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«Жанармай, катализ және электрохимия институты» АҚ

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EXTRACTION OF DYSPROSIUM BY D2EHPA FROM NITRATE MEDIUM

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Abstract. Rare earth elements (REE) are important metals that are often used in modern production. In nature, REEs are found in various ores, such as phosphorus-containing ores. Usually, a large amount of REE remains in the waste after processing and flotation of these ores. Therefore, it is essential to process and extract rare earth elements. In the waste of phosphorus-containing ores, dysprosium is found in significant quantities in comparison with other lanthanides. Optimal conditions for the decomposition of phosphate waste in a closed system have been studied. This work considers the extraction of dysprosium from standard solutions in a nitrate medium with the cation-exchange extractant di-2-ethylhexylphosphoric acid (D2EHPA). For this purpose, the effect of various diluents, such as hexane, kerosene, higher carboxylic acids (HCA), and paraffin on the extraction of dysprosium was studied. The optimal parameters were studied: extraction temperature, pH, concentration, and volume ratio of the aqueous phase and extractant. According to the results of the study, extraction with the D2EHPA — paraffin system at pH 1.1-6.0 is 94 %, and the optimal volume ratio of the aqueous phase and the extractant is 1:10. The D2EHPA — paraffin system is adequate for extracting dysprosium. The results obtained, which are considered with a standard solution of dysprosium, will be used to separate it from phosphate waste.

Keywords: extraction, rare earth metals, dysprosium, di-2-ethylhexylphosphoric acid (D2EHPA), paraffin

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НИТРАТТЫ ОРТАДАН ДИСПРОЗИЙДІ Д2ЭГФҚ-МЕН ЭКСТРАКЦИЯЛАУ

Аннотация. Сирек жер элементтері (СЖЭ) қазіргі заманғы өндірісте жиі қолданылатын маңызды металдар болып табылады. Табиғатта СЖЭ әртүрлі рудаларда, соның ішінде құрамында фосфоры бар кендерде кездеседі. Әдетте бұл кендерді өңдеуден және флотациялаудан кейін алынған қалдықтарда СЖЭ мөлшері көп болады. Сондықтан сирек жер элементтерін өңдеу және өндіру өте маңызды. Құрамында фосфоры бар кендердің қалдықтарында диспрозий басқа лантаноидтармен салыстырғанда айтарлықтай мөлшерде болады. Фосфат қалдықтарының жабық жүйеде ыдырауының оңтайлы шарттары зерттелді. Бұл жұмыста катионалмастырғыш ди-2-этилгексилфосфор қышқылы (Д2ЭГФҚ) экстрагентімен нитратты ортадағы стандартты ерітінділерінен диспрозийді бөліп алу қарастырылды. Диспрозий экстракциясына гексан, керосин, жоғары карбон қышқылдары (ЖКҚ), парафин сияқты әртүрлі еріткіштердің әсері зерттелді. Экстракцияның оңтайлы параметрлі қарастырылды: температура, pH, концентрация, сулы фаза мен экстрагенттің көлемдік қатынасы. Зерттеу нәтижелері бойынша Д2ЭГФҚ – парафин жүйесімен pH 1,1–6,0 кезінде экстракцияның бөліну дәрежесі 94% және сулы фаза мен экстрагенттің көлемдік қатынасы 1:10 құрады. Д2ЭГФҚ — парафин жүйесі диспрозийді бөліп алу үшін тиімді болып табылды. Диспрозийдің стандартты ерітіндісінен алынған нәтижелер оны фосфат қалдықтарынан бөліп алу үшін пайдаланылады.

Түйін сөздер: экстракция, сирек жер металдары, диспрозий, ди-2-этилгексилфосфор қышқылы (Д2ЭГФҚ), парафин

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ЭКСТРАКЦИЯ ДИСПРОЗИЯ С Д2ЭГФК ИЗ НИТРАТНОЙ СРЕДЫ

Аннотация. Редкоземельные элементы (РЗЭ) являются важными металлами, которые часто используются в современном производстве. В природе РЗЭ встречаются в разных рудах, такие как фосфорсодержащие руды. Обычно большое количество РЗЭ остается в отходах после обработки и флотации этих руд. Поэтому очень важно обрабатывать и извлекать редкоземельные элементы.

