CBCS SCHEME

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BCHES102/202

First/Second Semester B.E./B.Tech. Degree Examination, June/July 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.	What are electrochemical sensors? Explain its application in the measurement of dissolved oxygen.	07	L2	CO1
	b.	Describe the construction, working and applications of lithium ion battery.	07	L2	CO1
	c.	Explain the working principle of conductometric sensors.	06	L2	CO1
		OR			
Q.2	a.	Describe the application of electrochemical gas sensors for SO_x and NO_x.	07	L2	CO1
	b.	Describe the construction, working and applications of sodium ion battery.	07	L2	CO1
	c.	Explain the working principle of optical sensors.	06	L2	CO1
		Module – 2			
Q.3	a.	What are memory devices? Explain the classification of electronic memory devices with an example.	07	L2	CO2
	b.	Mention any four properties and applications of LCD.	07	L2	CO2
	c.	Mention any four properties and applications of QLED.	06	L2	CO2
		OR			
Q.4	a.	What are nano materials? Explain any four properties of polythiophenes (P_3HT) suitable for optoelectronic devices.	07	L2	CO2
	b.	Mention any four properties and applications of OLED.	07	L2	CO2
	c.	What are photoactive and electroactive materials.	06	L2	CO3
		Module – 3			
Q.5	a.	What is corrosion? Explain the electrochemical theory of corrosion with respect to iron.	07	L2	CO3
	b.	What is a cathodic protection? Explain sacrificial anodic method.	07	L2	CO3
	c.	What are concentration cells? Explain with an example.	06	L2	CO3

		OR			
Q.6	a.	What are reference electrodes? Explain the construction, working and applications of calomel electrode.	07	L2	CO3
	b.	Draw the nature of conductometric graph for the estimation of weak acid versus strong base and explain the nature of graph.	07	L2	CO3
	c.	Calculate the cell potential of the following concentration cell and comment on the spontaneity of the reaction $Cu \mid Cu^{2+} (0.01\ M) \parallel Cu^{2+} (0.015\ M) \mid Cu$	06	L2	CO3
		Module – 4			
Q.7	a.	What is number average and weight average molecular weight of polymer?	07	L2	CO4
	b.	What are conducting polymers? Explain the mechanism of conduction in polyacetylene.	07	L2	CO4
	c.	Explain the construction and working of photovoltaic cells.	06	L2	CO4
		OR			
Q.8	a.	Explain the preparation, properties and commercial applications of Kevlar.	07	L2	CO4
	b.	Explain the generation of energy (green hydrogen) by electrolysis of water and its advantages.	06	L2	CO4
	c.	Polymer sample contains six molecules having molecular weight of 1000 mol/kg. Five molecules having molecular weight of 2000 mol/kg and four molecules having molecular weight of 3000 mol/kg. Calculate number average and weight average molecular weight of polymer.	07	L3	CO4
		Module – 5			
Q.9	a.	Explain the characteristics and need of e-waste management.	07	L2	CO5
	b.	Explain the extraction of gold from e-waste.	07	L2	CO5
	c.	Explain the role of stake holders in environmental management of e-waste.	06	L2	CO5
		OR			
Q.10	a.	What is e-waste? Mention the sources and composition of e-waste.	07	L2	CO5
	b.	Explain any two different techniques used to recycling and recovery of e-waste.	07	L2	CO5
	c.	Mention any three toxic materials used in the manufacturing electronic products and electrical products and mention their health hazards.	06	L2	CO5

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Module-1

Q.1.a.

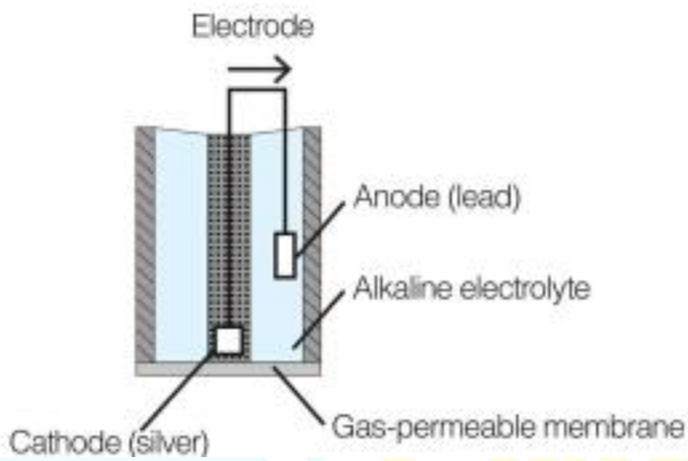
Electrochemical sensors designed for measuring dissolved oxygen typically use a Clark electrode, which consists of a cathode and an anode separated by an electrolyte. The anode serves as a reference electrode, providing a stable potential for the cathode.

