

# Oxidized nickel-cobalt-containing raw materials electro-chemical leaching

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### Abstract

The article presents cobalt electroextraction data using concerted electrochemical reactions, during which leaching chemical and reactions of metals transfer into solution are obtained simultaneously. Leaching was conducted in NaOH solution where leaching chemicals were obtained using sulfur-graphite electrode. Sulfur-graphite electrode served as a cathode while graphite served as anode. The optimal parameters of metals leaching into solution under experimental conditions are the following: current density 200 A/m<sup>2</sup>, alkali solution initial concentration 0.2 M, temperature 25<sup>0</sup>C. When leaching time increasing, cobalt extraction is also increased up to 120 minutes, after which the cobalt cooling is performed. Preliminary studies showed that concerted electrochemical reactions have prospects of using for cobalt extraction from complex and refractory raw materials.

Keywords: COBALT-CONTAINING RAW MATERIALS, COBALT, SULFUR-GRAPHITE ELECTRODE

## Introduction

The cobalt is usually produced as co-product in extraction technology of copper and nickel. At that, nickel production is the main source of cobalt in recent decades [1].

The main method of cobalt extraction from semi-finished product is acid leaching, particularly under high pressure. The leaching with hydrochloric acid, hydrogen nitrate and ammonia is also used [2].

Considerable costs and lack of technical solutions effectiveness in hydrometallurgy are caused by belated view of fundamental concept of inorganic aqueous solution microstructure and by lack of studying of problems associated with the effect of aqueous solutions of various energy depositions on microstructure [3-5].

The complexity of the chemical reactions in systems involving cobalt is emphasized. In particular, some papers show that in the vast majority of cases leaching is characterized by small speed due to mineral grains surface passivation during leaching. Also, from the literary data it can be concluded that modern researches do not take into account the conditions of interaction between base minerals and enclosing rock minerals. However, many technical solutions are aimed at difficulties overcoming of metals extracting caused by the nature of this interaction [6-7]. For example, in paper [6] it is pointed out that the stage of chemical interaction between pyrite and oxygen-containing compounds of raw materials is reaction, which limits the rate of oxidation process of base mineral (pyrite), which affects significantly the redox process in sulfide-oxide systems.

New technologies with the use of electric current are being developed; they became widely used in order to improve the efficiency of extracting metals into solution. We investigate the impact of the use of various parameters electric current, electrochemical technologies various hardware designs and electrical signal form [8].

It is interesting that the use of alternating current while dissolving as well as deposition of metal using electrochemical methods becomes widespread [9-10]. H.e., we can report that, currently, the possibility of the electric current effective use as a certain "chemical agent" in order to shift the chemical equilibrium towards the desired direction is shown by experiments. It is noted that the use

of alternating electric current provides energy transmission to the objects of chemical system, facilitates their transportation, increases the diffusion rate (including the crystal) and ensures substance recrystallization. Moreover, the use of electric current changes the structure of solutions and precipitations providing, for example, hydration shells asymmetry, which facilitates the elements extraction into the liquid phase. There is sufficient number of works, which demonstrate by experiment the utility of transient effects on the electrode-solution system [11].

Electroleaching is used quite widely in metallurgy [12-13]. This involves not only the electrochemical processes in the generally accepted sense of these technologies, but also basic material activating by electrical action in a separate activation chamber [13] using electrical impulses of different frequencies and amplitudes. Cathodic and anodic current densities also vary. However, the problem of the use of electrochemical technologies for the efficient processing of complex and refractory mineral raw materials continues to be relevant and attracts researchers' attention [14].

We are carrying out the researches on concerted electrochemical reactions use in order to improve the efficiency of metals extraction from complex and refractory raw materials, to reduce the technological cycle in the chain mineral – metal, to reduce the production costs of expensive chemicals and to recycle more waste of oil industry [15-18]. This article presents the results of search experiments on concerted electrochemical reactions use for the cobalt extraction from refractory multicomponent raw materials.

## Experimental

### *Laboratory experiments*

The chemical composition of the ore, %: Cr-0.78; Mn-0.95; Fe-12.90; Co-0.054; Ni-1.01; Zn-0.02; Pd-0.03; Cd-0.05.

The nickel-cobalt-containing fraction of size  $-0.1+0.1$  mm was used as the study material.

The experiments were conducted in reaction cell. The cell had three-electrode system consisting of a working electrode, reference electrode and auxiliary electrode. A sulfur-graphite electrode, wherein the ratio of sulfur and graphite is 65:35%, was used as working electrode. A silver-chloride electrode served as reference electrode, and graphite electrode served as auxiliary one. Alkaline

solution volume in the reaction vessel of 150 ml. A sample of a ratio of S: L = 1: 10 (ore 15 g: sodium hydroxide 150 ml) was placed in the vessel. The current density is  $i=50-250 \text{ A/m}^2$  and more, stirring rate – 480 r/min; leaching time – 5-6 hours. The alkali concentration in the solution 0.1 M, 0.2 M, 0.3 M, 0.5 M.

