = 87.6

Calculations

Using the mpy formula (area in in^2):
$CPR\text{ (mpy)} = (534 \times W(\text{mg})) / (D \times A(\text{in}^2) \times T(\text{hours}))$

Substitute values:
CPR (mpy) = (534 × 590000) / (7.90 × 120.00 × 17520)
CPR (mpy) = 18.9693 mpy
Using the mm/y formula (area in cm²):
CPR (mm/y) = (87.6 × W(mg)) / (D × A(cm²) × T(hours))

Substitute values:
CPR (mm/y) = (87.6 × 590000) / (7.90 × 774.192 × 17520)
CPR (mm/y) = 0.4823 mm/y

Results

Corrosion Penetration Rate (CPR):
- 18.9693 mpy
- 0.4823 mm/y

3 (b) **Identify and explain the types of corrosion taking place in following case**
(i) **Tin-Copper Solder Joints in electronic circuits**
(ii) **Half filled steel water tank**

(i) <u>Differential metal Corrosion:</u> When two dissimilar metals are in contact with each other a potential difference is set up resulting in a galvanic current. The two metals differ in their tendencies to undergo oxidation, the one with lower electrode potential or the more active metal acts as anode and the one with higher electrode potential acts as cathode. The anodic metal undergoes corrosion and the cathodic metal is generally unattacked.

At the anode (less O_2 concentration), $Fe \rightarrow Fe^{2+} + ne^-$

At the cathode (more O_2 concentration), $H_2O + \frac{1}{2} O_2 + 2e^- \rightarrow 2OH^-$

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

$2Fe(OH)_2 + 1/2 O_2 + H_2O \rightarrow [Fe_2O_3 . 3H_2O]$ (rust)

Example1- PCB solder joints : In printed circuit boards, tin/lead solder is in contact with copper tracks.
In presence of humidity, an electrochemical cell is formed. Tin/lead solder (less noble) corrodes, while copper (more noble) is protected. This weakens the solder joints and may cause open circuits.

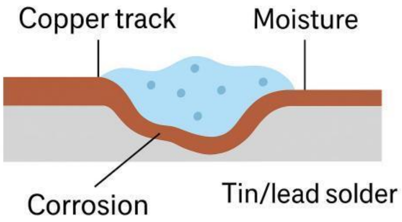


Fig. Differential metal corossion:

<u>Differential aeration corrosion:</u> Differential aeration corrosion occurs when a metal surface is exposed to differential air concentrations or Oxygen concentrations. The part of the metal exposed to higher oxygen concentration acts as a cathodic region and the part of the metal exposed to lower oxygen concentration acts as anodic region.
Corrosion of metal arising as a result of the formation of an oxygen concentration cell due to uneven

supply of air on the metal surface is known as differential aeration corrosion.

At the anode (less O_2 concentration), $Fe \rightarrow Fe^{2+} + ne^-$

At the cathode (more O2 concentration), $H_2O + ½ O_2 + 2e^- \rightarrow 2OH^-$

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

$2Fe(OH)_2 + 1/2O_2 + H_2O \rightarrow [Fe_2O_3 . 3H_2O]$ (rust)

Eg. Part of the nail inside the wall, being exposed to lower oxygen concentration than the exposed part, under goes corrosion.Paper pins inside the paper gets corroded, and the exposed part is free from corrosion.
Metal under dirt, dust, scale or water undergoes corrosion.

(ii) Water line Corrosion:
Water line corrosion is a case of differential aeration corrosion. The water line corrosion takes place due to the formation of differential oxygen concentration cells. The part of the metal below the water line is exposed only to dissolved oxygen (acts as anode) while the part above the water is exposed to higher oxygen concentration (acts as cathode) of the atmosphere. A distinct brown line is formed below the water line due to deposition of rust.

At the anode (less O_2 concentration), $Fe \rightarrow Fe^{2+} + ne^-$

At the cathode (more O_2 concentration), $H_2O + ½ O_2 + 2e^- \rightarrow 2OH^-$

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

$2Fe(OH)_2 + 1/2O_2 + H_2O \rightarrow [Fe_2O_3 . 3H_2O]$ (rust)

Consider a strip of pure iron partially immersed in an aerated solution of NaCl as shown below.

