

(AP-00, 34,41 – 18,33 %) үлесі, бастапқы ерітіндіге тәуелді. Қажетті маркалы тұздарды алу үшін, көрсеткіштердің есептемелік сипаттамасы берілді.

Түйінді сөздер: таза, техникалық аммоний перренаты; қайтакристалдау, қайта қанықтыру коэффициенті

SUMMARY

Results of impurity elements behavior researches at pure ammonium perrhenate (PAP) obtaining from the technical ammonium perrhenate (TAP) by recrystallization were presented in the article. Influence of coefficient of supersaturation (α) in the range 1.2 – 4.4 with a step 0.4, which was calculated taking into account the solubility of NH_4ReO_4 at 95 °C and 20 °C, was studied. Conventional equipment for recrystallization experiments was improved. In work used the production TAP obtained by extraction technology with content, by weight % : 65.0 Re; 0.088, K; 0.0009, Fe; 0.022, Na; 0.031 Zn; 0.063, Cd; 0.008, Pb; 0.0002, Ni; humidity – 9.8. Other normalized elements (Al, Ca, Mg, Mn, Mo, Cu) were not found. The salt is maize yellow with impregnations of black color. According to the X-ray phase analysis salt is represented mainly by NH_4ReO_4 . It was established that at cooling of the hot supersaturated solutions ($\alpha=1.2-4.4$) increasing of precipitation temperature (19-51 °C), a sediment output (16.29–73.0 %) and recovery of following elements in it, by %: K 72.9 – 99.9; Re 14 – 75.7; Na 72.9 – 84.4; Zn 45 – 60.3; Cd 30 – 44.6, is observed. The main phase of sediment is NH_4ReO_4 . Calculated crystallization coefficients are considerably > 1 , coefficients of distributions increase in range 16.15 – 400. Along with increase α equilibrium concentration of elements in mother solution changes differently: Re 44–46 g/dm³; other elements, mg/dm³: K 19,51–0,2; Na 4,08–8,5; Zn 13,5–36,2; Cd 4,2–13,2; Fe 0,72–2,7; Ni 0,3–0,4. From mother solutions by combining processes of evaporation and crystallization salts of PAP were obtained. Purity of NH_4ReO_4 and its yield depend on initial solution: $\alpha=1.2$ (APR-1, 64.36 %), $\alpha=2.0$; 2.4 (APR-0, 54.81; 42.28 %), $\alpha=2,8-4,4$ (ARR-00, 34.41–18.33 %). It was recommended taking into account parameters of dissolution for obtaining of necessary brand salt.

Keywords: technical ammonium perrhenate, pure ammonium perrhenate; recrystallization, supersaturation coefficient.

Поступила 11.05.2016

УДК 662.234.42

Комплексное использование
минерального сырья. № 3. 2016.

*B. K. KENZHALIYEV¹, A. N. BERKINBAYEVA², Z. D. DOSYMBAYEVA²,
R. CH. SHARIPOV², M. T. CHUKMANOVA^{2*}*

¹*“Institute of Metallurgy of Ore Benefication” JSC, Almaty*

²*“Kazakh-British Technical University” JSC, Almaty, *chukmanova_m@mail.ru*

EXTRACTION OF URANIUM FROM URANIUM-CONTAINING RAW MATERIALS

The article represents the results of a study on a comparative sulfuric acid catalytic oxidation of uranium (IV) from uranium-containing ore to uranium (VI) at stationary conditions. In this ore (the content of uranium, recalculated on uranium oxide is 17.18 %) the basic mineral is coffinite $\text{U}[\text{SiO}_4]$ which presence in the general balance of uranium mineralization is about 95 %. Uranium leaching studies were conducted using a ferric (III) solution, ammonium persulphate (APS) and sodium peroxoborate (SPB). Selectivity of catalyst M-1 on oxidation of uranium was determined. Applying the catalyst M-1 as an enhancer, uranium concentration in the sulfuric solution increases (S:L = 1:4), at which the further increase in the uranium concentration in the solution remains constant and equals to 86 mg/dm³. Two aspects were studied such as the increase in extraction of uranium by the sulfuric acid leaching from the poorly soluble uranium ore in the presence of a catalyst, and the possibility to complete its recovery by an increase of the process time. It was concluded that there is a need to conduct a study on the effect of mineralogical features of various uranium deposits on the efficiency of process of uranium extraction into solution. Thermodynamic data show a high probability of simultaneous behaviour of reaction of the uranium oxides with the sulfuric acid and reaction of calcium silicate with the sulfuric acid in the leaching process.

