CBCS SCHEME

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BCHES102/202

First/Second Semester B.E./B.Tech. Degree Examination, June/July 2023
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 sensors? Explain how Electrochemical gas sensors used to detect SO_x and NO_x gases.	07	L1	CO1
	b.	With a neat sketch explain the measurement of dissolved oxygen by electro-chemical sensors.	06	L1	CO1
	c.	Explain the construction and working of Li-ion battery. Write the charging and discharging reaction.	07	L1	CO1
		OR			
Q.2	a.	Explain the construction and working of sodium ion battery. Write the charging and discharging reaction.	07	L1	CO1
	b.	Explain the detection of pharmaceutical pollutant dichlofenac using electrochemical sensor.	07	L1	CO1
	c.	What are disposable sensors? Explain the detection of ascorbic acid. Write the oxidation reaction.	06	L1	CO1
		Module – 2			
Q.3	a.	What are memory device? Briefly explain the classification of memory device.	07	L1	CO1
	b.	Explain organic memory devices of p-type and n-type by taking example of Pentacene.	06	L2	CO1
	c.	Discuss the application of liquid crystals in display devices.	07	L2	CO1
		OR			
Q.4	a.	What are Photoactive and Electroactive material? Briefly discuss their role in opto-electronic devices.	07	L1	CO1
	b.	What are liquid crystals? Briefly explain the classification of liquid crystals with example.	07	L2	CO1
	c.	Discuss the application of Polyimide Polymeric material for organic memory device.	06	L1	CO1
		Module – 3			
Q.5	a.	What is corrosion? Explain Electrochemical theory of corrosion taking iron as example.	07	L2	CO3

	b.	What are reference electrodes? Explain the construction and working of calomel electrode.	07	L2	CO3
	c.	Two cadmium rods immersed in Cadmium Sulphate solution of concentration 0.002 M and 0.4 M. Write the cell representation, cell reaction and calculate the EMF at 25°C.	06	L2	CO3
		OR			
Q.6	a.	What are ion selective electrode? Explain the determination of pH of an unknown solution using glass electrode.	07	L1	CO3
	b.	What is anodizing? Explain the anodizing of aluminium.	07	L1	CO3
	c.	A thick steel sheet of area 450 cm^2 is exposed to air near ocean. After one year it was found to experience a weight loss of 385g due to corrosion. Calculate the rate of corrosion in mpy and mmpy. [Density of specimen 7.9 g/cm^3, k = 534 for mpy and k = 87.6 for mmpy]	06	L1	CO3
		Module – 4			
Q.7	a.	Discuss the conduction mechanism of Polyacetylene.	07	L1	CO4
	b.	With a neat sketch, explain the generation of Hydrogen by Alkaline Electrolysis of water.	07	L1	CO4
	c.	In a polymer sample 20% of molecules have molecular mass 15000 g/mol, 35% molecules have molecular mass 25000 g.mol and remaining percentage have molecular mass 20000 g/mol. Calculate number average and weight average molecular mass of the polymer	06	L1	CO4
		OR			
Q.8	a.	What are PV cell? Explain the construction and working of PV cell.	07	L2	CO4
	b.	Explain the preparation, properties and application of graphene oxide.	07	L2	CO4
	c.	What is green fuel? Mention the advantages of green fuel.	06	L2	CO4
		Module – 5			
Q.9	a.	What are e-waste? Explain the sources and composition of e-waste.	06	L1	CO5
	b.	Discuss the various steps involved in recycling of e-waste.	07	L1	CO5
	c.	Write a note on various stakeholders in e-waste management.	07	L2	CO5
		OR			
Q.10	a.	Explain the various steps involved in extraction of gold from e-waste.	07	L2	CO5
	b.	Discuss the extraction of metals from e-waste by pyrometallurgy.	07	L2	CO5
	c.	What are the toxic metal used in electrical and electronics products? Discuss their ill effects.	06	L1	CO5

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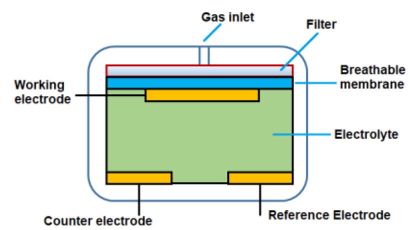
Module-1

Q.1.a. What are sensors? Explain how electrochemical gas sensors used to detect SOx and NOx gases.

A sensor is a detection device that can sense the measured data and convert it into electrical signals or other required forms of information output according to particular rules, in order to meet the requirements of data transmission, processing, storage, and display, as well as recording and control.

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.1.b. With a neat sketch explain the measurement of dissolved oxygen by electrochemical sensors.

An electrochemical sensor is a device that uses chemical reactions to detect and measure the concentration of various chemical species, such as gases and liquids. It converts the chemical reaction into an electrical signal that can be measured and analyzed. There are three methods available for measuring dissolved oxygen concentrations.

- **Electrochemical or optical sensor**.
- C**olorimetric method**
- **Winkler titration**.

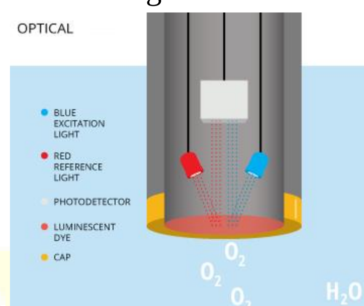
Optical Dissolved Oxygen Sensors

Optical dissolved oxygen sensors are sensors that use optical methods to measure the amount of dissolved oxygen in a liquid. They are commonly used in a variety of applications, including wastewater treatment, aquaculture, and environmental monitoring.

Construction:

An optical DO sensor consists of a

i. Semi-permeable membrane,
ii. sensing element,
iii. light-emitting diode (LED) and
iv. photodetector



Working:

- The sensing element contains a luminescent dye that is immobilized in sol-gel, xerogel or other matrix.
- When it is exposed to blue light, these dyes become excited and emit light as the electrons return to their normal energy state.
- When dissolved oxygen is present, the returned wavelengths are limited or altered due to oxygen molecules interacting with the dye.
- Optical dissolved oxygen sensors can measure either the intensity or the lifetime of the luminescence, as oxygen affects both.

