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Internal Assessment Test 2 – August 2023

Sub:	Applied Chemistry for CSE					Sub Code:	BCHES202	Branch:	ISE, AIML, AI&DS, CS-AIML
Date:	09-08-2023	Duration:	90 min's	Max Marks:	50	Sem / Sec:	II / A,B,C, D, E, F & G		OBE

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

		Question	MARKS	CO	RBT
1	(a)	What are photovoltaic cells? Explain construction and working of PV cells and mention its advantages.	[7]	CO2	L3
	(b)	Explain the working principle of electrochemical gas sensors for the detection of SOx and NOx.	[7]	CO4	L3
2	(a)	Define battery. Explain construction and working of Na-ion battery with charge and discharge reactions and mention its applications.	[6]	CO2	L3
	(b)	What are quantum dot solar cells? Explain its working principle with four applications.	[6]	CO2	L3
3	(a)	What are thermometric sensors? Describe their working principle and applications.	[6]	CO4	L2
	(b)	Explain the generation of hydrogen using PEM electrolysis method and mention any 4 advantages.	[6]	CO2	L2

4	(a)	Explain determination of dissolved oxygen (DO) using electrochemical sensor.	[6]	CO4	L2
	(b)	Describe the working, principle and applications of conductometric sensors.	[6]	CO4	L2
5	(a)	What are optical sensors? Describe their working principle and applications.	[6]	CO4	L2
	(b)	What are green fuels? Explain the generation of hydrogen using alkaline water electrolysis method.	[6]	CO2	L2
6	(a)	What are electrochemical sensors? Explain its application in determination of pharmaceuticals with an example.	[6]	CO4	L2
	(b)	What are disposable sensor? Explain the detailed principle of the disposable sensor in the detection of pesticides with an example.	[6]	CO4	L3
7	(a)	What are different sources of E-Waste, discuss its characteristics and composition.	[6]	CO3	L1
	(b)	Write a note on the toxic components present in E-Waste and discuss their health hazards.	[6]	CO3	L2

Solutions for Internal Assessment Test 2 – August 2023

Answer 1a:

Photovoltaic cells (Solar cells)

The device, which converts solar energy into electrical energy, is called photovoltaic cell and the phenomenon is called photovoltaic effect.

Construction:

1. Photovoltaic Cells consists of p-n junction semiconductor diode made of silicon coated with anti-reflective layer (TiO_2) at the top.

2. Two electrical contacts are provided, one in the form of metallic grid at the top of the junction and the other is a silver layer at the bottom of the cell

3. The antireflective layer coated in between the metallic grids which allow light to fall on the semiconductor.

Working of photovoltaic cell:

1. Electromagnetic radiation consists of particles called photons (hv). They carry a certain amount of energy given by the Plank quantum equation. $E = hc/\lambda$

Where, h = Planck's constant, c = velocity of light, λ = wavelength of the radiation
2. The photons of solar radiations enter **n-type** semiconductor breaks barrier potential and moves to **p-type** semiconductor where photons knock the electrons in p-type to form electron-hole pair.

3. The free electrons so formed will travels through the circuit from **n-type** and recombines with holes again in the **p-type** region.

4. The movement of electrons from n-type to p-type generates electric current. The electrical energy produced by the solar cell is used for various applications

Advantages of PV cells:

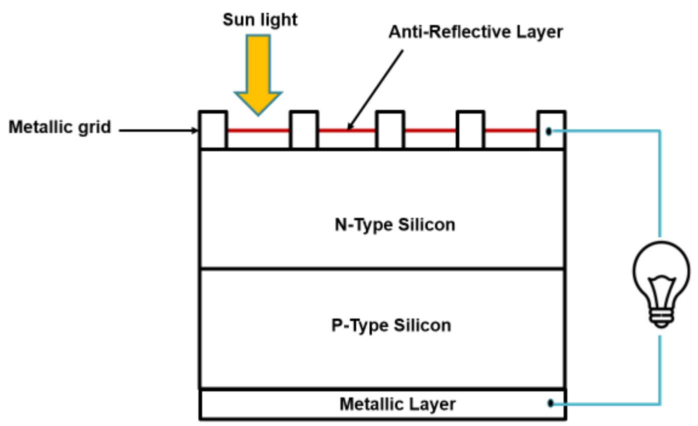
1. It is unlimited, inexhaustible and renewable source of energy.

