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AMP and Ambersep 920 IRA anion exchange resins for recovery of uranium from productive solution

Abstract: In the process of uranium production, one of the most important stages affecting the completeness of uranium extraction from productive solutions is the sorption stage. In order to study the effectiveness of ion exchange resins under dynamic conditions, sorption and desorption characteristics of anion exchangers, which used for recovery of uranium from sulfuric acid production solutions were studied.

In laboratory conditions, sorption and desorption of uranium from productive solution on anion exchange resins of the brands Ambersep 920 IRA and AMP were carried out. During the research work, sorption and desorption characteristics were studied, as well as sorption capacity of the resins. Despite the fact that dynamic exchange capacities of the resins are equal, the sorption characteristics are different. The concentration of uranium in the desorption eluate for Ambersep 920 IRA and AMP was 856.00 and 268.00 mg/l, respectively, which is 5 and 1.5 times higher than the initial concentration of uranium in the productive solution. The most efficient anion exchanger, Ambersep 920 IRA, has been identified, which has good sorption and desorption characteristics compare to AMP.

Key words: uranium industry, ion exchange resins, underground leaching, sorption – desorption of uranium.

Introduction

In contemporary world, the need of electricity is growing every year. These days many countries are view nuclear power as acceptable. According to the IAEA, annual report [1] 447 nuclear power reactors are in operation nowadays. In nearest future 60 more reactors will be built in 15 countries. The global capacity of nuclear power plants will grow by 42% in 2030, by 83% in 2040 and by 123% in 2050, as compared to the level of 2016. The increases of nuclear power plants in the world lead to produce significant amount of nuclear fuel.

For present time, uranium is still recognized as a leading fission material. It is most often considered as the irreplaceable raw material for nuclear industry [2] and demand for uranium is expected to continue to rise in the near future [3].

Better separation of uranium from ores is one of the leading tasks nowadays. One of the most essential stages in the processing of uranium ore is its sorption on ion-exchange resins. The ion-exchange resin plays an important role for the production of uranium. Today the market of ion-exchange resins is represented by a wide range of resins. The selection of ion-exchange resin which have the high sorption

and desorption, as well as kinetic characteristics is an urgent task for ensuring the maximum performance of this technological process. The sorption of uranium from sulphuric acid solutions by strongly basic anion exchange resin is widely described in literature [4-6]. Strongly basic anionic exchangers were often utilized in uranium industry and are even recognized as the most suitable ion exchangers for uranium recovery [7].

In this study we examined the sorption and desorption characteristic of two brands of anion exchangers from productive solutions: AMP (Smoly State Company, Ukraine) and Ambersep 920 IRA (® TMTrademark of The Dow Chemical Company (“Dow”) or an affiliated company of Dow). In the study [5] during the investigation of resins of two brands was revealed that AMP exchanger was the one with preferred characteristics, whereas in the course of this work AMP showed worse results comparing with Ambersep 920 IRA exchanger.

Materials and Methods

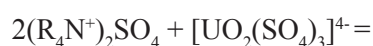
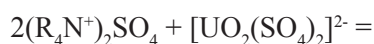
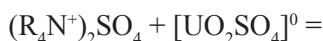
Preparation of productive solution

The laboratory agitation leaching was carried out for obtaining real uranium productive solution from

ore sample [8]. The sulfuric acid 2.5 % was used as a leaching reagent. The uranium productive solution with concentration of uranium equal to 173.12 mg/l was obtained as a result of leaching.

Strongly based ion – exchange resins

The sorption recovery of uranium from sulfuric acid leaching solutions by strongly basic anion exchangers can be described by reactions of complexation and ion exchange [9]:



In our case, strongly basic ion exchange resins AMP and Ambersep 920 IRA were set in columns (0.5x3) (Figure 1) for investigation of sorption and desorption process of uranium under dynamic conditions. The productive solution was passed through the resin (Figure 1) with a rate of 1 ml/min until the completely uranium saturation by the sorbent.



