Electrochemical Sensors

A sensor is a device that responds to a physical stimulus, such as heat, light, sound, pressure, magnetism, or movement, and transmits a resulting electrical impulse as a means of measuring the change of any intrinsic property of the constituent material. The origin of the word sensor comes from the Latin *sentire*, to feel. Semantically, sensors have the attribute of feeling into their surrounding environment to define a coupling relationship.

- Chemical sensors analyse our environment, i.e.they detect which substances are present and in what quantity.
- The use of chemical sensors had its beginnings in the 1950s, through the monitoring of industrial oxygen
- Laborers working in industries, related to the health and safety of the workers required the monitoring of toxic gases and fuels in confined spaces, led to the research towards electrochemical sensors that could exhibit good selectivity for the detection of different gases.
- Leland c. clark first proposed the oxygen sensor concept with the use of two electrodes of a cell with an oxygen permeable membrane separating the electrodes and the electrolyte solution
- The clark oxygen sensor found wide application in medicine and environmental and industrial monitoring.

A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or can be any molecule or substance such as analytes.

Types Of Sensors

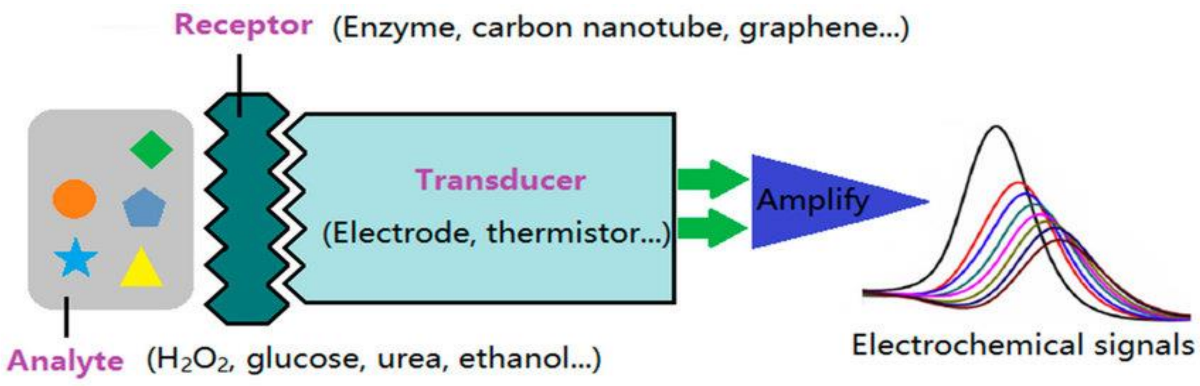
- **Semiconductor Sensors** e.g. Gallium Arsenide, Ge and Si – Solar Cells
- **Mass-Sensitive Sensors** e.g. Piezoelectric material –Weight measurement
- **Conductivity Sensors** e.g. Platinum Foil- measures conductivity in aq solutions
- **Capacitive Sensors** e.g. Capacitors detect are all types of metal, all types of plastic, wood, paper, glass, and cloth

- **Thermometric Sensors** e.g. Thermocouple, Thermistors and Semiconductor Based ICs
- **Calorimetric Sensors** e.g. Calorimeter sensor is used in determining the changes in enthalpy of the chemical substances
- **Electrochemical Sensors** e.g. Glucose Sensor- Measures Current
- **Optical Sensors** e.g. Used for medical application in pulse Oximeter (two lights with different wavelengths passed through the patient's body and absorbed in a photo detector on the other side)

ELECTROCHEMICAL SENSORS

Electrochemical sensors are a class of chemical sensors in which an electrode is used as a transducer element in the presence of an analyte.

- Modern electrochemical sensors use several properties to detect various parameters in our everyday lives, whether physical, chemical, or biological parameters.
- Electrochemical sensors transfer the effect of the electrochemical interaction of the analyte-electrode into a useful electric signal.
- Based on electrochemical species consumed or generated during an interaction process, the signal of this interaction is measured by electrochemical detector.



https://www.researchgate.net/publication/335398612_Electrochemical_Sensors_Fabricated_by_Electrospinning_Technology_An_Overview

Types of Electrochemical Sensors

- Potentiometric Sensors
- Amperometric Sensors
- Electrochemical Biosensors

1. Potentiometric Sensors

- Sensors that use the effect of concentration on the equilibrium of redox reactions occurring at the electrode-electrolyte interface of an electrochemical cell.
- The redox reaction takes place on the electrode surface:
  Oxidant + ne$^-$ → Reduced product
  (n is the no of electrons involved in the redox reaction)
- Mainly determine the analyte concentration by measuring the variation of potential difference between working and reference electrodes at different analyte concentrations.

Nernst Equation gives the potential of each half cell

In potentiometric sensor, two half-cell reactions take place at each electrode. Only one of the reactions should involve sensing the species of interest. The other reaction should be a well understood and non-interfering reaction.

- $E_{\text{cell}} = Eo + \text{RT/nF} \log(\frac{C_O}{C_R})$
- **At 298K,** $E_{\text{cell}} = \frac{0.0591}{n} \log(\frac{C_O}{C_R})$

C_O= Oxidant Concentration
C_R= reduced product concentration
n= no of electrons transferred per redox reaction
F= Faraday Constant
T= Temperature
R= Gas Constant
Eo= Electrode potential at a standard state

Types of Potentiometric Sensors

a. Ion Selective Electrode Sensors
   - Glass electrodes (e.g. pH-meter, Na^+, K^+, Li^+ Sensors
   - Solid membrane electrodes (e.g. based on AgX for X^-, and Ag_2S for other M^+).