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

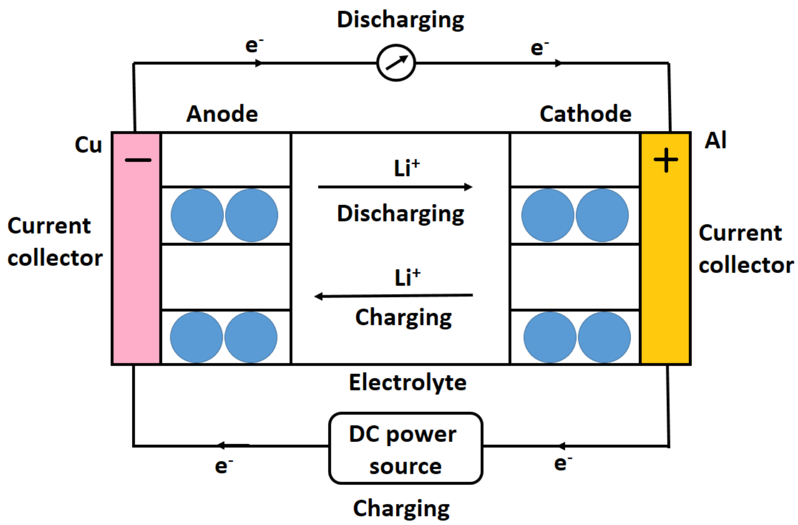
The white solid, $Pb(OH)_2$, that is produced by these reactions is precipitated out into the electrolyte solution. It neither coats the anode nor consumes the electrolyte, and thus does not affect the sensor's performance until the quantity becomes excessive.

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.1.b.

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.



Construction

- ***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

Working

- 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.1.c.

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.

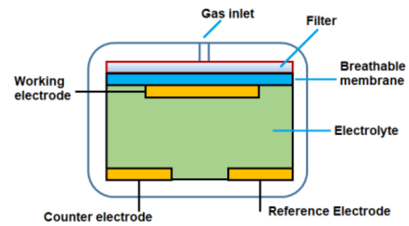
Working principle:

- **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.2.a. Answer:

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.b.

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

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

- 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.

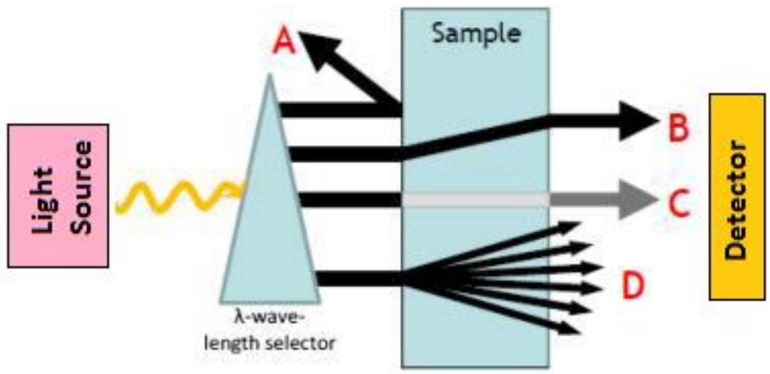
Q.2.c.

Optical sensor

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 optical sensor

- ***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.



Applications

- The following are the applications of optical sensors:
- It is used in remote sensing satellite
- Used in imaging
- Quality and Process Control applications

Module-2

Q.3.a.

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.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.3.c.

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

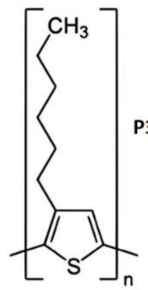
- QLED displays are commonly used in **televisions, monitors, smartphones**, and other electronic devices.
- QLEDs can also be used as a **source of lighting** in various applications, including automotive lighting, street lighting, and architectural lighting.
- QLEDs can be used in **medical imaging**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

Q.4.a.

