Non-radioactive scandium oxide receiving out of uranium ISR solutions

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Abstract. The task of the research was to study and determine an effective method for the preparation of non-radioactive scandium compounds from uranium In-Situ Recovery (ISR) solutions. The widespread use of scandium is restrained by the high price due to its small production volumes, low content in the raw materials (scandium is a scattered element and does not form its own deposits), as well as the complexity of technological schemes for its extraction. Scandium receiving out of uranium reverses ISR solutions technological scheme was experimental tested, including sorption on MTS 9580 (Purolite’s production) ion exchanger with recurrent ballast impurities desorption and receiving concentrate that contains scandium. New radiation cleaning technological sequencing based on different solubility of radioactive elements and scandium in carbonate solutions, that accompanied by insoluble macro components complex formation, that contains in deactivated scandium concentrate and allows to get scandium oxide with desired component maintenance more than 94 % and less than 0,3 kilobecquerels/kg specific activity level was developed. The developed technology is based on the ability to form soluble carbonate complexes of scandium and radioactive elements, while the main macro components of the concentrate - ferrum, aluminum, calcium, silicon and others under the conditions of carbonation of the concentrate are inert or form insoluble compounds. Optimal radioactive impurity removing from concentrate conditions and scandium leaching from deactivated residue of scandium and macro impurity were studied and identified in laboratory conditions and during pilot tests.

Key words: scandium concentrates, non-radioactive scandium oxide, recover, leaching

Nowadays there is a big interest to solving the scandium compounds receiving from different kinds of mineral and technogenic raw materials problem. The interest caused by opportunity of using scandium in production of new materials with improved performance characteristics such as fuel elements, luminescent materials, piezoelectrics, ferroelectrics, crystal phosphors etc.

It is well known that there is no naturally free scandium, so it’s receiving is very challenging technical problem because of following leaching of greater concentration elements from complex raw materials during scandium extraction.

Besides uranium – main ore element in Kazakhstan’s uranium regions there are also other valuable elements such as rhenium, selenium, vanadium, scandium, rare earth elements and others. Scandium concentration in recyclable solutions is less than 1 mg/l by comparision with concentration of ferrum, aluminum, alkaline and alkaline-earth elements. There are also titan, zirconium, vanadium, uranium in solution with concentration the same as scandium.
The creating effective technologies of extracting these valuable components from technogenic raw material as a result of extracting uranium by ISR method is a relevant problem.

Next problems should be solved during researches of extracting scandium combinations from uranium ISR solutions:

1. Find optimal conditions of sorption scandium concentration from uranium ISR solutions getting primary concentrates;
2. Study several ways of primary scandium concentrates radiation cleaning from radioactive elements (uranium and thorium);
3. Develop technological scheme of primary scandium concentrates recycling getting non-radioactive scandium oxide.

Nowadays, scandium primary concentration from uranium ISR solutions makes by sorption method. Scandium sorption specifications using Soviet and Russian industrial phosphorous containing ion exchanger CRP-20T-60 and PA-1 polyampholyte are reviewed in articles [2, 3].

The opportunity of sorption scandium concentrating from sulphate solutions was using Purolite’ production MTS 9580 phosphorous containing ion exchanger is studied in this research. MTS 9580 ion exchanger characteristics are given in table №1.

Table 1. Basic characteristics of ion exchanger MTS 9580

| Parameter                                | Characteristic                        |
|------------------------------------------|---------------------------------------|
| Polymer structure                        | Macro porous copolymer styrene and divinylbenzene |
| Exterior                                 | White granules                        |
| Functional group                         | Undefined phosphonic acid derivatives |
| Ionic form                               | Cl⁻                                  |
| Total exchange capacity, minimum, g-eq/l | 0,6                                  |
| Residual moisture in chloride form, %    | 44-50                                 |
| Particle size range, %                   | maximum 1300 mkm – 100 maximum 425 mkm – minimum 2,5 |
| Uniformity factor (minimum)              | 1,9                                   |
| Reversible swelling during transition FB → Cl⁻ (minimum), % | 20                                  |
| Specific gravity (with product humidity), g/l | 660 - 710                            |
| Bulk weight (approx.), g/sm³              | 0,60 - 0,65                           |
| Maximum operational temperature          | 80 °C                                 |
| Selectivity                              | Sc, Th, In                            |

IR spectrum of the above ionite is given in Figure 1.
Sorption extraction from scandium ISR solutions process was studied using scandium sulphate solution that imitates recycling solutions after underground uranium leaching.

