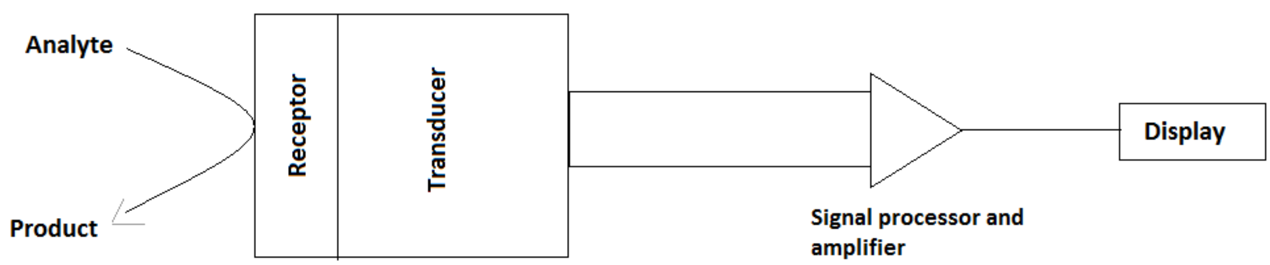
Electrochemical sensors

A chemical sensor is a device that interacts with a specific chemical or biological analyte, detects it and produces a signal proportional to its quantity.
Analyte is the target species which is being detected and measured using a sensor.
Main components of sensors are:

a. Receptor: Receptor is a chemical or biological recognition element which is capable of interacting with analytes specifically and selectively. It produces signals corresponding to interaction in the form of change in potential, conductivity, current, mass, heat, pH, color etc.
b. Transducer: during the interaction of sensing element with analyte certain physical or chemical properties of the sensing element changes proportionately to the analyte concentration. Transducer is used to convert the signal created by the receptor-analytic interaction into a readable value or measurable form of physical quantity.
c. Electrical signal and display: the electronic system analyzes signal given by the transducer, helps in the signal amplification and converts the signal from analog to digital form. Those amplified signals are then displayed. Signals can be displayed in various forms such as numeric value, graph, image, color etc.



Electrochemical sensors use electrodes as the transducer component. Transducer of an electrochemical sensor consists of working or sensing electrode, electrolyte, counter electrode and reference electrode. A sensing electrode has a chemically modified surface. This modification ensures the selectivity, facilitating the reduction or oxidation of the analyte. The electrolyte is part of the electric circuit of an electrochemical sensor system. The role of the electrolyte is to transport charge within the sensor.
Following steps are involved in the working of an electrochemical sensor.

- Diffusion of the analyte to the electrode (in the liquid phase).
- Adsorption onto 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 electrolyte or gas phase.

Application of electrochemical sensors

1. The oxygen sensor is used for detection of dissolved oxygen in water boilers and to monitor DO concentration in metal, glass and in the hydrogen fuel.
2. They are used in security and defense applications like detection of toxic gasses, warfare agents etc.
3. They are used in H_2O analysis and environmental monitoring like measurement of toxic metal concentration in H_2O, detection of oxides of N, S, CO, p^H of water etc.
4. They are used in diagnostic and health care applications like monitoring of glucose serum uric acid, blood Ca^{2+}, Fe^{2+} etc.
5. They are used in soil parameter analysis, evaluation and in agriculture applications.

Types of electrochemical sensors

1. Potentiometric sensors: change in potential during the chemical interaction between receptor and analyte is measured using a combination of an indicator electrode and a reference electrode.
2. Amperometric sensor: it is similar to a potentiometric sensor consisting of an electrolyte solution in which the electrodes are immersed. But, it is operated under an externally applied fixed voltage. This potential causes the analyte to react and a current to pass.
3. **Conductometric sensors:**

Conductometric sensors are consistent as a type of electrochemical sensor. An electrochemical sensor measures the electrochemical processes (redox reaction) at the surface of electrodes. But, a conductometric sensor is based on measurements of physical properties of a homogeneous bulk solution like electrolyte conductance by aqueous electrolyte solutions.

In conductometric sensors, determination of the concentration of analyte is based on measurement of changes that occur in electrolyte solution.

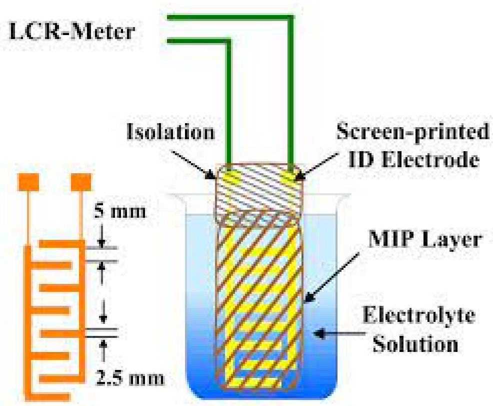
Conductance of the solution is based on;

A. The concentration (number) of ions contributes to conductivity of solution.

B. Mobility of each type of ion: mobility of an ion depends on its size. Smaller the size, higher is mobility and higher is electrolytic conductance.

Electrodes used in conductivity sensors are called conductivity cells. It is used to measure the change in electrolytic conductance of the solution during replacement of ions of a particular conductivity by ions of different conductivity. It is made of 2 Pt foils with unit cross sectional area and unit distance between them. Volume between 2 electrodes is 1 cm^3.

