CBCS SCHEME

USN | | | | | | | | | | | **BCHES102/202**

First/Second Semester B.E./B.Tech. Degree Examination, Dec.2024/Jan.2025

Applied Chemistry for CSE Stream

Time: 3 hrs.   Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. VTU Formula Hand Book is permitted.
3. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Explain the working principle of conductometric sensors (Conductometry) and applied sensors (Colorimetry).	7	L2	CO1
	b.	Write a note on Disposable sensors? Explain its advantages over classical sensors.	7	L3	CO2
	c.	Describe the construction, working and applications of Lithium-ion battery and mention its applications.	6	L4	CO3
		OR			
Q.2	a.	What are Electrochemical Sensors? Explain its applications in the measurement of Dissolved Oxygen (DO).	7	L3	CO2
	b.	What are Transducers? Explain the applications of Electrochemical gas sensors in sensing SO_X and NO_X.	7	L3	CO5
	c.	Describe the construction, working and applications of Sodium-ion battery and mention its applications.	6	L4	CO3
		Module – 2			
Q.3	a.	Explain the types of organic memory devices by taking P-type and n-type semiconductor materials.	7	L2	CO2
	b.	What are Memory Devices? Explain the classification of electronic memory devices with examples.	7	L1	CO2
	c.	Explain any four properties of polythiophenes (P3HT) suitable for optoelectronic devices.	6	L2	CO4
		OR			
Q.4	a.	Mention any four properties and applications of QLED.	7	L2	CO3
	b.	Mention any four properties and applications of LCD-displays.	7	L2	CO3
	c.	What are nanomaterials? Explain any four properties of poly (9-vinyl Carbazole) (PVK) suitable for optoelectronic devices.	6	L2	CO4
		Module – 3			
Q.5	a.	Define metallic corrosion. Describe the electrochemical theory of corrosion by taking iron as an example.	7	L3	CO2

	b.	Describe galvanizing and mention its applications.	7	L2	CO3
	c.	Define electrolyte concentration cell. A galvanic cell is obtained by combining two copper electrodes of concentrations 0.1 and 0.5 H immersed in copper sulphate solution at 25°C. Give the cell reaction and calculate EMF of the cell.	6	L3	CO4
		OR			
Q.6	a.	Explain the construction, working and applications of Calomel Electrode.	7	L2	CO2
	b.	What is CPR? A thick sheet of area 600 cm^2 (93 $inch^2$) is exposed to air near the ocean. After a 6 months it was found to experience a weight loss of 360 g due to corrosion, if the density of the steel is 7.9 g/cm^3. Calculate the corrosion penetration rate in mpy and mmpy (Given K = 534 in mpy and 87.6 mm/y)	7	L3	CO4
	c.	Explain : (i) Differential metal corrosion (ii) Water line corrosion.	6	L2	CO2
		Module – 4			
Q.7	a.	In a sample of a polymer, 150 molecules have the molecular mass 100 g/mol, 200 molecules have the molecular mass 1000 g/mol, 350 molecules have the molecular mass 10,000 g/mol. Determine number average and weight average molecular mass. Find the Index of Polydispersity.	7	L3	CO4
	b.	Explain the preparation, properties and commercial applications of Kevlar.	7	L2	CO2
	c.	Explain the generation of hydrogen of Alkaline Water Electrolysis.	6	L2	CO3
		OR			
Q.8	a.	Explain the synthesis of polyacetylene and mention its applications.	7	L2	CO2
	b.	Explain the generation of hydrogen by proton exchange membrane Electrolysis of water.	7	L2	CO3
	c.	Describe the construction and working of photovoltaic cells.	6	L2	CO2
		Module – 5			
Q.9	a.	Describe the sources and composition of e-waste materials.	7	L2	CO1
	b.	Explain the ill effects of toxic materials used in manufacturing electrical and electronic products.	7	L2	CO1
	c.	Discuss the extraction of gold from e-waste.	6	L2	CO3
		OR			
Q.10	a.	What are e-wastes? Explain the need for e-waste management.	7	L2	CO1
	b.	Write a brief note on role of stakeholders for example : Producers, Consumers, Recyclers and Statutory bodies.	7	L2	CO1
	c.	Explain the pyrometallurgy and direct recycling methods.	6	L2	CO2

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Module-1

Q.1.a.

Conductometric sensors (Conductometry):

A conductometric sensor is a sensor used to measure the conductivity of various solutions or the concentration of the overall ion in a sample. It is based on the measurement of the specific conductance of an analyte.

Working principle

The conductance depends on the mobility of ions as well as the number of ions migrating between the electrodes. The basic principle of a conductometric sensor involves a reaction that changes the ionic species concentration. This reaction leads to changes in ionic concentration as well as the conductance between the electrodes. That affects electrical conductivity or current flow. The analyzer applies an alternating voltage to the drive coil, which induces a voltage in the liquid surrounding the coil. The voltage causes an ionic current to flow proportional to the conductance of the liquid.

Optical sensors (Colorimetry):

An optical sensor is a device that can detect light, typically at a specific range of electromagnetic spectrum (ultraviolet, visible, and infrared) by converting it into electrical signals.

Working principle:

- **Transmitter (Light Source):** Optical sensors have a light source that emits light. This source can be an LED (Light-Emitting Diode) or laser diode.
- **Interaction with Target:** The emitted light interacts with the target or the environment. This interaction involves reflection, absorption, transmission, scattering, or diffraction of light by the target.
- **Light Detection (Receiver):** Optical sensors have a light detector, which can be a photodiode. The detector can sense the change in the properties of the light.
- **Conversion to Electrical Signal:** The light detector converts the detected optical signals into electrical signals. The amount of change in the electrical signal is related to the properties of the light interacting with the target.

Q.1.b.

Disposable Sensor

A disposable sensor is a type of sensor that is designed for single-use applications, after which it is discarded.