For analyzes, the samples were taken every hour. We determined the pH media, cathode potential (sulfur-graphite electrode) -  $E_k^0$ , electrical conductivity, Eh of solution and the dissolved oxygen concentration (DO) using 856 Conductivity Module, 867pH Module «Metrohm» (Switzerland), portable analyzer 156 SensIon of «HACH» firm (USA). The amount of metals transferred into solution was determined by atomic adsorption spectrometer «contrAA 300».

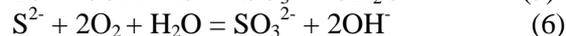
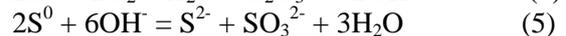
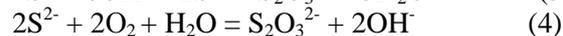
During electrochemical leaching, the elemental sulfur is reduced and polysulfide-ions are formed by reaction:



Then polysulfide-ions can be reduced to monosulphide:

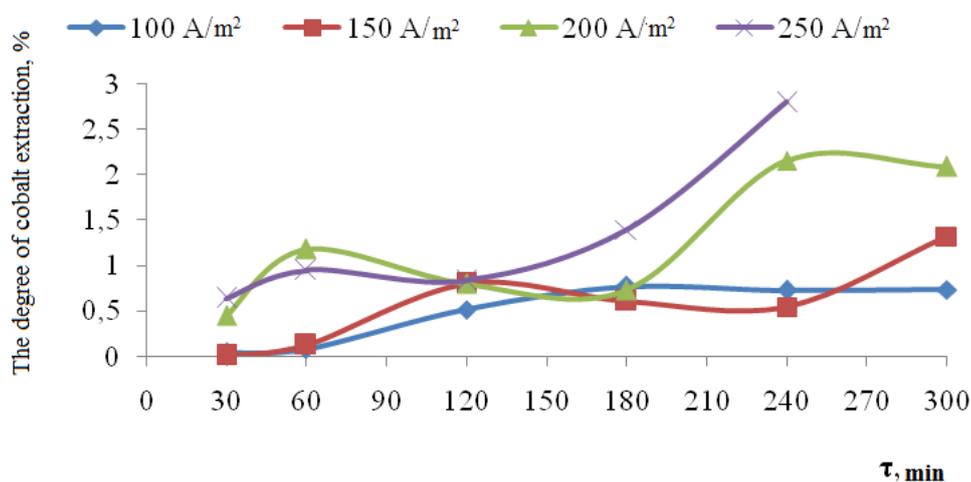


The following processes also can be carried at the cathode and in the solution:

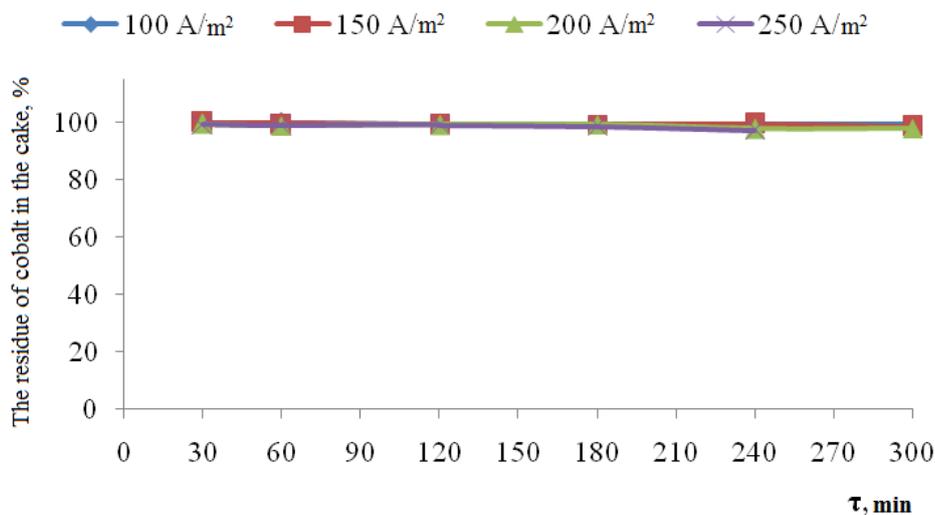


## Results and discussion

Extraction of cobalt in the solution depending on the current density at the sulfur-graphite electrode.



