UNIT-4

Radiation Sensors

- Intro
- Basic Characteristic
- Types of photo resistors / photo detectors
- X ray & Nuclear Radiation Sensors
- Fibre optic Sensors
- Electro analytical Sensors:
  - the Electro chemical cell
  - → the cell Potential – Standard Hydrogen Electrode (SHE)
  - → Liquid Junction & other Potentials
  - → Polarization
  - → Concentration Polarization
  - → Reference Electrodes
  - → Sensor Electrodes
  - → Electro Ceramics in Gas Media

(4).

* Radiation Sensors

→ Radiation Sensors detect & measure ionizing radiation.
- Such as alpha Particles, beta Particles, gamma rays, & neutrons.

Radiation: means energy travelling in the form of waves or Particles
ex:- Light
X-rays
Gamma rays

⇒ Radiation Sensor converts radiation energy to electrical signal
Radiation → electrical

Radiation	Device
X-ray →	Scanning
Nuclear →	Power Plant
Light →	mobile
Infrared →	TV remote

→ these Sensors are used in various fields
- Power plants
- medical (Scanning)
- Environment
- Space applications

* Characteristics of Radiation Sensors

1. Sensitivity: detect low levels of radiation.

~~2. Response time~~: $\text{Sensitivity} = \frac{\Delta \text{output}}{\Delta \text{Radiation}}$

2. Spectral Response:

→ tells the wavelength range

→ Variation of sensor o/p with the wavelength of incident radiation.

3. Response Time:

→ Time taken to respond
- when input changes

4. Resolution: Smallest change in radiation that can be detected by the sensor

5. Linearity: output $\propto$ to the incident radiation / i/p input

6. Noise: unwanted fluctuation in sensor
- caused by radiation.

7. Accuracy: Closeness of output to true value

8. Stability: ability to maintain a constant o/p for a constant i/p

type of resistor, when light falls resistance changes

* Types of Photoresistors / Photo detectors

→ Photo resistors & Photo detectors are light-sensitive devices

→ used in automation.

→ they convert light energy into electrical signals

Types of Photoresistors → LDR (Light dependent resistor)

1. Cadmium Sulfide (CdS) Photoresistor
   - type of photoresistor
   - made of cadmium sulfide.
   - ~~light ener~~
2. Lead Sulfide photoresistor.
3. Silicon Photoresistor.
4. Organic Photoresistor: made of organic materials

Types of Photo detectors ⇒ convert light → electric

1. Photodiode
2. Avalanche Photodiode
3. photovoltaic detectors
4. Photo transistor
5. Photovoltaic cell

Applications	Adv
- Street lights	- Fast
- alarms	- low noise
- camera	

* X-ray Sensors

→ Detect intensity of X-rays

→ Convert X-ray photons to electrical signal.

→ Based on semiconductor principle, ionization process

→ used in :- medical
- Security Scanners
- Airport Security.

→ It is a radiation sensor.

→ used to detect X-ray radiation.

→ X-rays are high-energy electromagnetic waves
- with small wavelength & high Penetration Power.

Adv	Dis
- Accurate	- Expensive
- high Penetration	- Harmful
	- Complex

* Nuclear Radiation Sensors

→ It is a radiation sensors

→ used to detect nuclear radiation &
- such as alpha, beta, gamma rays.

→ those alpha, beta, gamma rays convert into an electric signal.

→ works on ①. Ionization principle
②. Scintillation principle

Applications	Adv	Dis
- Power plants	- Accurate	- expensive
- Medical	- high Sensitivity	- complex
- Space research		- Harmful
- Research labs		

⇒ Detect α, β, γ radiation.

→ used for safety & monitoring

* Fibre-Optic Sensors

→ It is a sensor.

→ It detects temperature, Pressure, Strain, rotation.

Uses;

- bridges
- building
- medical

→ Transmit light through an optical fiber & analyze the changes in the light properties.

→ Light changes due to bending, wavelength.