2. The solar cell operates reliably for a long period of time with no maintenance.

3. Easy to operate

4. Quick installation.

5. Completely pollution free during its use.



Answer1b

Electrochemical gas sensor for NOx and SOx

Construction

The components of an electrochemical gas sensor are:

• ***Working electrode*** (sensing electrode): An electrochemical reaction occurs on the surface of the sensing electrode. (**Gold**)

• ***Counter electrode***: helps to measure the current flow through the system during the electrochemical reaction. (**Platinum**)

• ***Reference electrode***: Provide a stable potential to the working electrode (**Ag/AgCl**)

• ***Electrolyte***: ionically conducting materials (**3-7M H_2SO_4**)

• ***Membrane***: A gas-permeable membrane is used to control the gas flow reaching the electrode surface.

• ***Filter:*** to filter out the unwanted gas

Working

• The electrodes are separated and immersed in an aqueous medium (electrolyte).

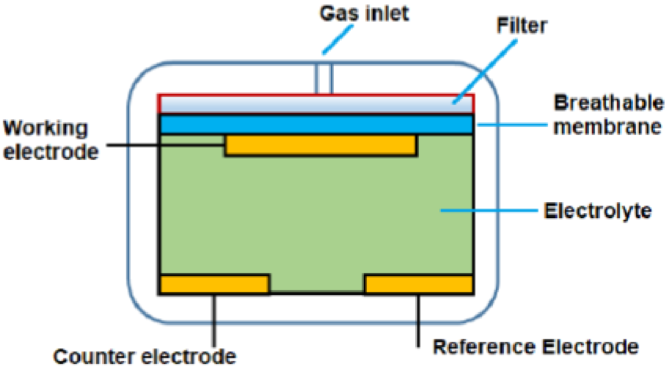
• The gas molecules diffuse through a porous membrane that is placed in contact with the working electrode.

• In this electrode surface, gas molecules lose electrons after the oxidation process.

• A reduction of oxygen occurs at the counter electrode in electrochemical sensors.

• Electrons move through wires connected to the electrodes and an external circuit.

• Flow of electrons generates an electrical signal proportional to the concentration of toxic gas



The medium provides hydrogen ions (H^+) that move through the aqueous solution
Electrochemical reactions for the SO_2 and NO gas sensors are:

Working electrode (Anode): $SO_2 + H_2O \rightarrow SO_3 + 2\,H^+ + 2\,e^-$

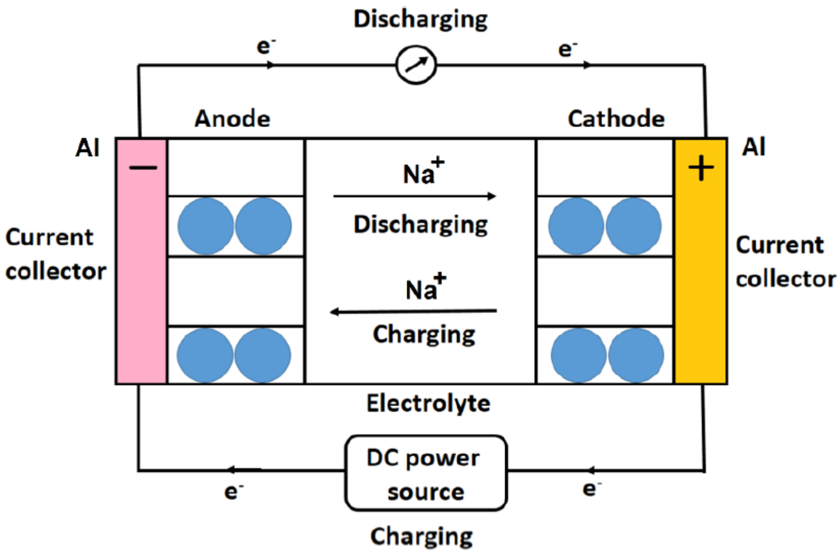
Counter electrode (Cathode): $(1/2)\,O_2 + 2H^+ + 2e^- \rightarrow H_2O$