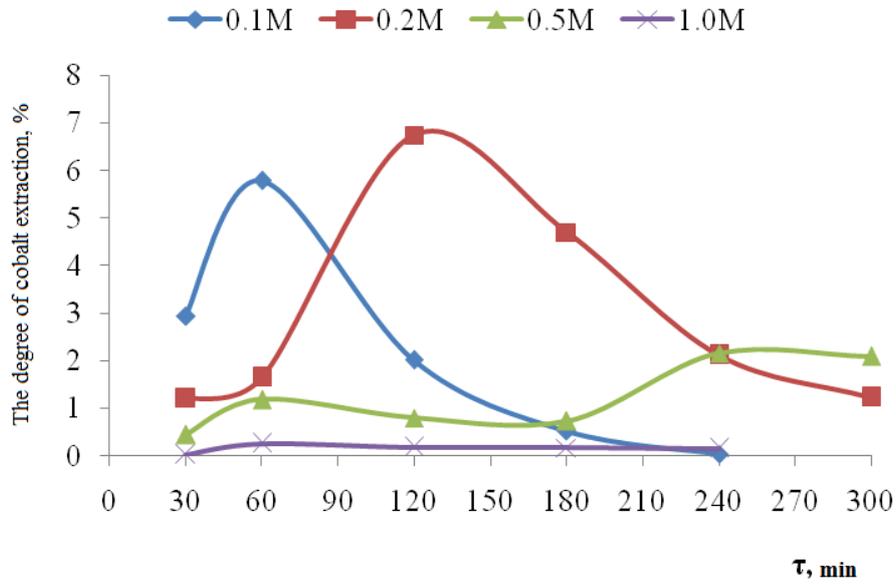
**Figure 1.**  $T_{\text{room}}=25^\circ\text{C}$ ;  $C_{\text{NaOH}}=0.5\text{M}$ ; current density -  $100 \text{ A/m}^2$ - $250\text{A/m}^2$  and more; S: L (1:10); cathode – uninterruptible power supply system; anode - graphite; stirring rate – 480 r/min



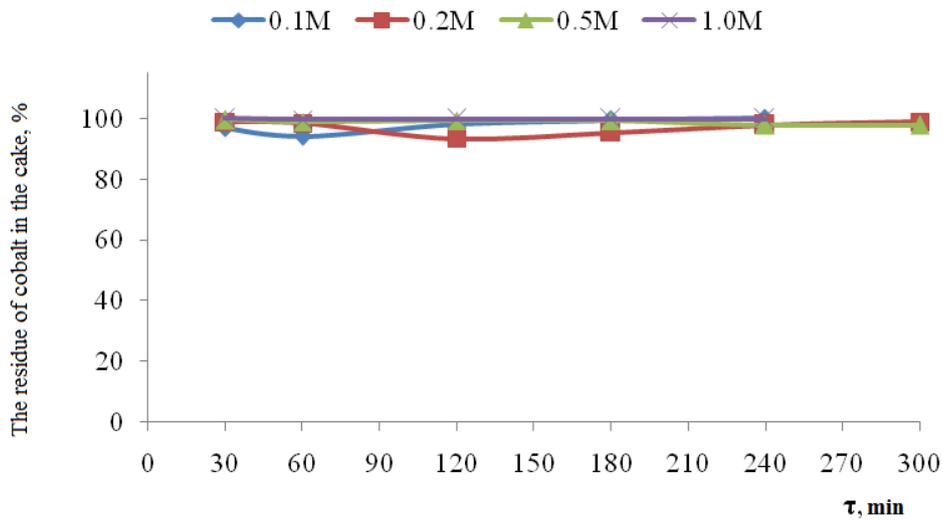
**Figure 2.** The residue of cobalt in the cake after the electrochemical leaching of nickel-cobalt-containing raw materials

Extraction of cobalt in the solution depending on the alkali concentration (NaOH) on sulfur-

graphite electrode:

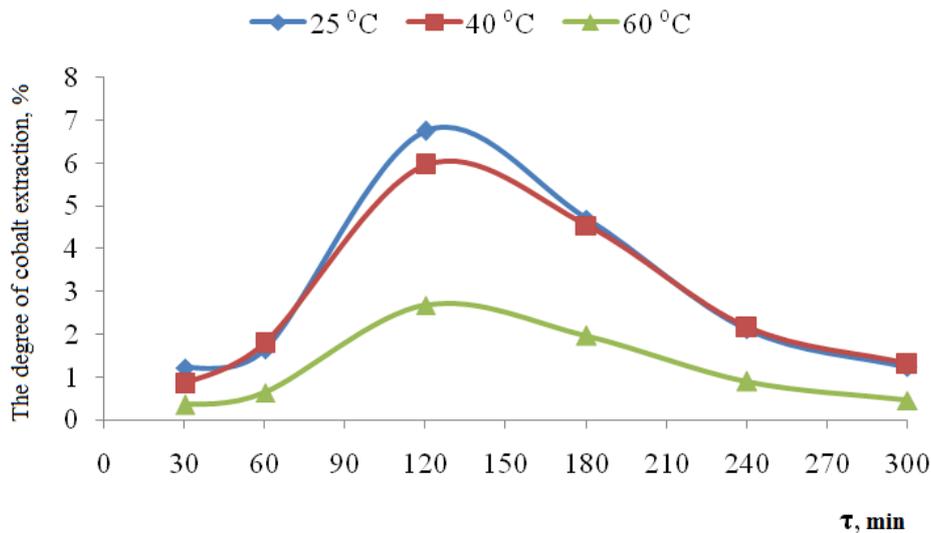


**Figure 3.**  $T_{\text{room}}=25^{\circ}\text{C}$ ;  $C_{\text{NaOH}}=0.1\text{M}-1.0\text{M}$ ; current density -  $i=200 \text{ A/m}^2$   $J=0,4\text{A}$ ; S: L (1:10); cathode – uninterruptible power supply system; anode - graphite; stirring rate – 480 r/min

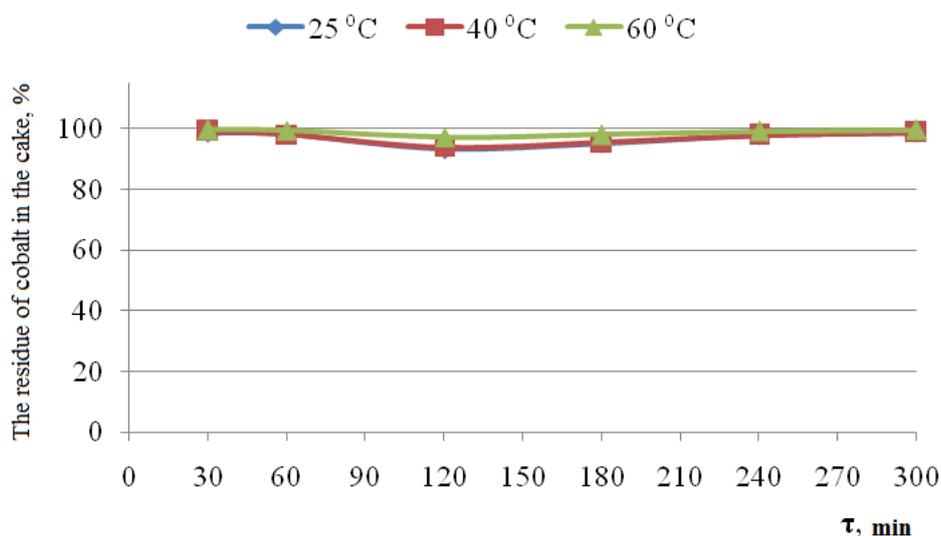


**Figure 4.** The residue of cobalt in the cake after the electrochemical leaching of nickel-cobalt-containing raw materials

Extraction of cobalt in the solution depending on the temperature on sulfur-graphite electrode:



**Figure 5.**  $T_{\text{room}}=25^{\circ}\text{C}$ ;  $C_{\text{NaOH}}=0.2\text{M}$ ; current density -  $i=200\text{ A/m}^2$   $J=0,4\text{A}$ ; S: L (1:10); cathode – uninterruptible power supply system; anode - graphite; stirring rate – 480 r/min



**Figure 6.** The residue of cobalt in the cake after the electrochemical leaching of nickel-cobalt-containing raw materials

## Conclusions

The process of cobalt leaching from complex raw materials by electrochemical method using sulfur-graphite electrode has been investigated. The leaching intensity of oxide nickel-cobalt-containing raw materials under specified conditions is not high. It is shown that the use of concerted electrochemical reactions for cobalt extraction from refractory materials can have certain prospects. It was found that the process of leaching chemical and metals dissolving from

metal-containing raw materials process combined obtaining is of quite complex nature, which is difficult to explain from a perspective of the existing views on aqueous solutions inorganic microstructure. It is shown that when using sulfur-graphite electrode as cathode, the cobalt extraction may reach 5.79% of leaching in 60 minutes and 6.74% in 120 minutes depending on the alkali concentration in the initial solution. The cobalt extraction in solution depending on the temperature under

optimal parameters of solution concentration and current density was also studied. With the increasing of leaching time and solution temperature, the reverse cobalt precipitation from solution may occur.

The use of the method of electrochemical cobalt extraction from refractory ores may have prospects when complex and refractory ores processing.

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