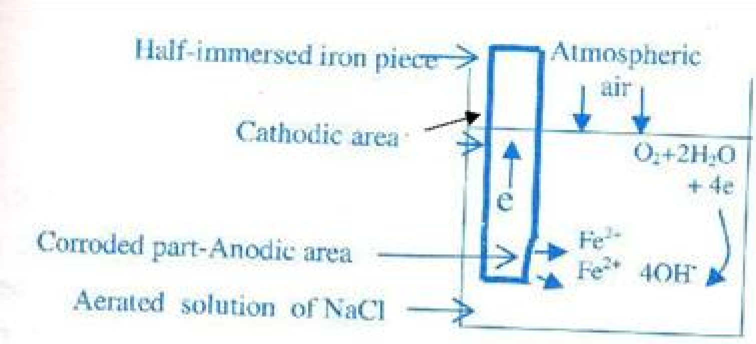


Fig. Differential aeration corrosion

The concentration of O_2 is high at the surface than that inside the solution. Since the cathodic reaction involves use of O_2, the cathodic area tends to concentrate near the waterline. Therefore, the bottom portion of iron strip act as anode and corrosion commences here. The reactions are same as given above.
Ex: Partially buried pipe line in soil or submerged in water undergoes corrosion below the soil or water

whereas the exposed part remains free from corrosion, Metal under dust, dirt or water undergoes corrosion

4 (a) **Define electroplating. Explain electroplating of Cr for hard and decorative coatings. Mention its applications.**

Electroplating is the process of depositing a thin layer of one metal onto the surface of another metal by passing an electric current through an electrolytic solution.

Electroplating of Chromium: Chromium is employed for either decorative purposes (as a thinner coat) or engineering purposes (as a thicker hard coat).

Mentioned below are coating specifications.

Chromium plating	**Decorative Chromium**	**Hard Chromium**
Bath composition	CrO_3: H_2SO_4 = 100: 1 ratio	CrO_3: H_2SO_4 = 100: 1 ratio
Temperature	45-55 °C	45 -66 °C
pH	2-4	2-4
Current density	100 – 200 mA/cm^2	215 – 430 mA/cm^2
Anode	Insoluble lead- Pb-Sb alloy or Pb-Sn alloy (with lead oxide coating)	Insoluble lead- Pb-Sb alloy or Pb-Sn alloy (with lead oxide coating)
Cathode	Surface cleaned object metal to be plated	Surface cleaned object metal to be plated
Application	Provide durable and good decorative finish on automobiles, surgical instrument etc.	Extensively used in industrial and engineering applications.

There is a complex sequence of reactions which control the concentration of Cr^{3+} in the plating bath. The plating bath contains CrO_3 in which Cr is in +6 oxidation state. This is reduced to Cr^{3+} by a series of complex reactions in the presence of SO_4^{--} furnished by H_2SO_4. Cr^{3+} ions are reduced to elemental Cr which gets deposit on the substrate.

$$CrO_3 + H_2O \dashrightarrow H_2CrO_4$$

$$2H_2CrO_4 \dashrightarrow H_2Cr_2O_7 + H_2O \dashrightarrow 2H^+ + Cr_2O_7^{2-} + H_2O$$

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \xrightarrow{\text{sulfate ion } (SO_4^{2-})} 2\,Cr^{3+} + 7H_2O$$

$$Cr^{3+} + 3e \dashrightarrow Cr$$

The amount of Cr^{3+} ions should be restricted in order to obtain good deposits.

<u>Insoluble anodes covered with PbO2</u> which oxidizes Cr^{3+} to Cr^{6+} and thus control the Cr^{3+} ion concentration.

$$2Cr^{3+} + 3O_2 \blacktriangledown \qquad 2CrO_3 + 6e^-$$

<u>Active chromium anode is not used because</u>

(i) Cr metal passivate strongly in acid sulphate medium.

(ii) Further the anode efficiency is nearly 100% and that of the cathode is only around 20% at the best, thus there will be increase in concentration of Cr^{3+} ions which results in poor quality electrodeposits (black deposits).

