Modified

CBCS SCHEME

USN | | | | | | | | | | |

1BCHES102

First Semester B.E./B.Tech. Degree Examination, Dec.2025/Jan.2026
Applied Chemistry for Smart Systems

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.
3. VTU formula Handbook is permitted.
4. Missing data, if any, may be suitably assumed.

		Module – 1	M	L	C
Q.1	a.	Explain p type and n type semiconductors with an example.	6	L2	CO1
	b.	Explain the synthesis of TiO_2-RAM nano material by the sol–gel method and mention its properties and applications.	7	L2	CO1
	c.	Describe the construction, working principle and applications of Active-Matrix Organic Light Emitting Diodes (AMOLEDs).	7	L2	CO1
		OR			
Q.2	a.	Explain the construction, working and advantages of pentacene semiconductor chip.	6	L2	CO1
	b.	What are liquid crystals (LCs)? Explain their classifications.	7	L2	CO1
	c.	Explain the construction and working principle of Organic Light Emitting Diodes (OLEDs) and mention its applications in electronic displays.	7	L2	CO1
		Module – 2			
Q.3	a.	Explain the construction, working and the applications of Quantum dot sensitized solar cells (QDSSCs).	6	L2	CO2
	b.	What is a Polymer? Explain the synthesis, properties of Nylon 6,6 and mention its applications.	7	L2	CO2
	c.	A polymer sample containing 50, 100 and 150 molecules having molar mass 1000, 2000 and 3000 respectively. Calculate the number and weight average molecular weights of polymer.	7	L3	CO2
		OR			
Q.4	a.	Describe the following structure property relationship of the polymer. a) Crystallinity b) Strength c) Chemical resistivity.	6	L2	CO2
	b.	Explain the wet chemical synthesis of Cd–Se quantum dots and mention its application.	7	L2	CO2
	c.	Polymers are generally known for their insulating nature. Applying the knowledge of conduction mechanism, highlight and explain the conduction mechanism in Polyaniline polymer. Mention its engineering applications.	7	L3	CO2

		Module – 3			
Q.5	a.	Describe the construction and working of Lithium-ion Battery.	6	L2	CO3
	b.	Explain the production of green hydrogen using TiO_2 photocatalytic water splitting method.	7	L2	CO3
	c.	The emf of a cell Ag(s) /$AgNO_3$(0.02M) // $AgNO_3$(XM) / Ag(s) is found to be 0.084V at 298 K. Find the value of X and write the cell reactions.	7	L3	CO3
		OR			
Q.6	a.	A fuel cell is considered as an efficient energy conversion device to convert fuel energy into electricity operating at wide temperature range. Apply the concept of energy conversion and outline the characteristics, construction and working of solid oxide fuel cell.	6	L3	CO3
	b.	Explain the construction and working of Sodium ion Battery and mention its applications.	7	L2	CO3
	c.	What is a battery? Outline the classification of battery with suitable examples.	7	L2	CO3
		Module – 4			
Q.7	a.	Explain the mechanism of Pitting corrosion and Waterline corrosion with suitable examples.	6	L2	CO4
	b.	Explain the principle, construction and application of Electrochemical sensors in the detection of NOx and Sox.	7	L2	CO4
	c.	What is CPR? A thick sheet of area 93 inch 2 is exposed to air near the ocean. After 6 months it was found to experience a weight loss of 360 g due to corrosion, if the density of the steel is 7.9 g/cm^3. Calculate the corrosion penetration rate in mpy and mmpy (Given K = 534 in mpy and 87.6 mm/y).	7	L3	CO4
		OR			
Q.8	a.	What is corrosion? Explain electrochemical theory of corrosion by taking iron as an example.	7	L2	CO4
	b.	Explain the application of Conductometric sensors in the estimation of acid mixture.	7	L2	CO4
	c.	Define the terms a) Transducer b) Actuators c) Sensors.	6	L2	CO4
		Module – 5			
Q.9	a.	Explain the role of artificial intelligence in e-waste management.	6	L2	CO4
	b.	Explain the synthesis and properties of alginate hydrogel with reference to its applications in brain–computer interfaces (BCIs).	7	L2	CO4
	c.	Explain the extraction of gold from e-waste by bioleaching method.	7	L2	CO4

		OR			
Q.10	a.	Explain the effects of e-waste on the Environment and Human Health.	6	L2	CO4
	b.	Explain the green synthesis of ZnO nano particles and mention its uses in magnetic Radio Frequency Identification. (RFID).	7	L2	CO4
	c.	Explain the synthesis and properties of polylactic Acid (PLA). Mention its uses in touch screen applications.	7	L2	CO4

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Revised Scheme Modifications of Applied Chemistry_2025 I sem

1BCHES102

"B Mahesh" <bmahesh@jssateb.ac.in> February 14, 2026 11:38 AM

To: boe@vtu.ac.in

Respected sir,

The scheme for I Semester Applied Chemistry (04 Streams) has been reviewed by the BOE members through a Google Meet session. The corrections as discussed are enclosed herewith for necessary action.

Kindly do the needful.

Yours sincerely,
BOE – Chemistry Composite Board

Dr.Mahesh B,
Dean Research,
Professor of Chemistry,
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"APPROVED"
Registrar (Evaluation)
Visvesvaraya Technological University
BELAGAVI - 590018

To,

13.2.2026

The Registrar (Evaluation),
Visvesvaraya Technological University, Belagavi.

Respected sir

Sub: Regarding the scheme and solution of Applied chemistry for smart systems (1BCHES102)

The scheme for Applied Chemistry for Smart Systems (1BCHES102) has been reviewed by the BOE members through a Google Meet session. The following observations were made during the review.

The necessary corrections shall be incorporated into the scheme and the corresponding solutions accordingly. The scheme and solutions for the remaining questions were found to be satisfactory.

Unit-2

Q3 C: Solution and marks

N1=50 m1=1000, N2=100 m2=2000, N3=150 m3=3000

Number average molecular weight= $\frac{N_1M_1+N_2M_2+N_3M_3}{N_1+N_2+N_3}$ --------1 Mark

$\frac{50x1000+100x2000+150x3000}{50+100+150}$ --------1 Marks

=2333g/mol ----------1 Mark

Weight average molecular weight= $\frac{N_1M_1^2+N_2M_2^2+N_3M_3^2}{N_1M_1+N_2M_2+N_3M_3}$ ----------1 Mark

$\frac{50x(1000)^2+100(2000)^2+150(3000)^2}{50x1000+100x2000+150x3000}$ ----------2 Marks

=2571g/mol ----------1 Mark

With regards,

BOE- Chemistry Composite Board

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13/2/2026

Visvesvaraya Technological University

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Scheme & Solutions

Signature Of Scrutinizer

Subject Title: Applied Chemistry for Smart Systems Subject Code :1BCHES102

Question Number	Solution	Marks Allocated
1a)	P -type-Pi conjugated system -majority charge carrier holes Eg: Pentacene with structure	2+1
	n -type-Pi conjugated system -majority charge -electrons Eg: perfluoropentacene with structure	2+1
1b)	Sol preparation, Gel formation, Aging, Drying, TiO2 nano material formation..... Properties : Any two..... Applications :Any two.....	5 1 1
1c)	Construction (anode ,cathode ,substrate) with figure..... Working Principle..... Applications :Any four.....	2+1 2 2
2a)	Construction (Substrate, di-electric insulator, semiconductor, encapsulation) with figure Working Principle..... Advantages :Any four.....	2 2 2
2b)	Definition ..... Classification Thermotropic Liquid crystals- and lyotropic Liquid crystals. Nematic, Smectic, Cholestreric with definition and examples ..... Lyotropic Liquid crystals: hydrophilic and hydrophobic.....	1 3 3
2c)	Construction- Substrate: glass/plastic Anode—holes, cathode—electrons, Hole injecting layer, Hole transporting layer, Electron blocking layer, Emissive Layer, electron transporting layer, electron injecting layer with figure Working Principle-Electrons and holes move towards the emissive layer, recombination takes place, large amount of energy is released, the energy released is emitted in the form of light. Applications: Any four.....	3 3 1

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13/2/2026

Subject Title: Applied Chemistry for Smart Systems Subject Code:1BCHES102

Question Number	Solution	Marks Allocated
3a)	Construction-Anode-FTO, coated with TiO2, which is coated with Quantum Dots. Cathode: Brass substrate coated with Pt, Electrolyte: poly sulphide	2
	Working Principle with figure.....	2
	Applications (any two)	2
3b)	Definition.....	1
	Synthesis with reaction	2
	n HOOC-(CH2)4 – COOH + n H2N-(CH2)6 – NH2 → [–OC-(CH2)4 – CO-NH-(CH2)6 – NH –]n + (2n – 1) H2O	
	Properties (any two)	2
	Applications (any two)	2
3c)	Number average molecular weights of polymer = 3800 g/mol	3
	Weight average molecular weights of polymer = 4210.5 g/mol	4
4a)	Crystallinity, Strength, Chemical resistivity	2+2+2
4b)	Preparation: Selection of precursor: Cadmium source and selenium source with example and reaction $CdCl_2 \rightarrow Cd^{2+} + 2Cl^-$ $Na_2SeO_3 + 4NaBH_4 + 7H_2O \rightarrow Na_2Se + 4B(OH)_3 + 14H_2\uparrow$.....	2
	Preparation of ReactionMedium-Addition of Stabilizer-Nucleation and Growth --Cd^{2+} + $Se^{2-} \rightarrow$ CdSe (Quantum Dots) -Final Product	4
	Applications (any two)	1
4c)	Mechanism -Partial oxidation, Protonation, formation of conducting polymer (3 steps)	3
	Explanation.....	2
	Applications (Any four)	2