Conductance of the unit volume of the solution is called specific conductance. There will be change in specific conductance of solution when there is change in number of ions or type of ion. This change is measured using a conductivity cell.



$$Specific\ conductance\ (k) = \frac{1}{R} \times \frac{l}{a}$$

Where l/a = cell constant

R = Resistance of the solution

The conductivity cell is dipped in the electrolyte solution taken in a beaker and it is connected to a conductance measuring device called a conductivity meter.

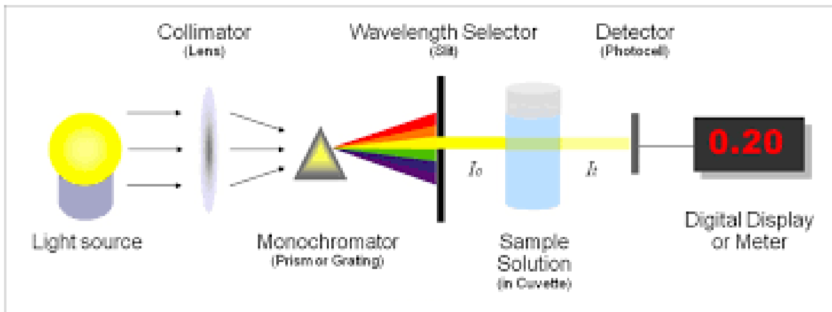
Applications of conductometric sensors

1. Conductometric sensors can be used to monitor any chemical which can change the electrolytic conductance of solution on chemical reaction.
2. It is used to estimate acids, bases and their mixtures in a sample.
3. It is used to check the amount of ionic impurities in water samples.
4. It is used in measuring acidity or alkalinity of seawater and fresh water.
5. Conductometric biosensors are used in biomedicine, environment monitoring, biotechnology and agriculture related applications.

Optical Sensors

Interaction of electromagnetic radiations with matter forms the basis of a broad range of analytical methods of analysis. Commonly known as spectrochemical methods of analysis. Commonly, electromagnetic radiation in the UV- Vis- IR domains is used for analytical purposes. A broad range of the chemical sensors have been developed on the ground of interaction of the sensing element with electromagnetic radiation. Sensors based on the transduction of interaction of electromagnetic radiation with the chemical species are called optical sensors.

Optical transduction can be based on emission, absorption, reflectance and scattering of light by the analyte. The optical signal arises from the interaction of the analyte with incident radiation. The interaction could result in absorption, emission, scattering or reflection of light. The type of interaction depends on the wavelength of the probing radiation and on the structure of the molecules in the analyte. The intensity of the radiation emanating from the analyte carries information on the analyte. It is measured by the optoelectronic instrumentation.



In the simple optical sensor used to measure the absorption of light, main components used are a light source, a wavelength selector, a photodetector and a display of the output.

In modern optical sensors, optical components such as a lens, optical couplers and connectors are used for coupling light into optical fibers and solid-state optoelectronic components. This has enabled the development of commercial portable optical sensors systems.

Simple optical sensors are used to determine the concentration of colored chemical species in solution. They are based on measurement of absorbance or transmittance of light of particular wavelength by coloured chemical species in the solution. They are governed by Beer-Lambert's law.

Applications of optical sensors:

1. Optical sensors can be used in the determination of any chemical species which can interact with electromagnetic radiation.
2. Optical sensors have been developed for a number of different types of chemical and biochemical molecules and ions.
   For example, ions in solution (p^H, metal ions, anions), gasses (CO_2, O_2, NH_3, SO_2, NO_2 etc.), vapors (moisture, volatile organic compounds) and molecules (glucose, pesticides, DNA, bacterias).
3. Optical sensors find important and varied uses in environmental, biotechnological, food, pharmaceutical, medical etc.
4. Optical fibers based (bio) sensors are used in screening of drugs, detection of food borne pathogens, detection of explosives and environmental monitoring.

Thermometric sensors

Thermometric sensors are based on the measurement of thermal changes during interaction between analyte and receptor. Thermal changes are converted to measurable changes in the temperature or potential.

Thermometric transduction is feasible only in those processes which generate sufficient heat to produce a measurable change of temperature. Chemical or biological species which undergo catalytic chemical reactions and enzyme- catalyzed reactions liberating heat (exothermic reaction) can be determined by thermometric sensors.

Working principle of a thermometric sensors:

Main components of a thermometric sensor is a small tubular catalytic reactor fitted with a temperature transducer. Analytes are fed into the reactor. The wall of the reactor is coated with a catalyst or enzyme capable of catalyzing the reaction, liberating the heat energy. Heat liberated is quantified by means of a temperature transducer. The change in temperature is converted into the output voltage by the transducer which is amplified and fed to the data storage and processing unit.

In order to convert change in temperature into an electrical signal, two main kinds of transducer which exhibit thermoelectric effect are used:

1. Resistive transducer : The most commonly used resistive transducer is the thermistor. It is a ceramic semiconductor device made of oxides of transition metals. Most thermistors have a negative temperature coefficient. That is, their resistance decreases with increasing temperature. The decrease in resistance is converted to output voltage using a Wheatstone bridge resistor.
2. Thermocouple : a thermocouple as a device that converts the temperature difference directly into an electrical voltage. It consists of a loop formed by two different materials (metals or semiconductors). The output voltage is proportional to the temperature difference between the two junctions.