Applications :

Decorative chromium provides a durable finish on cycles, automobiles, furniture, household fittings, aircraft, surgical and dental instruments.

Hard chromium is mostly used in industries in the making of gauzes, dies, cutting tools, piston rings, cylinder liners, crankshafts of marine and aero engines, bearings, hydraulic rams and in printing industry.

(b) **Discuss extraction of gold from e-waste using bioleaching process.**

The electronic waste also contains fair percentage of precious metals like Cu, Ag, Au, Pd, Rh etc. Gold can be extracted from e-waste using the bioleaching process, which employs microorganisms to solubilize gold from electronic scrap into a liquid solution, making it available for recovery.

This process typically involves following steps:

1. **Mechanical Pretreatment:** E-waste, especially printed circuit boards (PCBs), is disassembled and shredded into small particles to increase the surface area for microbial action.
2. **First-Step Bioleaching** (for base metals): Acidophilic bacteria, such as Acidithiobacillus ferrooxidans, are used to remove base metals like copper, which are more abundant than gold in e-waste. These bacteria convert insoluble metals into soluble forms, creating a liquid solution.
3. **Second-Step Bioleaching** (for gold): After base metals are removed, the remaining e-waste is treated with cyanide-producing bacteria like Chromobacterium violaceum or Pseudomonas species. These heterotrophic bacteria produce cyanide, which forms soluble gold-cyanide complexes with the gold present in the e-waste, mobilizing it into the liquid phase.

$4Au + 8CN^- + O_2 + 2H_2O \longrightarrow 4[Au(CN)_2]^- + 4OH^-$

4. **Recovery of gold** – The gold present in solution is finally recovered by adsorption on activated carbon, ion exchange resins, or by electrowinning.

5(a) **Define electroless plating. Explain electroless plating of copper on PCB.**

Definition: Electroless plating is the controlled deposition of a continuous film of a metal from its salt solution on a catalytically active surface of the substrate (Conductors, semiconductore or insulator) by a suitable reducing agent, without the use of electrical energy.

Schematically, it can be represented as,

$$M^{n+} + \text{Reducing agent} \xrightarrow{\textit{catalytically active surface}} M + \text{Oxidised product}$$

Electroless-plating of Copper on PCB : This process involves following steps

Activation of surface: The base of a printed circuit board is a plastic material such as epoxy or phenolic polymeror a glass fiber reinforced polymer composite. It is activated by treatment with acidified $SnCl_2$ and then with acidified $PdCl_2$ leads to deposition of Pd.

$$SnCl_2 + PdCl_2 \longrightarrow Pd + SnCl_4$$

In the manufacture of double sided PCB, the board is clad on either side with thin electroformed copper foils. Then both sides of the copper clad board are printed with etch-resistant circuit patterns. Rest of the unprotected

copper foil is etched (formation of tracks) away by using an acid. This leaves only the circuit patterns on both sides of the board. Electrical connection between the two sides of PCB is made by drilling a hole through the board. The hole is then activated & electroless plated with copper, as it can't be electroplated. The composition of the electroless plating bath & the procedure given below.

Constituents	**Purpose**
$CuSO_4$	Provides metal ions
HCHO	Reducing reagent
Rochelle salt	Complexing agent
NaOH	Provides alkaline medium
EDTA	Exaltant & complexing agent
pH	11.0
Temperature	25°C

Following reactions takes place during the process:

Reactions:

Oxidation of reducing reagent : $2HCHO + 4OH^{-} \dashrightarrow 2HCOO^{-} + 2H_2O + H_2 + 2e^{-}$

Reduction of metal ion over object surface : $Cu^{2+} + 2e^{-} \dashrightarrow Cu$

Overall reaction : $Cu^{2+} + 2HCHO + 4OH^{-} \dashrightarrow Cu + 2HCOO^{-} + 2H_2O + H_2\uparrow$

Electroless Plating on PCB:

- GRP (Glass reinforced plastic) is used to make PCB.
- GRP is cladded both the side by Cu.
- Circuit designs are printed on this using etch resistant ink.
- It is dipped into acidified $FeCl_3$ solution for etching
- Holes are made to made to make the connection between both the sides.
- Holes are activated by dipping it into $SnCl_2$ and $PdCl_2$ and electroless plating is carried out by using suitable plating bah.