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.

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

Properties of polythiophenes:



P3HT: Poly(3-hexylthiophene)

- 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.

Q.4.b.

Properties of OLEDs

- OLEDs are very **thin and flexible**, which makes them suitable for use in curved or flexible displays.
- OLEDs have a **high contrast** ratio i.e.; they can produce deep black and bright white images.
- OLEDs have a **fast response time** i.e.; they can switch on and off quickly, resulting in smooth video content.
- OLEDs have a **wide viewing angle** i.e.; the image quality is maintained even when viewed from different angles.

- OLEDs are **energy efficient**, as they do not require a backlight resulting in lower power consumption.

Applications of OLEDs

- OLED displays are used in **televisions, monitors, smartphones, and other electronic devices**.
- OLED displays are used as a **lighting source** in various applications, including automotive lighting, street lighting, and architectural lighting.
- OLEDs can be used in **automotive applications**, such as dashboard displays, interior lighting, and taillights.
- OLEDs can be used in **medical applications**, such as in surgical lighting and medical imaging.

Q.4.c.

A. Photoactive materials: Photoactive materials are those materials that can absorb light energy and undergo a photochemical reaction. They are used in photovoltaic cells which convert sunlight into electrical energy.
Examples: Silicon

Working principle

- **Absorption**: Photoactive materials must be able to absorb light energy in order to generate excited states.
- **Excited states**: After absorbing the light, it undergoes a photochemical reaction that generates excited states. These excited states are unstable and can decay back to the ground state by emitting light.
- **Energy transfer**: Excited states can transfer energy to other molecules, either within the same material or to a different material. This energy transfer can lead to the generation of electrical or chemical energy.

B. Electroactive materials: Electroactive materials are those materials that can conduct electricity and exhibit changes in their electrical properties in response to an external electric field.

Examples: Conductive polymers

Working principle

The principles that govern electroactive materials are based on the *interaction between the material and the electrical field*.

- **Conductivity**: Electroactive materials must be able to conduct electrical current in order to respond to an external electrical stimulus through the electrons or ions.

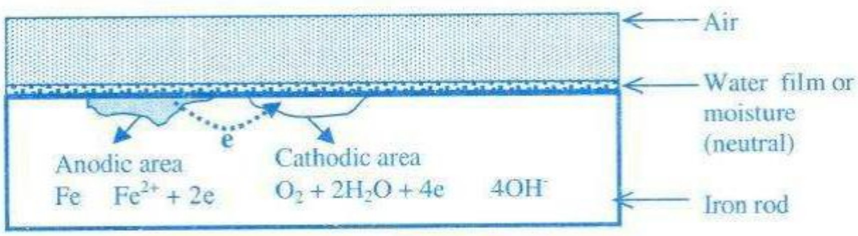
- **Response time**: Electroactive materials must be able to respond quickly to changes in the electrical field. The response time is determined by the mobility of the charge carriers.
- **Electrical properties**: The electrical properties of the material, such as its resistivity, permittivity, and capacitance, determine how it will respond to an external electrical stimulus.

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.

- <u>If the solution is aerated and almost neutral,</u>
  - $O_2 + H_2O + 2e^- \longrightarrow 2OH^-$
- <u>If the solution is deaerated and almost neutral:</u>

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

- <u>If the solution is deaerated and acidic:</u>

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

(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.

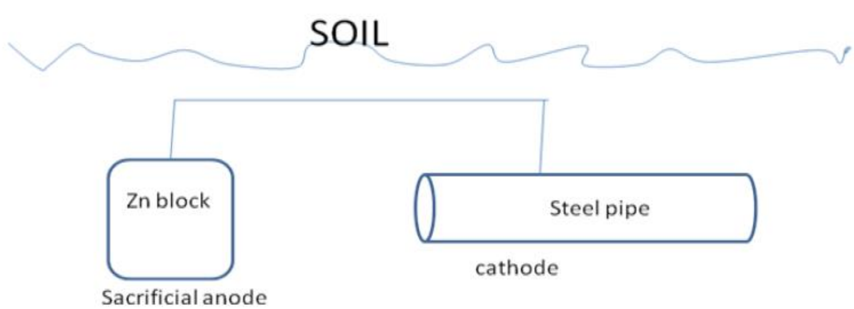
$$2Fe(OH)_2 + 1/2O_2 + H_2O \longrightarrow [Fe_2O_3.3H_2O]\ [Rust]$$

Q.5.b.

