207

Organic-inorganic ion-exchanger containing zirconium hydrophosphate for removal of UO_2^{2+} cations from water

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Organic-inorganic materials based on gel-like strongly acidic resin containing zirconium hydrophosphate have been synthesized. The synthesis method allows us to control purposefully composition of the inorganic constituent as well as a size of incorporated particles (up to 0.2–1 μm), which consist of nanoparticles (10–20 nm). Fractal analysis of SEM and TEM images of the composites gives fractal dimension of the aggregates of ≈2.5. Thus, the DLA model can be applied to the particle formation indicating diffusion of the nanoparticles as a rate-determining stage of zirconium hydrophosphate precipitation inside the polymer. Diffusion is controlled by the Fick's law, at the same time, the diffusion coefficients obeys Stokes equation. At last, certain radius of the nanoparticles is described quantitatively by the Ostwald-Freundlich equation. Combination of mentioned formulas followed by their adapting to ion exchange matrix gives a possibility to determine optimal conditions for obtaining of incorporated particles of certain size. For instance, a type of the compound, which is precipitated, as well as the solvent and ion exchange matrix affect a size of the incorporated particles.

Chemical composition of the particles depends on their location in one or another pores of the polymer, which have been recognized using a method of standard contact porosimetry. The synthesis procedure provides formation of the inorganic constituent containing both (di)hydrophosphate and –OH groups, which are responsible cation and anion exchange respectively. In owing to this, the composites demonstrate considerable sorption activity towards uranium(VI) compounds in a wide pH diapason (2–10). A small size of the inorganic particles provides high sorption rate, which is determined by film diffusion or particle diffusion similarly to ion exchange resins. This is an advantage of the composites in a comparison with the inorganic ion-exchangers like zirconium hydrophosphate. Sorption of uranium(VI) compounds on the materials of this type is complicated by chemical reaction, which is described by models of preudo-first and preudo-second orders. Thus, sorption rate on the organic-inorganic on-exchangers are determined by the polymer constituent. At the same time, sorption of U(VI) in a presence of Fe^{3+} ions is accompanied by chemical interaction. Probably this interaction is displacement of Fe^{3+} cations from undissociated ions pairs with functional groups of ion-exchangers (both polymer and inorganic ones). The composites show higher sorption rate in a comparison with the pristine resin. This is evidently caused by faster ion transport in the polymer constituent due to more regular structure of clusters, where functional groups are