Applications of a thermometric sensors

1. Thermal biosensors are based on the temperature change induced by a simple enzymatic reaction. They are used in the determination of metabolites, bioprocess monitoring and environmental control.
   An example is the determination of glucose using the glucose oxidase-catalyzed reaction.
2. Thermometric chemical sensors are used for determination of combustible gasses that react with oxygen at the surface of a suitable catalyst.

Sensors for the measurement of dissolved oxygen (DO)

Molecular free Oxygen O_2 is slightly soluble in water. Only about 8mg of oxygen is soluble in 1 liter of water. This oxygen present in dissolved form is called “Dissolved Oxygen”. It is an important water quality parameter. Because aquatic living beings depend upon this dissolved oxygen for their survival. Concentration of DO in boiler feed water plays an important role in corrosion of water boilers. In many industries, monitoring concentration of DO in metal melts and other materials is highly essential.

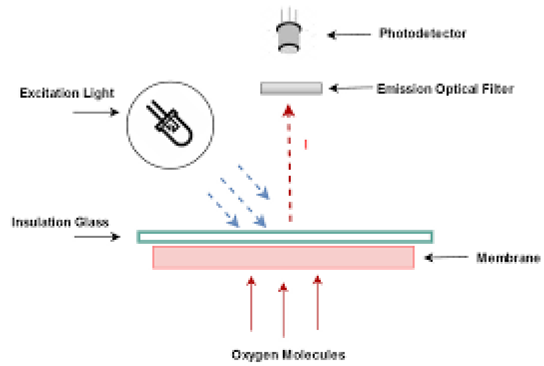
Two types of sensors are commonly used for measurement of DO

1. Optical sensors :

main components of an optical DO sensor are semipermeable membrane, sensing element, LED and photodetector. The sensing element contains a luminescent dye that is immobilized on a gel matrix.

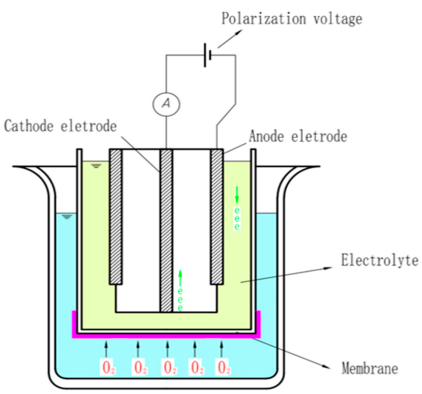
When this dye is exposed to blue light, it moves to excited state and while returning back to ground state, it emits light with a known intensity. When the dissolved oxygen crosses the semipermeable membrane and interacts with dye, it reduces the intensity of light emitted by the dye.

The intensity of light emitted by the dye is inversely proportional to DO concentration. Therefore, DO can be measured by measuring decrease in intensity of light emitted by luminescent dye using a photodetector.



2. Electrochemical sensor for the measurement of DO:

In an electrochemical DO sensor, two electrodes used are of dissimilar metals. Zn or Pb is used as anode and silver metal as inert cathode. The difference in potential between the anode and cathode should be more than 0.5V to reduce DO without an external applied potential. The electrolyte solution used is NaCl or any other inert electrolyte.



When the electrode assembly is dipped in water to measure its DO, anode undergoes oxidation liberating electrons.

$$2Zn \rightarrow 2Zn^{2+} + 4e^-$$

At cathode, DO undergoes reduction. Ag cathode is inert, it only passes electrons to oxygen for reduction.

$$O_2 + 2H_2O \rightarrow 4OH^-$$

Overall reaction is

$$2Zn + O_2 + 2H_2O \rightarrow 2Zn(OH)_2$$

The current produced by the reduction reaction of oxygen at cathode is proportional to the partial pressure of oxygen in the water sample. The Zinc hydroxide produced by these reactions is precipitated out into the electrolyte solution. This will gradually affect the sensor's performance. When the sensor readings are not stabilized then the electrolyte solution and Zinc anode have to be replaced to bring the sensor back to working condition.

Electrochemical sensors for the Pharmaceuticals

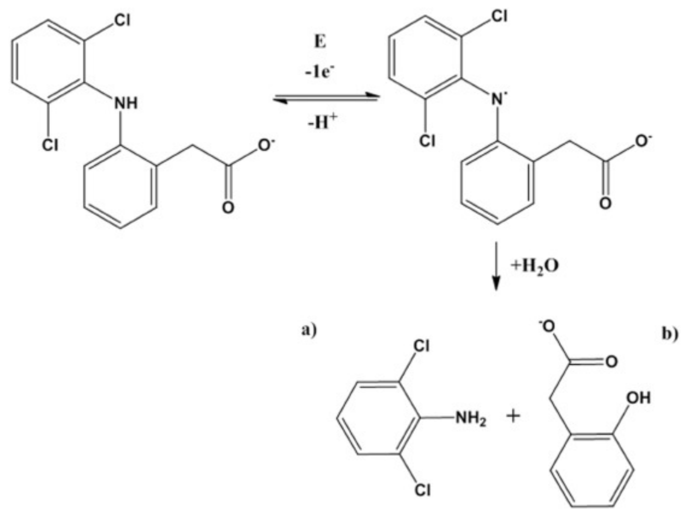
Pharmaceuticals are basically organic compounds, which are used extensively by human beings as a solution for various health issues. After usage they are excreted or washed off their hosts and enter into the environment through effluents of waste water. Even though the use of pharmaceuticals for various health conditions is well understood and documented.