Subject Title: Applied Chemistry for Smart Systems Subject Code:1BCHES102

Question Number	Solution	Marks Allocated
5a)	Figure.....	1
	Construction: Anode: Li intercalated graphite, Cathode: Partially Lithiated oxides of Mn, Co and Ni, Anode and cathode current collectors, Electrolyte: $LiPF_6$ dissolved in the binary solvents., separator: Micro porous polypropylene.	3
	Reactions.....	2
5b)	Principle: TiO2 acts as the semi-conductor catalyst to absorb light and splits water into hydrogen and oxygen.....	1
	Figure.....	1
	Explanation: Light Absorption, Water Oxidation (Oxygen Evolution), Hydrogen Evolution.....	3
	Reactions; $TiO_2 + h\nu \rightarrow e_{CB}^- + h_{VB}^+$	
	$2H_2O + 4h^+ \rightarrow O_2 + 4H^+$	2
	$4H^+ + 4e^- \rightarrow 2H_2$	
5c)	Substitution, Value of x with the unit...0.528M.....	4
	Cell reaction (anode, Cathode, overall reaction)	3
6a)	Figure.....	1
	Construction Anode: porous nickel–zirconia cermet, Cathode:Porous layer strontium-doped lanthanum manganite, Electrolyte: ceramic material, usually yttria-stabilized zirconia.....	2
	Working principle: Cathode: reduction of the oxygen-to-oxygen ion. Anode: fuel is oxidized at anode, releases electrons and generates electricity.....	2
	Reactions.....	1
6b)	Figure.....	1
	Construction Anode:Hard carbon,Cathode: Sodium transition metal oxide Electrolyte:Na salt dissolved in binary solvents,Separator: Microporous polypropylene or polyethylene.....	3
	Reaction with explanation.....	2
	Application (Any 2)	1

Subject Title : Applied Chemistry for Smart Systems Subject Code :1BCHES102

Question Number	Solution	Marks Allocated
6c)	Definition	1
	Classification with an example: Primary battery, Secondary battery, Reserve battery	2+2+2
7a)	a) Pitting corrosion: Explanation with example.....	3
	b) Waterline corrosion: Explanation with example.....	3
7b)	Principle:oxidation or reduction of the target gas at an electrode, which produces a current proportional to the gas concentration.The gas diffuses through a gas-permeable membrane into the sensor. And reacts at the working electrode in the presence of an electrolyte, producing electrons and measured current is directly proportional to the gas concentration in air.	2
	Figure.....	1
	Construction and working Working Electrode: Metal oxide-coated electrode ---reduction of NOx, Reference Electrode: gold, Counter Electrode (CE): Completes the circuit. Electrolyte: facilitates ion transport between electrodes, Gas-permeable Membrane: Controls diffusion of gases and prevents electrolyte leakage.	2
	Applications:(any four)	2
7c)	CPR in mmpy- (substitution, result with unit) = 1.54.....	1+2
	CPR in mpy- (substitution, result with unit) = 60.5	1+3
8a)	Definition.....	1
	Explanation- (formation of galvanic cell. Anode, cathode, corrosion product, corrosion current.....	3
	Reactions: Hydrogen Liberation Acidic medium:$2H^+ + 2e^- \rightarrow H_2\uparrow$ Neutral medium :$2H_2O + 2e^- \rightarrow 2OH^- + H_2\uparrow$.....	1
	Oxygen absorption Acidic medium:$2H^+ + \frac{1}{2}O_2 + 2e^- \rightarrow H_2O$	
	Neutral medium: $H_2O + \frac{1}{2}O_2 + 2e^- \rightarrow 2OH^-$	1
	Rust formation $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$, $4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 2[Fe_2O_3 \cdot 3H_2O]$ (Brown rust)	1

Subject Title: Applied Chemistry for Smart Systems Subject Code:1BCHES102

Question Number	Solution	Marks Allocated
8b)	Principle	1
	Procedure and tabulation.....	3
	Graph, Calculation.....	3
8c)	Transducer, Actuators, sensors	2+2+2
9a)	Data collection, AI Identification and classification, Smart sorting system, Recycling, Resource recovery Monitoring and Optimizations	1+1+1+1+ 1+1
9b)	Synthesis: Preparation of Alginate solution, Adding Calcium source, Ionic Cross linking Gel formation and washing	5
	Properties: (any four)	2
9c)	e-waste collection and preparation, Microbial activation, Bio oxidation reaction, Gold Liberation, Gold recovery	5
	Reactions	2
10a)	Effect of e waste on the environment.....	3
	Effect of e waste on human health.....	3
10b)	Synthesis 1.Starting material: Plant washed, drying in room temperature, grinding 2.Obtained Air dried leaves is subjected to ultrasonic Extraction assisted at 150w for 30 mins and 45°C by 3.To the Aqueous extract add Zinc acetate dihydrate at the pH of 10.5 with continuous stirring 4.heat in the water bath at 60^0C and centrifuse. 5. filter, wash the precipitate, dry and calcinated for 2 hours at 600^0C to obtain Zn nano particle.	5
	Applications: Any four.....	2

Subject Title: Applied Chemistry for Smart Systems Subject Code:1BCHES102

Question Number	Solution	Marks Allocated
10c)	Synthesis with reactions Glucose to Lactic acid, Formation of Lactide, Ring Opening Polymerization	3
	Properties (Any four)	2
	Applications (Any four)	2

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Module-1

December 2025 / Jan 2026

1)

a. Explain p-type & n-type semiconductors with examples.

→ * n-type semiconductor :- When a pure semiconductor is doped with a pentavalent impurity, it forms an n-type semiconductor.

Ex: Silicon doped with phosphorous (P) / Arsenic (As)

Explanation :-

- Silicon has 4 valence electrons.
- Phosphorous has 5 valence electrons.
- Four electrons form covalent bonds.
- The fifth electron becomes free.

Hence, electrons are majority charge carriers & holes are minority carriers.

* p-type semiconductor :- When a pure semiconductor is doped with trivalent impurity, it forms a p-type semiconductor.

Ex: Silicon doped with Boron (B)

Explanation :-

- Boron has only 3 valence electrons.
- One bond remains incomplete.
- This creats a hole.

Hence holes are majority charge carriers

b. Explain synthesis of TiO_2 - RAM nano materials by the sol-gel method & mention its properties & applications.

→ Synthesis :-

The sol-gel method is a low temperature chemical process used to prepare TiO_2 nanoparticles / materials with controlled particle size & high purity for reRAM applications.

Steps involved:-

(1) Preparation of precursor solution :-

Titanium isopropoxide is dissolved in alcohol to form a uniform solution.

(2) Hydrolysis & condensation:-

→ Controlled addition of water converts alkoxide into titanium hydroxide.

→ Hydroxyl groups condense to form a 3D Ti-O-Ti network, producing a sol that gradually turns into a gel.

$$Ti(OCH(CH_3)_2)_4 + H_2O \longrightarrow Ti(OH)_4 + 4(CH_3)_2CHOH$$

$$Ti(OH)_4 \longrightarrow TiO_2 + 2H_2O.$$

(3) Aging :- The gel is aged to improve structural strength & uniformity.

4) Substrate preparation:-

Clean substrate by sonication in acetone, Isopropanol & deionize. Dry the substrate under nitrogen stream or in an oven.

5) Thin film deposition:-

Spin coat the TiO_2 sol on the substrate at 2000-4000 rpm for 30-60 seconds.

6) Drying :- Dry the coated film at 1000°C for 10-15 min

7) Annealing :- Calcin the dried film in air at 400-500°C for 1-2 hrs to crystallize TiO_2.

8) Device fabrication:- Deposit the top electrode by evaporation to complete ReRAM devices

* Properties :-

- High resistive switching capability.
- Low power consumption.
- Eco-friendly & non-toxic
- Excellent thermal & chemical stability.

* Applications :-

- Non-volatile memory : faster & more energy efficient than flash memory.
- Used in flexible & transparent devices.
- Used in neuromorphic computing.

4

c. Describe construction, working principle & application of AMOLED.

→ AMOLED :-

Construction :-

→ An AMOLED is a OLED display that uses an active matrix thin film transistors (TFTs) to control each individual pixel.

→ It consists of :-

(1) Substrate :- Usually glass or flexible polymer providing mechanical support.

(2) TFT layer :- Each pixel is connected to a TFT that acts as switch, allowing precise control of current

(3) Organic layer :-

(a) HIL (Hole injection layer) :- Facilitates injection of holes from anode.

(b) HTL (Hole transport layer) :- Transports holes to the emissive layer.

(c) EML (Emmissive layer) :- Contains organic molecules that emitt light when electrons & holes recombine.

(d) ETL (Emissive transport layer) :- Transports electrons from cathode to emissive layer.

(e) EIL (Emissive injection layer) :- Aids electron injection from the cathode.

(4) Cathode & anode :- Transparent anode (Indium-tin oxide) & metal cathode.

(5) Encapsulation layer:- Protects organic material from moisture & oxygen.

Working :-

→ When a voltage is applied across a pixel the TFT switch turns on allowing current to flow through organic layer.

→ Electrons from the cathode & holes from ~~cathoo~~ anode meet in emissive layer.

→ Recombination of holes & electrons generate photons producing light.

→ Each pixel emitts light independently, enabling high contrast, fast response & precise colour control.

* Applications:-

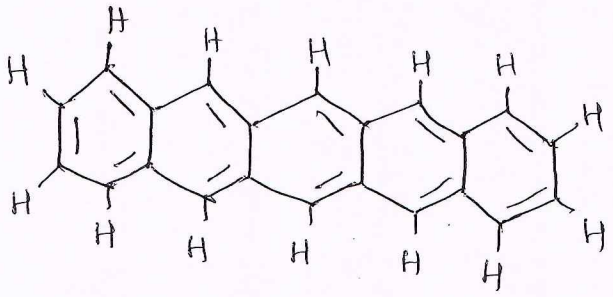
① Smart phone & tablet displays.
② Wearable devices like smart watches.
③ Television
④ Automotive display.

