What are electrochemical sensors? Explain the principle and working of electrochemical sensors and mention the applications of electrochemical sensors.

Working and Principle

Electrochemical sensors use electrodes as a transducer component. Transducers of an electrochemical sensor consist of working or sensing electrode, electrolyte, counter electrode and reference electrode. The sensing electrode has a chemically modified surface. The electrolyte is the part of the electric circuit of an electrochemical sensor system. The role of the electrolyte is to transport charge within the sensor, contact all electrodes effectively.

- Diffusion of the analyte to the electrode interface.
- Adsorption into the electrode surface
- Electrochemical reaction with electron transfer.
- Desorption of the products
- Diffusion of the products away from the reaction zone to the bulk of the electrolyte or gas phase.

Application

- Healthcare applications (e.g. monitoring glucose and uric acid levels)
- Water analysis and environmental monitoring (e.g. detecting pollutants like NOx, SOx, CO, and measuring pH)
- Soil parameter analysis and agriculture
- Detecting dissolved oxygen in water, monitoring oxygen concentration in metal melts and hydrogen fuel
- Security and defense

Discuss the principle, working and applications of conductometric sensors.

Working and Principle

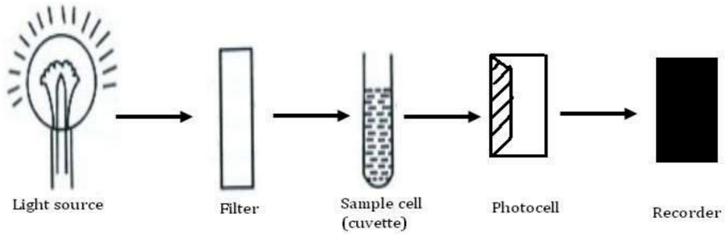
- Conductometric sensors work by measuring changes in the conductance of an electrolyte solution, which is dependent on the number and mobility of ions
- A conductivity cell, made up of two platinum foils with unit cross-sectional area and distance between them, is used to measure the conductance of the electrolyte solution.
- The conductance of unit volume of the solution is known as specific conductance and can be calculated using the formula $k = (V/R) \times (l/a)$, where V is the volume, R is the resistance, l is the distance between the electrodes, and a is the cross-sectional area of the electrodes.
- The migration of ions is induced by an electrical field when a potential difference is applied to the electrodes. The movement of positively charged ions is towards the cathode, while the negatively charged ions move towards the anode. This chemical change is recognized by the working electrode, and transducers convert this chemical change into an electrical signal.

Application

- Can detect chemicals that change the conductance of a solution through chemical reactions
- Can detect ionic impurities in water samples
- Are used to estimate acid-base mixtures in a sample
- Measure acidity or alkalinity of seawater
- Have applications in biomedicine, environmental monitoring, biotechnology, and agriculture

Discuss the principle, working and applications of optical sensors.

Working and Principle



Source: tungsten bulb or lamp is used as a light source.

Filter: It is a device to provide desired wavelength range

Sample cell: sample is hold in glass cell.

Photocell: Converts the emitted light into electrical signal.

- Optical sensors are devices that measure physical or chemical properties using the interaction of electromagnetic radiation with the analyte. They rely on the interaction of the analyte with incident radiation to generate an optical signal.
- Optical sensors are based on the interaction of electromagnetic radiation with chemical species, using UV-Visible-Infrared radiations.
- Analyte interaction with incident radiation can result in absorption, emission, scattering, or reflection of light, with radiation intensity indicating the analyte concentration.
- Optical sensors can determine the concentration of colored solutions by measuring their absorbance at specific wavelengths according to Beer-Lambert's law.
- Optical sensor components include a light source, filters, photocell, and display system.

Applications

- They have been developed for a wide range of chemical and biological molecules and ions.
- Applications of optical sensors include environmental monitoring, biotechnology, food, and pharmaceuticals.
- Optical fiber-based biosensors utilize these sensors to screen drugs, detect foodborne pathogens and explosives, and monitor the environment.