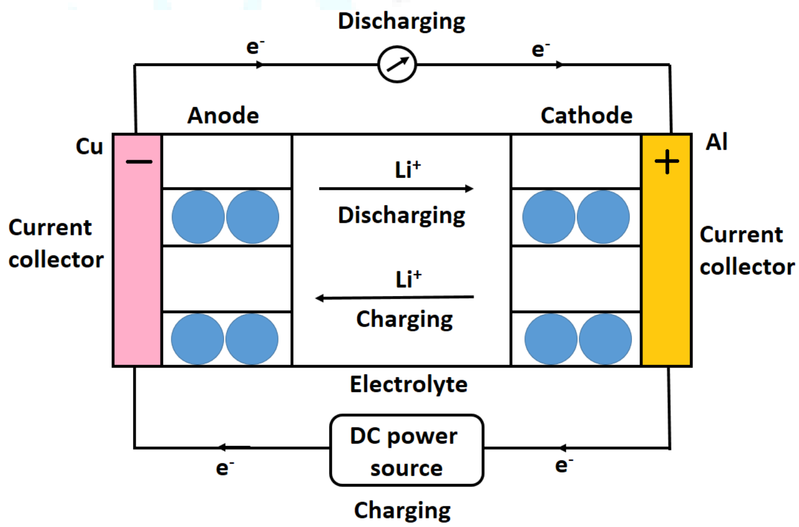
Advantages of disposable sensor over classical sensors

1. Cost-effective: Disposable sensors are typically less expensive than classical sensors since they are designed for single-use applications.
2. Reduced contamination risk: Disposable sensors are sterile and do not require cleaning or sterilization between uses. This reduces the risk of contamination and infection associated with reusing classical sensors.

3. Convenient and portable: Disposable sensors are often designed to be compact and portable, which makes them ideal for use in remote or mobile settings where classical sensors may not be practical.
4. More accurate results: Since disposable sensors are designed for single-use applications, they are often calibrated and optimized for maximum accuracy. This can result in more reliable and consistent results compared to classical sensors.
5. Reduced environmental impact: While the disposal of disposable sensors can generate waste they are often made from less environmentally harmful materials than classical sensors.

Q.1.c.

Li-ion battery is a type of rechargeable battery that uses lithium ions as the primary carrier of electric charge. The movement of lithium-ion takes place through the electrolyte from one electrode to another electrode.



<u>**Construction**</u>

- ***Anode***: Lithium intercalated graphite layer (Li_xC_6)
- ***Cathode***: Partially lithiated transition metal oxide, E.g. Lithium cobalt oxide ($LiCoO_2$)
- ***Electrolyte***: Lithium salts like LiCl, LiBr dissolved in propylene carbonate
- ***Separator***: Polyolefin polymer

<u>**Working**</u>

- Anode reaction: $Li_xC_6 \longrightarrow xLi^+ + xe^- + 6C$
- Cathode reaction: $Li_{1-x}CoO_2 + xLi^+ + xe^- \longrightarrow LiCoO_2$
- Overall reaction: $Li_{1-x}CoO_2 + Li_xC_6 \longrightarrow LiCoO_2 + 6C$

During ***discharge***, Li^+ ions are dissociated from the anode and then migrate from the anode to cathode through the electrolyte. Electrons travel through an external circuit. This process creates an electric current that can power a device or system.

*During **Charging:*** Li^+ ions move from the cathode to the anode through the electrolyte.

Application of Lithium-ion battery

- They are commonly used in smart phones, tablets, laptops
- They are used in medical devices
- They are used in spacecraft and satellites
- They are used in electric cars.

Q.2.a. Answer:

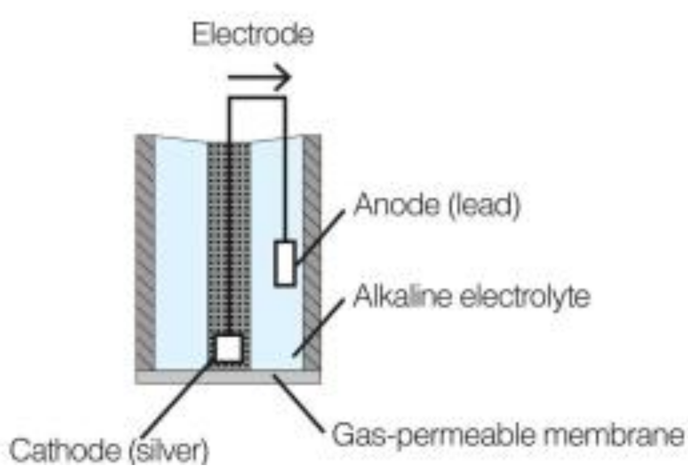
Electrochemical sensors designed for measuring dissolved oxygen typically use a Clark electrode, which consists of a cathode and an anode separated by an electrolyte. The anode serves as a reference electrode, providing a stable potential for the cathode.

Anode: Lead or Zinc

Cathode: Gold or platinum,

Electrolyte: NaOH

Separator: a thin layer of hydrophobic material, such as Teflon.



When the Clark electrode is immersed in a liquid sample, oxygen molecules diffuse through the hydrophobic layer and react with the cathode surface, producing a current that is proportional to the amount of oxygen present in the water.

Anode (Pb): $2Pb \rightarrow 2Pb^{2+} + 4e^-$

Cathode (Ag): $O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$

Overall reaction: $O_2 + 2H_2O + 2Pb \rightarrow 2Pb(OH)_2$

The white solid, $Pb(OH)_2$, that is produced by these reactions is precipitated out into the electrolyte solution. It neither coats the anode nor consumes the electrolyte, and thus does not affect the sensor's performance until the quantity becomes excessive.

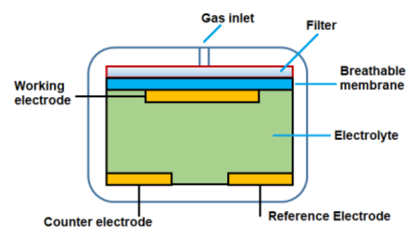
Applications

They are widely used in industrial and environmental applications, such as monitoring the oxygen levels in wastewater treatment plants, fish farms, and drinking water supplies.

Q.2.b.

Construction

The components of an electrochemical gas sensor are:



- ***Working electrode*** (sensing electrode): An electrochemical reaction occurs on the surface of the sensing electrode. (**Gold**)
- ***Counter electrode***: helps to measure the current flow through the system during the electrochemical reaction. (**Platinum**)
- ***Reference electrode***: Provide a stable potential to the working electrode (**Ag/AgCl**)
- ***Electrolyte***: ionically conducting materials (**3-7M H_2SO_4**)
- ***Membrane***: A gas-permeable membrane is used to control the gas flow reaching the electrode surface.
- ***Filter:*** to filter out the unwanted gas

Working

- The electrodes are separated and immersed in an aqueous medium (electrolyte).
- The gas molecules diffuse through a porous membrane that is placed in contact with the working electrode.
- In this electrode surface, gas molecules lose electrons after the oxidation process.
- A reduction of oxygen occurs at the counter electrode in electrochemical sensors.
- Electrons move through wires connected to the electrodes and an external circuit.
- Flow of electrons generates an electrical signal proportional to the concentration of toxic gas
- The medium provides hydrogen ions (H^+) that move through the aqueous solution

Electrochemical reactions for the SO_2 and NO gas sensors are:

Working electrode (Anode): $SO_2 + H_2O \rightarrow SO_3 + 2 H^+ + 2 e^-$
Counter electrode (Cathode): $(1/2) O_2 + 2 H^+ + 2 e^- \rightarrow H_2O$

Working electrode (Anode): $NO + H_2O \rightarrow NO_2 + 2 H^+ + 2 e^-$
Counter electrode (Cathode): $(1/2) O_2 + 2 H^+ + 2 e^- \rightarrow H_2O$

Q.2.c.