During comparative experiments of ion exchangers sorption characteristics it was identified that ion exchangers with sulphate and phosphonic groups including MTS 9580 ion exchanger have better sorption parameters. Using MTS 9580 ion exchanger in sorption scandium concentrating allowed extracting more than 92 % of scandium. During experiments was also found the opportunity to increase MTS 9580 ion exchanger scandium capacity by periodical desorption of ballast impurities from saturated ion exchanger using rinsing sulphuric acid solution.

An ammonium hydrodifluoride solution was used as the desorption solution. In order to increase the scandium concentration in the solution, the desorption solution was used in the cycle.

Scandium was precipitated using fluorine-containing compounds from the obtained desorbate, scandium and radioactive elements; the content in the obtained scandium concentrate required the development of radio purification technology with subsequent concentration of scandium.

An analysis of existing developments has shown that, despite the variety of scandium purification and concentration methods, extraction and deposition processes play a crucial role in its production technology.

It should be noted that these methods are used in a multi-stage version, and satisfactory results can be achieved when combining these methods.

The most widely considered and developed methods of processing scandium-containing concentrates include the operation of dissolving it using various mineral acids (sulfuric, hydrochloric, nitric), which leads to the need for acid-resistant equipment and involves the complete opening of the "primary" concentrate.

This approach increases the consumption of acids necessary to dissolve the accompanying macro elements, at the same time multicomponent solutions are formed, which contain milligrams of scandium and tens of grams in a liter of various impurity elements [4.5].
In the prevailing majority of cases, cation exchange and neutral reagents are used as industrial extractants of scandium.

Tributyl phosphate (TBP), which extracts scandium from neutral and strongly acidic nitrate solutions, is used most widely.

Di-2-ethylhexyl phosphoric acid (D2EHPA) has satisfactory selectivity, but has a low capacity.

We studied the processes of scandium extraction affinity from sulfate and nitrate solutions.

Partial purification of scandium from radioactive elements and macro-impurities is possible in the extraction systems TBP-scandium nitrate solution and D2EHPA-scandium sulphate solution; however, the level of scandium affinity achieved is not sufficient and requires three or more cycles of the extraction purification process.

Methods for carbonizing scandium-containing concentrates (red sludge) are known, however, scandium recovery is relatively low (not exceeding 20%).

Agent and gas carbonization of pulp was tested in industrial devices on the territory of «BAP-SUAL» OJSC, a rough scandium concentrate with a scandium content of up to 5% was obtained.

The soluble scandium compounds and some impurities adsorbed on the surface of the sludge particles as a result of carbonation accumulate in recycled solutions to certain concentrations, which makes it possible to obtain scandium concentrate [6] after preliminary purification of the solution and neutralization operation.

The technology of obtaining draft concentrate using a precipitator could not be implemented in BAZ-SUAL OJSC. Radionuclides in increased amounts were released into the concentrate during the enlarged experimental conditions [7].

The technological changes made to the working conditions made it possible to exclude contamination of concentrate with uranium and thorium. However, alumina wastes in which the content of radioactive substances was minimally used as feedstock in the above example.

Analysis of studies conducted in Ulba Metallurgical Plant showed the possibility of obtaining non-radioactive scandium oxide from a scandium-containing concentrate.

The developed technology is based on the ability to form soluble carbonate complexes of scandium and radioactive elements, while the main macro components of the concentrate - ferrum, aluminum, calcium, silicon and others under the conditions of carbonation of the concentrate are inert or form insoluble compounds. Selective removal of radioactive impurities from scandium-containing concentrate and production of deactivated scandium concentrate is possible with selection of required conditions of carbonate treatment. Preliminary removal of radioactive elements (efficiency 99%) made it possible to carry out carbonate leaching of scandium from the deactivated concentrate, to obtain a scandium solution that does not contain radioactive elements and to separate macro-impurities from scandium. Pure non-radioactive scandium oxide with a content of the desired component greater than 94 % and less than 0.3 kilobecquerels/kg specific activity level was developed, suitable for direct production of aluminum-scandium ligature or metallic scandium was obtained after precipitation of scandium from solution and calcination of the precipitate.

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