The concentration of dissolved oxygen (as measured by its partial pressure) is inversely proportional to luminescence lifetime as shown by the Stern-Volmer equation,

$$I_o / I = 1 + k_q * t_0 * O_2$$

I_o= Intensity or lifetime of dye luminescence without oxygen

I = Intensity or lifetime of luminescence with oxygen present

k_q = Quencher rate coefficient

t_0 = Luminescence lifetime of the dye

O_2 = oxygen concentration as a partial pressure

Advantages:

- It is more accurate than their electrochemical counterparts, and are not affected by hydrogen sulfide or other gasses.
- We can measure the dissolved oxygen at very low concentrations.

Disadvantages:

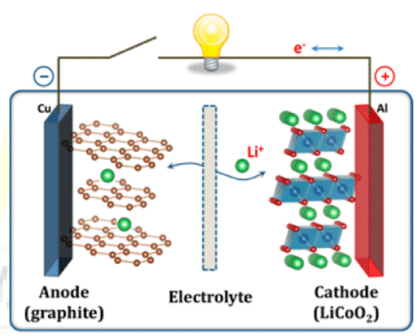
- Over a long period of time, the dye degrades and the sensing element and membrane will need to be replaced.
- Require more power.

Q.1.c. Explain the construction and working Li-ion battery. Write the charging and discharging reaction.

The batteries in which lithium ions are used instead of lithium metal and movement of lithium ion takes place through the electrolyte from one electrode to another electrode are called lithium-ion batteries. In general the battery consists of soluble lithium intercalated carbon/graphite is used as anode. The cathode material is made up of lithium liberating compounds.

Construction and working principle

During discharging lithium ions are dissociated from the anode and migrate through electrolyte to cathode. During charging, lithium from cathode material is ionized and moves towards the anode. At the same time the electrons travel through external circuit. The discharge and charge reactions are given below,



Anode: Lithium intercalated graphite layer having thin copper foil.

Cathode: Lithium cobalt oxide layer having aluminium foil as current collector.

Electrolyte: Li salts i.e., LiCl, LiBr, $LiAlCl_4$ dissolved in propylene carbonate and 1,2 dimethoxy ethane.

Representation: Graphite/$LiPF_6$ in organic solvent/$LiCoO_2$

$$\text{At Anode : } Li_xC_6 \longrightarrow XLi^+ + xe^- + 6C$$

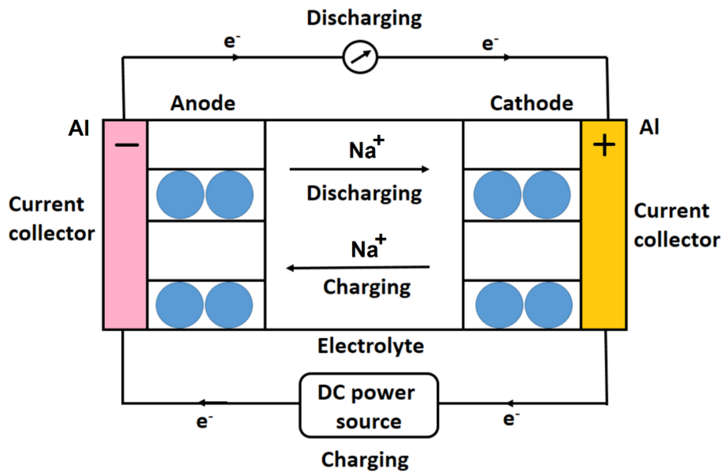
$$\text{At Cathode: } Li_{1-x}CoO_2 + XLi^+ + xe^- \longrightarrow LiCoO_2$$

$$\text{Net Reaction: } Li1_{-x}CoO_2 + Li_xC_6 \longrightarrow LiCoO_2 + 6C$$

Applications: Li-ion batteries are used in cardiac pacemakers, laptops, cell phones and aerospace applications.

Q.2.a. Explain the construction and working Na-ion battery. Write the charging and discharging reaction.

A sodium-ion battery (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 intercalated hard carbon

Cathode: Sodium cobalt oxide layer ($NaCoO_2$)

Current collector: Aluminum used in both anode and cathode

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 of Sodium-ion battery

- They are commonly used boats and ships
- They are used in medical devices
- They are used in military and defense

- They are used in electric cars.

Q.2.b.Explain the detection of pharmaceutical pollutant diclofenac using electrochemical sensors.

Diclofenac is a drug compound which is used for the treatment of several diseases. An overdose of diclofenac can cause adverse effects in the human body.

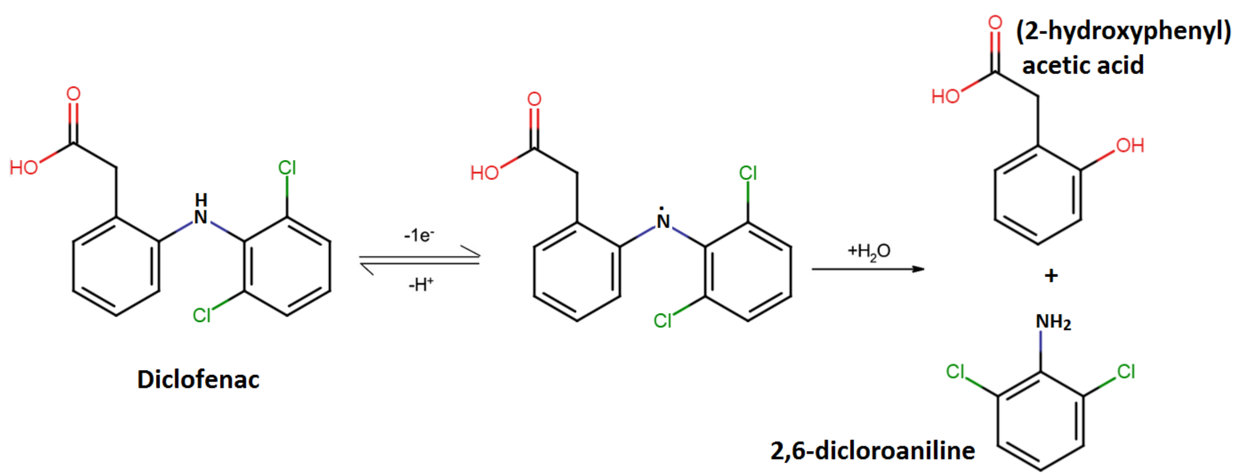
It is necessary to detect and control the amount of diclofenac drug present in a blood sample using an electrochemical sensor.