Keywords: uranium, sulfuric acid leaching, catalyst, oxidizing agent, thermodynamic analysis.

Introduction. The only and effective method of uranium production in Kazakhstan is in-situ leaching. In-situ leaching method has significant advantages over the traditional method of extraction of ore mining and processing them in factories, as it allows to

reduce the cost of uranium ore and make better use of raw uranium. The main advantages of in-situ leaching method include the ability to work on the deposits, confined to heavily watered the layers, including poor and off-balance method for the mining of ore, reduc-

ing the input field in the period of operation, the automation of production and processing of productive solutions on the surface.

Technology of uranium extraction process situ leaching is mainly uses aqueous solutions of mineral acids or alkali metal salts of carbonates. From the practice of conducting uranium in-situ leaching process, it follows that the choice of the type of solvent operating (leaching) solutions depends on the form of uranium mineralization, the material composition of ores and host rocks, as well as on the chemical nature of uranium minerals.

The analysis of a scientific literature has shown that one of the main areas to improve the extraction of uranium from the hard-open ores is the use of oxidants.

It is known that additives of oxidizing agent are especially needed in those cases where the ore has a high tetravalent uranium concentration, and sulfuric acid leaching solutions without oxidant additives is challenging. To increase the extraction of uranium, sulfuric acid is used in a mixture with various oxidants - nitric acid, pyrolusite, sodium perchlorate, ferric salts, etc. [1-3].

Usage of traditional methods requires the delivery, storage and dispensing of appropriate chemical reagents, resulting in increased product cost. Reduction in the reagent consumption can be avoided by the use of physical and electrical methods of leaching process intensification (wherein the ozone treatment, ultrasonication can be applied, etc.). However, the known "reagentless" methods have high capital and operating costs due to the need of expensive equipment and complex organization process.

Experimental part. In order to increase the degree of uranium extraction, research was conducted on a comparative sulfuric acid catalytic oxidation of uranium (IV) to uranium (VI) from Kazakhstan uranium ore (uranium concentration in conversion to uranium oxide – 17.18 %, where the main mineral is coffinite U [SiO₄] – at least 95 %) on the catalyst "M-1" containing manganese, cobalt, nickel, iron. The total metal concentrations in the catalyst were 0.3 g/dm³. A preliminary research data of the catalytic efficiency is represented in the research [4,5, 6-8].

Uranium-containing minerals are leucoxene, mica-kollofanom, and associated minerals are native selenium, cobalt-nickel-pyrite (bravoitom) and sphalerite. Uranium concentration: in the central part of the deposit – 0.031 %, the east – 0.037 %, on the west – 0.035 %, in the south-west – 0.02 %. The composition of rocks: quartz – 70-80 %, feldspars – 10-20 %, chert – 5-10 %, coalified plant detritus - up to 5 % and biotite - muscovite – 0-10 %.

Objects of research. Reagents. For the research, low-soluble uranium-containing ores, leaching pro-

cess enhancers and the catalyst to increase uranium extraction were used. The sulfuric acid was used at the leaching process (from 5 to 75 g/dm³).

The experimental methodology. The uranium extraction studies were carried out in stationary conditions using previously studied oxidants – ferric iron solution, ammonium and sodium persulphate (APS) and sodium peroxoboroate (SPB).

Experiments on leaching uranium from the samples were carried out under the following conditions: volume of the solution – 1000 ml, weight forever – 250 g, temperature – 25 °C.

During determination of the process optimum parameters of the uranium leaching, sulfuric acid concentration was being changed from 5 to 75 g/dm³, the ratio of S:L=1:2-1:8, a duration – 12-48 hours.

Based on thermodynamic analysis on the likelihood of the reaction behaviour of various chemical reactions during uranium leaching, calculations were conducted using HSC Chemistry 7 program, Outotec Research Oy.

Results and discussion. The results of studies of the sulfuric acid leaching using the catalyst "M-1" and the recycle solution after sorption containing uranium of 1 mg/dm³ are shown in Tables 1 and 2.

