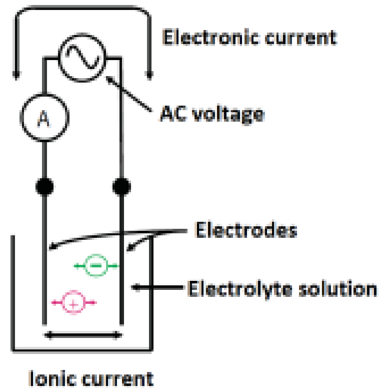
Module-1

Q.1.a. Answer:

A conductivity 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.

Construction

- A conductometric sensor consists of two inert metal electrodes.
- Those two electrodes are separated at a certain fixed distance before applying AC voltage, which later causes current flow.
- The sensor is immersed in the conductive liquid which acts as the electrical conductor between the sensor electrodes.



Working principle

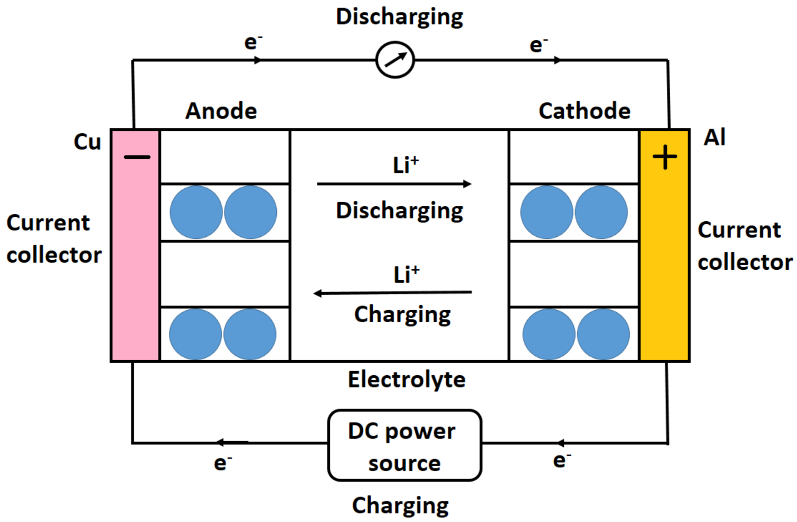
The conductance depends on the mobility of ions as well as the number of ions migrating between the electrodes. The basic principle of a conductometric sensor involves a reaction that changes the ionic species concentration. This reaction leads to changes in ionic concentration as well as the conductance 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.

Applications

- Monitoring the quality of human drinking water
- Monitoring the quality of industrial water
- Battery electrolyte density monitoring
- Making devices for producing electrolytic oxygen and hydrogen

Q.1.b. Answer:

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.

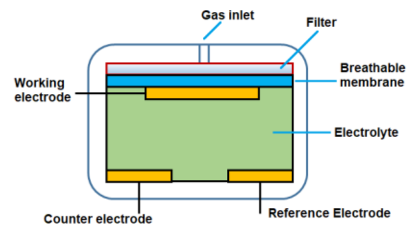
Application of Lithium-ion battery

- 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. 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.a. Answer:

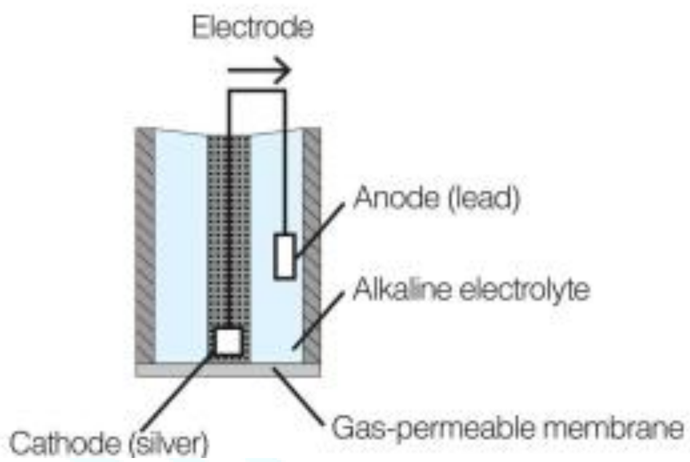
Electrochemical sensors designed for measuring dissolved oxygen typically use a Clark electrode, which consists of a cathode and an anode separated by an electrolyte. The anode serves as a reference electrode, providing a stable potential for the cathode.