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. Example:

Sacrificial anodic protection:

- The base metal is usually iron, copper or brass.
- The metal to be protected from corrosion is converted into cathode by connecting to a metal which is anodic to it.
- Metals like Mg, Al and Zn are more active and hence are used as anodes.
- Since the anodic metals are sacrificed to protect the metal structure, the method is known as sacrificial anode method.
- These metals being more active acts as anode undergo corrosion and supply electrons to the target metal.
- In this way the protected metals acts as cathode.



Advantages:

- The method is simple.
- Low installation cost.

- Minimum maintenance cost.
- Does not require power supply.

Applications:

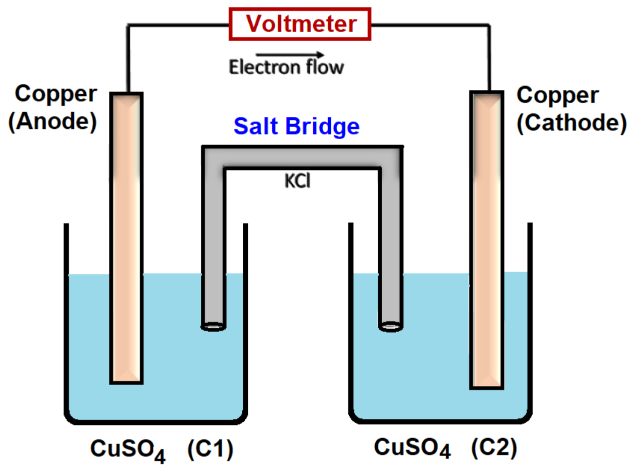
a) A magnesium block connected to a buried oil storage tank.

b) Mg bars are fixed to the sides of ocean going ships to act as sacrificial anodes.

c) Mg blocks are connected to buried pipe lines.

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.



Construction

There are three components

- ***Electrodes***: The two electrodes are called the cathode (right side) and the anode (left side). The anode loses electrons through oxidation reaction. The cathode gains electrons through reduction reaction.
- **Salt Bridge**: A salt bridge is a device used in an electrochemical cell for connecting its oxidation and reduction half cells. The main function of a salt bridge is to maintain the electrical neutrality within the internal circuit. It consists of a saturated solution of a salt such as KCl or NH_4NO_3.
- **Voltmeter:** The voltmeter is used to measure the cell potential of the cell.

Cell representation: Concentration cell is represented as,

Cu/Cu^{+2} (C1= 0.01M) || (C2= 0.1M) Cu^{+2}/Cu

Working

Anode: $Cu \longrightarrow Cu^{+2}$ (C1) $+2e^-$

Cathode: Cu^{+2} (C2) $+2e^- \longrightarrow Cu$

Net cell reaction: Cu^{+2} (C2) $\longrightarrow Cu^{+2}$ (C1)

The electrode potential for concentration cell is represented by

$$E_{cell} = E_{Cathode} - E_{Anode}$$

$$= (E^0_{Cathode} - \frac{0.0591}{n} \log C2) - (E^0_{Anode} - \frac{0.0591}{n} \log C1)$$

In concentration cell, both electrodes are same, hence

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

Now, E_{cell} will be positive only if C2 > C1.

Q.6.a. Answer:

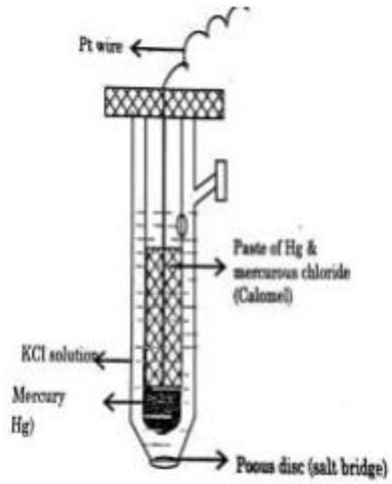
Construction and working of calomel electrodes:

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

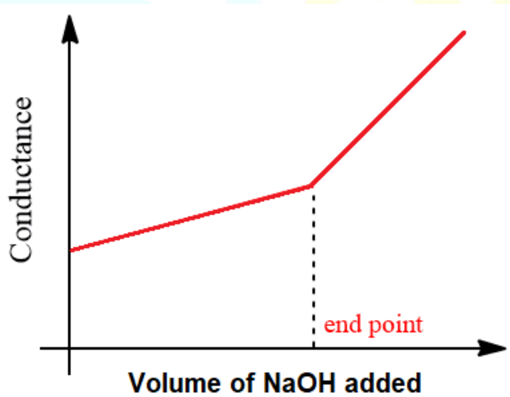
If the electrode behaves as cathode, the electrode reaction is:

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

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.



Consider the titration of acetic acid against NaOH. The conductance of the acid will be initially low since acetic acid is a weak electrolyte. When NaOH is added to the acid, the salt formed is highly ionized and the conductance increases. On complete neutralization of the acid, further addition of base leads to an increase in the number of mobile OH- ions.

Hence the conductance increases sharply.

$$\mathbf{CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O}$$

A plot of conductance against the volume of base added is shown in the figure. The point of intersection of two curves gives the neutralization point.

Q.6.c.

Cell representation: Concentration cell is represented as,

Cu/Cu^{+2} (C1= 0.01M) || (C2= 0.015M) Cu^{+2}/Cu

Working

Anode: $Cu \longrightarrow Cu^{+2}$ (0.01M) $+2e^-$

Cathode: Cu^{+2} (0.015M) $+2e^- \longrightarrow Cu$

Net cell reaction: Cu^{+2} (0.015M) $\longrightarrow Cu^{+2}$ (0.01M)

In concentration cell, both electrodes are same, hence

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

E_{cell} = 0.0591/2 log(0.015/0.01)

E_{cell} = 0.02955 x 0.1760

E_{cell} = 0.0052 V (The reaction is spontaneous)

Module-4

Q.7.a.

Number average molecular weight (Mn)

The number average molecular weight is the total weight of the polymer, divided by the number of polymer molecules. The average molecular weight (Mn) is given by,

$$M_n = \sum N_iM_i / \sum N_i$$

where Mi is the molecular weight of a molecule, and Ni is the number of molecules of that molecular weight.

Weight average molecular weight (Mw)

The weight average molecular weight is the weight fraction of molecules in a polymer sample. Mw is defined as,

$$M_w = \sum N_iM_i^2 / \sum N_iM_i$$

Q.7.b.

The polymers that can conduct electricity due to the presence of a conjugated system of delocalized electrons are called conducting polymers.

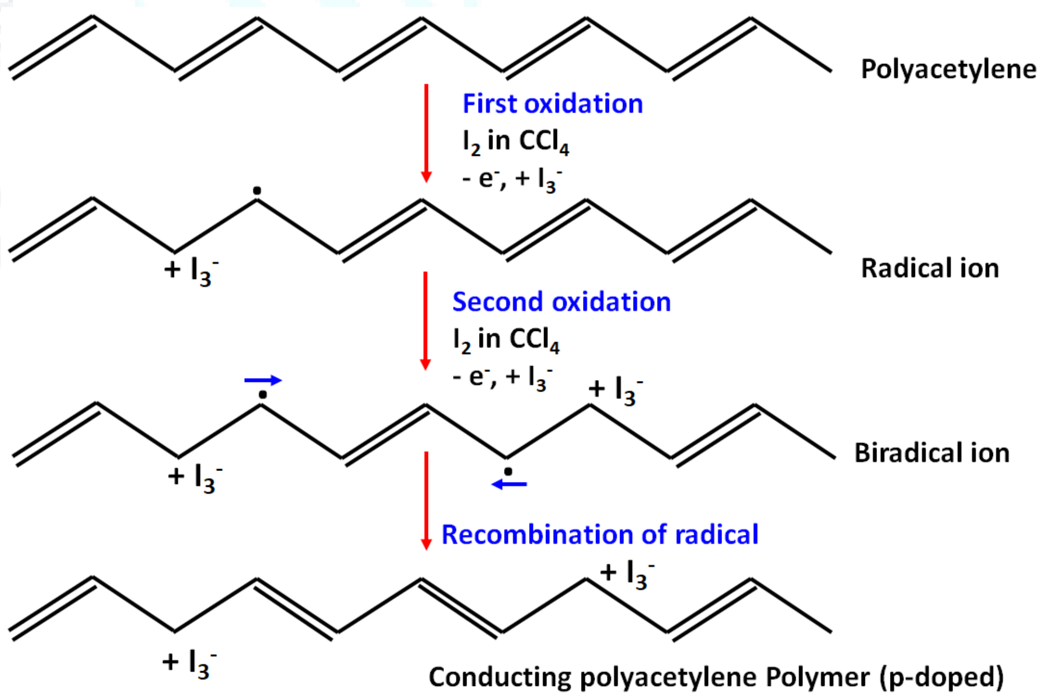
<u>Conducting mechanism of polyacetylene</u>

