KINETICS AND THERMODINAMICS FOR U(VI), Fe(III) AND Cr(VI) ADSORPTION USING AN ANION EXCHANGE RESIN

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Introduction:

Industrial wastewaters largely contain metal ions (U^{6+}, Fe^{3+}, Cr^{6+}) who presents risks to human health and can cause serious problems for environment. Because of this, the need to find adsorbent materials as efficient as possible is growing.

Results and Discussion:

In order to study U^{6+}, Fe^{3+}, Cr^{6+} adsorption onto Dowex-Marathon anionic exchange resin, kinetic and thermodynamic experiments were performed, and adsorption isotherms were studied.

Kinetic studies

Parameters	Initial concentrations of UO_2Cl_2 solution				
	0.02M	0.04M	0.05M	0.07M	0.1M
q_e, exp (mg/g)	34.69	67.34	81.66	108.96	142.5
Pseudo-first					
q_e, calc (mg/g)	27.23	45.47	60.06	76.98	96.83
k_1 (min^{-1})	0.1164	0.0928	0.089	0.080	0.0803
R^2	0.9776	0.9933	0.9948	0.9923	0.9974
Pseudo-second					
q_e, calc (mg/g)	38.50	74.02	89.36	119.61	155.76
k_2 (g/mg min)	6.26×10^{-3}	3.40×10^{-3}	2.48×10^{-3}	1.78×10^{-3}	1.46×10^{-3}
h (mg/ g min)	9.27	18.62	19.80	25.46	35.42
R^2	0.9990	0.9989	0.9988	0.9977	0.9979
Elovich eq.					
α (mg/g min)	27.58	55.98	58.98	76.16	111.48
β (g/mg)	0.1453	0.0769	0.0613	0.0467	0.0365
R^2	0.9776	0.9946	0.9951	0.9979	0.9970
Intraparticle diffusion					
k_i (mg/g $min^{0.5}$)	2.6854	6.1146	8.5598	10.0935	14.2182
R^2	0.9948	0.9770	0.9792	0.9959	0.9812

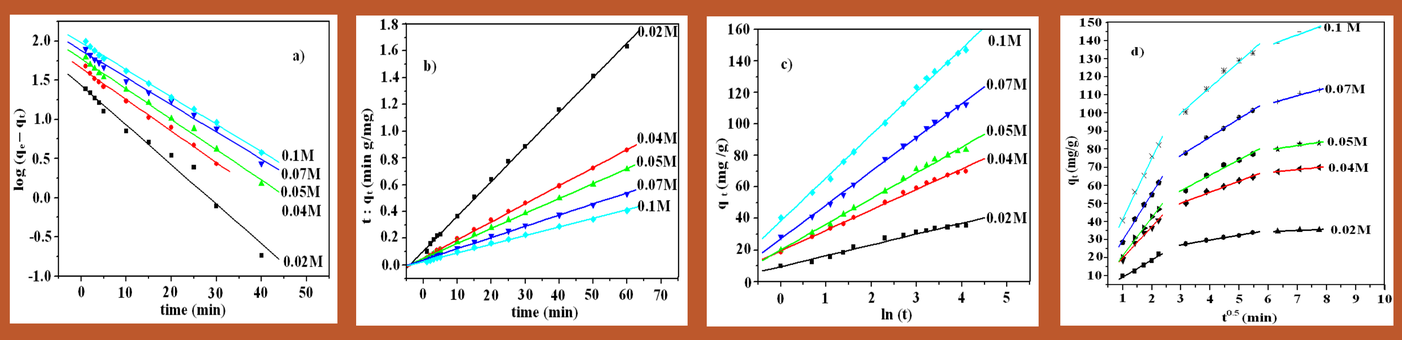


Table 1, Fig. 1. Kinetic data for the adsorption of U(VI) onto Dowex-Marathon resin. **a** the pseudo-first order model, **b** the pseudo-second order model, **c** the Elovich model, **d** the intraparticle diffusion model, for 0.02 – 0.1M UO_2Cl_2, at room temperature