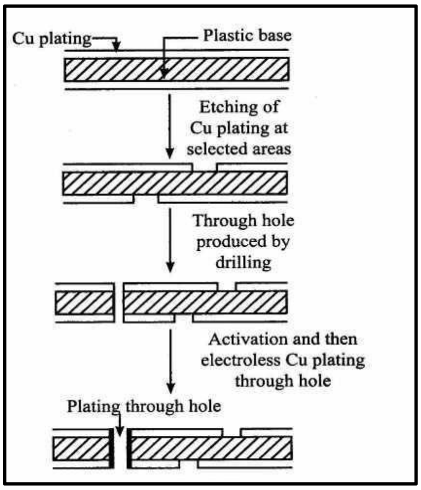


Fig: Electroless plating of Cu

(b) **What is cathodic protection? Explain impressed current method for corrosion control.**

Cathodic Protection: Cathodic protection is a method of protecting a metal or alloy from corrosion by converting it completely into cathodic and no part of it is allowed to act as anode. This can be achieved by providing electrons from an external source.

There are two methods of cathodic protection.

(i) Sacrificial anode method

(ii) Impressed current method

Impressed Current Method: In this method, by applying a direct current larger than the corrosion current, the base metal is made cathodic by connecting it to the cathode of the external source of current and the anode of the source is connected to an inert electrode (lead or graphite). The cathode is the structure to be protected and anode is resin bonded graphite rod, high silicon-iron alloy or platinised Ti connected to the positive terminal.

The metal structure being cathode, doesn't undergo corrosion. Anode being inert, remains unaffected.

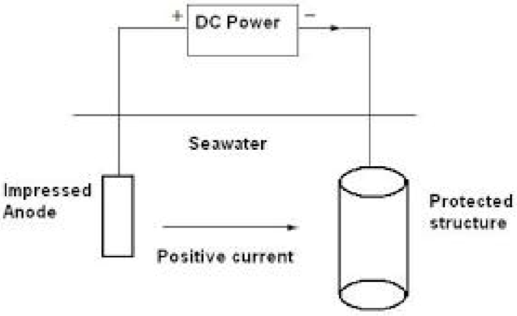


Fig : Impressed voltage method

6 (a) **Explain principle, instrumentation and application of potentiometric sensors in the estimation of iron in steel.**

Theory or Principle:

The estimation of concentration of substances in solution by the measurement of emf is known as potentiometric titration. Here, emphasis is laid on the changes in emf of an electrolytic cell as a titrant of known concentration is added.

Thus, the concentration can be calculated, provided Eo of the electrode is known.

Redox titrations can be carried out potentiometrically

For the reaction; Reduced form $\longrightarrow$ Oxidized form + n e-

The potential is given by Nernst equation

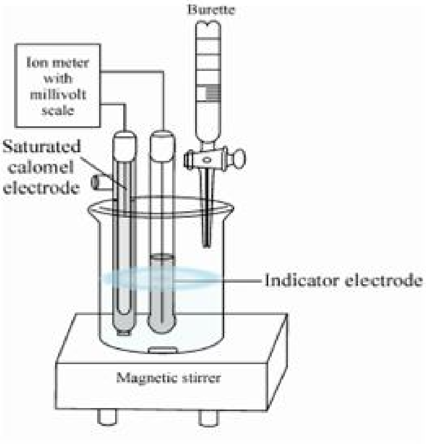
$$E = Eo + \frac{0.0591}{n} \log [\text{oxidized form}]/ [\text{Reduced Form}]$$

The potential of the system is controlled by the ratio of concentration of the oxidized to that of the reduced species. A plot of change in potential against volume is characterized by a sudden change of potential at the equivalent point. At the end point, potential is determined by large jump in the potential value.