Conductivity can be increased by doping the polymer. The conducting polymers are synthesized by doping, in which charged species are introduced in polymeric pi-back bone. The important doping reactions are:

- **Oxidative doping (p-doping)**
- **Reductive doping (n-doping)**

Oxidative doping (p-doping)

When the polymer is doped with an oxidant, it acquires a positive charge and the acceptor gets a negative charge. The oxidizing agent used in the p-doping of polyacetylene is iodine in CCl_4.



Mechanism:

- ➢ The removal of an electron from the polymer pi-backbone using a suitable oxidising agent leads to the formation of a delocalized radical ion (polaron).
- ➢ Second oxidation of a chain containing polaron, followed by the radical recombination yields two positive charge carriers of each chain.

- Positive charge sites on the polymer chains are compensated by I_3^- ions formed by the oxidizing agent.
- The delocalized positive charges on the polymer chain are mobile and are responsible for current carriers for conduction.

Q.7.c.

Construction:

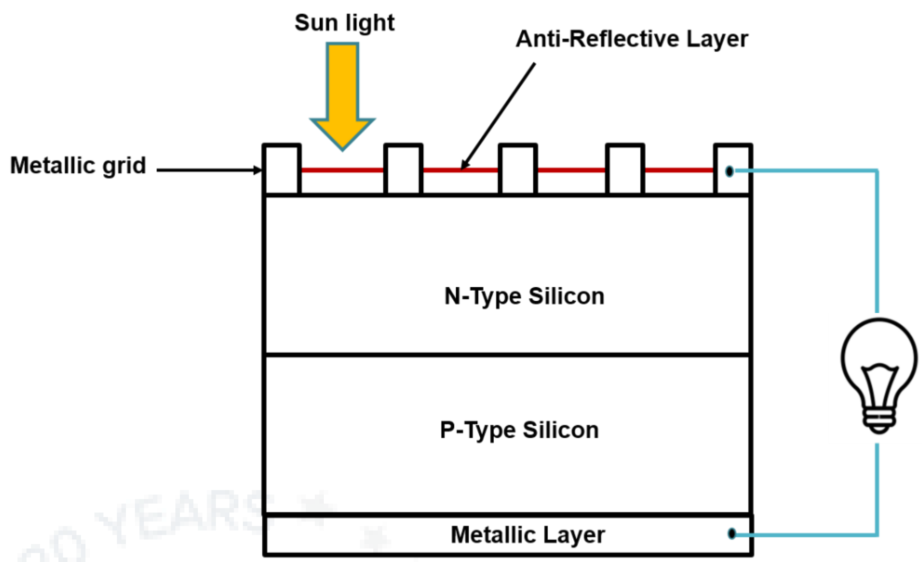
- Photovoltaic Cells consists of p-n junction semiconductor diode made of silicon coated with anti-reflective layer (TiO2) at the top.
- Two electrical contacts are provided, one in the form of metallic grid at the top of the junction and the other is a silver layer at the bottom of the cell
- The antireflective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

