ABSTRACT
to the thesis of BAUYRZHAN SURIMBAYEV
on the theme "DEVELOPMENT OF TECHNOLOGY FOR THE EXTRACTION OF GOLD FROM SULPHIDE ORES USING REAGENT-ACTIVATOR WITH INTENSIVE CYANIDATION",
presented for Doctor of Philosophy (PhD) degree by specialty 6D070900 – Metallurgy

Assessment of the current state of a scientific or technological problem being solved

Kazakhstan's gold reserves at the end of March, 2017 is 267.7 tons. Republic gold reserves Kazakhstan takes 15-th place in the world, 3-e in the CIS after Russia and Uzbekistan.

The raw material base of the gold mining industry of the Republic is represented mainly by small (with reserves of up to 25 tons) and medium (from 25 to 100 tons) deposits, which extracted about 70% produced from gold. On the level of reserves of the leading position occupied by East (around 52%), Northern and Central Kazakhstan (30%). According to the «Kazakhstan Business Magazine», there were 293 gold deposits, of which 38% complex, 60% gold ore and 2 % of placer.

Almost all known technologies for processing gold-bearing raw materials include the use of gravity enrichment methods in order to isolate free large, medium and small gold. However, the hydrometallurgical processing of gold-containing concentrates by traditional methods of cyanidation is difficult due to the lack of equipment of small productivity and significant losses of metal with cake. In recent years, for the processing of gravity concentrates, the method of intensive cyanidation has been increasingly used. For this purpose, special devices have been created that allow leaching coarse grains of metallic gold with cyanide solutions. The Acacia intensive cyanidation reactor was developed by AngloGold Australia for the Union-Reef plant in South Africa in 1999. In mid-2003, these reactors were used at 22 plants of leading foreign gold mining companies in Australia, Zimbabwe, Canada, South Africa, Papua New Guinea, Mongolia and Russia. In 1997, Australia's InLine Leach Reactor (ILR) intensive cyanidation apparatus was developed in Australia (Gekko Systems), originally introduced at a number of Ashanti Goldfields African factories, and is currently used in more than 20 foreign factories.

Many domestic gold mining companies, still using the traditional gold enrichment technology, are beginning to show interest in the process of intensive cyanidation. So, intense cyanidation Acacia reactor for enrichment of gold-bearing concentrates is installed and running on the fields Pustynnoye and Akbakai. To date, the inclusion in the technological scheme of intensive cyanidation process is one of the main solutions for the processing of gold gravity concentrates.

Technological schemes for the processing of gold-bearing raw materials are very diverse. The choice of a technology depends on many factors, of which the main ones are the chemical composition of the gold-bearing material, the nature of

gold in it and the properties of the minerals with which gold is associated, the presence of other valuable components, and the presence of components in the raw material that complicate the technology its processing.

Quite often, gold particles are covered with films of iron or manganese oxides, argentite, covellin, galena, and some other minerals. Films on small grains of gold can also be formed as a result of the hardening of mineral particles in the process of grinding ore. Solid and dense films prevent the dissolution of gold during cyanidation. If the coatings are porous or occupy only a part of the surface, then cyanidation of gold-bearing material is possible, but it proceeds at a slower rate. When gravity concentration of large gold-coated gold, enters the concentrate, but further extraction from the concentrate requires the use of special methods. The presence of films on a grain of gold must be considered when choosing a technological scheme for ore processing.

It is now widely known uses for the intensification of the process of cyanidation by dissolving films compounds, passivating the surface of precious metal, various chemical additives called activators. The advantage of using reagents-activators is their high technological effectiveness, ease of use, requiring no additional hardware, and, Furthermore, does not require replacement of the established process.

The implementation of the process of intensive cyanidation of gravity concentrates in the presence of activator reagents will significantly improve the processing efficiency of gold-bearing raw materials.

The basis and initial data for the research into the topic

The basis for the development of the thesis topic is the creation of technology for extracting gold from sulphide ores using an effective reagent-activator in the process of intensive cyanidation of gravity concentrates.

