

Effect of Coexistent Ions on Adsorption Behaviour of Lanthanum, Cerium and Samarium Ions on Organic–Inorganic Hybrid Exchange

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ABSTRACT

Adsorption of Sm^{3+} , La^{3+} and Ce^{3+} ions from aqueous solutions onto polyacrylamide ferric antimonate. Thermodynamic parameters such as ΔG^* , ΔS^* and ΔH^* have been calculated for the adsorption of Sm^{3+} , La^{3+} and Ce^{3+} ions onto ion exchange material. Attention was paid to study the adsorption competitive and the effect of coexistent ions onto adsorption behaviours. coexistent ions including Na^+ , Mg^{2+} and Ca^{2+} inhibited the adsorption of Sm^{3+} , La^{3+} and Ce^{3+} ions onto polyacrylamide ferric antimonate, because they competed for adsorption sites. The physico-chemical properties of the material were determined using AAS, ICPs elemental analysis, IR, TGA-DTA and XRD study. The selectivity coefficients of different cations were determined by mixed solution method which were found to be less than unity. The distribution study revealed that the cation-exchange material has a high selectivity for Sm^{3+} . Due to selective nature for cation-exchange material, absorption process was affected by the presence of competing cations and was observed that it reduced with increase in the concentration of competing cations in the suspension which may be probably due to the competition between these ions.

INTRODUCTION

Radioactivity either natural or artificial is a potential prediction of radioactive exposure to humans and its environment. The main sources of radioactive waste are the reactors and the processing plants. These wastes contain a varying concentration, a wide spectrum of fission products. Throughout the entire nuclear fuel cycle from mining to reprocessing of spent fuel, disposal of radioactive waste various amounts of radiation may enter and affect the environment. The industrial and nuclear waste contains large amount of radionuclides, which are strategically and economically important. Management and recovery of these products is a global problem in nuclear industry. This is necessary to proper treatment of these radioactive wastes, hence, avoid direct contact of environment. The methods of treatment include evaporation, chemical precipitation and use of inorganic ion exchangers, solvent extraction, and membrane separation. The radionuclides migration present in the environment may be affected by the presence of different rock born materials. This material has greater tendency to interact with metal ions and retards the migration in the environment. Among these materials one of the important categories are well known called ion exchangers that own property is dependent on its structure and other peculiarities [1].

Radioactive waste contains various elements such as lanthanides, actinides and so on. This can directly damage biological organization or produce reactive species (free radicals) that can subsequently react with bio-molecular when one inhales them from radiation source. For example, cancers, including lung cancer, bone cancer, etc. [2].

Rare earth metals (REMs) are the elements have active surface, which play an important role in the metallurgy of materials, such as refinement of microstructure, alloying and purification of materials and metamorphosis of inclusions. REMs is becoming increasingly important to their unique chemical and physical properties and their applications in the field of chemical engineering, metallurgy, nuclear energy, optical, magnetic, luminescence and laser materials, high temperature superconductors and secondary batteries, etc. REMs generally fell into two categories, viz. light rare earths (LREM) and heavy rare earths (HREM), with varying levels of uses and demand. Light rare earths include lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), samarium (Sm) [3]. The separation of individual lanthanides from their mixtures is still receiving considerable attention both from the practical point of view, as they are finding various applications in industry, and as an analytical and technological challenge. The ion exchange and extraction methods are commonly applied to the separation of many metal ions. In majority of cases the driving

force for the separation is a difference between the charge and charge density on various ions present in the solution. Thus, the ion exchange and coordination resin has different affinity towards different ions, what in many cases is enough to achieve the desired separation. Different techniques were used for the ions removal from solutions include the following processes: chemical precipitation, filtration, ion exchange, evaporation, adsorption, liquid-liquid extraction, solid phase extraction, electrochemical processes, and membrane technology^[4,5]. Among these methods is the use of ion exchangers. Ion exchangers are considerable interest; it has a high efficiency and low-cost of operations. The main advantages of ion exchange material are selectivity, recovery of metal ions value^[5]. Thus, this work is focused on investigate the possibility of separation of individual lanthanides and some other ions on the prepared material some other ions on synthesis material and determine the values of the thermodynamic functions associated with the ion-exchange processes^[6].

EXPERIMENTAL

Chemical Reagents and Instruments

The main reagents which used to materials synthesis were obtained from England and Loba Chemie (India). All the other reagents and chemicals were purity of analytical reagent grade and used without further purification. pH measurements were performed using pH meter, model 601A, USA., an atomic absorption spectrophotometer, ICPs, XRD and (DTA and TG) were made on a Shimadzu, Kyoto, Japan, while XRF was made on a Philips, Holland.

Preparation of Polyacrylamide

Polyacrylamide was prepared by mixing equal volume of 20% of acrylamide prepared in distilled water with 0.1 M potassium persulfate ($K_2S_2O_8$) prepared in 1 M HCl. A viscous solution was obtained by heating the mixture gently at $70 \pm 5^\circ C$ with continuous stirring.

Polyacrylamide Ferric Antimonate

Polyacrylamide ferric antimonate was prepared by adding 0.5 M of ferric chloride dissolved in distilled water into polyacrylamide and then added the content to 0.5 M antimony metal dissolved in aqua regia slowly with constant stirring using a magnetic stirrer at a temperature of $70 \pm 5^\circ C$. Produced homogenous solution was precipitate by using ammonia solution drop by drop until about $pH \approx 0.13$ red-brown precipitate. The precipitate was washed by distilled water until the release of fine particles. The supernatant liquid and gel was separated from each other filtered by using a centrifuge (about 104 rpm), dried at $70 \pm 5^\circ C$. The dried products were immersed in DMW to obtain small granules and converted to H^+ -form by treating with 1M HNO_3 for 24 h with occasional shaking intermittently replacing the supernatant liquid with fresh acid. The excess acid was removed after several washings with DMW, dried at $50^\circ C$ and sieved to obtain particles of size range (0.12-1.00 mm).