Types

① Active

② Passive

* Electro Chemical Cell

→ It is a device
→ It converts chemical energy into electrical energy
  – by means of redox reactions

→ Redox = oxidation, reduction reactions.
→ It is the basic element
  – used in electro-analytical sensors.
→ It consists of ~~of~~ ~~electrodes~~
  • Anode – oxidation occurs (~~-ve~~ terminal)
  • cathode – reduction occurs (~~+ve terminal~~)
  • Electrolyte

$$E_{cell} = E_{cathode} - E_{anode}$$

Types

① Galvanic cell (chemical → electrical)
② Electrolytic cell (electrical → chemical)

~~Construction~~

• Anode – (-ve terminal in Galvanic cell
  +ve in electrolytic cell)
  – oxidation
• Cathode – (+ve terminal in Galvanic cell
  -ve terminal in electrolytic cell)
  – reduction

Applications
- Batteries
- Medical
- pH sensors
- Gas sensors

Adv
- Sample
- accuracy

Dis
- Limited life
- Slow

Working

1. Oxidation at Anode (loss of electron)

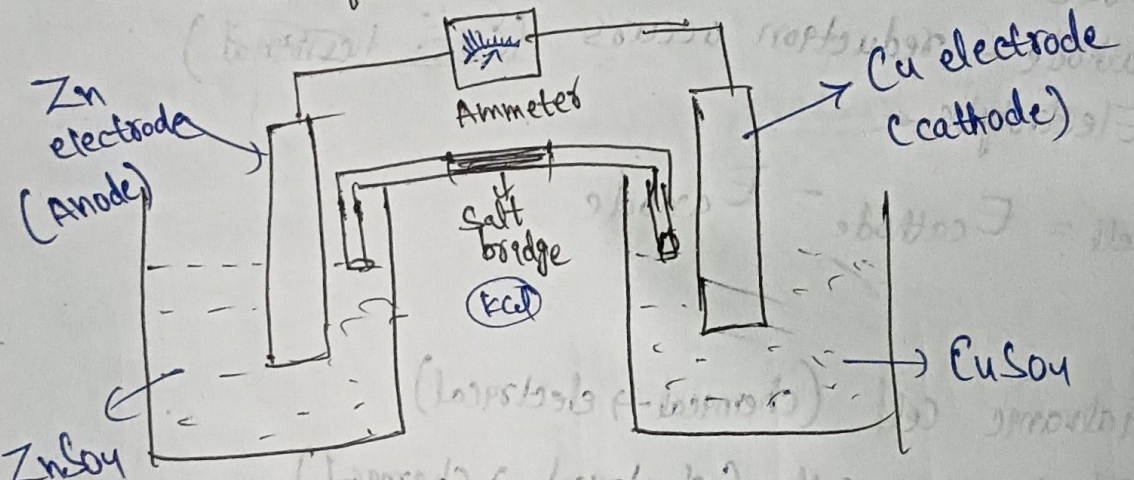
$$Zn \rightarrow Zn^{2+} + 2e^-$$

2. Reduction at cathode (gain of e^-)

$$Cu^{2+} + 2e^- \rightarrow Cu$$

3. Role of Salt Bridge
   - neutralize
   - allow SO_4^{2-}

4. Electron flow



At Anode: $Zn \rightarrow Zn^{2+} + 2e^{\ominus}$

At cathode: $Cu^{2+} + 2e^{\ominus} \rightarrow Cu$

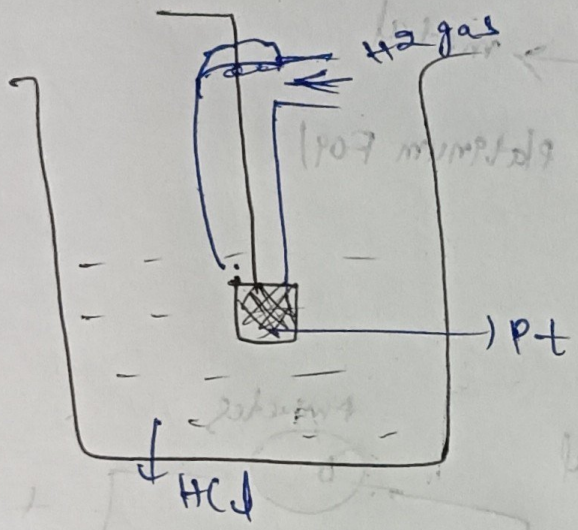
$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

SHE

→ SHE – Standard Hydrogen Electrode

→ Also called as Normal Hydrogen Electrode (NHE)