Na-ion battery is a type of rechargeable battery that uses sodium ions as the primary carrier of electric charge. The movement of sodium-ion takes place through the electrolyte from one electrode to another electrode.

Construction

Anode: Sodium interacted hard carbon

Cathode: Sodium cobalt oxide layer ($NaCoO_2$)

Electrolyte: $NaPF_6$ dissolved a mixture of carbonate solvents

Separator: Polypropylene polymer

Working

- Anode reaction: $Na_xC_6 \rightarrow xNa^+ + xe^- + 6C$
- Cathode reaction: $Na_{1-x}CoO_2 + xNa^+ + xe^- \rightarrow NaCoO_2$
- Overall reaction: $Na_{1-x}CoO_2 + Na_xC_6 \rightarrow NaCoO_2 + 6C$

During discharge, Na+ ions are dissociated from the anode and migrate from the anode to cathode through the electrolyte. Electrons travel through an external circuit. This process creates an electric current that can power a device or system.

During Charging: Na+ ions move from the cathode to the anode through the electrolyte.

Application of Lithium-ion battery

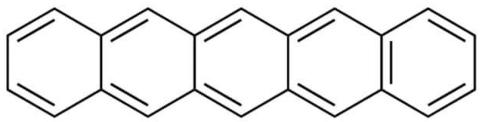
- They are commonly used boats and ships
- They are used in medical devices
- They are used in military and defence
- They are used in electric cars.

Module-2

Q.3.a.

Organic memory devices use p-type and n-type semiconductor materials to create a heterojunction that can be used to store data.

A. **p-type semiconductors materials** that have an excess of positively charged holes, which can conduct electricity. *Examples*: Pentacene.

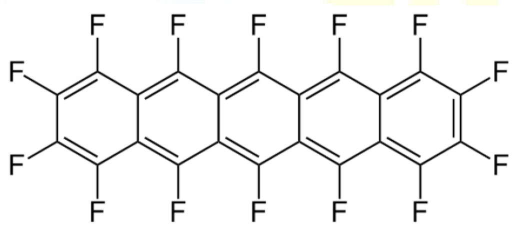


Application: It is used in organic flash memory and organic resistive random access memory (RRAM).

Characteristics

- It has **high hole mobility**, which makes it a good material for organic memory devices.
- It has a **low ionization potential**,
- It is highly **sensitive to light** and has **high photoconductivity**.
- It has a **long carrier diffusion length**.
- It is a **stable material**.

B. **n-type semiconductor materials** that have an excess of electrons in their conduction band. *Examples*: Perfluoropentacene.



Application: It is used in the construction of organic electronic devices such as organic field-effect transistors.

Characteristics

- It has **high electron mobility**, which allows electrons to move quickly through the material.
- It has a **high electron affinity**
- It is a **stable material**
- It has **low ionization potential.**
- It is **highly sensitive to light** and has **high photoconductivity**.

Q.3.b.

Memory devices are electronic components that can store and retrieve digital data. These devices are used to hold data and programs that a computer needs to access quickly.

Classification of electronic memory devices

A. **Transistor type electronic memory devices:** Such type memory device uses transistors as the building blocks for data. The basic principle of transistor-type electronic memory is that it stores data as charges on the gates of transistors, which act as switches. The data can be read from the transistor by measuring the voltage level on the gate.

Examples: Dynamic Random Access Memory (DRAM), Static Random Access Memory (SRAM)

B. **Capacitor type electronic memory devices:** Such type memory device uses capacitors to store digital data. The basic principle of capacitor type electronic memory is that it stores data as electrical charge on a capacitor. When the data needs to be read, the charge on the capacitor is measured and translated into a digital value.

Examples: NAND Flash Memory, Ferroelectric RAM (FeRAM)

C. **Resistor type electronic memory devices:** Such type memory device store the digital data using the resistance of a material. The basic principle is that it stores data as the resistance level of a resistor. The data can be read by measuring the resistance of each resistor.

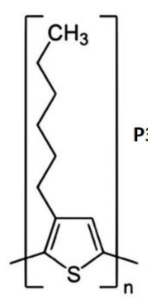
Examples: Resistive Random Access Memory (RRAM), Phase-Change Memory (PCM)

D. **Charge transfer type electronic memory devices:** Such type memory devices use the transfer of charge between capacitors or other circuit elements to store and retrieve digital data. The data can be read by measuring the voltage level on the capacitor or other element.

Examples: Charge-Coupled Device (CCD) Memory, Ferroelectric Random Access Memory (FRAM)

Q.3.c.

Polythiophene: It is a semiconducting polymer, an excellent candidate for optoelectronic devices.



P3HT: Poly(3-hexylthiophene)

Properties of polythiophenes:

- They have **high charge carrier mobility**, which is crucial for efficient charge transport in optoelectronic devices.

- They are **highly soluble** in common organic solvents, making them easy to process into thin films required for optoelectronic devices.
- They have a **high absorption coefficient** in the visible range, which allows them to absorb light in solar cells and photodetectors efficiently.
- They have **tunable optical and electrical properties** which allows them for specific optoelectronic applications.

Applications

- These materials are used as active layers in **organic solar cells**.
- These materials are used in the fabrication of **Organic Light-Emitting Diodes** as emissive or charge-transporting layers.
- These materials are used in **photodetectors** to sense light and convert it into an electrical signal.
- These materials are incorporated into field-effect transistors (FETs) to create **Light-Emitting Transistors**.

Q.4.a.

Properties of QLEDs

- QLEDs can produce **highly accurate and vibrant colors** due to quantum dots, which emit light of a specific color when they are excited by an electrical current.
- QLEDs are more **energy-efficient** than traditional LCD displays because they do not backlight.
- QLED displays have **high contrast** ratios, they can produce deep black and bright white images.