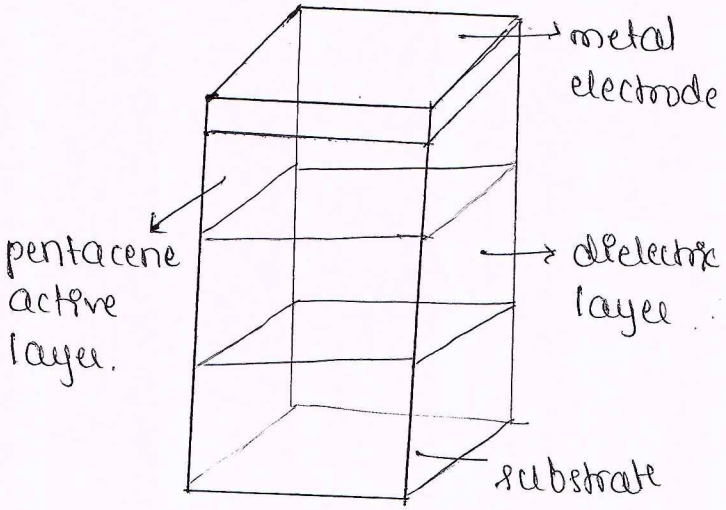
2]

a. Explain construction, working & advantages of pentacene semiconductor chip.

→ Pentacene chip :-

- Pentacene is a stable & inexpensive organic molecule, widely used in memory devices.
- Consists of five linearly fused benzene rings, forming a planar conjugated π - systems.





Construction :-

- Substrate : Base support layer.
- Dielectric layer : Insulating layer placed above structure.
- Pentacene active layer : Organic semiconductor layer.
- Metal electrodes : Two electrodes placed on either side for charge injection & collection.

*Working :-

- Pentacene has:
  - HOMO (Highest Occupied Molecular Orbital) - Topmost filled energy level.
    → Electrons are removed from here to create holes.
  - LUMO (Lowest unoccupied molecular orbital) - Lowest empty energy level.
    → Electrons can be injected here during operation.

When voltage is applied:

1. Electron flow from n-type electrode into pentacene layer.
2. These electrons are accepted by the pentacene molecules.
3. Charge transport occurs through the conjugated π-system of pentacene.
4. Since pentacene is p-type, hole transport dominates.

Advantages :-

- Chemically stable.
- Allows fast charge transport.
- Flexible & light weight.
- Environment friendly
- Low cost.

b. What are liquid crystals (LCs)? Explain their classifications.

→ Liquid crystals are special class of materials that exhibit properties intermediate between those of a liquid & a solid crystal.

Classifications :-

Liquid crystals are mainly classified into 2 types
(i) Thermotropic liquid crystals.
(ii) Lyotropic liquid crystals.

(i) Thermotropic LC :- It exhibits liquid crystal behaviour with variation of temperature
There are 4 types
① Nemantic
② Chiral
③ Smectic
④ Columnar.

① Nemantic :- Formed by optically inactive molecules, have elongated shape, oriented parallel to direction.
Ex: p-azoxyanisole.

② Chiral :- Formed by optically active molecules with a chiral center.
- Molecules acquire spontaneous helical twist.

Ex: Cholesteryl benzoate.

③ Smectic:- Exhibit orientational & some positional order.

Sub-types :-

- Smectic A: Director perpendicular to layer plane.
- Smectic B: Molecules are arranged in hexagonal order.
- Smectic C: Director tilted at an angle other than 90°.

(4) Columnar:- Formed by disc-like molecules.

- Molecules orient along the director & assemble into columns
- Columns further arrange in a hexagonal lattice.

(ii) Lyotropic LC:- Formed by the variation in concentration of a compound dissolved in a solvent.

Ex: Soap water mixture.

c. Explain the construction & working principle of Organic Light Emitting diodes (OLED's) & mention its applications in electronic displays.

→ Construction:

- Substrate: Glass / flexible plastic.
- Anode: Transparent electrode that injects holes into organic layer.
- Organic layer:
  - Hole transport layer (HTL):- Facilitates hole movement from anode to emissive layer.
  - Emissive layer (EML):- Made of conjugate organic molecules Light is generated here when $e^{\ominus}$s & holes recombine.

- Electron transport layer (ETL):- Guides electrons from cathode to the emissive layer efficiently.

- Cathode:-

  Metal electrode that injects electrons into device.

Working :-

- When voltage is appleed across the electrodes, holes are injected from the anode & electrons from the cathode.
- These charge carriers move through HTL & ETL into the emissive layer.
- Electron hole recombination occurs in the emissive layer, forming excitons.
- Excitons release energy in the form of visible light when they decay radiatively.
- The emitted light passes through the transpaunt anode & substrate to produce a visible display.

* Applecations :-

- Displays
- Wearable electronics.
- Lighting
- Advanced applecations.

Module-2

3)

a. Explain the construction, working & the applications of Quantum dot sentisized solar cells (QDSSCs).

→ * Construction :-

- Photoanode:

→ A conducting glass substrate is coated with semiconductor layer (commonly TiO_2). The outer surface is then sentisized with QDs.

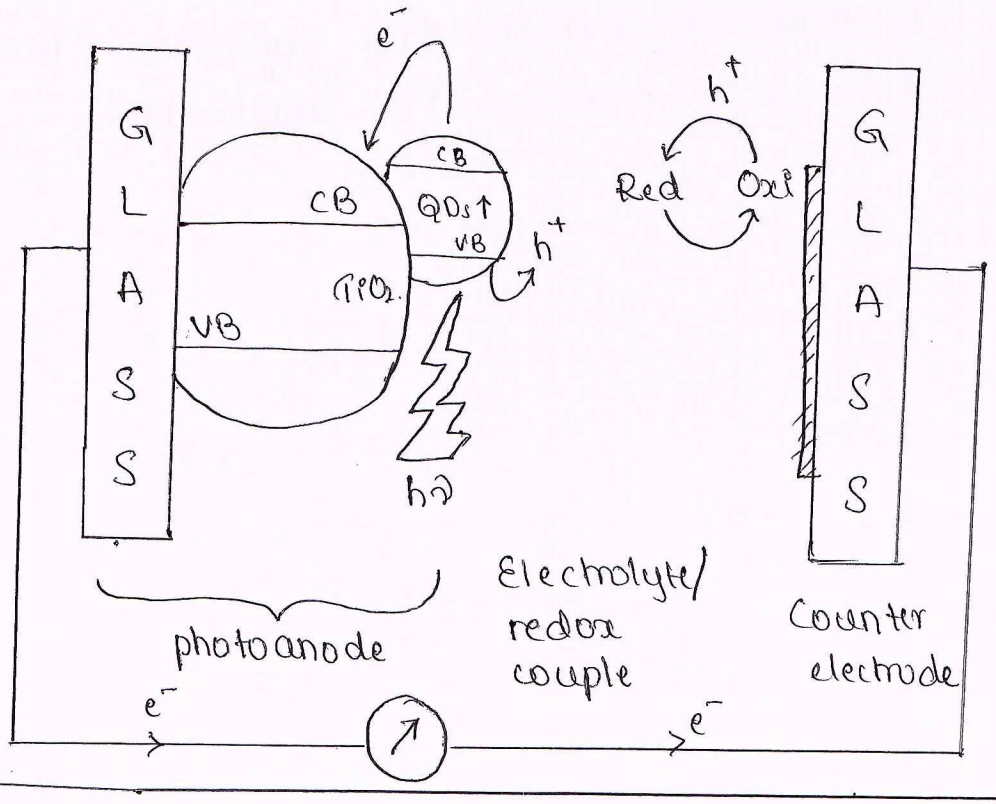
- Electrolyte:

→ A redox electrolyte, usually polysulfide, acts as a hole conductor & facilitates charge transfer.

- Cathode electrode:

→ It helps regenerate the electrolyte & completes the circuit

* Working



(1) QDs absorb sunlight & electrons are excited from valence band to the conduction band.

(2) The excited electrons are transferred to the semiconductor layer, leaving holes behind on the QD's surface

(3) The electrolyte captures these holes & undergoes reduction reactions.

(4) Electrons move from the photoanode to the cathode through the external circuit, producing current.

(5) At the cathode, the electrolyte is regenerated by gaining electrons.

* Applications:-

- Biological labelling & imaging.
- Detection systems & fluorescence resonance energy transfer donors.
- Used in LED's, photodetectors & photovoltaic devices.
- Used in chemical reactions.

b. What is polymer? Explain the synthesis, properties of Nylon 6,6 & mention its applications.

→ A polymer is a large molecule built from long chains of smaller, repeating chemical units called monomer.

Synthesis of nylon 6,6 :-

Nylon 6,6 is produced when equal amounts of adipic acid & hexamethylene diamine undergo polycondensation reaction with formation of amide bond, releasing water as a byproduct.

$n\,HOOC-(CH_2)_4-COOH + n\,H_2N-(CH_2)_6-NH_2$

adipic acid — hexamethylene diamine

$\downarrow -H_2O$

$-\{CO-(CH_2)_4-CO-NH-(CH_2)_6-NH\}_n-$

amide bond with elimination of by products.

* Applications :-

1. Textile industry :- clothing, carpets, rugs etc.
2. Industrial applications :- Ropes, cords, fishing nets.
3. Mechanical parts :- Gears, bearings etc.
4. Automotive parts :- Engine covers.
5. 3D printing etc.

c. A polymer sample containing 50, 100, 150 molecules having molar mass 1000, 2000 & 3000 respectively. Calculate the number & weight average weights of polymer.

→ Given : $N_1 = 50$, $M_1 = 1000$

$N_2 = 100$ $M_2 = 2000$

$N_3 = 150$ $M_3 = 3000$

$\sum N_i = N_1 + N_2 + N_3 = 50 + 100 + 150 = 300$

$\sum N_i M_i = N_1M_1 + N_2M_2 + N_3M_3$

$= (50)(1000) + (100)(2000) + (150)(3000)$

$= 50,000 + 2,00,000 + 4,50,000$

$= 7,00,000$

$$\sum N_i M_i^2 = N_1 M_1^2 + N_2 M_2^2 + N_3 M_3^2$$

$$= (500 \times 1000^2) + (100 \times 2000^2) + (150 \times 3000^2)$$

$$= 50,000,000 + 40,0\,00,000 + 1,35,00,00,000$$

$$= 1,80,00,00,000$$

$$\bar{M}_n = \frac{\sum N_i M_i}{\sum N_i}$$

$$= \frac{700000}{300}$$

$$\boxed{\bar{M}_n = 2333.33 \text{ g/mol}}$$

$$\bar{M}_w = \frac{\sum N_i M_i^2}{\sum N_i M_i}$$

$$= \frac{1800000000}{700000}$$

$$\boxed{\bar{M}_w = 2571.43 \text{ g/mol}}$$

4.

a] Describe the following structure property relationship of the polymer.

