ISSN 1061-9348, Journal of Analytical Chemistry, 2019, Vol. 74, Suppl. 1, pp. S1–S10. © Pleiades Publishing, Ltd., 2019.
Russian Text © The Author(s), 2019, published in Zhurnal Analiticheskoi Khimii, 2019, Vol. 74, 7S, pp. S3–S15.

REVIEWS

New Directions in Using Ionic Liquids in Analytical Chemistry. 2: Electrochemical Methods

I. V. Pletnev[a], *, S. V. Smirnova[a], and N. V. Shvedene[a]

[a] *Department of Chemistry, Moscow State University, Moscow, 119991 Russia*

**e-mail: pletnev@analyt.chem.msu.ru*

Received February 27, 2018; revised April 10, 2018; accepted January 26, 2019

Abstract—The second, final part of the review. The use of ionic liquids in voltammetry and amperometry as organic electrolytes for carrying out electrochemical processes, extraction, and voltammetric analysis and for the development of composite materials and the creation of electrochemical sensors is discussed. The most important use of ionic liquids for modifying electrode membranes is considered: as an inert matrices allowing the immobilization of ionophore components and also as ionophore components of membranes of liquid-based and solid-state ion-selective electrodes.

Keywords: ionic liquids, voltammetry, amperometry, ion-selective electrodes

DOI: 10.1134/S1061934819070177

The high dissolving power, non-volatility, high conductivity and thermal stability, and a wide electrochemical "window" and electrochemical stability—all these properties make ILs attractive for use in electrochemical methods of analysis. We can note the following directions of using ILs [1]:

- as organic electrolytes for carrying out electrochemical processes difficult-to-implement in usual solvents;
- for extraction and voltammetric determinations;
- in the development of composite materials and the creation of electrochemical sensors (conductive polymers, conductive gels, etc.);
- for modifying of electrode membranes.

VOLTAMMETRY AND AMPEROMETRY

Recently more and more publications have appeared on the use of ionic liquids in voltammetry. The width of the electrochemical "window" of ILs is determined by the nature of ions forming the IL and also by the material of the used indicator electrode. In using ILs as organic supporting electrolytes, one should take into account that, at high potentials, electrodes made of carbon materials can interact with fluorinated anions of the IL. In addition, the width of the "window" is affected by the impurity of water and the presence of foreign easily oxidized substances in the IL. Studies on the use of ILs as media for the investigation of complex electrochemical processes were conducted. A wide range of potentials of conducting ILs ensures the investigation of diverse redox reactions in their media. Information in this direction we summarized in the review [1], which covered publications up to 2007. In this review, we will dwell on the works of the last years. In general, let us note that, in recent years, the use of ILs in voltammetry has been concentrated on the study of properties and potentials of modified electrodes made of different materials.

Cyclic voltammetry on a graphite electrode was described for studying electrochemical properties of lutetium bisphthalocyanine ($LuPc_2$) in the medium of an IL and tetraoctylphosphonium bromide [2]. A mixture of an IL with $LuPc_2$ was applied onto a graphite electrode, and a film was obtained on the electrode surface after drying. Tetraoctylphosphonium bromide is a viscous, gel-like ionic liquid acting as a matrix containing $LuPc_2$. The modified electrode was immersed in an aqueous solution and the electric transformation of $LuPc_2$ was investigated depending on the nature and concentration of anions in the aqueous solution: ClO_4^-, Br^-, or Cl^-. The conducted research using an electrode modified by a IL + $LuPc_2$ film indicated that the stage determining the rate of electric transformation of $LuPc_2$ at the interface organic phase–aqueous solution was the transfer of ions from the aqueous phase to the IL.

Ionic liquids are finding more and more wide application as matrices in the creation of amperometric sensors. They are usually used in combination with various compounds: polymers, cellulose, carbon nanotubes, metal nanoparticles, or graphene.

The first work with the description of a composite based on ILs and carbon nanotubes was published in 2003 by Japanese researchers [3]. As a rule, nanotubes