Table 1 – Research results of the sulfuric acid leaching of uranium on the catalyst "M-1"

Catalyst concentration, g/dm ³	pH	ORP, mV	U, mg/dm ³	Acid consumption (C _{H₂SO₄} = 5,0 mg/dm ³), uranium g/g
0	2,00	378	35	39,1
0,3	2,01	388	80	14,2
0,6	1,99	396	82	12,8
0,9	1,98	402	84	11,1
1,2	2,00	408	86	9,7

Table 2 – Research results of the sulfuric acid leaching of uranium on the catalyst "M-1" from the recycle solution after sorption.

Catalyst concentration, g/dm ³	pH	ORP, mV	U, mg/dm ³	Acid consumption (C _{H₂SO₄} = 5,0 mg/dm ³), Uranium g/g
0	2,04	368	33	41,7
0,3	2,05	377	60	15,6
0,6	1,95	388	65	13,7
0,9	1,94	396	74	12,0
1,2	2,05	402	75	10,4

The presented data shows that the application of the catalyst "M-1" leads to a substantial increase in uranium leaching from the ore deposit. With the increasing catalyst concentration, the increase in the ORP is observed (from 378 mV to 408 mV (Table 1),

and from 368 mV to 402 mV (Table 2), the pH changes insignificantly.

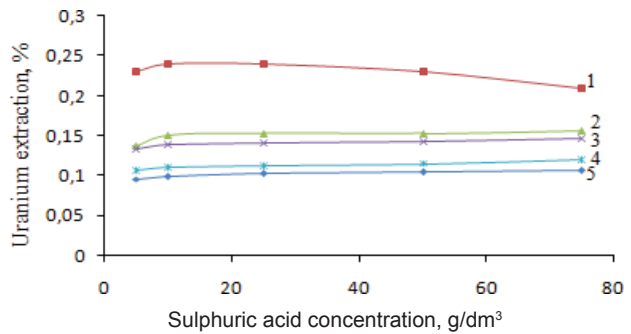
In the next stage of the research, experiments carried out to identify the influence of the sulfuric acid concentration on the uranium extraction. The results are shown in Figure 1 and Table 3.

Table 3 – Research results of the influence of sulfuric acid concentration on the extraction of uranium in the presence of an iron catalyst (III), ammonium and sodium persulfate (APS) and sodium peroxoborate (SPB).

Optimal H ₂ SO ₄ consumption, g/g		39	41,7	51,35	65,7	92,3	
without catalyst	C(H ₂ SO ₄), g/dm ³	Initial	5,0	10,0	25,0	50,0	75,0
		Final	3,64	8,5	23,1	47,5	71,4
Optimal H ₂ SO ₄ consumption, g/g		9,4	9,65	17,4	21,1	31,3	
with catalyst	C(H ₂ SO ₄), g/dm ³	Initial	5,0	10,0	25,0	50,0	75,0
		Final	4,21	9,17	23,5	48,2	72,4
without catalyst	ORP, mV	Initial	266,6	271	273,1	278,1	278,2
		Final	260,1	266,8	275,4	277,7	280
with catalyst	ORP, mV	Initial	266,6	271	273,1	278,1	278,2
		Final	260,3	265,9	273,1	277,2	279,4
The uranium concentration in the solution							
without catalyst	U, mg/dm ³	35	36	37	38	39	
with catalyst	U, mg/dm ³	84	86	86	85	83	
Fe (III)	U, mg/dm ³	50	55	56	56	57	
APS	U, mg/dm ³	49	50,5	51,4	52,3	53,4	
SPB	U, mg/dm ³	39,1	40,1	41,3	42,2	43,5	

As it is seen in Figure 1, an increase in the sulfuric acid concentration from 5 g/dm³ to 75 g/dm³ contributes to increase uranium extraction in all studied cases. For example, for the Fe oxidant (III), the degree of uranium concentration in the solution was 57 mg / dm³ per day.