Construction

- *Working electrode*: Carbon coated with MWCNT
- *Counter Electrode*: Platinum mesh (Pt)
- *Reference Electrode*: Ag/AgCl
- *Electrolyte* : Aqueous solution of LiCl salt

Working

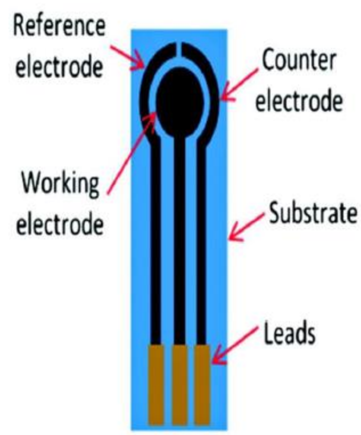
- When electrochemical sensor is immersed into the sample containing diclofenac drug compound (pH 7.2), an electrochemical oxidation of diclofenac occurs on the surface of the working electrode to which a potential is applied with respect to the reference electrode while the corresponding current is measured.
- The change in potential of the reaction gives the concentration of diclofenac.



Q.2.c. What are disposable sensor? Explain the detection of ascorbic acid. Write the oxidation reaction.

Disposable sensors are low-cost and easy-to-use sensing devices intended for short-term or rapid single-point measurements.

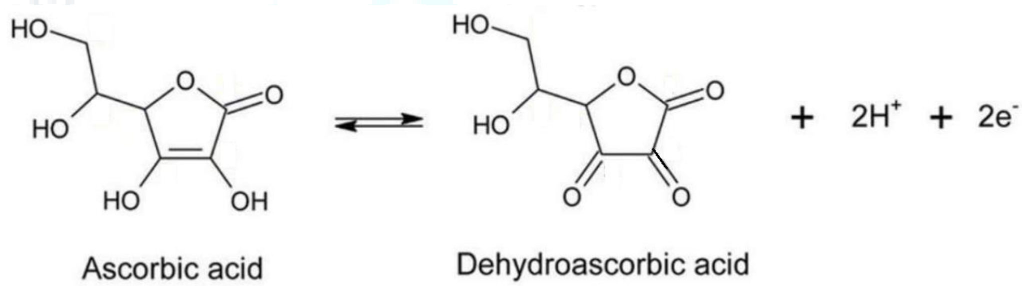
Construction



- *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.



Module-2

Q.3.a. What are memory device? Briefly explain the classification of memory device.

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, such as the operating system, applications, and user files.

According to the device structure, electronic memory devices can be divided into three primary categories such as:

- Transistor type electronic memory devices
- Capacitor type electronic memory devices
- Resistor type electronic memory devices
- Charge transfer type electronic memory devices

A. Transistor-type electronic memory devices

Transistor-based electronic memory devices are a type of memory device that uses transistors as the building blocks for data storage due to their speed, reliability, and low power consumption. The basic principle of transistor-type electronic memory is that it stores data as charges on the gates of transistors, which act as switches. When the transistor gate is charged, it represents a binary "1", and when it is discharged, it represents a binary "0". The data can be read from the transistor by measuring the voltage level on the gate.

Examples:

1. Dynamic Random Access Memory (DRAM) is a type of volatile memory that uses a capacitor and a transistor to store a single bit of data. DRAM is commonly used in computers and other electronic devices as temporary storage for data and program instructions.

2. Static Random Access Memory (SRAM) is a type of volatile memory that uses transistors to store data in a flip-flop circuit. SRAM is faster and more power-efficient than DRAM but is also more expensive and has a lower storage density.

B. Capacitor type electronic memory devices

Capacitor type electronic memory refers to a type of non-volatile memory that 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. The charge can be stored in the capacitor for an extended period, making it a non-volatile memory. When the data needs to be read, the charge on the capacitor is measured and translated into a digital value.

Examples:

1. DRAM (Dynamic Random Access Memory): It is commonly used in computer memory and is volatile, which means that the data is lost when power is turned off.

2. NAND Flash Memory is a type of non-volatile memory that is commonly used in storage devices like USB drives, memory cards, and solid-state drives (SSDs). It stores data in a series of capacitors, and the data can be accessed quickly and efficiently.

C. Resistor type electronic memory devices

Resistor type electronic memory devices are a type of non-volatile memory that store the digital data using the resistance of a material. The basic principle of resistor type electronic memory is that it stores data as the resistance level of a resistor. Each resistor represents a bit of data, with a high resistance representing a binary "1" and a low resistance representing a binary

"0". The data can be read by measuring the resistance of each resistor. There are several types of resistor memory devices, including:

1. Resistive Random Access Memory (RRAM): By applying a voltage to the material, the resistance can be changed and data can be stored.

2. Phase-Change Memory (PCM): By applying heat, the material can be switched between amorphous and crystalline states, changing its resistance and allowing data to be stored.

D. Charge transfer type electronic memory devices

Charge transfer type electronic memory devices uses the transfer of charge between capacitors or other circuit elements to store and retrieve digital data. The basic principle of charge transfer type electronic memory is that it stores data as the charge stored in a capacitor or other circuit element. The data can be read by measuring the voltage level on the capacitor or other element.

Examples

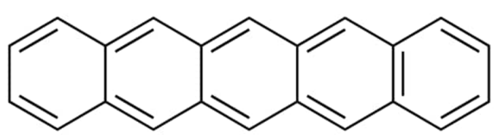
1. Charge-Coupled Device (CCD) Memory: The charge is transferred between capacitors in a linear or circular fashion, and data is read by sensing the charge stored in each capacitor.

2. Charge-Trap Flash (CTF) Memory: The charge is trapped in the charge trap layer by applying a voltage, and it can be read by sensing the current flowing through the layer.

Q.3.b. Explain organic memory devices of p-type and n-type by taking example of Pentacene.

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

P-type semiconductors materials that have an excess of positively charged ***hole***s (deficiency of electrons in their valence band), which can conduct electricity. Example of p-type organic semiconductor materials used in organic memory devices is ***pentacene***.

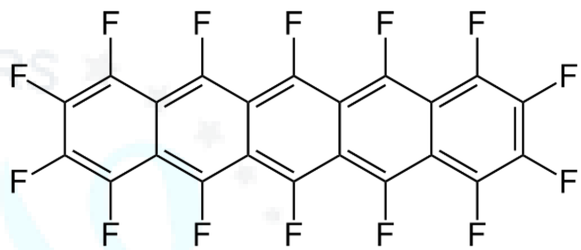


- Pentacene has a high "hole" mobility, which makes pentacene a suitable material for use in memory devices.

- Pentacene is used in organic memory devices like ***organic flash memory*** *and* ***organic resistive random access memory (RRAM)*** due to its excellent performance, with fast switching speeds, low power consumption and good stability.