→ It as a reference electrode



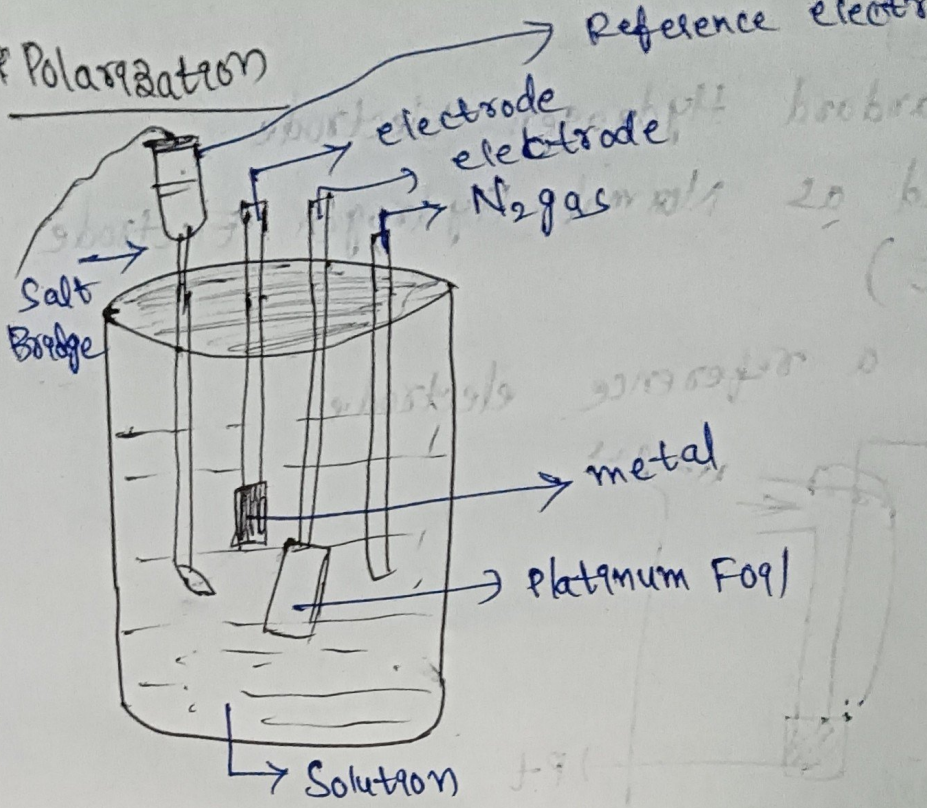
→ To increase Pt surface

→ Then H_2 gas absorbed totally

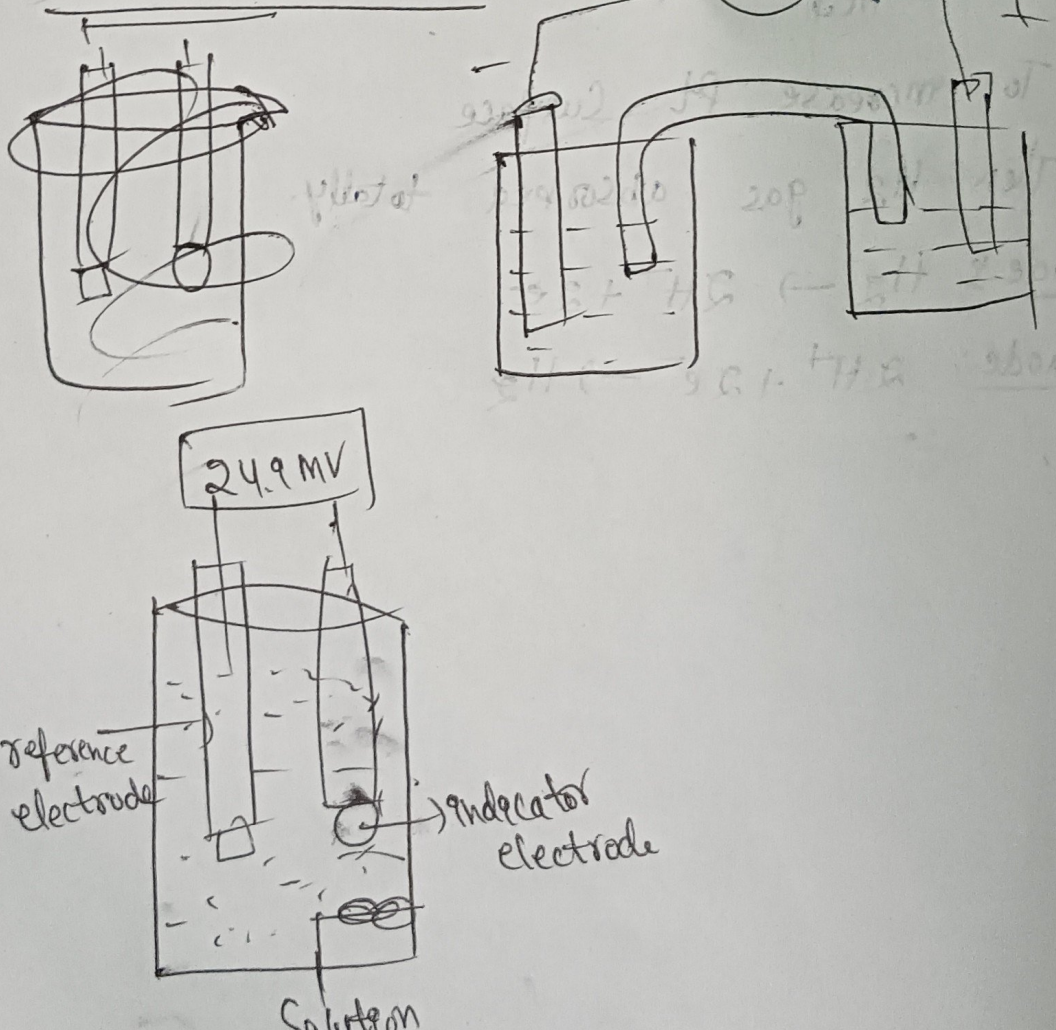
Anode: $H_2 \rightarrow 2H^+ + 2e^-$

Cathode: $2H^+ + 2e^- \rightarrow H_2$

* Polarization



* Liquid Junction potential



Liquid Junction Potential

- Occurs when **two electrolyte solutions of different concentrations** come in contact.
- Due to **unequal movement of ions** across the junction.
- Produces an **undesired voltage**.
- Causes **measurement error** in electrochemical sensors.
- Reduced using salt bridge or similar electrolytes.

Other Potentials

- Electrode potential
- Contact potential
- Reference electrode potential
- All together affect total cell voltage.

2️⃣ Polarization

Meaning

- Polarization is the **change (drop) in electrode potential** when current flows in an electrochemical cell.

Why it occurs

- Slow chemical reactions
- Accumulation of ions or gases at electrodes

Effect

- Reduces output voltage
- Affects accuracy of sensors

3️⃣ Concentration Polarization

Meaning

- Occurs due to **difference in concentration of ions** near the electrode surface and bulk solution.

Causes

- High current
- Slow diffusion of ions

Effects

- Limits maximum current
- Reduces sensor performance

Example

- Battery voltage dr vhen heavy load is connected.

4️⃣ Reference Electrodes

Purpose

- Provide a **stable and known potential**.
- Used for comparison with sensor electrode.

Characteristics