Sensors are used for the detection of pharmaceuticals to monitor their concentration and know their toxic effects.

Electrochemical sensor for the detection of Diclofenac

Diclofenac is one of the most frequently prescribed non-steroidal anti-inflammatory drugs (NSAID) with antipyretic and analgesic effects. It is safe in prescribed doses, but may cause adverse effects at higher doses. Electrochemical sensors can be used to detect diclofenac in lower concentrations.

In the electrochemical sensor used to detect diclofenac, the sensing (working) electrode is graphite carbon coated with multi walled carbon nanotubes (MWCNT) and gold nanoparticles. In the detection along with sensing electrodes, counter electrodes and reference electrodes are used. When the sample containing diclofenac is put in the sensor, the following oxidation reaction of diclofenac occurs on the surface of the sensing electrode. The change in potential of the reaction gives the concentration of diclofenac.



PAHs

Among the dangerous hydrocarbon pollutants ***polycyclic aromatic hydrocarbons*** (PAHs) are widely found in the air, waste, water, soil and food.

Eg: naphthalene, chrysene, pyrene etc.

PAHs are known carcinogenic and mutagenic compounds. They can enter the human body through inhalation and diet. So detection of PAHs is essential to monitor their toxicity and carcinogenic risk.

1-Hydroxypyrene

- ☐ 1-hydroxypyrene is a commonly found hydroxyl PAH in urine samples. Electrochemical sensors are being developed for the detection of 1-hydroxypyrene in urine samples. These sensors are fast, low-cost and sensitive.
- ☐ In the electrochemical sensor used to detect 1-hydroxypyrene, the sensing electrode is graphite carbon coated with chromium containing metal organic framework and graphene oxide. This material has excellent chemical and hydrothermal stability, a large surface area, large pore windows and numerous unsaturated chromium sites making it suitable sensing material for electrochemical sensors.
- ☐ The hydroxypyrene structure contains electrochemically active hydroxyl groups, which can be oxidized by the anode active material. This is used for electrochemical detection.
- ☐ In the detection, along with sensing electrodes, counter electrodes and reference electrodes are used.
- ☐ When a sample containing 1-hydroxypyrene is put into the electrochemical sensor, an oxidation reaction will take place on the surface of the electrode.
- ☐ The concentration of 1-hydroxypyrene is determined from the change in potential of the reaction.

Electrochemical gas sensor

Electrochemical gas sensor is used in monitoring of concentration of gaseous analytes. They are used mainly in the concentration of air pollutants, detection of leakage of chemicals in industries and in defense, military and space applications.

Electrochemical gas sensors for SO_x and NO_x

Electrochemical sensors are used to measure the concentration of gasses like NO_2 , NO and SO_2 . In principle, any gaseous compound which can undergo a redox reaction on the surface of an electrode can be measured with an electrochemical sensor.

But the receptor coated on the surface of the sensing electrode (working electrode) is different for each gas. Reaction that occurs on the surface of the electrode is also different for each case.

Detection of NO_2 in an amperometric gas sensor in aqueous electrolyte is based on the following electrochemical reduction reaction on the surface of sensing electrode. Au, Pt/Nafion sensing electrode with 10M H_2SO_4 is used as electrolyte.

$$\mathbf{NO_2 + 2H^+ + 2e^- \rightarrow NO + H_2O}$$

Detection of NO in an amperometric gas sensor in an aqueous electrolyte is based on the following electrochemical oxidation reaction on the surface of sensing electrode. Au/ NaSICON- NaNO2 is used as a sensing electrode and electrolyte.

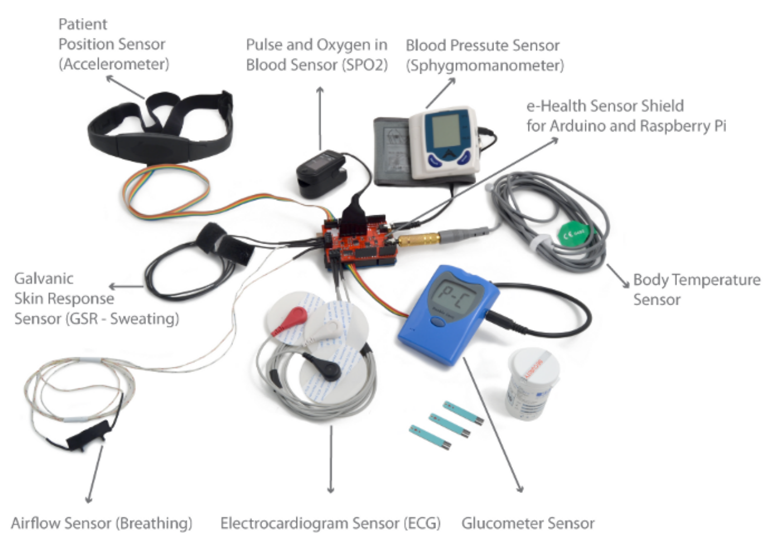
$$\mathbf{NO + 2H_2O \rightarrow NO_3^{2-} + 4H^+ + 3e^-}$$

Detection of SO2 in an amperometric gas sensor in aqueous electrolyte is based on the following electrochemical oxidation reaction on the surface of sensing electrode. Au/Nafion sensing electrodes with 0.5M H2SO4 are used as electrolytes.