Applications of QLEDs

- QLED displays are commonly used in **televisions, monitors, smartphones**, and other electronic devices.
- QLEDs can also be used as a **source of lighting** in various applications, including automotive lighting, street lighting, and architectural lighting.
- QLEDs can be used in **medical imaging** applications, such as in MRI machines, to produce high-resolution and accurate images.

Q.4.b.

Properties of LCDs:

1. Low Power Consumption: LCDs consume very little power compared to other types of displays.
2. High Contrast Ratio: LCDs have a high contrast ratio, which is the ratio between the brightest and darkest parts of the display. This property allows for better image quality.
3. Wide Viewing Angle: LCDs have a wide viewing angle, meaning that the displayed image remains clear and readable even when viewed from off-center angles.
4. Fast Response Time: LCDs have a fast response time, which means that they can switch between different images quickly.

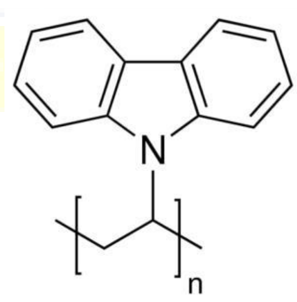
Applications of LCDs:

1. Mobile Devices: LCDs are commonly used in smartphones and tablets, providing a high-quality display with low power consumption.
2. Computer Monitors: LCDs are used in computer monitors, providing high resolution and a wide viewing angle.
3. Televisions: LCDs are used in flat screen televisions, providing high-quality images and a thin profile.
4. Medical Devices: LCDs are used in medical devices, such as ultrasound machines and patient monitors.

Q.4.c.

Nanomaterials are commonly defined as materials with an average particle size of less than 100 nm. They exhibit unique physical and chemical properties that differ from their bulk counterparts.

Poly (9-vinylcarbazole) (PVK) is a light-emitting material which is used in optoelectronic devices due to its desirable properties.



Properties

- PVK has a **high optical transparency** in the visible range, which makes it suitable for use as a transparent electrode in optoelectronic devices.
- PVK has **good charge transport properties**, allowing for efficient movement of electrons and holes through the polymer.

- PVK has **high thermal stability**, which means that it can withstand high temperatures without degradation.
- PVK is **soluble in common organic solvents**, such as chloroform and toluene, which makes it easy to process and fabricate into thin films for use in optoelectronic devices.

Applications

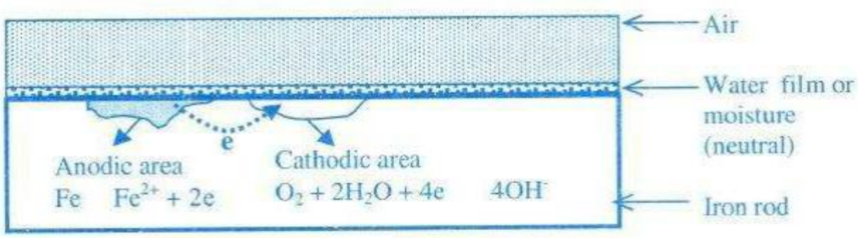
- PVK can be used as a hole transport layer in **organic light-emitting diodes**.
- PVK can be used as a hole-transporting material in **organic photovoltaic devices**.
- PVK can serve as an active material in **photodetectors**, converting incoming light into electrical signals.
- PVK-based devices can be used as **sensors** for detecting various environmental factors, including temperature, humidity, and gas concentrations.

Module-3

Q.5.a.

Destruction of metal surface in surrounding environment due to chemical or electrochemical reaction is known as corrosion. eg rusting of iron.

Electrochemical theory of corrosion:



(i) According to electrochemical theory, corrosion of metals takes place due to the formation of minute galvanic cells over the surface of metal. Thus anodic and cathodic regions are formed on the same metal surface or when two metals are in contact with each other in the presence of a conducting medium.

(ii) At the anodic region oxidation reaction takes place and the metal gets converted into its ions by liberating electrons. Consequently, metal undergoes corrosion at the anodic region.

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

(iii) 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,
  - $O_2 + H_2O + 2e^- \longrightarrow 2OH^-$
- If the solution is deaerated and almost neutral:

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

- If the solution is deaerated and acidic:

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

(iv) 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 $(OH)_2$.

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

(Ferrous hydroxide)

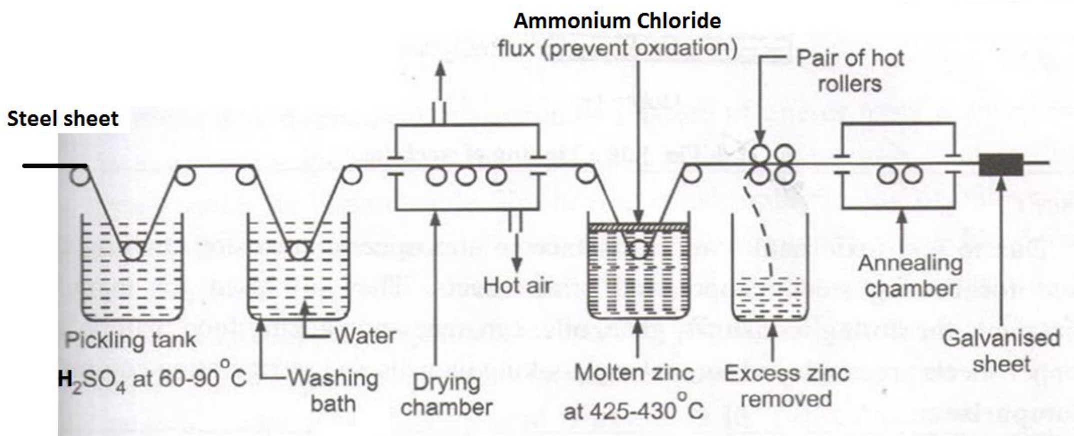
(v) In an oxidizing environment, it is oxidized to ferric oxide and the rust is hydrated ferric oxide.

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

Q.5.b.

Galvanization is a process of coating a base metal surface with Zinc metal. Galvanization consists of hot dipping method which involves the following steps.

- The metal surface is washed with organic solvents to remove organic impurities such as oil and grease present on it.
- Then metal surface is washed with dilute sulphuric acid (pickling) to remove rust and other inorganic deposits.
- Then it is washed well with water and air dried.
- The metal is treated with mixture of aqueous solution $ZnCl_2$ and NH_4Cl which acts as flux and dried.
- The metal is then dipped in molten zinc maintained at 450°C.
- Excess zinc is released by passing the metal through rollers (or) by wiping.



