# SCIENCE OF MEASUREMENT

# What are biosensors?

- A device that uses specific biochemical reactions mediated by isolated enzymes , immuno systems, tissues, organelles or whole cells to detect chemical compounds usually by electrical, thermal or optical signals.

# Principle of Biosensors

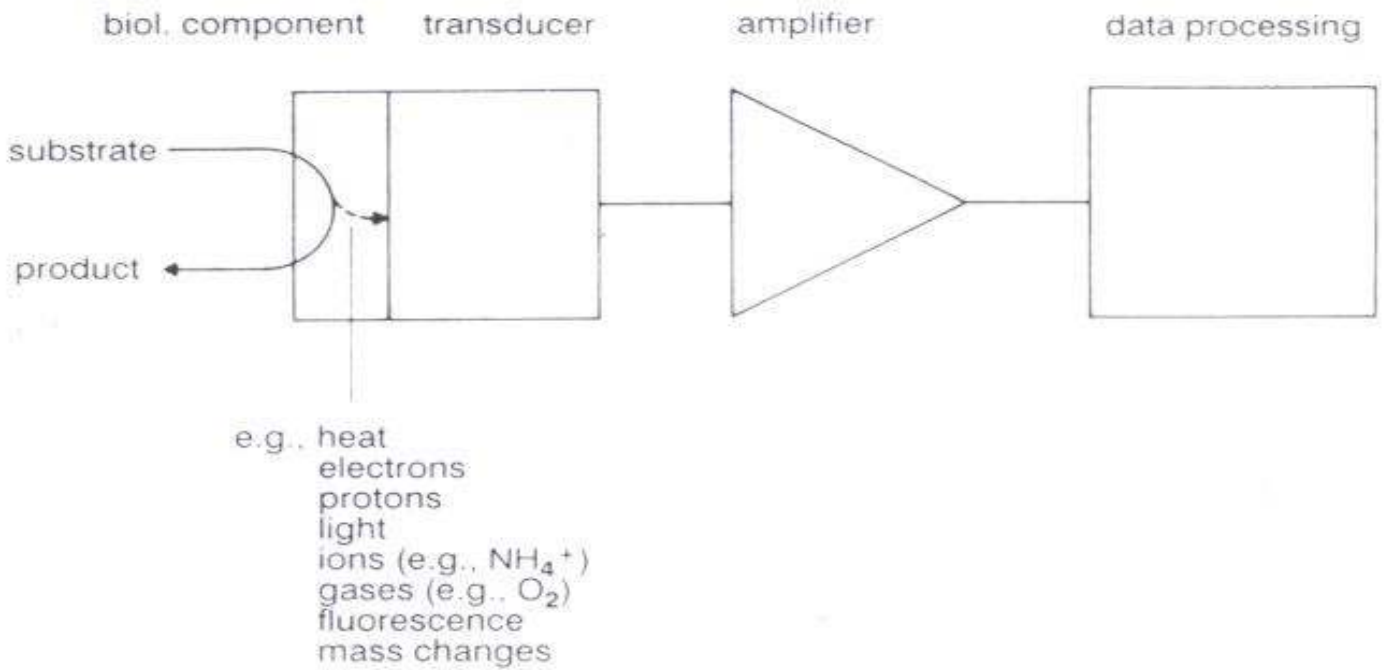


Fig. 2. Principles of biosensors.

# Required Characteristics

- Sensitivity
- Low detection limits
- Cost
- Simplicity
- Reliability
- Speed
- Accuracy
- Precision
- Utility
- Field portability
- Ruggedness
- Reproducibility
- Ease of calibration
- Stability
- Room for improvement

# Types of biosensors

- Based on use of different biological material and sensor devices following are the main types –
  - Electro - chemical Biosensor
  - Amperometric Biosensor
  - Thermistor containing Biosensor
  - Bioaffinity sensor
  - Whole cell Biosensors
  - Opto- electronic Biosensor

# Define Measurement

- **Measurement** is the assignment of a number to a characteristic of an object or event, which can be compared with other objects or events.

In the metric and SI systems, one unit is used for each type of measurement:

| Measurement | Metric | SI |
|---|---|---|
| Length | meter (m) | meter (m) |
| Volume ($m^3$) | liter (L) | cubic meter |
| Mass | gram (g) | kilogram (kg) |
| Time | second (s) | second (s) |
| Temperature | Celsius ( °C) | Kelvin (K) |

# Define Calibration

- The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, and the corresponding standard or known values derived from the standard .