For process efficiency, the enhancers of the uranium leaching at the sulphuric acid concentration of 5 g/dm³ with appropriate uranium concentration in the solution may be placed in the following sequence: catalyst (84 mg/dm³) > Fe (III) (50 mg/dm³) > APS (49 mg/dm³) > SPB (39.1 mg/dm³) > without catalyst (35 mg/dm³)



S:L = 1:4, duration – 24 hours

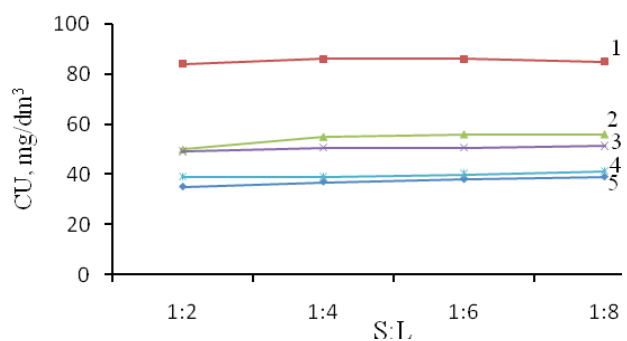
1 – with catalyst, 2 – Fe (III), 3 – APS, 4 – SPB, 5 – without catalyst

Figure 1 – The degree of uranium extraction at the increasing concentration of sulfuric acid

At the next stage of the research, the influence of the S:L ratio on the uranium extraction was studied where the sulfuric acid concentration was 5 g/dm³, the duration – 48 hours. As it seen in Figure 2, the change in the S:L ratio influences on the uranium leaching from the solution without the application of catalyst: uranium concentration increases from 35 mg/dm³ to 39 mg/dm³ with the increasing S:L of from 1:2 to 1:8. In the case of application of the conventional oxidizing agents also observed an increase in the uranium extraction under the increasing the S:L ratio up to 56 mg/dm³ for the ferric iron solution, up to 51.3 mg/dm³ for ammonium persulphate and up to 41.2 mg/dm³ for sodium peroxoborate.

By applying a catalyst “M-1” as an enhancer, the dependence of uranium leaching from this indicator is less expressed: the uranium concentration in the solution increases with the increasing ratio of S:L up to 1:4, with a further increase of which the uranium concentration of the solution remains constant and equals to 86 mg/dm³.

In the case of leaching without catalyst, change in the ratio S:L has practically no effect on the uranium extraction.



C(H₂SO₄) – 25 g/dm³, duration – 48 hours

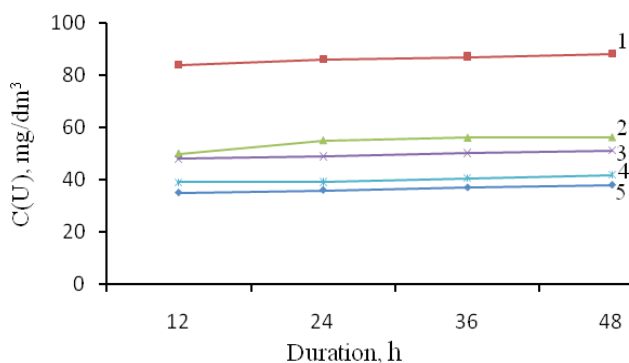
The S:L ratio 1 – 1:2, 2 – 1:4, 3 – 1:6, 4 – 1:8

1 – with catalyst, 2 – Fe (III), 3 – APS, 4 – SPB, 5 – without catalyst

Figure 2 – The uranium content in the solutions at S:L changes

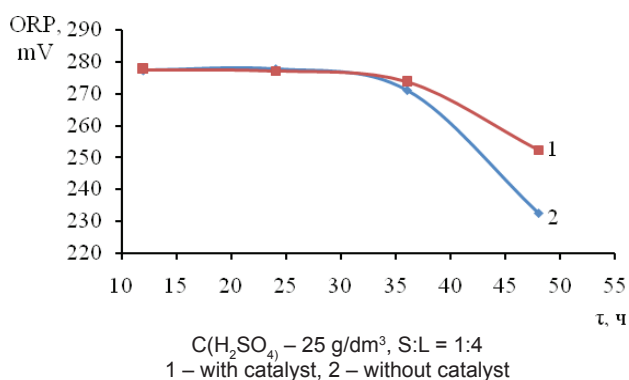
At the next stage of the research, experiments were carried out on dependency of uranium extraction from duration. The uranium concentration in the leaching solution without the use of catalyst was 35 mg/dm³ after 12 hours of the experiment and increased to 38 mg/dm³ after 48 hours after the start of leaching process. In the case of application the conventional oxidizing agents, it also showed an increase in the uranium extraction by increasing leaching duration. Applying the catalyst “M-1” after 12 hours of the experiment, the uranium content was 84 mg/dm³, with increasing leaching duration, this value changed significantly – up to 88 mg/dm³.