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

Biosensors

Biosensors are devices that are used to detect and measure bioanalytes. They are used in qualitative and quantitative analysis of biomolecules, biological structures, microorganisms etc. Number of biosensors are used in healthcare, food, industrial and environmental fields for the detection of various bio analytes like glucose, cholesterol, ethanol, creatinine etc.



Disposable sensor

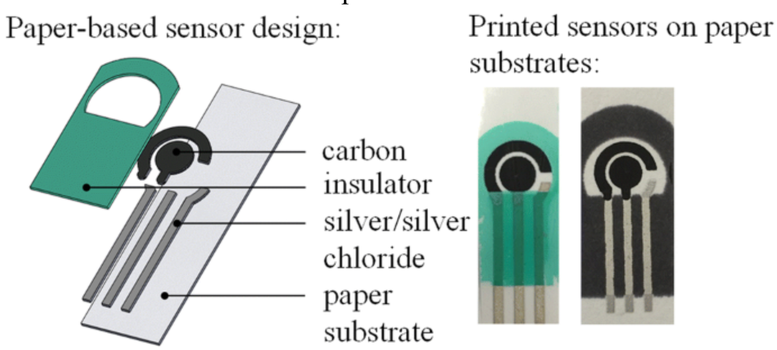
In the analysis of samples from Healthcare, food, Industrial and environmental fields. portable sensors with the capability of on-the-spot analysis is required. Portable Glucometer used in monitoring of blood sugar level at home with disposable strips is an example of such a disposable biosensor.

Disposable strip of a biosensor is a special type of paper over which the receptor and electrode are coated. They are coated in the form of a thin film strip using screen printing technology. In such a system, all the electrodes namely reference, working and counter electrodes and a bio receptor are printed on a single platform. These electrodes are called screen-printed electrodes and are the main components of a disposable biosensor. These strips can be inserted into the portable systems and used for on-site sample analysis.

Disposable electrodes in the detection of Biomolecules

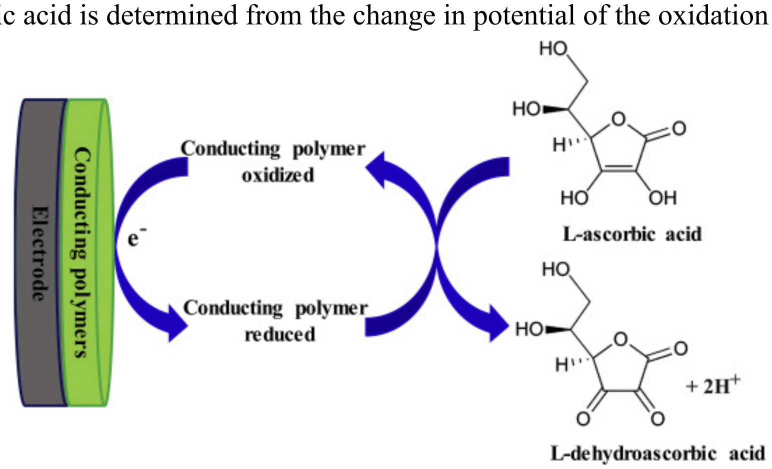
Monitoring of levels of bio molecules like carbohydrates, proteins, lipids, nucleic acid, enzymes, hormones etc. is very essential to maintain a healthy body. Because, any deficiency or excess of these molecules may result in biological disorders such as Alzheimer's disease, Parkinson's disease, diabetes, heart attack, pregnancy complications etc. resulting in decreased average life-span of the humans. Several types of disposable biosensors have been developed for continuous monitoring of these bioanalytes.

Disposable pre-activated screen printing electrodes have been developed for on spot analysis of glucose, ascorbic acid, uric acid, lactic acid, creatine in human blood samples.



Detection of Ascorbic Acid

Chemical name of vitamin C, a water-soluble vitamin, is Ascorbic acid. Electrochemical sensors which can detect ascorbic acid in various samples in lower concentration are developed. These sensors can be used for on the spot analysis. In the disposable strip, active materials of the sensing electrode, counter electrode and reference electrode printed on the disposable papers strip using screen printing technology. Active material coated on sensing electrodes 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 cross linking agent can be used as sensing (working) electrode in ascorbic acid disposable biosensor. It oxidizes ascorbic acid into dehydroascorbic acid. Concentration of ascorbic acid is determined from the change in potential of the oxidation process.



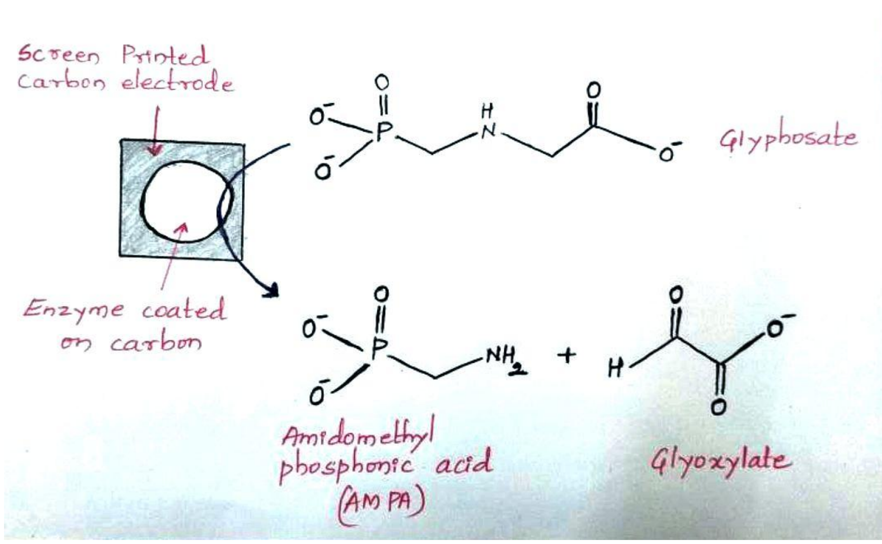
Disposable electrodes in the detection of pesticides