Galvanizing of Steel sheet

Q.5.c.

The concentration cells consist of identical electrodes immersed in the solutions of the same electrolytes but with varying concentrations. Potential difference arises due to difference in electrolyte concentration.

Cell representation: Concentration cell is represented as,

Cu/Cu^{+2} (C1= 0.1M) || (C2= 0.5M) Cu^{+2}/Cu

Working

Anode: Cu $\longrightarrow$ Cu^{+2} (0.1M) +2e^-

Cathode: Cu^{+2} (0.5M) +2e^- $\longrightarrow$ Cu

Net cell reaction: Cu^{+2} (0.5M) $\longrightarrow$ Cu^{+2} (0.1M)

In concentration cell, both electrodes are same, hence

$$E_{cell} = \frac{0.0591}{n} \log \frac{C2}{C1} \text{ at 298K}$$

E_{cell} = 0.0591/2 log(0.5/0.1)

E_{cell} = 0.02955 x 0.69897

E_{cell} = 0.0207 V

Q.6.a. Answer:

Construction and working of calomel electrodes:

It is a metal-insoluble salt electrode, where metal in contact with its insoluble salt and the solution contains the anion of the salt. Mercury is placed at the bottom of the glass tube above which a paste of mercury and mercurous chloride are present. It is filled on the top with the saturated solution of KCl. A platinum wire sealed into a glass tube is dipped into mercury and used to provide the external electrical contact. Depending on the nature of the other electrode it can either acts as anode or cathode.

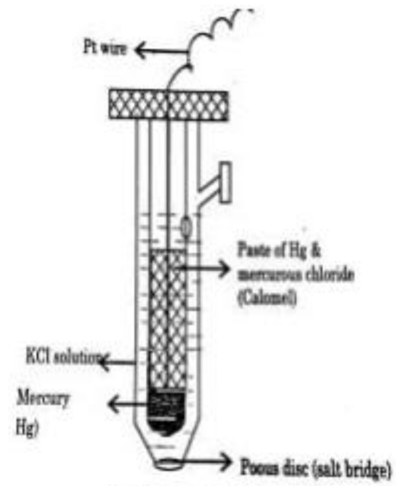
Electrode representation: $Hg(s)/Hg_2Cl_2$ (paste);Cl-

If the electrode behaves as anode, the electrode reaction is:

$$2Hg_{(l)} \rightarrow Hg_2^{+2} + 2e^-$$

$$Hg_2^{+2} + 2Cl^- \rightarrow Hg_2Cl_{2(s)}$$

$$2Hg_{(l)} + 2Cl^- \rightarrow Hg_2Cl_{2(s)} + 2e^-$$



Calomel electrode

If the electrode behaves as cathode, the electrode reaction is:

$$Hg_2^{+2} + 2e^- \rightarrow 2Hg_{(l)}$$

$$Hg_2Cl_{2(s)} \rightarrow Hg_2^{+2} + 2Cl^-$$

$$Hg_2Cl_{2(s)} + 2e^- \rightarrow 2Hg_{(l)} + 2Cl^-$$

The electrode potential of calomel electrode depends on concentration of chloride ions. For saturated KCl; E=0.2422V (called Saturated calomel electrode)

Application: It is used as a secondary reference electrode in the measurement of single electrode potential. It is the most commonly used reference electrode in all potentiometric determination.

Q.6.b.

The speed at which any metal in a specific environment deteriorates due to a chemical reaction in the metal when it is exposed to a corrosive environment.

The CPR is calculated as follows:

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

Corrosion penetrating rate in mpy CPR = KW/DAT	Corrosion penetrating rate in mm/y CPR = KW/DAT

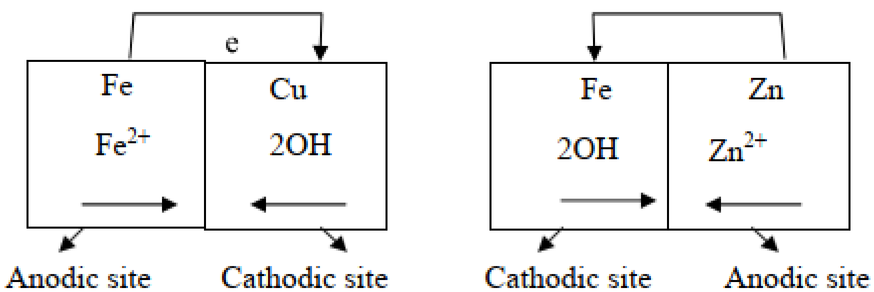
Weight loss, W= 360 × 10^3 mg	Weight loss, W= 360 × 10^3 mg
Density, D = 7.9 g/cm, Time, T = 6 ×24x30	Density, D = 7.9 g/cm, Time, T = 6 ×24x30
Area A = 93 $inch^2$	Area A = 600 cm^2
CPR = $\frac{534\times360\times10^3}{7.9\times93\text{x}\ 6\times24\times30}$	CPR = $\frac{87.6\times360\times10^3}{7.9\times600\times6\times24\times30}$
CPR = 60.57 mpy	CPR = 1.54 mm/y

Q.6.c.

Differential metal corrosion

- When two dissimilar metals are in contact with each other, the metal with ***lower reduction potential*** undergoes oxidation whereas the metal with ***higher reduction potential*** undergoes reduction.
- The potential difference between the two metals is the cause for corrosion, higher the difference faster is the rate of corrosion. The anodic metal undergoes corrosion and the cathodic metal is unaffected.

Let us consider a bimetallic sample of iron and copper as shown below.



Case 1: The standard electrode potential **of Fe is – 0.44 V** which is less than that of Cu whose standard electrode potential is **0.34 V**. Hence in this case iron acts as anode and undergoes corrosion whereas copper acts as cathode and remains unaffected.

Cell reactions:

During differential metal corrosion when Fe is in contact with Cu

At anode: $Fe \rightarrow Fe^{2+} + 2e^-$

At cathode: either hydrogen evolution or oxygen absorption

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

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

Water line corrosion

- This take place due to the formation of different oxygen concentration.
- The part of metal exposed to ***lower concentration*** of oxygen (dissolved oxygen) acts as anodic area and undergoes corrosion.

- The part of the metal above the water level is exposed to ***higher concentration*** of oxygen acts as cathodic are and remains unaffected.
- A ***distinct brown line*** is formed just below the ***water line*** due to the deposition of rust.
- Water line corrosion is observed usually in steel water tanks and ships floating in sea water for a long time.

