A novel adsorbent for Sr2+ prepared by grafting the DB18C6 on D564 resins

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Abstract. A novel adsorbent was prepared by grafted the Dibenzo-18-Crown-6-Ether (DB18C6) on D564 resins and characterized by Thermogravimetry (TG) and Fourier Transform Infrared Spectroscopy (FTIR). Adsorption of Sr^{2+} from aqueous solutions was investigated in batch method as a function of contact time, concentration of Sr^{2+} and pH of the solution. It is found that the adsorbent has good selectivity for Sr^{2+}. The efficient adsorption of Sr^{2+} is obtained at pH 5-6 before adsorption or pH 7-8 after adsorption. And the adsorption amount increases with the Sr^{2+} concentration and decreases with the temperature of the solution.

1. Introduction

Strontium and its compounds have numerous industrial applications and they are typical fission products resulting from nuclear reactions[1]. Radioactive ^{90}Sr, is one of the most frequently found radionuclides in the soil and groundwater at nuclear weapon test sites and nuclear waste repositories[2]. In addition, because of the chemical similarity to calcium, Sr^{2+} can easily replace Ca^{2+} in human bodies and cause anemia, leukemia, as well as other chronic illnesses. Hence, it is very important to concentrate and separate the Sr(II) ions from the waste solutions[3].

The examined methods for isolation of Sr include: chemical precipitation[4], solvent extraction[5], ion exchange[6], and adsorption[7]. So far, various adsorbents have been tested for sequestering of Sr^{2+} such as: zeolites[8], kaolinite[9], activated carbon[10], carbon nanotube[11], and magnetite[12]. Although some appreciable results have been achieved, there are still need for more efficient adsorbents in low cost and an environmentally friendly fabrication process.

DB18C6 is known to display strong and selective binding for alkaline earth metal divalent cations as well as alkali metal univalent cations. It was always used as the extractant for Sr^{2+} removing from the aqueous solutions[13]. Although it has good selectivity, extraction process is complex and difficult to operate.

In this paper, a novel adsorbent was prepared by DB18C6 grafted on the D564 resin. And the adsorption of Sr^{2+} from the aqueous solutions was investigated. The effects of the contact time, concentration of Sr^{2+} and pH of the solution were studied comprehensively.

2. Experiments

2.1. Preparation of the adsorbent (D564-DB18C6)

The reactions for the adsorbent synthesis were shown in Fig. 1.

(1) 10 g DB18C6 was immersed in 200 mL $CHCl_3$ and the mixture was stirred until DB18C6 was completely dissolved. 4 mL Br_2 was added to the mixture and the solution was heated up to 70°C and refluxing for 8 h. Then the solvent was removed by a rotary evaporator after cooled. Finally, the white powder (Br-DB18C6) was dried at 30°C.

(2) 12.5 g D564 resin was dispersed in 250 mL $CHCl_3$ and 20 mL 20% NaOH was added by

dropping. The mixture reacted at 70°C for 2 h. After that, 5.0 g Br-DB18C6 was put into the mixture and refluxing for 24 h at 70°C. When the reaction was complete, the resin was washed by $CHCl_3$ and EtOH for several times and dried at 30°C.

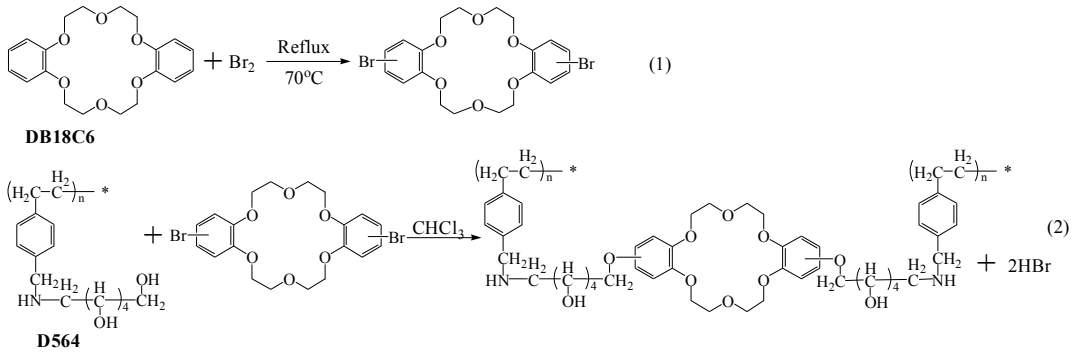

Fig.1 The reactions of the adsorbent synthesis

2.2. Characterizations

TG curves of samples were recorded on a TGDTA92 (SETARAM, France) apparatus in N_2 with a heating rate of 10°C/min.

FTIR spectra of samples were taken following the usual KBr pellet technique on a Nexus FTIR spectrometer (Thermo-Nicolet, USA). Spectral resolution was 4 cm^{-1} and the spectra were obtained using 64 scans.