Working electrode (Anode): $NO + H_2O \rightarrow NO_2 + 2\,H^+ + 2\,e^-$

Counter electrode (Cathode): $(1/2)\,O_2 + 2H^+ + 2\,e^- \rightarrow H_2O$

Answer 2a

Battery is a device that converts chemical energy directly into electrical energy via electrochemical oxidation and reduction reaction.



Construction

Anode: Sodium interacted Hard carbon

Cathode: Sodium cobalt oxide layer ($NaCoO_2$)

Electrolyte: $NaPF_6$ dissolved a mixture of carbonate solvents

Separator: Polypropylene polymer

Working

Anode reaction: $Na_xC_6 \longrightarrow xNa^+ + xe^- + 6C$

Cathode reaction: $Na_{1-x}CoO_2 + xNa^+ + xe^- \longrightarrow NaCoO_2$

Overall reaction: $Na_{1-x}CoO_2 + Na_xC_6 \longrightarrow NaCoO_2 + 6C$

During ***discharge***, Na^+ ions are dissociated from the anode and migrate from the anode to cathode through the electrolyte. Electrons travel through an external circuit. This process creates an electric current that can power a device or system.

During ***Charging:*** Na_+ ions move from the cathode to the anode through the electrolyte.

Application of Lithium-ion battery

• They are commonly used boats and ships

• They are used in medical devices

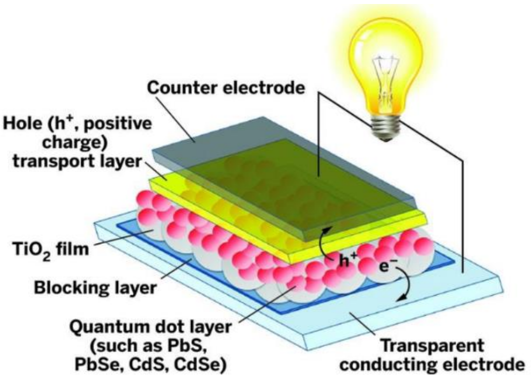
• They are used in military and defence

• They are used in electric cars.

