PRODUCTION OF RADIONUCLIDES ^{55}Fe AND ^{58}Co IN THE NUCLEAR REACTOR WWR - SM INP AS RU.

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The radionuclides ^{55}Fe and ^{58}Co are used in different fields of science, technology and in medicine. Recently, the production of radionuclides ^{55}Fe and ^{58}Co has been developed and started on the basis of the nuclear reactor WWR - SM and enterprise "Radiopreparat" INP AS RU.

1. RADIOCHEMICAL SCHEME OF ^{55}FE PRODUCTION.

^{55}Fe ($T_{1/2}$=2,7 year) can be obtained from manganese cyclotron targets by reaction ^{55}Mn(d,2n)^{55}Fe or in the nuclear reactor from ^{54}Fe enriched targets by reaction ^{54}Fe (n,γ)^{55}Fe. ^{55}Fe is used as a source of the mild X-ray radiation for different studies in X-ray structured analyses of materials [1,2]. It is known that the sources on the base of ^{55}Fe are used for the preparation of flexible applicators in nuclear medicine [3,4].

Different methods were used for the separation of ^{55}Fe from targets and its purefication: extraction [5], electrochemical [6] and ion - exchange chromatography [7,8]. Danilin and others [7] purified the nuclear reactor produced ^{55}Fe by means of DOWEX 2x8 anion - exchange chromatography in 8 M HCl. Authors of the article [8] offered for the separation of cyclotron produced ^{55}Fe on anion - exchanger AG 1x2 in 9 M HCl. The used targets by were the metallic powder enriched % by ^{54}Fe isotope up to 98. At the irradiation targets in the nuclear reactor, besides the main reactions also a nuclear reaction with formation of ^{54}Mn runs: ^{54}Fe(n,p)^{54}Mn having section 0,011 barn. Production of radiochemical pure ^{55}Fe is based on the procedure of ^{54}Fe and ^{54}Mn separation.

Experiment

Used reagents had a high degree of the purity. Liquid anion - exchanger trioctylamine (TOA) of the company "Merck" (Germany). Solid extragent TOA - Teflon was prepared by covering fluid TOA on the surface of Teflon powder. Chromatographic columns were made from transparent glass (10 mm and 150 mm) and filled by solid extragent .

Radiometric measurements conducted on NP-424L four-channel nuclear spectrometer with ND-424D scintillation detector and data measuring complex, consisting of the analyser NTA-1024 with Ge(Li) detector.

Results and Discussion.

For the development of ^{55}Fe radiochemical scheme separation the statical extraction of iron and manganese in systems TOA (xylene) - HCl and TOA (xylene) -HNO_3 has been considered. The obtained results are shown in the table 1. The table.1 data shows that the manganese is not extracted from HCl and HNO_3 solutions into TOA phase. From table.1 the Iron (+3) is almost not extracted from HNO_3 solutions. For this purposes the better approach is to use HCl solutions for Iron(+3) extraction, since the extraction of Fe (+3) grows with the increasing Hcl concentrations.

Table 1. Extraction of Fe(+3) and Mn(+2) in systems of 0,4 M TOA (xylene) -HCl and HNO_3 solutions.

Water solution and Elements	Concentration of water solution , mol/l							
	0,1	0,2	0,5	1,0	2,0	4,0	6,0	8,0
HCl Fe(+3)	0,03	0,12	0,63	4,8	14,7	48,0	94,0	312,0
HNO_3 Fe(+3)	$5x10^{-3}$	$2x10^{-2}$	$1x10^{-2}$	$7x10^{-3}$	$9x10^{-3}$	10^{-2}	10^{-2}	10^{-2}
HCl, HNO_3 Mn(+2)	not extracted							

Distribution factors of elements in explored systems which calculated by the next formula:

$$D= (Co * Vaq)/(Caq * Vo) \qquad (1)$$

where, Co and Caq are concentration of Fe (+3) in organic and water phases, accordingly. Vo and Vaq are the volume of organic and water phases, accordingly.

Calculation of dynamic extraction on solid extragent in the column was help held at the formula:

$$Kd = (V\ max - V)/ m \qquad (2)$$

where Vmax is an eluate volume prior to the maximum on elution curve; V is water solution volume in the column's free volume; m is mass of solid extragent .

Calculated in the formula (2) distribution factors are shown in the table 2.

Table 2. Distribution factors of Fe (+3) and Mn (+2) in the system TOA - Teflon.

[HCl] , M	Distribution Factors of	
	Fe (+3)	Mn (+2)
4,0	6,3x10	not extracted
6,0	$1,1x10^{3}$	not extracted
8,0	$2,0x10^{3}$	not extracted
10,0	$2,1x10^{3}$	$2x10^{-2}$

From tables 2 it is observed that Mn (+2) is not extracted from HCl solution into TOA phase and that allows to use this system in radiochemical technology of ^{55}Fe production for the purifying from ^{54}Mn.

In the figure 1 elution curves of ^{54}Mn and ^{55}Fe from chromatographic column are represented.

Technology.