An **n-type semiconductor** organic material is a type of organic material that has an excess of electrons in its conduction band. This material is used in the construction of organic electronic devices such as ***organic field-effect transistors*** (OFETs).

Perfluoropentacene is an n-type semiconductor organic material that is used in organic memory devices. It is a fluorinated derivative of pentacene.



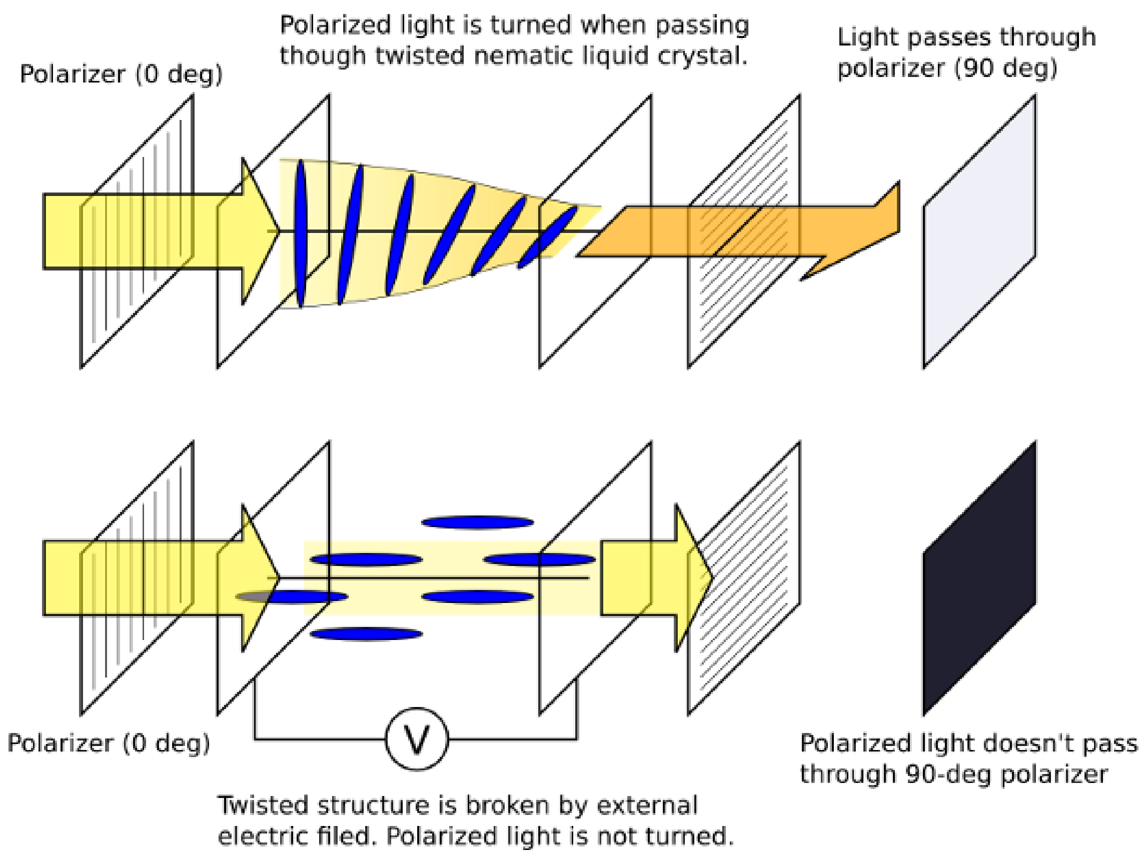
Perfluoropentacene has a high electron mobility and low ionization potential, which makes it a promising candidate for use in organic memory devices.

Q.3.c. Discuss the application of liquids in display devices.

Liquid crystal displays (LCDs) are widely used in electronic devices such as televisions, computer monitors, and mobile phones.

Working principle:

- In an LCD, a thin layer of liquid crystals is sandwiched between two transparent electrodes, and the electrodes are connected to a power source.
- When an electric field is applied, the liquid crystal molecules align themselves along the direction of the electric field, changing the orientation of their polarization, and this in turn modifies the optical properties of the liquid crystal.
- A backlight behind the LCD panel shines light through it.
- The liquid crystal layer selectively blocks or transmits the light, depending on the orientation of the liquid crystal molecules.
- The result is that different areas of the LCD can appear either light or dark, creating images and text.



Q.4.a. What are Photoactive and electroactive material? Briefly discuss their role in opto-electronic devices.

Photoactive materials are those materials that can absorb light energy and undergo a photochemical reaction. They can convert light energy into chemical or electrical energy.

The principles that govern photoactive materials are based on the absorption of light by the material and the subsequent generation of excited states.

1. Absorption: Photoactive materials must be able to absorb light energy in order to generate excited states. The absorption spectrum of a material determines which wavelengths of light it can absorb and how efficiently it can do so.

2. Excited states: When a photoactive material absorbs 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.

3. 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.

Photoactive materials are used in photovoltaic cells which convert sunlight into electrical energy, and photocatalysts, which use light energy to catalyze chemical reactions. Photoactive materials have significant applications in display systems.

Electroactive materials are those materials that can conduct electricity and exhibit changes in their electrical properties in response to an external electric field. Examples of electroactive materials include conductive polymers, which have electrical conductivity similar to metals.

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

1. Conductivity: Electroactive materials must be able to conduct electrical current in order to respond to an external electrical stimulus. This can be achieved through the presence of mobile charge carriers, such as electrons or ions.

2. Response time: Electroactive materials must be able to respond quickly to changes in the electrical field. The response time of the material is determined by the mobility of the charge carriers and the speed at which they can move through the material.

3. 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.b. What are liquid crystals? Briefly explain the classification of liquid crystals with example.

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.

Liquid crystals can be classified as:

- **Thermotropic liquid crystals**
- **Lyotropic liquid crystals**

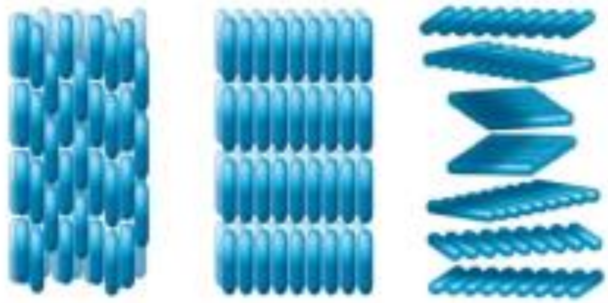
A. Thermotropic liquid crystals

- When long-chain organic solids are heated, they undergo sharp phase transitions at particular temperatures yielding liquid crystals.
- The phase transition involving these intermediate phases is mostly naturally affected by the changing temperature and hence, they are ***thermotropic liquid crystals***.