В отходе фосфорсодержащих руд встречается диспрозий в значительных количествах по сравнению с остальными лантаноидами. Изучены оптимальные условия разложения фосфатного отхода в закрытой системе. В работе рассматривается извлечение диспрозия из стандартных растворов в нитратной среде с катионообменным экстрагентом ди-2-этилгексилфосфорной кислотой (Д2ЭГФК). Исследовано влияние различных разбавителей, такие как гексан, керосин, высшие карбоновые кислоты (ВКК) и парафин на экстракцию диспрозия. Изучены оптимальные параметры экстракции: температура, pH, концентрация и объемное соотношение водной фазы и экстрагента. По итогам исследования экстракция с системой Д2ЭГФК – парафин при pH 1,1–6,0 составляет 94 %, а оптимальное объемное соотношение водной фазы и экстрагента 1:10. Система Д2ЭГФК – парафин является эффективным для извлечения диспрозия. Полученные результаты, которые рассмотрены со стандартным раствором диспрозия будет применяться для выделения его из фосфатных отходов.

Ключевые слова: экстракция, редкоземельные металлы, диспрозий, ди-2-этилгексилфосфорная кислота (Д2ЭГФК), парафин

Introduction

Currently, rare earth metals (REM), i.e. 14 f-elements (Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) and 3 d-elements (Sc, Y, La) are critically important elements for the production of magnets, fluorescent lamps, lithium hydride batteries, etc. In nature, REM occurs in the form of various ores, such as monazite, bastnesite, xenotime, and others. In our work, the extraction of dysprosium from phosphate waste is considered. In phosphate slag, the amount of dysprosium is greater than the rest of the REE. Therefore, it is important to quantify the extraction of dysprosium in the waste of phosphorus-containing ores.

One of the effective methods of extraction of rare earth elements is extraction. D2EHPA is often used for the extraction of REE (Acharya et al., 2015; Kolarik, 2010; Mowafy & Aly, 2006; Ohashi et al., 2007; Pei et al., 2012; Turanov et al., 2004; Wannachod et al., 2014a; Wannachod et al., 2014b; Wannachod et al., 2015) as a cation-exchange extractant, that is, it is a selective extractant for REE. Also, the results of the work of other authors who used D2EHPA with various diluents as an effective extractant for the extraction of rare earth metals from different media are presented in Table 1.

The authors of (Erust et al., 2021) performed an extraction of Nd and Dy from a neodymium magnet with Cyphos IL 101 and D2EHPA at pH 4.5 at room temperature. The extraction results showed that 72.3 % Tv and 66.3 % Vn were isolated with Cyphos IL 101 and 98.7 % Tv, 82.6% Vn using 0.4 M D2EHPA. Here you can see that the effect of Cyphos IL 101 is significantly lower than D2EHPA.

N.A. Ismail et al. (Ismail et al., 2019) used a bifunctional extractant – di (-2-Ethylhexyl) phosphate (P_2O_4) with IL Aliquat 336 (A 336), which is diluted in n-heptane. The ratio of organic and aqueous phases is 4:1 at room temperature. Samarium showed the highest separation factor of 2.81, and the separation factor of samarium from europium was 2.26. Samarium is easily separated from a mixture of Sm-Eu-Gd solutions in the first stage of extraction, and Eu and Gd in the second stage of extraction. For re-extraction, nitric, hydrochloric, and sulfuric acids were used for comparison. Among them, HNO_3 gives a high possibility of separation than HCl and H_2SO_4. Aliquat 336 as an extractant was used in the following work (Jürjo et al., 2021) compared with D2EHPA, extraction was carried out in a highly acidic medium pH 1.5 to extract lanthanides from Estonian phosphor ore. It has been found that U, Th, and Tl (in ore) can be selectively extracted using A336[NO_3] with concentrated nitric acid. However, the extraction of REE from A336[NO_3] is insignificant. Thus, A336[NO_3] cannot be proposed as a good extractant for REE. And D2EHPA is more selective compared to A336[NO_3].

In the following work (Mishra & Devi, 2020), one can also see the extraction of samarium in a monocyte, in which 0.1 mol/L D2EHPA in kerosene and 0.1 mol/L trihexyltetradecylphosphonium bis(2-ethylhexyl)phosphate [P66614][D2EHPA] in kerosene were used as a cation exchanger. The optimal separation coefficient Sm/La = 130.83. And in this work it is also noted that D2EHPA is a better extractant than [P66614] [D2EHPA].