(a) Crystallinity (b) Strength (c) Chemical resistivity

→ (a) Crystallinity :- Crystallinity refers to the degree of ordered packing of polymer chain.

- Linear polymers have straight chains without bulky side groups, allowing close packing & high crystallinity.

Ex: Polyethylene $(-CH_2-CH_2-)$

- Branched polymers have side chains that prevent close packing resulting in lower crystallinity
  Ex: polyvinylacetate
- Isotactic polymers are more crystalline than atactic polymers due to regular side-group arrangement.

(b) Strength:-

- Tensile strength is the maximum stress a polymer can withstand before breaking.
- Increases with molecular weight upto about 2000, after which the increase is negligible.
- Low molecular weight polymers are soft & gummy.
- High molecular weight polymers are tough & heat resistant.
- Cross linked polymers have higher tensile strength than linear polymers.

(c) Chemical strength/resistivity:-

Chemical ~~tresistivity~~ is the ability of a polymer to resist swelling, softening or dissolution when exposed to chemicals.

- Polymers with polar groups dissolve in polar ~~sy~~ solvents.
- Polymers with non-polar groups dissolve in non-polar solvents
- Chemical resistance increases with:
  → Higher crystallinity
  → Greater degree of cross-linking.

b. Explain the wet chemical synthesis of Cd-Se quantum dots & mention its application.

→ Synthesis :-

Step 1: Selection of precursors :-

- Cd source : $CdCl_2$, $Cd(CH_3COO)_2$ or $Cd(NO_3)_2$

$$CdCl_2 \longrightarrow Cd^{2+} + 2Cl^-$$

- Selenium source : Na_2Se or Na_2SeO_3

$$Na_2SeO_3 + 4NaBH_4 + 7H_2O \longrightarrow Na_2Se + 4B(OH)_3 + 14H_2\uparrow$$

OR

$$Se\ powder + NaBH_4 + H_2O \xrightarrow{Inert\ gas} NaHSe\ soln$$

Step 2: Preparation of reaction mixture :-

- Dissolve cadmium precursor in aqueous or organic solvent Adjust pH to mildly alkaline if needed.

Step 3: Addition of stabilizer / capping agent :-

- Agents like thioglycolic are added. These prevent aggregation & control nanoparticle growth.

$$CdSe + R-SH \longrightarrow Cd-Se-(SR)$$

Step 4: Nucleation & growth :-

→ Controlled heating with constant stirring (50 - 100°C)

→ Selenium precursors is slowly introduced into the cadmium solution.

→ Reaction is often carried out under inert atmosphere to prevent oxidation.

→ Particle size is tuned by varing temperature, precursor ratio & reaction time.

$$Cd^{2+} + Se^{2-} \longrightarrow CdSe\ (QD)$$

Step 5: Separation & purification:-

→ The QDs are precipitated, centrifuged & washed with solvents. Excess unreacted species & are removed.

Step 6: Final product:-

→ Stable colloidal Cd-Se QDs with size dependent photoluminescence.

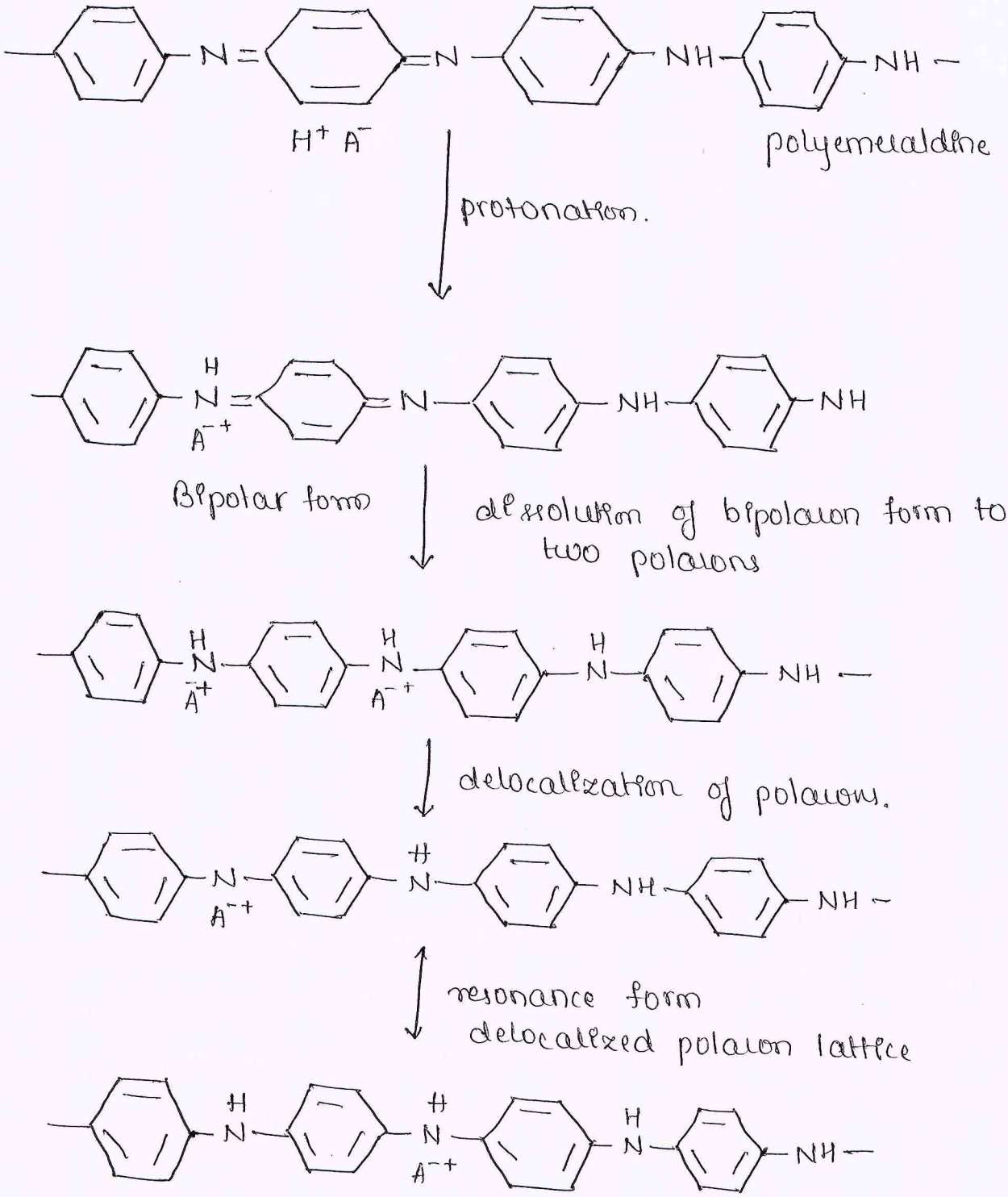
* Applications:-

(1) Optoelectronics.
(2) Biological imaging.
(3) Solar cells
(4) Sensors
(5) Photocatalysis.

c. Polymers are generally known for their insulating nature. Applying the knowledge of conduction mechanism, highlight and explain the conduction mechanism in polyaniline polymer. Mention its engineering applications.

→ Mechanism of polyaniline polymer:-

The synthesis of conducting polyaniline is an example of doping technique. In this technique current carrying species (-ve /+ve) are created by the protonation of imine nitrogen.



→ Polyaniline exists in several different oxidation states of which only emaraldine salt conducting.

→ Polyaniline is partially oxidized using a suitable oxidizing agent, into a base form of aniline which contains alternating reduced & oxidized forms of aniline polymer back bone.

→ Base form of aniline treated with aqueous HCl (1M), undergoes protonation of imine nitrogen atom, creating current carrying species on the polymer backbone. Their charges are compensated by the anions (Cl^-) of the doping agent giving the corresponding salt.

* Applications :-

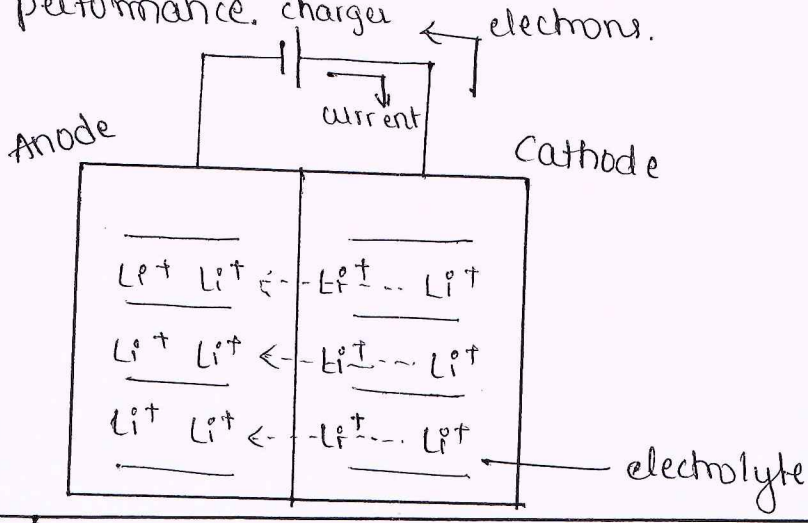
- Conductive coatings for electronics & textiles
- Corrosion protection on metals through protective coatings.
- Chemical & biosensors for detecting gases, humidity & biomolecules.
- Electrode material in batteries & rechargable devices.
- Flexible electronics such as OLEDs, wearable sensors.

Module - 3

5]

a) Describe the construction & working of Lithium - ion Battery.

→ Li - ion battery is rechargable battery best suited to mobile devices that require small size, light weight & high performance.



- Anode : Lithium intercalatable graphite.
- Cathode : Lithium metal oxides ($Li-MO_2$)
- Electrolyte : Lithium salt such as $LiPF_6$ dissolved in organic solvents like propylene carbonate, ethyle carbonate etc.
- Separator : Microporous polypropylene or polyethylene.
- Li-ion battery develops a potential of 3.6V.