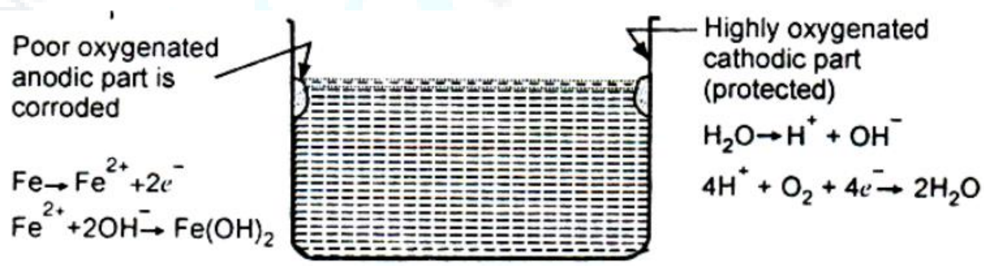
Cell Reaction:

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

At the cathode (more O_2 concentration): $O_2 + 2\,H_2O + 4e^- \rightarrow 4\,OH^-$

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

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



Module-4

Q.7.a.

Number average molecular mass:

Total weight = (150 x 100) + (200 x 1000) + (350 x 10000) = 15,000 + 200,000 + 3,500,000

= 3,715,000

Total number = 150 + 200 + 350 = 700

$$M_n = \frac{\Sigma M_i N_i}{\Sigma N_i}$$

Mn = 3715000 / 700 = 5307.143 **g/mol**

Weight average molecular mass:

$$M_W = \frac{\Sigma N_i (M_i)^2}{\Sigma N_i M_i}$$

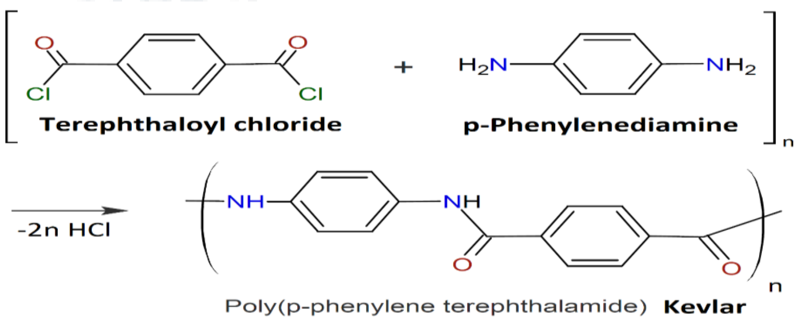
$$M_w = \frac{\{[(150 \times (100)^2] + [(200 \times (1000)^2] + [(350 \times (10000)^2]\}}{3{,}715{,}000}$$

M_w = 35,201,500,000 / 3,715,000

M_w = 9475.5 g/mol

Q.7.b.

Kevlar is prepared by polycondensation between aromatic dichloride like ***terephthaloyl acid chloride*** and aromatic diamines like ***p-phenylenediamine***.



Properties:

- It is exceptionally strong, 5 times stronger than steel and 10 times stronger than aluminium.
- It is thermally stable up to 450°C.
- It is also stable at very low temperatures (up to -196°C)
- Kevlar can resist attacks from many different chemicals,

Applications:

- Kevlar is widely used in the production of bulletproof vests, military helmets and body armour.
- Kevlar is used in protective clothing for military personnel, law enforcement officers and firefighters.
- Kevlar is used in various industrial applications, such as conveyor belts, hoses, and gaskets
- Kevlar is employed in the aerospace and aviation industries for its lightweight properties and ability to withstand high temperatures.

Q.7.c.

Alkaline Water Electrolysis:

- It consists of two electrodes i.e. anode and cathode.
- Both electrodes are made up of Ni based metal, because it is more stable during the oxygen evolution.
- These electrodes are immersed in KOH solution (25-35%).
- Both electrodes are separated by porous diaphragm prevent gases crossover and allows only hydroxide ions.
- When electricity is passed, at anode hydroxide ions lose electrons and forms water molecules.
- At cathode, water molecules accept electrons and liberate hydrogen gas and forms hydroxide ions.
- These hydroxide ions move from cathode to anode through diaphragm and process continues.

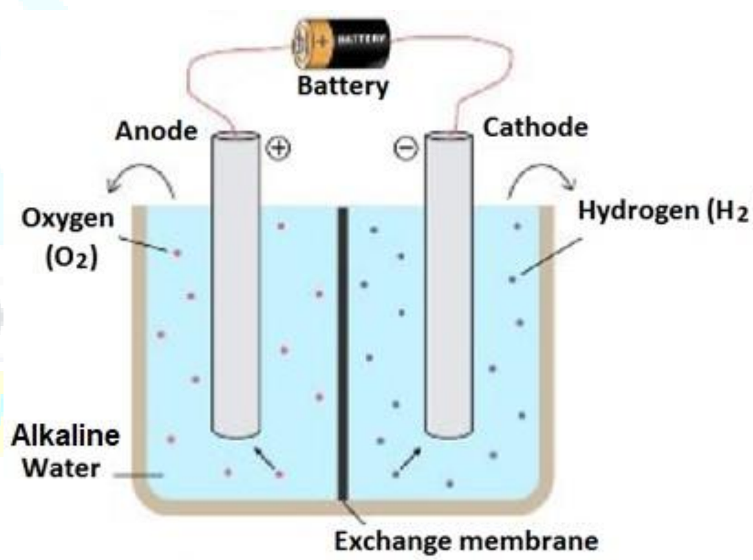
Anode Reaction (Oxidation process): $4\ OH^- (aq) \rightarrow O_2 (g) + 2H_2O + 4\ e^-$

Cathode Reaction (Reduction process): $4\ H_2O + 4\ e^- \rightarrow 2H_2 (g) + 4\ OH^- (aq)$

