

Adsorption Studies of Ternary Metal Ions (Cs^+ , Sr^{2+} , Co^{2+}) from Water Using Zeolite@magnetic Nanoparticles ($\text{Z@Fe}_3\text{O}_4$ NPs)

Nguyen Van Tung,¹ Nguyen Thi Lien,¹ Nguyen Thu Thi Ha,¹ Thu-Huong Le²

¹ Institute for Technology of Radioactive and Rare Elements, Hanoi, Vietnam.

² Faculty of Chemistry and Environment, Thuyloi University, Hanoi, Vietnam

Correspondence should be addressed to lethuhuong@tlu.edu.vn

Adsorption experiments

Effect of the adsorbent weight

The effect of the adsorbent weight on the removal efficiency (Re%) and adsorption capacity (qe) of ternary metal ions (Cs^+ , Sr^{2+} , and Co^{2+}) from aqueous solution are performed at diverse amounts of $\text{Z@Fe}_3\text{O}_4$ NPs in the range 0.1 to 0.5 g at room temperature in the glove box (Figure 3). The pH, initial concentration of ions, and contact time are maintained at 6.9, 105 mg/L of each metal ion, and 60 min, respectively.

Effect of the pH solution

The effect of pH on the adsorption behaviour was examined by taking 0.2 g of $\text{Z@Fe}_3\text{O}_4$ NPs adsorbent material added to 100 ml of ternary metal ions solution (105 mg/l of each metal ion) with varying pH values ranging from 3 - 10, at room temperature, followed by stirring during 60 mins. The pH of metal ion solutions was adjusted to the desired value by HCl 0.05 M or NaOH 0.05 M.

Effect of the contact time

One of the important parameters that affect the adsorption process is the contact time between the adsorbent and adsorbate. The equilibrium time was determined by taking 0.2 gram of the adsorbent $\text{Z@Fe}_3\text{O}_4$ NPs with 100 ml of ternary metal ions solution (105 mg/l of each metal ion) at a pH of 6.3, followed by stirring at room temperature for various time intervals ranging from 5 – 180 mins in the glove box.

Effect of the initial concentration of metal ions

The initial concentration remains a fundamental parameter that allows for ascertaining the adsorption capacity of an adsorbent. The effect of initial concentrations of ions on the adsorption behavior ions was investigated by taking 0.2 g of $\text{Z@Fe}_3\text{O}_4$ NPs material with 100 ml of ternary metal ions solution with different initial concentrations (varying from 10 to 150 mg/L) at pH about

6.2 under room temperature with stirring for 60 min in the glove box. The concentrations of Co^{2+} , Sr^{2+} , and Cs^+ in the aqueous phase before and after the adsorption period were determined by ICP-MS spectrometry.