Table 1 - Extraction of REE with D2EHPA with various diluents in different years (Ni'am et al., 2020)

REE	Extractant	Diluent	R, %	Year	References
Nd(III)	D2EHPA	Kerosene	92.9	2012	(Pei et al., 2012)
Eu (III)	D2EHPA	Kerosene	94.2	2011	(Pei et al., 2011)
Nd (III)	D2EHPA	Heptane	94.5	2014	(Wannachod et al., 2014b)
Nd, Dy and Pr	D2EHPA	Isopar-L	83.5, 81.55, and 87.93	2020	(Ni'am et al., 2020)
Nd (III)	D2EHPA	Aliphatic	90.0	2018	(Batchu & Binnemans, 2018)
Nd (III)	D2EHPA	Kerosene	90.2	2019	(Kumari et al., 2019)
Dy (III)	D2EHPA	Hexane	67	2022	In this work
Dy (III)	D2EHPA	Paraffin	94	2022	
Dy (III)	D2EHPA	HCA	70	2022	

Also, extracts of REE with D2EHPA with various diluents and other extractants are presented in the works (Gergoric et al., 2017; Kurdakova et al., 2017; Maslennikova & Sinegribova, 2017; Matsumiya et al., 2021; Mohammadi et al., 2015; Raji et al., 2017; Daware et al., 2021; Seyed Alizadeh Ganji et al., 2016; Yoon et al., 2016).

In this work, various diluents with the cation-exchange extractant D2EHPA for the separation of dysprosium from nitrate media are considered. The influence of various factors on metal extraction has been studied, and optimal conditions for the dissolution of phosphate waste have also been studied. As part of the waste, dysprosium occurs in significant quantities. Therefore, in the future, the separation of dysprosium from phosphate waste will be considered.

Materials and methods

2.1 Reagents

The following reagents were used for the experiment: nitric acid HNO_3 (67 %), D2EHPA (purity 95 %), dysprosium oxide (purity 98 %), hexane (purity 95 %), kerosene, paraffin, phosphate waste.

2.2 Aparatus

Inductively coupled plasma - mass spectrometer ICP-MS (Agilent 7500 A, USA), muffle furnace (SNOL 7,2/1300, Lithuania), microwave sample preparation system (Speedwave four "Berghof", Germany), photocolorimeter KFK-2MP (Russia), I-160 MI Ionomer (Russia)

2.3 Acid leaching of phosphate waste

Acid leaching of phosphate slag was carried out in a closed system in an autoclave. 0.1000 g of phosphate waste put in a Teflon dish with a volume of 60 mL, and 5 mL of a freshly prepared mixture of $HNO_3 + H_2O_2$ is added. The autoclave is hermetically sealed and placed in a microwave oven to a temperature of 220°C in 1 hour.

2.4. Extraction procedures with diluents

For extraction, 10% D2EHPA and the diluents hexane, paraffin, and HCA were used as an extractant. A standard solution of dysprosium with a certain concentration (9203.2 micrograms /L) was taken into a 25.0 mL volumetric flask and diluted with distilled water. For liquid extraction, the solution was poured into a dividing funnel, pre-prepared extractant was poured and shaken for 3 minutes. They were left for complete delamination of the organic and aqueous phases. After 20 minutes, the phases were separated and the equilibrium pH of the aqueous phase was measured. For solid-phase extraction, the solution was poured into extraction flasks, pre-prepared suspended solid powder of the extractant was poured, heated in an electric stove until the extractant completely melted (do not allow the solution to boil). After stirring for 3 minutes, extraction was carried out and cooled. The extract formed on the surface was separated and the equilibrium pH value of the aqueous phase was measured. In case of the formation of a turbid solution after extraction, the solution was filtered. After extraction, the content of dysprosium in the aqueous phase was determined by photometric, ICP-MS method.

2.5 Photocolorimetric determination of dysprosium

After extraction, the concentration of dysprosium in the aqueous phase was determined using a photocolorimetric method. To do this, aliquots were taken from the solution after extraction and transferred to glass. Added 1 ml ascorbic acid, 1 ml buffer solution pH = 3.5, and 2 ml Arsenazo III. On the I-160MI ionomer, the pH of the solution was adjusted to 2.6 ± 0.1, the solution was brought into a measuring flask with a volume of 25.0 ml, then the optical density was measured on a photocolorimeter at a wavelength of 670 nm. The metal content is determined according to the calibration schedule. The concentration of dysprosium in the aqueous and organic phases was calculated by equations 1 and 2:

$$C^{w} = (C_{init} - C^{c.g.}) \cdot \text{undiluted} \qquad (1)$$

$$C_{org} = (C_{init} - C_{w}) \qquad (2)$$

where C^{w} is the concentration of the aqueous phase, C_{org} is the concentration of the organic phase, C_{init} is the concentration of the initial solution, $C^{c.g.}$ is the concentration of the calibration graph.