Figure 1 – Scheme of sorption under dynamic condition

Since significant amount of sulfate anion complexes of uranium formed at a pH of 2, as a result the pH of productive solution was brought to this value. The obtained fractions after sorption and desorption of uranium were collected every 5 ml of volume for establishing the breakthrough point. 1.8 M solution of ammonium nitrate was used as a desorbing solution [10].

Determination of uranium concentration

The titanium-phosphate-vanadate titration method was used for determination of the uranium concentration in the sorption cells and desorption eluates.

This measurement technique establishes a volumetric titrimetric titanium-phosphate-vanadate method of determination of the uranium concentration in uranium productive solutions in the range of mass concentrations from 0.001 g/l to 1.00 g/l.

An aliquot of the sample (2-10 ml), depending on the expected uranium concentration, was placed in a 100 ml conical flask then distilled water was added to a total volume of 10 ml. 1-2 drops of urea were added, mixed, and then 10 ml of concentrated phosphoric acid was added. After that, chloride of tetravalent titanium was added for appearing a violet color. The solution was cooled and a solution of sodium nitrate was added, the excess of which was destroyed by the addition of urea. Sodium salt of diphenylamine-4-sulfonic acid was added as an indicator. The following reaction occurs as a result of titration:



The mass concentration of uranium (X) g/l calculated by the following formula:

$$X = \frac{T \cdot (V_2 - V_1) \cdot 1000}{A}$$

where: V_1 is volume of ammonium metavanadic acid solution, consumed for titration of a blank sample with addition of Mohr salt, ml; V_2 is volume of a solution of ammonium metavanadic acid, spent on titration of uranium, ml; A is aliquot of the analyzed sample, ml; T is the titer of a solution of ammonium metavanadic acid in uranium g/ml.

Determination of the dynamic exchange capacity

Determination of the exchange capacity of resins under dynamic conditions fully represents the sorption process in practice. It makes possible to determine the working exchange capacity, which is equivalent of dynamic exchange capacity, before the

breakthrough point. Dynamic exchange capacity is calculated by the following formula [11]:

$$DEC = C \cdot \frac{V_{ps}}{V_{resins}}$$

where: V_{ps} is volume of the passed solution, l; V_{resins} is volume of the resins, cm^3 ; C is concentration of the uranium in the productive solution, mg/l.

Results and discussions

Based on the obtained data (Table 1), after the titration of the sorption cells of uranium on the an-

ion exchange resin AMP, the dependence shown in Fig. 1 was constructed.

According to the curve shown in Figure 2, the breakthrough point of uranium is observed in the first 5 ml of the volume of the productive solution. The concentration of the uranium slightly increases to equalize the concentrations in the influent and effluent solutions. The plateau was established on the volume of the passed solution equal to 200 ml. Desorption of the uranium from the ion exchanger was carried out after completely saturation of the resin. The uranium concentration in the desorption eluates was determined titrimetrically (Table 2). The desorption curve was constructed (Figure 3).

Table 1 – Data obtained after titration of the sorption cells of uranium on the anion exchange resin AMP (measurement error is 0.25 ml).

Sample	$V_{Pr,s}, ml$	$C_u, mg/l$
1	5	62.9
10	50	131.27
20	100	134.00
25	125	142.21
30	150	142.21
40	200	142.24
45	225	139.47
50	250	139.47