1. Ethyl-*p*-azoxycinnamate (Solid) $\xrightarrow{140°C}$ Ethyl-*p*-azoxycinnamate (liquid crystal)
2. *p*-cholesteryl benzoate (Solid) $\xrightarrow{145°C}$ *p*-cholesteryl benzoate (liquid crystal)

Thermotropic liquid crystals have been classified into the following types:

1) **Nematic liquid crystals**
2) **Smectic liquid crystals**
3) **Cholesteric liquid crystals**



(1) Nematic (or thread-like liquid crystals)

- The molecules move either sideways or up and down. Each molecule can also twist or rotate around its axis giving rise to a twisted nematic.
- Since the molecules are oriented in one direction, they exhibit anisotropy.
- 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*** – as the temperature is increased, the degree of orientation of the nematic crystals decreases and they change into isotropic liquids.

Examples: p-azoxyphenetole, anisaldazine.

(2) Smectic (or soap-like liquid crystals)

- The molecules in smectic crystals are oriented parallel to each other as in the nematic phase but in layers.
- These layers can pass each other because the force between the layers is weak.
- They are denoted by alphabet letters A, B, C, etc. Some common types of smectic liquid crystals are given below.

(a) Smectic A In smectic A, the molecules are aligned perpendicular to the layer planes.

(b) Smectic C The arrangement of molecules is similar to smectic A except that the molecules are slightly tilted.

- They have high viscosity and are not suitable for devices.

(3) Cholesteric liquid crystals

- This type of mesophase is formed by derivatives of cholesterol such as cholesteryl esters.
- Like the nematic phase, the molecules in this type of crystal are also parallel to each other but arranged in layers.
- 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.
- ***Cholesteryl benzoate***, the first known liquid crystal, is of cholesteric type. Its transition temperature is 146 °C and its melting point is 178.5 °C.

B. Lyotropic liquid crystals

- The orientational behaviour of lyotropic crystals is a function of concentration and solvent.
- These molecules are amphiphilic – they have both hydrophilic and hydrophobic ends in their molecules.
- The hydrophilic end is attracted towards the water, whereas the hydrophobic end is water-repellent and attracted towards non-polar solvents.
- At low concentrations, these molecules are randomly oriented but as the concentration increases, the molecules start arranging themselves.
- Cell membranes and cell walls are examples of lyotropic liquid crystals. Soaps and detergents form lyotropic crystals when they combine with water.

Q.4.c. Discuss the application of Polyimide polymeric material for organic memory device.

Polyimide-based polymeric materials have found several applications in the field of organic memory devices. Organic memory devices offer advantages such as low cost, flexibility, and low power consumption, and polyimides contribute to their functionality in various ways:

1. Dielectric Material: Polyimides can serve as an insulating dielectric material in organic memory devices.

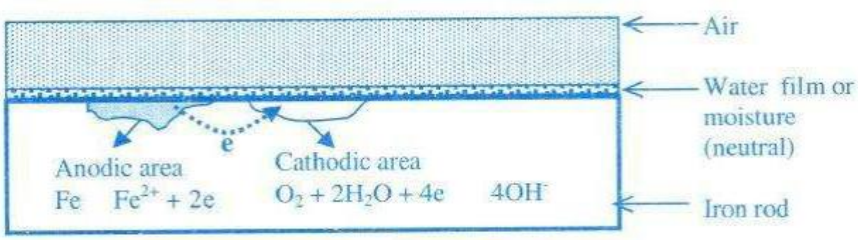
2. Charge Storage: Polyimides can be functionalized or engineered to incorporate charge storage sites or traps. These traps can capture and hold charges, representing the 0s and 1s of digital data.
3. Non-volatile Memory: Organic memory devices using polyimide dielectrics can function as non-volatile memory, where data is retained without the need for a continuous power supply.
4. Flexible and Bendable Memory: Polyimides are known for their flexibility and mechanical robustness.
5. Low Power Consumption: Organic memory devices, with polyimide components, often have lower power consumption compared to traditional silicon-based memory devices.

Module-3

Q.5.a. What is corrosion? Explain electrochemical theory of corrosion taking iron as example.

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.

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

Q.5.b. What are reference electrode? Explain the construction, working and application of calomel electrode.

Reference Electrodes: The electrodes whose potentials is known and constant and they are used to determine the potential of another unknown electrode are known as reference 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.

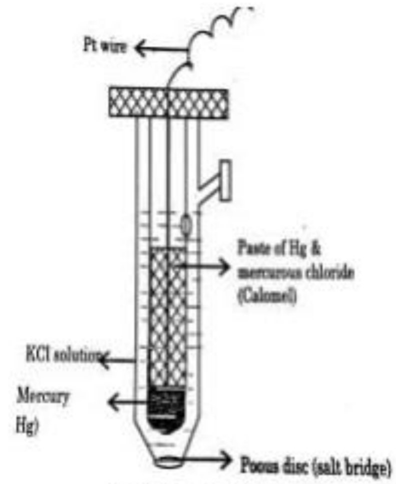
Electrode representation: $Hg(s)/Hg_2Cl_2$ (paste);Cl-

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

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

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

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



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.5.c. Two cadmium rods immersed in Cadmium sulphate solution of concentration 0.002M and 0.4M. Write the cell representation, cell reaction and calculate the EMF at 25°C.

Cell representation: $Cd/Cd^{2+}(0.002M)//Cd^{2+}(0.4M)/Cd$

Cell reaction:

Anode: $Cd \rightarrow Cd^{2+}\ (0.002M) + 2e^-$

Cathode : $Cd^{2+}\ (0.4M) + 2e^- \rightarrow Cd$

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 = 0.4 M

C_1 = Concentration of electrolyte at anodic compartment = 0..002 M
n = 2

Substituting the above values in above formula,

$$E_{cell} = 0.0591/2\ [\log 0.4/0.002]$$

$$E_{cell} = 0.02955\ [\log 200]$$

E_{cell} = 0.02955 x 2.301

E_{cell} = 0.0679 V

Q.6.a. What are Ion-selective electrodes? Explain the determination of pH of a solution using glass electrode.

