INVESTIGATION OF THE PROCESS OF GETTING GOLD AND SILVER FROM ORES FROMDIFFERENT MINES

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Abstract - In this paper we analyze the process of getting gold and silver from a mixture of ores from different sources. Overall, a mechanism for extracting the precious metals is suggested along with the most optimal modes. The mechanism is made up from the following processes: cheek and conical crashing of extracted ore – averaging size of crushed ore – crushing averaged ore in round mills to make it smaller, decomposition of crushed ore with cyanide solution - gold and silver carbon adsorption, desorption and electrolysis. Final result is a 999.9-degree gold sol. with 99.9% purity.

Keywords - Gold, Silver, Crushing, Adsorption, Desorption, Electrolyzes

I. INTRODUCTION

Of the noble metals, gold and silver are chemically stable, hard-to-grasp, chiseled, charming exterior metals. Since ancient times, people used these noble metals. That was due to the valuable characteristics of gold and silver. These metals do not lose their shine in the air, do not corrode, do not dissolve even in dense solutions of acids. And because endurance and perseverance have always been attributes of honesty, people have called gold and silver noble metals.

Gold and silver extraction are usually not separated from each other because silver accompanies gold throughout whole technological cycle to bring it to metal state. For this reason, their metallurgy is often called - gold metallurgy.

Traditionally, gold and silver, like many other metals, were extracted using pyrometallurgical methods. Those methods had several considerable disadvantages: they caused air pollution, water and land contamination and they resulted in sizable losses of gold and silver. Partly, because of those disadvantages new methods of gold extraction has been introduced throughout history and that method is hydrometallurgy.

Throughout this paper a method for extracting gold and silver from different ores has been introduced. According to experimental data the method allows to extract 999.9-degree gold sol. with 99.9%.

II. DESCRIPTION OF GOLDS AND SILVERS PROCESSING METHOD

The following method has been developed for extracting gold and silver from ores “cheek and conical crashing of extracted ore – averaging size of crushed ore – crushing averaged ore in round mills to make it smaller, decomposition of crushed ore with cyanide solution - gold and silver carbon adsorption, desorption and electrolysis”. Figure 1 presents the scheme of developed method.

III. CRUSHING OF ORE

Crushing of ores is required because as a rule of thumb, minerals extracted in gold mines are disproportional. Due to regular movements of rich sites of ore, they mix with poor sites and empty minerals. As a result, even minerals extracted from the same mine have variable chemistry and mineral composition. Therefore, if there is a significant difference in their composition, it is appropriate, even mandatory, for ores processed with cheek and conical crushers be averaged prior to recycling, especially if the ore has been shipped from different mines. The process of averaging is organized by mixing certain weights of crushed ore, using equipment designed for it (bridge cranes, scales, graders and bulldozers, etc.). Figure 1 represents the averaging scheme1 – stack, 2 – composition of stacks 3 – stack mechanisms

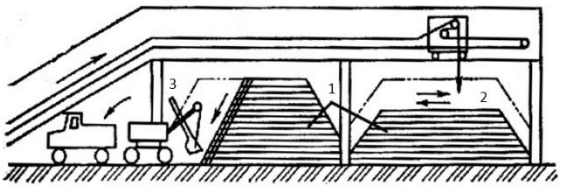


Fig.1. scheme of averaging ores of different components.

Mediation is the displacement and rearrangement of large ore masses for mixing them, usually carried out in stacks of up to 100,000 tons (1). Shaping is done with thin parallel layers of sloping or horizontally arranged material (2). Material damming is done in layers as well, however perpendicular to composed layers of stacks. Each unit size of materials

