Module-1

Q.1.a. Answer:

An electrochemical sensor is a chemical sensor that measures the concentration of a specific substance or analyte in a sample by an electrochemical reaction.

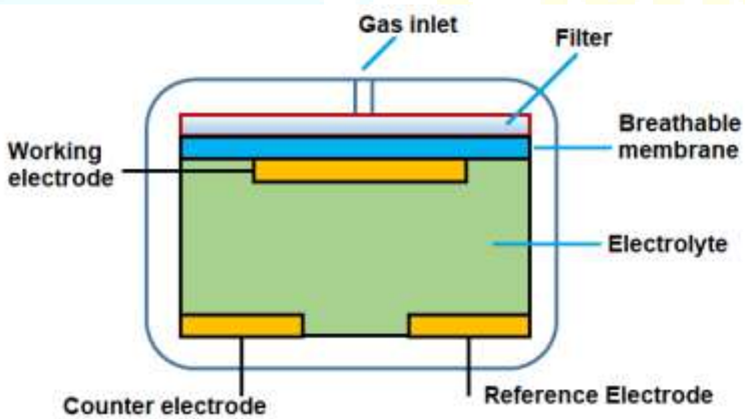
Construction

- ***Working electrode*** (sensing electrode): electrochemical reaction occurs on the surface of the sensing electrode.
- ***Counter electrode***: helps to measure the current flow during the electrochemical reaction.
- ***Reference electrode***: Provide a stable potential against which the working electrode's potential is measured.
- ***Breathable membrane***: A gas-permeable membrane is used to control the gas flow reaching the electrode surface.
- ***Filter:*** to filter out the unwanted analyte

Working principle

The principle of an electrochemical sensor is based on the measurement of electrical signals generated as a result of electrochemical reactions occurring on the sensor electrode surface.

- The electrical signal will be proportional to the analyte concentration.
- All electrodes act as a ***transducer*** to convert the chemical reaction into a measurable electrical signal.

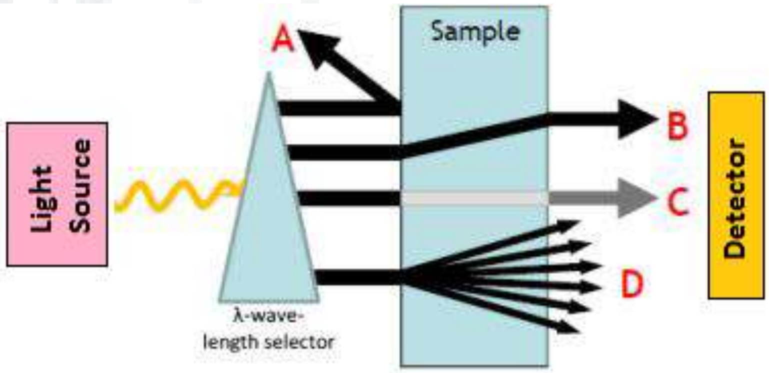


Q.1.b. Answer:

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

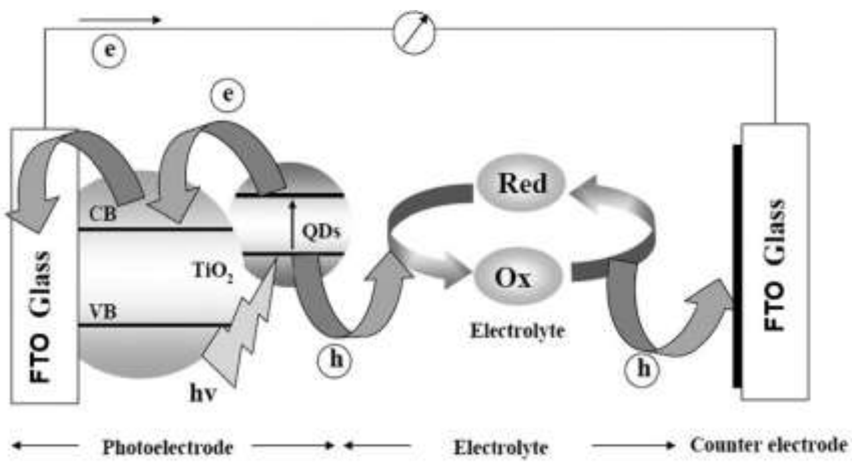
- The following are the applications of optical sensors:
- It is used in remote sensing satellite

Q.1.c. 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.

Construction

- ***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.