In this case, in contrast to the conventional oxidants, there is a tendency of further increase in the uranium extraction under the increasing duration of the leaching process (Figure 3). This indicates an increase in the uranium extraction by the sulfuric acid leaching from the low – soluble uranium ore in the presence of a catalyst and the possibility of its almost complete extraction while increasing the process duration.



C(H₂SO₄) – 25 g/dm³, S:L = 1:4
1 – with catalyst, 2 – Fe (III), 3 – APS, 4 – SPB, 5 – without catalyst

Figure 3 – Changing of uranium content in the solution under time



C(H₂SO₄) – 25 g/dm³, S:L = 1:4
1 – with catalyst, 2 – without catalyst

During the experiment, there was a decrease in the ORP values from 278.1 mV to 252.2 mV, for a solution with a catalyst and up to 232.6 mV without catalyst (Figure 4).

The obtained results show an increase in uranium extraction from hard-open ores by sulfuric acid leaching in the presence of a developed catalyst “M-1”.

The data of a comparative sulfuric acid catalytic oxidation of uranium shows a high activity of the catalyst “M-1” with respect to the target metal.

These results suggest the need to investigate the influence of mineralogical characteristics of the uranium deposits on the efficiency of manufacturing processes of the uranium extraction to solution. This conclusion can be drawn on the basis of thermodynamic analysis of the likelihood reaction behaviour during the leaching of uranium. For example, Table 4 shows the calculation of the equilibrium constants of uranium oxide and calcium silicate reactions with sulfuric acid.

Table 4 – Calculation of the equilibrium constants of uranium oxide and calcium silicate reactions with sulfuric acid.

T, K	$UO_2 + 2H_2SO_4 = U(SO_4)_2 + 2H_2O$	$UO_3 + H_2SO_4 = UO_2SO_4 + H_2O$	$CaSiO_3 + H_2SO_4 = CaSO_4 + H_2SiO_3$
273	$2,214 \cdot 10^{28}$	$1,913 \cdot 10^{16}$	$1,888 \cdot 10^{33}$
373	$6,825 \cdot 10^{19}$	$3,709 \cdot 10^{11}$	$2,416 \cdot 10^{24}$
473	$5,695 \cdot 10^{14}$	$6,069 \cdot 10^8$	$1,124 \cdot 10^{19}$
573	$2,598 \cdot 10^{11}$	$9,075 \cdot 10^6$	$2,898 \cdot 10^{15}$
673	$1,278 \cdot 10^9$	$4,968 \cdot 10^5$	$7,109 \cdot 10^{12}$
773	$2,952 \cdot 10^7$	$6,274 \cdot 10^4$	$7,075 \cdot 10^{10}$
873	$1,904 \cdot 10^6$	$1,374 \cdot 10^4$	$1,796 \cdot 10^9$
973	$2,520 \cdot 10^5$	$4,416 \cdot 10^3$	$8,819 \cdot 10^7$
1073	$5,642 \cdot 10^4$	$1,874 \cdot 10^3$	$7,039 \cdot 10^6$
1173	$1,881 \cdot 10^4$	$9,804 \cdot 10^2$	$8,130 \cdot 10^5$
1273	$8,555 \cdot 10^3$	$6,026 \cdot 10^2$	$1,254 \cdot 10^5$

From the Table 4, according to the results of the calculation the equilibrium constants of reactions $UO_2 + 2H_2SO_4 = U(SO_4)_2 + 2H_2O$; $UO_3 + H_2SO_4 = UO_2SO_4 + H_2O$; $CaSiO_3 + H_2SO_4 = CaSO_4 + H_2SiO_3$, it is obvious that the standard methods of calculation the dependency of the equilibrium constants these reactions from the temperature do not give an opportunity to assess of how actually undergo above mentioned reactions during the leaching process. The showed data of the changes in the equilibrium constant indicates the changes in the parameters of the substances during leaching, which are not taken into account during the process of uranium extraction to solution. The closeness of the equilibrium constant values of the reaction between uranium oxides and the sulfuric acid and reaction of calcium silicate with sulfuric acid indicates a high probability of the simultaneous occurrence of these reactions in the leachate, which is also not included in the technological process of leaching uranium mineral sources.