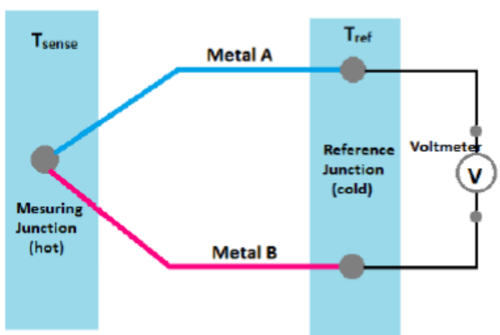
Answer 2b

QDSSCs
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. Quantum dots are nanometer-sized semiconductor particles with unique optical and electronic properties.
Working
Light Absorption: Quantum dots' bandgap, which determines the wavelengths of light they can absorb, can be tuned by controlling the size and composition of the quantum dots.
Generation of Excitons: When a photon is absorbed by a quantum dot, it excites an electron within the quantum dot, creating an electron-hole pair, known as an exciton.
Charge Separation: After the excitons are created, an electric field within the QDSC helps to separate the electron and hole.
Electron and Hole Transport: The electron transport layer (ETL) assists in collecting the electrons and moving them to the electrode (anode), while the hole transport layer (HTL) helps transport the holes to the counter electrode.
Electricity Generation: The movement of electrons and holes towards the electrodes creates an electric current within QDSC which can be used for various applications.
Reactions:
Excitation process: $QDs + hn \rightarrow QDs^*$
Exciton dissociation: $QDs^* \rightarrow e^{-*} + h^{+*}$ (free carriers)
Injection process: $QDs^* + TiO_2 \rightarrow TiO_2(e^{-*}) + QDs^+$
Energy generation: $TiO_2\,(e^{-*}) + C.E \rightarrow TiO_2 + e^{-*}$ (CE) + electrical energy

QDSCs applications
Applications:
I. For Solar energy conversion such as photovoltaic panels and solar-powered devices.
II. For Portable electronics: such as smartphones, laptops, and wearable devices.
III. For Building-integrated photovoltaics (BIPV): such as windows, roofs, and walls, allowing for the conversion of light into electrical energy within a building.
IV. Stand-alone power systems in remote locations

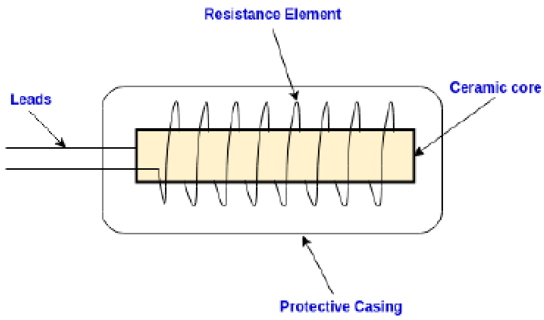


Answer 3a: **Thermometric sensor:** A temperature sensor is a device, typically, a thermocouple or resistance temperature detector, that provides temperature measurement in a readable form through an electrical signal.
Working principle of thermometric sensors
The working principle of a thermometric 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.



• **Resistance temperature detector (RTD)**

Here, the electrical resistance of certain metals (mainly used platinum, copper and Nickel) changes with temperature. When the temperature of the RTD changes, the electrical resistance of the material changes in a repeatable manner. This change in resistance is then correlated to the temperature using calibration curves.



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.

•They can also be used to study the temperature effect in the instruments.

Answer 3b:

PEM Electrolysis

Construction:

Anode: Ir (Iridium) based electrode

Cathode: Pt (Platinum) based electrode

Electrolyte: Solid polymer electrolyte (PFSA)

Separator: Nafion. (Separates both electrodes).

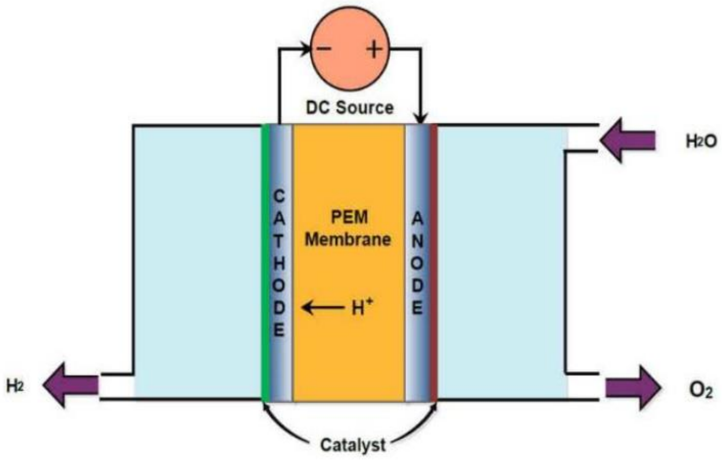
Working: PEM water electrolysisis involving the pumping of water to the anode where it is spilt into oxygen (O_2), protons (H^+) and electrons (e−).

Anode: $H_2O \rightarrow 2H^+ + ½O_2\uparrow + 2e^-$

The electrons flow through an external circuit and the hydrogen ions selectively moves across the PEM to the cathode. Where they combine to liberate hydrogen gas.