Ion selective electrodes selectively respond to a specific ion in a mixture and potential developed is a function of concentration of that ion in the solution. Eg. Glass electrode.

Determination of pH using glass electrode

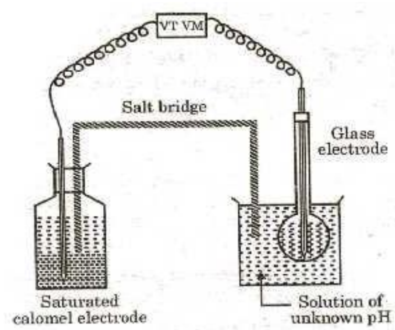
To determine the pH of given solution, glass electrode is dipped in a solution whose pH is to be determined. It is combined with a saturated calomel electrode (ref electrode) through a salt bridge. The cell assembly is represented as,

$Hg / Hg_2Cl_2 / Cl^- //$ solution of unknown pH / glass / 0.1N HCl / AgCl / Ag

EMF of the so formed cell is determined by using electronic voltmeter.

$E_{cell} = E_{cathode} – E_{anode}$ (Conventionally glass electrode is cathode)

$E_{cell} = E_G - E_{cal}$



Substituting value of E_G from Eq. 5 into above equation

$E_{cell} = E^{\circ}_G - 0.0591pH - E_{cal}$

$pH = E^{\circ}_G - E_{cal} – E_{cell} / 0.0591$

$pH = K – E_{cell}/0.0591$

where, K is known as *glass electrode assembly constant*.

E°_G value or K is evaluated by dipping the glass electrode in a solution of known pH and measuring EMF of the cell formed when coupled with a calomel electrode. Next the same assembly is dipped into test solution and the pH of test solution can be determined.

Q.6.b. What is anodizing? Explain the anodizing of aluminium.

Anodizing is the process of oxidation of outer layer of metal to its metal oxide by electrolysis. Metal oxide layer formed over the metal itself acts as protective layer.

In anodization of aluminium, clean and polished aluminium is taken as anode and immersed in an electrolytic cell containing chromic acid. Inert electrode like lead is generally used as cathode. The anodic oxide film formed on Al in bath as aluminium oxide, which is porous. The pores are finally sealed by dipping in hot water to produce $Al_2O_3.H_2O$, which acts as a non-porous protective layer preventing corrosion.

Anode reaction: $2Al + 3H_2O \rightarrow Al_2O_3 + 6H^+ + 6e^-$

Cathode reaction: $6H^+ + 6e^- \rightarrow 3H_2$

Advantages:

1. Anodized $Al_2O_3 .H_2O$ act as a protective layer, increasing the corrosion resistivity of the surface as it prevents further oxidation.
2. They have harder and durability than normal aluminium.
3. The anodized surface shows good adhesion to paint and gives a colored appearance.

Applications:

1. Anodization is used for aluminium pressure cookers and cooking pots.
2. Aluminium window frames are anodized.

Q.6.c.

CPR = KW/DAT

Corrosion penetrating rate in mpy	Corrosion penetrating rate in mm/y
CPR = KW/DAT	CPR = KW/DAT
Weight loss, W= 385×10^3 mg	Weight loss, W= 385×10^3 mg
Density, D = 7.9 g/cm^3; Time, T = 1×24×365	Density, D = 7.9 g/cm^3; Time, T = 1×24×365
Area A = 450 x 6.45 inch^2	Area A = 450 cm^2
CPR = $\frac{534 \times 385 \times 10^3}{7.9 \times 450 \times 6.45 \times 1 \times 24 \times 365}$	CPR = $\frac{87.6 \times 385 \times 10^3}{7.9 \times 450 \times 1 \times 24 \times 365}$
CPR = 42.59 mpy	CPR = 1.08 mm/y

Module-4

Q.7.a. Discuss the conducting mechanism in polyacetylene.

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

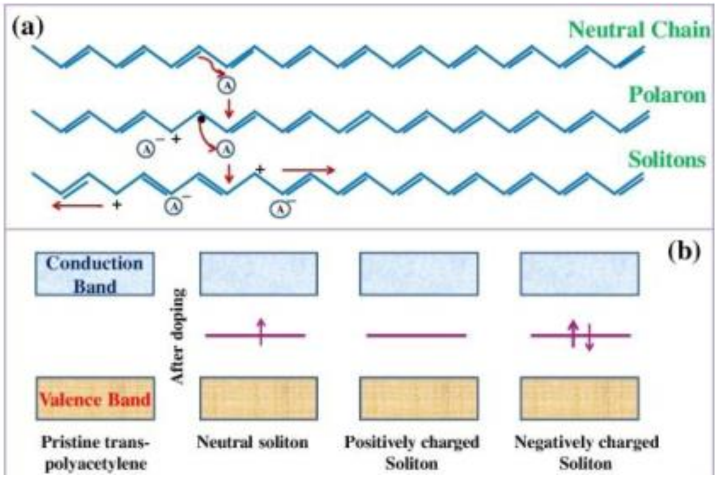
Mechanism of Conduction:

i. When the oxidative dopart such as iodine is added, it takes away an electrons from the π-back bone of the pollyacetylene chain and creates a positive centre (hole) on one of the carbon.

ii. The other π-electron resides on the other carbon making it a radical. The radical ion formed is called Polaron. A dipolar on (soliton) is formed on further oxidation.

iii. These radicals migrate and combine to establish a backbone double bond. As the two electrons are removed, the chain will have two positive centre (holes).

iv. The chain as a whole is neutral, but holes are mobile and when a potential is applied the migrate from one chain as a whole is neutral but holes are mobile and when a potential is applied they migrate from one carbon to another and account for conductivity. This depicted by the sequence of reaction.



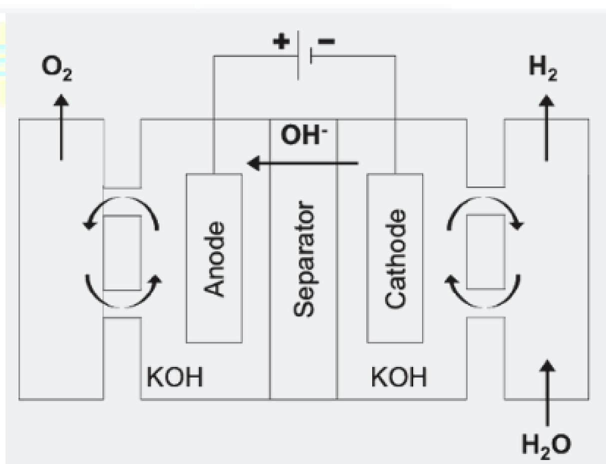
Q.7.b. With a neat sketch, explain the generation of hydrogen by alkaline electrolysis of water.