Instrumentation:

A potentiometer consists of:

I. Calomel electrode as a reference electrode,
II. Platinum electrode as an indicator electrode,
III. A device for measuring the potential
IV. Stirrer to mix the solution

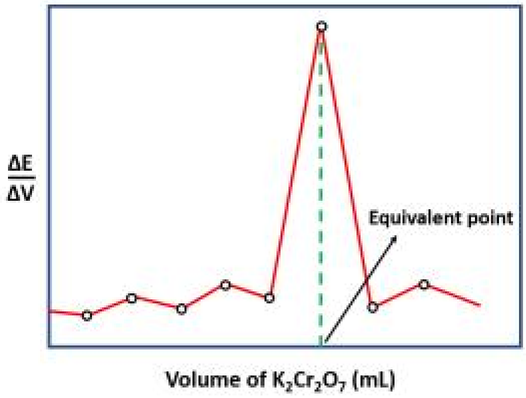


Application in estimation of Fe in steel: Potentiometric estimation of Fe using standard $K_2Cr_2O_7$ solution

Pipette out 25ml of iron solution into a beaker. Add 1 t.t dil H2SO4. Immerse calomel electrode + platinum electrode into it. Connect the assembly to a potentiometer and measure the potential by adding K2Cr2O7 in the increments of 0.5ml.

Plot graph E/ V against volume of K2Cr2O7, and determine the equivalence point. From the normality and volume K2Cr2O7, solutions calculate the normality and the weight of FAS in the given solution.

$Cr_2O_7^{2-} + 14\,H^+ + Fe^{2+} \rightarrow Fe^{3+} + Cr^{3+} + 7H_2O$



Advantages:

(i) They give results more reliable than those obtained from titrations using indicators
(ii) The method is applicable to both coloured and turbid solutions also

(b) **What are reference electrodes? Describe the construction and working of calomel electrode. Mention its 2 applications.**

Reference electrodes are the electrodes whose potentials are known and constant and they are used to determine potentials of other electrodes.

Eg: .Calomel electrode, Silver-silver chloride electrode

It is a metal – metal salt ion electrodes and also a secondary reference electrode.

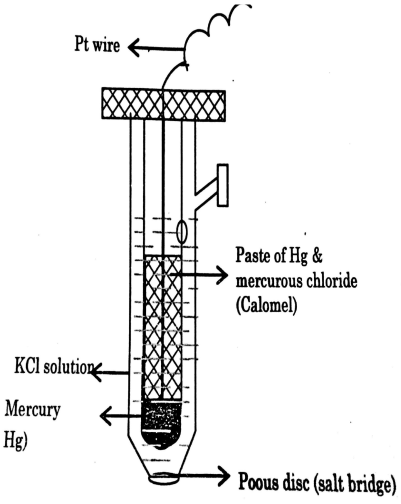
Construction: It consists of mercury, mercurous chloride and a solution of KCl. It is made up of glass tube, Hg is placed at the bottom of the glass tube. It is covered with a paste of calomel ($HgCl_2$) and KCl solution. A solution of KCl is introduced above the paste through the side tube. Electrical contact is made through Pt wire (dipped in Hg). This glass tube is taken into another glass tube, which has a side tube and a porous plug at the bottom. This porous plug act as salt bridge. The conc of KCl solution used is either decinormal, normal or saturated. Correspondingly, the electrode is known as decinormal, normal or saturated calomel electrode. This constitutes one half cell. Calomel electrode can act as either anode or cathode. It is connected to the other half cell through salt bridge.

Half cell (Electrode) representation

The calomel electrode is represented as,

$Hg / Hg_2Cl_2 (s) / Cl^-$ (anode)

Or $Cl^- / Hg_2Cl_2 (s) / Hg$ (Cathode)



Calomel electrode

Working

Depending on the potential of electrode with which the calomel electrode is connected, calomel electrode acts as anode or cathode.

