

ABSTRACT

of the dissertation work on the topic:

«INTENSIFICATION OF THE PROCESS OF HEAP LEACHING OF GOLD USING VARIOUS REAGENTS AND VARIOUS PHYSICAL AND CHEMICAL METHODS»,

submitted for the degree of Doctor of Philosophy (PhD)

in the specialty 6D070900 – «Metallurgy»

YESSENGARAYEV YERLAN KAIRATOVICH

The purpose of the dissertation research.

The purpose of the dissertation is to scientifically substantiate the intensification of the process of heap leaching of gold through the use of hydrogen peroxide and sodium acetate to increase the rate of dissolution and extraction of gold from oxidized low-sulfide ores of the Sari Gunay deposit.

Objectives of the study.

The tasks presented below and solved in this dissertation work are logically related to the rest and are aimed at achieving the overall goal of the research:

- to conduct a technological assessment of the initial gold-bearing ore of the Sari Gunay deposit and the feasibility of its processing by heap leaching;
- to conduct a patent-information search and analysis of the literature on the possible use of various chemical reagents that intensify the process of gold leaching;
- to conduct thermodynamic analysis of possible reactions, justify the choice of hydrogen peroxide and sodium acetate for oxidation of sulfides and dissolution of insoluble compounds;
- to study the method of ore processing and the kinetics of the influence of reagents on the process of heap leaching of gold;
- to study the conditions for heaping gold leaching;
- to study the technology of processing of low-sulfide gold-containing ore using hydrogen peroxide and sodium acetate;
- to conduct laboratory tests in an agitator apparatus for bottle, ultrasonic tests and in a column test of an enlarged laboratory analogue of heap leaching, simulating industrial installations;
- to perform an economic assessment of the use of new reagents in gold recovery technology.

Research methods.

The main methods of research and analysis used in the performance of dissertation work include:

- calculation of thermodynamic characteristics of possible reactions of interaction of hydrogen peroxide and sodium acetate with passivating compounds and sulfide minerals of gold-containing ore, carried out using the HSC Chemistry 8.0 thermodynamic calculation program of Outokumpu Technology Engineering Research;

– chemical analysis of the elemental composition of samples and productive solutions, performed using atomic absorption spectrometry on the instrument model Kvant-M (Russia), atomic emission spectrometer with inductively coupled plasma Plasma Quant 9000 (Analytik Jena, Germany) and assay-gravimetric method;

– X-ray diffractometric analysis of average samples performed on a DRON-4 diffractometer with Cu-radiation and a graphite monochromator;

– monitoring of the air environment, carried out in automatic mode with the help of a hydrocyanic acid alarm device SSK-4;

– the pH of the medium was measured using the Inolab "pH-7110" ionomer for routine measurements with reproducible measurement results and increased measurement accuracy.

All studies were carried out in accredited laboratories using various instruments and measuring instruments that have passed the state metrological verification.

Main provisions to be defended.

The following provisions are submitted for the defense of the dissertation work:

– the results of the analysis of literature data and patent information search, the substantiation of the possibility of using such reagents as hydrogen peroxide and sodium acetate as a reagent for oxidation and dissolution of sulfide minerals, and ultrasonic exposure to intensify the leaching process;

– results of thermodynamic analysis of the possibility of using hydrogen peroxide and sodium acetate in cyanide leaching of gold-containing raw materials;

– results of kinetic studies of the process of cyanide leaching of gold in the presence of hydrogen peroxide and sodium acetate;

– the results of bottle tests carried out with the use of various reagents and the simultaneous imposition of ultrasonic exposure;

– results of enlarged laboratory studies on heap leaching of gold using hydrogen peroxide and sodium acetate.

Description of the main results of the study.

The paper reveals the possibility of using sodium acetate as a solvent for sulfide minerals in an alkaline oxidizing environment. This is explained by the reactions of oxidation of sulfide minerals with hydrogen peroxide and interaction with sodium acetate. This eliminates the passivation of the surface of gold - sodium acetate reacting with minerals leads to the formation of soluble metal acetates (iron, lead, etc.). Oxidation of sulfides with hydrogen peroxide and dissolution of minerals blocking the surface of gold particles leads to intensification of gold leaching with sodium cyanide.

