Self-organizing structures of sodium bis-(2-ethylhexyl)phosphate and lecithin in water-oil-surfactant systems and functional nanomaterials based on them

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Abstract

Relevance of the work. Self-organizing nanostructures of surfactants, such as micelles, microemulsions (ME), and lyotropic liquid crystals (LC), are promising media for chemical technology and medicine. They are thermodynamically stable and form spontaneously, which greatly facilitates the industrial production of such structures with well reproducible properties. On the basis of self-organizing surfactant structures, it is possible to create functional nanomaterials by introducing reagents into their composition (for example, extractants, reagents for chemical reactions, biologically active substances, etc.). Micellar systems, ME, and lyotropic LC can promote better compatibility of polar and non-polar substances, playing the role of a “universal solvent”, affect the rate and selectivity of chemical reactions, and also play the role of templates in the synthesis of nanoparticles of a certain shape. The list of existing and possible areas of application of self-organizing surfactant nanostructures includes cleaning surfaces from contaminants, increasing oil recovery of wells, targeted delivery of drugs, cosmetics, food industry, polymerization reactions, synthesis of inorganic nanoparticles, separation of substances in analytical chemistry, processes of liquid extraction of inorganic and organic substances.

Self-organizing surfactant nanostructures can be used to solve the urgent problem of creating new energy- and resource-efficient technologies, including solation and separation of substances in chemical technology and hydrometallurgy. Microemulsions based on salts of the well-known industrial extractant bis-(2-ethylhexyl)phosphoric acid (DEHPA), for example, sodium bis-(2-ethylhexyl)phosphate (NaDEHP), are promising for the development of functional nanomaterials for the isolation and separation of metal compounds.

In medicine, one of the urgent tasks is the development of carriers for targeted delivery of drugs. Self-organizing nanostructures of lecithin, a common surfactant of natural origin, can be used to create functional nanomaterials intended for targeted delivery of drugs. Nanomaterials for medicine based on lecithin have such advantages as biocompatibility, the ability to solubilize biologically active substances while maintaining their activity, and the ability to accelerate transport through the skin. Unlike liposomes, ME, micelles, and LC are lyophilic colloidal systems; they form spontaneously when the necessary components are mixed. Since

they contain an aqueous and oil phase, their advantage is the possibility of including both water- and oil-soluble medicinal substances.

The aim of this work is to develop colloid-chemical foundations for creating functional nanomaterials for leaching of metals from oxide raw materials and for transdermal delivery of drugs based on self-organizing structures in systems sodium bis-(2-ethylhexyl)phosphate - oil - water and lecithin - oil - water.

Tasks:

• analysis of the effect of extractants of various nature (bis-(2-ethylhexyl)phosphoric acid and tributyl phosphate) on the properties of microemulsions of sodium bis-(2-ethylhexyl) phosphate;

• development of a method of metal leaching using extractant-containing microemulsions;

• development of lecithin microemulsions with oleic acid as a cosurfactant;

• development of self-organizing structures in lecithin - oil - water systems (organogels, microemulsions and lyotropic liquid crystals) as carriers for transdermal drug delivery based on commercial lecithin samples.

Scientific novelty

It has been shown that the effect of the acidic extractant DEHPA on the region of existence and properties of NaDEHP microemulsion in decane and in kerosene manifests itself in two ways, depending on its concentration: at low concentrations, it acts as a co-surfactant, promoting the formation of a reverse microemulsion; at high concentrations, its action as a second solvent that prevents the formation of a microemulsion prevails. For a neutral extractant tributyl phosphate (TBP), the effect on the region of existence and electrical conductivity of the microemulsion is less pronounced than for DEHPA.

For the first time it was proposed to use extractant-containing microemulsions for metal leaching. The method of microemulsion leaching involves the selective extraction of metals from solid-phase raw materials by contacting it with an extractant-containing microemulsion, which makes it possible to combine leaching and extraction in one process.

On the example of a model system with CuO, it was found that the rate of copper extraction into the reverse NaDEHP microemulsion in kerosene increases significantly with an increase in the concentration of the extractant and temperature, for a microemulsion with an extractant DEHPA, the extraction of copper proceeds with the formation of $Cu(DEHP)_2$.

It has been shown that a reverse microemulsion with a droplet size of a few nm exists in the system lecithin - oleic acid - dodecane - water at a molar concentration ratio of $C_{oleic\ acid}/C_{lecithin} > 0.6$, the region of its existence is determined at $C_{oleic\ acid}/C_{lecithin} = 0.8$.

For the first time, the formation of lecithin organogels was established in systems containing saturated aliphatic hydrocarbons and lecithin with a low degree of purification: soy lecithin with 69.3 wt% purity (gelation in n-alkanes C8-C16), 52.9 wt% (gelation in dodecane and hexadecane) and 40 wt% (gelation in vaseline oil). An increase in the concentration of impurities of other phospholipids in lecithin leads to an expansion of the region of existence of the organogel and a decrease in its viscosity.

Practical significance

Compositions of extractant-containing microemulsions have been developed in the systems NaDEHP - DEHPA - kerosene - water and NaDEHP - a mixture of TBP and acetic acid - kerosene - water for leaching of non-ferrous metals from oxide raw materials of natural or technogenic origin. On samples of oxidized cobalt-copper concentrate and copper-containing galvanic sludge, the possibility of extracting of non-ferrous metals, including selective extracting, into an extractant-containing microemulsion was shown.

Nanostructured materials for transdermal delivery of drugs based on soy lecithin with low purity have been developed: lecithin organogels in the system lecithin – vaseline oil - water, lyotropic LC in the systems lecithin - vaseline oil - water and lecithin - fatty vegetable oil - essential oil - water and ME in the system lecithin - oleic acid - vaseline oil - fatty vegetable oil - essential oil – water.

Together with the Hematological Scientific Center of RAS, a remedy for the prevention of thrombosis and improvement of peripheral circulation based on lecithin organogel in vaseline oil has been developed; together with Gorbatov Federal Research Center of Food Systems of RAS, the possibility of using reverse microemulsions and lamellar liquid crystals of lecithin as a basis for wound healing medicines containing a protein-peptide extract has been shown.

On the basis of the data obtained, the laboratory work "Phospholipid nanostructures in the lecithin - oil - water system" was developed and introduced into the educational process for bachelor students at the Department of Nanomaterials and Nanotechnology of the Mendeleev University of Chemical Technology of Russia.

Provisions for defense:

• influence of extractants D2EHPA and TBP on the structure and properties of ME D2EHPNa;

• method of microemulsion leaching of metals from oxide raw materials;

• microemulsions in systems lecithin - oleic acid - oil – water;

• organogels, ME and LC based on commercial preparations of lecithin with low purity as nanomaterials for transdermal drug delivery.