Test of Amberlite Irn150 Resin in Cr(VI) Recovery

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Abstract

The aim of the present study is the removal of Cr(VI) ions by Amberlite IRN150 resin. Batch exchange experiments were carried out to study the effects of pH, temperature, contact time, chromium initial concentration and the presence of competitive ions. The recovery of Cr(VI) ions from the resin was evaluated through desorption experiments. The obtained results show that the removals of Cr(VI) by Amberlite IRN150 resin was fast and endothermic. The exchange capacity estimated by the Langmuir equation was about 75 mg/g at pH 7. The presence of chloride ions had no effect on Cr(VI) removal, while that of sulfate ions led to its decrease. The recovery of Cr(VI) ions from IRN150 resin by KCl solution reached 49%.

Keywords: *Cr(VI), Amberlite IRN150, Wastewater treatment, heavy metals*

I. Introduction

Chromium is used in chemical industries (dyes, paints, rubber, and pharmaceuticals), metal finishing industry and various other activities [1]. It exists in eleven valence states ranging from -IV to +VI [2]. However, in environment, it is usually encountered as Cr(III) and Cr(VI) [3].

The toxicity of chromium depends on its concentration and its oxidation state. Cr(VI) is highly toxic. It can be easily diffused into cell membranes causing adverse effects on human health [4].

Among the numerous physicochemical methods used for the treatment of wastewater charged with heavy metals, ion exchange technology is increasingly used. It is an alternative technology for wastewater depollution due to numerous advantages such as high efficiency and rapid kinetics [5]. The objective of the present work is the use of Amberlite IRN150 resin in the removal and the recovery of Cr(VI) ions.

II. Material and methods

Amberlite IRN150 resin is a commercial resin characterized by cationic and anionic exchange capacities. The FTIR spectrum of the resin recorded by Hyper IR Shimadzu E spectrometer (Fig. 1) confirms the presence of the characteristic bands of amine and sulfite groups.

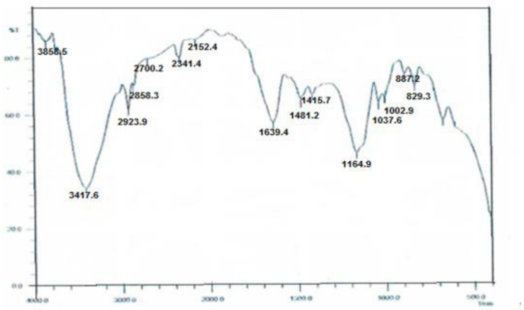

Figure 1. FTIR spectrum of Amberlite IRN150

The chromium exchange experiments were carried out in batch. The effects of pH, temperature, contact time, chromium initial concentration and the presence of competitor ions were evaluated. In each experiment, chromium solution was mixed with a dose of Amberlite IRN150 resin and stirred. The suspension pH was adjusted by HCl or NaOH solutions. Desorption experiments were carried out using KCl solution.

In all experiments, the residual concentration of Cr(VI) was determined in the supernatant recovered after filtration by UV-Visible using Shimadzu 1650 PC spectrophotometer.

III. Results and discussion

A. *Effect of pH*

The obtained results (Fig. 2) show that the Cr(VI) removal rate decreases with the pH increase. A maximum elimination is obtained at very acidic pH. No removal is observed at pH greater than 8. This evolution is identical to that observed in several stidies using other resins for Cr(VI) removal [6-8].

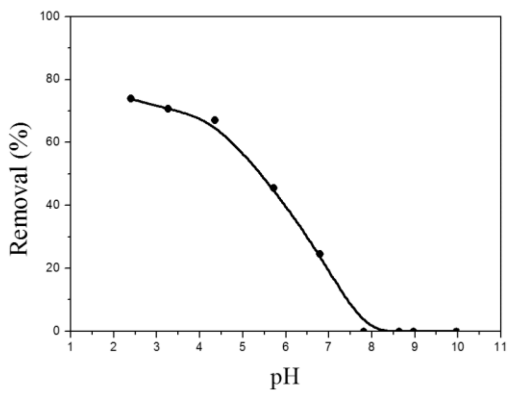

Figure 2. Effect of pH on Cr(VI) removal by Amberlite IRN150 resin ($C_{Cr(VI)}$: 200mg/L; t: 60min; resin dose: 1g/L)

B. *Effect of temperature*

The thermodynamic parameters calculated using the equations shown below (Eqs. (1)-(3)), indicate that the exchange process has an endothermic character with an increase of the disorder in the system (Table 1)

$$K_C = \frac{C_{Ae}}{C_{Se}} \quad (1)$$

$$\Delta G^0 = -RT \ln k_c \quad (\quad (2)$$

$$\ln k_c = \frac{\Delta s^0}{R} - \frac{\Delta H^0}{RT} \quad (3)$$

Endothermic exchange reaction was also observed for Cr(VI) removal by IRA743 [7], D354 [6] and Amberlite IRA 96 [9]. However, exothermic exchange reaction was observed for Dowex 1×8 [9], D301 and D314 [6].