    - Liquid membrane electrodes (e.g. containing a ligand for M^+ complexation e.g. Ca^{2+} and K^+ sensors).

b. Gas Potentiometric Sensors
    - pH-meter-based gas detectors (e.g. CO_2, NH_3 etc).
    - Solid oxide sensors (e.g. zirconia-based O_2 sensor (λ-sensor)).

Advantages of potentiometric sensors

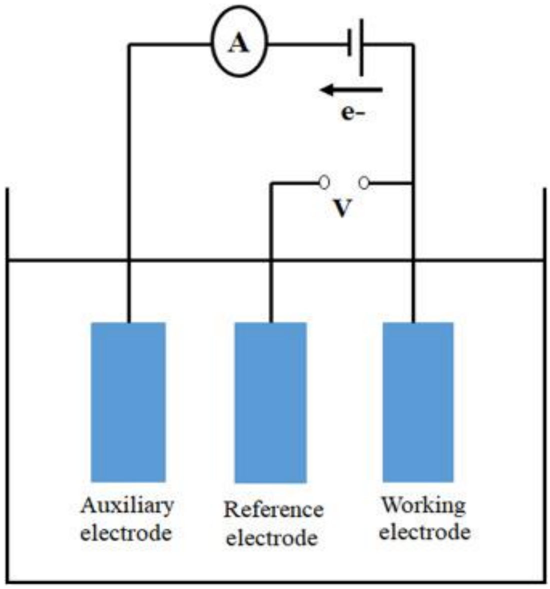
- Applied to detect various analytes qualitatively and quantitatively.
- Gives accurate, sensitive and high selective determination
- Zero consumption of analytes during measurements
- Traces of analytes can be estimated
- Short response time, wide linear working range, low energy consumption, low cost

Limitations of potentiometric sensors

- Calibration every time is necessary
- Presence of impurities can affect the potentials
- Signal obtained strictly depends on the temperature

2. Amperometric Sensors

- Measure the current in response to detect the concentration of the analyte at a fixed potential.
- The applied potential drives the electron transfer reaction of the analytes, and the measured current indicates the analyte concentration.
- Amperometric sensors quantify the current output between Working and the reference electrode. The sensor is usually composed of 3 electrodes, that is working, auxiliary, and reference electrode.
- It's very difficult to regulate a steady potential with the passage of current, but the utilization of the 3 electrodes permits an exact enforcement of the potentials and current estimation.



- The working electrode is the electrode at which the reaction of interest occurs, the reference electrode (e.g.; Ag/AgCl, Hg/Hg_2Cl_2) provides a stable potential compared to the working electrode.
- An inert conducting material (e.g.; platinum, graphite) is usually used as auxiliary electrode.
- A supporting electrolyte is used in controlled-potential experiments to eliminate electromigration effects, decrease the resistance of the solution and maintain the ionic strength constant.

Advantages of amperometric sensors

- Electroreducible and non-reducible analytes can be determined
- More accurate and sensitive
- Traces of reducible species can be determined accurately
- Several non-reducible substances like Mg^{2+}, PO_4^{3-}, SO_4^{2-} etc can be determined by titrating them with reducible titrant. Eg. Mg^{2+} can be titrated against reducible titrant Oxine.
- Apparatus used is simple and easy to set up.

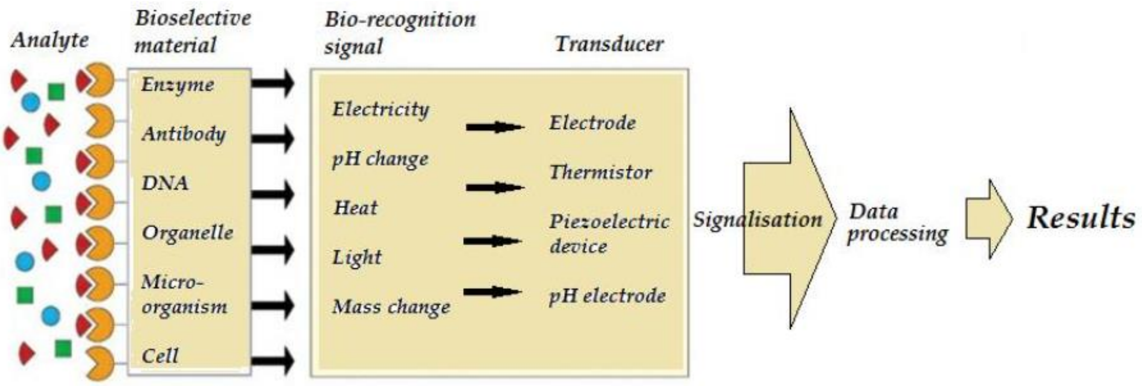
Limitations of amperometric sensors

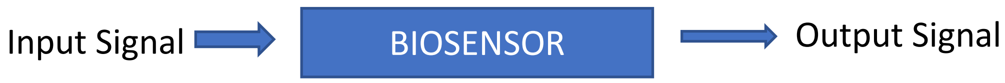
- Working potential applied should be for limited time or may lead to damage of the electrode.
- Coprecipitation gives inaccurate results.
- These sensors cannot be used with applied voltage more negative than -2V because hydrogen will be evolved.
- More time is required to remove dissolved oxygen.

3. Electrochemical Biosensors

- A biosensor is an analytical device which is used to determine the presence and concentration of a specific substance in a biological analyte.

- A biosensor is a measurement system for the detection of an analyte that combines a biological component with a physicochemical detector





Advantages of electrochemical biosensors

- Easy miniaturization, excellent detection limits, also with small analyte volumes
- Ability to be used in turbid biofluids with optically absorbing and fluorescing compounds
- Infectious diseases can be easily detected
- Linear output, low power requirements and good resolution

Limitations of electrochemical biosensors

- Narrow or limited temperature range.
- Poor Sensitivity
- Short or limited shelf life