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.

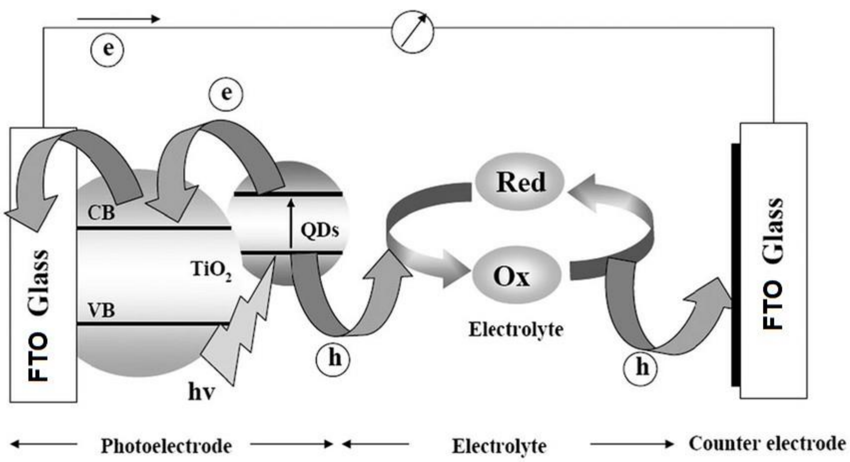
Q.2.b. Answer:

A quantum dot solar cell (QDSC) is a type of solar cell that utilizes quantum dots as a light-absorbing material to convert sunlight into electricity.

<u>Construction</u>

- ***Transparent conducting electrode***: FTO glass (Fluorine-doped Tin Oxide)
- ***Transparent Conductive Oxide Layer***: TiO_2 film

- ***Quantum dots layer***: Light-absorbing semiconductor materials (CdSe or CdS)
- ***Electrolyte***: Polysulphide is used as a redox electrolyte.
- ***Counter Electrode***: used to complete the circuit and helps to generate electricity.



Working

a) Upon absorption of a photon, a quantum dot is excited from the ground state (QDS) to a higher energy state (QDS*)

Excitation process: QDs + $h\nu \rightarrow$ QDs*

b) The absorption process results in the creation of electron-hole pair in the form of the ***exciton***. Dissociation of the exciton occurs if the thermal energy exceeds its binding energy

Exciton dissociation: QDs* → e- + h+* (free energy)

c) The excited electron is then injected in the conduction band of the wide bandgap semiconductor nanostructured TiO_2 thin film. This process will cause the oxidation of the photosensitizer

Injection process: QDs* + $TiO_2 \rightarrow TiO_2e^{-}$* + QDs^{+}

d) The injected electron is transported between the TiO_2 nanoparticles, and then gets extracted to a load where the work done is delivered as electrical energy.

Energy generation: TiO_2e-* + C.E → TiO_2 + e* (CE)

Applications

- It is used as light-emitting Diodes
- It is used as a photoconductor and photodetector
- It is used as a photovoltaic
- It is used in biomedicine and environment.

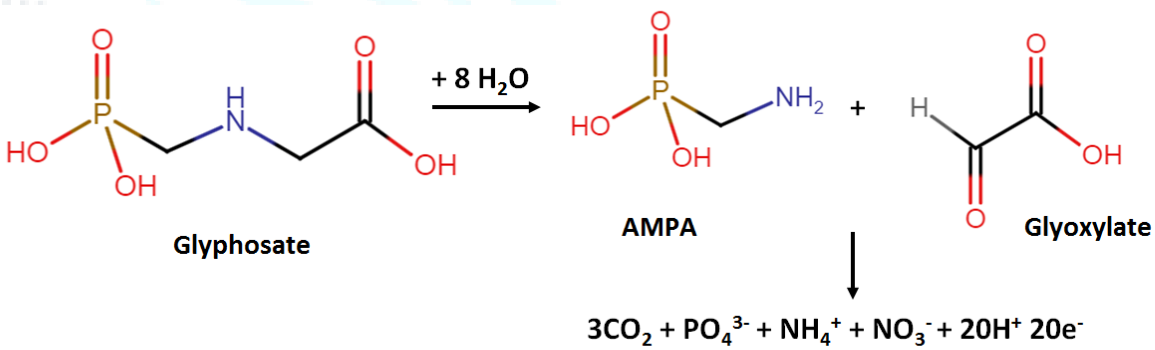
Q.2.c. Answer:

Construction

- The sensor is a silicon-based chip comprising of three-electrode system.
- ***Working Electrode***: A gold electrode of 4 mm diameter coated with ***200nm*** thickness gold nanoparticles.
- ***Counter electrode***: A gold electrode of 4 mm diameter coated with ***20nm*** thickness gold nanoparticles.
- ***Reference Electrode***: Ag/AgCl

Working

- The electrochemical detection is based on the oxidation of Glyphosate on gold working electrode.
- A potential of 0.78V is applied on working electrode, there is an interaction between analyte and electrode surface.
- Glyphosate oxidizes on the working electrode brings a change in current in the electrolyte medium.
- The change in the current is a measure of concentration of Glyphosate



Module-2

Q.3.a. Answer:

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)

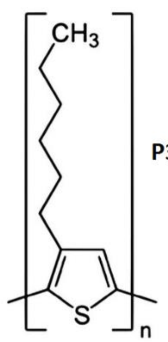
D. **Charge transfer type electronic memory devices:** Such type memory devices use the transfer of charge between capacitors or other circuit elements to store and retrieve digital data. The data can be read by measuring the voltage level on the capacitor or other element.

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

Q.3.b. Answer:

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.



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.

Q.3.c. Answer:

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.

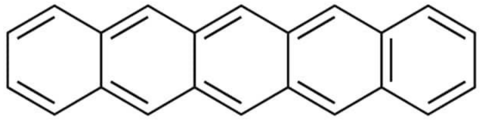
Applications of QLEDs

- 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. Answer:

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.

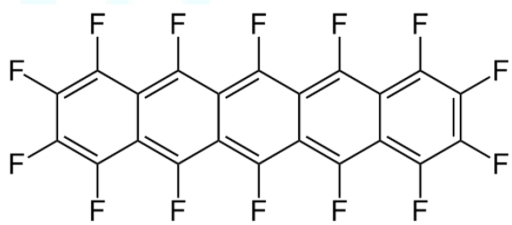


Application: It is used in organic flash memory and organic resistive random access memory (RRAM).

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.4.b. Answer:

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.

Q.4.c. Answer:

Properties of Liquid Crystals

- Liquid crystals are **anisotropic**, i.e., they exhibit different properties in different directions.
- Liquid crystals are **birefringent**, i.e., they can split light into two polarized components.
- Some liquid crystals are **optically active**, i.e., they rotate the polarization of light.

Applications of liquid crystals

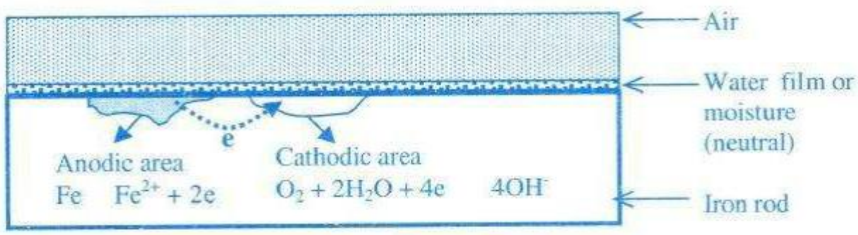
- Liquid crystals are used in **Liquid Crystal Displays** (LCD) for the display of images.
- Liquid crystals are used in various **sensor applications** such as temperature sensing, humidity sensing, and chemical sensing.
- Liquid crystals are used in various **optical devices** which are used in optical communication systems, spectroscopy and imaging.

