Experimental Study on the Uranium(VI) Extraction Rate from a Sulfate Leach Liquor with Alamine 336 in a Single Drop Column

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Abstract
In this study, the degree of uranium extraction was investigated from a leach liquor by Alamine 336 in a single drop column. Alamine 336 diluted in kerosene was selected as the dispersed. The effect of different operating parameters and structural parameters were separately studied. The obtained results shown that the increasing of the extractant concentration has a direct impact on degree of uranium extraction. Also, the increasing of the sulfate concentration to 0.2 causes an increase in degree of extraction rate, but with a further increasing in the sulfate content, a decreasing trend is observed. The information obtained from the results of the present study can be used for the design of the extraction column.

Keywords: Uranium, extraction rate, Single drop column, Alamine 336

Introduction
Uranium is a very major element because it supplies with nuclear fuel used to generate electricity in nuclear power plants. Therefore, the uranium extraction from the ores is important [1]. Solvent extraction method has been routinely used for uranium recovery from the ores on the industrial scale. Considering the literature reported on the extraction of uranium, many amine-based extractants have been utilized for extraction of uranium from various sources as sulfate solutions. Type tertiary amine extractants (like Alamine 336) are effective components for the extraction of uranium from the sulfate leach liquors [2].
Mass transfer performance to and from drops is common in solvent extraction process [3]. Most studies on single drop showed that mass transfer and droplet dynamics are important parameters in the free fall time [4]. An overview of experimental methods for measuring the mass transfer rate in liquid-liquid extraction systems can be found in various references. There is little experimental works on a suitable method for directly measuring mass transfer rate during droplet formation, and most research is limited to very long formation time [5].
According to above studies, the intention of this investigation is to investigate the operating and constructional parameters on the uranium extraction rate. Hence, the process parameters and the constructional parameters were investigated on degree of uranium extraction. Therefore, the information obtained from the results in a single drop column study can be used for the design of the solvent extraction column.

Experimental
The chemical compositions of leach liquor as continuous phase solution are presented in Table 1. The organic phase was prepared by solving commercial Alamine 336 as in the commercial grade of kerosene as diluent.

Table 1. The chemical combination of the leaching dissolution from Ghachin site of Bandar Abbas

Component	Analysis Apparatu	Value (g L^{-1})
U(VI)	ICP	0.25
Ca	ICP	0.9
Fe	ICP	1.06
Al	ICP	1.2
Mn	ICP	1.6
Mg	ICP	5.97
Cl^-	IC	3.25
SO_4^{2-}	IC	21.5

Extraction of uranium from the sulfate leach solution by Alamine 336 is performed at interfacial area according to the following reaction [6]:

$$2[(R_3NH)_2SO_4]_{org} + [UO_2(SO_4)_3^{4-}]_{aq} \leftrightarrow [(R_3NH)_4UO_2(SO_4)_3]_{org} + 2[SO_4^{2-}]_{aq} \quad (1)$$

The drops of organic phase before the start of the experiment has an initial concentration of C_{Ao}. During the rising of the droplet in the continuous phase, some of the desired component is transferred from the continuous phase to the dispersed phase. If the concentration obtained at a certain height from column C_A and C_A^* is the equilibrium concentration, the degree of extraction rate is calculated as follows:

$$E = \frac{C_A - C_A^*}{C_{A0} - C_A^*} \quad (2)$$

Results

Figure 1 shows the degree of uranium extraction rate versus Alamine 336 concentrations changes. The fraction of solute extracted is increased during extractant concentration increases. The results show that at first the changes of these parameters are severe with Alamine 336 concentration increases (from 0.01 M to 0.15 M) but at a concentration higher than 0.15 M the increasing trend is slowed down.