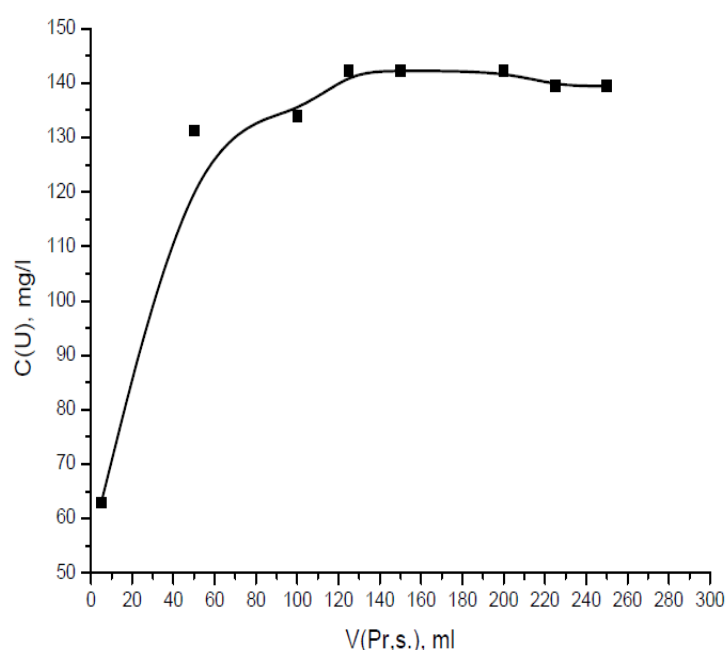


Figure 2 – The output curve of the uranium sorption on the anion exchange resin AMP (measurement error it 0.25 ml)

Table 2 – Data obtained after titration of uranium desorption eluates on the anion exchange resin AMP (measurement error is 0.25 ml).

Sample	$V_{\text{desorp.el.}}$, ml	C_U , mg/l
1	5	268.01
2	10	103.92
5	25	5.469
10	50	0

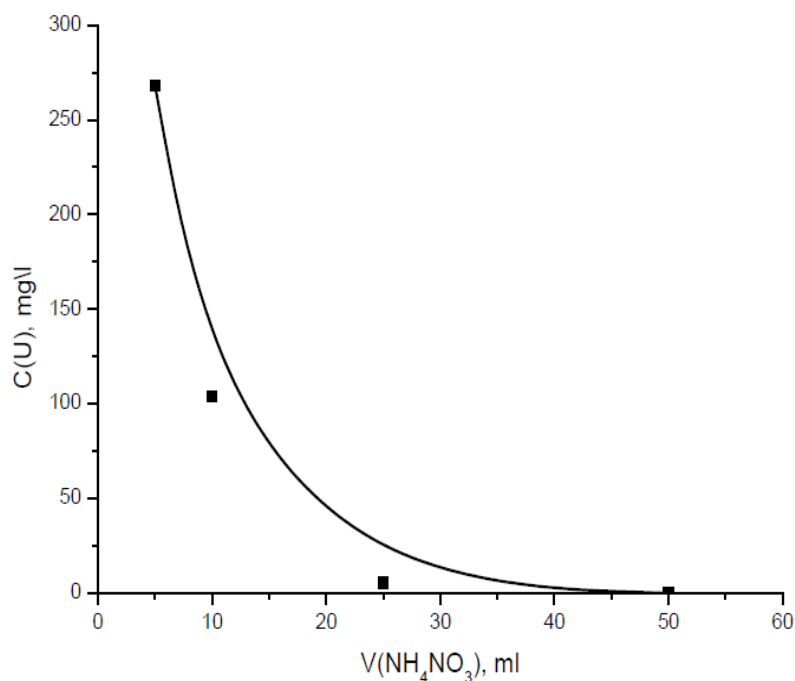
**Figure 3** – The output curve of uranium desorption on the anion exchange resin AMP (error of measurement it 0.25 ml)

Figure 3 shows that uranium is elutriated first by 5 ml of a desorbing solution. The maximum amount of uranium in the eluate was 268.00 mg/l, which is almost 1.5 times higher than the concentration of uranium in the initial productive solution. According to the data on the curve, the resin reaches a zero value of the uranium concentration when 50 ml of desorbing solution passes, this indicates a good

desorption characteristic of the AMP resin. Based on the experimental data, the DEC (dynamic exchange capacity) was calculated, which was equal to 1.47 mg/cm³.