2.6 Extraction of dysprosium

D2EHPA is a cation-exchange extractant, so the reaction mechanism can proceed in the following form:

$$[Ln^{3+}]_{aq} + 2\,[(HA)_2]_{org}\ \ [LnA_3{\cdot}HA]_{org} + 3H^+ \qquad (3)$$

where, Ln – Dy, HA - D2EHPA, K_A – equilibrium constant;

$$K_A = \frac{[LnA_3{\cdot}HA]_{org}\,[H^+]^3}{[Ln^{3+}]_{aq}\,([(HA)_2]_{org})^2} \qquad (4)$$

The 3- and 4-equations show the extraction mechanism between lanthanides and a cation-exchange extractant.

$$[Dy^{3+}]_{aq} + 2\,[(HA)_2]_{org}\ \ [DyA_3{\cdot}HA]_{org} + 3H^+ \qquad (5)$$

$$K_A = \frac{[DyA_3{\cdot}HA]_{org}\,[H^+]^3}{[Dy^{3+}]_{aq}\,([(HA)_2]_{org})^2} \qquad (6)$$

The 5th and 6th equations present the mechanism of the extraction process between the aqueous phases of dysprosium and the organic phases - D2EHPA.

Extraction proceeds according to the following degrees: dissolution of organic reagents in the aqueous phase; formation of the extracted complex and distribution of the extracted complex in the aqueous and organic phase.

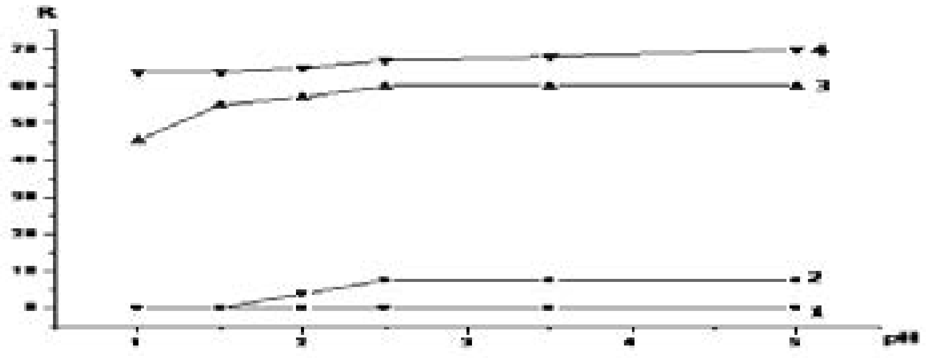
Results and discussian

Extraction of dysprosium by organic substances of various classes

This section presents the results on the effect on the extraction of dysprosium D2EHPA of the nature of the solvent, the concentration of the metal in the aqueous and the reagent in the organic phase, the ratio of the organic and aqueous phase.

The effectiveness of extraction reagents depends on the nature of the diluent. In some cases, the diluents themselves act as an extractant. Therefore, it is necessary to choose the optimal reagent and diluent for the extraction of dysprosium. Various cation exchange reagents have been used as diluents, which can themselves be good extractants. Organic substances of various classes were used as diluents: hexane, kerosene, higher carboxylic acids (HCA), paraffin.

The results of extraction of dysprosium with different diluents are shown in Figure 1. Extraction can be accompanied by polymerization, solvation, ionization in two phases. Therefore, it is reasonable to use the distribution coefficient of dysprosium for the quantitative description of extraction, which is equal to the ratio of the total concentrations of the substance in two phases, organic and aqueous, and on its basis to calculate the degree of extraction.



C_{Dy}=1,1·10^{-4} mol/L, t=20-70 ^{0}C; = 3 min;
1 - kerosene; 2 - hexane; 3 - HCA; 4 – paraffin

Fig. 1 - The effect of the acidity of the medium on the extraction of dysprosium with various solvents

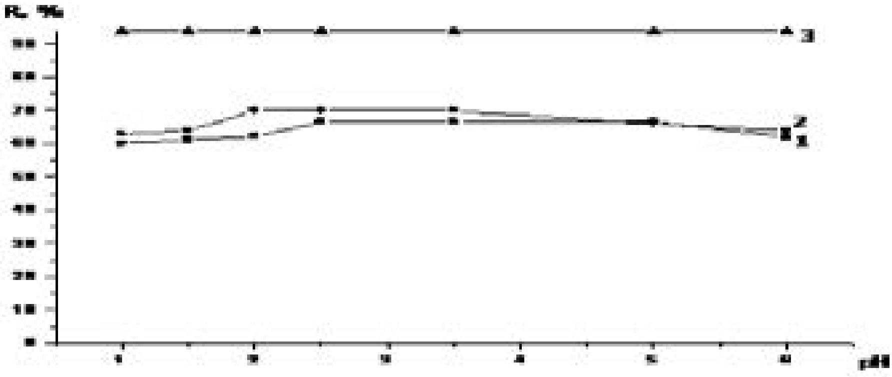
Figure 1 shows the extraction of dysprosium with various diluents. Extraction with hexane and kerosene was carried out at room temperature, and with paraffin and HCA at 70˚C. During the study, an interesting phenomenon of metal distribution between the aqueous and nonpolar organic phase is observed without the reaction of the formation of complexes for the solvents paraffin, hexane and kerosene. As a result of the study, hexane and kerosene extracted dysprosium up to 7 % in the pH range 1–5. And with high-temperature extraction, the degree of metal extraction with paraffin is 65 %, and with HCA is 59 %.