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

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 + *hv* → 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)

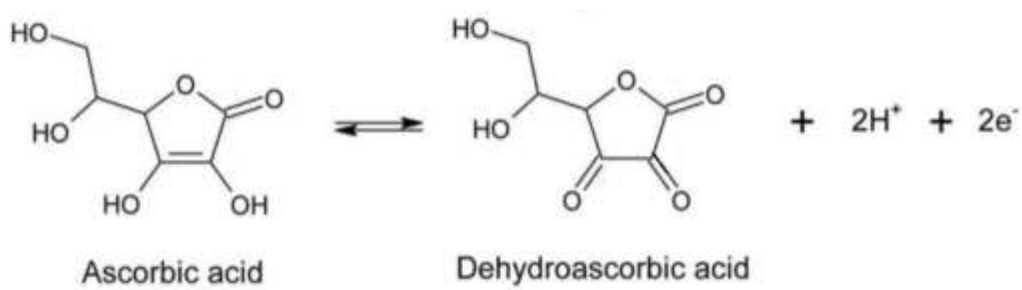
Q.2.a. Answer:

Construction

- *Working Electrode*: Active materials like CNT/GO printed on the electrode.
- *Counter electrode*: Platinum mesh (Pt)
- *Reference Electrode*: Ag/AgCl

Working:

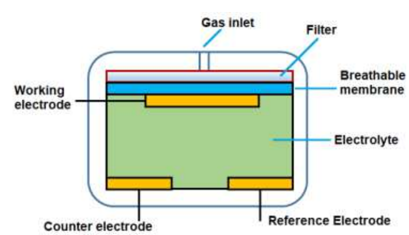
- When the disposable sensor is immersed in the analyte, the analyte diffuses and adsorbed on the sensing electrode.
- The sensing electrode oxidizes ascorbic acid into dehydroascorbic acid and produces electric current and it is proportional to the concentration of the ascorbic acid.



Q.2.b. 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

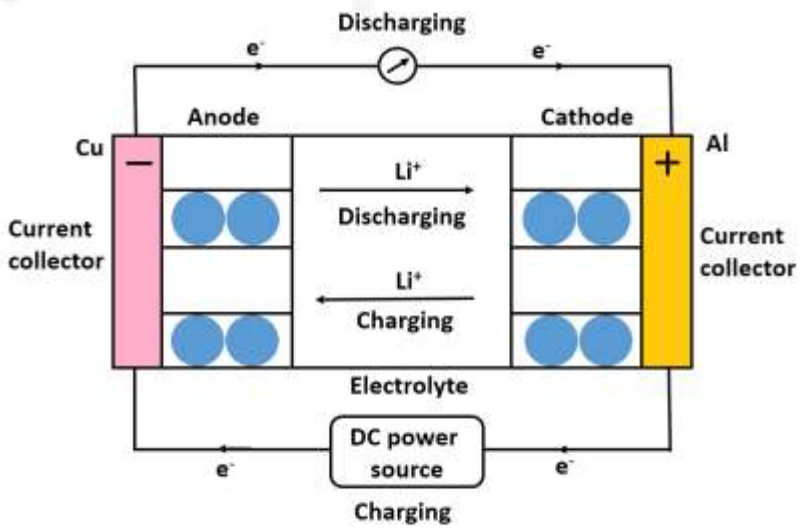
Electrochemical reactions for the SO_2 and NO gas sensors are:

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.c. 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.



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

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

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:

Optoelectronic devices are electronic devices that can detect or emit light, or that use light to perform some type of function.

Working principle:

The working principle of optoelectronic devices depends on the specific device and its function, but in general, optoelectronic devices convert between electrical and optical signals.

For example, in a **solar cell**, the device uses a similar process, but in reverse. Light is absorbed by the semiconductor material, generating electron-hole pairs that can be separated by an electric field to generate an electrical current.

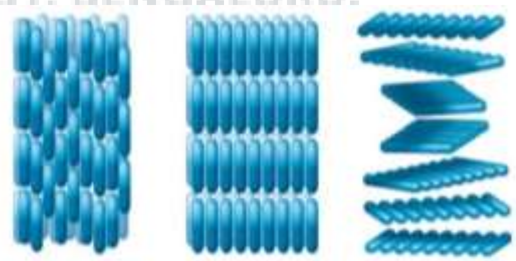
In a **light-emitting diode (LED)**, the device operates in the opposite direction, converting an electrical signal into light. When a voltage is applied across the semiconductor material, electrons and holes combine to emit photons, producing light

Q.3.c. Answer:

An ordered fluid mesophase of an organic long-chain molecules possessing both solid-like molecular order and liquid-like character is known as a liquid Crystal.

