Biosensors

B. Tech.

Course No.: EEL 3050

L-T-P [C]: 3–0–2 [4]

Prof. AJAY AGARWAL

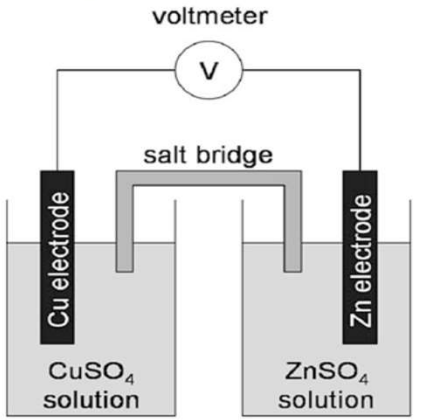
ELECTRICAL ENGINEERING

IIT JODHPUR

Lecture 25 dated 21st Oct. 2024

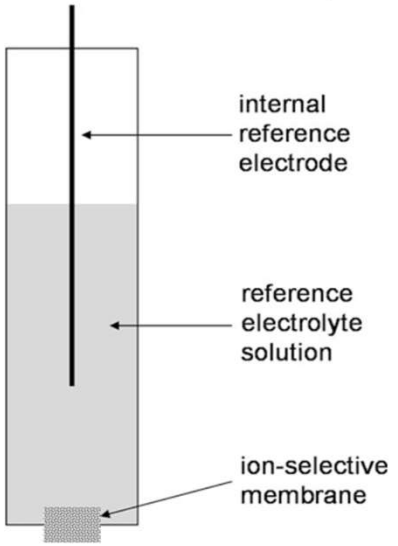
Ion-Selective Electrodes (ISEs; Potentiometric):

- The half-cells can be used to measure the concentration of a specific ion.
- When a half-cell is used for ion concentration measurement, it is called an ion-selective electrode (ISE).



Electrochemical cells with two **half-cells**

- The **electrolyte solution in the electrode** makes contact with the **surrounding liquid** through a membrane that allows only a specific type of ion to pass through.



Ion-selective electrode (ISE)

ISEs are classified in three types of membranes:

i. solid-state,
ii. liquid, and
iii. Glass membrane.

i. Solid-state ISEs contain a crystalline membrane that is cut from a single crystal.

- Ex., a fluoride ISE uses a solid crystal of LaF3, which allows only fluoride ions (F–) to pass through its membrane.
- The solid-state ISEs can also measure also include: Ag^{+}, Cl^{-}, Br^{-}, SCN^{-}, and S^{2-}.

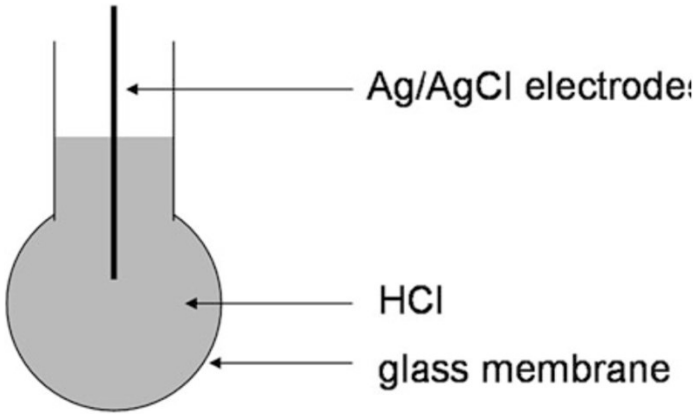
ii. Liquid membrane ISEs contain a plastic membrane, and the liquid ion-exchange material is absorbed into it.

- Vallinomycin-absorbed polyvinyl chloride (PVC) is an example of an ISE to selectively detect potassium ions (K+).
- Liquid membrane ISEs can be used for NO_3^{-}, Cu^{2+}, Cl^{-}, BF_4^{-}, ClO_4^{-}, & K^{+}.

iii. **Glass membrane ISEs** contain a membrane made from thin glass that is very specific to hydrogen ions (H^+).

- The usual composition of the glass employed for detecting H^+ is:
  22 % Na_2O, 6 % CaO, & 72 % SiO_2.
- Glass membrane ISEs, or simply glass electrodes, can be used to detect other types of ions, but they are primary used to measure H+, or in other words, **pH**.

- The **detection limit** of **ISEs** is very low, ranging between 10^{-8} to 10^{-11} M (10 nM to 10 pM) of target ions.
- ISEs are suitable for measuring low concentrations in **small sample volumes**; since they **do not chemically influence samples**.