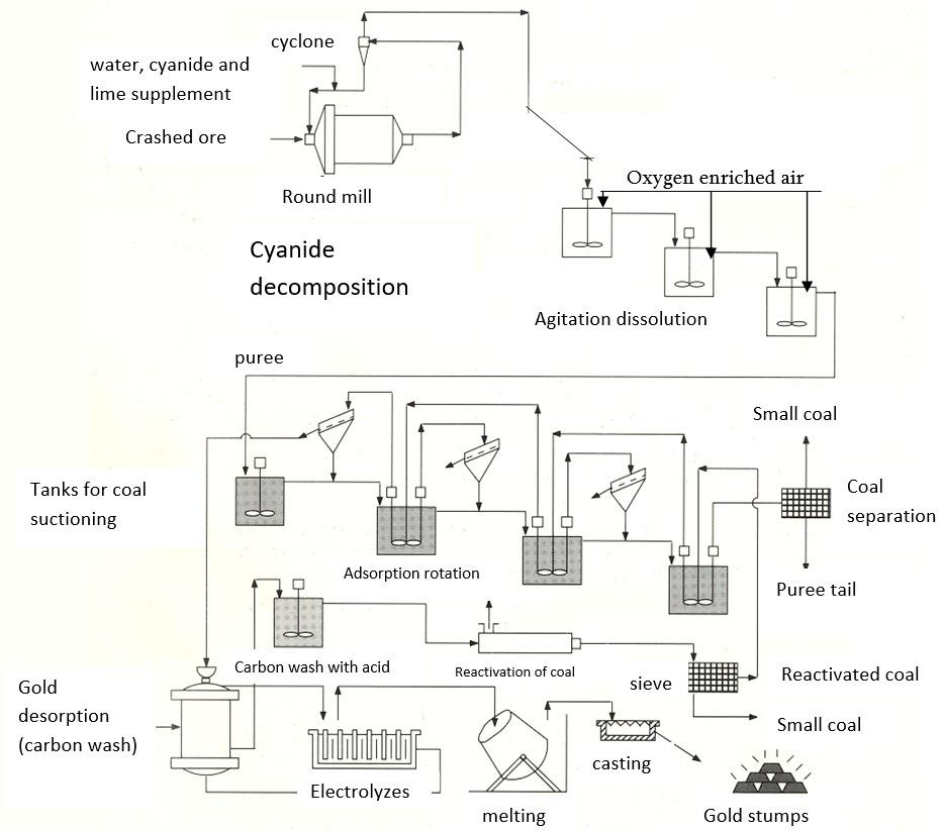


Fig. 2. Scheme for getting gold and silver from ores of different mines

damming, including all formed layers, corresponds to the average composition of the material in the stack. Averaging reservoir has at least two stacks, one in which formation is carried out and the second one from where removal to metallurgical processing site is done.

IV. CYANIDE DECOMPOSITION OF ORE

Dissolution reactions in the cyanide solution are superficial in nature.Major interactions occur between surface of gold metal and cationic particles, free cyanide ions carrying a negative charge (Figure 3).

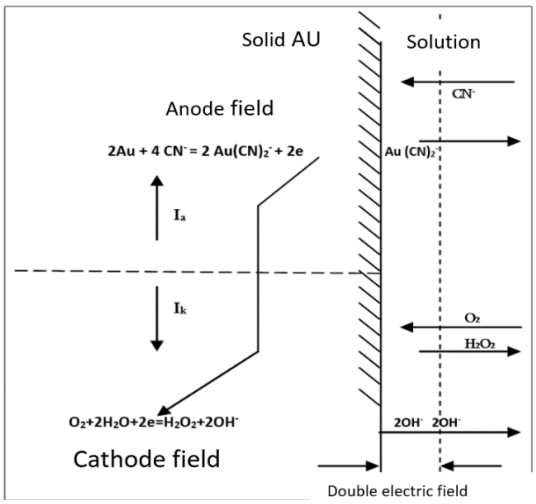


Fig.3:Ion scheme of gold decomposition in cyanide solution

Anode reactions: In basic cyanide solutions, gold is oxidized and dissolved to form Au(I) cyanide complex $Au(CN)2^{-}$.Au(III) complexes also occur in $Au(CN)_4^-$ but Au(I) complexes are more stable than Au (III) complexes.That is why the stoichiometric reaction of the gold solution is as follows

$$Au(CN)_2^- + e = Au + 2CN^-$$

For the above reaction Nernsts equation has following look

$$E = -0{,}6 + 0{,}118pCN + 0{,}059\log a_{Au(CN)_2^-}$$

Cathode reactions: The anode reaction of gold solution in fused basic cyanide solutions is accompanied by a cathodic oxygen recovery reaction. According, to experimental data it is

$$O_2 + 2H^+ + 2e = H_2O_2$$
$$E = -0{,}69 - 0{,}059\log pH - 0{,}295pO_2$$

Hydrogen peroxide is a strong oxidizer that can participate in further oxidation reactions:

$$H_2O_2 + 2e = 2OH; E_0 = 0{,}88V$$

In alkaline cyanide solutions previously exposed to aerosolization, the complete reaction of gold decomposition becomes more accurate by adding the following parallel reactions.