(a). **When it acts as anode, electrode reaction is**

$$\begin{array}{lcl} 2Hg & \longrightarrow & Hg_2^{2+} + 2e^- \\ Hg_2^{2+} + 2Cl^- & \longrightarrow & Hg_2Cl_2 \\ \hline 2Hg + 2Cl^- & \longrightarrow & Hg_2Cl_2 + 2e^- \end{array}$$

(b) **When it acts as cathode, electrode reaction is**

$$\begin{array}{lcl} Hg_2^{2+} + 2e^- & \longrightarrow & 2Hg \\ Hg_2Cl_2 & \longrightarrow & Hg_2^{2+} + 2Cl^- \\ \hline \end{array}$$

$$Hg_2Cl_2 + 2e^- \longrightarrow 2Hg + 2Cl^-$$

Thus, Net reversible electrode reaction is

$$\boxed{Hg_2Cl_2 + 2e^- \rightleftharpoons 2Hg + 2Cl^-}$$

Electrode potential is calculated using Nernst equation,

$$E_{cal} = E^\circ - 0.0591 \log [Cl^-] \text{ at } 298\text{ K}$$

From the above equation it is evident that, the electrode potential of the calomel electrode is mainly depends on the concentration of KCl used. At 298 K the electrode potential are as follows-

For, 0.1 N KCl = 0.334V

1 N KCl = 0.280V

Sat KCl = 0.242 V

Applications:

1. It is used as secondary reference electrode in all potentiometric determinations.
2. Used in glass or combined electrode to determine the pH of the unknown solution.

7 (a) **What are E-waste? Discuss the effect of E-waste on environment and human health.**

E-waste or electronic waste means discarded electrical or electronic devices or components. This includes working and broken items that are thrown in the garbage or donated to a charity reseller, their components, consumables, parts, and spares.

Effects of e-waste on environment and human health: E-waste is a serious issue for our environment because it releases harmful toxic chemicals from the metals due to chemical reactions and these toxic chemicals harm our environment, therefore they must be handled with care when no longer wanted or needed.

Electronic scrap components, such as CPUs, contain potentially harmful materials such as lead, cadmium, beryllium, or brominated flame retardants. Improper disposal of e-waste is highly dangerous to the global environment involving significant risk to the health of workers and their communities

The consequences of improper e-waste disposal in landfills or other non-dumping sites pose serious threats to current public health and can pollute ecosystems for generations to come. When electronics are improperly disposed of and end up in landfills, toxic chemicals are released, impacting the earth's air, soil, water, and ultimately, human health.

Effects on Air quality: Contamination in the air occurs when e-waste is informally disposed of by dismantling, shredding, or melting the materials, releasing dust particles or toxins, such as dioxins, into the environment that cause air pollution and damage respiratory health. Chronic diseases and cancers are at a higher risk to occur when burning e-waste because it also releases fine particles, which can travel thousands of miles, creating numerous negative health risks to humans and animals. The air pollution caused by e-waste impacts some animal species more than others, which may be endangering these species and the biodiversity of certain regions that are chronically polluted. Over time, air pollution can hurt water quality, soil, and plant species, creating irreversible damage to ecosystems.

Effects on Soil: When the improper disposal of e-waste in regular landfills or in places where it is dumped illegally, both heavy metals and flame retardants can seep directly from the e-waste into the soil, causing contamination of underlying groundwater or contamination of crops that may be planted nearby or in the area in the future. When the soil is contaminated by heavy metals, the crops become vulnerable to absorbing these toxins, which can cause many illnesses and doesn't allow the farmland to be as productive as possible.

Effects on Water: After soil contamination, heavy metals from e-waste, such as mercury, lithium, lead, and barium, then leak through the earth even further to reach groundwater. When these heavy metals reach groundwater, they eventually make their way into ponds, streams, rivers, and lakes. Through these pathways, acidification and toxicity are created in the water, which is unsafe for animals, plants, and communities even if they are miles away from a recycling site. Clean drinking water becomes problematic to find.

Effects on Humans: Electronic waste contains toxic components that are dangerous to human health, such as mercury, lead, cadmium, polybrominated flame retardants, barium, and lithium. The negative health effects of these toxins on humans include brain, heart, liver, kidney, and skeletal system damage. It can also considerably affect the nervous and reproductive systems of the human body, leading to disease and birth defects.

