Roll No. | | | | |

Internal Assessment Test 2 – June 2025

Sub:	Applied Chemistry for CSE				Sub Code:	BCHES202	Branch:	ISE , CS-AIML, AIML & AIDS	
Date:	18-06-2025	Duration:	90 min's	Max Marks: 50	Sem / Sec:	II / / A, B, C, D, E, F, G & H		OBE	

<u>Question no. 1 is COMPULSORY and answer any THREE FULL Questions from the rest.</u>

		MARKS	CO	RBT
1 (a)	Define liquid crystals. Describe the classification of liquid crystals with suitable examples.	[7]	CO1	L2
(b)	What are sensors? Explain the working principle of electrochemical gas sensors and mention its applications.	[7]	CO4	L3
2 (a)	What are Memory Devices? Classify the electronic memory devices and discuss any 2 types in detail.	[6]	CO1	L2
(b)	Define photoactive and electroactive materials and explain their working principle in the display system.	[6]	CO1	L3
3 (a)	Explain any four properties and applications of light emitting material, Poly [3-hexyl thiophene] (P3HT) suitable for optoelectronic devices.	[6]	CO1	L2
(b)	Explain organic memory devices of p-type and n-type semiconducting materials by taking suitable examples.	[6]	CO1	L3
4 (a)	What are QLED? Discuss their properties and applications.	[6]	CO1	L1

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(Chief Course Instructor)

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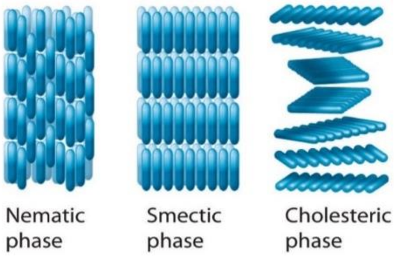
(Chief Course Instructor)

1a.

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

<u>Classification</u>



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

Thermotropic liquid crystals are three types:

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

Example: p-azoxyphenetole,

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

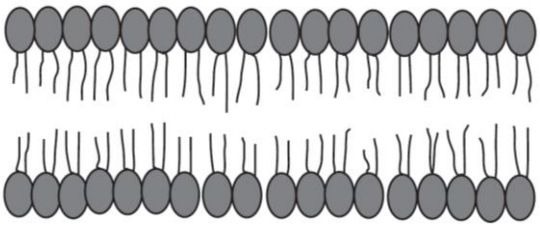
Example: smectic–A (*SmA*)

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

Example: Cholesteryl benzoate

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

Example: Cell membranes



1b.

Electrochemical sensor

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

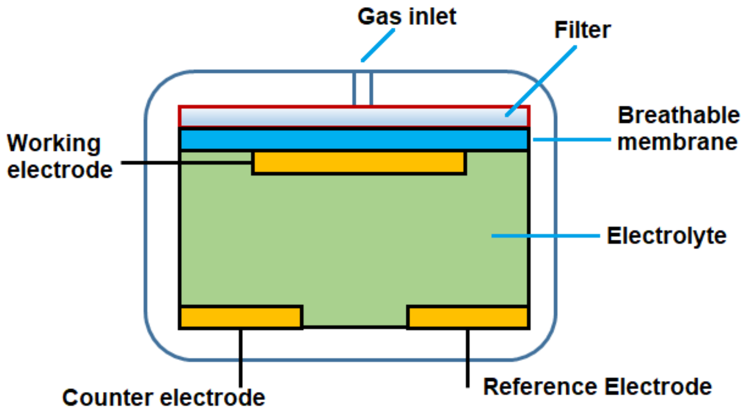
Construction

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

Working principle

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

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



Applications:

- Widely used in agriculture, food, and oil industries
- Environmental and biomedical applications
- Detection of toxic gases with high selectivity and sensitivity
- Used in water analysis and environmental monitoring

2a.

Memory devices are electronic components that can store and retrieve digital data. These devices are used to hold data and programs that a computer needs to access quickly.

Classification of electronic memory devices

A. **Transistor type electronic memory devices:** Such type memory device uses transistors as the building blocks for data. The basic principle of transistor-type electronic memory is that it stores data as charges on the gates of transistors, which act as switches. The data can be read from the transistor by measuring the voltage level on the gate.

Examples: Dynamic Random Access Memory (DRAM), Static Random Access Memory (SRAM)

B. **Capacitor type electronic memory devices:** Such type memory device uses capacitors to store digital data. The basic principle of capacitor type electronic memory is that it stores data as electrical charge on a capacitor. When the data needs to be read, the charge on the capacitor is measured and translated into a digital value.