Overall cell reaction: $2H_2O (aq) \rightarrow 2H_2 (g) + O_2 (g)$

Advantages

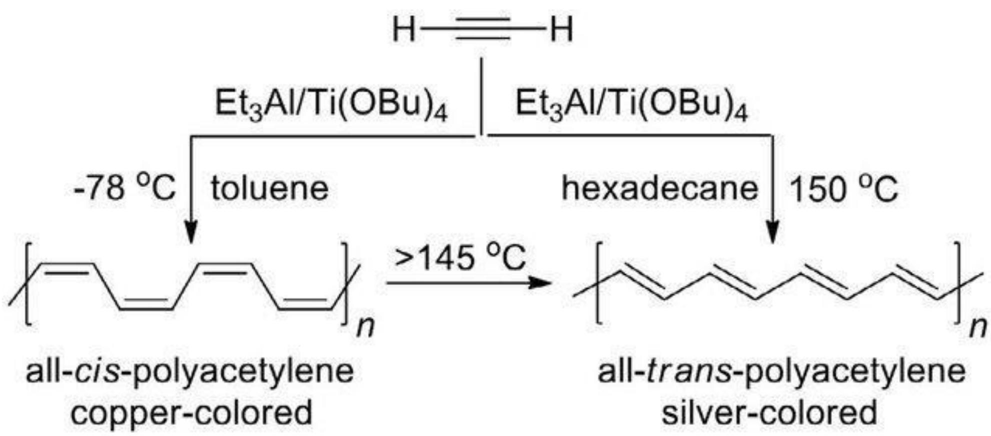
- Well established technology
- Low cost technology
- The energy efficiency is 70–80%
- Commercialized



Q.8.a.

Synthesis:

When acetylene gas is bubbled through heptane/toluene solvent containing Ziegler-Natta catalyst, Polyacetylene solid film is formed at the gas-liquid interface



Application:

- Non-volatile memory devices based on organic transistors.
- Fabrication of organic photovoltaic cells.
- Fabrication of organic light-emitting devices (OLED).
- Conducting polymer actuators and Micropumps.

Q.8.b.

In this electrolysis process, water is electrochemically split into hydrogen and oxygen at their respective electrodes such as hydrogen at the cathode and oxygen at the anode.

- It consists of two electrodes i.e. anode and cathode.
- Both are separated by ***proton exchange membrane*** (PEM).
- When electricity is passed, oxidation takes place at anode, it gives H+ ions and electron, also liberates oxygen gas.

At Anode: $2\ H_2O(l) \rightarrow O_2(g) + 4\ H^+(aq) + 4e^-$

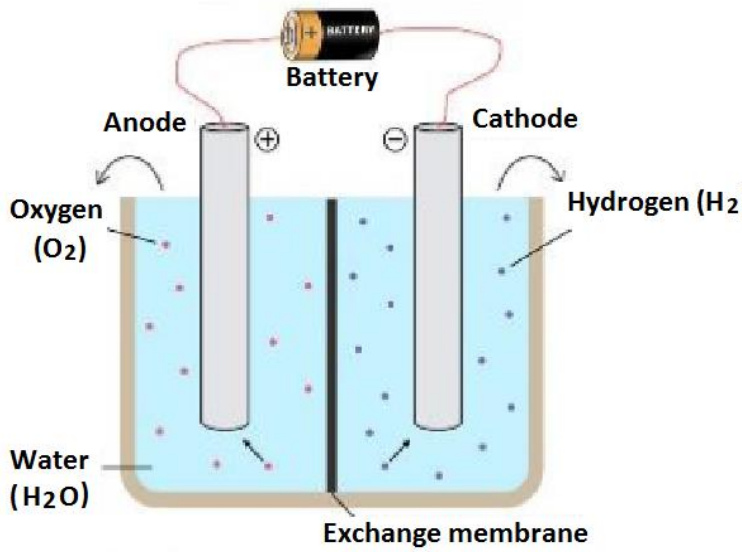
- The H^+ ions move into cathodic compartment through PEM membrane and electrons move from anode to cathode through external circuit.
- At cathode the H^+ ions accepts electrons and forms H_2 gas. This liberated hydrogen gas is used as a fuel.

At Cathode: $4H^+(aq) + 4e^- \rightarrow 2H_2(g)$

Overall cell reaction: $2H_2O\ (aq) \rightarrow 2H_2\ (g) + O_2\ (g)$

Advantages

- Compact system design
- Quick Response
- Greater hydrogen production rate with High purity of gases (99.99%)
- Higher energy efficiency (80–90%)
- High dynamic operation



Q.8.c.

Construction:

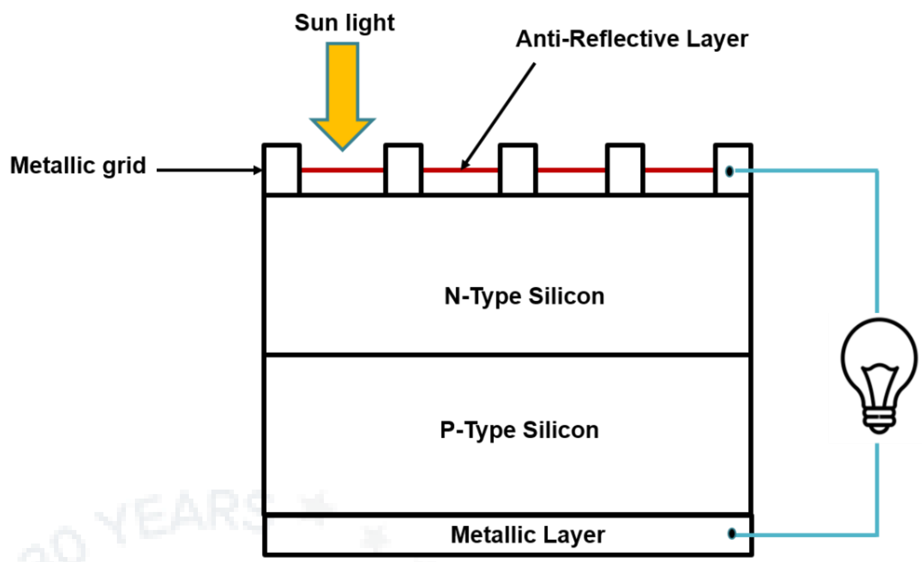
- Photovoltaic Cells consists of p-n junction semiconductor diode made of silicon coated with anti-reflective layer (TiO2) at the top.
- Two electrical contacts are provided, one in the form of metallic grid at the top of the junction and the other is a silver layer at the bottom of the cell
- The antireflective layer coated in between the metallic grids which allow light to fall on the semiconductor.

Working of photovoltaic cell:

- Electromagnetic radiation consists of particles called photons (hv). They carry a certain amount of energy given by the Plank quantum equation. $E = hc/\lambda$

Where, h = Planck's constant, c = velocity of light, λ = wavelength of the radiation

- The photons of solar radiations enter **n-type** semiconductor breaks barrier potential and moves to **p-type** semiconductor where photons knock the electrons in p-type to form electron-hole pair.
- The free electrons so formed will travels through the circuit from **n-type** and recombines with holes again in the **p-type** region.
- The movement of electrons from n-type to p-type generates electric current. The electrical energy produced by the solar cell is used for various applications



Advantages of PV cells:

- It is unlimited, inexhaustible and renewable source of energy.
- The solar cell operates reliably for a long period of time with no maintenance.
- Easy to operate
- Quick installation.
- Completely pollution free during its use.