Justification of the novelty and importance of the results obtained.

The novelty of the topic lies in the development of technology for intensifying the process of cyanide heap leaching of gold using hydrogen peroxide and sodium acetate.

The main results obtained are:

1. Bottle tests have been carried out proving the possibility of using hydrogen peroxide to intensify the process of gold recovery during cyanide leaching of ore with a size of $-12+0$ mm or more. To eliminate the destruction of sodium cyanide and intensify the leaching process, pre-treatment of the ore with a solution of hydrogen peroxide (0.5%) is necessary.

2. For the first time in bottle tests, it was revealed that the addition of sodium acetate to the leaching cyanide solution intensifies the leaching process and increases gold recovery.

3. For the first time in bottle tests, the effect of ultrasonic exposure on gold recovery indicators was investigated. Thus, with ultrasonic exposure lasting 6 hours with the addition of sodium acetate, the degree of gold recovery increases by 2.96%, and when treated with hydrogen peroxide - by 0.97%, compared with tests conducted without the addition of reagents.

4. Studies on a column installation simulating heap leaching conditions have established that the use of sodium acetate in an amount of 0.5 kg/t intensifies the leaching process of gold-containing ore, while the extraction of gold from the ore increases by 4%.

The paper reveals the possibility of using sodium acetate and hydrogen peroxide as a solvent for sulfide minerals in an alkaline oxidative environment. This is due to the course of oxidation reactions of sulfide minerals with hydrogen peroxide and interaction with sodium acetate. Sodium acetate reacting with ore minerals leads to the formation of soluble metal acetates (iron, lead, etc.), which eliminates the passivation of the surface of gold. Oxidation of sulfides and dissolution minerals blocking the surface of gold particles with hydrogen peroxide leads to intensification of gold leaching with sodium cyanide.

Compliance with the directions of development of science or state programs.

Research work was carried out in accordance with international research projects noted in the Strategy Kazakhstan-2050, and plans for research work of the department «Metallurgy and mineral processing» of the Satbayev University. Dissertation work was carried out at the department «Metallurgy and mineral processing», also in the laboratory Zarkuh mining company of the Islamic Republic of Iran (a joint Kazakh Eurasia metals company) and in the laboratory of precious metals of the Branch of the RSE National Center on Complex Processing of Mineral Raw Materials of the Republic of Kazakhstan, Kazmekhanobr State Scientific Production Association of Industrial Ecology.

Description of the doctoral student's contribution to the preparation of each publication.

The personal participation of the doctoral student consists in direct participation at all stages of work:

- setting research objectives and specific objectives on the research topic;
- thermodynamic analysis of possible reactions of the interaction of sodium acetate and hydrogen peroxide with passivating compounds and sulfide minerals;
- preparation of materials and samples for experiments, analysis of starting materials and obtained products;
- conducting experiments on the topic of research, processing and analysis of the data obtained;
- writing articles on the topic of dissertation;
- generalization of research results, formulation of conclusions and scientific novelty.

According to the results of the dissertation work, 8 printed works were published, including:

- one article in a publication with a non-zero impact factor included in the scientometric database Scopus;
- three articles in journals recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan.

The main provisions and results are published in the proceedings and proceedings of international conferences:

- International Scientific and Practical Conference "Intensification of hydrometallurgical processes of processing of natural and man-made raw materials. Technologies and Equipment", St. Petersburg, Russia, 2018.
- International Scientific and Practical Conference "Rational Use of Mineral and Man-Made Raw Materials in the Conditions of Industry 4.0", Almaty, 2019.
- International Scientific and Practical Conference "Innovations in Integrated Processing of Mineral Raw Materials", Almaty, 2018.

Based on the results of the research, a patent for a utility model of the Republic of Kazakhstan was obtained.

Structure and scope of the dissertation. The thesis consists of an introduction, 5 chapters, a conclusion and annexes. The work is presented on 111 pages of typewritten text, contains 26 tables and 43 figures. The list of sources used includes 121 titles.