Accumulation of pesticides in soil as well in agriculture products can induce a number of diseases such as asthma, diabetes, birth defects etc. Therefore monitoring the level of pesticides in soil, water and cultivated group products is one of the best ways to detect the abuse of pesticides.

Enzyme modified screen printed disposable paper strip electrodes are coated with enzymes. Pesticides interact with the immobilized enzymes and lead to the formation of electroactive species. This results in decreased enzyme activity which can be measured quantitatively.

Detection of glyphosate

Various analytical methods based on electrochemical biosensors have been designed and used for glyphosate determination. Glycine oxidase can catalyze the oxidative deamination of various amines and cleave the C-N bond in glyphosate. The glycine oxidase enzyme immobilized on a screen-printed carbon electrode can be used as sensing (working) electrode in glyphosate disposable biosensor. It oxidizes glyphosate into aminomethylphosphonic acid AMPA and glyoxylate. Concentration of glyphosate is determined from the change in potential of the oxidation process.



Battery

A battery is a device that consists of two or more galvanic cells connected in series or parallel or both, which converts chemical energy into electrical energy through redox reactions.

Example: Lead-Acid battery, Nickel-Cadmium battery etc.

Basic components of battery

1. Anode (negative electrode) : It releases electrons into the external circuit by undergoing oxidation.

$$\mathbf{M \rightarrow M^{n+} + ne^-}$$

2. Cathode (positive electrode) : It accepts electrons coming from anode through an external circuit. Thereby reduction of the active species occurs at cathode.

$$\mathbf{M^{n+} + ne^- \rightarrow M}$$

3. Electrolyte: It provides the medium for transfer of ions inside the cell between the anode and cathode.
4. Separator : It is used to separate anode and cathode compartments in a battery to prevent internal short circuiting. A separator allows transport of ions from anode to cathode and vice versa to maintain the electrical neutrality.

   Example: Cellulose, Cellophane etc.

Classification of batteries

1. Primary batteries: A battery which cannot be charged and discarded when the battery has delivered all its electrical energy.

   Example: Zn-MnO2 battery, Li-MnO2 battery etc.

2. Secondary batteries: A battery which can be recharged by passing current through it in the opposite direction to that of the discharge.

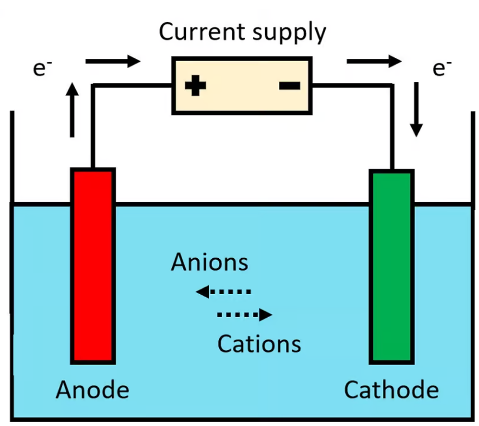
   Example: Lead Storage battery. Ni-Cd battery etc

3. Reserve batteries: One of the components is stored separately and is incorporated into the battery when required.

   Example: Mg-AgCl and Mg-CuCl, both can be activated whenever required just by adding water.

Working of Battery

Working of the battery involves discharging and recharging.



Conversion of chemical energy into electrical energy occurs when anode and cathode are externally connected and hence the circuit is closed.

During discharge, anode undergoes oxidation by releasing the electrons and thus, metal atoms move into the solution as metal ions (cations).

$$\mathbf{At\ anode,\ M_1 \rightarrow M_1^{n+} + ne^-}$$

Hence, cationic concentration increases in the anodic compartment. The released electrons flow from anode to cathode through an external circuit and thus constitute the flow of current.

At cathode, electrons are accepted for the reduction of the metal ions to metal atoms and hence anionic concentration becomes more in the cathodic compartment.

$$\textbf{At cathode, } M_2^{n+} + ne^- \rightarrow M_2$$

During discharge, concentration of active species at anode gradually decreases and hence EMF of the battery decreases.

During recharge, the current flow is reversed with the aid of a DC power supply. The negative terminal of the power supply is connected to the anode of the battery and positive terminal to the cathode of the battery. Under this condition metal ions are reduced to metal atoms at anode and anionic concentration decreases.

At cathode, oxidation occurs by releasing electrons and hence, cationic concentration increases in the cathodic compartment.

$$\textbf{At cathode, } M_2 \rightarrow M_2^{n+} + ne^-$$

Electrode reactions are reversed and hence electroactive materials are restored. Hence the original EMF of the battery is restored.