* Working :-

The principle behind working is that during charging lithium ion in the cathode moves from layer to layer in crystallized carbon anode. Charge balance in cathode is ensured by oxidation of Co(+3) to Co(+4) Electrons released by such oxidation are transferred to anode through external circuit. During discharge lithium ions from anode move to the cathode & Co(+4) is reduced to Co(+3).

* Cell reactions :-

- During discharge

Anode : $LiC_6 \rightleftharpoons Li^+ + 6C + e^-$

Cathode : $MO_2 + Li^+ + e^- \longleftrightarrow LiMO_2$.

Overall reaction : $LiC_6 + MO_2 \rightleftharpoons LiMO_2 + 6C$.

(M = Co)

* During charging :-

At cathode : $LiMO_2 \longrightarrow Li_{1-x}MO_2 + Li^+ + e^-$

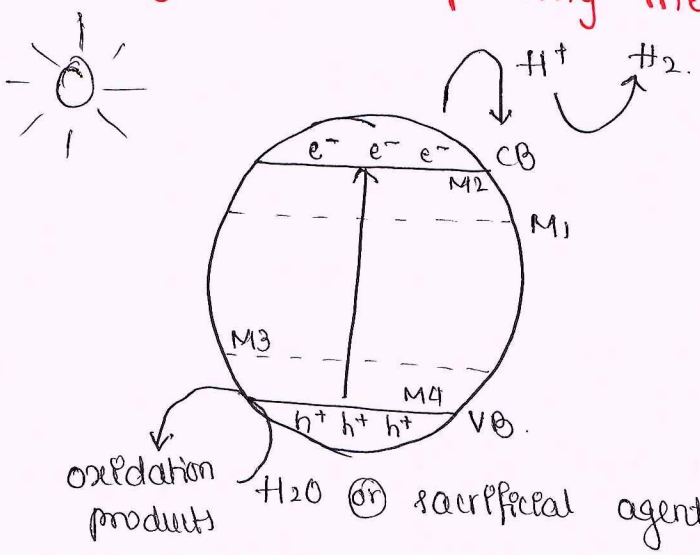
Anode : $Li^+ + 6C + e^- \longrightarrow LiC_6$

overall reaction : $LiMO_2 + 6C \rightleftharpoons LiC_6 + MO_2$

(M = Co)

b. Explain the production of green hydrogen using TiO_2 photocatalytic water splitting method.

→



M1 – schottky barrier or SPR.

M2 – Acceptor level

M3 – Donor level

M4 – generation of gap states by interaction with TiO_2 VB states.

→ Photocatalytic water splitting is a solar-driven process that mimics natural photosynthesis. It uses a semiconductor catalyst such as TiO_2 to absorb light energy & drive the splitting of water into H_2 & O_2. This generates green hydrogen, a clean fuel with zero carbon emissions.

1. Light absorption:- When TiO_2 absorbs a photon with energy greater than its band gap, it excites an electron from valence band to conduction band leaving behind a hole.

$$TiO_2 + h\nu \longrightarrow e^-_{CB} + h^+_{VB}$$

2. Water oxidation:- Holes oxidize water molecules at the catalyst surface.

3. Hydrogen evolution:- The electrons reduce proton (H^+) to form hydrogen gas:

$$4H^+ + 4e^- \longrightarrow 2H_2.$$

Co-catalyst are often deposited on TiO_2 to enhance H_2 production & suppress electron-hole pair.

c. The emf of a cell $Ag(s)/AgNO_3(0.02\ M)//AgNO_3(X\ M)/Ag(s)$ is found to be 0.084 V at 298K. Find the cell reaction & find the value of X.

→

$$E = \frac{0.0591}{n} \log \frac{C_2}{C_1}$$

$$0.084 = \frac{0.0591}{1} \log \frac{X}{0.02}.$$

$$\frac{0.084}{0.0591} = \log \frac{X}{0.02}.$$

$$\log \frac{X}{0.02} = 1.421.$$

$$\frac{X}{0.02} = 10^{1.421} \Rightarrow X = 26.4 \times 0.02.$$

$$\boxed{X = 0.528M} \simeq 0.53\ M$$

Anode : $Ag_{(s)} \longrightarrow Ag^{+}_{(0.02M)} + e^{-}$

Cathode : $Ag^{+}_{(0.53M)} + e^{-} \longrightarrow Ag$

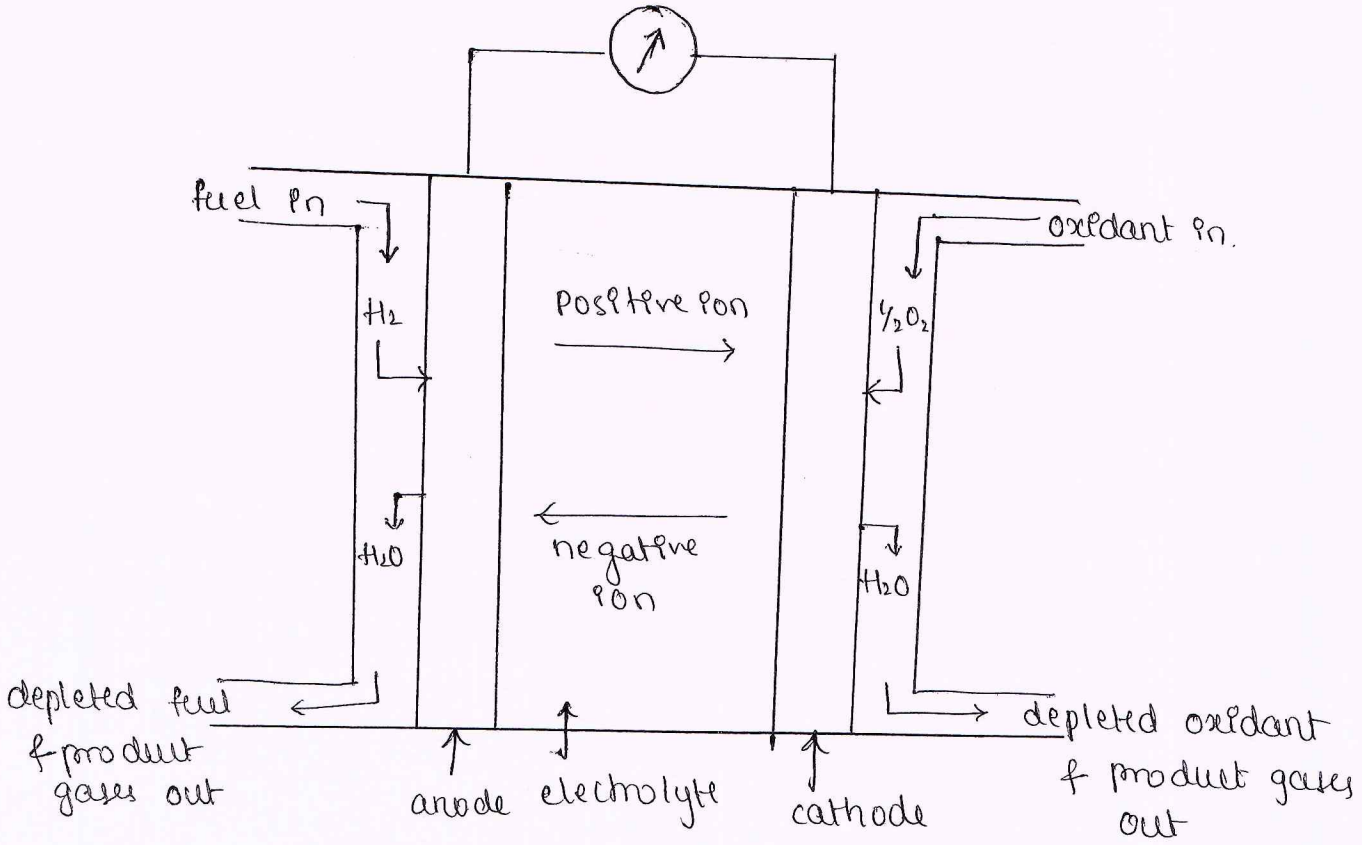
overall cell reaction : $Ag^{+}(0.53M) \longrightarrow Ag^{+}(0.02M)$

6]

(a) A fuel cell is considered as an efficient energy conversion device to convert fuel energy into electricity operating at wide temperature range. Apply the concept of energy conversion & outline the characteristics, construction & working of solid oxide fuel cell.

→ Construction :-

SOFC is an electrochemical device that directly converts the chemical energy of fuels into electricity through a high temperature electrochemical reaction.



- Anode (negative electrode) :- Typically, a porous nickel-zirconia cermet, where fuel (H_2 or hydrocarbons) is oxidized ($Ni-ZrO_2$)
- Cathode (positive electrode) :- Usually porous layer strontium-doped lanthanum manganite, where oxygen from air is reduced.

  Ex: Strontium doped lanthanum manganate ($LaMnO_3$)
- Electrolyte :- A solid ceramic material, usually yttria-stabilized zirconia, which conducts oxygen ions (O^{2-}).
- Interconnects :- Conduct electricity & separate the cells.

* Working principle :-

Air (oxygen) is supplied to cathode, where oxygen molecules are reduced to oxygen ions (O^{2-}). These oxygen ions diffuse through the electrolyte towards anode. Fuel enters the anode reacting with oxygen ions. The reaction releases electrons, which flow through an external circuit, generating electricity. The electrons returns to the cathode to reduce oxygen molecules, completing the circuit.