Characterization of the Prepared Polyacrylamide Ferric Antimonate

We studied some of the physical and chemical properties of the polyacrylamide ferric antimonate. This study was carried out by using different techniques such as X-ray diffraction patterns (XRD), X-ray fluorescence spectrometry (XRF), infrared (IR), and thermal analysis (TGA and DTA).

Chemical Stability

The chemical stability of the polyacrylamide ferric antimonate was studied in water, acid of (HNO_3 and HCl) at different concentrations [0.5, 1, 2, 3 and 4 M] and base of (KOH and NaOH) at different concentrations [0.1 M and 1 M], by mixing 0.1 g of each of samples of polyacrylamide ferric antimonate and 50 ml of the desired solution with intermittent shaking for about one week at $25 \pm 1^\circ C$.

Distribution and Selectivity Studies

The distribution coefficient (K_d) of Sm^{3+} , La^{3+} and Ce^{3+} ions onto polyacrylamide ferric antimonate were determined by using batch equilibration. Sample was taken of the solid material and immersed in metals chloride solution of 50 ppm of La (III), Ce (III) and Sm (III) ions with V/m ratio 50 ml/g as a function of different pH values. The mixture was placed in shaker thermostat adjusted at $30 \pm 1^\circ C$. After overnight standing (sufficient to attain equilibrium), the liquid phases were separated and measured by using inductive coupled plasma spectrometer (ICPS-7500) and atomic absorption spectrophotometer (AA-6701F). From The following relation, we can calculate the distribution coefficient (K_d):

$$K_d = \frac{[A_0 - A_f]}{A_f} \times V/m \quad ml/g \quad (1)$$

Where: A_0 : the initial concentration of the element in solution.

A_f : the final concentration of the element in solution.

V: is the volume of the solution, ml.

m: is the weight of the exchanger, g.

Separation Factor

The separation factor may be considered as the relative tendency of two ions to be adsorbed in an exchanger from solutions of equal concentration. It is used as a measure of possibility of chromatographic separation and is also expressed as the ratio of the distribution coefficients of the elements to be separated as:

$$(\alpha_B^A) = K_d(A) / K_d(B)$$

Where $K_d(A)$ and $K_d(B)$ are the distribution coefficients for the two competing species A and B in the ion-exchange system.

Effect of Major Inorganic Ions on Adsorption

The effect of major inorganic ions including Na^+ , Mg^{2+} and Ca^{2+} on adsorption operation, the study depended on competitive adsorption experiments: adsorption of Sm^{3+} , La^{3+} and Ce^{3+} ions onto polyacrylamide ferric antimonate in the presence inorganic ions with a different concentration. During the experiments the pH of the solutions was constantly adjusted to 4.5 ± 0.1 , and metal ion concentration was measured after shaken for 12 h. The same method was used for assessing the influence of all metals.

Column Operation

Breakthrough column chromatographic investigation was conducted as follows 1 grams of polyacrylamide ferric antimonate was packed in glass column (.3 cm diameter and 3 cm heights) to give bed heights of 1.2 cm volume. 300 ml of the desired solutions (pH=3.29) containing 50 ppm of Sm^{3+} , La^{3+} and Ce^{3+} ions was passed through the column beds at a flow rate of 2-3 drops/min, the concentrations were continuously measured using atomic absorption spectrophotometer and inductively coupled plasma (ICPs) the values of breakthrough capacity were calculated using the formula;

$$\text{Breakthrough capacity} = V_{50\%} \times \frac{C_0}{m} \quad (2)$$

$V_{50\%}$; was the effluent volume at 50% breakthrough

C_0 ; was the initial concentrations of feed solution

M ; was the amount of the column bed per gram

Differential Thermal and Thermogravimetric Analyses

Polyacrylamide ferric antimonate was analyzed for DTA and TGA with sample holder made of Al_2O_3 in N_2 atmosphere using a Shimadzu DTG-60/60H. The heating rate was maintained at $20^\circ\text{C}/\text{min}$ with using alumina powder as reference material.

Infrared Spectra

The IR spectrum of polyacrylamide ferric antimonate was carried out with mixed the solid material with potassium bromide in ratio 1:5 and ground to a very fine powder. A transparent disc was formed in a moisture free atmosphere. The FTIR spectra were recorded using BOMEM-FTIR spectrometer in the range $400\text{-}4000\text{ cm}^{-1}$.

X-ray Analysis

X-ray diffraction patterns of polyacrylamide ferric antimonate was carried out using a Shimadzu XD-D1, X-ray diffractometer with Cu $K\alpha$ radiation tube source and graphite monochromator operating at 30 kV and 30 mA. The measurements were done in 2θ ranges from 5 to 90 with scan speed $2^\circ/\text{min}$.

ICPs-7500

An inductive coupled plasma emission spectrometer model, ICPs-7500, Shimadzu Sequential Type, Kyoto "Japan" was used for measuring the trace concentrations of the different metals in the applied part of the work.

AA-6701

An atomic absorption spectrophotometer model, AA-6701 F-Shimadzu, Kyoto, Japan was used for measuring the trace concentrations of the different metals in the applied part of the work.

RESULTS AND DISCUSSION

This material appears to be a promising hybrid material with good chemical stability. The main results of solubility in water and various concentrations of HNO_3 and HCl and presented in **Table 1**. It was found that the ion exchange material is stable in water, nitric acid and hydrochloric acid [1, 2, 3 and 4M], as well as potassium and sodium hydroxide (0.1, 1M). However, ion exchanger was physically very stable up to 4M hydrochloric acid.