Examples: NAND Flash Memory, Ferroelectric RAM (FeRAM)

2b.

Photoactive materials: Photoactive materials are those materials that can absorb light energy and undergo a photochemical reaction. They are used in photovoltaic cells which convert sunlight into electrical energy.
Examples: Silicon

Working principle

- **Absorption**: Photoactive materials must be able to absorb light energy in order to generate excited states.
- **Excited states**: After absorbing the light, it undergoes a photochemical reaction that generates excited states. These excited states are unstable and can decay back to the ground state by emitting light.
- **Energy transfer**: Excited states can transfer energy to other molecules, either within the same material or to a different material. This energy transfer can lead to the generation of electrical or chemical energy.

Electroactive materials: Electroactive materials are those materials that can conduct electricity and exhibit changes in their electrical properties in response to an external electric field.

Examples: Conductive polymers

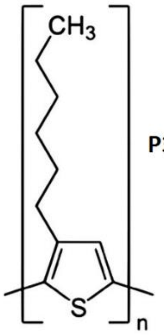
Working principle

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

- **Conductivity**: Electroactive materials must be able to conduct electrical current in order to respond to an external electrical stimulus through the electrons or ions.
- **Response time**: Electroactive materials must be able to respond quickly to changes in the electrical field. The response time is determined by the mobility of the charge carriers.
- **Electrical properties**: The electrical properties of the material, such as its resistivity, permittivity, and capacitance, determine how it will respond to an external electrical stimulus.

3a.

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



P3HT: Poly(3-hexylthiophene)

Properties of polythiophenes:

- They have **high charge carrier mobility**, which is crucial for efficient charge transport in optoelectronic devices.
- They are **highly soluble** in common organic solvents, making them easy to process into thin films required for optoelectronic devices.
- They have a **high absorption coefficient** in the visible range, which allows them to absorb light in solar cells and photodetectors efficiently.
- They have **tunable optical and electrical properties** which allows them for specific optoelectronic applications.

Applications

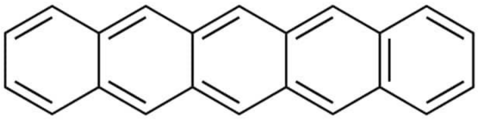
- These materials are used as active layers in **organic solar cells**.
- These materials are used in the fabrication of **Organic Light-Emitting Diodes** as emissive or charge-transporting layers.
- These materials are used in **photodetectors** to sense light and convert it into an electrical signal.

- These materials are incorporated into field-effect transistors (FETs) to create **Light-Emitting Transistors**.

3.b

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

<u>p-type semiconductors materials</u> that have an excess of positively charged holes, which can conduct electricity. *Examples*: Pentacene.



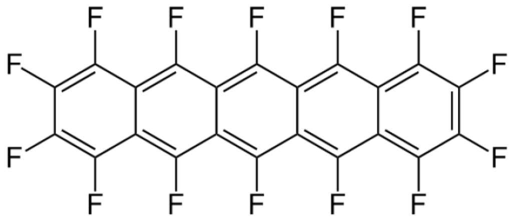
Application: It is used in organic flash memory and organic resistive random access memory (RRAM).

<u>Characteristics</u>

- It has **high hole mobility**, which makes it a good material for organic memory devices.
- It has a **low ionization potential**,
- It is highly **sensitive to light** and has **high photoconductivity**.
- It has a **long carrier diffusion length**.
- It is a **stable material**.

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

Examples: Perfluoropentacene.



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

<u>Characteristics</u>

- It has **high electron mobility**, which allows electrons to move quickly through the material.
- It has a **high electron affinity**
- It is a **stable material**
- It has **low ionization potential.**
- It is **highly sensitive to light** and has **high photoconductivity**.

4a.

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

Properties of QLEDs

- QLEDs can produce **highly accurate and vibrant colors** due to quantum dots, which emit light of a specific color when they are excited by an electrical current.
- QLEDs are more **energy-efficient** than traditional LCD displays because they do not backlight.
- QLED displays have **high contrast** ratios, they can produce deep black and bright white images.
- QLEDs have a **longer lifespan** than traditional LCD displays.