As initial data for the development of the research topic, we selected: sulfide gold-bearing ores from the Raygorodok deposit («RG Gold» company), the reserves of which according to JORC standards classify this deposit as the largest in Kazakhstan.

Relevance of the thesis topic

Gravity concentration is widely used in the processing of gold-bearing ores. Processing scheme of gravity concentrates allow us to obtain a richer Gold-containing product sent to melting. In this case, the extraction of gold in the "golden head" does not exceed 70% (most often at the level of 50%).

One of the effective ways of processing gold-containing gravity concentrates is the process of intensive cyanidation, which allows achieving high gold recovery in an acceptable process time. It is known that in addition to the use of high concentrations of sodium cyanide, in the process of intensive cyanidation, chemical additives are also used that destroy passivating films on the surface of grains of gold. However, the known activator reagents used in gold technology to intensify the process of cyanidation, in addition to the destruction of the gold-blocking films, lead to the decomposition of free cyanic ions and gold cyanide complexes, which contributes to significant costs of the expensive solvent of sodium cyanide. In addition, the known activator reagents are distinguished by

environmental hazards, which leads to an increase in the environmental burden on the environment.

In the light of the above, finding an effective reagent-activator leading to intensification of the process of leaching gold from gold-bearing raw materials significantly reduces the duration of the operation and enhancing leaching recovery precious metal into productive solutions is relevant and important technological challenge gold production.

The novelty of the topic concludes in the development of technology for extracting gold from sulphide ores by intensive cyanidation of the extracted gravity concentrate using acetic acid solutions as an activating agent.

It has been established and experimentally proved that acetic acid can be used as an activator of intensive cyanide leaching of gravity concentrates in an alkaline oxidizing environment, which is caused by the dissolution of sulfide minerals and their decomposition products, which passivate the surface of gold, to form solutions of metal acetates.

The following new scientific results were obtained:

- thermodynamically justified the probability of interaction of acetic acid with passivating compounds on the surface of gold at a pH of solutions above 10;
- the kinetic laws of cyanide leaching of gold in the presence of acetic acid were established. It is shown that leaching proceeds in the diffusion mode and has a multistage character;
- based on the results of the research, a new technology of intensive cyanidation of gravity concentrates in the presence of acetic acid was proposed.

The purpose of the research is to substantiate and develop the technology for extracting gold from sulphide ores of the Raygorodok deposit using acetic acid solutions as an activating agent for intensive cyanidation of gravity concentrate, its laboratory testing and integrated laboratory testing.

The object of research is the sulfide ores of the Raygorodok deposit and gravity concentrates obtained from them, which are further processed by the intensive cyanide leaching method in the presence of an activator reagent.

The subject of research is the thermodynamic justification, kinetics and mechanism of action of acetic acid as a reagent-activator for intense cyanidation of gravity concentrates, as well as a study on the process conditions of intensive cyanidation of gravity concentrate in the presence of a reagent-activator, as well as integrated studies of the composition of the equilibrium phases.

The objectives of the study, their place in the performance of research work in general:

- to analyze the literature data on the possible use of chemicals that intensify the process of gold cyanidation;
- carry out a technological assessment of the original gold ore and gravity concentrate of the deposit Raygorodok of the Republic of Kazakhstan;
- thermodynamically justify the choice of reagent-activator in order to dissolve compounds that passivate the surface of gold; to identify the main patterns, mechanism and kinetics of the influence of the reagent-activator on the

process of intensive cyanidation of gravity concentrate; construct a mathematical model of the process;

- to study the conditions for intensive cyanidation; develop a technology for processing sulphide gold-bearing ore using an activator reagent and conducting laboratory tests in devices of intensive cyanidation of various types simulating industrial installations; conduct an economic assessment of the proposed technology.

Each task is logically linked to the other and are aimed at achieving the research objectives.