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

Totalreaction: $H_2O \rightarrow ½O_2 + H_2$



Advantages •Commercialized technology •Operates higher current densities •High purity of the gases •Compact system design •Quick response

Answer 4a: Electrochemical dissolved oxygen (DO) sensor

Construction and working

Electrochemical sensors designed for measuring dissolved oxygen typically 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.

Anode: Lead or Zinc

Cathode: Gold or platinum,

Electrolyte: NaOH

Separator: a thin layer of hydrophobic material, such as Teflon.

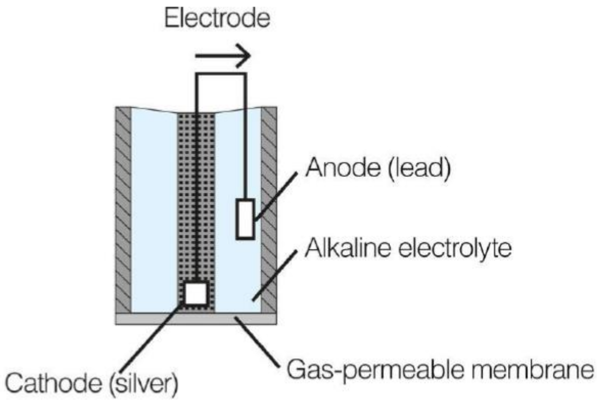
When the Clark electrode is immersed in a liquid sample, oxygen molecules diffuse through the hydrophobic layer and react with the cathode surface, producing a current that is proportional to the amount of oxygen present in the water.

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

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

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

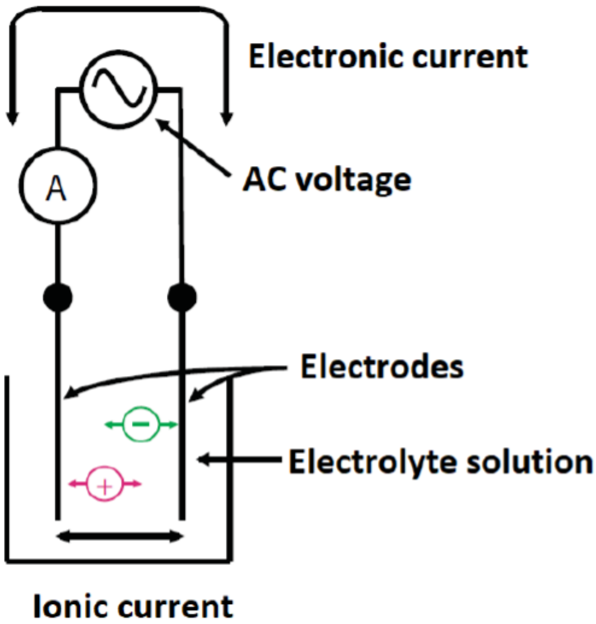
The white solid, $Pb(OH)_2$, that is produced by these reactions is precipitated out into the electrolyte solution. It neither coats the anode nor consumes the electrolyte, and thus does not affect the sensor's performance until the quantity becomes excessive.



Answer 4b: **Conductometric sensor:** A conductivity sensor is a sensor used to measure the conductivity of various solutions or the concentration of the overall ion in a sample. It is based on the measurement of the specific conductance of an analyte.

Construction

- A conductometric sensor consists of two inert metal electrodes.
- Those two electrodes are separated at a certain fixed distance before applying AC voltage, which later causes current flow.
- The sensor is immersed in the conductive liquid which acts as the electrical conductor between the sensor electrodes.



Working principle

The conductance depends on the mobility of ions as well as the number of ions migrating between the electrodes. The basic principle of a conductometric sensor involves a reaction that changes the ionic species concentration. This reaction leads to changes in ionic concentration as well as the conductance between the electrodes. That affects electrical conductivity or current flow. The analyzer applies an alternating voltage to the drive coil, which induces a voltage in the liquid surrounding the coil. The voltage causes an ionic current to flow proportional to the conductance of the liquid.