Table 1. Chemical stability of polyacrylamide ferric antimonate (mg/l) at 30 °C relative errors about ± 10%.

HCL	g/L	HNO ₃	g/L	KOH	g/L
0.5	0.0026	0.5	0.0103	0.1	0.4230
1	0.0134	1	0.0165	1	4.9237
2	0.0146	2	0.0176	NaOH	-
3	0.0152	3	0.0200	0.1	0.2683
4	0.0447	4	0.0460	1	3.1324

The prepared ion exchanger was analyzed using infrared spectrophotometer at 50 °C as shown in **Figure 1**. The main absorption band observed for polyacrylamide ferric antimonate at 3250 cm⁻¹ can be attributed to the overlapped between the symmetric stretching vibration of NH₂ group and H₂O, the band at 1680 cm⁻¹ from stretching vibration of C=O, the band at 1625 cm⁻¹ from the bending vibration of NH₂ group, the band at 1450 cm⁻¹ from overlapped of stretching vibration of CH₂ group band and bending mode of M-O-H which show the presence of Sb-O-H, The band at 1375 cm⁻¹ from stretching vibration of C-N band, the band at 1240 cm⁻¹ from the a symmetric vibration of C-C band [7-9] and the band at 650-550 cm⁻¹ due to formation metal oxide which confirmed by thermal analysis.

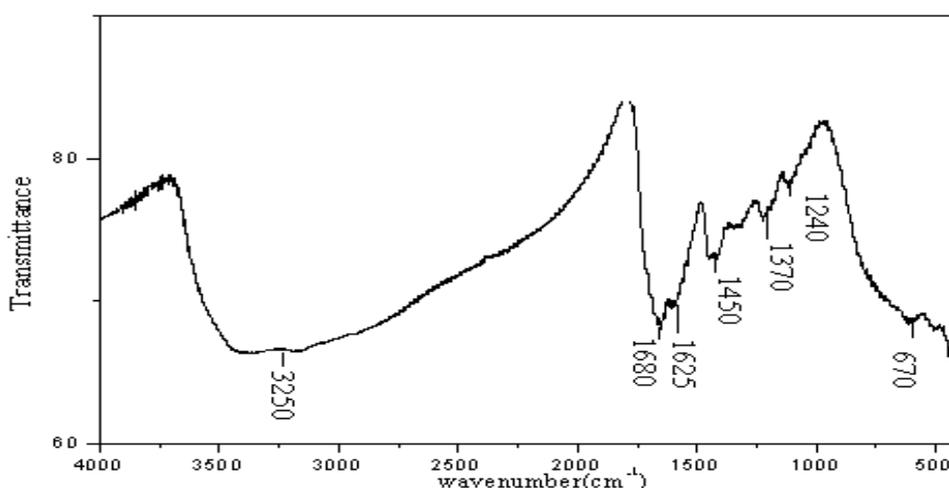


Figure 1. Infrared spectra of polyacrylamide ferric antimonate dried at 50 ± 1 °C.

Thermogravimetric (TG) and differential thermal analysis (DTA) curves for the prepared polyacrylamide ferric antimonate are given in **Figure 2**. The thermograms shown that the first characteristic endothermic peak of the exchanger is due to loss of free water observed at ~84.5 °C, the second exothermic peaks at ~ 249.5 and 447.7 °C due to decomposition of polyacrylamide [10,11]. It was found that, the weight losses were continued up to 600 °C, and no weight loss occurred in the range ~600-1000 °C. The trends are like that reported for zirconium phosphate. This supports the fact that polyacrylamide ferric antimonate has a good thermal stability comparing with the other inorganic ion exchangers [12].

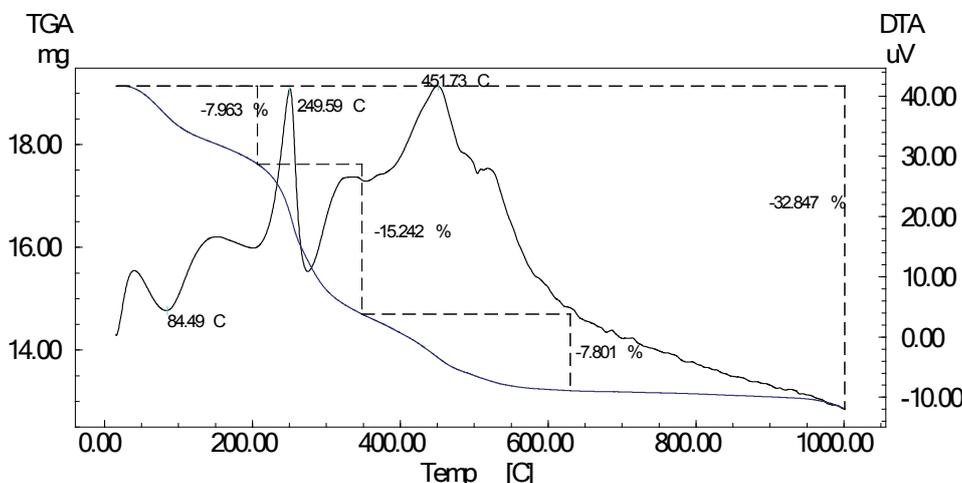


Figure 2. DTA- TG Thermograms of polyacrylamide ferric antimonate.

The X-ray diffraction patterns of the ion exchange material are represented in **Figure 3** it is shown that the prepared material dried at 50 °C have amorphous structure [13].