Disadvantages of PV cells:

- High installation cost.
- Energy can be produced only during the day-time.
- The efficiency of solar cells depends on climate.
- Space required to generate unit power output is relatively more.
- Solar cell generates DC current. It needs to be converted to AC for use.

Module-5

Q.9.a.

Sources of e-waste

- Consumer electronics such as smart phones, laptops, televisions, and household appliances.
- Office equipment such as computers, printers, copiers, and fax machines.
- Medical equipment such as X-ray machines, monitors, and diagnostic equipment.
- Electronic toys and games.
- Obsolete technology such as outdated computer equipment, projectors and VCRs.

- Discarded or broken electronic devices.

Composition of e-waste

- ***Metals*** such as copper, gold, silver, and aluminium.
- ***Plastic*** components, including casings, insulation, and cables.
- ***Glass components***, such as screens and lenses.
- ***Circuit boards***, which contain a mixture of metals and other materials.
- ***Batteries***, which can contain hazardous materials such as lead, mercury, and cadmium.
- ***Hazardous materials***, such as flame retardants, heavy metals, and polychlorinated biphenyls (PCBs).

Q.9.b.

Health hazardous:

a) **Poisoning:** Toxic substances, such as lead, cadmium, and mercury can cause poisoning if they enter the body.

b) **Respiratory problems:** Exposure to dust and fumes generated can cause respiratory problems, such as asthma and bronchitis.

c) **Neurological effects:** Toxic substances such as lead and mercury, can cause neurological effects, including memory loss.

d) **Reproductive problems:** toxic substances such as cadmium, can cause reproductive problems.

e) **Cancer:** Exposure to carcinogenic substances, such as dioxins and polychlorinated biphenyls (PCBs), found in e-waste, can increase the risk of cancer.

Q.9.c.

Principle:

The principle behind the extraction of gold from e-waste is that gold is a relatively non-reactive metal, which allows it to be recovered from complex electronic waste matrices through a series of chemical and physical processes.

Experimental procedure:

1. ***Collection and segregation of e-waste***: The first step involves collecting and segregating the e-waste into different categories, such as computer motherboards, cell phones, and other electronic devices.
2. ***Physical separation***: The e-waste is physically separated into different components, such as plastics, metals, and glass.
3. ***Leaching***: The metals, including gold, are leached from the e-waste using a suitable reagent, such as aqua regia (a mixture of hydrochloric acid and nitric acid), to dissolve the gold.

$$Au + HNO_3 + 4HCl \rightarrow HAuCl_4 + NO + 2H_2O$$

4. **Precipitation**: The dissolved gold is then precipitated out of the solution through the addition of a suitable reducing agent, such as sodium metabisulfite.

$$2H[AuCl_4] + 3Na_2S_2O_5 + 3H_2O \rightarrow 2Au + 3SO_2 + 3Na_2SO_4 + 8HCl$$

5. **Purification**: The precipitated gold is then purified through processes such as ion exchange, electro-winning, or distillation, to remove impurities and improve its quality.
6. **Recovery**: The purified gold is then recovered for reuse.

Q.10.a. Answer:

Electronic waste refers to discarded electrical or electronic devices, such as computers, televisions, mobile phones, and household appliances.

<u>Need of e-waste management</u>

- ***Protecting the environment***: E-waste contains toxic substances, such as lead, mercury and cadmium that can have harmful effects on the environment and human health if not properly managed.
- ***Conserving resources***: E-waste contains valuable resources, such as metals, that can be recovered and reused through proper recycling.
- ***Reducing greenhouse gas emissions***: Proper recycling and disposal of e-waste can reduce the release of greenhouse gases, such as carbon dioxide, into the atmosphere.
- ***Reducing land filling***: It results in the release of toxic materials into the environment and contributes to soil and water pollution.
- ***Protecting public health***: Improper handling and disposal of e-waste can expose workers and the general public to hazardous materials and cause serious health problems.
- E-waste can be ***toxic***, is ***not biodegradable*** and accumulates in the environment, in the soil, air, water and living things.

Q.10.b.

In of e-waste management, the following stakeholders play an important unique role:

1. Producers

Producers have a responsibility to design and produce products that are environmentally friendly and can be easily recycled or reused at the end of their useful lives. They should also participate in e-waste collection and recycling programs and contribute to the development of sustainable e-waste management systems

2. Consumers

Consumers play a critical role in reducing e-waste by choosing to purchase products that are designed to be environmentally friendly, and by properly disposing of their old electronics. Consumers can also participate in e-waste collection and recycling programs and can advocate for the development of more sustainable e-waste management systems.

3. Statutory bodies

Statutory bodies such as governments, are responsible for creating and enforcing regulations and policies to manage e-waste and promoting public awareness and education about e-waste management.

Q.10.c.

Pyrometallurgy:

E-waste pyrometallurgical methods refer to the process of extracting valuable metals and other materials from electronic waste using high temperatures.

- **Collection and sorting**: Electronic waste is collected and sorted into different categories based on the materials present.
- **Shredding or grinding**: The electronic waste is shredded or ground into small particles to increase the surface area for the extraction process.
- **Smelting**: The shredded electronic waste is then heated in a furnace, along with a fluxing agent, to extract the metals. The fluxing agent helps to separate the metals from the other components of the waste.
- **Separation**: The melted waste is then cooled, and the metals are separated from the slag (non-metallic waste) using a variety of techniques, such as skimming, tapping, and slag fuming.
- **Purification**: The extracted metals are then purified to remove impurities.

Direct Recycling:

Direct recycling of e-waste refers to the process of refurbishing and reusing electronic devices, such as computers, smartphones, and televisions, without disassembling them into individual components. The following are the steps involved in a typical direct recycling process:

- **Collection and sorting**: Electronic waste is collected and sorted into different categories based on the type of device and its condition.
- **Testing**: The electronic devices are tested to determine their functional status and identify any repairs that need to be made.

- **Repair and refurbishment**: The electronic devices are then repaired and refurbished, which may include replacing broken or damaged components, cleaning and upgrading the software, and restoring the device to a functional state.
- **Distribution**: The refurbished devices are then distributed for reuse, either by selling them directly to consumers or by donating them to organizations or individuals in need.