Research and analysis methods

The main research methods and analyzes used in the performance of the thesis include:

– thermodynamic characteristics of the possible reactions of acetic acid interaction with passivating compounds, forming part of the films on the surface of gold performed by using thermodynamic calculations program HSC Chemistry company 8.0 Outokumpu Technology Engineering Research;

– analysis of metals by atomic-absorption spectrometry conducted on the device model SavantAA;

– X-ray diffraction analysis of initial samples and intermediate products of the developed technology was carried out on an automated diffractometer DRON-3;

– X-ray fluorescence analysis of gravity concentrate was performed on a portable analyzer brand Alpha InnovXSystems;

– crystal-optical method of analysis of the original trial and concentrates the polarizing microscope brand LEICA DM 2500 P;

– IR-spectroscopic research method after intensive leaching of the tails carried out on the device IR Fourier Spectrometer Thermo Scientific Nicolet iS5;

– monitoring of the air environment was carried out in automatic mode using the signal of hydrocyanic acid SSK-4.

Research carried out using instruments and measuring instruments, past the state metrological verification.

Provisions for the defense of a doctoral dissertation

The following provisions are submitted to the defense of the thesis:

- the results of the analysis of literature data, the rationale for the choice of use as an acetic acid activator reagent;

- the results of thermodynamic analysis of the probability of using acetic acid as an activator of cyanide leaching of gold-containing raw materials;

- the results of kinetic studies and modeling of the process of gold cyanide leaching in the presence of acetic acid;

- the results of research on intensive leaching of gold from gravity concentrates;

- results of integrated tests of the developed technology of intensive cyanidation of gold-containing gravity concentrate in the presence of acetic acid.

Practical significance of the work:

- conditions have been developed for intensive cyanide leaching of gold in the presence of an activating reagent (acetic acid) from gold-containing gravity concentrate;

- gravity concentration of gold-bearing ores from the Raygorodok deposit is shown;

- proposed conditions for cyanide leaching of gold-containing gravity concentrate in the drum and cone type apparatus;

- a technological scheme of intensive cyanidation of gold-containing gravity concentrate was developed and tested on an integrated laboratory scale, which is recommended for conducting semi-industrial tests with the aim of its possible use in gold extracting enterprises of the Republic of Kazakhstan.

Publications and approbation of the work

According to the results of the thesis, 13 articles were published, including:

– 2 articles in journals included in the database Scopus (News of the National academy of science of the Republic of Kazakhstan. Series of geology and technical sciences, IF 0,06);

– 4 articles in journals recommended by the Committee for Control of Education and Science of Republic of Kazakhstan Department of Education and Science.

The main provisions and results of the work were presented at international conferences:

– The International Scientific and Practical Conference «Prospects for the development of modern science» (Jerusalem, Israel, 2016);

– 49th International October Conference on Mining and Metallurgy (Bor, Serbia, 2017);

– The International Scientific and Practical Conference «Intensification of hydrometallurgical processes of recycling of natural and technogenic raw materials. Technologies and equipment» (St. Petersburg, Russia, 2018);

– The International Scientific Conference «Modern problems of complex processing of refractory ores and technogenic raw materials» (Plaksin readings) (Krasnoyarsk, Russia, 2017);

– The International Scientific and Practical Conference «Innovations in complex processing of mineral raw materials» (Abishev readings) (Almaty, 2016);

– The International Scientific and Practical Conference «The Effective Technologies of Non-Ferrous, Rare and Precious Metals Manufacturing» (Almaty, 2018);

– The International Scientific Conference «Innovations in complex processing of mineral raw materials», section «Strategy for the development of metal production in the Republic of Kazakhstan and the assessment of mineral raw materials» (Almaty, 2018).

According to the results of the research, an application for the invention of the Republic of Kazakhstan was submitted on the subject “Method of processing gold-containing gravity concentrates” №2018/0134.1 of February 28, 2018, confirmed the positive result of the formal expertise.

The structure and scope of the thesis. The thesis consists of introduction, 6 chapters, conclusion and applications. The work contains 51 tables and 40 figures. The list of references includes 135 tiles.