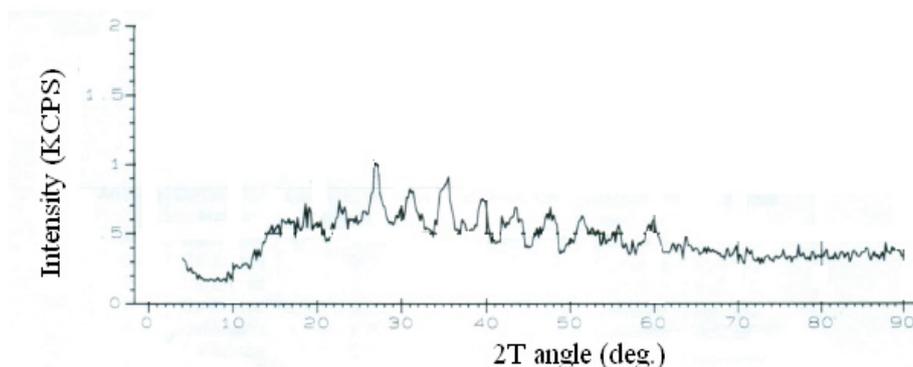


Figure 3. X-ray diffraction patterns of polyacrylamide ferric antimonate at 50 °C.

Distribution and Selectivity Studies

The distribution coefficient was calculated at different pH values of Sm³⁺, La³⁺ and Ce³⁺ ions on polyacrylamide ferric antimonate. The preliminary studies indicated that the equilibrium time for the exchange within 5 h (sufficient to attain equilibrium) in a shaker thermostat adjusted at 30 ± 1 °C. In order to investigate the selectivity coefficient for Sm³⁺, La³⁺ and Ce³⁺ ions, distribution studies (K_d) for metal ions was calculated and the results are shown in **Table 2**.

Table 2. K_d values and separation factors (α) of Sm³⁺, La³⁺ and Ce³⁺ ions as a function of pH on polyacrylamide ferric antimonate at 30 °C.

pH	K _d (ml g ⁻¹)		
	*Sm ³⁺	**La ³⁺	Ce ³⁺
1.40	155.2	47.8 *(3.25)	41.9 *(3.70) **(1.14)
2.43	190.2	90 *(2.11)	72.5 *(2.62) **(1.24)
3.29	449.8	280.2 *(1.60)	266.4 *(1.68) **(1.05)
4.49	252.1	150 *(1.68)	135.3 *(1.86) (1.11)

For all metal ions studied on polyacrylamide ferric antimonate at different condition, the values of distribution coefficient and the separation factor at different pH values is presented in **Table 2**. From the obtained results, it was observed that the distribution coefficients for all metal ions studied increase with increasing pH from 1.40-3.29 but decrease at (pH=4.49). The obtained results of separation factors indicate that the best removal of metals at pH=3.29 and the pH=1.40 more selectivity for Sm³⁺ and high separation factor. The plots of log K_d against pH for the metals ions studied onto polyacrylamide ferric antimonate are shown in **Figures 4-6**.

Table 3 shows the effect of reaction temperature on the absorption of Sm³⁺, La³⁺ and Ce³⁺ ions on polyacrylamide ferric antimonate. The obtained results indicate that the absorption of metals ions increase with increasing reaction temperature and the distribution coefficient and the separation factor at different temperatures is presented in **Table 3**. From the obtained results, it is observed that all metal ions that studied have best removal at about 65 °C.

Thermodynamic Parameters

The values of thermodynamic parameters are relevant for the practical application of absorption process^[14,15]. Isotherm data related to absorption of Sm³⁺, La³⁺ and Ce³⁺ ions onto polyacrylamide ferric antimonite at various temperatures were analyzed to obtain the values of thermodynamic parameters from Van't Hoff plot of the absorption of Sm³⁺, La³⁺ and Ce³⁺ ions as shown in **Figure 7**. The values of thermodynamic function ΔG*, ΔS* and ΔH* were evaluated using Van't Hoff's equation, which is given by:

$$\Delta G^* = \Delta H^* - T\Delta S^* \tag{3}$$

$$\Delta G^* = \Delta H^* - T\Delta S^* \tag{4}$$

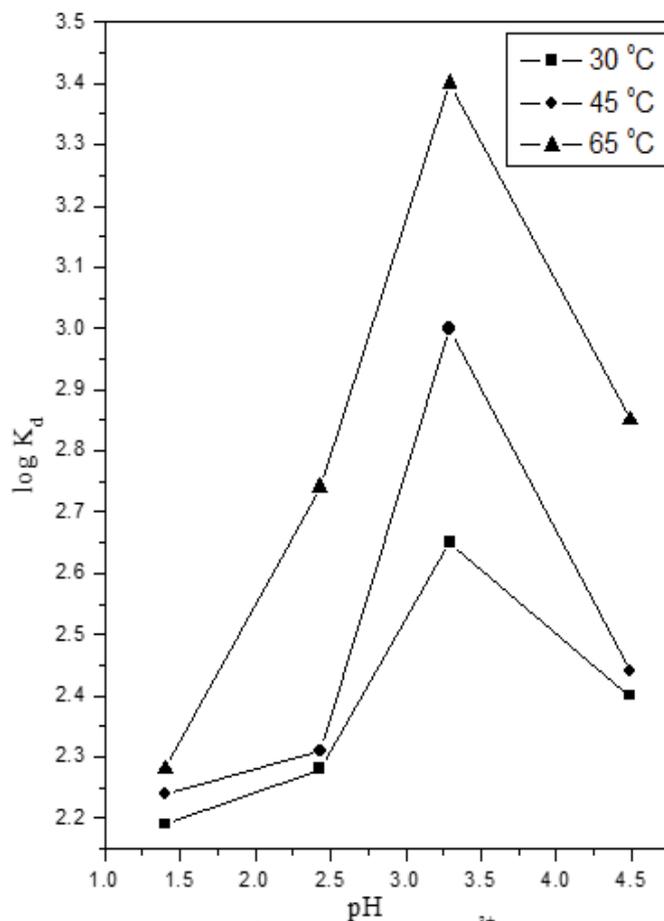


Figure 4. Log K_d as a function of pH of Sm³⁺ ions on polyacrylamide ferric antimonate at different reaction temperatures.