2.3. Batch adsorption experiments

In the batch adsorption experiments, 1.0 g adsorbent weighed into the 100 mL plastic bottles thoroughly mixed with Sr^{2+} solutions (20 mL) of the different initial concentrations, and pH was adjusted to the desired value. The suspension in flask was shaken for equilibrium in a thermostatic bath. After phase separation, the concentration of Sr^{2+} ion in the aqueous phase was analyzed by the ICS-1100 ionic chromatograph (Dionex Corporation). The amounts of metal ions adsorbed by the adsorbent were determined by mass balance. The adsorption capacity, q (mmol/g) can be calculated with the following equation:

$$q = \frac{(C_0 - C_e)V}{m} \quad (1)$$

where C_0 and C_e are the initial and equilibrium concentrations (mmol/L) of metal ions in solution, respectively. V is the volume of solution (mL) and m is the weight of the adsorbents used (g).

3. Results and discussion

3.1. TG analysis

The TG curves of DB18C6, Br-DB18C6, D564 resin and D564-DB18C6 are shown in Fig. 2 (a) and (b). As it can be seen from Fig. 2, they all start to decompose at 200°C and completed at 400°C. However, the shape of the curves is not uniform with each other. The rate of weight loss of D564-DB18C6 is larger than D564 at 200 to 400°C. It shows that DB18C6 is successfully loaded on D564.

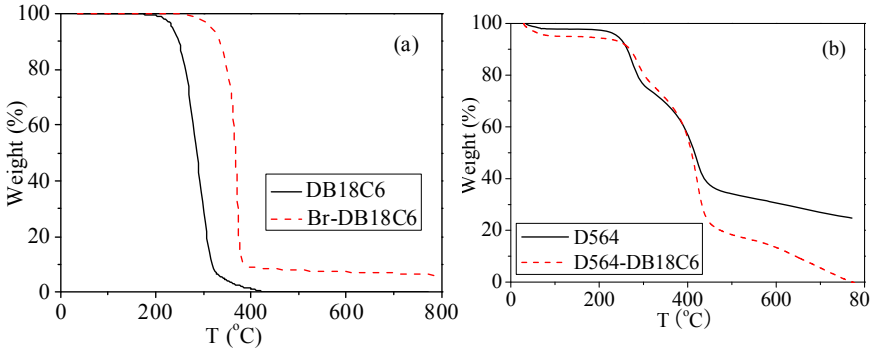

Fig. 2 TG curves

3.2. FTIR analysis

The FTIR spectra ofDB18C6, Br-DB18C6, D564 resin and D564-DB18C6 are shown in Fig.3 (a) and (b), respectively. As it can be seen from Fig. 3 (a), a new band is appeared at 648 cm^{-1} which could be assigned to the structural C-Br groups in the Br-DB18C6. Moreover, the band at 741 cm^{-1} which is assigned to the 1,2-substituted benzene become weaker, and that indicated the reaction between Br_2 and DB18C6 is achieved. From Fig.3 (b), several bands of D564 resin are disappeared after the reaction with Br-DB18C6.

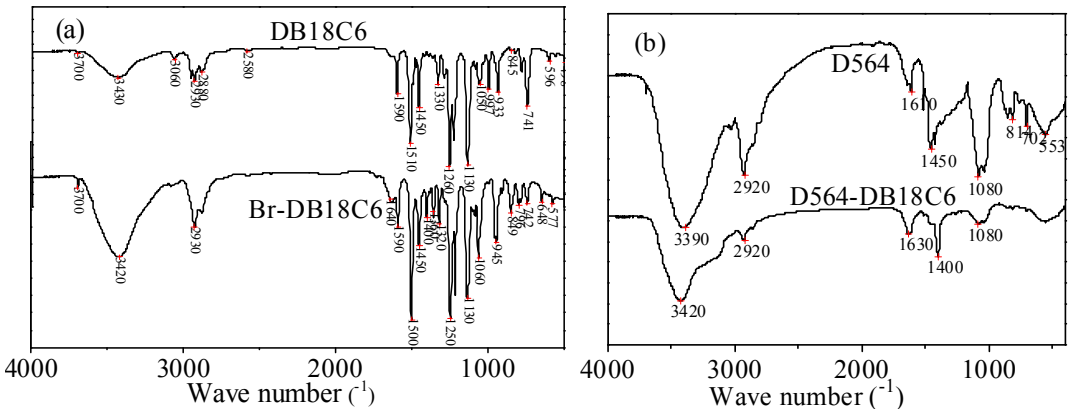

Fig.3 FTIRs of DB18C6, Br-DB18C6, D564 resin and D564-DB18C6

3.3 Adsorption kinetics

Fig. 4 illustrates the effect of contact time on adsorption. The most impressive of the kinetic data is that in the first 2 h at 25°C and 1 h at 50°C, Sr^{2+} is removed more than 80%, which is a rapid kinetic behavior. In the next time, the removal of Sr^{2+} continues but with lower rates, reaching the equilibrium after 6 h at 25°C and 2 h at 50°C. The adsorption rate is faster than grapheme-oxide-magnetite adsorb Sr2+ and Co2+ ions, but it is slower than zeolite adsorb cesium and strontium[14].