Table 1. Thermodynamic parameters of the removal of Cr(VI) ions by Amberlite IRN150 resin

ΔH^0 ($Kj.mol^{-1}$)	ΔS^0 ($Kj.K^{-1}mol^{-1}$)	ΔG^0 ($kj.mol^{-1}$)					
		295	303	308	313	318	323
65.20	0.26	-10.52	-12.85	-14.31	-15.77	-16.61	-17.65

C. *Effect of contact time – kinetic study*

The uptake of Cr(VI) ions by Amberlite IRN150 is fast (Fig. 4). For a concentration of 100mg/L, the equilibrium time is about 45 min. In order to investigate the kinetics of Cr(VI) ions removal, several kinetic models were used to test the experimental data: first order (Eq. 4), second order (Eq. (5)), intraparticular diffusion (Eqn.6) and external diffusion (Eqns. 7-8).

$$\ln(Q_e - Q_t) = \ln Q_e - k_1 t \quad (4)$$

$$\frac{t}{Q_t} = \frac{1}{K_2 Q_e^2} + \frac{t}{Q_e} \quad (5)$$

$$Q_t = k_{d_1} t^{1/2} + c \quad (6)$$

$$-\ln(1 - F) = K_{d_2} t \quad (7)$$

$$-\ln(1 - F^2) = K_{d_3} t \quad (8)$$

The calculated correlation coefficients show that the experimental data can be described by several models (Tab. 2). However, the calculated curves reveal that the second-order model is the most suitable (Fig. included in Fig. 4).

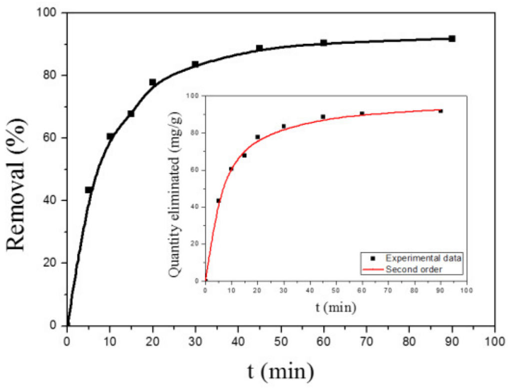

Figure 4. Kenitic of Cr(VI) removal by Amberlite IRN150 resin ($C_{Cr(VI)}$: 100mg/L; resin dose: 1g/L; pH: 5)

Table 2. Parameters of the kinetic models of Cr(VI) removal by the Amberlite IRN150 resin

Pseudo-first-order	Pseudo-second-order	Intraparticulaire diffusion	Film diffusion	Interparticulaire diffusion
R : 0.992	R : 0.999	R : 0.857	R : 0.992	R : 0.997
Q_e : 58.99 ($mg.g^{-1}$)	Q_e : 98.72 ($mg.g^{-1}$)	K_{d1} : 8.1696 ($mg.g^{-1}.min^{-1/2}$)	K_{d2} : 0.0635 (min^{-1})	K_{d3} : 0.0589 (min^{-1})
K_1 : 0.0636 (min^{-1})	K_2 : 0.0017 ($g.mg^{-1}.min^{-1}$)	C : 33.84		

D. *Effect of initial concentration-isotherm*

The increase in initial chromium concentration implies an increase in the exchange capacity and a decrease in the exchange rate (Fig. 5).

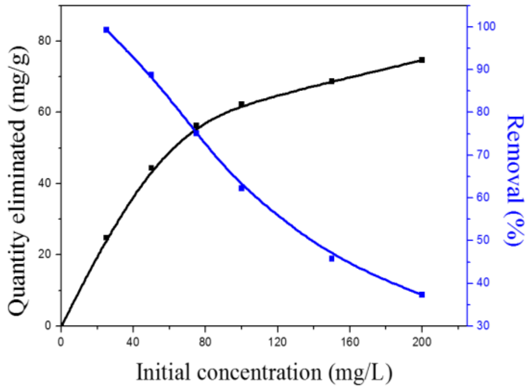

Figure 5. Effect of initial concentration on Cr(VI) removal of by Amberlite IRN150 resin
(t: 60min; resin dose: 1g/L; pH: 7)

The experimental isotherm shows that Cr(VI) has a significant affinity for Amberlite IRN150 in dilute solutions (Fig. 6). The initial part of the isotherm is therefore vertical. The application of Langmuir (Eqs.(9)) and Freundlich (Eqs.(10)) equations gives the parameters summarized in Tab.3.

$$\frac{C_{eq}}{Q} = \frac{1}{Q_{max} \cdot k_L} + \frac{C_{eq}}{Q_{max}} \quad (9)$$

$$\ln Q = \ln k_F + n \ln C_{eq} \quad (10)$$

The calculated correlation coefficients (Tab. 3), show that the two models can be applied for describing the experimental data. However, only the non linear curve of Langmuir equation is suitable (Fig. 6). This is in agreement with what has been found in the case of Cr(VI) removal by other resins [3, 10].

