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Rubidium and cesium ion adsorption by an ammonium molybdophosphate–calcium alginate composite adsorbent

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ABSTRACT

A composite spherical adsorbent was prepared with ammonium molybdophosphate (AMP), sodium alginate (NaALG), and calcium chloride. Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used to characterize the composite adsorbent. The adsorption of rubidium and cesium ions onto the composite adsorbent in aqueous solutions was investigated comprehensively by varying the initial metal ion concentration, pH, ionic strength, and temperature. The adsorption kinetics of both rubidium and cesium was described by the first-order and second-order kinetic models. The second-order rate constant and the initial adsorption rate increase with increasing temperature. In general, the equilibrium adsorption amount of both rubidium and cesium increases with the increase in initial metal ion concentration, but decreases with increasing ionic strength and temperature. Maximum adsorption of rubidium and cesium occurs in the solution with an equilibrium pH value of 3.5–4.5. Under similar conditions, cesium shows a higher adsorption amount than rubidium. The composite adsorbent is easy to prepare and highly porous. It has a fast adsorption rate and an adsorption capacity of 0.58 and 0.69 mmol g^{-1} for rubidium and cesium, respectively. The composite adsorbent is effective for the adsorption of rubidium or cesium ions from solutions containing some other alkali metal ions, such as sodium ions.

1. Introduction

Rubidium and cesium metal and compounds have special chemical and physical properties. They have been used in fiber optic telecommunication systems, night-vision equipments, and metal-ion catalysts [1–3]. In addition, rubidium and cesium have close relationship to human health [4]. In recent years, rubidium and cesium have been applied extensively to some new technical fields, such as new materials and new energy [3,5,6]. It is well known that rubidium and cesium resources are rare all over the world. With the increase in demands, the price of rubidium and cesium metals and compounds is increasing [7]. So the research on rubidium and cesium is attracting more and more attention [8–13].

Brine is one of the important rubidium and cesium resources. The abundance of rubidium and cesium in brine depends on the brine types. China is very rich in brine resources. Some works have been carried out on the determination methods of rubidium and cesium in brine or oilfield water, and on the phase chemistry of rubidium or cesium containing systems [14–18]. However, because of the close similarity in the physical and chemical properties of sodium, potassium, rubidium, and cesium, the separation of rubidium and cesium from the systems containing mixed alkali metal ions, such as brine systems is difficult. Therefore, the development of a simple, inexpensive, and practical method for the separation of rubidium and cesium from brine is very important.

Inorganic exchangers have specific selectivity, exceptional stability and resistance to temperature and radiation [19,20]. Inorganic exchangers based on heteropoly acid salts show selective ion exchange behavior towards cesium [21–23], in which ammonium molybdophosphate (AMP) is specific for cesium adsorption from salt loaded solutions [24]. The main disadvantage of AMP is its microcrystalline structure, which makes the column operation difficult [25,26]. Some researchers handled this problem by binding AMP with organic polymer [27–30], silica gel [25], Al_2O_3 [31], and zirconium phosphate [32]. However, the binding is not so easy.

Biopolymer alginates are good matrix materials. The gel-forming property of alginates has led to their extensive use in biomedicine and biotechnology to immobilize or encapsulate enzymes and living cells [33]. Thus the prominent immobilizing

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Table 1
Adsorption experimental conditions.

Experiments	Initial RbCl or CsCl concentration ($mol\,L^{-1}$)	Solution pH adjustment	NaCl concentration ($mol\,L^{-1}$)	Temperature (°C)
Adsorption kinetics	0.006, 0.008, 0.01	Not adjusted	0	25, 40, 55
Effect of solution pH on the equilibrium adsorption amount	0.01	Adjusted with HCl or NaOH solutions	0	25
Effect of ionic strength on the equilibrium adsorption amount	0.01	Not adjusted	0, 0.01, 0.02, 0.05, 0.1, 0.5, 1, 1.5, 2, 2.5	25
Adsorption isotherms	0.001, 0.002, 0.003,. . ., 0.01	Not adjusted	0	25, 40, 55

ability of alginates would be effective for the granulation of fine AMP particles.

In the present study, calcium alginate is selected as a binder to prepare AMP composite adsorbent. This adsorbent was used to adsorb rubidium and cesium from solutions. The adsorption kinetics and equilibrium under various experimental conditions were studied. Pseudo first-order and pseudo second-order models were used to analyze the adsorption kinetics. The Langmuir and Freundlich isotherms were used to fit the adsorption equilibrium data. The results obtained would be helpful for the understanding of the adsorption process and for the adsorption separation of rubidium and cesium ions from brines.