Explain Electrochemical sensor's application in the measurement of Dissolved Oxygen (DO)

- Electrochemical sensors are used to measure the concentration of Dissolved Oxygen (DO) in water. In this sensor, two electrodes are used, a zinc or lead anode, and a silver cathode. The electrochemical reaction that takes place in the sensor is:
- Anode reaction: $2\ Zn \rightarrow 2\ Zn_2+ + 4e-$
- Cathode reaction: $O_2 + 2\ H_2O + 4e- \rightarrow 4\ OH-$
- Overall reaction: $Zn_2+ + O_2 + 2\ H_2O \rightarrow 2\ Zn(OH)_2$
- The current produced by the reduction of oxygen at the cathode is directly proportional to the partial pressure of oxygen in the water sample. Thus, by measuring the current produced, we can determine the concentration of DO in water.
- However, the zinc hydroxide produced in the process is precipitated out into the electrolyte solution, which can affect the sensor's performance over time. To ensure accurate and reliable measurements, the electrolyte solution and the zinc anode must be replaced periodically.

Discuss the working principle of electrochemical gas sensors for the detection of SOx and NOx.

Electrochemical gas sensors are used to measure the concentration of gasses like NO2, NO and SO2. In principle, any gaseous compound which can undergo redox reaction on the surface of electrode can be measured with an electrochemical sensor

- Electrochemical gas sensors are used to detect the concentration of NO_2.
    i. The amperometric gas sensor in aqueous electrolyte is used to detect NO_2.
    ii. It uses a gold or platinum/Nafion sensing electrode with a 10M H_2SO_4 electrolyte.
    iii. The electrochemical reduction reaction for NO2 detection is: $NO_2 + 2H^+ + 2e^-$ ------> $NO + H_2O$
- Electrochemical gas sensors are used to detect the concentration of NO.
    i. The Gold/NASICON-NaNO2 electrode with an electrolyte is used for NO detection.
    ii. The electrochemical oxidation reaction for NO detection is: $NO + 2H_2O$ -----> $NO_3^{2-} + 4H^+ + 2e^-$
- Electrochemical gas sensors are used to detect the concentration of SO2.
    i. The Gold/Nafion sensing electrode with a 0.5M H2SO4 electrolyte is used for SO2 detection.
    ii. The electrochemical oxidation reaction for SO2 detection is: $SO2 + 2H_2O$ -----> $SO_4^{2-} + 4H^+ + 2e^-$

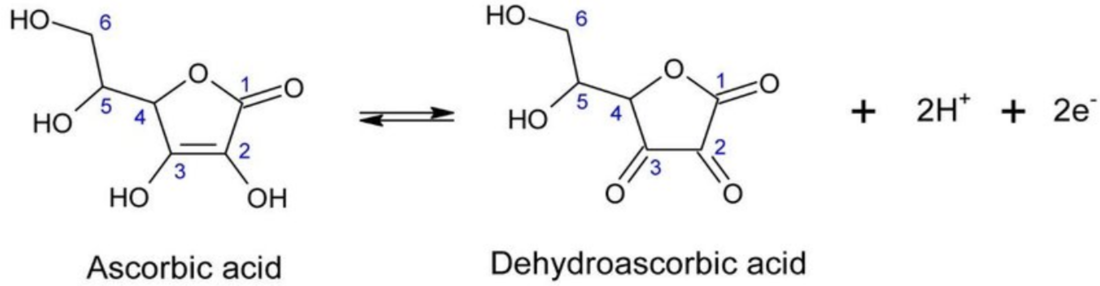
What are disposable sensors? Mention the advantages of disposable sensors. ?

Disposable sensors are inexpensive and easy-to-use devices that are used for short-term or rapid single-point measurements. They detect physical, chemical, or biological changes in their environment and convert them into an analytical signal. Below are the advantages of disposable sensors:

- Low cost and easy to use.
- Biodegradable and sustainable.
- Short duration of analysis and fast response times.
- Provide digitized chemical and biological information.
- Prevent contamination of samples.

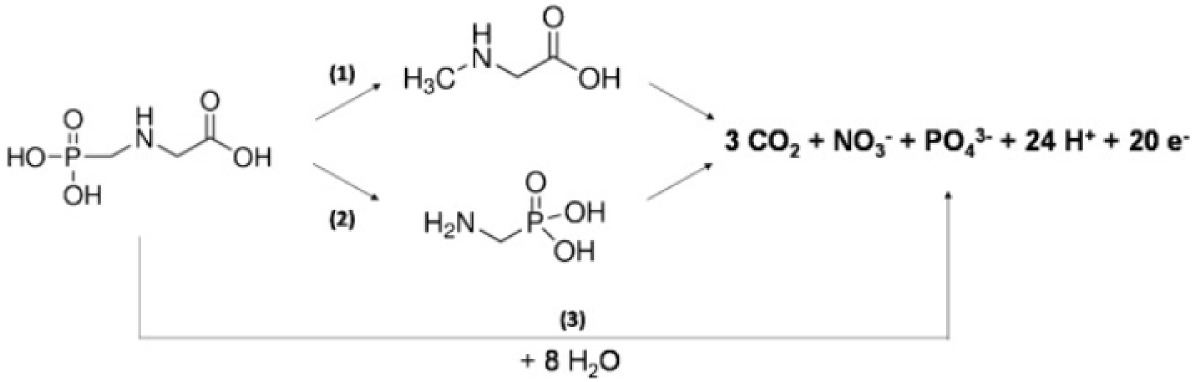
Disposable electrodes are commonly used for the detection of biomolecules such as carbohydrates, proteins, lipids, nucleic acids, enzymes, etc. Monitoring the levels of these biomolecules is crucial for maintaining a healthy body, as any deficiency or excess can lead to biological disorders.