In the considered pH range, there is no sharp change in the extraction of dysprosium for all diluents. But when using kerosene and hexane, the solution is emulsified, which complicates the separation process. Therefore, for further research, a mixture of paraffin and HCA can be chosen as a solvent, because one of them is inert, and the second increases the extraction properties of the extractant. The extracts obtained after extraction are solid and homogeneous, easily separated from the solution after cooling, and the solutions are translucent, which makes it possible to determine dysprosium by photometric method.

3.2 The effect of diluents on the extraction of dysprosium with D2EHPA

It is necessary to identify the effect of cation exchange reagents, in particular higher carboxylic acids, on the extraction of dysprosium D2EHPA. Therefore, we considered the extraction of dysprosium with (10%) D2EHPA with diluents such as hexane, higher carboxylic acids (in HCA), paraffin.

The results of the extraction of dysprosium D2EHPA are shown in Figure 2.



C_{Dy}=1,110^{-4} mol/L, t=70˚C; = 3 min;
1 - D2EHPA - hexane, 2 - D2EHPA-HCA, 3 - D2EHPA-paraffin

Figure 2 - Extraction of dysprosium D2EHPA in various diluents depending on the acidity of the aqueous phase

The extraction curve of dysprosium D2EHPA-hexane (1) and HCA (2) increases slightly with an increase in pH at a medium acidity of 1.2–2.5 to 67 %, with an increase in acidity, extraction decreases slightly. The degree of dysprosium extraction when using HCA was R_{Dy}~70 %. The use of carboxylic acids did not improve the extraction of dysprosium. Extraction of D2EHPA – paraffin (3) metal proceeds in a wide pH range. At a pH of 1.1–6, the extraction is R_{Dy}~94 %. At pH 1–5.0, dysprosium is in the aqueous phase in the form of cationic hydroxo-ion. At low concentrations of hydrogen ions, D2EHPA is a cation exchange reagent. As a result of the study, the cation-exchange extractant D2EHPA was proved, since it has high extraction properties, is available and is widely used in the technology of obtaining dysprosium, and paraffin as a diluent.

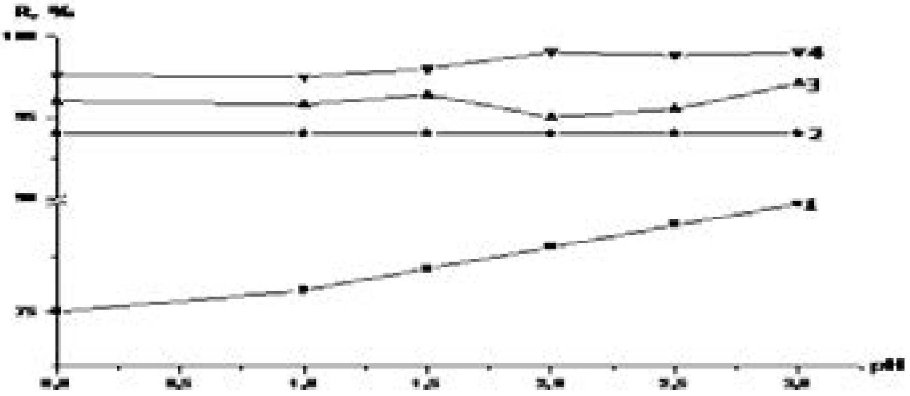
3.3 Effect of the extractant concentration on the extraction of dysprosium with the D2EHPA - paraffin system

The influence of the extractant concentration plays an important role in the study of the metal extraction process. This section studies the extraction of dysprosium D2EHPA of different concentrations in paraffin, depending on the acidity of the medium. In slightly acidic and neutral solutions, D2EHPA exhibits the nature of a cation-exchange reagent. As a result of dimerization of D2EHPA, the extracted complexes obtained during extraction may possibly be solvated by acid molecules. Therefore, the study of the effect of the concentration of D2EHPA on the extraction of dysprosium makes it possible to determine the metal ratio: the extractant in the complex and the optimal concentration of the extractant for practical use. Extraction extraction of metal was carried out by D2EHPA-paraffin melt. The concentration of the reagent varied from 5 to 20 %.