$$2Au + 4CN^- + O_2 + 2H_2O = 2Au(CN)_2^- + H_2O_2 + 2OH^-$$
$$2Au + 4CN^- + H_2O_2 \rightleftarrows 2Au(CN)_2^- + 2OH^-$$

And the sum reaction is the following

$$4Au + 8CN + O_2 + 2H_2O = 4Au(CN)_2^- + 4OH^-$$

The rate of reaction of gold decomposition depends on the concentration of oxygen and cyanide, temperature and pH of solution, forms of gold present, intensity of mixing and presence of other ions in the solution.Cyanide concentration is relatively easy to regulate by adding a concentrated solution or a crystalline cyanide.Oxidant concentration regulation is difficult due to low solubility in water under atmospheric pressure. Therefore, the maximum dissolution rate of gold is determined by the temperature and pressure under which the process is carried out.Experimental data show that the dissolved oxygen concentration at sea level and 25^0C is 8.2 mg/l.This concentration corresponds to approximately 0.005% CN, that is 0.01% NaCN, to ensure maximum gold extraction.In practice, the maximum gold decomposition rate is 0.03 mg/h, which is reached at 0.02% in the case of NaCN, and for silver that rate is 0.015 mg/h.The dissolution rate of gold increases with increasing temperature. This is explained by the increased diffusion activity of the interacting particles. The maximum gold recovery rate is observed at 85 °C.Above this temperature, the solubility of oxygen decreases, which negatively affects the decomposition of gold. In practice, only 20-25% of the solubility of gold increases, so it is raised to 85^0C. The best pH index is in the range of 9-9.5, in which case gold oxidation and oxygen recovery are sufficient. Typical processes are carried out at pH = 9.4.

Interaction surface of gold is directly proportional to the dissolution rate. It can be augmented by oxidizing processing prior to cyanidation. Decomposition of gold is a process that is regulated by bulking, so its velocity depends on thickness of diffusion layer and mixing characteristics of the solution.

The thickness of diffusion layer decreases to a minimum at the highest value for solid particle movement speed. In practice, it is performed by mechanical mixing or by air.Some divalent cations can have a significant effect on the rate of gold dissolution. Traces of Pb-Ç, Hg-Ç, Ti-Ç, Bi-Çdepolarize the gold surface and stop or slow the passivating effect observed at the polarization curve of 0.4V. When there is no Pb, Hg, Ti, Bi in the ores, soluble salts of Pb are added to increase the rate of gold dissolution.

Saturated oxygen concentration at 25°C is 8.2 mg/l. For such an oxygen concentration, the cyanide concentration for the maximum gold dissolution rate is 0.005% or 0.002M CN^-.Increasing the temperature increases the rate of dissolution of gold. In the case of the 85^oC it is highest.

For pH values 9 to 9.5, the dissolution rate is highest. The dissolution time depends on the temperature.For 30-45^0C it takes 7.5 - 8 hours.Most favorable conditions for gold decomposition in cyanide concentrate are: solution temperature: 85 - 95^0C, acidity index: pH = 9.0-9.5, NaCN concentration> 0.1%, stirring duration: 5-10 hours, oxygen quantity greater than stoichiometry.

V. GOLD ADSORBTION ON ACTIVATED CARBON

Activated carbon is similar to graphite in its microstructure. It consists of two base structures: small spaces of elementary crystals, composed of atoms arranged approximately parallel to each other and a cross-linked network of irregularly arranged hexagonal crystals, more clearly expressed in activated carbon formed from high oxygen content materials.