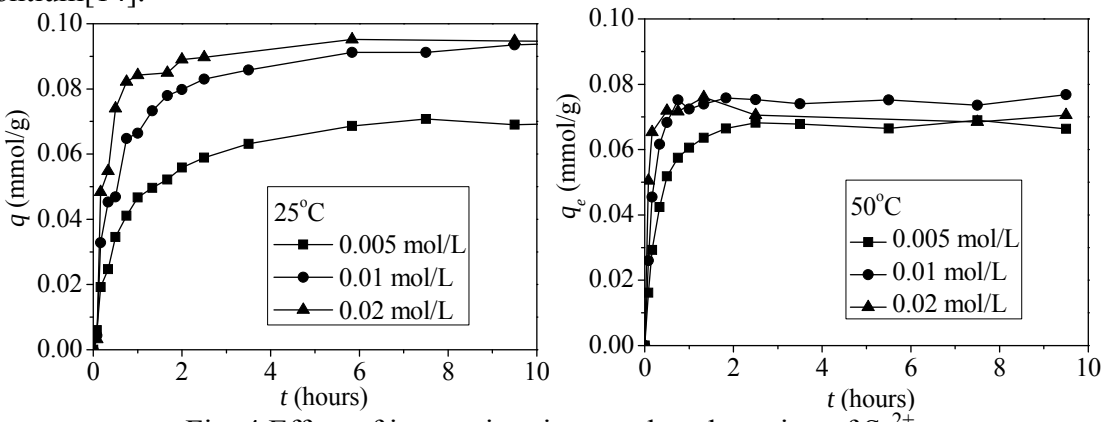

Fig. 4 Effect of immersion time on the adsorption of Sr^{2+}

3.4. Adsorption isotherms

Fig. 5 depicts the adsorption isotherms of Sr^{2+} on D564-DB18C6 at 25 and 50°C, respectively. In general, the equilibrium adsorption amount decreases with increasing temperature. The adsorption already reaches saturation when concentration of Sr^{2+} is 9 mmol/L at 50°C. While the adsorption do not reach saturation when concentration of Sr^{2+} is 14.5 mmol/L at 25°C.

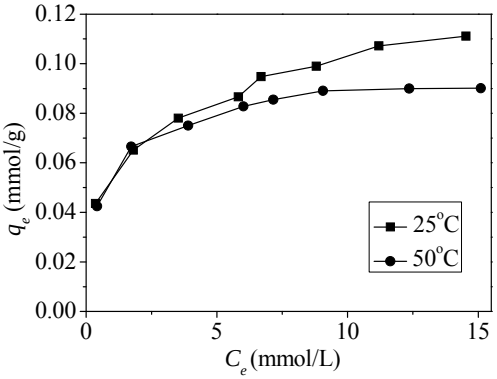

Fig.5 Adsorption isotherms

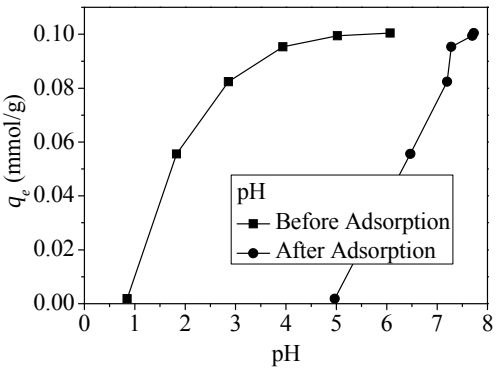

Fig. 6 Effect of the solution pH on the equilibrium adsorption amount.

3.5. Effect of pH

The effect of the pH on the adsorption of Sr^{2+} is studied in the pH range from 0.85 to 6.07 before adsorption and the results are shown in Fig. 6. After adsorption, all the pH of the solutions become higher than before. And the highest adsorption amount is achieved at pH 5-6 before adsorption and 7-8 after adsorption. This tendency is uniform with antimony silicate, alginate and grapheme oxide–magnetite adsorb strontium[15, 16].

4. Conclusion

A novel adsorbent was prepared by grafted the DB18C6 on D564 resins and used to adsorb Sr^{2+} from the solution. The TG curves and FTIR analysis exhibited that D564-DB18C6 by the reaction process. The results of the adsorption experiments showed that D564-DB18C6 has good adsorption properties for $Sr2^{+}$. The adsorption amount decreased with the increasing of temperature indicating that adsorption is exothermic nature. Solution pH has a significant effect on the equilibrium adsorption amount. Compared with acidic solution, in neutral solution, D564-DB18C6 could react with Sr^{2+} more easily. The highest adsorption amount is obtained at pH~7.

Acknowledgments

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