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Ion-Selective Electrode (ISE) Based on PVC Membrane Formed from Heterocyclic Quinazoline Compounds as Ionophore

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Abstract: Heterocyclic compound of S and N with cyclic structure like Furans, thiophenes and related azole analogs are important as ligand because of readily available, stable and easily functionalized. Among the various types of heterocyclic molecules quinazolines and their derivatives contain important chromophores with desirable electrochemical properties to be applied for application in sensor field. Metal complexes of these compounds have demonstrated significant electrochemical properties as ionophore or electroactive material for the fabrication of ISEs with different polymeric membranes. R. Selva Kumar, et al.; 2019 reported the use of dibutyl(8-hydroxyquinolin-2-yl)methylphosphonate as ionophore in PVC metrix for the fabrication of potentiometric thorium(IV) ion-selective electrode [1]. These quinazoline based membranes with other additives and plasticizers are very useful for the development of potential difference across the membrane in electrochemical sensing devices in required proportions [2-4]. Analytes such as Butralin, Hydroxylamine, Nitrite, heavy metal ions like Fe^{3+}, Th^{4+} have also been determined using quinazoline based membrane sensors. ISE based electrochemical sensors are very useful in analysis of food products, drinking water, beverages, fertilizers, soil industrial effluents etc. These alos finds application in potentiometric titrations as indicator electrode.

Keywords: Electrochemical Sensor; membrane electrode; Quinazoline; Heterocyclic

1. Introduction

An ion-selective electrode (ISE) based on a polyvinyl chloride (PVC) membrane is a type of electrochemical sensor used to measure the concentration of specific ions in a solution. The PVC membrane serves as the selective barrier that allows only the target ion to pass through and interact with the internal electrode. This type of electrode is widely used in various fields, including environmental monitoring, medical diagnostics, and industrial processes. Preparing an ion-selective electrode (ISE) involves several steps, including the creation of the PVC membrane, assembling the electrode, and performing calibration [1]. A general overview for the preparation of an ISE based on PVC membrane:

2. Materials and Equipment

- PVC polymer
- Ionophore specific to the target ion
- Plasticizer (e.g., dioctylphthalate)
- PVC solvent (e.g., tetrahydrofuran)
- Internal electrode (usually a silver or silver/silver chloride electrode)
- Reference electrode (e.g., Ag/AgCl electrode)

Preparation of PVC Membrane

1. Dissolve the PVC polymer in the solvent (tetrahydrofuran) to create a solution.
2. Add the ionophore specific to the target ion into the PVC solution. The ionophore concentration should be carefully chosen based on the desired sensitivity and selectivity of the electrode.
3. Add a plasticizer (e.g., tributylphthalate) to improve the flexibility and permeability of the membrane. The plasticizer helps to ensure the membrane is more responsive to ion changes.
4. Mix the PVC solution thoroughly to ensure uniform distribution of the ionophore and plasticizer.
5. Use a membrane solution casting equipment to apply a thin layer of the PVC membrane solution onto the surface of the internal electrode.
6. Allow the membrane to dry, creating a stable PVC membrane layer on the electrode.

The fabrication of ion-selective electrodes (ISEs) allows for the selective sensing of particular ions utilizing a variety of ionophores. One such class of ionophores that can be used to make ISEs for the specific identification of particular ions is heterocyclic quinazoline compounds. These compounds have structural characteristics that enable them to interact with certain ions in a selective manner [2]. Due to their capacity to selectively detect particular ions, ion-selective electrodes (ISEs) based on quinazoline compounds as ionophores have found uses in a variety of sectors. High selectivity, sensitivity, and stability for ion detection can be provided by quinazoline-based ISEs. Their chemical structure can be modified to impart selectivity for certain ions, making them suitable candidates for ion-selective membrane development. However, the use of quinazoline compounds as ionophores in ISEs would require careful design, synthesis, and characterization (Figure 1).

In previous studies, a method was developed by R. Selva Kumar and his co-workers in 2019 for the selective measurement of Th^{4+} was devised using dibutyl(8-hydroxyquinolin-2-yl)methylphosphonate as an ionophore, sodium tetraphenylborate (NaTPB) as excluder, and dioctyl phthalate (DOP) as a plasticizer. The PVC membrane composition produces the optimum electrode response for Th^{4+}: DOP: Ionophore: NaTPhB (33%: 59%: 4%: 4%, respectively). The electrode works well in the pH range of 4 to 6.5, has a response time of 5 s, a detection limit of 1 x 10^{8} M, and a service life of approximately three months [3].