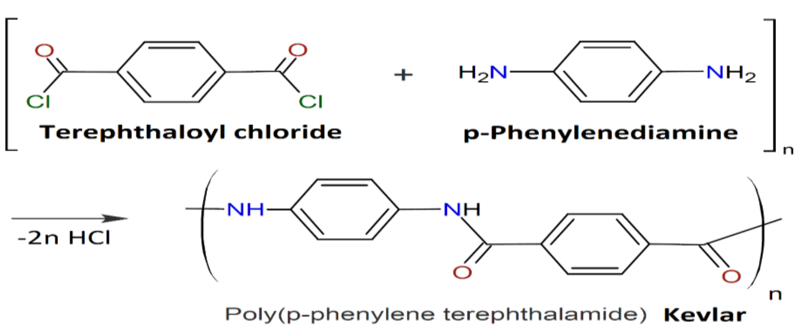
- It is unlimited, inexhaustible and renewable source of energy.
- The solar cell operates reliably for a long period of time with no maintenance.
- Easy to operate
- Quick installation.
- Completely pollution free during its use.

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.

Q.8.a.

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

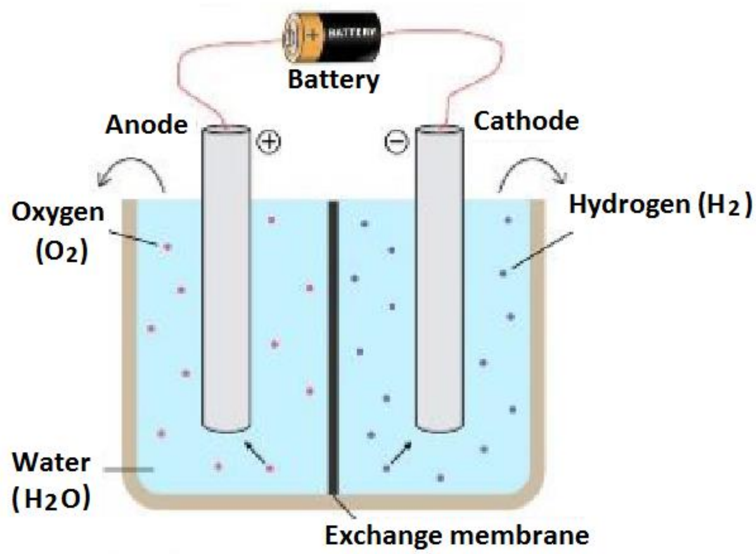
- The H^+ ions move into cathodic compartment through PEM membrane and electrons move from anode to cathode through external circuit.
- At cathode the H^+ ions accepts electrons and forms H_2 gas. This liberated hydrogen gas is used as a fuel.

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.

Number average molecular mass:

Total weight = (6 x 1000) + (5 x 2000) + (4 x 3000) = 6,000 + 10,000 + 12,000

= 28000

Total number = 6 + 5 + 4 = 15

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

Mn = 28000 / 15 = 1866.67 **g/mol**

Weight average molecular mass:

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

$$\mathbf{M_w} = \frac{\{[(6 \times (1000)^2] + [(5 \times (2000)^2] + [(4 \times (3000)^2]\}}{28000}$$

$\mathbf{M_w}$ = 62,000,000 / 28000

$\mathbf{M_w}$ = **2214.29 g/mol**

Module-5

Q.9.a.

***Characteristics* of e-waste**

- **Complexity:** E-waste often contains a complex mixture of materials, making it challenging to recycle and dispose of properly.
- **Hazardousness** such as heavy metals, flame retardants, and batteries, can pose significant environmental and health risks including soil and water contamination, air pollution, and harm to human health.
- **Global issue:** the electronic devices are manufactured, used and discarded worldwide.
- **Resource depletion:** The extraction of raw materials for electronic devices contributes to resource depletion.

Need of e-waste management

- ***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.9.b.

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.9.c.

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.a.

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

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.10.b.

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.

Q.10.c.

Toxic materials

a) **Lead** is a toxic heavy metal commonly used in batteries, computer monitors, and other electronic components.

a) **Mercury** is used in some fluorescent lights, batteries, and other electronic devices.

b) **Cadmium** is a toxic heavy metal used in rechargeable batteries, pigments, and plastic stabilizers.

c) **Polyvinyl Chloride (PVC)** is used in electronic cables, which release toxic chemicals, such as dioxins, when burned or during disposal.

d) **Brominated flame retardants (BFRs)** are toxic and can harm the environment and human health.

e) **Lithium** is used in rechargeable batteries, but it can be toxic if not handled properly.

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.