2. Experimental

2.1. Preparation of the composite spherical adsorbent

4 g ammonium molybdophosphate (AMP, Tianjin Kermel Chemical Reagent Co., Ltd., China), 2 g sodium alginate (NaALG, Tianjin

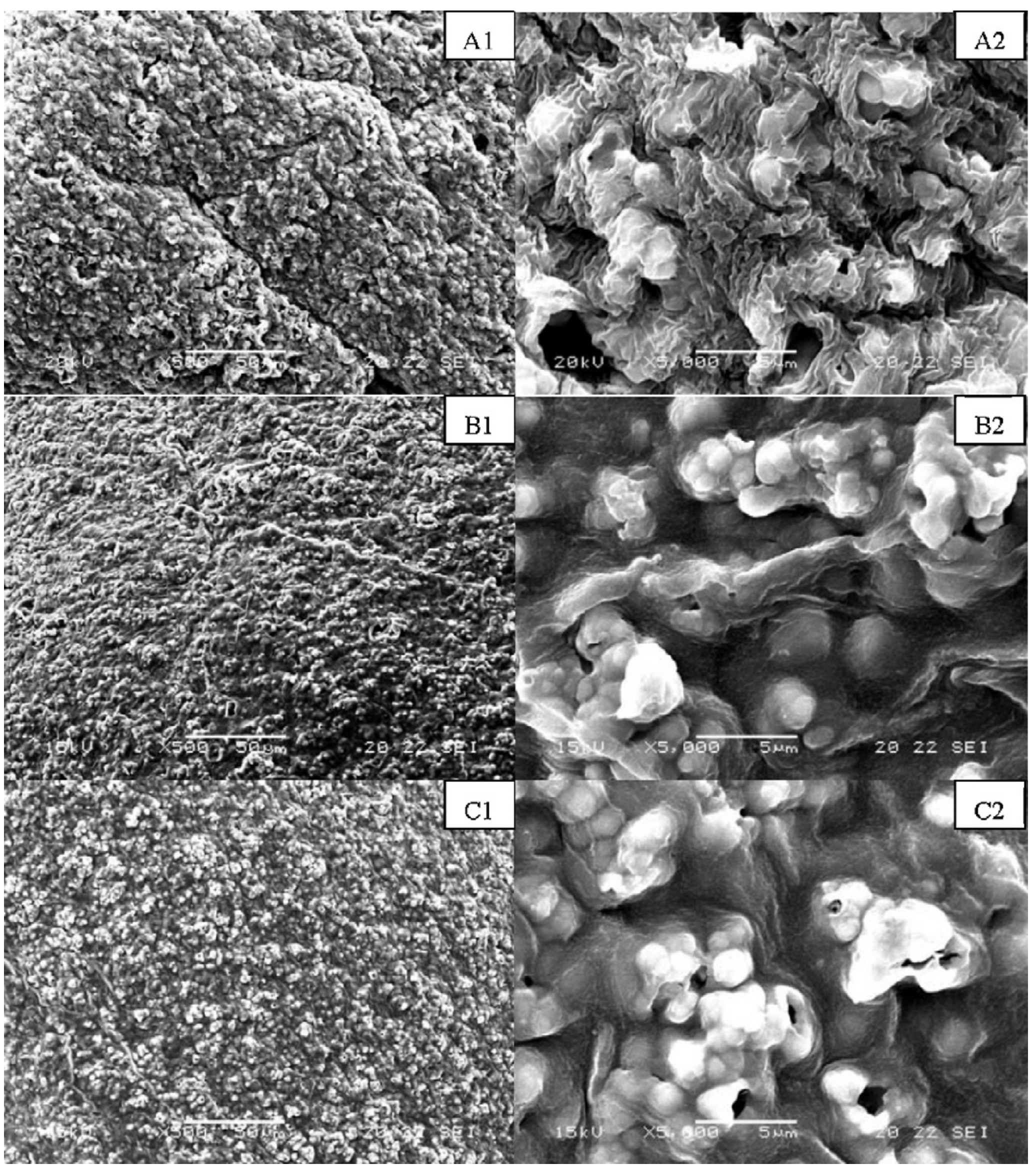

Fig. 1. SEM images of the composite adsorbent. (A) Before adsorption; (B) after adsorption of rubidium; (C) after adsorption of cesium.