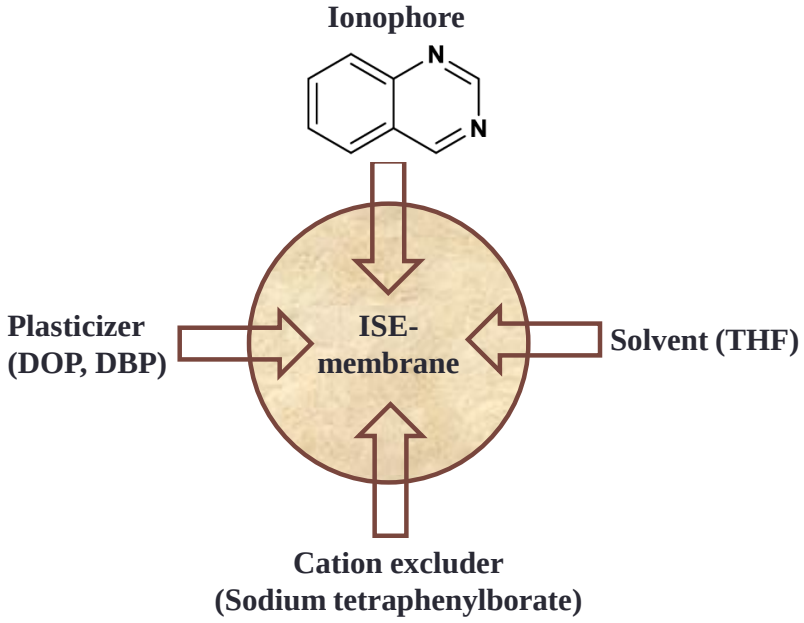

Figure 1. Ion-selective electrode (ISE) fabrication with Quinazoline ionophore in PVC.

In another study in 2007, Ganjali et al. developed a Th^{4+} ion-selective membrane sensor by using a poly (vinyl chloride) (PVC) matrix membrane that contained 2-(diphenylphosphorothioyl)-N′,N′-diphenyl acetamide (DPTD) as a carrier, potassium tetrakis (p-chlorophenyl) borate (KTpClPB) as anion excluder. The response time of the electrode was 30 s. The sensor worked in the pH range 3.0–9.0 for about 6 weeks of liletime [4].

Various other quinazoline compounds, for example Erlotinib, Gefitinib and different derivatives have been studied for their potential as kinase inhibitors, antitumor agents, antibacterial agents, and anti-inflammatory agents [5]. Researchers have explored the synthesis of diverse quinazoline compounds with varying substituents to modulate their properties for specific potential use as ionophores in ion-selective electrodes [6].

Here are some potential uses for ISEs built on ionophores based on quinazoline compounds:

Clinical Diagnostics

Measurement of blood electrolytes: Quinazoline-based ISEs can be used to measure ions like sodium, potassium, and calcium in blood samples, aiding in diagnosing and monitoring medical conditions such as electrolyte imbalances and kidney disorders.

Environmental Monitoring

Water quality assessment: Quinazoline-based ISEs can detect ions like heavy metals (e.g., lead, cadmium) and anions (e.g., nitrate, chloride) in water sources, contributing to environmental monitoring and pollution control efforts.

Pharmaceutical Analysis

Drug analysis: ISEs can be employed to determine the concentration of specific ions in pharmaceutical formulations, helping to ensure the quality and effectiveness of drugs.

Agriculture and Soil Analysis

Soil nutrient monitoring: Quinazoline-based ISEs can measure ions like potassium and ammonium in soil samples, aiding in optimizing agricultural practices and managing nutrient levels.

Food and Beverage Industry

Quality control: ISEs can be used to measure ions such as sodium, calcium, and chloride in food and beverage products, contributing to quality control and compliance with regulatory standards.

Biotechnology

Cell culture monitoring: Quinazoline-based ISEs can be integrated into bioreactors to monitor ion concentrations in cell culture media, helping to optimize conditions for cell growth and production.

Industrial Process Monitoring

Industrial process optimization: ISEs can be employed to monitor and control ion concentrations in industrial processes, such as wastewater treatment and chemical production.

The success of quinazoline-based ISEs in these applications relies on factors such as the selectivity of the chosen ionophore, the stability of the membrane, and proper calibration and maintenance procedures.

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