Discuss the detection of a bio-molecule ascorbic acid using disposable sensors and also write the electro oxidation reaction.



- Vitamin-C, also known as ascorbic acid, is a water-soluble vitamin that is essential for life and acts as an antioxidant in the body. Excessive use of ascorbic acid can cause side effects such as diarrhea, nausea, vomiting, headache, insomnia, gastric irritation, renal problems, loss of food taste, and vomiting.
- Electrochemical sensors with disposable strips are used to detect ascorbic acid.
- Active materials of the sensing electrode, counter electrode, and reference electrode are printed on the disposable paper strip using Screen Printing Technology.
- The active material coated on the sensing electrode must be capable of oxidizing ascorbic acid on its surface.
- The ascorbate oxidase enzyme immobilized on a screen-printed carbon electrode with polyethylene glycol and diglycidyl ether as a crosslinking agent can be used as a sensing electrode in an ascorbic acid disposable biosensor.
- The enzyme oxidizes ascorbic acid into dehydroascorbic acid, and the concentration of ascorbic acid is determined from the change in potential of the oxidation process.

Explain the detection of Herbicide-Glyphosate with reactions.



- The sensor is a silicon-based chip with a three-electrode system made by electrodeposition technique.
- The three electrodes are:
    i. Working electrode: A 4 mm diameter gold electrode coated with 200 nm thick gold nanoparticles.
    ii. Counter electrode: A 4 mm diameter gold electrode coated with 20 nm thick gold nanoparticles.
    iii. Reference electrode: Ag/AgCl/Cl-
- Electrolytes are added to increase solution conductivity and minimize resistance between the working and counter electrodes.
- The electrochemical detection is based on the oxidation of Glyphosate on the gold working electrode.
- A potential of 0.78V is applied to the working electrode, and as Glyphosate oxidizes on the electrode surface, it causes a change in current in the electrolyte medium. The change in current is measured and used to determine the concentration of Glyphosate.

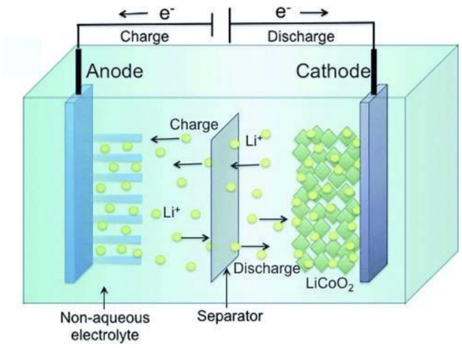
Define a battery. Give the classification of batteries with examples.

A battery is an electrochemical device that is used to store and convert chemical energy into electrical energy. The chemical reactions inside the battery result in a potential difference between the electrodes, which can be harnessed to power an external circuit.

Classification of batteries:

- Primary Batteries: These batteries are not rechargeable, and once the chemical reactions inside are exhausted, they cannot be reused. Examples include alkaline batteries, zinc-carbon batteries, and lithium primary batteries.
- Secondary Batteries: These batteries are rechargeable, and the chemical reactions can be reversed through an external current. Examples include lead-acid batteries, nickel-cadmium batteries, and lithium-ion batteries.
- Reserve Batteries: These batteries are not intended for continuous use but are designed to provide power in emergency situations. Examples include backup batteries for emergency lighting or critical systems. Magnesium- water activated batteries, zinc-silver oxide battery

What is a secondary battery? Explain the construction and working of Li-Ion batteries.



Composition and Construction

- Anode: Made of graphite with high energy density and large lithium ion doping capacity.
- Cathode: Consists of metal oxide material containing lithium which dedopes lithium ion during charging and undergoes lithium doping during discharging.
- Electrolyte: Composed of lithium salts (LiPF6, LiBF4, or LiClO4) dissolved in organic solvents like ether.
- Separator: Made of polypropylene material.
- Output Voltage: The battery generates a voltage of 3.6V.