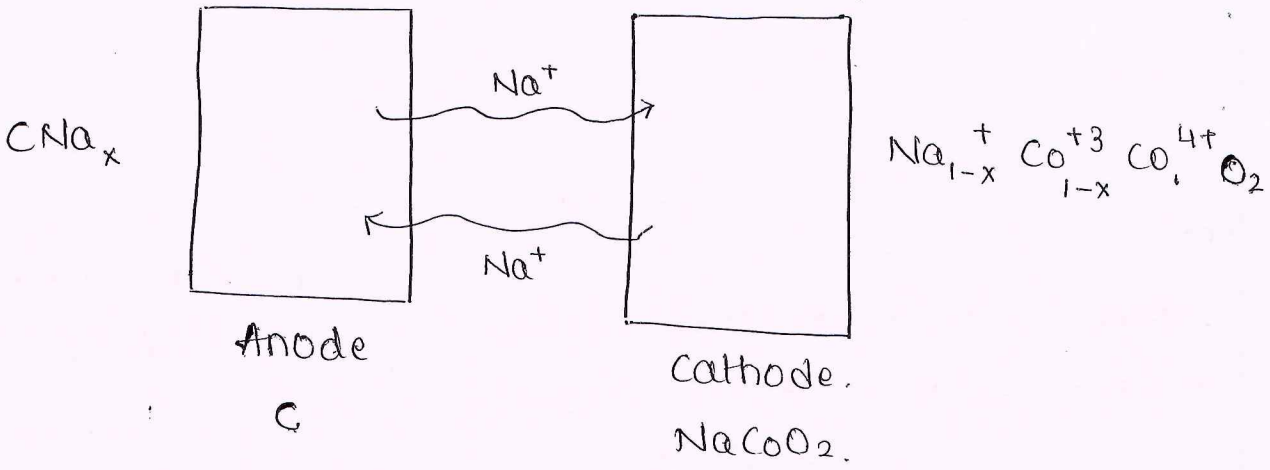
At cathode : $\frac{1}{2} O_2 + 2e^- \longrightarrow O^{2-}$

At anode : $H_2 + O^{2-} \longrightarrow H_2O + 2e^-$

Overall reaction : $H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$.

b. Explain the construction & working of sodium ion Battery and mention its applications.

→ Construction :-



- Anode : Hard carbon.
- Cathode : Layered sodium cobalt oxide.
- Electrolyte : Sodium dissolved in organic solvent.
- Porous separator : Microporous polypropylene.
- Sodium ion battry develops a potential of 3.0V.

* During charging :

During charging, sodium ions de-intercalatable from the cathode & migrate through the electrolyte to be stored in the haud carbon anode, while electrons move via the external circuit.

At cathode undergoes oxidation, releasing sodium ions & electrons:

$$Na_xMO_2 \longrightarrow Na_{x-y}MO_2 + yNa^+ + ye^-$$

MO_2 (M = transition metal like Co (or) Fe).

At anode, reduction happens as sodium ions embed in the carbon structure.

$$y\,Na^+ + ye^- + C \longrightarrow Na_yC.$$

* Applications :-

- Used in electric vehicles, large scale energy storage technology like wind, solar & wave.

c. What is a battery ? Outline the classification of battery with suitable example.

→ A battery is a compact device consisting of a number of galvanic cells that can generate electric power & can act as a portable source of electrical energy.

→ It stores chemical energy in the form of active materials & on demand converts it into electrical energy through redox reactions.

→ Used in calculators, watches, hearing aids etc.

* Classification of batteries :-

1. Primary batteries : These are the batteries in which the cell reactions are irreversible. Hence such batteries are not rechargable. Such batteries are called as primary batteries.

Ex: Dry cell.

2. Secondary batteries : These are the batteries in which cell reactions are reversible. They are also called storage batteries. Hence such batteries can be recharged for number of times.

Ex: Lead storage batteries, nickel-cadmium battery etc.

3. Reserve batteries :- The batteries which can be stored in an inactive state & made ready for use by activating them prior to the applications are called reserved batteries.

Advantages of reserved batteries are :-

- To prevent corrosion at contact points during storage.
- Self-discharging reactions during storage can be eliminated or avoided.
- They can be used whenever they are required.

Ex: Mg-water activated batteries, $Zn-Ag_2O$ battery etc.

7a Explain the mechanism of pitting corrosion and waterline corrosion with suitable examples

Pitting corrosion

Corrosion of metals leading to the formation of pits or cavities or holes is called pitting corrosion. Pitting corrosion is very aggressive, localised corrosion. It occurs when the metal is in contact with stagnant solution.

Part of metal exposed to lower concentration in the medium is the cause for corrosion as it acts as anode undergoes corrosion. steel corrodes at less oxygenated point as —

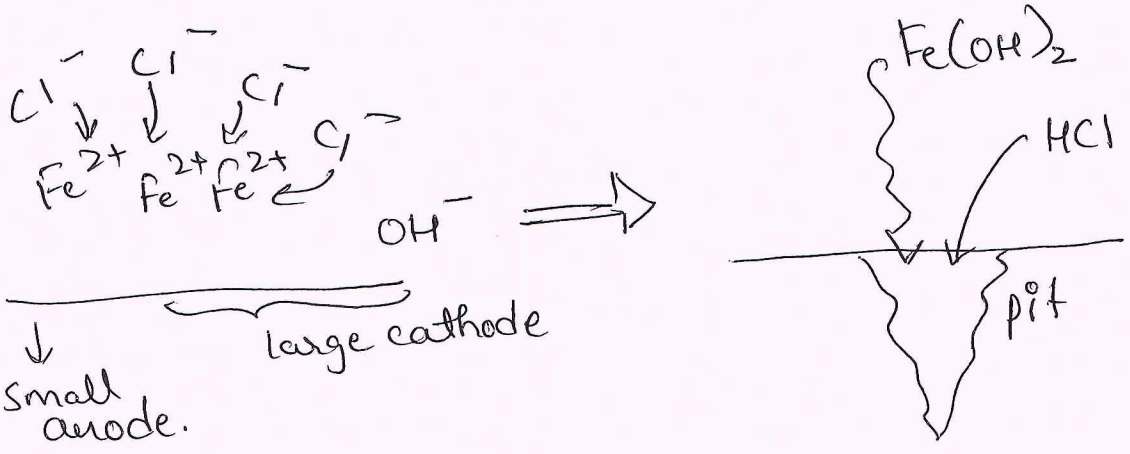
$Fe \longrightarrow Fe^{2+} + 2e^-$

Cathodic reduction at more oxygenated metal surface $\frac{1}{2}O_2 + H_2O + 2e^- \longrightarrow 2OH^-$

In stagnant solution, Fe^{2+} ions at anodic area attract the oppositely charged ions say Cl^- ions and form the salt $FeCl_2$. The salt on hydrolysis precipitates $Fe(OH)_2$ with generation of HCl. Corrosion of steel is promoted beneath the deposit. Also, acid formed accelerates the corrosion. The pitting corrosion is autocatalytic in nature.

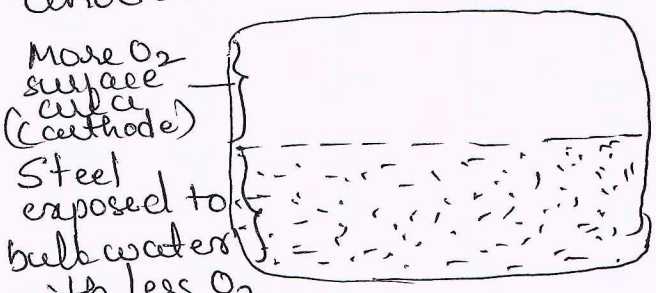
Salt hydrolysis at anode

$2H_2O + FeCl_2 \longrightarrow Fe(OH)_2\downarrow + 2HCl$



Water line corrosion

Metal corrosion that occurs along the water line is called waterline corrosion.
Ex: When steel tank is used for storing water, there is formation of O_2 concentration cell. Steel metal part exposed to more oxygenated surface water act as cathode. Steel part exposed to less oxygenated bulk water act as anode.



Suppose a steel tank partially filled with H_2O following reactions occur.

Anodic corrosion reaction beneath the water surface level

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

Cathodic reduction reaction at water surface level

$$\frac{1}{2}O_2 + H_2O + 2e^- \longrightarrow 2OH^-$$

Fe^{2+} ions and OH^- ions react to form $Fe(OH)_2$ participate.

7b Explain the principle, construction and application of electrochemical sensors in the detection of NOx and SOx

Detection of NOx

The sensor works on the oxidation or reduction of the target gas at an electrode, which produces a current proportional to gas concentration.

The target gas diffuses through a gas permeable membrane into sensor.

→ It reacts at working electrode in the presence of electrolyte, producing electrons.

→ The measured current is directly proportional to the gas concentration in air.

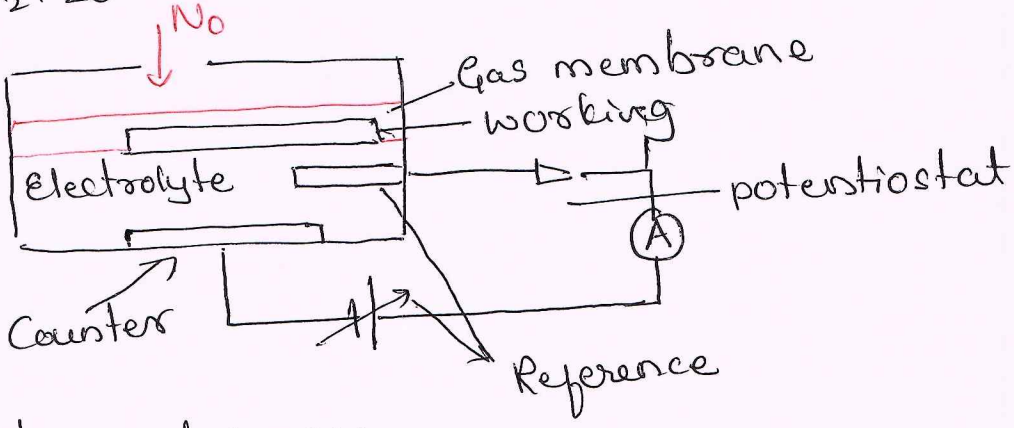
For Nox (NO and NO_2) detection, the reactions are –

1) Oxidation of NO at the working electrode

$$2NO + O_2 \longrightarrow 2NO_2 + 2e^-$$

2) Reduction of NO_2 (in some sensor types)

$$NO_2 + 2e^- \longrightarrow NO + O^{2-}$$



construction of sensor

→ Working Electrode: Metal oxide-coated electrode where NOx reduction occurs.

→ Reference Electrode: Usually gold, maintains stable potential.

→ Counter electrode: Completes the circuit

→ Electrolyte: liquid or solid medium that facilitates ion transport between electrodes.

→ Gas permeable membrane: Controls diffusion of NOx gas and prevents electrolyte leakage.