Gibbs energy calculations for these reactions is indicative. From the figures 5, 6, 7, it is clear that the probability of occurrence of these reactions in the leaching is virtually the same. It is noteworthy that according to thermodynamic data, the probability reaction behaviour between tetravalent uranium and sulfuric acid is somewhat higher than between the hexavalent uranium with sulfuric acid.

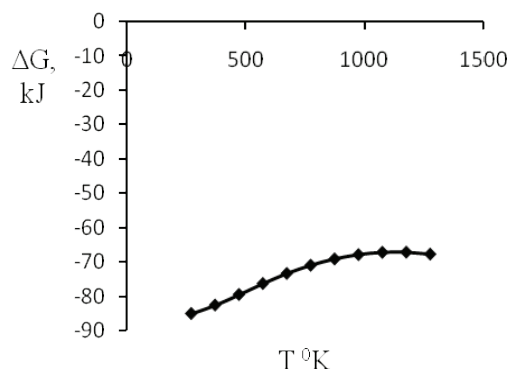


Figure 5 – Dependence of Gibbs energy on temperature for the reaction $\text{UO}_3 + \text{H}_2\text{SO}_4 = \text{UO}_2\text{SO}_4 + \text{H}_2\text{O}$

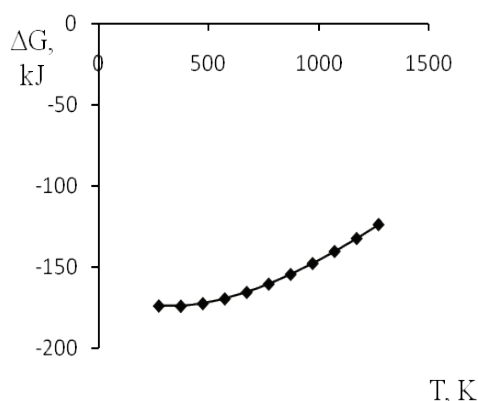


Figure 6 – Dependence of Gibbs energy on temperature for the reaction $\text{CaSiO}_3 + \text{H}_2\text{SO}_4 = \text{CaSO}_4 + \text{H}_2\text{SiO}_3$

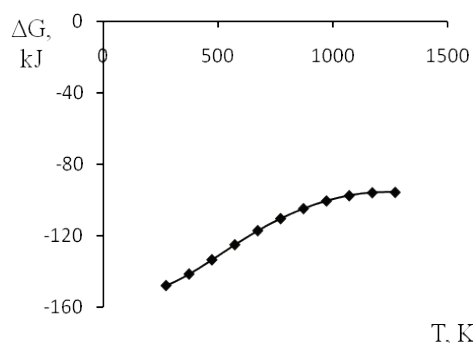


Figure 7 – Dependence of Gibbs energy on temperature for the reaction $\text{UO}_2 + 2\text{H}_2\text{SO}_4 = \text{U}(\text{SO}_4)_2 + 2\text{H}_2\text{O}$

Results of the equilibrium constant values for uranium oxide and calcium silicate reactions with sulfuric acid, which are conducted in the normal

way and the Gibbs energy calculations for these reactions suggest that the study of uranium extraction to the solution and the influence of mineralogical characteristics of the uranium deposits on the process efficiency of uranium extraction is an urgent problem and the need urgent solutions.

Conclusions. Investigations were conducted to improve the uranium applying the “M-1” catalyst containing manganese, cobalt, nickel, iron. The total concentration of metal in the catalyst was 0.3 g/dm^3 .

An increase in the sulfuric acid concentration from 5 g/dm^3 to 75 g/dm^3 contributes to increase in degree of uranium extraction in all studied cases. According to efficiency of the enhancers, they may be placed in the following order: a catalyst (84 mg/dm^3) > Fe (III) (50 mg/dm^3) > APS (49 mg/dm^3) > SPB (39.1 mg/dm^3) > without a catalyst (35 mg/dm^3).

An increase in the ratio S:L = 1:2 to 1:8 increases the degree of uranium extraction without using a catalyst (up to 39 mg/dm^3), and in the case of conventional oxidants: ferric iron solution (up to 56 mg/dm^3), ammonium persulphate (up to 51.3 mg/dm^3), and sodium peroxoborate (up to 41.2 mg/dm^3). Applying a catalyst “M-1” as enhancer, uranium concentration in the solution increases with the ratio S:L=1:4, with a further increase of the catalyst the uranium concentration in the solution remains constant and equals to 86 mg/dm^3 .