Results and Discussion

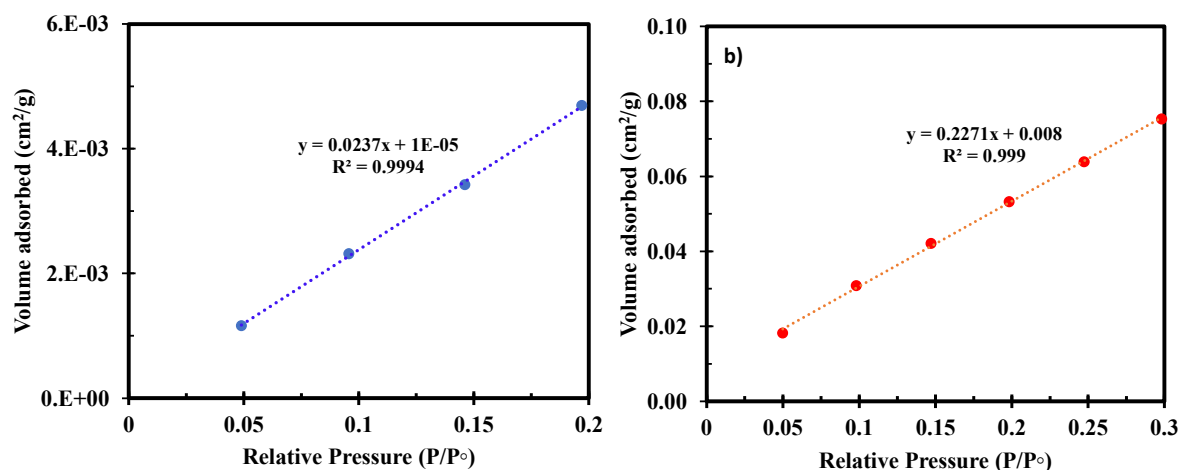


Figure S1: Surface area plot of Z@Fe₃O₄ NPs (a) and zeolite

Table S1: Effect of the adsorbent weight

Time (min)	pH	Volume (L)	Weight (g)	C _o (mg/L)			C _e (mg/L)		
				Cs ⁺	Sr ²⁺	Co ²⁺	Cs ⁺	Sr ²⁺	Co ²⁺
60	6.9	0.1	0.1	105	105	105	58.11	5.64	0.00
60	6.9	0.1	0.2	105	105	105	23.06	36.66	23.81
60	6.9	0.1	0.3	105	105	105	17.18	47.61	26.26
60	6.9	0.1	0.4	105	105	105	11.51	63.49	38.20
60	6.9	0.1	0.5	105	105	105	9.23	74.70	49.50

Table S2: Effect of Ph

Time (min)	pH	Volume (L)	Weight (g)	pH after abs	C _o (mg/L)			Ce (mg/L)		
					Cs ⁺	Sr ²⁺	Co ²⁺	Cs ⁺	Sr ²⁺	Co ²⁺
60	3.4	0.1	0.2	4.9	105	105	105	28.00	74.78	90.60
60	4.3	0.1	0.2	5.5	105	105	105	23.62	75.98	87.52
60	5.4	0.1	0.2	6.4	105	105	105	23.21	77.00	87.55
60	6.3	0.1	0.2	6.3	105	105	105	22.77	70.88	81.9
60	7.2	0.1	0.2	6.4	105	105	105	23.06	68.34	81.19
60	8.1	0.1	0.2	7.4	105	105	105	23.60	68.87	77.61
60	9.0	0.1	0.2	8.5	105	105	105	34.55	29.35	44.18
60	10.1	0.1	0.2	8.6	105	105	105	34.66	26.44	3.52

Table S3: Effect of the contact time

Time (min)	pH	Volume (L)	Weight (g)	C _o (mg/L)			Ce (mg/L)		
				Cs ⁺	Sr ²⁺	Co ²⁺	Cs ⁺	Sr ²⁺	Co ²⁺
2	6.3	0.1	0.2	105	105	105	42.21	86.81	93.59
5	6.3	0.1	0.2	105	105	105	33.69	84.58	91.69
10	6.3	0.1	0.2	105	105	105	24.01	75.88	86.42
15	6.3	0.1	0.2	105	105	105	18.75	73.06	82.99
30	6.3	0.1	0.2	105	105	105	18.92	72.98	84.17
40	6.3	0.1	0.2	105	105	105	18.49	70.00	81.81
50	6.3	0.1	0.2	105	105	105	20.06	68.34	81.19
60	6.3	0.1	0.2	105	105	105	18.42	67.32	78.00
80	6.3	0.1	0.2	105	105	105	18.73	69.74	80.99
120	6.3	0.1	0.2	105	105	105	18.76	64.08	75.60
180	6.3	0.1	0.2	105	105	105	42.21	86.81	93.59

Table S4: Effect of the initial concentration of metal ions

Time (min)	pH	Volume (L)	Weight (g)	C _o (mg/L)			Ce (mg/L)		
				Cs ⁺	Sr ²⁺	Co ²⁺	Cs ⁺	Sr ²⁺	Co ²⁺
60	6.2	0.1	0.2	10	10	10	0.63	0.26	0.49
60	6.2	0.1	0.2	20	20	20	1.77	1.71	3.60
60	6.2	0.1	0.2	30	30	30	1.76	6.22	12.86
60	6.2	0.1	0.2	40	40	40	2.52	7.67	17.68
60	6.2	0.1	0.2	50	50	50	4.85	26.98	35.16
60	6.2	0.1	0.2	60	60	60	5.96	17.51	38.15
60	6.2	0.1	0.2	70	70	70	8.88	37.89	50.95
60	6.2	0.1	0.2	80	80	80	9.46	26.35	53.73