Module-3

Q.5.a. Answer:

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)

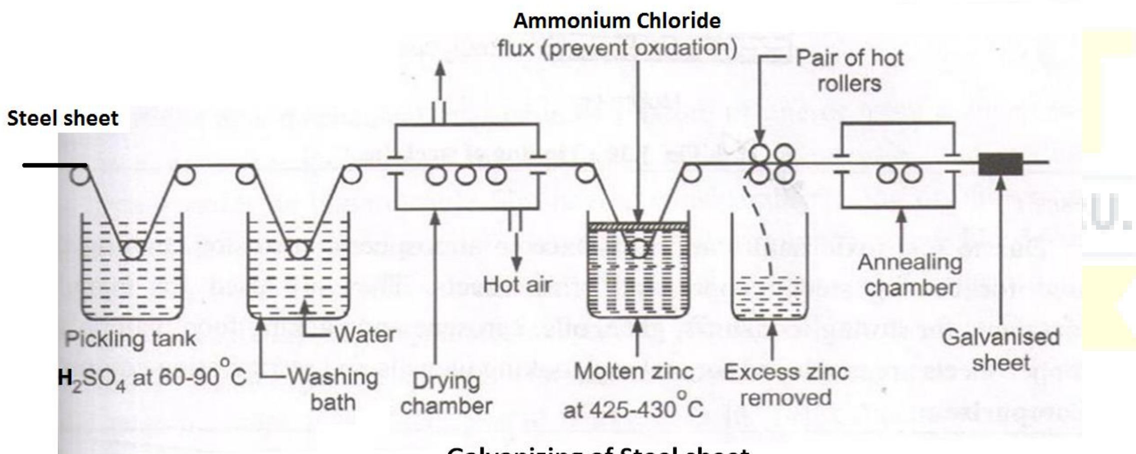
(v) In an oxidizing environment, it is oxidized to ferric oxide and the rust is hydrated ferric oxide.

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

Q.5.b. Answer:

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. Answer:

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	Corrosion penetrating rate in mm/y
CPR = KW/DAT Weight loss, W= 375×10^3 mg Density, D = 8.73 g/cm, Time, T = 2×24×365 Area A = 400 inch^2 CPR = $\frac{534 \times 375 \times 10^3}{8.73 \times 400 \times 2 \times 24 \times 365}$ CPR = 3.273 mpy	CPR = KW/DAT Weight loss, W= 375×10^3 mg Density, D = 8.73 g/cm, Time, T = 2×24×365 Area A = 400 x 6.45 cm^2 = 2580 cm^2 CPR = $\frac{87.6 \times 375 \times 10^3}{8.73 \times 2580 \times 2 \times 24 \times 365}$ CPR = 0.0832 mm/y

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.

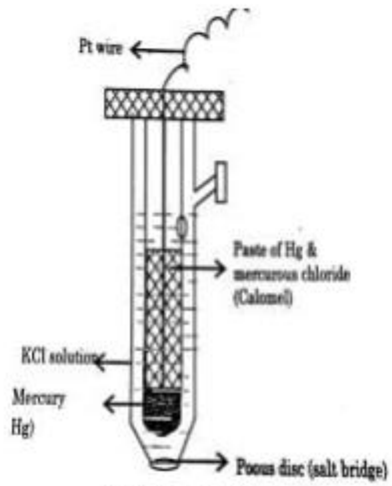
Electrode representation: $Hg(s)/Hg_2Cl_2$ (paste);Cl-

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. Answer:

Theory

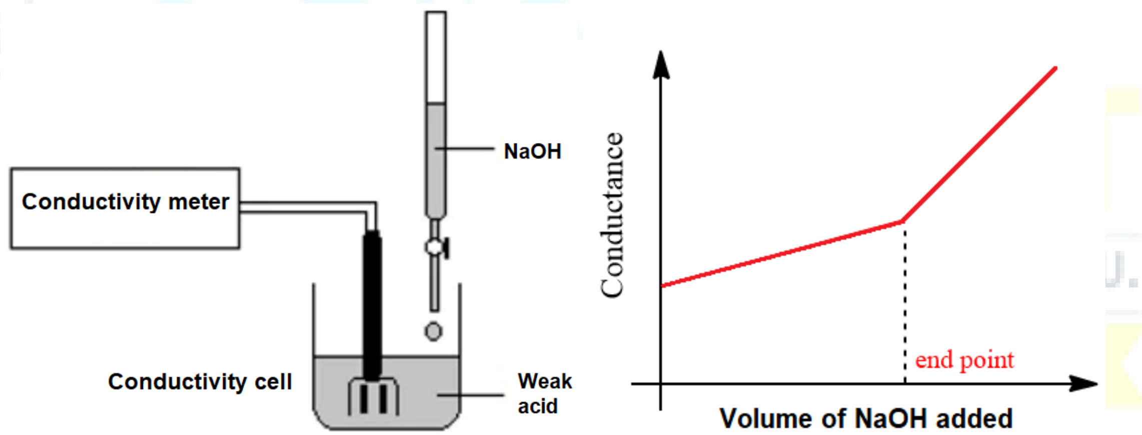
Electrolyte solution conducts current by the migration of ions under the influence of an electric field. This experiment is based on Ohm's law which states that the current' I ' flow through conductor is directly proportional to the applied potential, E and inversely to the resistance R of conductor.