The particle sizes of activated carbon range from 0.9-1.2nm in height and 2-2.3nm in width. Micronutrient sizes are maximum 100-200 nm and the smallest is 1.6nm.res of 0.6-1.6nm are also found. Adsorption properties of activated carbon are due to both its chemical and physical properties.Chemically bonded oxygen interacts with aquatic molecules by following reactions:

$$O_2 + 4H_2O + 4e = 2H_2O + 4OH^-$$
$$O + 2H_2O + 2e = H_2O + 2OH^-$$

where O is the chemically bonded oxygen on the oxidized surface of the carbon and H_2O is the hydrogen group.

Surface effects are due to the adsorption capacity of carbon, whereby gold can sit on activated carbon surface by the following mechanismsadsorption as cyanide ion of Au (I),adsorption as a molecular AuCN,recovery and adsorption as metal Au,adsorption by merging with any metal cation. Decomposition solutions typically contain, in addition to gold, Ag, Cu, Ni, Zn, Fe, and Hg, which can also be adsorbed on activated carbon. Of these, copper and mercury can contaminate the final product.

Fortunately, activated charcoal is capable of selectively adsorbing metal ions. The probability of adsorption of cyanide complexes is determined by the following comparative series

$$Au(CN0 > Hg(CN) > Ag(CN) > Cu(CN) > Zn(CN) > Ni(CN) > Fe(CN)$$

VI. GOLD DESORPTION ON ACTIVATED CARBON

The process of separation of gold from gold-loaded activated carbon in the gold adsorption process is

desorption, that is, golds removal from the surface of the coal, which results in a small volume but high gold content from which gold can be easily extracted through cementation and electrolyzes. Unloaded coal is then returned to the adsorption cycle after reactivation to repeat the technological cycle. It should be noticed that coal is used in 100 to 400 adsorption-desorption cycles depending on its quality and effectiveness of the reactivation process. Golds desorption process is represented by the following reaction

$$M^{n+}[Au(CN)_2^-]n(ads) \Leftrightarrow nAu(CN)_2^- + M^{n+}$$

Where $M^{n+}$is the metal ion that is attached to the gold cyanide complex, more often Ca^{2+}.
And since desorption is the reverse reaction of adsorption, then all the physical and chemical factors that hinder adsorption process generally contribute to desorption.

Solutions temperature is the most important factor for accelerating the gold desorption process. Thus, at 180°C the desorption rate is about 8 times higher than at 90°C.It also reduces unloading time. However, at temperatures above 100^0C, high atmospheric pressure is required to maintain fluid environment.

The rate of desorption can be significantly increased by adding organic solvents, including alcohols, acetone and glycols to aqueous solutions.
They increase the activity of other ions in the solution, in particular the activity of smaller cyanide ions against larger ions, such as gold cyanide.This increases the effectiveness of unloading gold from activated carbon.

Among alcohols, ethanol, methanol and isopropanol can be used whose addition in solution by 15-25% will reduce loading time by a factor from 3 to 4.However, alcohols have a high risk of making fire, so it is more convenient to use low-efficiency (about half) glycols, such as ethylene and propylene glycols, at the same concentrations as alcohols. Acetonitrile, acetone and DMF solvents are also used.

The dissolution rate is usually expressed as the number of weights worked out per hour. It refers to the rotation of solvent flow or how many times it passes through given fraction in an hour. The greater is the number, the less residual gold is remained on the processed carbon. Practically at a speed of 5-6 revolutions per hour, the coal is completely unloaded, and gold is completely passed into eluate.
As the concentration of gold in the solution increases, the dissolution rate decreases, and the amount of residual gold on the coal increases.This is a very important factor that directly affects the rate of metal extraction. It also affects the efficiency of the subsequent electrocution or zinc deposition process.

