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Synthesis and characterization of a novel hybrid material titanium amino tris(methylenephosphonic acid) and its application as a cation exchanger

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Abstract

In the present work, a novel hybrid ion-exchange material was synthesized by a sol–gel route, by treating titanium tetrachloride with claw-type amino tris(methylenephosphonic acid) (ATMP) to give titanium amino tris(methylenephosphonic acid) (Ti-ATMP). Ti-ATMP was characterized by elemental analysis (ICP-AES and C, H, N analysis), spectral analysis (FTIR), thermal analysis (TGA), XRD, SEM, and EDX spectroscopy, including physicochemical and ion-exchange characteristics. The equilibrium exchange of transition-metal ions (viz., Cu2+, Ni2+, Co2+ Zn2+) and heavy-metal ions (viz., Pb2+,Cd2+, Hg2+) with the H+ ions contained in ATMP was studied at constant ionic strength and varying temperatures, and various thermodynamic parameters such as the equilibrium constant (K), standard Gibbs free energy (ΔG°), enthalpy (ΔH°), and entropy (ΔS°) were evaluated. The Nernst–Planck equation was used to study the ion-exchange kinetics, and various kinetic parameters, namely, the self-diffusion coefficient (D0), energy of activation (Ea), and entropy of activation (ΔS*), were evaluated under conditions favoring a particle-diffusion-controlled mechanism. Metal-ion adsorptions with variations in concentration and temperature were studied using the Langmuir and Freundlich adsorption isotherms. The distribution coefficient (Kd) and breakthrough capacity (BTC) values for transition- and heavy-metal ions were determined. Based on Kd (mL·g–1), the selectivity order for metal ions toward Ti-ATMP was found to be Cu2+ (19820) > Zn2+(3280) > Co2+ (2630) > Ni2+ (2390) among transition-metal ions and Pb2+ (3590) > Cd2+ (2340) > Hg2+ (610) among the heavy-metal ions. The elution behavior of these metal ions was studied using different acids and electrolytes. A study on regeneration and reuse of the ion exchanger Ti-ATMP shows that it is effective up to five cycles without much decline in performance, which indicates that Ti-ATMP has good potential for use as a cation exchanger.

Keywords: methylenephosphonic; Freundlich