Applications

- Monitoring the quality of human drinking water
- Monitoring the quality of industrial water
- Battery electrolyte density monitoring
- Making devices for producing electrolytic oxygen and hydrogen

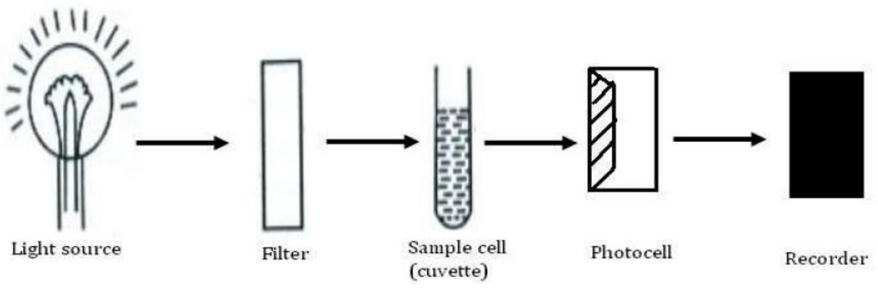
Answer 5a: Optical Sensors:

1. These sensors based on the interaction of electromagnetic radiation with the chemical species. Commonly UV-Visible-Infrared electromagnetic radiations are used. In an optical sensor, the optical signal arises from the interaction of the analyte with an incident radiation. This interaction could results in absorption, emission, scattering and reflection of light. The intensity of the radiation gives the information on the concentration of the analyte.
2. Optical sensors are used to determine the concentration of coloured solution. It is based on the measurement of absorbance of the coloured solution at particular wavelength. It is governed by Beer-Lambertz law.
3. The optical sensors components are light source, filters, photocell and display system.

Working:

A monochromatic light is pass through analyte at particular wavelength. A part of light is absorbed by the analyte. The absorbance depends on the concentration of the solution and the path length of the light through the solution. The photocell converts emitted light into electrical signal. These signals are recorded and displayed.

Schematic diagram is as follows



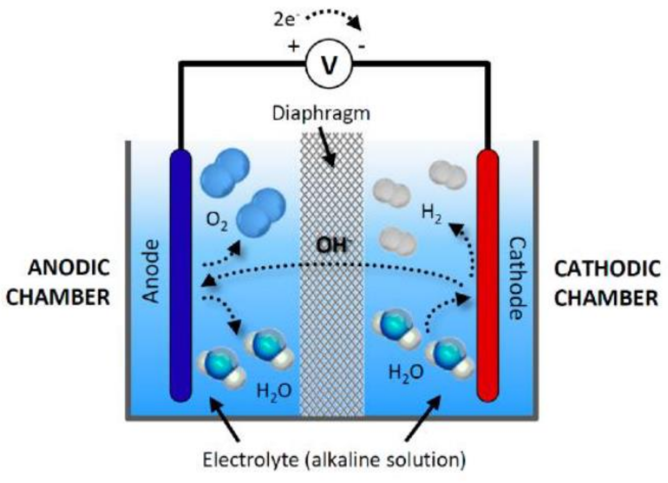
Schematic diagram of colorimeter

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.

Applications

- It is used in remote sensing satellite
- Used in imaging
- Quality and Process Control applications
- Metrology
- Medical instruments

Answer 5b: The hydrogen produced through the decomposition of water using a renewable energy source is called green hydrogen.
Alkaline Water Electrolysis
Construction:
Anode & Cathode: Made of Ni based metal
Electrolyte: KOH solution (25-35%).
Separator: Diaphragm (Asbestos/Zirfon). Both electrodes are separated by porous diaphragm prevent gases cross over and allows only hydroxide ions.
Cell voltage: 1.3–2V
Working: When electricity is passed at anode hydroxide ions lose electrons and forms water molecules.
Anode: $2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
At cathode, water molecules accept electrons and liberate hydrogen gas and forms hydroxide ions. These hydroxide ions move from cathode to anode through diaphragm and process continues.
Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$
Totalreaction: $H_2O \rightarrow \frac{1}{2}O_2 + H_2$
Advantages •Well established Technology •Commercialized for industrial applications •Noble metal-free electrocatalysts •Relatively low cost •Long-term stability



Answer 6a: 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.