→ Housing: Encases the sensor and provides electrical connections.

Working

NO_x gas diffuses through the membrane to the working electrode. At the metal oxide coated working electrode, NO_x is reduced to NO, producing a flow of electrons. The current generated flows through the circuit and is measured to determine the NO_x concentration.

Applications:
→ Environmental monitoring
→ Automotive emission control
→ Industrial safety

Advantages
→ Real time NO_x detection
→ High sensitivity and selectivity
→ Compact, low power operation suitable for continuous monitoring

Sox detection.

Electrochemical gas sensor work on the principle of redox reactions occuring at the electrode-electrolyte interface. When a target gas (eg. SO_2) diffuses into the sensor, it undergoes oxidation or reduction at the working electrode. This reaction generates a current proportional to the gas concentration, which can be measured and correlated with its amount in the air sample.

Construction:
→ Working electrode
Coated with a catalyst where the analyte gas undergoes oxidation/reduction
→ Counter electrode
Balances the current by completing the circuit.
→ Reference electrode: Maintains a stable potential for accurate measurement.

→ Electrolyte: ionic medium that facilitates charge transfer
→ Gas diffusion membrane allows controlled diffusion of the gas into the sensor, preventing interference.
→ Housing: Protects the component and ensures selective entry of gas.

Detection principle.

At the working electrode, SO_2 undergoes oxidation:

$$SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e^-$$

→ At the counter electrode, oxygen reduction occurs to complete the electrochemical circuit O_2

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$$

The generated electrons produce a measurable current proportional to SO_2 concentration.

7c What is CPR? A thick steel of area 93 inch^2 is exposed to air near the ocean. After 6 months it was found to experience a weight loss of 360g due to corrosion, if the density of steel is 7.9 g/cm^3. Calculate CPR in mpy & mmpy. (Given K = 534 in mpy and 87.6 in mmpy)

CPR in mpy

K = 534
W = 360g = 360 × 1000mg
D = 7.9 g/cm^3
A = 93 inch^2
T = 6 months
= 6 × 30 × 24 hrs

$$CPR\ (mpy) = \frac{KW}{DAT}$$

$$= \frac{534 \times 360 \times 1000}{7.9 \times 93 \times 6 \times 30 \times 24}$$

$$= 51.7660.56$$

CPR in mmpy

K = 87.6
W = 360g = 360 × 1000mg

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$D = 7.9\ g/cm^3$

$A = 93\ inch^2$

$= 93 \times 6.45\ cm^2$

$= 599.85\ cm^2$

$T = 6$ months

$= 6 \times 30 \times 24$ hrs

$$CPR \text{ in } (mmpy) = \frac{KW}{DAT}$$

$$= \frac{87.6 \times 360 \times 1000}{7.9 \times 599.85 \times 6 \times 30 \times 24}$$

$$= \frac{31,536,000}{17059734}$$

$$= 1.84\ mmpy$$

CPR

The CPR is the speed at which any metal or alloy deteriorates in a specific corrosive environment through chemical or electrochemical reactions.

8a What is corrosion? Explain Electrochemical theory of corrosion by taking steel as (iron) an example.

Corrosion:

Destruction or disintegration of metals when exposed to surrounding corrossive stating at their surface by either chemical or electrochemical means is metallic corrosion.

Electrochemical theory

→ It is characterized by the formation of small galvanic cell due to heterogenesis

→ Part of metal acts as anode and another part acts as cathode.

Anodic part of metal undergoes destruction by oxidation.

Steel undergoes corrosion by following reaction

Anodic oxidation

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

Reduction depends on the contents in the medium Some important reactions are —

a) H_2 Evolution type:

$$2H^+ + 2e^- \longrightarrow H_2 \text{ [when the medium is acidic]}$$

$$2H_2O + 2e^- \longrightarrow H_2 + 2OH^- \text{ [when the medium is natural or slightly alkaline]}$$

It is characterized by presence of large anodic area and a small cathodic area. Corrosion is uniform & less aggressive. Higher the acidity of medium, higher is the corrosion rate.

b) O_2 absorption type:

$$\tfrac{1}{2}O_2 + H_2O + 2e^- \longrightarrow 2OH^-$$

[Presence of dissolved oxygen, when the medium is acidic]

Oxygen absorption type is characterized by Presence of small anodic area and a large cathodic area. Corrosion is localised and very aggressive. Higher is the oxygen contained in the medium higher is the corrosion rate.

Ferrous hydroxide is formed as corrosion product. Excess of O_2 can oxidize it further to yellow rust or black rust.

$$Fe^{2+} + 2OH^- \longrightarrow Fe(OH)_2 \text{ or } FeO \cdot H_2O$$

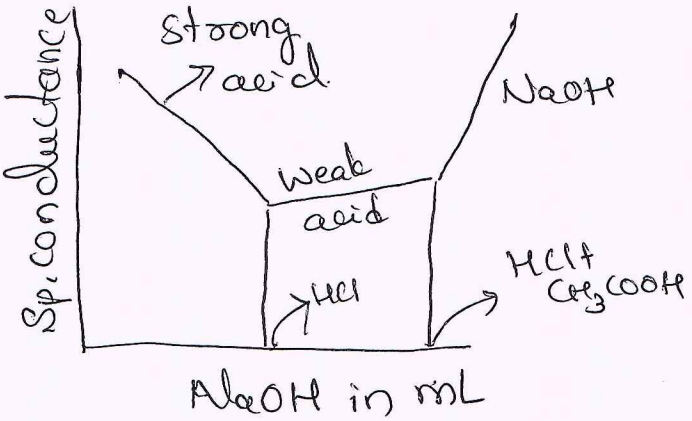
$$2Fe(OH)_2 + H_2O + \tfrac{1}{2}O_2 \longrightarrow 2Fe(OH)_3 \text{ or } Fe_2O_3 \cdot 3H_2O$$

$$3Fe(OH)_2 + \tfrac{1}{2}O_2 \longrightarrow Fe_3O_4 \cdot 3H_2O \text{ (magnetite)}$$

Black rust.

8b) Explain the application of conductometric sensors in the estimation of acid mixture

Conductometric sensors in estimation of acid mixture.



In this curve there are two break points. The first break point corresponds to the neutralisation of strong acid. When the strong acid is completely neutralised only then the weak acid starts neutralising.

The second break point corresponds to neutralisation of weak and after that conductance increases due to excess of OH^- ions incase of a strong base as the titrant However, when the titrant is a weak base it remains almost constant after the end point.

$$(H^+Cl^-) + (Na^+OH^-) \longrightarrow (H^+OH^-) + (Na^+Cl^-)$$

$$(CH_3COO^-H^+) + (Na^+OH^-) \longrightarrow (CH_3COO^-Na^+) + (H^+OH^-)$$

In this way a mixture of strong acid and weak acid ($HCl + CH_3COOH$) mixture titrated against NaOH.

→ From the titration NaOH required for the neutralisation of HCl & CH_3COOH is obtained.

→ Applying $N_1V_1 = N_2V_2$ formula Normality of HCl & CH_3COOH is determined.

→ Further amount is calculated by Normality of acid & its eq. wt.

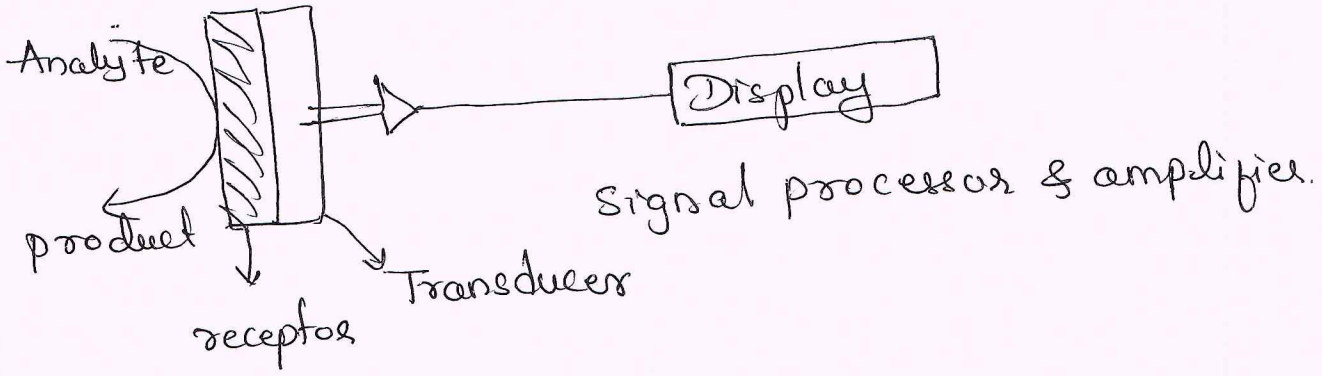
8c Define the terms a) Transducer b) Actuators and sensors.

Sensors:
are basically devices which "read" a physical stimulus and then convert that reading into an electrical signal output.

Physical stimulus:

Transducer: It converts one form of energy to another form

An actuator: Converts electrical energy into Mechanical energy.



Module 5

9a Explain the role of artificial intelligence in Ewaste management.

1) Identification of hazardous chemicals.
AI tools detect and classify toxic chemicals such as Pb, Hg, Antimony, Cd and brominated flame retardants in ewaste using advanced sensor data & pattern recognition.

2) Chemical composition analysis.
Machine learning models process spectral data (XRD, XRF, FTIR) to rapidly determine the composition of metals, plastics and semiconductors, enabling targetted substances.

3) Intelligent sorting and separation.
AI-driven robotic systems utilize chemical property data to effectively separate recyclable

metals, plastics. groom hazardous or non recyclable substances.

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→ Prediction of toxic leaching
AI predicts the leaching behaviour of chemicals from e-waste into soil and water, supporting the design of eco-friendly chemical treatments and containment strategies.

→ Optimization of recycling processes.
Algorithms recommend green chemical methods such as bioleaching and solvent extraction for efficient recovery of valuable metals like gold, copper & palladium

→ Environmental impact monitoring:
AI Models continuously track chemical pollution levels in air, water and soil around e-waste sites, ensuring compilance with environmental safety standards

→ Waste-to-resource conversion:
AI supports chemical upcycling, transformation hazardous e-waste materials into valuable products such as nanomaterials and catalysts.