The concentration of dysprosium was $1.1 \cdot 10^{-4}$ mol/L, the extraction time was 3 minutes, the temperature was 70˚C, the volume ratio of water and organic phase was

1:10. The extraction of dysprosium D2EHPA depending on the acidity of the aqueous phase is shown in Figure 3.

As can be seen from Figure 3, the degree of extraction of the extraction curve at 5%-D2EHPA-paraffin was 75–85 %, and the extraction curves with melts of 10 %, 15 %, 20 % D2EHPA-paraffin are close to each other, in this regard, a mixture of 10% D2EHPA-paraffin was selected for further study.



1–5 % D2EHPA-paraffin, 2–10 % D2EHPA-paraffin, 3–15 % D2EHPA-paraffin, 4–20 % D2EHPA-paraffin; C_{Dy}=1.1$10^{-4}$ mol/L, t=70°C; = 3 min

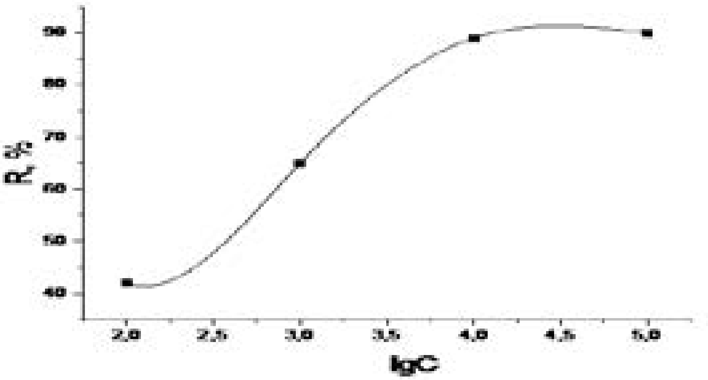
Figure 4 - The effect of medium acidity on the extraction of dysprosium with different concentrations of D2EHPA

3.4 Effect of dysprosium concentration on extraction efficiency

Extraction was carried out by a D2EHPA melt with a constant concentration in paraffin and a metal concentration in the range of $1.0 \cdot 10^{-2}$–$1.0 \cdot 10^{-5}$ mol/L in the aqueous phase. The study was carried out at constant values: the ionic strength of the solution, the ratio of the aqueous and organic phase, temperature, extraction time. At concentrations of dysprosium greater than

10^{-3} mol/L, a sharp decrease in metal extraction is observed. At metal concentration values

$1.0 \cdot 10^{-4}$–$1,0 \cdot 10^{-5}$ mol/L the degree of extraction of dysprosium does not change. Thus, the concentration of dysprosium in the aqueous phase of $1.0 \cdot 10^{-4}$ mol/L was selected for further study.



10 % D2EHPA-paraffin, t = 70°C; τ = 3 min;
pH = 2; V_{org}: V_{aq}= 1: 10

Figure 5 - Effect of dysprosium concentration on extraction efficiency

3.5 Effect of the phase ratio

One of the factors influencing metal extraction is the volume ratio of phases. The extraction process in most cases is determined by the process of complexation, which is greatly influenced by the phase ratio. Metal extraction was carried out by D2EHPA-paraffin melt, the volume ratio of the organic and aqueous phase varied between 1:10–:500. The concentration of the extractant was 0.304 mol/L, the concentration of dysprosium in the aqueous phase was $1 \cdot 10^{-4}$ mol/L, the extraction time was 3 minutes, the temperature was 70°C. The pH of the medium remained constant pH = 2. Table 2 shows the dependences of the degree of extraction of dysprosium at different phase ratios at constant pH. With a ratio of the organic phase and the aqueous phase of 1:100, the degree of extraction is already quite low – 40 %.

Table 2 - Effect of the phase ratio on the extraction of dysprosium by D2EHPA-paraffin melt

V_{org}/V_{aq}	R, %
1:5	98
1:10	98
1:20	99
1:50	84
1:100	40
1:200	7
1:500	5

C_{ex} = 0.304 mol/L; pH=2; C_{Dy} = 110^{-4} mol/L; t = 70–90°C ; = 3 min

As follows from the table, for the quantitative extraction of dysprosium, a high ratio of the aqueous phase and the extractant should not be taken. The most optimal volume phase ratios are 1:5–1:20.

Thus, the obtained optimal conditions for the extraction of dysprosium have found practical application in extracting it from phosphate waste.

3.6 Results of decomposition of phosphate waste in a closed system

A mixture of concentrated nitric acid and hydrogen peroxide was used to decompose phosphate waste. The scheme of the decomposition process is given below:

Sample of phosphate waste $HNO_{3\,(conc.)} + H_2O_2$ ICP-MS analyses.

