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Effective removal of trace antimony(III) from aqueous solution by phosphonic acid-functionalized hollow mesoporous silica spheres as a novel adsorbent

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ABSTRACT

This study focused on the preparation of phosphonic acid-functionalized hollow mesoporous silica spheres (PHMSs) and their adsorption performance of trace antimony(III) from water under room temperature. Firstly, monodisperse carbon microspheres (CS) synthesized by the glucose-oxygen hydrothermal method was used as the hard template, and cetyltrimethylammonium bromide as the soft template to synthesize hollow mesoporous silica spheres (HMSs). Then, phosphate groups were grafted by the post-grafting method to synthesize PHMSs. The characterization of the materials was investigated by scanning electron microscopy, Fourier-transform infrared spectroscopy, transmission electron microscopy methods, and Beckman Laser laser particle size analyzer. The results showed that PHMSs have a regular mesoporous structure, monodisperse particle size distribution, and a stable shell-core structure. The CS synthesized in this study with glucose precursors is superior in the uniformity of particle size to sucrose and starch precursors. The addition of ammonia could accelerate the hydrothermal polymerization of carbon microspheres during the hydrothermal reaction. The reducing conditions provided by the hydrothermal heat promoted the carbonization reaction and increased the average particle size of the carbon microspheres from 395 nm to 11.5 μm. The average pore size of the synthesized HMSs is 2.5 nm. The hollowness of the hollow spheres can be controlled by adjusting the particle size of the hard template. The content of each component in the reaction system has a great influence on the shell thickness and pore size of the formed HMSs. Infrared spectroscopy showed that on the surface of HMSs, the phosphate groups were highly compatible with the silanol groups. The adsorption experiment results showed that PHMSs have high adsorption of Sb(III) with an initial concentration of 100 μg L^{-1} and can be used as an effective adsorbent for trace amounts of antimony(III) in water. The maximum adsorption capacity is 87.46 mg g^{-1}, the maximum removal rate is 96.02% and the adsorption equilibrium time is 6 h. The fitting degree of the Langmuir equation is 99.96%, indicating that the chemical adsorption is the main adsorption mechanism.

Keywords: Trace antimony(III) adsorption; Hollow mesoporous silica spheres; Phosphonic acid-functionalized silica; Hard and soft templet method

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