$$E = I R$$

Specific conductance of an electrolyte solution is the conductance of the solution present between two parallel electrodes of 1cm3 area of cross-section and 1cm apart.

Instrumentation

1. It consists of a platinum electrode each of unit area of cross-section placed unit distance a part.
2. The electrodes are dipped in the electrolyte solution taken in a beaker.
3. It is connected to a conductivity meter.
4. The titrant (NaOH) is added from a burette and solution is stirred.
5. The conductance is measured after the addition of the titrant at intervals of 1.0 ml.



Application: Weak acid v/s Strong base (CH_3COOH v/s NaOH)

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.

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

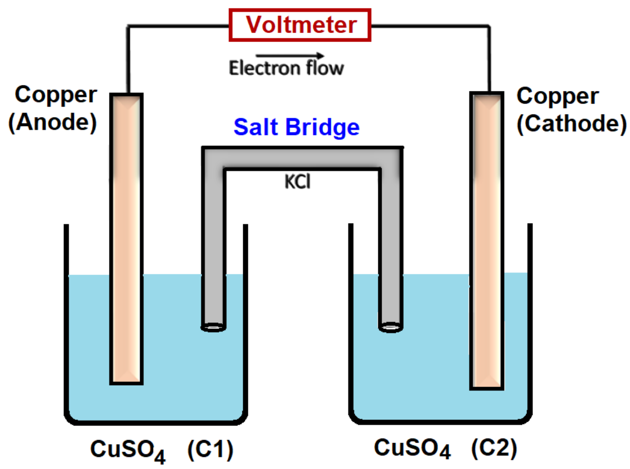
A plot of conductance against the volume of base added is shown in the figure. The point of intersection of two curves gives the neutralization point.

Q.6.c. Answer:

Definition

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.

Diagram



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$^-$ ⟶ Cu

Net cell reaction: Cu^{+2} (C2) ⟶ 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.

Module-4

Q.7.a. Answer:

Number average molecular mass:

Total weight = (1 x 10000) + (2 x 50000) + (2 x 100000) = 10000 + 100000 + 200000

= 310000

Total number = 1 + 2 + 2 = 5

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

Mn = 310000 / 5 = **62000 g/mol**

Weight average molecular mass:

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

$$\mathbf{M_w} = \frac{\{[(1 \times (10000)^2] + [(2 \times (50000)^2] + [(2 \times (100000)^2]\}}{(1 \times 10000) + (2 \times 50000) + (2 \times 100000)}$$

M_w = 80968 g/mol

Q.7.b. Answer:

Green fuels are energy sources that can be used as substitutes for traditional fuels, such as diesel and natural gas. Due to lower carbon emissions green fuels are considered more environmentally friendly.

Example: Biodiesel, hydrogen gas, and solar power.

Advantages

(a) Reduced Greenhouse Gas Emissions: when Green fuels are used in vehicles, they emit fewer greenhouse gases compared to fossil fuels.

(b) Energy Security: Green fuels can be produced domestically, reducing dependence on foreign oil and enhancing energy security.

(c) Improved Air Quality: They produce fewer harmful air pollutants, which can improve air quality and public health.

(d) Sustainability: It can help to conserve natural resources and reduce environmental degradation.

(e) Renewable and Abundant: Some green fuels, like biofuels and hydrogen, are derived from renewable resources, ensuring a long-term and abundant supply.

(f) Technological Innovation: Developing and using green fuels promotes technological innovation and creates job opportunities.

(g) Reduced Noise Pollution: Electric vehicles and hydrogen-powered vehicles reduce noise pollution in urban areas.

Q.7.c. Answer:

Construction:

- Photovoltaic Cells consists of p-n junction semiconductor diode made of silicon coated with anti-reflective layer (TiO_2) 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.