Applications of QLEDs

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

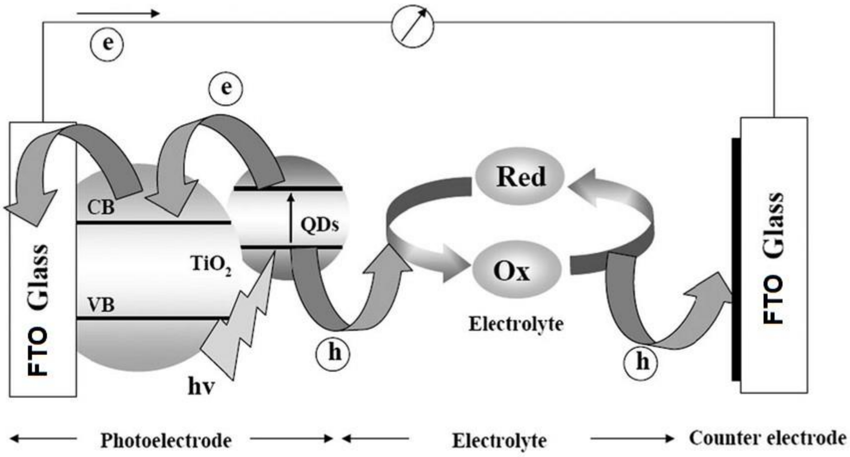
4.b

QDSCs

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

Construction

- ***Transparent conducting electrode***: FTO glass (Fluorine-doped Tin Oxide)
- ***Transparent Conductive Oxide Layer***: TiO_2 film
- ***Quantum dots layer***: Light-absorbing semiconductor materials (CdSe or CdS)
- ***Electrolyte***: Polysulphide is used as a redox electrolyte.
- ***Counter Electrode***: used to complete the circuit and helps to generate electricity.



Working

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

Excitation process: QDs + $hv \rightarrow$ QDs*

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

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

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

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

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

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

QDSCs applications

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

5.a

E-waste

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

***Sources* of e-waste**

- Consumer electronics such as smart phones, laptops, televisions, and household appliances.
- Office equipment such as computers, printers, copiers, and fax machines.
- Medical equipment such as X-ray machines, monitors, and diagnostic equipment.
- Electronic toys and games.
- Obsolete technology such as outdated computer equipment, projectors and VCRs.
- Discarded or broken electronic devices.

***Composition* of e-waste**

- ***Metals*** such as copper, gold, silver, and aluminium.
- ***Plastic*** components, including casings, insulation, and cables.
- ***Glass components***, such as screens and lenses.
- ***Circuit boards***, which contain a mixture of metals and other materials.
- ***Batteries***, which can contain hazardous materials such as lead, mercury, and cadmium.
- ***Hazardous materials***, such as flame retardants, heavy metals, and polychlorinated biphenyls (PCBs).

***Characteristics* of e-waste**

- **Complexity:** E-waste often contains a complex mixture of materials, making it challenging to recycle and dispose of properly.
- **Hazardousness** such as heavy metals, flame retardants, and batteries, can pose significant environmental and health risks including soil and water contamination, air pollution, and harm to human health.
- **Global issue:** the electronic devices are manufactured, used and discarded worldwide.
- **Resource depletion:** The extraction of raw materials for electronic devices contributes to resource depletion.

5.b

Toxic materials

a) **Lead** is a toxic heavy metal commonly used in batteries, computer monitors, and other electronic components.
a) **Mercury** is used in some fluorescent lights, batteries, and other electronic devices.
b) **Cadmium** is a toxic heavy metal used in rechargeable batteries, pigments, and plastic stabilizers.
c) **Polyvinyl Chloride (PVC)** is used in electronic cables, which release toxic chemicals, such as dioxins, when burned or during disposal.

d) **Brominated flame retardants (BFRs)** are toxic and can harm the environment and human health.
e) **Lithium** is used in rechargeable batteries, but it can be toxic if not handled properly.

Health hazardous

a) **Poisoning:** Toxic substances, such as lead, cadmium, and mercury can cause poisoning if they enter the body.
b) **Respiratory problems:** Exposure to dust and fumes generated can cause respiratory problems, such as asthma and bronchitis.
c) **Neurological effects:** Toxic substances such as lead and mercury, can cause neurological effects, including memory loss.
d) **Reproductive problems:** toxic substances such as cadmium, can cause reproductive problems.
e) **Cancer:** Exposure to carcinogenic substances, such as dioxins and polychlorinated biphenyls (PCBs), found in e-waste, can increase the risk of cancer.

6.a

In of e-waste management, the following stakeholders play an important unique role:

1. Producers

Producers have a responsibility to design and produce products that are environmentally friendly and can be easily recycled or reused at the end of their useful lives. They should also participate in e-waste collection and recycling programs and contribute to the development of sustainable e-waste management systems

2. Consumers

Consumers play a critical role in reducing e-waste by choosing to purchase products that are designed to be environmentally friendly, and by properly disposing of their old electronics. Consumers can also participate in e-waste collection and recycling programs and can advocate for the development of more sustainable e-waste management systems.