According to the scheme of the decomposition process, the sample is cooled to room temperature, then poured into a 50 mL volumetric flask and brought to the mark with bidistilled water. The resulting phosphate waste solution was filtered through white filtered paper, and then a quantitative analysis of the composition of the sample with ICP-MS was carried out. The results obtained after the decomposition of the sample are shown in Table 3.

Table 3 - ICP-MS results after decomposition of the waste by microwave autoclave method

REE	ω, %
Eu	
Tb	
Dy	
Ho	
Er	
Tm	
Yb	
Lu	
Σ	

According to the results of the decomposition of phosphate waste, it can be concluded that the content of dysprosium in the sample is quite high, compared with other REE. The content of REE in the composition of the waste decreases in the series Dy>Er>Ho>Tm> Eu >Tr >Yb>Lu.

Conclusion

Comparative indicators of diluents with the extractant D2EHPA in an acidic medium are considered. The effectiveness of diluents decreases in the series paraffin> HCA > hexane = kerosene. The paraffin - D2EHPA system is the most optimal for the separation of dysprosium. Optimal conditions of metal extraction and decomposition of phosphate waste have been investigated. In the phosphate waste, the concentration of dysprosium is greater than the rest of the REE. Therefore, further work will be devoted to quantitatively separation of dysprosium from the waste, while taking into account the optimal parameters with a standard metal solution, which are presented in this work.

REFERENCES

Acharya S., Mishra S., & Misra P.K., 2015 — Studies on extraction and separation of La(III) with DEHPA and PC88A in petrofin. *Hydrometallurgy*, *156*. Pp. 12–16. https://doi.org/10.1016/j.hydromet.2015.05.005

Batchu N.K. & Binnemans K., 2018 — Effect of the diluent on the solvent extraction of neodymium(III) by bis(2-ethylhexyl)phosphoric acid (D2EHPA). *Hydrometallurgy*, *177*(Iii). Pp. 146–151. https://doi.org/10.1016/j.hydromet.2018.03.012

Daware S., Gupta S. & Rai B., 2021 — Recovery of Neodymium and Dysprosium from Waste Hard Disk Magnets: Roasting, Selective Leaching, Extraction and Stripping. *Transactions of the Indian Institute of Metals*, *74*(8). Pp. 1855–1863. https://doi.org/10.1007/s12666-021-02221-w

Erust C., Akcil A., Tuncuk A., Deveci H. & Yazici E.Y., 2021 — A Multi-stage Process for Recovery of Neodymium (Nd) and Dysprosium (Dy) from Spent Hard Disc Drives (HDDs). *Mineral Processing and Extractive Metallurgy Review*, *42*(2). Pp. 90–101. https://doi.org/10.1080/08827508.2019.1692010

Gergoric M., Ekberg C., Steenari B.M. & Retegan T., 2017 — Separation of Heavy Rare-Earth Elements from Light Rare-Earth Elements Via Solvent Extraction from a Neodymium Magnet Leachate and the Effects of Diluents. *Journal of Sustainable Metallurgy*, *3*(3). Pp. 601–610. https://doi.org/10.1007/s40831-017-0117-5

Ismail N.A., Hisyam A. & Shariff S., 2019 — Separation of Sm-Eu-Gd mixed solutions using bifunctional ionic liquid [A336][P204]. *AIP Conference Proceedings*, *2124*(July). https://doi.org/10.1063/1.5117113

Jürjo S., Siinor L., Siimenson C., Paiste P. & Lust E., 2021 — Two-step solvent extraction of radioactive elements and rare earths from estonian phosphorite ore using nitrated aliquat 336 and bis(2-ethylhexyl) phosphate. *Minerals*, *11*(4). https://doi.org/10.3390/min11040388

Kolarik Z., 2010 — Review: Dissociation, self-association, and partition of monoacidic organophosphorus extractants. *Solvent Extraction and Ion Exchange*, *28*(6). Pp. 707–763. https://doi.org/10.1080/07366299.2010.515172

Kumari A., Panda R., Lee J.Y., Thriveni T., Jha M.K. & Pathak D.D., 2019 — Extraction of rare earth metals (REMs) from chloride medium by organo-metallic complexation using D2EHPA. *Separation and Purification Technology*, *227*(January), 115680. https://doi.org/10.1016/j.seppur.2019.115680