60	6.2	0.1	0.2	105	105	105	25.98	72.61	85.13
60	6.2	0.1	0.2	150	150	150	102.94	147.43	144.92

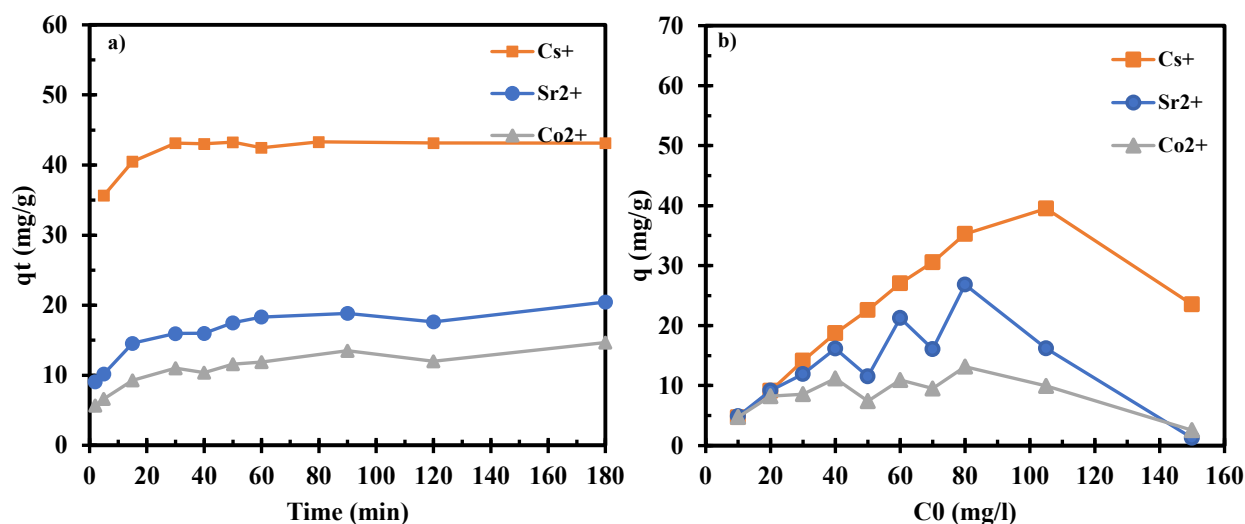


Figure S2: Effect of the contact time (a) and initial concentration of metal ions (b) on the adsorption capacity (q_e) of ternary metal ions (Cs⁺, Sr²⁺, and Co²⁺) from aqueous solution.

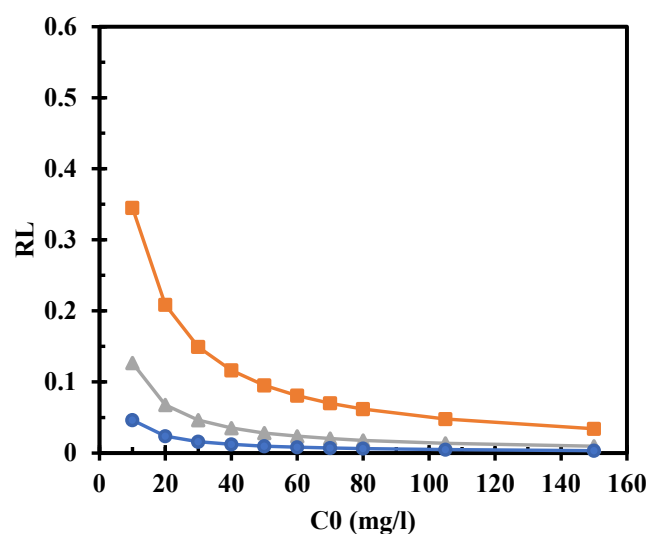


Figure S3: The dependence of the separation factor RL values on the initial concentrations of three metal ions C_0