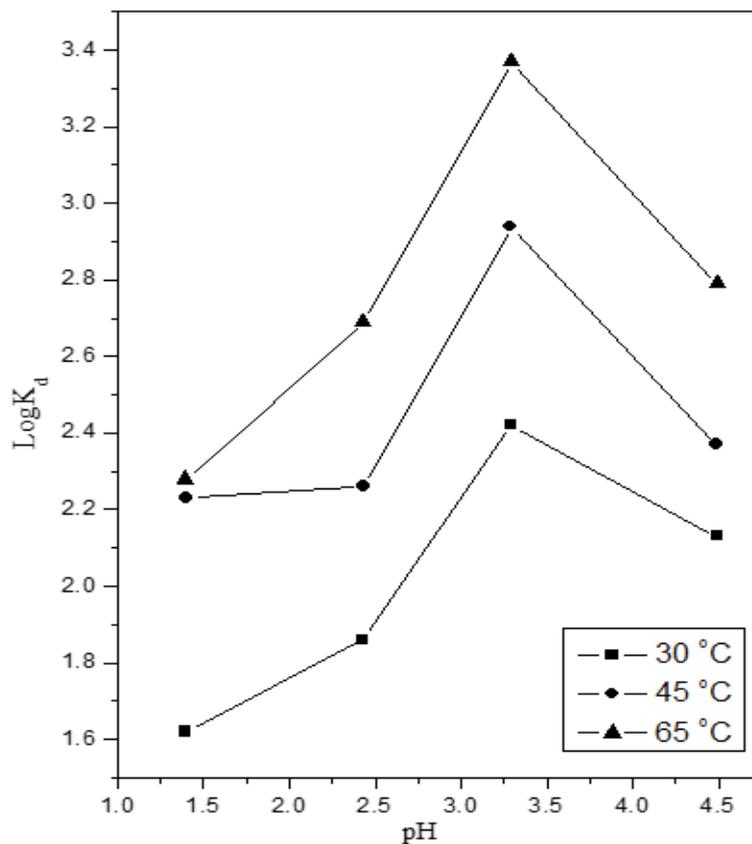


Figure 5. Log K_d as a function of pH of La³⁺ ions on polyacrylamide ferric antimonate at different reaction temperatures.

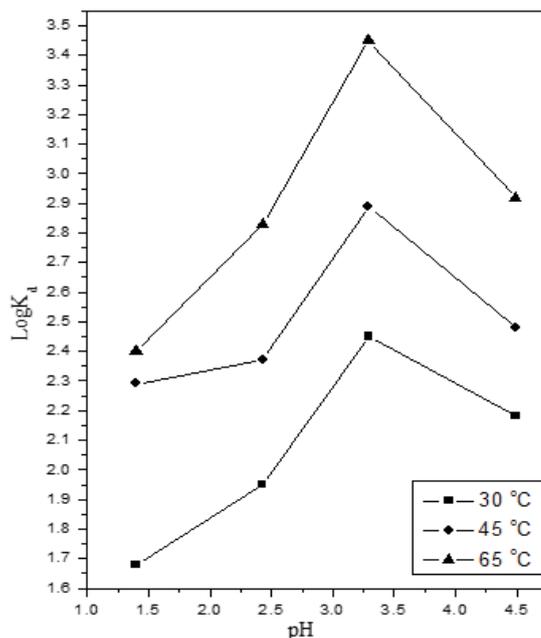


Figure 6. Log K_d as a function of pH of Ce^{3+} ions on polyacrylamide ferric antimonate at different reaction temperatures.

Table 3. K_d values and separation factors (α) of Sm^{3+} , La^{3+} and Ce^{3+} ions as a function of temperatures on polyacrylamide ferric antimonate at pH=3.29.

Temperature	K_d ($ml\ g^{-1}$)		
	* Sm^{3+}	** La^{3+}	Ce^{3+}
30 °C	449.8	266.4 *(1.68)	280.2 *(1.60) **(0.95)
45 °C	1002.2	862.6 *(1.16)	788.4 *(1.27) **(1.09)
65 °C	2531.6	2339 *(1.08)	2841.2 *(0.89) **(0.82)

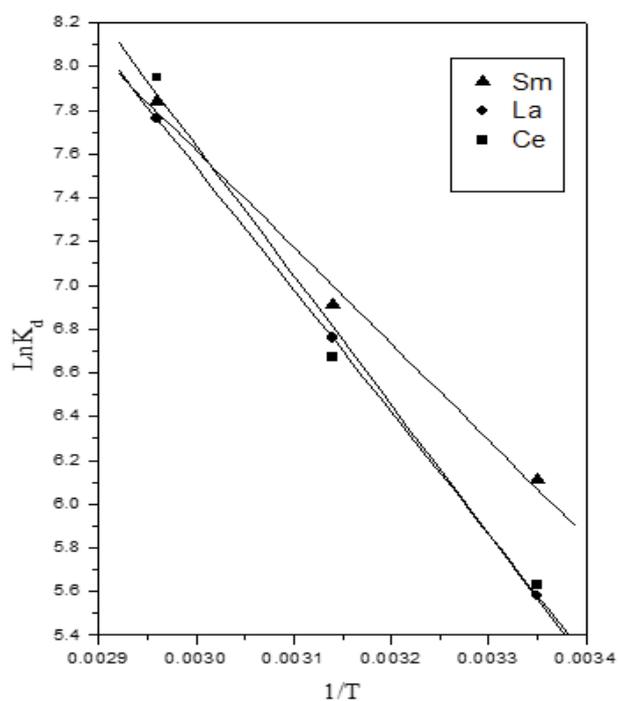


Figure 7. Van't Hoff plot of the adsorption of Sm^{3+} , La^{3+} and Ce^{3+} ions on ferric antimonate.

