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层状金属硫属化物对水中锌的离子交换性能研究

Ion exchange property of layered metal chalcogenide for Zn^{2+} removal in water

关键词：金属硫属化物 离子交换 锌离子 动力学 等温模型

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摘要：通过水热反应制备的层状金属硫属化物$K_{1.9}Mn_{0.95}Sn_{2.02}S_6$(KMS),对水中$Zn^{2+}$具有良好的吸附性能.采用X射线衍射仪(XRD)、场发射扫描电镜(FE-SEM)和能谱仪(EDS)等手段表征了KMS吸附前后的结构、化学组成和微观形貌.Zn^{2+}与K^+发生离子交换后,会与硫产生共价键作用而被吸附,材料的层间距由0.851 nm变为1.123 nm.化学吸附导致吸附后的KMS表面会变得粗糙.考察了pH、反应时间、初始浓度、反应温度和共存离子等因素对KMS吸附Zn^{2+}的影响.在pH=3~6之间,溶液的pH对吸附量没有明显影响.在不同温度下,动力学数据符合准二级动力学模型,而且速率控制步骤主要由液膜扩散控制.吸附过程的活化能为40.24 kJ · mol^{-1}.在10 ℃、25 ℃和40 ℃下,KMS对Zn^{2+}的最大吸附量分别是:111.67 mg · g^{-1}、142.91 mg · g^{-1}和161.02 mg · g^{-1}.Langmuir等温吸附模型可以用来描述吸附平衡过程.碱金属和碱土金属离子对Zn^{2+}去除率的影响较小,影响顺序是Ca^{2+}> Mg^{2+}> Na^+,而重金属离子对Zn^{2+}的去除影响较大,影响顺序是Cd^{2+} >Pb^{2+} >Cu^{2+} >Ni^{2+}.离子交换后的KMS不会再释放出Zn^{2+},可以作为一种永久储存重金属的废弃物.

Abstract：Hydrothermally synthesized layered metal chalcogenide, $K_{1.9}Mn_{0.95}Sn_{2.02}S_6$ (KMS), exhibited excellent adsorption properties for Zn^{2+} removal in water. X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM) and energy dispersive spectrometer (EDS) were used to characterize the crystal structure, chemical composition and micro-morphologies of KMS before and after adsorption. Zn^{2+} can covalently bind with the sulfur atoms after exchanged with K^+. The interlayer spacing of KMS was changed from 0.851 nm to 1.123 nm after adsorption. The surface of KMS after adsorption became coarse which might be resulted from the chemical adsorption. The effects of pH, reaction time, initial concentration, reaction temperature and coexisting ions on Zn^{2+} removal by KMS were investigated. The pH had no obvious effect on the adsorption capacity in the range of 3 to 6. Kinetic data fit well to a pseudo-second-order kinetic model and the rate controlling step was mainly controlled by external film diffusion at different temperatures. The activation energy for the adsorption process was calculated to be 40.24 kJ · mol^{-1}. The maximum adsorption capacity of KMS at temperature of 10 ℃, 25 ℃ and 40 ℃ were 111.67 mg · g^{-1}, 142.91 mg · g^{-1} and 161.02 mg · g^{-1}, respectively. The Langmuir adsorption isotherm was used to fit the adsorption equilibrium process. The alkaline and alkaline earth metal ions had slight effect on the removal efficiency of Zn^{2+} and the degree of inhibition followed the sequence: Ca^{2+} >Mg^{2+} >Na^+. The heavy metal ions had great effect on the removal efficiency of Zn^{2+} and the degree of inhibition followed the sequence: Cd^{2+}> Pb^{2+}> Cu^{2+}> Ni^{2+}. The exchanged KMS can be considered as an excellent permanent waste form without the leaching risk of Zn^{2+}.

Key words：metal chalcogenide ion exchange Zn^{2+} kinetics isothermal model

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