Based on the obtained data (Table 3), after the titration of the sorption cells of uranium on the anion exchange resin Ambersep 920 IRA, the dependence shown in fig. 3 was constructed.

Table 3 – Data obtained after titration of the sorption cells of uranium on the anion exchange resin Ambersep 920 IRA (measurement error is 0.25 ml).

Sample	$V_{\text{Sorp.cells}}$, ml	C_U , mg/l
1	5	13.67
10	50	87.51
15	75	84.77
20	100	101.19

Continuation of table 3

Sample	$V_{\text{Sorp.cells}}, \text{ ml}$	$C_U, \text{ mg/l}$
25	125	131.27
30	150	139.47
35	175	123.07
40	200	134.00
45	225	131.27
50	250	155.88
55	275	150.41
60	300	164.09
65	325	134.00
70	350	150.41
75	375	150.41
80	400	161.31

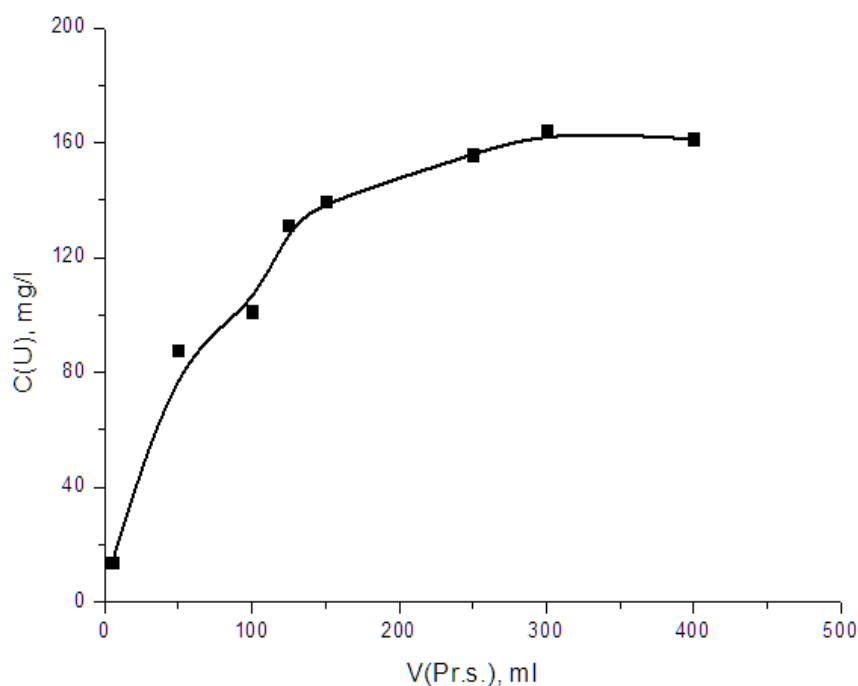


Figure 4 – The output curve of the uranium sorption on the anion exchange resin Ambersep 920 IRA (measurement error it 0.25 ml)