Electrochemical sensor for pharmaceuticals (Diclofenac)

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

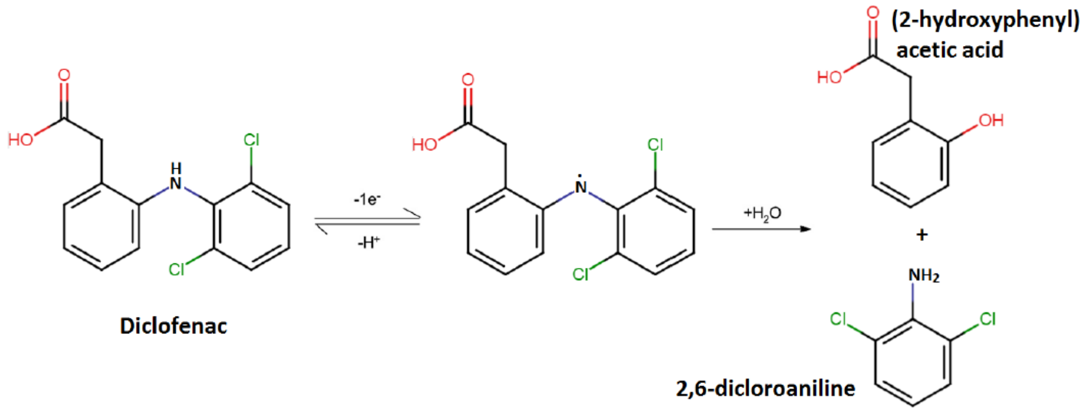
It is necessary to detect and control the amount of diclofenac drug present in a blood sample using an electrochemical sensor.

Construction

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

Working

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



Answer 6b: Disposable sensor

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

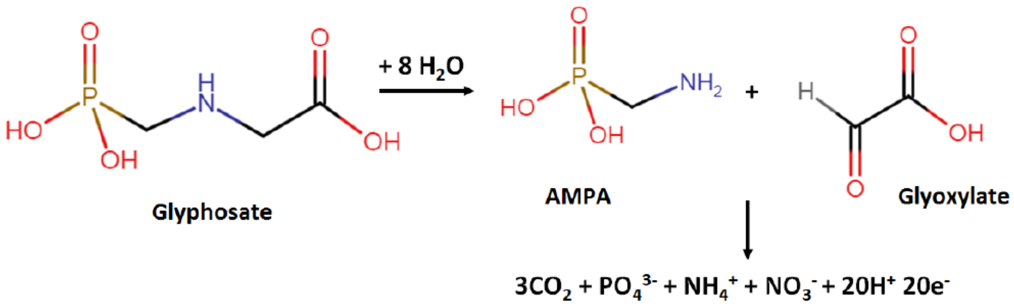
Detection of glyphosate (pesticides) using disposable sensor

Construction

- The sensor is a silicon-based chip comprising of three-electrode system.
- *Working Electrode*: A gold electrode of 4 mm diameter coated with 200nm thickness gold nanoparticles.
- *Counter electrode*: A gold electrode of 4 mm diameter coated with 20nm thickness gold nanoparticles.
- *Reference Electrode*: Ag/AgCl

Working

- The electrochemical detection is based on the oxidation of Glyphosate on gold working electrode.
- A potential of 0.78V is applied on working electrode, there is an interaction between analyte and electrode surface.
- Glyphosate oxidizes on the working electrode brings a change in current in the electrolyte medium.
- The change in the current is a measure of concentration of Glyphosate