Lithium ion battery

A lithium ion battery is a type of rechargeable battery that makes use of charged particles of lithium to convert chemical energy into electrical energy. Lithium ion batteries possess many advantages over-traditional rechargeable batteries, such as lead acid and Ni-Cd batteries. They include high voltage, high energy density, and high cyclic life.

Construction

Lithium-ion batteries are composed of three parts: anode, cathode and an electrolyte. Anode and cathode are able to insert Lithium ions into their layered structure reversibly.

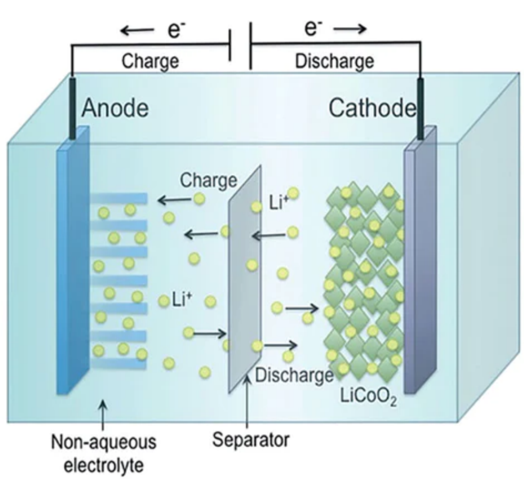
The anode: Lithium atoms inserted into graphite carbon.

The cathode: Lithium-metal oxide (Li-MO_2), where M is commonly Co or Mn.

Electrolyte : A Lithium salt such as $LiPF_6$ dissolved in binary organic solvent mixture such as ethylene carbonate-dimethyl carbonate.

Cell representation:

$$\textbf{Li / Li}^+\textbf{, C / LiPF}_6\textbf{ in ethylene carbonate / Li}^+\textbf{-MO}_2\textbf{ / Li-MO}_2$$



Reactions:

During discharging of a battery, Lithium atoms present in the graphite layer are oxidized, liberating electrons and Lithium ions.

Electrons flow through an external circuit to the cathode and Li+ ions flow through the organic electrolyte towards the cathode.

$$\textbf{Li-C}_6 \rightarrow \textbf{Li}^+ + \textbf{6C} + \textbf{e}^-$$

At cathode, Li+ ions are reduced to Li atoms and are inserted into the layered structure of metal oxide.

$$Li^{+} + e^{-} + MO_2 \rightarrow Li\text{-}MO_2$$

During charging of the battery, Li atoms present in layered structure of metal oxide are oxidized, liberating electrons and Li+ ions. Electrons flow through an external circuit and Li+ ions flow through the organic electrolyte towards graphite carbon electrodes.

$$Li\text{-}MO_2 \rightarrow Li^{+} + e^{-} + MO_2$$

At graphite electrodes, Li+ ions are reduced to Li atoms and are inserted into the layered structure of graphite.

Applications:

- In digital cameras: Lithium ion batteries as a power source.
- Personal digital assistant, smartphone, laptops.
- Watches
- Portable power packs
- Solar energy storage
- Emergency power backup
- Surveillance and alarm systems
- Electric vehicles and mobility scooters
- Marine vehicles
- Medical equipment
- Pacemakers

Sodium ion battery (SIB)

Construction and working of a sodium Ion battery (SIB)

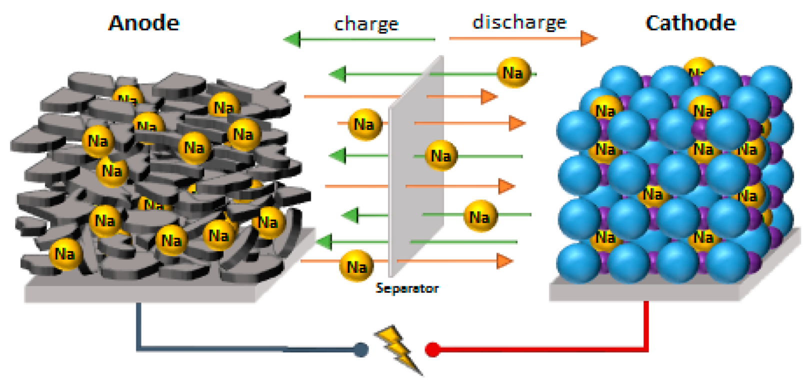
construction and working of a typical SIB is very similar to LIB.

Anode material used in SIB is hard carbon.

Cathode material is Sodium inserted in layered metal oxide CoO2 or MnO2.

Electrolyte used is a salt like NaPF6 dissolved in binary organic solvent mixture such as ethylene carbonate-dimethyl carbonate.

In SIB, cheaper Aluminum foil is used as a current collector. whereas, costly copper metal foil is used as a current collector in LIB.



During discharging

At anode: $$C\text{-}Na \rightarrow Na^{+} + C + e^{-}$$

Electrons flow from anode to cathode through an external circuit. Sodium ions move through the electrolyte and separator to reach the cathode.

At cathode

Sodium ions are reduced to sodium atoms and are inserted into the layered structure of metal oxide.

$$Na^{+} + e^{-} \rightarrow Na\text{-}MO_2$$

Reactions are reversed during charging of the battery.