3. Recyclers

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

4. Statutory bodies

Statutory bodies such as governments, are responsible for creating and enforcing regulations and policies to manage e-waste and promoting public awareness and education about e-waste management.

6.b

Principle:

The principle behind the extraction of gold from e-waste is that gold is a relatively non-reactive metal, which allows it to be recovered from complex electronic waste matrices through a series of chemical and physical processes.

Experimental procedure:

1. ***Collection and segregation of e-waste***: The first step involves collecting and segregating the e-waste into different categories, such as computer motherboards, cell phones, and other electronic devices.
2. ***Physical separation***: The e-waste is physically separated into different components, such as plastics, metals, and glass.
3. ***Leaching***: The metals, including gold, are leached from the e-waste using a suitable reagent, such as aqua regia (a mixture of hydrochloric acid and nitric acid), to dissolve the gold.

$$Au + HNO_3 + 4HCl \rightarrow HAuCl_4 + NO + 2H_2O$$

4. **Precipitation**: The dissolved gold is then precipitated out of the solution through the addition of a suitable reducing agent, such as sodium metabisulfite.

$$2H[AuCl_4] + 3Na_2S_2O_5 + 3H_2O \rightarrow 2Au + 3SO_2 + 3Na_2SO_4 + 8HCl$$

5. **Purification**: The precipitated gold is then purified through processes such as ion exchange, electro-winning, or distillation, to remove impurities and improve its quality.
6. **Recovery**: The purified gold is then recovered for reuse.

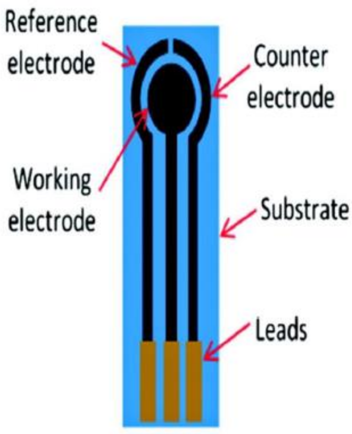
7.a

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

Advantages

- Cost-effective: no need for expensive cleaning, recalibration, or maintenance procedures.
- Disposable sensors are biodegradable and sustainable

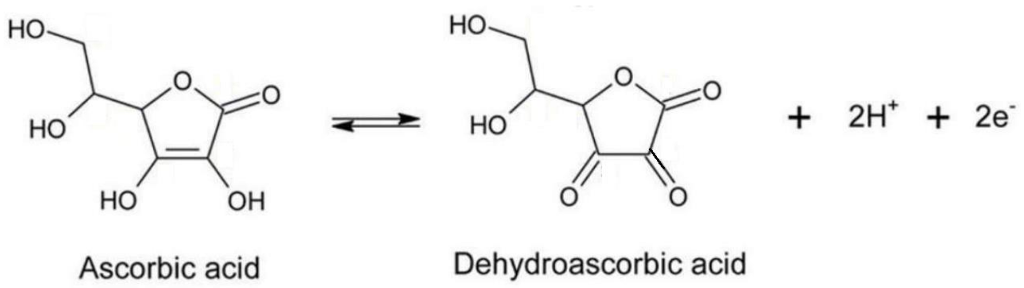
Construction



- In the disposable strip, all three electrodes (working, counter electrode and reference) and receptor is printed on a single platform as shown in the figure.
- An active material is coated on sensing electrode which can help to perform the electrochemical oxidation of ascorbic acid.
- The active surfaces of the counter electrode and working electrode have been coated with a conductive ink of MWCNT and modified with gold nanoparticles.
- Reference electrode is 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.



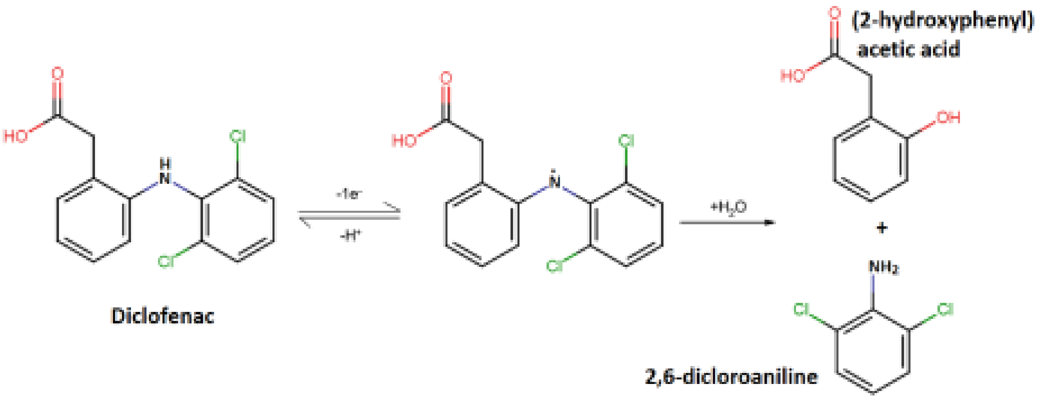
7.b

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.



