Electrochemical sensors

Electrochemical sensors are devices that use electrochemical principles to detect and measure the concentration of specific chemicals in a solution. These sensors are widely used in various applications, including environmental monitoring, medical diagnostics, industrial process control, and consumer electronics. There are different types of electrochemical sensors, and two common categories are potentiometric and amperometric sensors.

Potentiometric sensors

Potentiometric sensors operate based on the measurement of the potential difference between two electrodes in an electrochemical cell. These sensors are commonly used to determine the concentration of ions in a solution. Here's a general overview of how potentiometric sensors work

- Potentiometric sensors consist of a working electrode and a reference electrode. The working electrode is sensitive to the ion being measured, while the reference electrode provides a stable and known potential against which the working electrode potential is measured.
- Common reference electrodes include the silver/silver chloride electrode (Ag/AgCl) or a saturated calomel electrode (SCE).
- The working electrode is often coated with an ion-selective membrane (ISM) that selectively interacts with the specific ion of interest. The ISM allows only the target ions to pass through, generating a potential difference.
- The potential difference between the working electrode and the reference electrode is measured in millivolts (mV). This potential difference is directly related to the concentration of the ion being measured.

Potentiometric sensors are widely used in glucose detection, especially in the development of glucose sensors for diabetes management. These sensors typically employ enzyme-based technology to measure the concentration of glucose in a biological sample.

- The enzymatic reaction between glucose and glucose oxidase generates H_2O_2:

  $$\text{Glucose} + O_2 \rightarrow \text{Gluconic Acid} + H_2O_2$$

The H_2O_2 generated is oxidized at the working electrode, leading to a potential difference. This potential difference is measured using a reference electrode, providing a signal that is proportional to the concentration of glucose in the sample.

Amperometric Sensors

Amperometric sensors operate based on the measurement of current flow in an electrochemical cell. These sensors are commonly used to detect and quantify the concentration of a specific analyte in a solution. The basic components of an amperometric sensor include a **working electrode**, a **reference electrode**, and a **counter electrode**

Working Electrode:

- The working electrode is typically made of a material that facilitates the electrochemical reaction with the target analyte.

Reference Electrode:

- The reference electrode is used to maintain a constant potential against which the working electrode potential is measured.
- Common reference electrodes include silver/silver chloride (Ag/AgCl) or saturated calomel electrode (SCE).

Counter Electrode:

- The counter electrode completes the electrical circuit and allows the current to flow between the working and reference electrodes. It is often made of an inert material, such as platinum.

The flow of electrons generated by the electrochemical reaction constitutes an electric current. This current is measured and is directly proportional to the concentration of the analyte.

Amperometric sensors are commonly employed in the detection of uric acid, a compound that is produced as a result of purine metabolism in the human body. Elevated levels of uric acid in the blood can be an indicator of conditions such as gout or kidney disorders.

Uricase is an enzyme commonly used in amperometric uric acid sensors. It catalyzes the oxidation of uric acid to form allantoin and hydrogen peroxide (H_2O_2):

$$\text{Uric Acid} + O_2 + H_2O \rightarrow \text{Allantoin} + H_2O_2$$

The H_2O_2 is then oxidized at the working electrode. The oxidation of H_2O_2 at the working electrode generates a measurable current. The magnitude of this current is directly proportional to the concentration of uric acid in the sample.