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*Corresponding author

Bahram Rezai, Department of Mining Engineering, Amirkabir University of Technology, Tehran, Iran

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Cerium; Solvent Extraction; Synergism; Rare Earth Elements

Short Communication

Extraction of Cerium from Nitric Acid Medium using Cyanex 302 and Cyanex 572

Ebrahim Allahkarami and Bahram Rezai*

Department of Mining Engineering, Amirkabir University of Technology, Iran

Abstract

In this paper, the extraction of cerium from the synthetic environment ([Ce]=0.04 M) was investigated using the solvent extraction method with a mixture of solvents. Considering that the synergy of extractants can lead to the improvement of cerium extraction, Cyanex 302 solvent was used for synergy with Cyanex 572. The results showed that the combination of Cyanex 572-Cyanex 302 can extract a high percentage of cerium (> 90%). Also, the value of ΔG is equal to 18.61 (kJ/mol), so the extraction reaction of Ce (III) is non-spontaneous.

Introduction

Rare earth elements play an important role in many advanced industries due to their specific spectral and magnetic properties. However, due to the increasing need of industries for these materials, it is necessary to enrich the ore containing these elements and extract them [1]. These elements are found in many minerals such as monazite, xenotime and other minerals. After beneficiation of ore containing rare earth elements by methods such as magnetic, gravity and flotation and similar cases, a valuable concentrate of rare earth elements is obtained [2]. Membrane, ion exchange resin, adsorption (clays, biological materials, etc.) and solvent extraction methods are used to purify the leach liquor solution. All these methods have many disadvantages, such as low recovery of rare earth elements, removal of sediments, increase in environmental pollution caused by the storage of radioactive substances and release of harmful gases. Ion exchange is also one of the common methods to recover different ions, which has disadvantages such as slow absorption and desorption rates, poor selective recovery, and on the other hand, it requires a solution rich in electrolytes for recovery. The solvent extraction method is more suitable than other methods due to its low cost and high efficiency. Also, the selectivity of this method and its ability to be industrialized on a large scale are other significant advantages of the solvent extraction method [3].

The current research was conducted with the aim of investigating the extraction of cerium from nitric acid medium using solvent extraction process. In this paper, the extraction of cerium from the synthetic environment ([Ce]=0.04 M) was investigated using the solvent extraction method with a mixture of Cyanex 572 and Cyanex 302.

Results and Discussion

The percentage of metal ion extraction in the organic phase is expressed as the following equation:

$$E\% = \frac{D}{1+D} \times 100 \quad (1)$$

In synergistic systems, synergistic factor R is used to calculate synergistic effects (double combination) on metal ions. Based on the synergy extraction theory, the synergy factor can be calculated as the following equation:

$$R = \frac{D_{mix}}{D_A + D_B} \quad (2)$$

Which D_{mix} indicates the distribution ratio, when the metal is extracted with a combination of two organic solvents, and D_A and D_B are the distribution ratio of each of the solvents that are used separately. If R is greater than 1, the extraction is synergistic and if it is smaller than 1, it is non-synergistic [4].

First, preliminary experiments were conducted to select the appropriate pH to check synergy. The results showed that pH 4 is a suitable pH for investigating the synergy of two extractants. Figure 1 shows the extraction of cerium by Cyanx 302, Cyanx 572 and the combination of Cyanx 302 and Cyanx 572 at initial pH 4 and equal volume ratio of aqueous to organic phase. $X_{Cyanex\ 302}$ shows the molar fraction of Cyanex 302. The distribution coefficient of cerium was calculated in the state of mixing two extractants with Cyanex 302 molar fraction and keeping the total concentration of two extractants constant at 0.5 M. The synergistic effect of Cyanex 302-Cyanex 572 on cerium extraction can be clearly seen. The best combination of two extractants was obtained in XD2EHPA equal to 0.20. As shown in Figure 2, the slope of the linear graph of log D in terms of 1000/T shows the enthalpy change of the reaction.

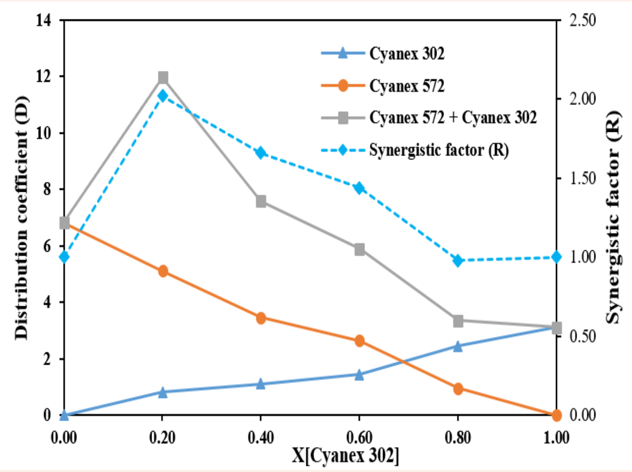

Figure 1: Distribution coefficient of cerium with Cyanex 302, Cyanex 572, and the combination of Cyanex 302 and Cyanex 572 (pH=4, aqueous to organic phase volume ratio = 1, [Cyanex 302] + [Cyanex 572] = 0.5 M).

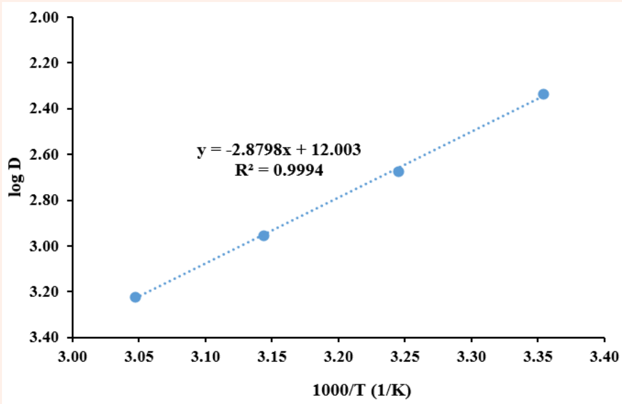

Figure 2: Effect of temperature on cerium distribution coefficient (0.04 M cerium (III), 0.4 M Cyanex 572, 0.1 M Cyanex 302 and 0.5 M nitrate concentration)

Therefore, the value of ΔH for cerium extraction by Cyanex 572-Cyanex 302 was calculated as 55.14 (kJ/mol). As can be seen in Table 1, the value of ΔG is equal to 18.61 (kJ/mol), so the extraction reaction of Ce (III) is non-spontaneous. The positive value of ΔS (122.53 J/mol K) indicates that more disorder is created in the system after Ce (III) extraction.

Table 1: Thermodynamic parameter values of cerium extraction by Cyanex 572 and Cyanex 302.

Thermodynamic Parameters	Enthalpy (kJ/mol)	Entropy (J/mol K)	Gibbs free energy (kJ/mol)
Value	55.14	122.53	18.61

Conclusion

The current research was conducted with the aim of investigating the extraction of cerium from nitric acid medium using a mixture of Cyanex 572 and Cyanex 302. The best combination of two extractants was obtained in XD2EHPA equal to 0.20. The thermodynamic parameters indicated that the value of ΔH for cerium extraction by Cyanex 572-Cyanex 302 was calculated as 55.14 (kJ/mol). Furthermore, the value of ΔG and ΔS were equal to 18.61 (kJ/mol) and 122.53 J/mol K, respectively. Therefore, the positive value of ΔG showed that the extraction reaction of Ce (III) was non-spontaneous.

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