→ Data driven policy and management.
AI systems provide actionable insights for policymakers to regulate toxic chemical disposal and promote sustainable, advanced recycling technologies.

9b Explain the synthesis and properties of alginate hydrogel with reference to its applications in brain-computer interfaces (BCIs)

Synthesis of Alginate hydrogel (Ionotropic gelation)

→ Starting Material: Sodium alginate, a linear polysaccharide from brown seaweed. Composed of β-D-mannuronic acid (M) and α-L-gluronic acid (G) units.

→ Dissolution: Sodium alginate is dissolved in H_2O to form a viscous polymer solution.

→ Cross linking: A solution of divalent cations, typically $CaCl_2$, is added. Calcium ions (Ca^{2+}) replace sodium ions (Na^+) in G-blocks of alginate chains.

9c Explain the extraction of gold from E-waste by bioleaching method.

It involves 3 steps.

Pretreatment of E-waste:

Printed Circuit boards and gold plated parts are shredded and pulverized to increase surface area. Chemical leaching with nitric / sulphuric acid and hydrogen peroxide removes base metals like copper, nickel and zinc that interfere with gold dissolution.

Microbial culture preparation:

Cyanogenic bacteria such as chromobacterium violaceum or pseudomonas aeruginosa are cultured under optimized pH, temperature and nutrient conditions. These microbes enzymatically convert substrates into hydrogen cyanide, which dissociates into cyanide ions (CN^-)

Microbial cyanide generation:

$$C_2H_5NO_2 + O_2 \longrightarrow HCN + CO_2 + H_2O$$

Biocyanidation (Two steps leaching)

Step 1: Microbes are grown until exponential phase to maximize cyanide production

step 2: The spent culture medium (rich in CN^-) is separated and added to pretreated e-waste. This indirect contact avoids microbial exposure to toxic heavy metals.

Gold leaching reaction: Cyanide ions dissolve metallic gold in the presence of oxygen, forming a stable dicyanoaurate complex:

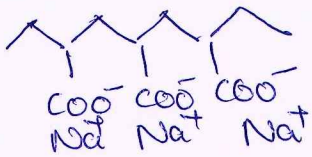
$$4Au + 8CN^- + O_2 + 2H_2O \longrightarrow 4[Au(CN)_2]^- + 4OH^-$$

Recovery of gold:

Gold is recovered from the leachate by zinc cementation, activated carbon adsorption or electrowinning, followed by refining to pure metal.

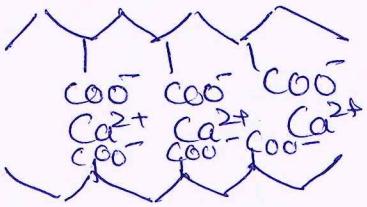
Gelation:
Ionic bridges form between polymer chains, entrapping water. Results in a stable, 3D hydrogel network. Described by the egg box model, where Ca^{2+} fits into cavities.

Sodium alginate polymer chain

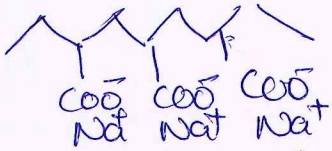


Ca^{2+} →

Calcium alginate gel



Insolubility



water soluble

Properties of Alginate-hydrogel
→ Biocompatibility & biodegradability: supports cell adhesion and growth.
→ High water content & porosity: Facilitates nutrient and ion transport.
→ Ionic conductivity: Hydrated ions allow electrical signal conduction.
→ Tissue-like mechanical properties: soft, flexible tunable stiffness.
→ Low Immunogenecity: Minimal inflammatory response resistant to protein absorption.

Applications:
→ Soft Electrode Interface: Conforms closely to brain tissue. reducing inflammation and motion artefacts.
→ Signal Enhancement: Ionic conductivity and integration with conductive materials improve signal to noise ratio for electrophysiological recordings.
→ Hybrid hydrogel systems: Can incorporate conductive polymers/nanoparticles to enhance electrical properties while maintaining softness.

Q10
10a Explain the effects of E-waste on the environment & Human health.

→ Soil contamination: Toxic metals (lead, cd, Hg) seep into soil, reducing fertility and entering the food chain.
→ water pollution: leaching of heavy metals & acids contaminates groundwater and surface water sources.
→ Air pollution: Open burning of plastics and circuits boards release dioxins, furans and other harmful gases.
→ Loss of biodiversity: Toxic chemicals harm aquatic life plants & animals, disrupting ecosystems
→ Resource depletion: Failure to recycle valuable metals increase dependence on mining.

On human health
→ Neurological damage: Lead and Hg exposure affects brain function, especially in children
→ Respiratory issues: Inhalation of toxic fumes from burning e-waste causes long diseases and breathing problems.
→ Kidney and liver damage: Cd and other metals accumulate in vital organs, impairing their function.
→ Cancer risk: Long term exposure to carcinogenic substances like dioxins, assenic, and brominated flame retardants.
→ Reproductive and developmental disorders. Toxic chemicals affect fertility, pregnancy and child development.
→ skin and eye irritation: Direct contact during informal recycling causes rashes, burns & eye problems.

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10 b. Explain the green synthesis of ZnO nano particles and Mention its uses in magnetic Radio frequency Identification (RFID)

Solution combustion synthesis (SCS) is a rapid and energy efficient route for producing zinc oxide nanoparticles. The process becomes greener when sugarcane juice is used as the fuel.

Sugarcane juice contains sucrose, glucose and fructose which act as natural reducing and complexing agents. During combustion, these sugars decompose to release gases (CO_2, H_2O) creating porosity and leaving ZnO nanoparticles as the final product.

→ Dissolve 3.65g of Zinc Nitrate hexahydrate in distilled water.

$$Zn(NO_3)_2 \longrightarrow Zn^{2+} + 2NO_3^-$$

→ Add 7.3 ml sugarcane juice typically has ~12% w/v sugar in stoichiometric fuel to oxidizer ratio. For sucrose ($C_{12}H_{22}O_{11}$) as the main fuel.

→ Stirr and ultrasonicate the solution for 30 mins to form homogeneous mixture.

→ Heat gently at 80-90°C until a viscous gel forms

→ place the gel in a preheated furnace (300-600°C)

→ Combustion occurs spontaneously, producing flame & ~~forth~~ froth as gases (CO_2, H_2O, N_2) evolve.

$$24\,Zn(NO_3)_2 \cdot 6H_2O + 5\,C_{12}H_{22}O_{11} \longrightarrow 24\,ZnO + 60\,CO_2 + 199\,H_2O + 24\,N_2$$

→ Cool to obtain porous ZnO ash

→ Calcine the powder at 400-500°C for 2-3 hr. to remove carbon residues and enhance crystallinity

ZnO Nanoparticles in magnetic RFID

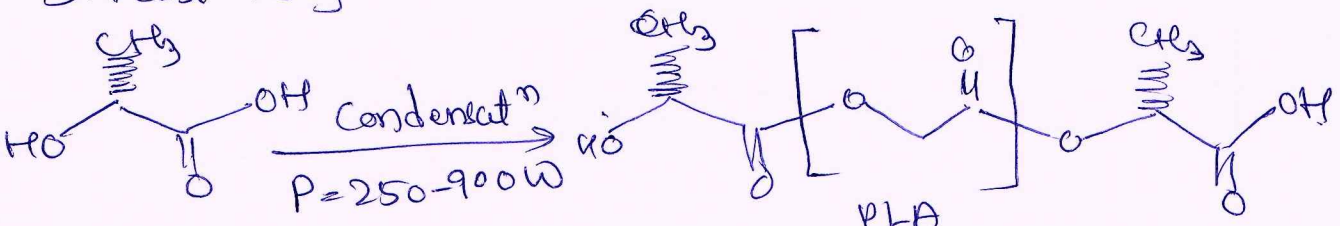
→ Doping ZnO with Fe, Ni or Co induces room temperature ferromagnetism

→ Magnetic ZnO allows higher ~~area~~ data density & nonvolatile memory in RFID tags.

→ Magnetic behaviour makes RFID tags harder to clone or tamper with

10c Explain the synthesis and properties of Polylactic acid (PLA). Mention its uses in touch screen applications.

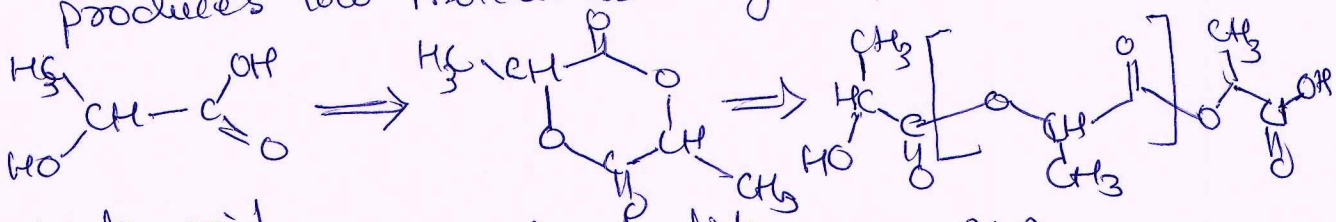
Direct Polycondensation of Lactic acid



(L+) Lactic acid

Ring opening Polymerization of lactide

1) Step 1
Formation of lactide
2) Step 2: Polymerization of Lactide
produces low molecular weight polymers.



lactic acid — cyclic lactide monomer — PLA

Properties:
→ Linear, thermoplastic polymer with ~ 37% crystallinity
→ Glass transition temp 50-80°C
→ Melting point 170-180°C
→ Mechanical properties: Good tensile strength; can be processed into fibers.

Applications:
1) Flexible substrate.
PLA thin films can be used as lightweight, flexible substrate for touch screens.
2) Ecofriendly Material:
Reduces environmental impact compared to petroleum based plastics.
3) Protective coating
Transparent PLA coatings improve scratch resistance.

4) Printable surface:

PLA allows for easy deposition of conductive layers like ITO or silver nanowires) for capacitive touch sensors.

5) Biocompatability

Safe for devices with frequent human contact.

(Dr. Sneha. k)