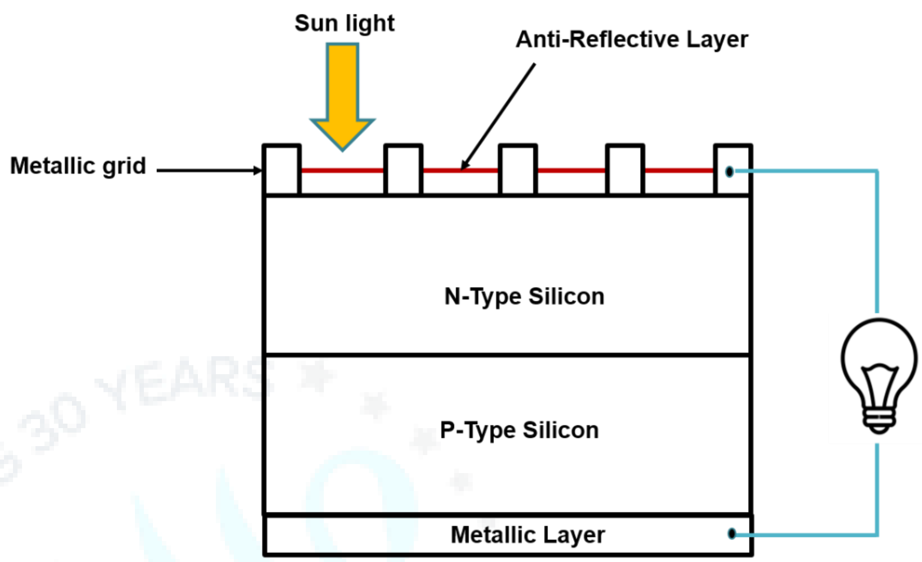
Working of photovoltaic cell:

- Electromagnetic radiation consists of particles called photons (hν). 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. Answer:

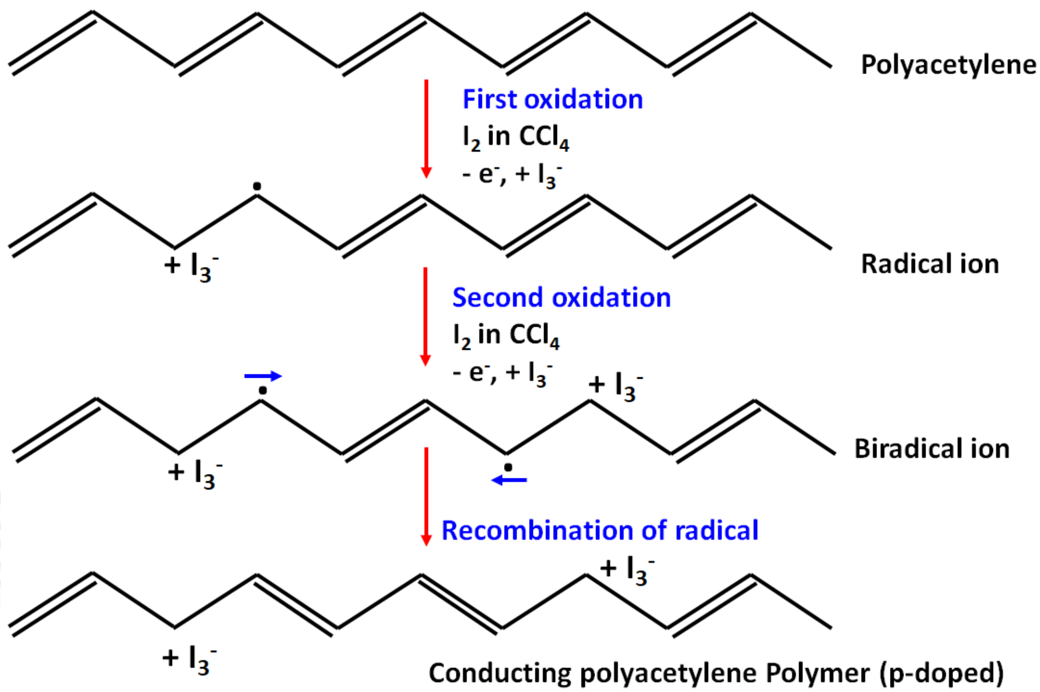
Conducting mechanism of polyacetylene:

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.8.b. Answer:

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.