<u>Classification</u>

A. **<u>Thermotropic liquid crystals</u>:** When long-chain organic solids are heated, they undergo sharp phase transitions at a particular temperature yielding liquid crystals.



Thermotropic liquid crystals are three types:

1. **<u>Nematic</u>:** The molecules move either sideways or up and down. In this case, the molecules are readily aligned in the same direction in the presence of ***electric and magnetic fields***. The alignment of molecules is ***temperature sensitive***.

Example: p-azoxyphenetole,

2. **<u>Smectic</u>:** The molecules in smectic crystals are oriented parallel to each other as in the nematic phase but in layers. These layers can pass on each other because the force between the layers is weak.

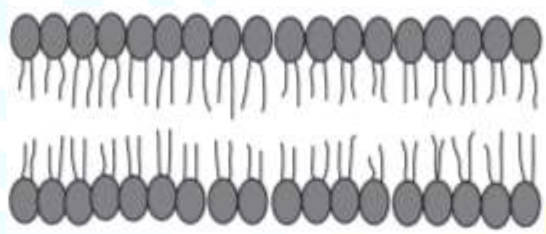
Example: smectic–A (*SmA*)

3. **<u>Cholesteric</u>:** The molecules in successive layers are slightly twisted or rotated with respect to the layers above and below to form a continuous helical or spiral pattern.

Example: Cholesteryl benzoate

B. <u>Lyotropic liquid crystals:</u> The orientational behaviour of lyotropic crystals is a function of concentration and solvent. These molecules are amphiphilic in nature–they have both hydrophilic and hydrophobic ends in their molecules. At low concentrations, these molecules are randomly oriented but as the concentration increases, the molecules start arranging themselves.

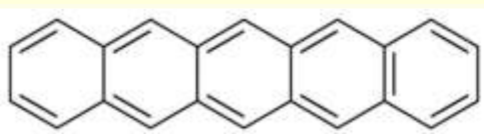
Example: Cell membranes



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. <u>p-type semiconductors materials</u> 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).

<u>Characteristics</u>

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

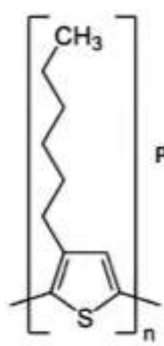
Application: It is used in the construction of organic electronic devices such as organic field-effect transistors.

<u>**Characteristics**</u>

- 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:

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



P3HT: Poly(3-hexylthiophene)

<u>**Properties of polythiophenes**</u>:

- 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.

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.4.c. Answer:

Quantum Dot Light Emitting Diode (QLED) is a display technology that utilizes quantum dots to enhance the color performance and efficiency of the display.

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

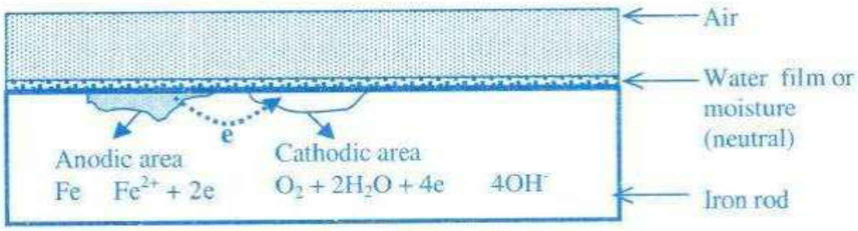
- QLED displays are commonly used in **televisions, monitors, smartphones**, and other electronic devices.
- QLEDs can also be used as a **source of lighting** in various applications, including automotive lighting, street lighting, and architectural lighting.
- QLEDs can be used in **medical imaging**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

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.

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

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

$$\mathbf{2H_2O + 2e^- \longrightarrow H_2 + 2OH^-}$$

- If the solution is deaerated and acidic:

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

(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 $(OH)_2$.