# Types of calibration methods

*External Calibration:*

- Signal is proportional to concentration -established using externally prepared standards
- Assumes that the sensitivity (signal/ conc) is the same for samples and standards
- Assumes that the signal arises only from the analytein most cases
- Does not account for sample matrixor instrumental drift

*Standard Addition:*

- Known amounts of analyte are added to aliquots of sample
- Signals are measured as a function of concentration added
- Accounts for sample matrix, but not for instrumental drift

# Error

- Error is the difference between the true value of the variable and the measured value.
- Errors are classified as

1. Gross error /Human error (human mistakes and instrument malfunctions)

2. Random errors (Noise/Interference)

3. Systematic errors (which may be either constant or variable)-Due to shortcoming of the instruments

# Random Errors

Associated to any measurement or electronic signal we find random, non -deterministic variations as the result of different sources:

- Electronic noise (Johnson, shot,..)
- Interference
- Even though interference is systematic ,for the easiness of modeling, it can be rendered as random.

All the random sources are independent.

# Gross error

- Instrumentation misuse, calculation errors and other human mistakes (mistakes in reading, recording )are the main source of Gross errors.
- Gross error mainly occur due to carelessness or lack of experience of a human being or incorrect adjustments of instruments .

- These errors can be minimized by
  - 1.Taking great care while taking reading, recordings and calculating results.
  - 2. Taking multiple readings preferably by different persons.

# Systematic errors

A constant uniform deviation in the operation of an instrument is known as systematic error.

- There are three types of systematic errors as
  - Instrumental errors
  - Environmental errors
  - Observational errors

# Systematic Errors

**Observational Errors**

Error introduced by the observer

- **Few souces are:**
  - Parallax error while reading the meter,
  - Wrong scale selection,
  - Habits of individual observer
- **Elimination**

Use the

  - instrument with mirrors,
  - instrument with knife edgepointers,
  - Instrument having digital display

# Systematic errors

## INSTRUMENTAL ERRORS

- **Misuse of instrument**

A good instrument if used in way gives abnormal misleading results.

- Poor initial adjustments,
- Improper zero setting,
- Using leads of high resistance .

**Elimination :** Use the instrument intelligently & Correctly

- **Loading effects**

Loading effects due to

- Improper way of using the instrument

**Elimination :** Use the instrument intelligently & Correctly

# Systematic Errors

- **Environmental Errors** (due to the External Conditions)
  - The various factors : Temperature changes, Pressure, vibratons , Thermal emf., stray capacitance, cross capacitance, effect of External fields, Aging of and Frequency sensitivity

# Error due to Other Factors

- ***Effect of the Time on Instruments***

  - There is a possibility of change in calibration error in the instrument with time . This may be called ageing of the instrument .

- ***Mechanical Error***

  - Friction between stationary and rotating parts and residual torsion in suspension wire cause errors in instruments . So, checking should be applied . Generally, these errors may be checked from time to time .

# Error Analysis

- Repeating Measurements
- Calculation of Mean and Standard Deviation
- The Gaussian distribution
- Propagation of Errors
- Significant Figures

# Error and Uncertainty

- It is important to distinguish between error and uncertainty .
- Error is defined as the difference between an individual result and the true value of the measurand.
- Error is a single value.
- In principle, the value of a known error can be applied as a correction to the result .
- Error is an idealized concept and a single number, which cannot be known exactly .
- Uncertainty takes the form of a range, and, if estimated from an analytical procedure and a defined sample type, may apply to all determinations so described .
- In general, the value of the uncertainty cannot be used to correct a measurement result .
- The difference between error and uncertainty should always be borne in mind.
- The result of a measurement after correction can unknowably be very close to the unknown value of the measurand, and thus have negligible error,
- Even though it may have a large uncertainty

# Uncertainty Analysis

- The estimate of the error is called the uncertainty .
  - It includes both bias and precision errors .
    - Identify all the potential significant errors for the instrument(s) .
  - All measurements should be given in three parts
    - Mean value
    - Uncertainty
    - Confidence interval on which that uncertainty is based (typically 95% C.I.)
- Uncertainty can be expressed in either absolute terms (i.e., 5 Volts ± 0.5 Volts) or in % terms (i.e., 5 Volts ± 10%)

(relative uncertainty = $\Delta V$ / V x 100)