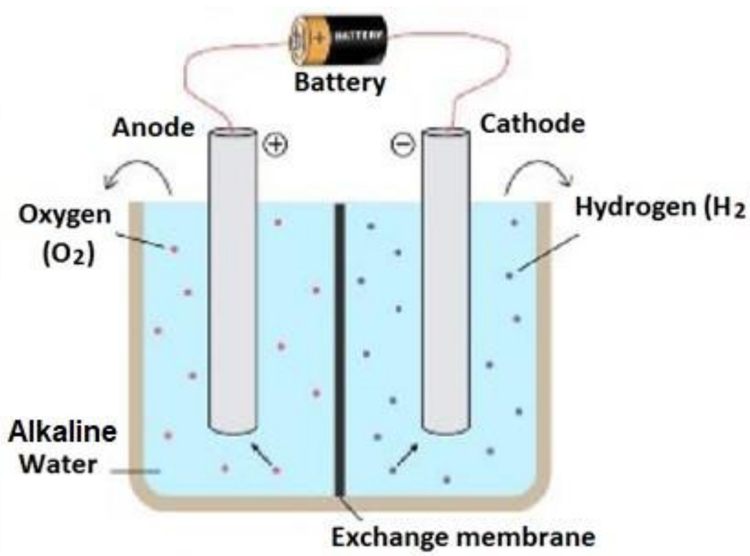
Anode Reaction (Oxidation process): $4\ OH^-\ (aq) \rightarrow\ O_2\ (g) + 2H_2O + 4\ e^-$

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

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

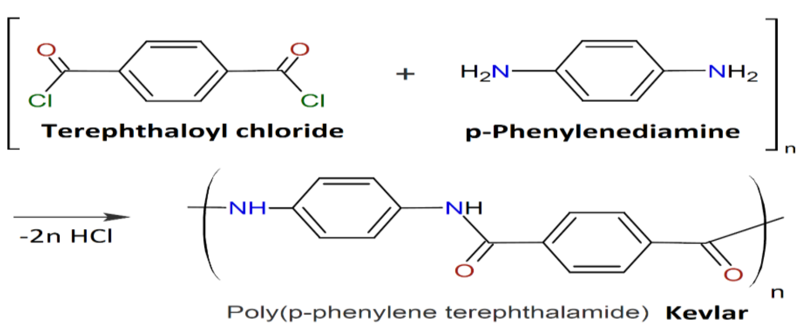
Advantages

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



Q.8.c. Answer:

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.

Module-5

Q.9.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.9.b. Answer:

The process of e-waste recycling typically involves the following steps:

- **Collection and transportation:** E-waste is collected from various sources such as households, businesses, and recycling facilities. It is then transported to a recycling plant for processing.
- **Sorting and dismantling:** E-waste is sorted into different categories based on the type of material and the manufacturer. The recyclers then dismantle the devices to separate the valuable materials from the hazardous components.
- **Shredding:** The e-waste is shredded into smaller pieces to make it easier to separate the different materials. The shredded pieces are then sorted into different categories based on their composition.
- **Separation:** The valuable materials, such as metals, plastics, and glass, are separated from the other components through a series of physical and chemical processes.
- **Processing:** The separated materials are processed to remove any impurities and contaminants, and to prepare them for reuse. For example, metals are smelted to produce pure metal alloys, while plastics are melted and moulded into new products.
- **Disposal of hazardous waste:** The hazardous components of e-waste, such as batteries and LCDs, are properly disposed of to prevent pollution and health hazards.

Q.9.c. Answer:

Hydrometallurgical extraction

It is a process used to extract valuable metals and other materials from electronic waste through chemical reactions in aqueous solutions.

- **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.
- **Leaching**: The crushed electronic waste is then treated with a solution, such as sulfuric acid, that dissolves the metals and minerals.
- **Separation**: The metal-rich solution is then separated from the solid waste. The metals and minerals present in the solution are then recovered using a variety of techniques, such as precipitation, ion exchange, and solvent extraction.
- **Purification**: The recovered metals and minerals are then purified to remove impurities

Pyrometallurgical extraction:

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.

Q.10.a. Answer:

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.b. Answer:

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. Answer:

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.