Parameters	Initial concentrations of $FeCl_3$ solution				
	0.05M	0.07M	0.1M	0.13M	0.15M
q_e, exp (mg/g)	19.00	25.83	36.00	47.28	56.66
Pseudo-first					
q_e, calc (mg/g)	12.79	19.11	21.61	28.99	36.97
k_1 (min^{-1})	0.081	0.074	0.059	0.059	0.060
R^2	0.9707	0.9917	0.9865	0.9917	0.9930
Pseudo-second					
q_e, calc (mg/g)	20.56	27.76	38.30	50.50	60.90
k_2 (g/mg min)	11.52×10^{-3}	7.36×10^{-3}	5.89×10^{-3}	4.27×10^{-3}	3.24×10^{-3}
h (mg/ g min)	4.86	5.67	8.63	10.89	12.01
R^2	0.9992	0.9991	0.9978	0.9985	0.9986
Elovich eq.					
α (mg/g min)	19.45	20.62	49.61	48.48	45.52
β (g/mg)	0.302	0.217	0.1767	0.1263	0.100
R^2	0.9785	0.9879	0.9929	0.9953	0.9930
Intraparticle diffusion					
k_i (mg/g $min^{0.5}$)	1.2718	1.5804	2.722	4.0321	5.3240
R^2	0.9702	0.9782	0.9910	0.9815	0.9974

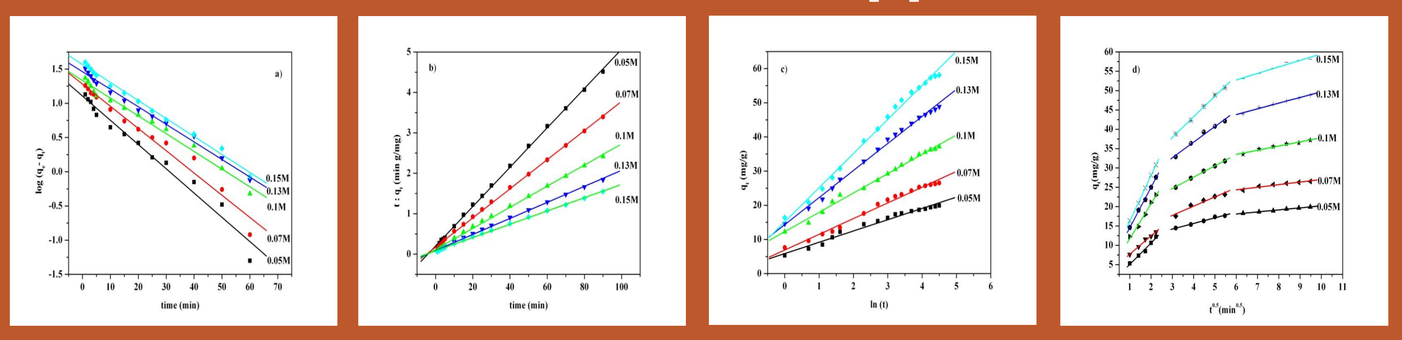


Table 2, Fig. 2. Kinetic data for the adsorption of Fe(III) onto Dowex-Marathon resin. **a** the pseudo-first order model, **b** the pseudo-second order model, **c** the Elovich model, **d** the intraparticle diffusion model, for 0.05–0.15 M $FeCl_3$, at room temperature

Parameters	Initial concentrations of $K_2Cr_2O_7$ solution		
	0.1 g/L	0.2 g/L	0.3 g/L
q_e, exp (mg/g)	102.44	171.31	208.92
Pseudo-first			
q_e, calc (mg/g)	123.86	140.85	175.78
k_1 (min^{-1})	0.0769	0.0695	0.0421
R^2	0.9570	0.9484	0.9889
Pseudo-second			
q_e, calc (mg/g)	121.50	204.08	239.80
k_2 (g/mg min)	0.6527×10^{-3}	0.426×10^{-3}	0.412×10^{-3}
h (mg/ g min)	9.63	17.74	23.69
R^2	0.9970	0.9920	0.9936
Elovich equation			
α (mg/g min)	25.18	43.10	60.99
β (g/mg)	0.0412	0.0232	0.0213
R^2	0.9711	0.9688	0.9688
Intraparticle diffusion			
k_i (mg/g $min^{0.5}$)	17.38	26.36	31.25
R^2	0.9825	0.9813	0.9805