- In the case of alkaline water electrolysis, where a strong base is used as the electrolyte, the hydroxide anions are transferred through the electrolyte to the anode surface, where they lose electrons that then return to the positive terminal of the DC power source.
- Nickel (Ni) is a popular choice due to its low cost, good activity, and easy availability.
- KOH is preferred over sodium hydroxide (NaOH) because the former electrolyte solutions have higher conductivity.

Cathode $2\,H_2O + 2\,e^- \rightarrow H_2 + 2\,OH^-$ ($E^0 = -0.83$ V *vs.* SHE) (4)

Anode $2\,OH^- \rightarrow \frac{1}{2}\,O_2 + H_2O + 2\,e^-$ ($E^0 = 0.40$ V *vs.* SHE) (5)

Overall $H_2O \rightarrow H_2 + \frac{1}{2}\,O_2$ ($E_0 = -1.23$ V *vs.* SHE) (3)



Advantages:

- Well established technology

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

Q.7.c. In a polymer, 20% molecules have molecular mass 15000 g/mol, 35% molecules have molecular mass 25000 g/mol, and remaining molecules have molecular mass 20000 g /mol, calculate the number average and weight average molecular masses of the polymer.

Number average molecular mass:

Total weight = (20 x 15000) + (35 x 25000) + (45 x 20000) = 300000 + 875000 + 900000

= 2075000

Total number = 20 + 35 + 45 = 100

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

Mn = 2075000 / 100 = **20750 g/mol**

Weight average molecular mass:

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

$$\mathbf{M_W} = \frac{\{[(20 \times (15000)^2] + [(35 \times (25000)^2] + [(45 \times (20000)^2]}{(20 \times 15000) + (35 \times 25000) + (45 \times 20000)}$$

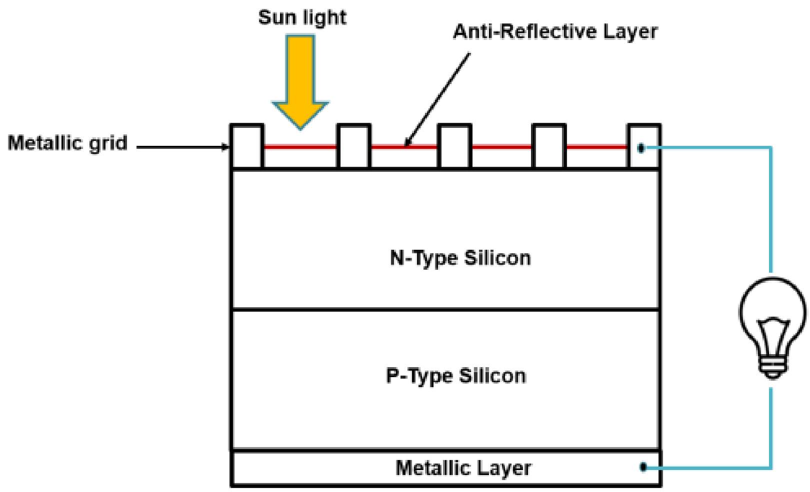
M_W = 21385 g/mol

Q.8.a. What are PV Cell? Explain construction and working of PV cell.

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 (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 (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

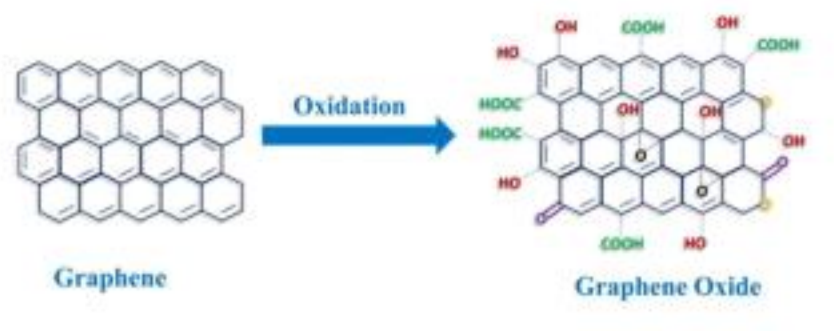
Q.8.b. Explain the preparation, properties and commercial application of graphene oxide.

Graphene oxide (GO) is a layered carbon structure with oxygen-containing functional groups (=O, -OH, -O-, -COOH) attached to both sides of the layer as well as the edges of the plane.

Preparation (Hammers Method):

- There are several ways to prepare graphite oxide/graphene oxide. The most common way is to use an oxidizing agent in an acidic environment.
- In this procedure, phosphoric acid is mixed with sulphuric acid in the ratio 1:9 and potassium permanganate and graphite added in the ratio 6:1 in an ice bath.
- The mixture is then heated at 50^oC and stirred for 12 h. After cooling down, the mixture is poured onto ice.
- Finally, 30% H_2O_2 is added in order to remove the excess of potassium permanganate.
- Phosphoric acid works as a dispersive and etching agent, as well as a stabilizer of the oxidation process, which makes the synthesis of GO safe.

- This route produces a higher yield of GO with a higher level of oxidation and a more regular structure.



Properties:

i. It has high surface area
ii. GO is highly hydrophilic due to the presence of oxygen functional groups on its surface.
iii. The chemical properties of GO can be tuned by controlling the degree of oxidation and the type of functional groups present on its surface.
iv. GO is not as conductive as graphene due to the presence of oxygen functional groups, it still has a significant level of electrical conductivity.

Applications:

i. GO can be used in energy storage devices such as batteries, supercapacitors, and fuel cells.
ii. GO can be used to make sensors for various applications, including gas sensors, biosensors, and chemical sensors.
iii. GO can be used to remove contaminants from water due to its high surface area, adsorption capacity, and hydrophilicity.
iv. GO has potential applications in drug delivery, tissue engineering, and biosensors due to its biocompatibility and ability to interact with biological molecules.

Q.8.c.What is green fuel? Mention the advantages of green fuel.

Green fuel is a term used to describe any type of fuel that is produced from renewable resources, such as biomass, algae, or other organic matter. Some common examples of green fuels include biodiesel, ethanol, hydrogen, and methane.

