Removal of Chromium(III) from aqueous solution using ZnO nanoparticles

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Abstract

Chromium (III) , is essential in the diet of humans and animals in trace amounts, it is found in many vegetables, fruits, meats and grains. Cr (III) is also used in industry as dyes and pigments which lead to contaminations in ground and drinking water. In this research, batch studies were performed with the use of Nanoparticles of metal oxides to investigate the binding of Cr(III) to ZnO nanoparticles. The effects were investigated using a series of batch studies which included: pH, time, interferences, kinetics and isotherm studies. Cr (III) concentrations were determined using the ICP-OES. Thermodynamic studies were performed at temperatures of 4°,25° and 45° in order to determine the binding capacity of Cr(III) to ZnO nanoparticles at different temperatures. Interference studies were also investigated using various cations and anions to determine if any effects were present in the binding of Cr (III) to the ZnO nanoparticle.pH studies were also performed , the optimal pH for binding consisted of a pH of 3

Methods

ICP-OES : The parameters using for the ICP-OES analysis were as follows:

Parameter	Setting
λ	267.716 nm
RF power	1500 W
Nebulizer	Gemcone (low flow)
Plasma Flow	15 L/min
Auxiliary Flow	0.2 L/min
Nebulizer Flow	0.55 L/min
Sample Flow	1.50 mL/min
Injector	2.0 mm Alumina
Spray Chamber	Cyclonic
Integration Time	10-20 seconds
Replicates	3

Table 1: Operating parameters for the analysis of chromium binding to the ZnO nanoparticles

X-ray Diffraction (XRD):

XRD analysis was performed on a Bruker D2 Phaser Diffractometer. The ZnO adsorbent was analyzed from a range of 5 - 60° in 2θ. With a step size of 0.05 ° with step of count size of 2 seconds per step.

pH studies

The binding of Chromium (III) ions of a concentration of 300 ppb were tested in a pH range of 2-6. The solutions were adjusted using HNO_3 or NaOH in-order to increase or decrease pH . The pH adjusted samples and control were adjusted in sets of 3 and equilibrated for 1 hour. Samples and controls were centrifuged at a rpm of 3500. Samples containing ions and ZnO were decanted and supernatants were used for analysis. The analyzation of supernatants samples were performed in an ICP-OES.

Thermodynamic Studies

The thermodynamic studies consisted of various temperatures ranging from 4˚C, 23˚C, and 45˚C and determined from the capacity studies, and standard thermodynamic relationships.

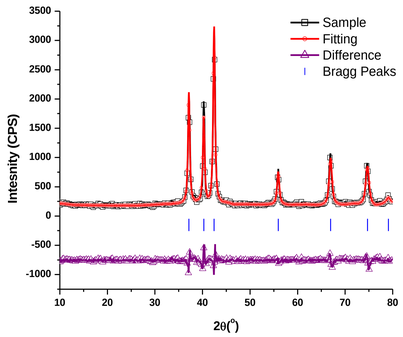
Interference Studies

The Interference studies were performed using various cations (Mg, Ca, Na, K,) and combination of all cations. The ion concentrations analyzed consisted of 0.3, 3.0, 30, 100, 300 and 1000 ppm for each set to observe effects on the binding of Cr(III) to ZnO.

Time Studies

The rate and order of the reaction ion species Cr (III) was achieved by performing the reactions between the Cr Ions and ZnO at specific timed lapses

Results



Fitting parameters for ZnO Lattice
P 63 m c (hexagonal)
a=b=3.2465 Å
C= 5.260 Å
α= 90
β=90
γ=120
X^2=3.82

Figure 1: XRD pattern for the synthesized ZnO nanoparticles

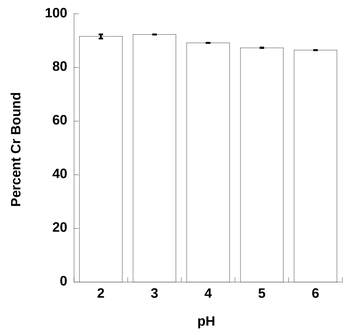


Figure 2: pH dependence of the binding of Cr(III) to the synthesized ZnO nanoparticles

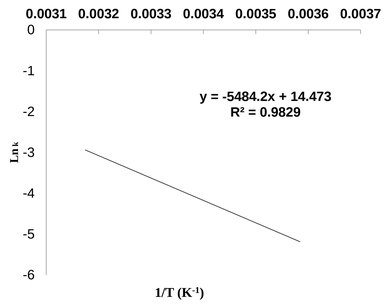


Figure 3: Arrhenius plot for the binding of Cr(III) to the synthesized ZnO nanoparticles

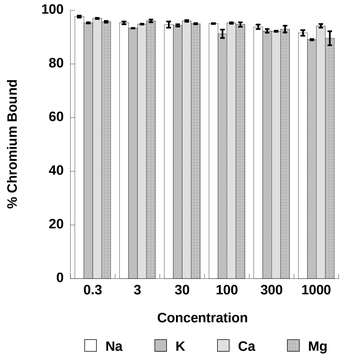


Figure 4: Effect of individual interferences on the binding of Cr(III) to the synthesized ZnO nanoparticles

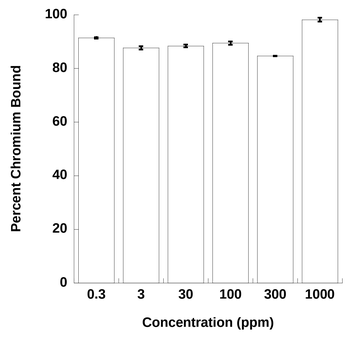


Figure 5: Effect of combined interferences on the binding of Cr(III) to the synthesized ZnO nanoparticles

Results

Chromium ion	Equation	Ea (kJ)
Cr(III)	y = -5484.2x + 14.473	45.59

Table 1: Activation energy from an Arrhenius plot

Chromium ion	Equation	R^2	Temperature(°C)	Capacity (mg/g)
Cr(III)	y = = -6423.4x + 21.832	R^2 = 0.9467	4	29.41
			25	50
			45	212.76

Table 2: Binding capacities for the binding of cr(III) to the ZnO nanoparticles

Chromium Ion	ΔG (kJ/mol)	ΔH (kJ/mol)	ΔS (J/mol)
Cr (III)	2.62 (277K) 0.86 (298K) -4.83 (318K)	-53.4	181.5

Table 3: Thermodynamics of the binding of Cr(**III**) to the ZnO nanoparticles.

Discussion

pH studies

- At a pH of 3 there was an optimal binding for Chromium (III).

Capacity studies

- The ZnO nano particles acting as an absorbent were tested with different Cr(III) concentrations to determine the binding capacity. The gathered data was best fit using the Langmuir Isotherm model.
- The Langmuir Isotherm model was used to analyze the data obtained from the investigation.

Thermodynamic studies

- Spontaneous binding of Cr(III) occurred between the temperature ranges of 25-43°C
- The thermodynamics revealed an increase of entropy and enthalpy for the binding of Cr(III)

Interference Studies

- Concentrations of 100 -1000 ppm of the Cations and combo had a significant change in binding, greater concentration of the cations decreased percent bound.
- A synergistic effect could be observed from the concentration of 0.3- 30 ppm. A slight increase in percent bound was obtained at lower concentrations
- An antagonistic effect could be observed in the Combo set of ions which resulted in a percent bound of 89%

Time Studies

- Percent bound of ZnO had no significant change during different time studies performed
- Percent bound remained constant on an average of 86%

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