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

(Ferrous hydroxide)

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

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

Q.5.b. Answer:

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	CPR = KW/DAT
Weight loss, W= 375×10^3 mg	Weight loss, W= 375×10^3 mg
Density, D = 7.9 g/cm, Time, T = 2×24×365	Density, D = 7.9 g/cm, Time, T = 2×24×365
Area A = 400 $inch^2$	Area A = 400 x 6.45 cm^2 = 2580 cm^2
CPR = $\frac{534 \times 375 \times 10^3}{7.9 \times 400 \times 2 \times 24 \times 365}$	CPR = $\frac{87.6 \times 375 \times 10^3}{7.9 \times 2580 \times 2 \times 24 \times 365}$
CPR = 3.6170 mpy	CPR = 0.0919 mm/y

Q.5.c. Answer:

A reference electrode is an electrode that has a stable and well-known electrode potential. This electrode is used to determine the electrode potential of other electrodes

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:

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

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

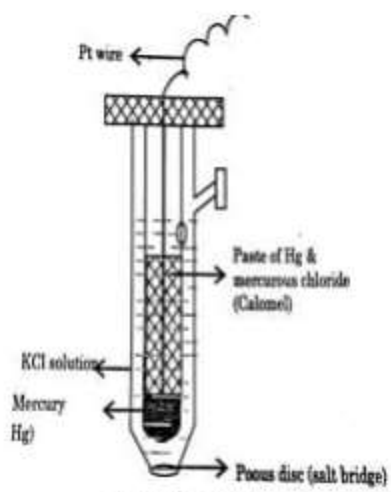
$$2Hg_{(l)} + 2Cl^- \rightarrow Hg_2Cl_{2(s)} + 2e^-$$

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

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

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

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



Calomel electrode

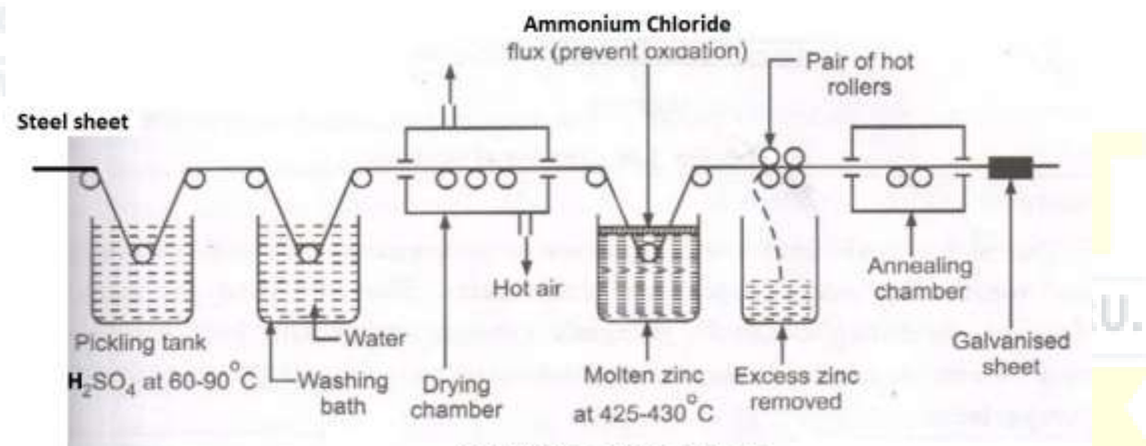
The electrode potential of calomel electrode depends on concentration of chloride ions. For saturated KCl; E=0.2422V (called Saturated calomel electrode)

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.a. 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

Application:

1. Galvanized steel beams and columns enhance durability in infrastructure projects.
2. Vehicle parts are galvanized to resist corrosion and extend their lifespan.
3. Galvanized fencing and irrigation systems withstand exposure to harsh environmental conditions.

Q.6.b. Answer:

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.

Under the given condition (T=25℃)

$E_{cell} = 0.0591/n \log [C_2/C_1]$

Where C_2 = Concentration of electrolyte at cathodic compartment = 0.5 M

C_1 = Concentration of electrolyte at anodic compartment = 0.005 M
n = 1

Substituting the above values in above formula,

$E_{cell} = 0.0591/1 [\log 0.5/0.005]$

$E_{cell} = 0.0591 [\log 100]$

$E_{cell} = 0.0591 \times 2$

$\mathbf{E_{cell} = 0.1182\ V}$

Q.6.c. Answer:

Theory

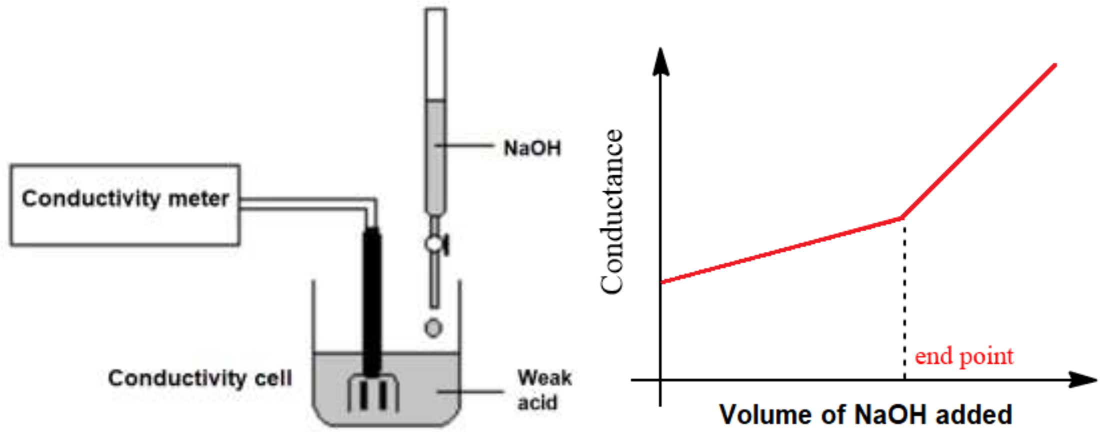
Electrolyte solution conducts current by the migration of ions under the influence of an electric field. This experiment is based on Ohm's law which states that the current' I ' flow through conductor is directly proportional to the applied potential, E and inversely to the resistance R of conductor.

$$E = I R$$

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.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

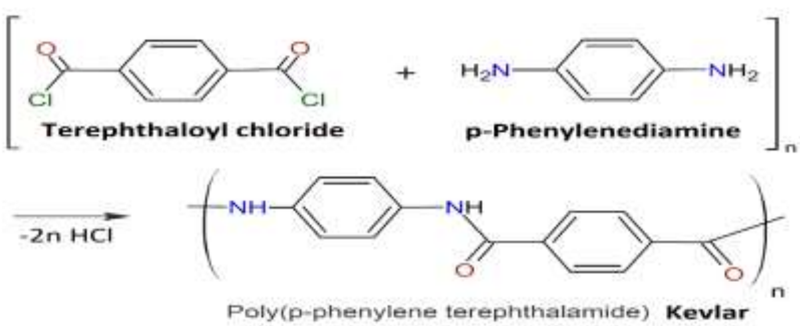
A plot of conductance against the volume of base added is shown in the figure. The point of intersection of two curves gives the neutralization point.

Module-4

Q.7.a. Answer: Question is have some missing values.

Q.7.b. 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.

Q.7.c. Answer:

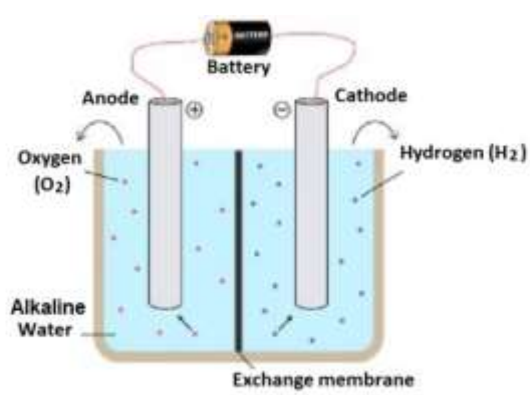
- It consists of two electrodes i.e. anode and cathode.
- Both electrodes are made up of Ni based metal, because it is more stable during the oxygen evolution.
- These electrodes are immersed in KOH solution (25-35%).
- Both electrodes are separated by porous diaphragm prevent gases crossover and allows 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. Answer:

Conducting polymers are organic polymers that conduct electricity. Example: Poly(acetylene).

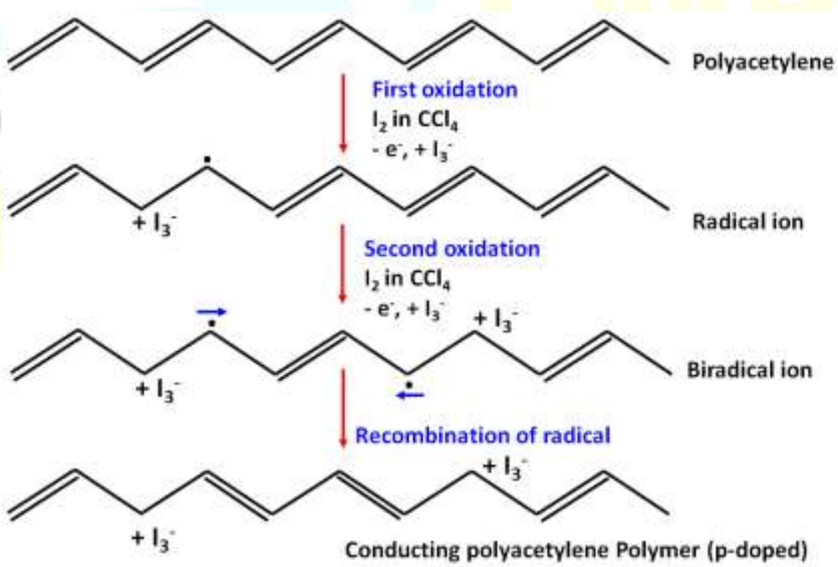
Conducting mechanism of polyacetylene:

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.

Application:

- Non-volatile memory devices based on organic transistors.
- Fabrication of organic photovoltaic cells.

Q.8.b. Answer:

The device, which converts solar energy into electrical energy, is called photovoltaic cell and the phenomenon is called photovoltaic effect.

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.

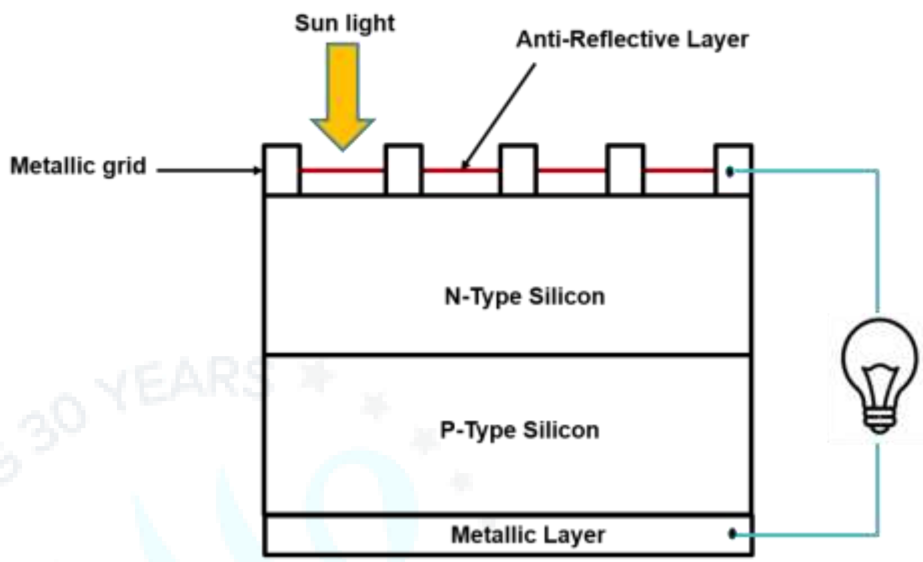
Working of photovoltaic cell:

- Electromagnetic radiation consists of particles called photons (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



<u>**Advantages of PV cells**</u>:

- 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

<u>**Disadvantages of PV cells**</u>:

- High installation cost.
- Energy can be produced only during the day-time.
- The efficiency of solar cells depends on climate.

Q.8.c. Answer:

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.

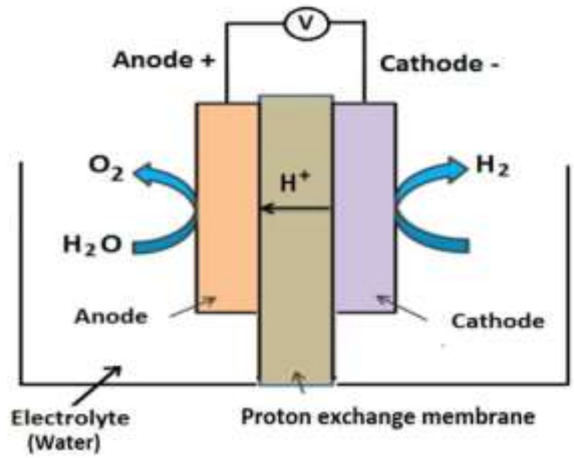
- At cathode the H^+ ions accepts electrons and forms H_2 gas. This liberated hydrogen gas is used as a fuel.

  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



Module-5

Q.9.a. Answer:

E-waste

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.9.b. Answer:

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. Answer:

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:

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. Answer:

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. Recyclers

Recyclers and waste management companies are responsible for collecting, treating, and disposing of e-waste in a safe and responsible manner. They should use environmentally friendly methods for extracting valuable materials from e-waste, and should properly dispose of any hazardous waste generated during the process.

4. 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.