A glass electrode

pH Electrode (Potentiometric):

- pH is a measure of H+ concentration.

$$pH = -\log a_{H^+} \approx -\log [H^+] \quad \ldots \quad (17)$$

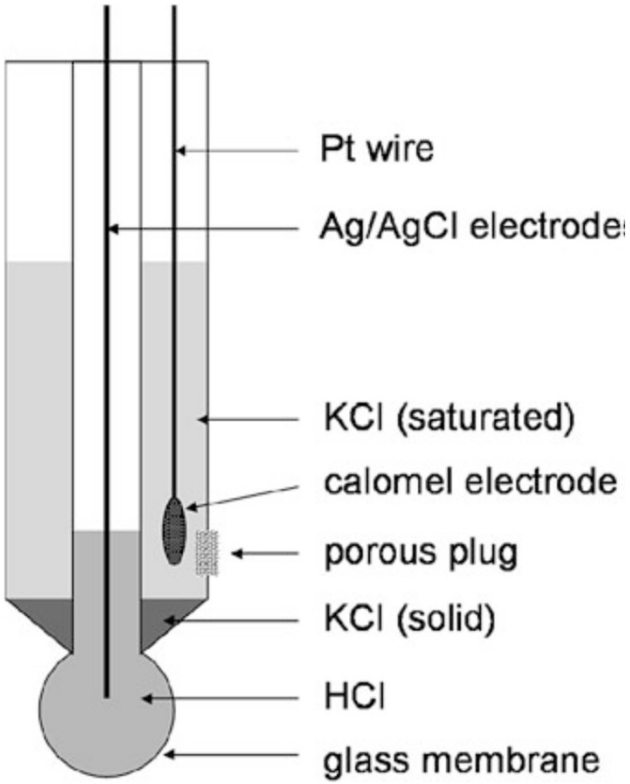
$$E = E^\circ + 0.059/n \times \log [M^+] \quad \ldots \quad (9)$$

Plugging Eq. 17 into Eq. 9 gives

$$E = E^\circ - 0.059 \times pH$$

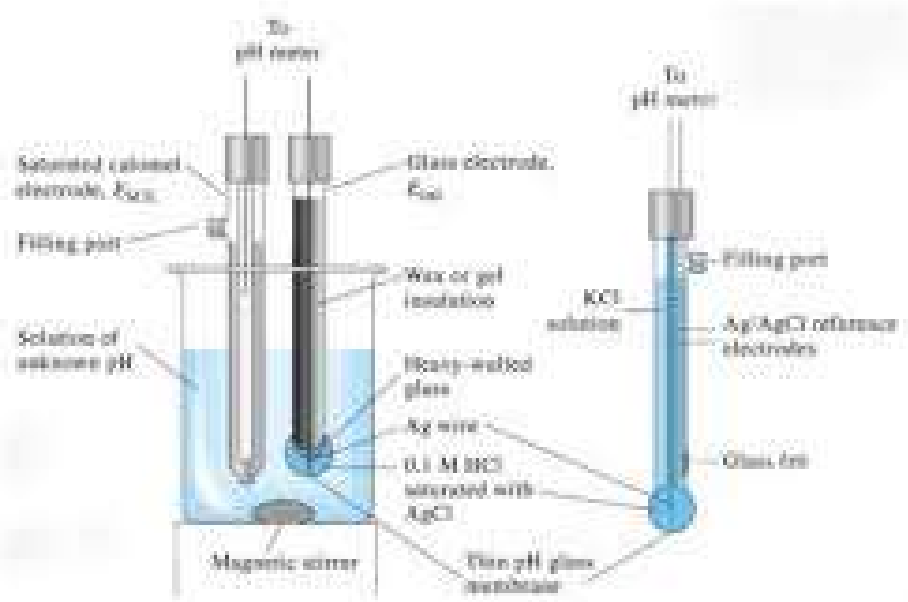
- That is voltage **decreases** by 0.059V or 59mV, per unit increase in pH
- A **glass electrode** is used to **measure pH** if an appropriate reference electrode is used.
- A **calomel** electrode is most frequently used as such reference.
- The two electrodes can be dipped into a soln., & the voltage difference between them can be measured, to evaluate the pH of the soln.

- the two electrodes are combined into a single electrode, known as a **combined pH electrode**
- At a neutral pH of 7, the combined pH electrode **generates 0 mV**.
- If the pH of the solution increases by a unit, the **voltage** can drop by 59 mV or vice versa
- the pH electrode produces 59 mV/pH unit, which is measured and displayed in pH units by the meter.
- The meter is a voltmeter that displays measurements in pH units instead of volts.
- pH electrodes generate a lot of noise, & 59 mV/pH output is low, an op-amp is required in order to construct a pH meter.



A combined pH electrode

pH meters:



Parts of a pH meter

Questions and Discussion?