Working of LIB:

During charging lithium ions in cathodic side (positive electrode) is migrated and move towards anodic side (negative electrode)

$$Cathodic\ Reaction: LiCoO_2 \rightarrow Li_{(1-x)}CoO_2 + xLi^+ + xe^-$$
$$Anodic\ Reaction: xLi^+ + xe^- + 6C \rightarrow xLiC_6$$
$$Overall\ Reaction: LiCoO_2 + 6C \leftrightarrow Li_{(1-x)}CoO_2 + xLiC_6$$

During discharging lithium ions move from anode to cathode.

$$Anodic\ Reaction: xLiC_6 \rightarrow xLi^+ + xe^- + 6C$$
$$Cathodic\ Reaction: Li_{(1-x)}CoO_2 + xLi^+ + xe^- \rightarrow LiCoO_2$$
$$Overall\ Reaction: Li_{(1-x)}CoO_2 + xLiC_6 \rightarrow LiCoO_2 + 6C$$

Application

- Mobile phones
- Cameras
- Calculators
- LCD TVs
- Pagers
- Laptop computers
- Aerospace applications

What is a secondary battery? Explain the construction and working of Na-Ion battery.

- Reactive species at anode: Carbon - Carbon is used as the anode material, which undergoes intercalation with sodium ions during charging and de-intercalation during discharging.
- Reactive species at cathode: NaCoO2 - NaCoO2 is used as the cathode material, which undergoes deintercalation of sodium ions during charging and intercalation during discharging.
- Electrolyte: Ethylene carbonates (EC), Diethyl carbonate (DEC) - Ethylene carbonates and Diethyl carbonate are used as the electrolyte, which provides a medium for ion transfer between anode and cathode.

- Separator: Polypropylene - Polypropylene is used as a separator, which prevents direct contact between the anode and cathode and allows the flow of ions.
- Output Voltage: 1.85 to 3.45 V - The output voltage of the battery ranges from 1.85 to 3.45 V depending on the specific configuration and application of the battery

Working of SIB:

During charging sodium ions in cathodic side (positive electrode) is migrated and move towards anodic side (negative electrode)

$Cathodic\ Reaction: NaCoO_2 \rightarrow Na_{(1-x)}CoO_2 + xNa^+ + xe^-$

$Anodic\ Reaction: xNa^+ + xe^- + 6C \rightarrow xNaC_6$

$Overall\ Reaction: NaCoO_2 + 6C \leftrightarrow Na_{(1-x)}CoO_2 + xNaC_6$

During discharging sodium ions move from anode to cathode.

$Anodic\ Reaction: xNaC_6 \rightarrow xNa^+ + xe^- + 6C$

$Cathodic\ Reaction: Na_{(1-x)}CoO_2 + xNa^+ + xe^- \rightarrow NaCoO_2$

$Overall\ Reaction: Na_{(1-x)}CoO_2 + xNaC_6 \rightarrow NaCoO_2 + 6C$

Advantages of SIB:

- Rechargeable sodium ion for energy storage.
- Capable of working at room temperature, good efficiency.
- Low market prices
- Easier to recycle

Write the properties and applications of Quantum Dot Sensitized Solar Cell (QDSSC).

Working and principle

- Quantum dots are nanoscale semiconductor particles with unique optical and electronic properties, often referred to as artificial atoms.
- They have adjustable band gaps that can be modified by changing the size of the dots, making them promising materials for use in solar cells, particularly as a replacement for traditional, bulkier materials like silicon and copper indium gallium selenide.
- QDs are exposed to sunlight. QDs absorb solar energy, electrons move from valence band to conduction band. These electrons are transferred to the semiconductor, leaving behind holes on the surface of QD's.
- Electrolyte takes up the holes from the surface of QD's and gets reduced. Electrons flow from anode to cathode through an external circuit. At the cathode, the electrolyte is regenerated taking up electrons from the cathode.

Properties

- They have a favorable power to weight ratio with high efficiency.
- Their power consumption is low.
- There is an increase of electrical performance at low production costs.
- Their use is versatile and can be used in windows, not just rooftops.

Applications

- It is used as photovoltaic in solar cells.
- It is used in light-emitting diodes, photoconductors, and photodetectors.
- It is used for biological labeling, imaging, detection, and as efficient fluorescence resonance energy transfer donors.
- It is used in biomedicine and environment.
- It is used in catalysis and other reactions.