Kurdakova S.V., Kovalenko N.A., Petrov V.G. & Uspenskaya I.A., 2017 — Liquid-Liquid Equilibria in Multicomponent Systems Containing o-Xylene, Di-(2-ethylhexyl)phosphoric Acid, Water, Nitric Acid, and Europium (Gadolinium, Dysprosium) Nitrate at 298.15 K. *Journal of Chemical and Engineering Data*, *62*(12). Pp. 4337–4343. https://doi.org/10.1021/acs.jced.7b00696

Maslennikova L.S. & Sinegribova O.A., 2017 — Extraction of Gd, Tb, and Dy from nitrate media with a mixture of technical di-2-ethylhexyl phosphoric acid and tributylphosphate. *Theoretical Foundations of Chemical Engineering*, *51*(5). Pp. 850–857. https://doi.org/10.1134/S0040579517050153

Matsumiya M., Nomizu D., Tsuchida Y. & Sasaki Y., 2021 — Synergistic solvent extraction of lanthanide ions with mixtures of D2EHPA and MIDPA in phosphonium-based ionic liquids. *Hydrometallurgy*, *199*(July 2020), 105539. https://doi.org/10.1016/j.hydromet.2020.105539

Mishra B.B. & Devi N., 2020 — Study on the Extraction and Separation of Samarium from Chloride Medium Using D2EHPA and [P66614][D2EHP] and Their Application to Monazite Ore. *Transactions of the Indian Institute of Metals*, *73*(9). Pp. 2247–2257. https://doi.org/10.1007/s12666-020-02033-4

Mohammadi M., Forsberg K., Kloo L., Martinez De La Cruz J. & Rasmuson Å., 2015 — Separation of ND(III), DY(III) and Y(III) by solvent extraction using D2EHPA and EHEHPA. *Hydrometallurgy*, *156*. Pp. 215–224. https://doi.org/10.1016/j.hydromet.2015.05.004

Mowafy E.A. & Aly H.F., 2006 — Extraction behaviors of trivalent lanthanides from nitrate medium by selected substituted malonamides. *Solvent Extraction and Ion Exchange*, *24*(5). Pp. 677–692. https://doi.org/10.1080/07366290600762322

Ni'am A.C., Wang Y.F., Chen S.W., Chang G.M. & You S.J., 2020 — Simultaneous recovery of rare earth elements from waste permanent magnets (WPMs) leach liquor by solvent extraction and hollow fiber supported liquid membrane. *Chemical Engineering and Processing - Process Intensification*, *148*(January), 107831. https://doi.org/10.1016/j.cep.2020.107831

Ohashi A., Hashimoto T., Imura H. & Ohashi K., 2007 — Cloud point extraction equilibrium of lanthanum(III), europium(III) and lutetium(III) using di(2-ethylhexyl)phosphoric acid and Triton X-100. *Talanta*, *73*(5). Pp. 893–898. https://doi.org/10.1016/j.talanta.2007.05.012

Pei L., Wang L. & Yu G., 2011 — Separation of Eu(III) with supported dispersion liquid membrane system containing D2EHPA as carrier and HNO3 solution as stripping solution. *Journal of Rare Earths*, *29*(1). Pp. 7–14. https://doi.org/10.1016/S1002-0721(10)60394-8

Pei L., Wang L. & Yu G., 2012 — Study on a novel flat renewal supported liquid membrane with D2EHPA and hydrogen nitrate for neodymium extraction. *Journal of Rare Earths*, *30*(1). Pp. 63–68. https://doi.org/10.1016/S1002-0721(10)60640-0

Raji M., Abolghasemi H., Safdari J. & Kargari A., 2017 — Pertraction of dysprosium from nitrate medium by emulsion liquid membrane containing mixed surfactant system. *Chemical Engineering and Processing: Process Intensification*, *120*. Pp. 184–194. https://doi.org/10.1016/j.cep.2017.06.010

Seyed Alizadeh Ganji S.M., Shafaei S.Z., Goudarzi N. & Azizi A., 2016 — Investigating the best mixture extraction systems in the separation of rare earth elements from nitric acid solution using Cyanex272, D2EHPA, and 8-Hydroxyquinoline. *Geosystem Engineering*, *19*(1). Pp. 32–38. https://doi.org/10.1080/12269328.2015.1084243

Turanov A.N., Karandashev V.K., Yarkevich A.N., Safronova Z.V., Kharitonov A.V., Radygina N.I. & Fedoseev A.M., 2004 — Extraction of U(VI), Th(IV), Pu(IV), Am(III), and rare-earth elements from nitric acid solutions with diphenyl(dialkylcarbamoylmethyl)phosphine oxides substituted in the methylene bridge. *Radiochemistry*, *46*(5). Pp. 461–467. https://doi.org/10.1007/s11137-005-0010-0

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