^{54}Fe metallic powder (200 mg, enrichment more than 98%) was irradiated in the nuclear reactor at the flux of heat neutrons $0,5x10^{14}$ $n*sm^{-2}*s^{-1}$ during 1 year. Irradiated target was dissolved in 3 ml of 8,0 M HCl with the addition of 0,02 ml 30% H_2O_2. Then solution was evaporated dry and the remainder was dissolved in 25 ml of 11,5 M HCl. $^{55}FeCl_3$ solution was applied to the chromatographic column. Then the column was washed by 8,0 M HCl at 0,2 ml/min flow rate. 120-130 ml of 8,0 M HCl ensures full separation of ^{55}Fe from ^{54}Mn. ^{55}Fe iones were eluted in 13-15 ml of 0,1M HCl at flow rate 0,10-0,15 ml/min. Obtained product has the following characteristic:

Specific activity ^{55}Fe is more than 25 Ci/g;

Radioactive concentration is more than 375 mCi/ml;

Contents: ^{59}Fe is less than 10^{-5} %; ^{54}Mn is not discovered;

Radiochemical purity is 99,9%

2. RADIOCHEMICAL SCHEME OF ^{58}CO PRODUCTION.

One of the known ^{58}Co production methods is based on the cyclotron nuclear reaction ^{57}Fe(d,n)^{58}Co. However the peferable approach is connected with the nuclear reaction ^{58}Ni(n,p)^{58}Co. Cross section of the last reaction is explored by many authors [9-12].

DOWEX 1x8 ion - exchange chromatography in 9 M HCl was used for separation of ^{58}Co from irradiated targets [13]. Another method of the separation is based on extraction of ^{58}Co by organic solvents from radionuclide solutions [14].

The main sources of the radioisotope admixture after irradiation of nickel targets in the nuclear reactor are reactions: ^{60}Ni(n,p)^{60}Co and ^{59}Co(n,)^{60}Co which lead to formation of ^{60}Co. This circumstance makes a necessity to use the enriched ^{58}Ni targets with high degree of the purity by the cobalt-59.

Experiment.

The targets were used in state of metallic ^{58}Ni or oxide ^{58}NiO enriched up to 99,8% by ^{58}Ni. The reagents had a high degree of purity. Distilled water deionised. Solid extragent TOA - Teflon was prepared by TOA (liquid anion-exchanger - trioctylamine) sorbtion on the surface of Teflon powder.

Radiometric measurements were conducted on NP-424L four-channel nuclear spectrometer with ND-424D scintillation detector and data measuring complex consisting of the analyser NTA-1024 with Ge(Li) detector. Radioactive indicator ^{57}Co («Tezlatgich» INP AS RU) was used for the technology developing.

Results And Discussion.

At the beginning he extraction of cobalt and nickel by solution TOA in xylene from HCl was explored. Results of this research are shown in the table 3.

Table 3. Extraction of cobalt and nickel by 0,5 M TOA in xylene from HCl.

Element	Concentration HCl, M						
	0,1	0,5	1,0	2,0	4,0	6,0	8,0
Co	0,002	0,008	0,1	0,20	0,44	6,1	29,0
Ni	not extracted						

The distribution factors calculated by the formula (1) for Co (+2) are shown in the Table.3. Results in table.3 indicate that nickel is not extracted from HCl solutions into TOA phase, while Co(+2) is extracted at HCl concentration above 4 M.

Analytical data for radioactive ^{58}Co solution obtained by the irradiation of different targets are provided in the table 4. Content of radionuclides ^{58}Co and ^{60}Co were defined by the area of their gamma-peaks with the energy 511 and 810 keV for ^{58}Co and energy of 1173 and 1332 keV for ^{60}Co by means of gamma data measuring complex. Results of these studies show that it is better to use the enriched ^{58}Ni or Nickel specially refined from the cobalt as the targets.

Table 4. Results of the analyses of radioactive solution ^{58}Co.

Targets	Area of gamma-peaks, impulse			
	Energy of γ-radiation of ^{58}Co, keV		Energy of γ-radiation of ^{60}Co, keV	
	511	810	1173	1332
1. Enriched ^{58}Ni (99,8 %)	9026	19496	-	-
2. NiO without Co chemical pure	6180	13287	-	-
3. NiO, impurificating from Co	6020	12687	212	245

Technology

The targets of enriched ^{58}Ni (in state of metallic or oxide) up to 99,8 % were irradiated in the nuclear reactor at the flux of fast neutrons $1x10^{13}$ $n*sm^{-2}*s^{-1}$ during 100 hours. Irradiated targets were dissolved in concentrated HCl. Solutions were applied to the chromatographic column filled with solid extragent of TOA - Teflon. The column was washed with 100 ml 8 M HCl. ^{58}Co was eluted from the column in 20 ml 3 M HCl. Solutions of radioactive cobalt were evaporated and dry remainder was dissolved in 2-3 ml 0,1 M HCl. The washing flow rate should be 0,3-0,4 ml/min, flow rate of ^{58}Co elution not more than 0,15 ml/min. The product has the following characteristic:

Chemical form is ^{58}Co(+2) in 0,1 M HCl;

Specific activity is more than 5000 Ci/g. Content of ^{60}Co is less than 10^{-3}%;

Contents of inactive admixtures (Ni, Fe, Cu and others) are less than 10^{-3} mg/ml.

Technological yield was not less than 95% of ^{58}Co radionuclide.

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