Application of sodium ion battery (SIB)

1. Cost and sustainability: SIBs should be less expensive than LIBs as sodium abundance and predictable supply of raw materials. Sodium compounds are synthesized from seawater and limestone. So no concern about the scarcity of sodium.
2. Abundant natural resource
3. Less expensive
4. Bulky
5. Stable at a wide range of temperature
6. Good low temperature performance
7. Rapid charge/discharge
8. Greater life span
9. Non-flammable battery
10. Easy to safety recycle sodium Ion batteries

Quantum dots sensitized solar cells

Solar cells are photovoltaic devices that directly convert a solar photon into electricity via photoelectric effect. Designing a low cost and effective solar photovoltaic is a challenge to solve the energy and environmental crisis of humankind.

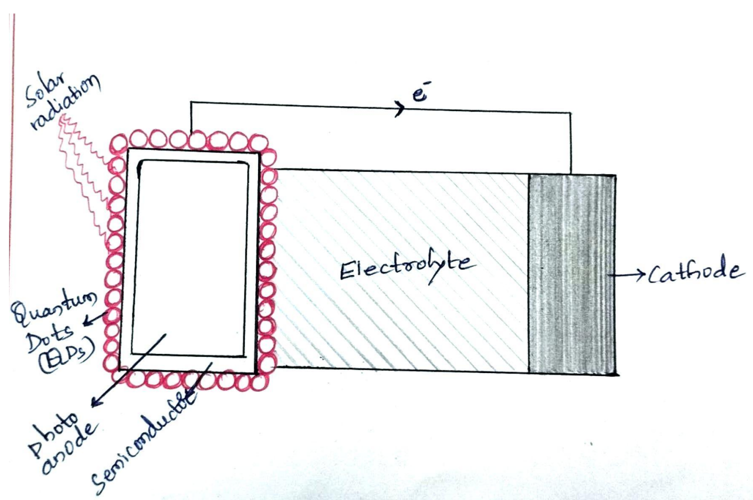
Among the third generation of solar cells, QDSSCs have potential to become alternatives to presently used Si based solar cells. This is due to unique properties of QDs like wide tunable band gaps and easy solution process ability.

Quantum Dots are the main component of QDSSCs. They must possess appropriate band gap and high absorption coefficient energy to maximize the harvesting efficiency of incident light. The energy level of QDs must match that of wide gap semiconductors. Cd chalcogenide (CdX, S, Se, ot Te) QDs are commonly used. Other kinds of QDs such as PbS, PbSe are also used.

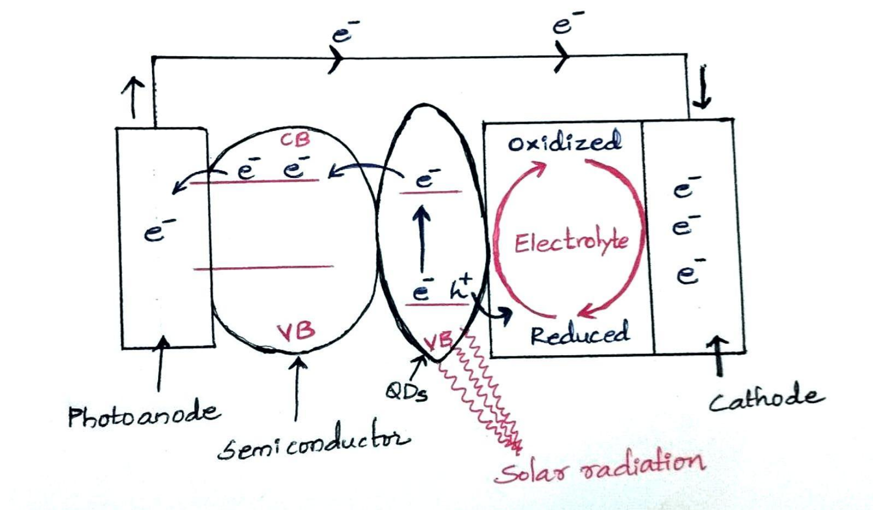
Construction

A QDSSC's consists of three components:

1. Photo anode: Photo anode is the working electrode in the cell. It is a conducting glass, over which a wide-band gap semiconductor like TiO_2, Nb_2O_5, ZnO, SnO_2 is coated with thickness of 10 mm and a porosity of 50-60%. Outer layer of photoanode is coated with sensitizer, Quantum Dots (QD's) in colloidal form
2. Electrolyte: Photoanode is in contact with a redox electrolyte. It is a hole conductor. A polysulfide redox couple S^{2-}/S_x^{2-} which can effectively take up holes from QDs is used as an electrolyte.
3. Cathode electrode: It is used to regenerate electrolyte and complete the circuit.



Working:



1. QD’s present on photoanode is exposed to sunlight.
2. QD’s absorb solar energy and generate charge carriers (electrons) and cause electrons to move from valence band to conduction band. These ejected electrons are transferred to the semiconductor, leaving holes on the surface of QD’s.
3. Electrolyte takes up holes from the surface of QD’s and gets reduced.

$$\mathbf{S^{2-} + 2h^{+} \rightarrow S}$$

4. Electrons flow from photo anode to cathode through an external circuit generating an electric current.
5. At the cathode, the electrolyte is regenerated taking up electrons from the cathode.

$$\mathbf{S + 2e^{-} \rightarrow S^{2-}}$$

Application

- Biological labeling
- Imaging and detection and as coefficient fluorescence resonance energy transfer donors.
- It is used as a light emitting diode (LED).
- It is used as photoconductors and photodetectors.
- Is used as photovoltaic.
- It is used in biomedicine and enrollment.
- It is used in catalysis.