- Potential should not change with time
- High stability
- Reproducible voltage

Examples

- Standard Hydrogen Electrode (SHE)
- Calomel electrode
- Silver/Silver chloride electrode

6️⃣ Electro-ceramics in Gas Media

Meaning

- Ceramic materials that **change electrical properties** when exposed to gases.

Working

- Gas reacts with ceramic surface
- Causes change in resistance or voltage

Applications

- LPG gas sensors
- CO and NO_2 sensors
- Air pollution monitoring

Advantages

- Can work at high temperatures
- Long life
- Good chemical stability

Disadvantages

- Slow response
- Aging effect
- Needs heating element

1. Sensor Electrodes

→ these are conducting plates / wires
- that collect or deliver electrical signals from a sensing material.

→ Electrodes used in sensors

→ It allows electrical interaction b/w sensing medium & measuring circuit.

Materials Inert metals
Carbon
Stainless steel

→ Electrodes acts as interface b/w sensor material & external circuit.

→ they pick up changes in voltage, current generated by sensor

→ Made of metals like Pt, Au, Ag, Cu
- bcz they conduct well

→ used in electrochemical sensors, bio-sensors, capacitive sensors etc.

→ Should be : chemically stable
corrosion-resistant
highly conductive

Types

① Active electrode : directly contacts sensing medium

② Reference electrode : Provides stable voltage

③ Counter electrode : Completes the circuit.

→ Shape can be planar, needle, thin-film or wire

Applications

- PH meters
- ECG sensors
- humidity sensors