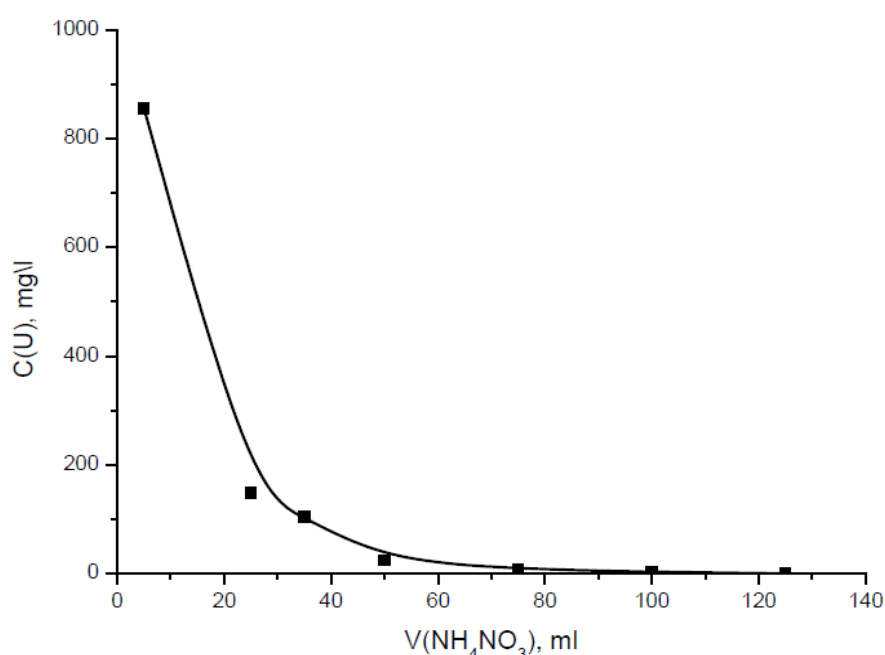
This curve shows a breakthrough point in the first 5 ml of the volume of the productive solution. The concentration of the uranium slightly increases to equalize the concentrations in the influent and effluent solutions. The plateau was established on the volume of the passed solution equal to 350 ml. The uranium was eluted from the column, and the data given in Table 4 were obtained. The uranium concentration in desorption eluates was determined titrimet-

rically. The output desorption curve was constructed (Figure 5).

Figure 5 shows that uranium is elutriated first by 5 ml of a desorbing solution. The maximum amount of uranium in the eluate was 856.00 mg/l, which is almost 5 times higher than the concentration of uranium in the initial productive solution. Based on the experimental data, the DEC (dynamic exchange capacity) was calculated, which was equal to 1.47 mg/cm³.

Table 4 – Data obtained after titration of uranium desorption eluates on the anion exchange resin Ambersep 920 IRA (measurement error is 0.25 ml)

Sample	$V_{\text{Desorp.el.}}, \text{ ml}$	$C_U, \text{ mg/l}$
1	5	856.00
5	25	147.68
7	35	103.92
10	50	24.6
15	75	8.2
20	100	2.7
25	125	0

**Figure 5** – The output curve of uranium desorption on the anion exchange resin Ambersep 920 IRA (error of measurement is 0.25 ml)**Table 5** – Comparative characteristics of the obtained results

Ion – exchange resin	DEC, mg/cm^3	C_U at the time of breakthrough point, mg/l	C_U in the desorption eluates, mg/l	C_U in the productive solution, mg/l
Ambersep 920 IRA	1.47	13.67	856.00	173.12
AMP	1.47	62.90	268.00	

Based on Table 5, it can be seen that the dynamic exchange capacity for both resins has the same value, but the value of the uranium content at the time of breakthrough for the resins is different. So, for the Ambersept 920 IRA, the concentration of uranium in the sorption cell at the time of the breakthrough is 13.67

mg/l , while the same value for the anion exchanger AMP is 62.9 mg/l . In addition, it should be noted the preferential desorption characteristics of the ion-exchange resin Ambersept 920 IRA, where the uranium content in the desorption eluate is 3 times higher than the uranium content in the AMP desorption eluates.

Conclusion

Based on the sorption and desorption characteristics of the strongly basic ion-exchangers AMP and Ambersep 920 IRA, it was found that the Ambersep 920 IRA anion exchanger has greater sorption and desorption advantages in comparison with AMP exchanger. Thus, the final uranium content in the desorption eluate for Ambersep 920 IRA and AMP was 856.00 and 268.00 mg/l, respectively, which is 5 and 1.5 times higher than the initial uranium content in the production solution. The breakthrough of uranium for the Ambersep 920 IRA resin is observed with lower concentration of uranium than the AMP resin, which indicates better sorption ability of the resin. Thus, the results of the conducted studies show the prospects of using the Ambersep 920 IRA anion exchange resin in the sorptional extraction of uranium from productive solutions of sub-surface leaching.

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