(b) **Explain the theory, instrumentation and applications of colorimetry by taking estimation of copper in PCBs as an example.**

Principle: When a monochromatic light of intensity I_0 is incident on a transparent medium, a part I_a of is absorbed, a part I_r is reflected and the remaining part is transmitted I_t.

$$\mathbf{I_0 = I_a + I_r + I_t}$$

For a glass-air interface I_r is negligible, therefore,

$$\mathbf{I_0 = I_a + I_t}$$

$\mathbf{I_t / I_0 = T}$ called the transmittance, $\mathbf{\log 1/T = \log I_0 / I_t}$ is called the absorbance or optical density.

Colorimetry measurements are based on ***Beer-Lambert's law***. This law gives the relation between absorbance A, concentration c (expressed in mo1/dm^3) and path length t, (expressed in cm).

Beer-Lambert's law: When monochromatic light passes through a transparent medium, the amount of light absorbed is directly proportional to the concentration and path length of the solution.

$$\mathbf{A \propto ct}$$

$$\mathbf{A = \log I_0/I_t = \varepsilon ct}$$

Where **ε** is the molar extinction coefficient, **c** is the concentration, **t** is the path length and is a constant for a given substance at a given wavelength. If the length is kept constant (t),

$$\mathbf{A \propto c}$$

Hence a plot of absorbance against concentration gives a straight line.

Instrumentation: The instrument used to measure the absorbance of a solution is called photoelectric colorimeter.

It consists of

(i) Tungsten lamp as the light source.

(ii) A filter which provides the desired wavelength range wherein the solution gives the maximum absorbance.

(iii) A sample cell

(iv) A photocell detector

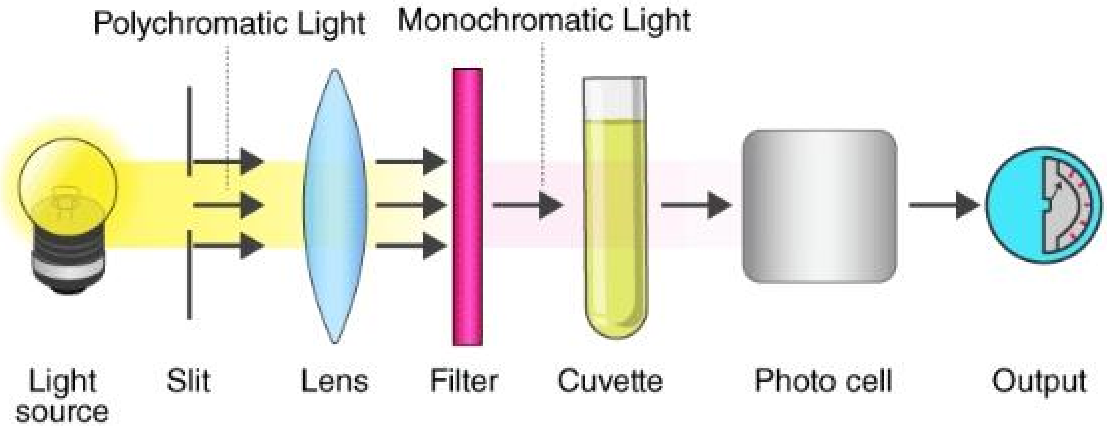


Fig: Schematic layout of colorimeter

Application in estimation of Copper in PCBs:

Transfer the given copper sulphate solution (stock solution) to a burette and draw out **2**, **4**, **6**, **8** and **10** mL of the solution into a 50 mL volumetric flask. Add 5 mL of ammonia solution to each of them and dilute up to the mark with ion exchange water. Stopper the flasks and mix the solutions well. add 5 mL of ammonia solution to the given test solution and then dilute up to the mark with ion exchange water and mix well.

Prepare a blank solution by diluting 5 mL of ammonia solution in a 50 mL measuring flask up to the mark with ion exchange water and mixing well. Measure the absorbance of the solutions against the blank at 620 nm using a photoelectric colorimeter. Tabulate the readings as shown. Draw a calibration curve by plotting the absorbance against the volume of copper sulphate solution. Using the calibration curve, find out the volume of copper sulphate solution given i.e., the volume of the test solution and calculate the amount of copper in the given solution.