8a.

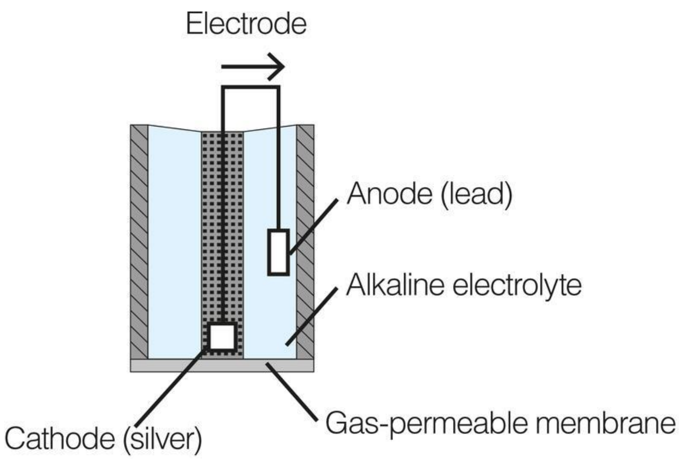
Dissolved oxygen

Dissolved oxygen (DO) refers to the amount of oxygen gas that is dissolved in water. The concentration of dissolved oxygen in water can be measured via electrochemical DO sensor.

Construction

Electrochemical DO sensors mainly use a **Clark electrode**, which consists of a cathode and an anode separated by an electrolyte. The anode serves as a reference electrode, providing a stable potential for the cathode.

- **Working electrode** (Anode): Lead or Zinc
- **Counter electrode** (Cathode): Gold or platinum
- ***Electrolyte***: Aqueous NaOH
- ***Separator***: a thin layer of hydrophobic material, such as Teflon.



Working

When the Clark electrode is immersed in a liquid sample, oxygen molecules diffuse through the hydrophobic layer and react with the cathode surface, producing a current that is proportional to the amount of oxygen present in the water.

Anode (Pb): $2Pb \rightarrow 2Pb^{2+} + 4e^-$

Cathode (Ag): $O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$

Overall reaction: $O_2 + 2H_2O + 2Pb \rightarrow 2Pb(OH)_2$

The white solid, $Pb(OH)_2$, that is produced by these reactions is precipitated out into the electrolyte solution. It neither coats the anode nor consumes the electrolyte, and thus does not affect the sensor's performance until the quantity becomes excessive.

8.b

Thermometric sensor

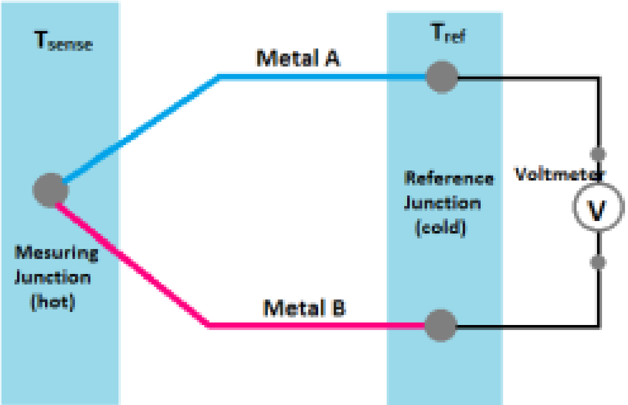
A temperature sensor is a device, typically, a thermocouple or resistance temperature detector, that provides temperature measurement in a readable form through an electrical signal.

Working principle of thermometric sensors

The working principle of a thermometric sensor is based on the concept that the physical properties of materials change with temperature. They are composed of two dissimilar metals that generate an electrical voltage or resistance when a temperature change occurs by measuring the voltage across the diode terminals.

- ***Thermocouples***

In this case, when there is a temperature gradient between the measuring junction and reference junction, a voltage is generated. The magnitude of this voltage depends on the temperature difference between the two junctions and the types of metals used in the thermocouple.



Applications

- Used for verifying design and construction.
- Used to measure the temperature rise during the process of curing concrete.
- They can measure rock temperatures near liquid gas storage tanks
- It can measure water temperatures in reservoirs and boreholes.