REFERENCES

- Antonov D.C., Iskakov Z.A., Zhatkanbayev E.E., Aleksandrov U.S., Mukusheva A.S. *Issledovanie uranonosnykh peskov mestorozhdeniya Inkai* (Investigation of uranium-bearing sands deposits Inkai). *Sbornik XI mezhdunarodnoj nauchno-prakticheskoy konferentsii "Polyarnoe siyanie 2008"* (Collection of the XII International Scientific and Practical conference), Saint-Petersburg, Russia. 178-179 (in Russ.).
- Brovin K.G., Grabovnikov V.A., Shumilin M.V., Yazikov V.G. *Prognoz, poiski, razvedka i promyshlennaya ocenka mestorozhdeni iurana dlya otrabotki podzemnym vyvelachivaniem* (Prediction, searches, exploring and industry rating of uranium deposits for testing underground leaching). Almaty: Gylm (Science), 1997. 384 (in Russ.).
- Ergozhin E.E., Mukhitdinova B.A., Shekeeva B.Zh., Boranbaev B.Zh. *Podzemnoe vyvelachivanie urana (obzor)* (Underground leaching of uranium (review)). *Khimicheskii zhurnal Kazakhstana = Chemical Journal of Kazakhstan*. 2008. 2. 5-28 (in Russ.).
- Aibassov E.Zh., Umirkulova Zh.S. Getting the uranium catalyst based on natural zeolite deposits Chankanayskogo. *Symposium "Fronties of Organometallic Chemistry"*. Saint-Petersburg, Russia. 2012. 90 (in Eng.).
- Aibassov E.Zh., Aibassova S.M. The New reactions of Arsenic. Introduction to Organic Chemistry of Arsenic, Actinides, Lanthanides, Os¹⁸⁷ and Re. *Gitel Publishing House, Inc.* New York, The USA. 2011. 100 (in Eng.).

6. Aibassov E.Zh., Yemelyanova V.S., Shakieva T.V., Tussupbaev N.K. and Blagikh E. Getting and X-ray Diffraction Analysis of the Microsphere Catalyst U, Nd on the Basis Fly Ash of Thermal Power Plants. *J. Chem.Chem. Eng.* **2014.** 8. 544-546 (in Eng.).

7. Aibassov E.Zh., Kenzhaliev B.K., Tussupbaev N.K., Berkinbaeva A., Chukmanova M., Iskhakova R., Bulenbayev M.Z. Preparation of Uranyl Complexes with Sugars. *Journal of Chemistry and Chemical Engineering.* **2014.** 8. 641-646 (in Eng.).

8. Aibassov E.Zh., Kenzhaliev B.K., Berkinbaeva A., Chukmanova M., Iskhakova R., Tussupbaev N.K., Bulenbayev M.Zh. Chemical Interaction UO_2Cl_2 with α - and β -Amino Acids in Aqueous and Organic Solution. *J. Chem.Chem. Eng.* **2014.** 8. 751-756 (in Eng.).

ЛИТЕРАТУРА

1 Антонов Д.С., Исакаков З.А., Жатканбаев Е.Е., Александров Ю.С., Мукушева А.С. Исследование ураноносных песков месторождения Инкай // Сборник XI международной научно-практической конференции «Полярное сияние 2008». – Санкт-Петербург, 2008. – С. 178-179.

2 Бровин К.Г., Грабовников В.А., Шумилин М.В., Языков В.Г. Прогноз, поиски, разведка и промышленная оценка месторождений урана для отработки подземным выщелачиванием. – Алматы: Фылым, 1997. – 384 с.

3 Ергожин Е.Е., Мухитдинова Б.А., Шекеева Б.Ж., Боранбаев Б.Ж. Подземное выщелачивание урана (обзор) // Химический журнал Казахстана. – 2008. – № 2. – С. 5-28.

4 Aibassov E.Zh., Umirkulova Zh.S. Getting the uranium catalyst based on natural zeolite deposits Chankanayskogo // Symposium "Frontiers of Organometallic Chemistry". – Saint-Petersburg. – 2012. – 90 p.

5 Aibassov E.Zh., Aibassova S.M. The New reactions of Arsenic. Introduction to Organic Chemistry of Arsenic, Actinides, Lanthanides, Os¹⁸⁷ and Re // Gittel Publishing House, Inc. – New York. – 2011. – 100 p.