Where ΔG^* change in Gibbs free energy (J mol^{-1}), R universal gas constant ($8.314 \text{ JK}^{-1} \text{ mol}^{-1}$), T temperature (Kelvin), ΔH^* change in enthalpy (Jmol^{-1}), ΔS^* change in entropy ($\text{Jmol}^{-1} \text{ K}^{-1}$).

The results given in **Table 3** show that the change of free energy for physisorption is generally between -20 and 0 kJ mol^{-1} , the physisorption together with chemisorption is at the range of -20 to -80 kJ mol^{-1} and chemisorption is at a range of -80 to -400 kJ mol^{-1} [16]. As can be seen from **Table 3**, for all metals which studied the adsorption at temperature 298 and 318 K are physisorption and the adsorptions at 338K for all metals are physisorption with chemisorption. The overall standard free energy changes ΔG^* during the absorption process were negative for the experimental range of temperatures, corresponding to a spontaneous. The decrease in the value of ΔG with the increase of temperature shows that the reaction was more spontaneous at high temperature which indicated that the sorption processes are favoured when temperature increases [17]. The positive value of the enthalpy change ΔH^* indicates that the adsorption process is endothermic and this value also indicates that the adsorption follows a physisorption mechanism, and indicate the heat of absorption of Sm^{3+} less than La^{3+} and Ce^{3+} ions so that the adsorption capacity of Sm^{3+} ion more than other ions as calculated from column chromatography [18]. The positive entropy change ΔS^* value corresponds to an increase randomness at the solid/solution interface during the adsorption of Sm^{3+} , La^{3+} and Ce^{3+} ions onto polyacrylamide ferric antimonite.

Effect of Na^+ , Ca^{2+} and Mg^{2+} on Polyacrylamide Ferric Antimonate

The effect of Na^+ , Mg^{2+} and Ca^{2+} onto the absorption operation of Sm^{3+} , La^{3+} and Ce^{3+} ions onto polyacrylamide ferric antimonite, was investigated as follow: 0.100 g of polyacrylamide ferric antimonite material with a certain volume of a mixtures of Sm^{3+} , La^{3+} and Ce^{3+} ions solution then added different concentrations of Na^+ , Mg^{2+} and Ca^{2+} ions. During the experimental operation, adjusted the pH of the solutions was constantly at about 3.29 ± 0.1 , and metal ions concentration was measured after shaking for 12 h, the results shown in the **Tables 4-6**.

Table 4. Thermodynamic parameters for adsorption of Sm^{3+} , La^{3+} and Ce^{3+} ions on polyacrylamide ferric antimonate at different reaction temperature.

Metal ions	Temp (K)	ΔG^* , (KJ mol ⁻¹)	ΔH^* , (KJ mol ⁻¹)	ΔS^* , (J mol ⁻¹ K ⁻¹)
Sm^{3+}	298	-15.39	36.7	171.90
	318	-18.27		172.80
	338	-22.03		173.70
La^{3+}	298	-14.10	46.5	200.00
	318	-17.80		202.00
	338	-21.80		202.10
Ce^{3+}	298	-14.20	49.2	209.20
	318	-17.60		210.10
	338	-22.30		211.50

Table 5. Effect of Na^+ ion on K_d values and separation factors (α) of Sm^{3+} , La^{3+} and Ce^{3+} ions as a function of pH on polyacrylamide ferric antimonate at 30 °C.

Conc.	K_d (ml g ⁻¹)		
	Sm^{3+}	Ce^{3+}	La^{3+}
10^{-3}	38413.46	2547.46 (15.11)	271.42 (141.52) (9.38)
10^{-2}	49950	2547.40 (19.61)	293.75 (170.04) (8.67)
5×10^{-2}	49950	2547.40 (19.61)	312.31 (159.94) (8.16)

Table 6. Effect of Ca^{2+} ion on K_d values and separation factors (α) of Sm^{3+} , La^{3+} and Ce^{3+} ions as a function of pH on polyacrylamide ferric antimonate at 30 °C.

Conc.	K_d (ml g ⁻¹)		
	Sm^{3+}	Ce^{3+}	La^{3+}
10^{-3}	179.85	152.02 (1.18)	157.98 (1.14) (0.96)

10 ⁻²	521.43	415.12 (1.25)	237.68 (1.75) (1.74)
5 × 10 ⁻²	639.65	2275.58 (0.28)	292.93 (2.18) (7.77)

The effect of Na⁺, Mg²⁺ and Ca²⁺ onto the absorption operation of Sm³⁺, La³⁺ and Ce³⁺ ions onto polyacrylamide ferric antimonite. And calculate the distribution selectivity and the results are shown in **Tables 5-7**. The plots of uptake against concentrations of polyacrylamide ferric antimonite are shown in **Figures 8 and 9** for Sm³⁺, La³⁺ and Ce³⁺ ions. It is showed the generally increasing trends in absorption capacity of all metals with increasing concentrations of Na⁺, Mg²⁺ and Ca²⁺ ions. while the effects increasing with absorption of Sm³⁺ [19,20]. The degree of inhibition on absorption by the ions followed the sequence: Na⁺<Ca²⁺<Mg²⁺. However, more complicated effects occurred for different metals. The **Tables 5, 6 and 7** indicate that Sm²⁺ ion can be separated from other ions at some certain concentrations [19,20].