Answer 7a: Sources of electronic waste (e-waste):

The main sources of electronic waste (e-waste) include:

1. Consumer electronics such as smart phones, laptops, televisions, and household appliances.
2. Office equipment such as computers, printers, copiers, and fax machines.
3. Medical equipment such as X-ray machines, monitors, and diagnostic equipment.
4. Electronic toys and games.
5. Colleges often use electronic equipment such as projectors, computer equipment, and audio-visual equipment in classrooms and laboratories.

Composition of E-waste

1. Metals: E-waste often contains valuable metals such as copper, gold, silver, and aluminium.
2. Plastics: Many electronic devices contain plastic components, including casings, insulation, and cables.
3. Glass: Electronic devices often contain glass components, such as screensand lenses.
4. Circuit boards: Many electronic devices contain circuit boards, which contain a mixture of metals and other materials.
5. Batteries: Some electronic devices contain batteries, which can contain hazardous materials such as lead, mercury, and cadmium.
6. Other hazardous materials: E-waste may also contain other hazardous materials, such as flame retardants, heavy metals, and polychlorinated biphenyls (PCBs).

Characteristics of E-waste:

1. **Complexity:** E-waste often contains a complex mixture of materials, making it challenging to recycle and dispose of properly.
2. **Hazardousness:** E-waste can contain hazardous materials such as heavy metals, flame retardants, and batteries, which can pose significant environmental and health risks.
3. **Resource depletion:** The extraction of raw materials for electronic devices contributes to resource depletion, and the improper disposal of e- waste can lead to environmental contamination and waste of valuable resources.
4. **Volatility:** E-waste is a rapidly growing waste stream due to the increasing use of electronic devices and the limited lifespan of many electronic products.

Answer 7b: Electronic and electrical products can contain a variety of toxic materials, including:

1. **Lead:** Lead is a toxic heavy metal commonly used in the manufacture of batteries, computer monitors, and other electronic components.
2. **Mercury:** Mercury is used in some fluorescent lights, batteries, and other electronic devices.
3. **Cadmium:** Cadmium is a toxic heavy metal used in rechargeable batteries, pigments, and plastic stabilizers.
4. **Polyvinyl Chloride (PVC):** PVC is a common plastic used in electronic cables and other components. It can release toxic chemicals, such as dioxins, when burned or during disposal.
5. **Brominated flame retardants (BFRs):** BFRs are used in the manufacture of electronic products to prevent fires. However, they are toxic and can harm the environment and human health.
6. **Barium:** Barium is used in some electronic components, including cathode ray tubes.
7. **Rechargeable Batteries contains** Lithium is used in batteries, but it can be toxic if not handled properly. Cadmium, Lead, Sodium, Lithium, Nickel etc.

8. **Chlorofluorocarbons (CFCs)** are toxic chemicals that were widely used as coolants and solvents in electronic products, such as refrigerators, air conditioners. They cause ozone depletion.

Health hazardous due to exposure of e waste:

Poisoning: E-waste can contain toxic substances, such as lead, cadmium, and mercury that can cause poisoning if they enter the body.

Respiratory problems: Exposure to dust and fumes generated during the dismantling and disposal of e-waste can cause respiratory problems, such as asthma and bronchitis.

Neurological effects: Exposure to toxic substances in e-waste, such as lead and mercury, can cause neurological effects, including memory loss, tremors and coordination problems.

Reproductive problems: Exposure to toxic substances in e-waste, such as cadmium, can cause reproductive problems, including infertility and birth defects.

Cancer: Exposure to carcinogenic substances, such as dioxins and polychlorinated biphenyls (PCBs), found in e-waste, can increase the risk of cancer. It is important to effectively manage e-waste to minimize the exposure of workers and the public to hazardous materials and to prevent serious health problems.