6 Aibassov E. Zh., Yemelyanova V. S., Shakieva T. V., Tussupbaev N. K., Blagikh E. Getting and X-ray Diffraction Analysis of the Microsphere Catalyst U, Nd on the Basis Fly Ash of Thermal Power Plants // *J. Chem.Chem. Eng.* –2014. – Vol. 8. – P. 544-546.

7 Aibassov E.Zh., Kenzhaliev B.K., Tussupbaev N.K., Berkinbaeva A., Chukmanova M., Iskhakova R., Bulenbayev M.Z. Preparation of Uranyl Complexes with Sugars // *Journal of Chemistry and Chemical Engineering.* – 2014. – Vol. 8. – P. 641-646.

8 Aibassov E.Zh., Kenzhaliev B.K., Berkinbaeva A., Chukmanova M., Iskhakova R., Tussupbaev N.K., Bulenbayev M. Zh. Chemical Interaction UO_2Cl_2 with α - and β -Amino Acids in Aqueous and Organic Solution // *J. Chem.Chem. Eng.* – 2014. – Vol. 8. – P. 751-756.

ТҮЙІНДЕМЕ

Мақалада стационарлық жағдайда уран кен орнының уран(IV)-тен уран (VI)-ға дейінгі күкіртқышқылды каталитикалық тотығу зерттеулерінің нәтижелері көрсетілген. Аталған кен орнының кенінде (уран тотығына есептегенде уранның құрамы 17,18 %) құрамы жалпы баланстағы уранның минералдануы 95%-тен кем емес негізгі минерал коффинит $U[SiO_4]$ болып табылады. Шаймалау бойынша зерттеулер үшвалентті темір, күкіртқышқылды аммоний және натрий пероксобораты ерітінділерінің пайдалануымен жүргізілді. М-1 катализаторының уранды тотықтыру бойынша тиімділігі анықталды. Еруі қиын құрамында ураны бар кендерден М-1 катализаторының қатысында күкіртқышқылды шаймалаумен уранды бөліп алуды арттыру зерттелді. М-1 катализаторын интенсификатор ретінде қолданған кездегі қаттының сұйыққа қатынасын 1:4 дейін арттырғанда уранның ерітіндідегі концентрациясы артады, ары қарай арттырғанда уранның құрамы тұрақталады және ол 86 мг/дм³ тең. Уранның ерітіндіге өтудегі технологиялық процесстердің тиімділігіне әр түрлі уранды кен орындарының минералдық ерекшеліктерінің әсерін зерттеу керектігіне шешім жасалды. Термодинамикалық мәліметтер бойынша IV-валентті уранның күкірт қышқылымен реакцияға түсу ықтималдығы VI-валентті уранның реакцияға түсу ықтималдығынан сәл жоғары.

Түйін сөздер: уран, күкіртқышқылды шаймалау, катализатор, тотықтырғыш, термодинамикалық талдау.

РЕЗЮМЕ

В статье приведены результаты исследования по сравнительному серноокислотному каталитическому окислению урана (IV) до урана (VI) уранового месторождения в стационарных условиях. В руде данного месторождения (содержание урана в пересчете на оксид урана – 17,18 %) основным минералом является коффинит $U[SiO_4]$, составляющий в общем балансе урановой минерализации не менее 95 %. Исследования по выщелачиванию урана проводились с применением раствора трехвалентного железа, надсерноокислого аммония и пероксобората натрия. Определялась селективность катализатора М-1 по окислению урана. При использовании в качестве интенсификатора катализатора «М-1», концентрация урана в растворе растет при увеличении соотношении Т:Ж до 1:4, при дальнейшем увеличении которого содержание урана в растворе остается постоянным и равным 86 мг/дм³. Исследовалось повышение извлечения урана серноокислотным выщелачиванием из труднорастворимых урансодержащих руд в присутствии катализатора и возможность практически полного его извлечения при увеличении времени процесса. Сделан вывод о необходимости исследования влияния минералогических особенностей различных урановых месторождений на эффективность технологических процессов извлечения урана в раствор. Термодинамические данные показывают высокую вероятность одновременного протекания реакций оксидов урана с серной кислотой и силиката кальция с серной кислотой в ходе выщелачивания.

Ключевые слова: уран, серноокислотное выщелачивание, катализатор, окислитель, термодинамический анализ.

Поступила 14.07.2016