Table 7. Effect of Mg²⁺ ion on Kd values and separation factors (α) of Sm³⁺, La³⁺ and Ce³⁺ ions as a function of pH on polyacrylamide ferric antimonite at 30 °C.

	Sm ³⁺	Ce ³⁺	La ³⁺
10 ⁻³	160.52	1385 (0.12)	170.51 (0.59) (5.12)
10 ⁻²	242.39	2727.7 (0.11)	202.51 (1.19) (13.47)
5 × 10 ⁻²	33283.3	2807.1 (11.86)	282.50 (117.82) (9.94)

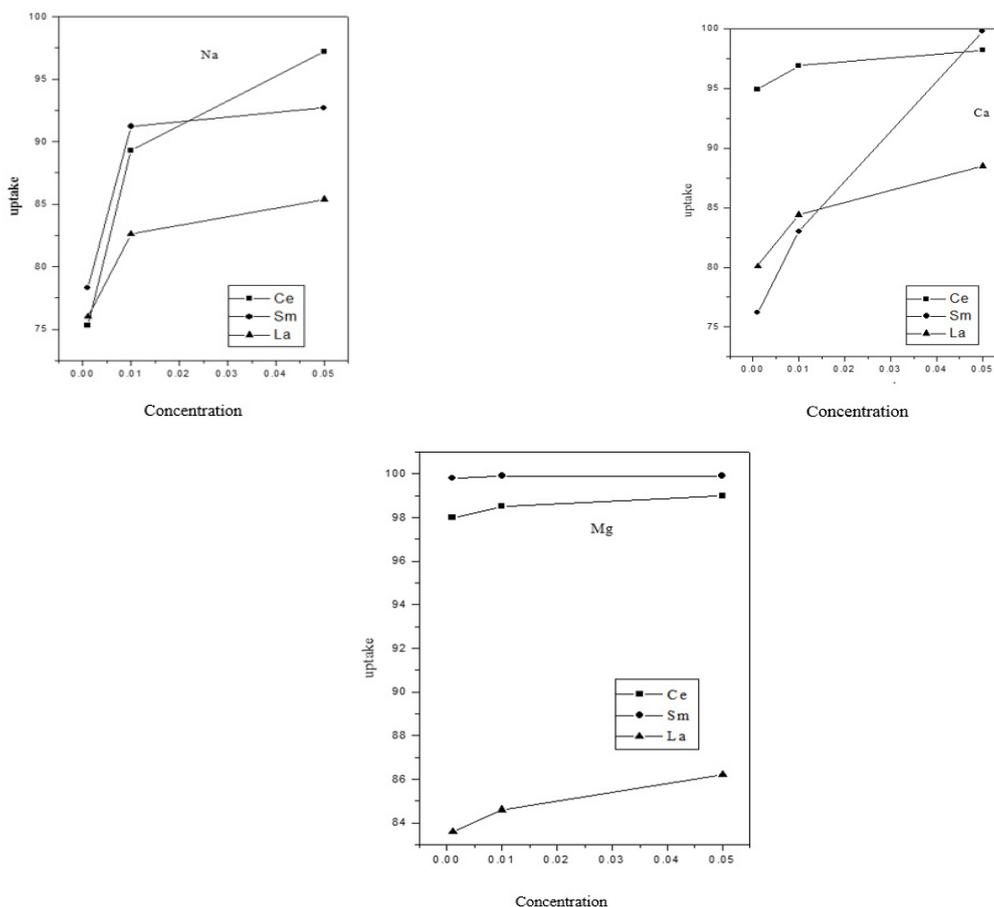


Figure 8. Effect of different concentrations of Na⁺, Ca²⁺ and Mg²⁺ ions on the uptake of Sm³⁺, La³⁺ and Ce³⁺ ions on polyacrylamide ferric antimonite.

