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Separation of rare earth elements (REEs) from choghart ore leach liquor by precipitation method

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Abstract

In recent years, the separation of rare earth elements (REEs) from Thorium sources has been considered. One of the effective methods for this goal is precipitation. In this study, First, the compounds of the choghart ore leach liquor were precipitated by NaOH. Then, in order to find the optimal pH range to separate thorium from rare elements, raffinate leaching was performed at various pH. The results showed that pH=3 is the optimum. Then Elements and compounds were precipitated by NaOH and a new raffinate was obtained. Result of new raffinate showed the amount of thorium decreased by 93% and amount of Y(III) and Ce(III) increased approximately three times.

Keywords: Precipitation; Choghart Ore; Rare Earth Elements; Thorium.

Introduction

The demand for rare earth elements has risen dramatically in recent years, resulting in the development of new procedures for extracting rare earth elements from a variety of sources [1]. Uranium and thorium are frequently present in rare earth minerals via lattice substitution due to their comparable chemical structures to rare earths, resulting in radiation concerns in rare earth processing [2]. Uranium can be sold as nuclear fuel if it can be recovered economically as a by-product. However, thorium is currently just a nuclide that could be utilised in the nuclear power sector in the future. At the moment, the market for thorium is very modest, if not non-existent. As a result, thorium is frequently the primary source of radiation risk in rare earth processing [3]. For REEs recovery from leaching solutions originated from ores by acid decomposition, methods such as precipitation, crystallization, solvent extraction, ion exchange have been systematically studied [4]. In 2001, Vijayalakshmi et al [5], investigated the proccessing of xenotime concentrate by sulfuric acid digestion and thorium precipitation for separation of rare earths. The leaching solution used by them was a mixture of 3 M sulfuric acid, 10 g/L REO, and 0.42 g/L ThO_2. In their study, precipitation was performed by 4 M ammoina. Where, the best pH in single-stage precipitation was 1.8 and in the two-stage precipitation, the best pH was 1.5 for first stage and 1.9 for second stage. They were able to removal thorium almost compeletly and showed that rare earth elements, especially Y, can be recovered up to 99%. In this paper, the precipitation of thorium from choghart ore leach liquor for the separation of rare earth elements is inventigated. Important minerals in choghart ore include thorite, magnetite, albite, and augite. Rare earth elements in this ore are Ce and Y.

Experimental

First, the choghart ore was crushed and ground. The size of choghart ore powder mesh used in this research is 120 μm (d80 106 μm).
Choghart ore leaching was performed using 2.5 M H_2SO_4 according to the conditions stated in Table 1.

Table 1. Conditions for leaching process.

L/S	Temperature (°C)	Digestion time (min)	Stirring speed (rpm)
3	80	185	250

In order to remove thorium by selective precipitation method to separation rare earth elements, first, the pH of the leaching solution (500 mL) was gradually increased by adding solid NaOH (80 gr) to pH=9 (in 30 °C and by 250 rpm) and then filtered.
The raffinate was placed in an oven at 50 °C for 48 hours to dry (weight of dry raffinate almost 110 gr).
Raffinate leaching was then performed at various pH (1-5). For leach at the every pH, 10 gr of raffinate was mixed with 30 mL of distilled water and was brouth to the required pH by gradully addition sulfuric acid

(purity 95-98%). After attaining the required pH, the slurry was digested for 120 minutes and then filtered.

Results and discussion

The results of ICP-OES[1] analysis of the choghart ore leach liquor prepared for rare earth elements and thorium are presented in Table 2.

Table 2. Results of ICP-OES analysis of the choghart ore leach liquor for REEs and thorium.

Elements	Ce	Y	Th
Concentration (mg/L)	21	19	450

The result of the raffinate XRF[2] analysis are presented in the Table 3.

Table 3. Result of XRF analysis of the raffinate

Componds	wt%	Componds	wt%
Al_2O_3	0.61	**Cr_2O_3**	400 (ppm)
SiO_2	1.11	**MnO**	0.41
P_2O_5	6.54	**Fe_2O_3**	24.12
SO_3	63.25	**CuO**	0.26
Cl	900 (ppm)	**ZnO**	0.24
CaO	1.14	**Y_2O_3**	850 (ppm)
TiO_2	0.24	**Ce_2O_3**	550 (ppm)
V_2O_5	300 (ppm)	**ThO_2**	0.86

The result of ICP-OES analysis for the obtained solution at various pH are reported in Table 4.

Table 4. Result of ICP-OES analysis for the obtained solution at various pH

pH range of raffinate leaching solutions	Ce (mg/L)	Y (mg/L)	Th (mg/L)
1	20.7	18.9	406
2	18.9	17.8	62
3	14.2	15.8	1.9
4	6.9	7.3	0.2
5	1.14	0.43	0

As can be observed in Table 4, the amount of thorium decreased significantly with pH increment. The porpose of precipitation experiments is to achieve a range of pH where thorium can be effectively separated from rare earth elements. As shownin Table 3, this happened at range of pH=3.

For prepare a concentrate of choghart ore that higher amounts of rare earth elements and also a lower amount thorium, like before, pH of the optimal raffinate leaching solution (pH=3) was gradually increased by adding solid NaOH to pH=9 and then filltered and the new raffinate was placed in an aven to dry.

The result of the new raffinate XRF analysis are presented in the Table 5.

Table 5. Result of XRF analysis of the new raffinate

Componds	wt%	Componds	wt%
Al_2O_3	1.53	**Fe_2O_3**	26.6
SiO_2	0.66	**NiO**	550 (ppm)
SO_3	66.68	**CuO**	0.45
K_2O	350 (ppm)	**ZnO**	0.59
CaO	0.93	**Y_2O_3**	0.26
TiO_2	300 (ppm)	**Ce_2O_3**	0.19
V_2O_5	400 (ppm)	**ThO_2**	550 (ppm)
MnO	1.36		

Conclusions

The separation of rare earth elements (REEs) from choghart ore leach liquor by precipitation method was investigated (by NaOH). The compounds of the choghart ore leach liquor were precipitated by NaOH to raffinate prodution. Leaching of raffinate was investigated at various pH. At pH=3, a favorable difference was observed between the amount of thorium and rare elements. Comparing the results of XRF analysis in tables 3 and 5, it can be seen that thorium has been removed by 93% and also the amounts of cerium and yttrium have increased significantly (approximately tripled). The results showed that the precipitation is a suitable method for separation of rare earth elements (REEs) from choghart ore leach.

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[1] Inductively coupled plasma optical emission spectrometry

[2] X-ray Fluorescence spectrometry