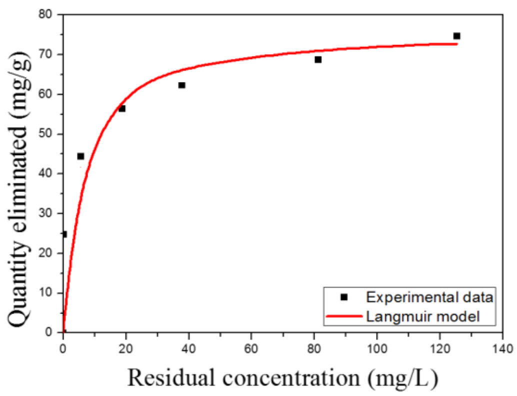

Figure 6. Isotherm of Cr(VI) removal by Amberlite IRN150 resin (t: 60min; resin dose: 1g/L; pH: 7)

Table 3. Parameters of the isotherm models of Cr(VI) removal by Amberlite IRN150 resin

Model	Parameters
Langmuir	R: 0.994
	Q_{max}: 75.41 (mg.g^{-1})
	K_L: 0.22 (L.mg^{-1})
Freundlich	R: 0.997
	n: 0.17
	K_F: 33.34

E. Effect of competitive ions

The removal of Cr(VI) ions by Amberlite IRN150 resin in the presence of chloride and sulfate is shown in Fig. 7. For a same concentration than that of Cr(VI), the presence of Cl^- has no effect. A decrease in Cr(VI) removal is observed in the presence of SO_4^{2-}. Consequently, the competition is in relation to the ion charge.

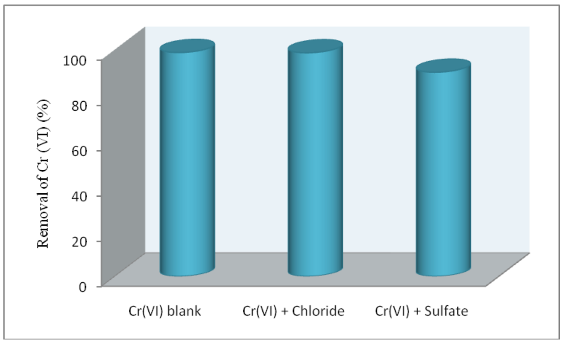

Figure 7. Cr(VI) removal by Amberlite IRN150 in the presence of competitor ions ($C_{Cr(VI)}$: 50mg/L; t: 60min; resin dose: 1g/L; pH: 5)

F. Desorption

Cr(VI) desorption from Amberlite IRN150 resin is fast (Fig. 8). The use of KCl implies the recovery of more than 45% of Cr(VI) for 5 minutes of contact time.

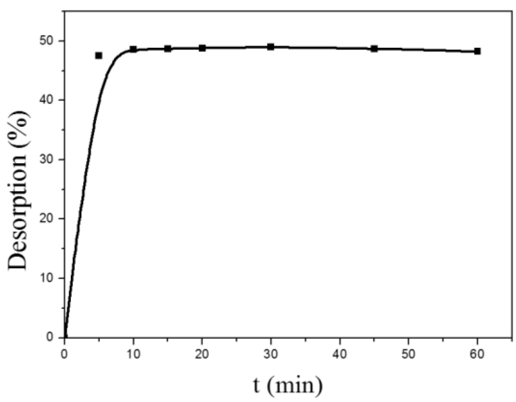

Figure 8. Kinetic of Cr(VI) recovery from Amberlite IRN150 by KCl

IV. Conclusion

The results obtained in the present study show that the Amberlite IRN150 resin has a satisfactory efficiency for the removal of Cr(VI) ions at acidic pH. The removal kinetics depends on the resin dose and the chromium concentration. The exchange isotherm implies the homogeneity of the exchange sites. The resin efficiency towards Cr(V) removal decreases in the presence of sulfate ions and remains unchanged in the presence of chloride ions.

List of symbols

K_C: Equilibrium constant.
C_{Ae}: Adsorbed concentration at equilibrium (mg/L).
C_{Se}: Equilibrium concentration in solution (mg/L).
Q_e : Adsorption capacity at equilibrium (mg/g).
Q_t : Adsorption capacity at time t (mg/g).
K_1 : First order rate constant (min^{-1})
K_2 : Second order rate constant ($mg.g^{-1}.min^{-1}$)
K_{d1}: Intraparticulaire diffusion constant ($mg.g^{-1}.min^{-1/2}$).
C : constant.
F : (Q_t/Q_e).
K_{d2} and K_{d3}: Diffusion constants (min^{-1}).
Q_{max}: Maximum adsorption capacity (mg/g).
Ceq : Equilibrium concentration (mg/L).
K_L : Langmuir constant.
K_F : Freundlich Constant.
n : Freundlich coefficient.

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