Advantages of Green Fuel:

- Environmental Benefits: Green fuels are produced and consumed with a lower carbon footprint, resulting in reduced greenhouse gas emissions.
- Energy Security: Green fuels reduce dependency on fossil fuels, which can be subject to supply disruptions and price volatility.
- Sustainability: Many green fuels are made from sustainable resources, such as agricultural crops, algae, or organic waste materials.

- Renewable Resource Utilization: Green fuels are derived from resources that can be naturally replenished, such as plant-based feedstocks or sunlight.
- Improved Air Quality: The combustion of green fuels often results in fewer harmful air pollutants, such as sulfur dioxide and nitrogen oxides, which can lead to better air quality and reduce health risks for local communities.
- Energy Efficiency: Some green fuels, like hydrogen and electricity, can be used in highly efficient systems, such as fuel cells or electric vehicles. This results in improved energy efficiency, reducing waste and energy consumption.

Module-5

Q.9.a. What are e-waste? Explain the sources and composition of e-waste.

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

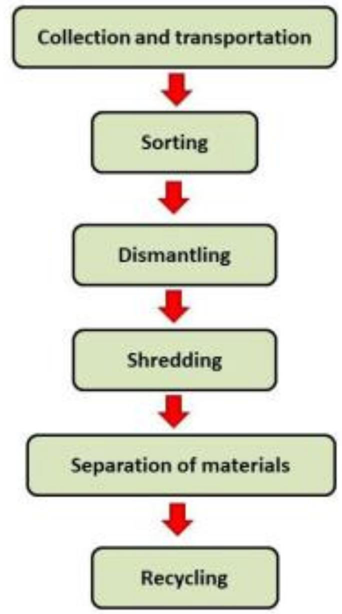
Sources:

- **Households**: A significant portion of e-waste is generated from homes, as people upgrade their electronics and dispose of their old devices. This includes items such as computers, televisions, mobile phones, and other household appliances.
- **Businesses**: Companies and organizations also generate a large amount of e-waste, as they upgrade their computer systems and replace old equipment.
- **Government agencies**: Government agencies and institutions, such as schools and hospitals, also contribute to the e-waste stream as they upgrade and replace their electronics.
- **End-of-life products**: Many electronics have a limited lifespan and eventually reach the end of their useful life, at which point they become e-waste.
- **Imports**: Some countries import e-waste from other countries, either for recycling or disposal, which can contribute to the overall e-waste stream.

Composition:

- Metals: Electronic devices contain a variety of metals, including iron, steel, aluminum, copper, gold, silver, and others. These metals are valuable resources and can be recovered and recycled.
- Plastics: Many electronic devices contain different types of plastic, such as polyvinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), and others.
- Glass: Electronic devices also contain glass, often in the form of screens and lenses.
- Hazardous materials: Many electronic devices contain hazardous materials, such as lead, cadmium, and mercury, which can be harmful to human health and the environment if not properly managed.
- Other materials: Other materials that can be found in e-waste include batteries, printed circuit boards, and components such as capacitors and resistors.

Q.9.b. Discuss the various steps involved in recycling of e-waste.



- **Collection and transportation**: E-waste is collected from various sources and transported to a facility where it can be processed.
- **Sorting**: The first step in e-waste separation is to sort the waste into different categories based on the type of material contained in each device, such as plastics, metals, and circuit boards.
- **Dismantling**: The next step is to disassemble the electronic devices and separate the individual components, such as the batteries, power supplies, and other components.
- **Shredding**: Some electronic devices, such as televisions and monitors, are shredded into smaller pieces to make it easier to separate the materials contained in them.
- **Separation of materials**: Once the devices have been dismantled and shredded, the individual components are sorted based on the type of material they contain. For example, metals such as copper and aluminum can be separated from plastics, which can then be further sorted by type.
- **Recycling**: The separated materials are then processed for recycling, either through traditional recycling processes or through specialized e-waste recycling methods.

By separating e-waste into its individual components, it is possible to reduce the environmental impact of discarded electronics, recover valuable resources, and promote sustainable use of materials.

Q.9.c. Write a note on various stake-holders in e-waste.

1. **Producers**: Manufacturers 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**: The government plays a critical role in establishing and enforcing regulations and policies that govern the collection, transportation, treatment, and disposal of e-waste. This includes setting standards for the management of e-waste, establishing collection systems, and ensuring that e-waste is properly disposed of.

Q.10.a. Explain the various steps involved in extraction of gold from E-waste.

Gold can be extracted from electronic waste (e-waste) using a variety of methods, including *hydrometallurgical* and *pyrometallurgical* methods. The most commonly used method for extracting gold from e-waste is ***hydrometallurgical extraction***, which involves the use of chemical reactions and water-based solutions to extract the gold.

The process of hydrometallurgical extraction of gold from e-waste typically involves the following steps:

- **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 cyanide or thiourea that dissolves the gold. This solution is referred to as the leachant.
- **Separation**: The gold-rich solution is then separated from the solid waste. The gold present in the solution is then recovered using a variety of techniques, such as precipitation, ion exchange, and solvent extraction.
- **Purification**: The recovered gold is then purified to remove impurities.

Q.10.b. Discuss the extraction of metals from e-waste by pyrometallurgy.

Pyrometallurgical methods of e-waste recycling involve the use of high temperatures to extract metals and minerals from electronic waste. The following are the steps involved in a typical pyrometallurgical process:

- **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.c. What are the toxic materials used in electrical and electronic products? Discuss their ill effects.

The manufacturing of electronic and electrical products often involves the use of toxic materials that can be harmful to human health and the environment. Some of the most commonly used toxic materials include:

- **Lead**: Lead is commonly used in the manufacture of batteries and as a component of solder on printed circuit boards. Lead is a toxic heavy metal that can cause serious health problems, including neurological damage and developmental disorders.
- **Cadmium**: Cadmium is used in the manufacture of rechargeable batteries, as well as in electronic components such as capacitors and resistors. Cadmium is a toxic heavy metal that can cause cancer and other health problems.
- **Mercury**: Mercury is used in the manufacture of switches, relays, and fluorescent light bulbs. Mercury is a toxic heavy metal that can cause neurological damage and other health problems.
- **Brominated flame retardants**: Brominated flame retardants are used in the manufacture of electronic devices to reduce the risk of fire. Some types of brominated flame retardants are toxic and can harm human health and the environment.
- **Phthalates**: Phthalates are used as plasticizers in the manufacture of electronic devices. Some types of phthalates are toxic and can harm human health and the environment.