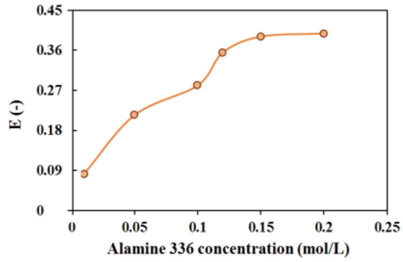

Figure 1. Effect of extractant concentration on the degree of extraction rate

The presence of sulfate ions is desirable for the formation of extractable uranium species in the aqueous phase. The maximum uranyl sulfate extraction is done at presence of slight of sulfate in the aqueous phase. The results of the effect of sulfate ion concentration study on the degree of extraction rate from the leach liquor solution are presented in Figure 2. According to this figure, this parameter increases with increasing sulfate ion concentration to 0.2 M and then with increasing sulfate ion concentration up to 0.2 M will has a decreasing trend.

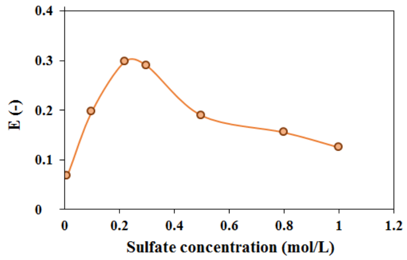

Figure 2. Effect of sulfate concentration on the degree of extraction rate

The variation of the extraction rate degree with temperature for different nozzles size is presented in Figure 3. As shown in this figure, this parameter increase with increment of temperature. On the other hand, the average increment of the droplet mass transfer coefficient for smaller droplets is about 30%. However, as the droplets become larger (increasing the nozzle diameter), a decreasing trend is observed in the degree of extraction rate. Molecular diffusion is the most important parameter for this trend, which is directly dependent on the absolute temperature of the solution and the viscosity of the solvent.

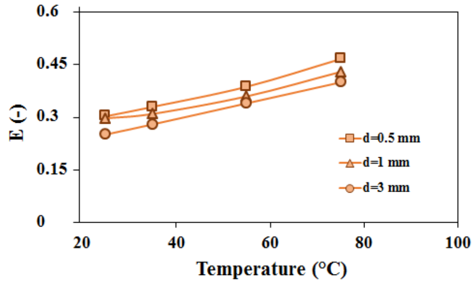

Figure 3. Variation of degree of extraction rate with nozzle size at different temperatures

Conclusions

The extraction rate degree were calculated using equations in single drop technique method. At first, the changes of uranium extraction rate are severe with Alamine 336 concentration increases but at a concentration higher than 0.15 M the increasing trend is slowed down. The studied parameters in this research increase with increasing sulfate ion concentration to 0.2 M and then with increasing sulfate ion concentration up to 0.2 M will have a decreasing trend. With increasing the column height, the degree of uranium extraction rate from sulfate leach liquor increases and a decrease in the mass transfer coefficient values is observed. The variation of the extraction rate degree with temperature shown that this parameter increase with increment of temperature.

References

[1]. J. R. Kumar, J. S. Kim, J. Y. Lee, and H. S. Yoon, "A brief review on solvent extraction of uranium from acidic solutions," Sep. & Purify. Reviews, vol. 40, pp. 77–125, 2011.

[2]. F. Khanramaki, A. S. Shirani, J. Safdari, and R. Torkaman, "Investigation of liquid extraction and thermodynamic studies on uranium from sulfate solution by Alamine 336 as an extractan", International Journal of Environmental Science and Technology, vol. 15 (7), pp. 1467-1476, t, 2017.

[3]. J. Temos, H. R. C. Pratt, and G. W. Stevens, "Mass Transfer to Freely Moving Drops," Chem. Eng. Sci., vol. 51, pp. 27-36, 1996.

[4]. R. Clift, J. R. Grace, and M. E. Weber, Bubbles, Drops and Particles: New York: Academic Press, 1978.

[5]. M. Henschke and A. Pfennig, "Mass-Transfer Enhancement in Single-Drop Extraction Experiments," AIChE Journal, vol. 45, 1999.

[6]. F. Khanramaki, A. S. Shirani, J. Safdari, and R. Torkaman, "Equilibrium and kinetics of uranium(VI) extractionfrom a sulfate leach liquor solution by Alamine 336using single drop technique," Chem. Eng. Res. Des., vol. 125, pp. 181-189, 2017.