Nanocomposites based on polymer and inorganic matrices for removal of soluble uranium compounds from aqueous solutions

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Introduction

The maximal permissible concentration for uranium in a form of soluble compounds is 0.015 mg dm^{-3}, even lower values are recommended due to radioactivity and toxicity of this element. In order to reach this level, adsorption and ion exchange are the most suitable. However, the removal rate is very slow for selective sorbents (inorganic materials or chelate resins), their regeneration is difficult. Strongly acidic or strongly basic ion-exchange resins demonstrate high sorption rate but no selectivity. A solution of the problem is incorporation of small inorganic particles into polymer sorbents, such as ion-exchange resins.

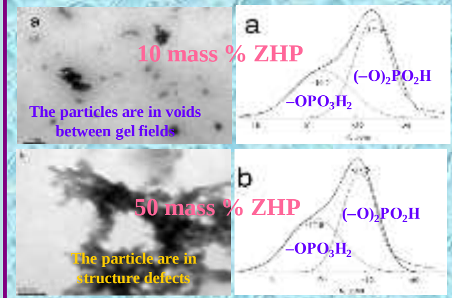
Experimental

A Dowex HCR-S gel-like strongly acidic resin was modified with zirconium hydrophosphate (ZHP). Solutions containing U(VI) and HCl were used as sorbates. These solutions containing UO_2^{2+} cations are formed during recycling of monazite minerals. ZHP sorbent was also used.

Methods

- Standard contact porosimetry (for investigations of the polymer constituent);
- NMR ^{31}P, X-ray fluorescence analysis, trans-mission electron microscopy (for investigations of the inorganic constituent).

Results and discussion

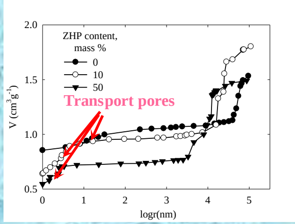


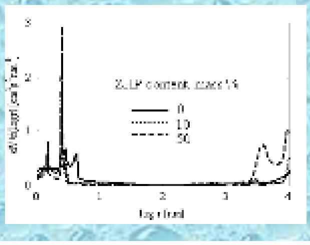
Increasing in ZHP content in the polymer causes higher molar ratios of Zr:P and dihydrogen phosphate and hydrogen phosphate groups.

Characteristics of sorbents

Modification features		ZHP morphology		ZHP amount, mass %	Molar ratio of Zr:P	Grain diameter, mm
Cycles	$ZrOCl_2$ before ZHP precipitation	Dominant particles (size, nm)	Size of nanopar-ticles, nm			
–	–	–		0	–	0.53
1	Removed	Aggregates (up to 200-300 along minor axis)	≈50	10	1:0.30	0.63
1	Not removed	Aggregates (up to 200) and agglomerates (several microns)	≈20	50	1:0.43	0.88
7	Removed	Aggregates (up to 300)	≈80	15	1:0.25	0.64

Integral and differential pore size distributions





Increasing in ZHP content in the polymer causes reducing of water content in the polymer and squeezing of transport pores. However, the particles in voids between gel fields (small amount of ZHP) impart functional properties of ZHP to the composite – sorption is complicated by chemical interaction of UO_2^{2+} species with phosphate groups.

UO_2^{2+} and Fe(III) sorption

Multicomponent modeling solution of following composition (mol/dm^3) were investigated: U(VI) (2.1×10^{-4}), Fe(III) (4.5×10^{-3}), HCl (0.02).

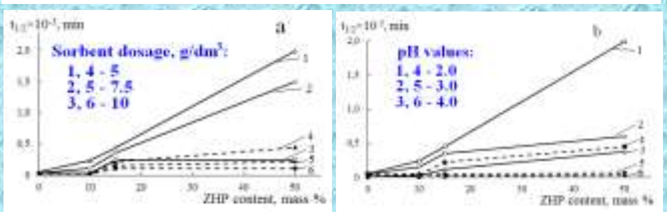


Fig. Half-time of U(VI) (1-3) and Fe(III) (4-6) exchange as a function of ZHP content in the polymer (a, b).

Incorporated ZHP particles slow down ion exchange of both Fe(III) and U(VI) species evidently due to transformation of porous structure of the polymer constituent, increase of grain size of the composites and interaction of ions with functional groups of ZHP. Increasing of the sorbent dosage and solution pH results to decreasing in the values for Fe(III) and U(VI).

Conclusions

ZHP particles in voids between gel fields of the polymer (up to 200-300 nm) are characterized by the lowest molar ratios of $-OPO_3H_2$ and $(O)_2PO_2H$ groups. Moreover, U(VI) sorption from multicomponent solutions on the composites with lower content of the inorganic constituent is faster, higher sorption degree is realized.

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