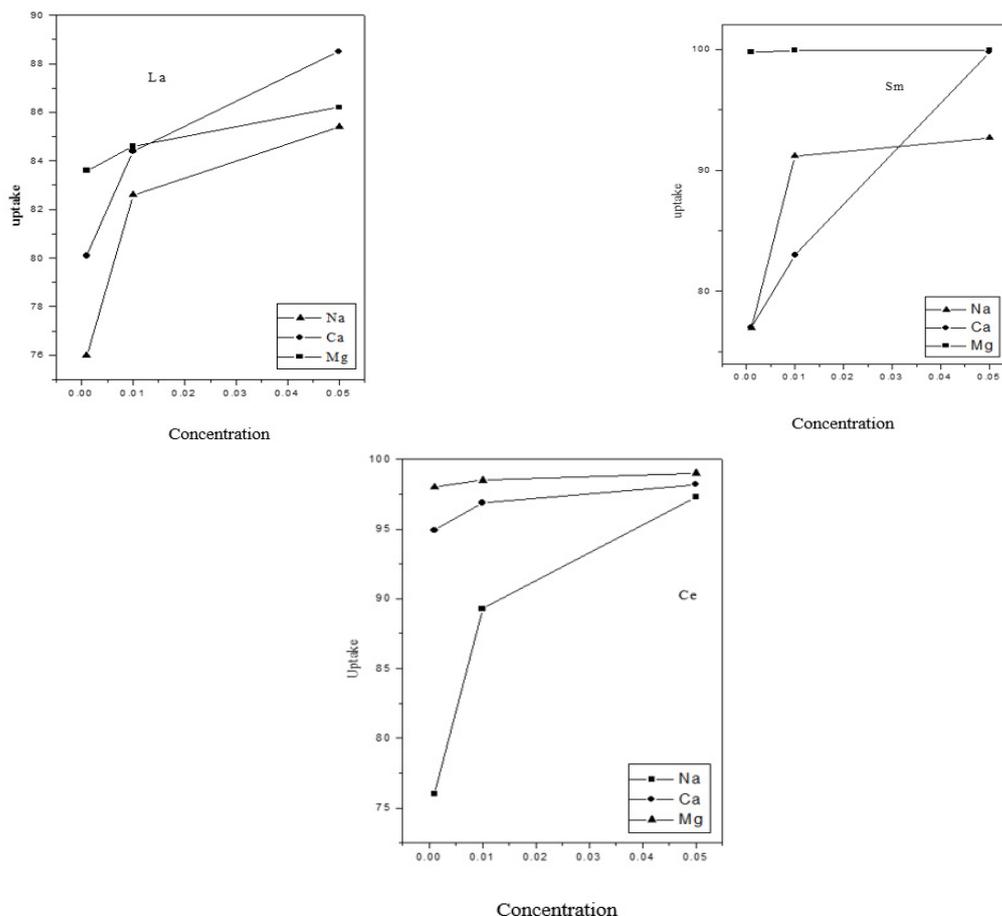


Figure 9. Effect of Na⁺, Ca²⁺ and Mg²⁺ ions on uptake of Sm³⁺, La³⁺ and Ce³⁺ ions on polyacrylamide ferric antimonate at different concentrations.

It was found that the values of uptake increase with the increasing concentrations. The data given in **Tables 6 and 7** indicate that the distribution coefficients have affinity sequence Sm³⁺>La³⁺>Ce³⁺. This sequence may be due to the selectivity of material for metals ions. The separation factors of the studied cations were calculated and indicated that, Sm³⁺ ion has a higher separation factor respectively, onto polyacrylamide ferric antimonate [19,20]. These values indicate that Sm³⁺ ion can easily be separated from the other solutions including the above cations.

Column

In column investigation, when polyacrylamide ferric antimonate are used as ion exchanger material for separation of metal from others in simulated solutions, the solutions is percolated through affixed bed of polyacrylamide ferric antimonate. The column is operated down flow by running the solution through the exchanger from top to bottom. The solution which enters the column is called the influent, and the filtrate from the column is called the effluent.

The procedure may be shown with curves of the ratio C/C₀ between the effluent and influent concentrations as function of time or effluent volume.

Column Techniques

Glass column had internal diameter are 0.3 cm and 1 cm height at flow rate of 0.2 ml/min. which were filled with 1 gram of polyacrylamide ferric antimonite material.

The first step: Prepared mixed solutions of 50 ppm of Sm³⁺, La³⁺ and Ce³⁺ ions were circulated many times through the column with rate at about 0.2 ml/min. This process continues until the concentrations of effluent and influent are the same, to ensure that maximum exchange of metal ion onto the ion exchange material.

Breakthrough capacities have been calculated from **Figure 10** by using the following equation;

$$\text{Breakthrough capacity} = V_{50\%} \times \frac{C_o}{m} \tag{5}$$

The breakthrough capacities of all studied metal were calculated and were found to be 11.13, 7.14 and 5 mg/g for Sm³⁺, La³⁺ and Ce³⁺ ions respectively.

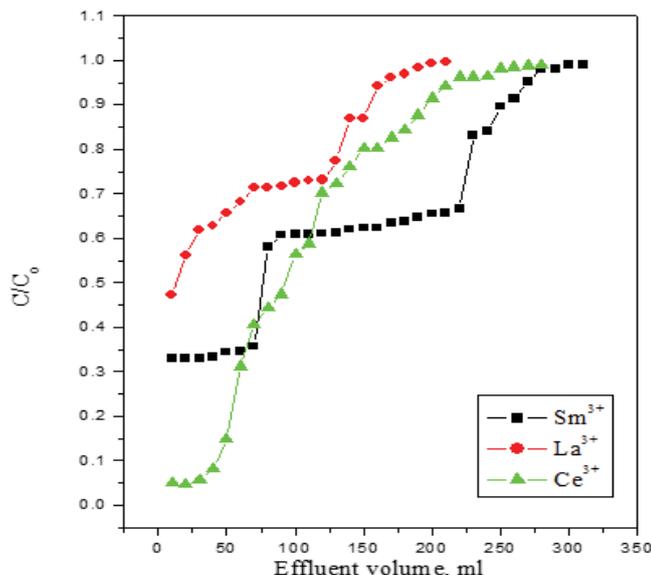


Figure 10. Breakthrough curves of mixture of Effect of Sm³⁺, La³⁺ and Ce³⁺ ions on polyacrylamide ferric antimonate at pH=1.40.

CONCLUSION

The research which carried out in this study clearly suggests that polyacrylamide ferric antimonate composites acts as a good adsorbent material for removal and separation of some metals from each other's of solutions including the Sm³⁺, La³⁺ and Ce³⁺ ions. Polyacrylamide ferric antimonate is an important 'organic-inorganic' composite which have many desirable properties like solvent resistance, thermal stability, characterized using atomic absorption spectrophotometry (AAS), CHN elemental analysis, ICPS, X-ray (XRD and XRF), IR and TGA-DTA. The obtained results it is observed that the distribution coefficients for the all metal ions which studied increasing with increase pH from 1.40-3.29 but decrease at pH=4.49. The obtained result of separation factors indicates that the best removal of metals at about pH=3.29 and the pH=1.40 more selectivity for Sm³⁺ and high separation factor. And also the obtained results showed that all metal ions which studied have best removal at a about 65 °C. The decrease in the value of ΔG with the increase of temperature shows that the reaction was more spontaneous at high temperature which indicated that the sorption operations prefer the high temperature. The degree of inhibition on absorption by the inorganic ions followed the sequence: Na⁺<Ca²⁺<Mg²⁺. However, more complicated effects occurred for different metals. The results indicate that Sm²⁺ ion can be separate from other ions at a certain concentration.

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