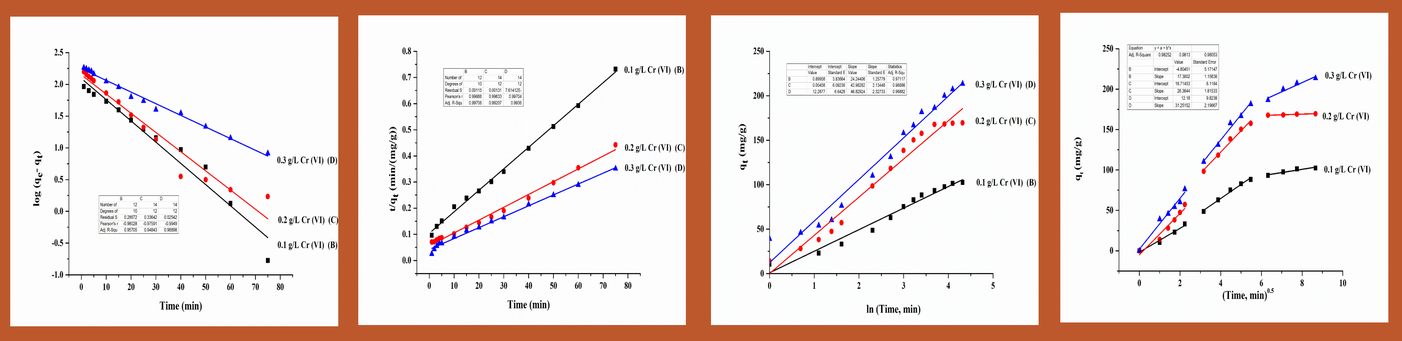
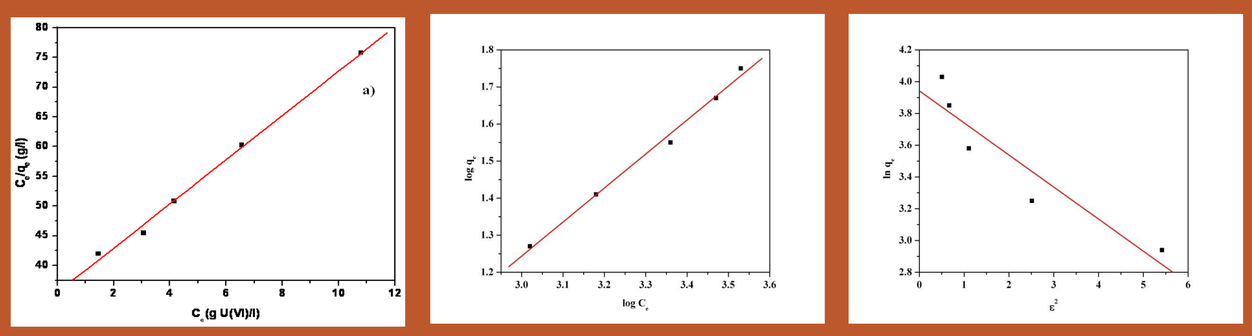


Table 3, Fig. 3. Kinetic data for the adsorption of Cr(VI) onto Dowex-Marathon resin. **a** the pseudo-first order model, **b** the pseudo-second order model, **c** the Elovich model, **d** the intraparticle diffusion model, for 0.1–0.3 g/L Cr (VI), at room temperature

