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HIGHLIGHTS

Recent development of ion-selective electrodes

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An ion-selective electrode (ISE) is a device to transduce the activity of a specific ion to the electrode potential based on the Nernst equation [1]. The most familiar ISE is a glass electrode having a selective response to the activity of the proton. Since ISEs enable the easier monitoring of components in solutions, the development of ISE is active in the environmental, industrial, agricultural, and clinical fields [2–4].

The simplest ISE for the anion is a metal electrode modified with its insoluble salt. The electrode potential responds to the activity of the anion in the solution such as the silver-silver chloride electrode [5]. Recently, a phosphate ISE constructed with a cobalt modified with its phosphate salt is reported [2, 6]. Since phosphate is a significant nutrient for plants, phosphate monitoring is important in agriculture. Molybdenum and tungsten electrode electrolyzed in phosphate buffer also have response to the phosphate [7, 8].

The normal ISEs contain an ion-sensitive membrane. The ion-sensitive membrane is a liquid membrane constructed with an organic matrix containing plasticizer, electrolyte, and ligands. The liquid membrane separates the inner solution containing the target ion at a certain concentration and the sample solution. Since the membrane also contains the target ion, the membrane potential is determined due to the activity ratio of the target ion in the sample and inner solutions. Therefore, the membrane containing hydrophobic salts of the target ion plays a role of an ion-sensitive membrane. For example, tetraazaannulene nickel complex salts provide the sensitivity of mono anion [9], tetraalkylammonium nitrate provides the sensitivity of nitrate [2, 3, 10, 11], tricaprylmethylammonium salt of bisphenols provides the sensitivity of bisphenol S [12] to the membrane. However, the membrane containing only the hydrophobic salt is weak for the pollution with hydrophobic ions [11].

The affinity and selectivity of ligand to the target ion determine the performance of ISE. Therefore, the exploration of effective ligands for solvent extraction is an important topic for the ISE investigation unintentionally, for example, hexaoctylnitrilotriacetamide for technetium (VII) [13]. The synergistic effect of ligands [14] will be important in the development of ISE.

Multiple ion monitoring is a hot topic in the recent ISE development. Simultaneous monitoring of nitrate and ammonium in water [3] is an important subject for quantification of the nitrogen cycle in the environment. The simultaneous monitoring of three major nutrients for the plants, that is, potassium, nitrate, and phosphate enables the automatic management of the hydroponic culture solution [2].

The existence of the inner solution in ISE limits the miniaturization and the lifetime of the sensor. Therefore, the development of the all-solid-type ISE has been vigorously investigated. In the all-solid-type ISE, the sensitive membrane is connected to a conductive material called solid contact. The solid contact employs to transduce the potential in the membrane as the electrode potential. Because the identification of the chemical reaction between the sensitive membrane and the solid contact is quite difficult, the conductive materials having large surface area such as carbon nanotube [12] are frequently used as the contact. Improvement of the stability of the all-solid-type ISE will require the elucidation of the interfacial reaction.

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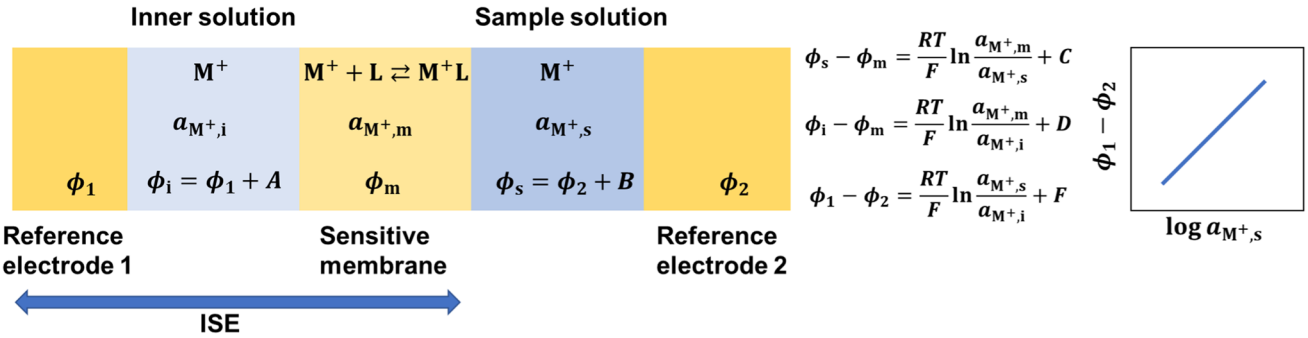

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