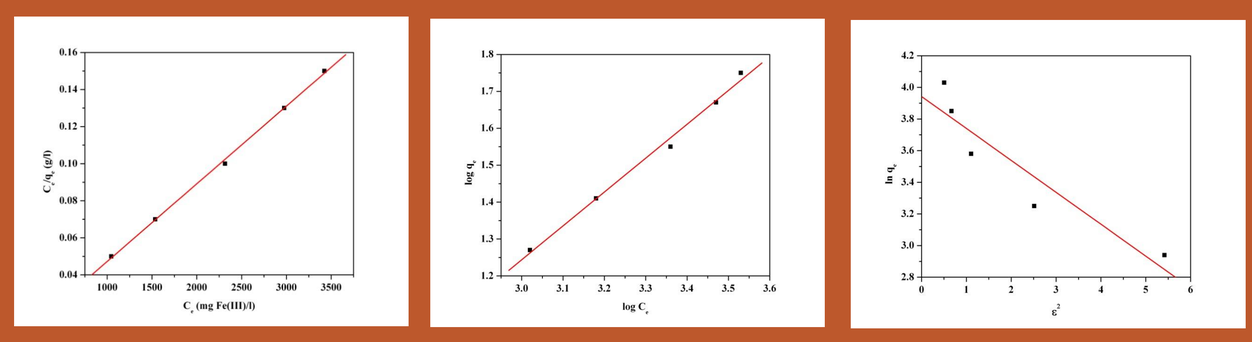
Thermodynamics and adsorption isotherms

a. Uranium(VI) adsorption onto Dowex-Marathon resin



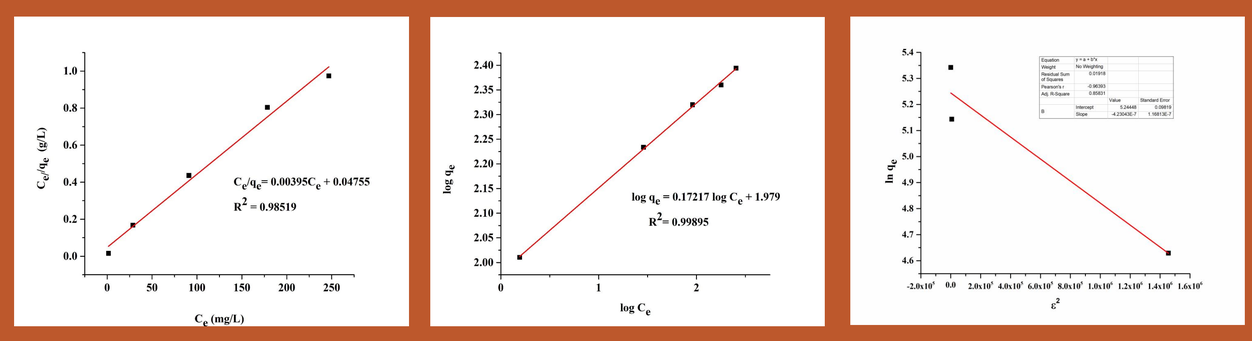
t (°C)	K_C	ΔG° (kJ/mol)	ΔH° (kJ/mol)	ΔS° (J/mol K)
20	14.27	–6.37		
30	17.08	–7.08		
40	19.28	–7.80	14.57	71.48
50	22.42	–8.51		
60	28.28	–9.23		

b. Iron (III) adsorption onto Dowex-Marathon resin



t (°C)	K_C	ΔG° (kJ/mol)	ΔH° (kJ/mol)	ΔS° (J/mol K)
30	3.14	- 7.91		
50	3.87	- 10.39		
60	4.51	- 12.48	35.60	143.31
70	4.80	- 3.68		

c. Chromium (VI) adsorption onto Dowex-Marathon resin



t (°C)	K_C	ΔG° (kJ/mol)	ΔH° (kJ/mol)	ΔS° (J/mol K)
20	6.84	- 16.66		
30	7.02	- 17.68	16.07	111.33
40	7.16	- 18.63		
50	7.43	- 19.95		
60	7.65	- 21.17		

Pseudo-second order kinetics

Spontaneous and endothermic adsorption

Conclusions:

Dowex-Marathon anionic resin is suitable for uranium, iron and chromium ions adsorption from aqueous solutions, thus contributing to the elimination of polluting and toxic ions.