VII. GOLD EXTRACTION THROUGH ELECTROLYSIS

In practice, cathode deposition of gold from rich eluates occurs at –1.0… –1.1 volts. Silver precipitates with gold as its equilibrium reaction potential is -0.45 V.
In case of forced electrolyte delivery, deposition rate of metals present will depend on mass transport rate of charged particles on cathode surface.According to practical data, under these conditions the recovery of gold $Au(CN)_2^-$ complexes from alkaline cyanide solution starts at -1,056V potential, silver complexes at -0.656V and hydrogen cations at-0.956V potentials.
Potential values for thin-wire steel cathodes, now widely used in cyanide gold electrification practice, should increase in positive potentials from their edge to center. Data is represented in figure 4.
When potential is already -0.756 W or higher, gold recovery and sedimentation do not occur practically. In these conditions, silver can be restored to the cathode.It follows that cathode width must be equal to distance at which mass transport is controlled to effectively accommodate metal. Obviously, this distance depends on the conductivity of electrolyte. Latter can be increased by the following ways:with rising temperatures,by increasing ion density,by increasing volume of pores in the cathode body,by increasing degree of curvature in the cathode body.

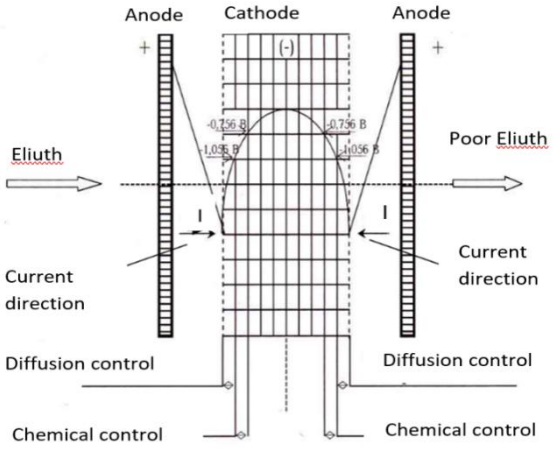


Fig.4:Scheme of potential distribution over three-d dimensional cathode bath

In this respect, cathode blocks made of stainless-steel thin wire with more than 90% total porosity are more suitable for electrolysis of relatively rich ionic solutions.
It is important to choose the flow direction of the electrolysis cell. When the flow direction isparallel to the electric current (as shown in the figure), transition of charged particles through the cathode axis is excluded, where values of negative potential are very low and therefore insufficient for cathode gold recovery.The cathode recovery of gold and silver is accompanied by a reaction of hydrogen

depletion$2H_2O + 2e = H_2 + 2OH^-, E^o = -0.828V$.whose speed is not controlled by mass transport. In addition, the water dissolved in the cathode also restores oxygen:$O_2 + 2H_2O + 4e = 4OH^- E^o = -0.410V$.the presence of which in flow is due to anode of the water oxidation reaction.

Amount of current consumed by hydrogen recovery reaction does not depend on mass transport rate of charged particles and is of a certain magnitude. And the amount of current consumed on oxygens reaction, on the reverse, depends on currents speed and therefore, on the speed of recovery reaction of gold and silver. And given that more than 50% of cathode current is actually spent on oxygen recovery reaction, it becomes apparent that increasing the rate of extraction dramatically reduces the efficiency of the current.According to research, the optimum electrolyte flow rate for baths with three-dimensional cathodes is found to be 150 - 200 l/min.Cathode current density is about 40 A/m^2, the cell voltage is 2 - 5V. In terms of electricity, the output of metal varies between 5 and 12% depending on structure of bath.

According to experimental data, cathode sediment is a powdered Dore alloy containing ≈ 44.5% and ≈ 55.5%, by melting which in induction electric furnace and electrodeposition 999.9-degree gold sol. with 99.9% puritycan be obtained in the first phase.

VIII. CONCLUSION

Multiple conclusions have been reached in the paper. Firstly, extraction of gold and silver from average oxidized quartz ore of different mines can be accomplished by a more efficient technological cycle through its cyanide dissolution, concentration of dissolution, and then by a three-dimensional electrolytic doped bath. Secondly, optimal modes of gold decomposition in cyanide lubrication are: solutions temperature 85-95^{o}C, acidity pH = 9-9.5, concentration of NaCN > 0.1%, mixing duration 5-10 hours.

Thirdly, during electrolyzes phase optimal regimes are cathode currents density 40A/m^2, cell voltage 2-5 V.And finally, cathode sediment is a powdered Dore alloy containing ≈ 44.5% and ≈ 55.5%, by melting which in induction electric furnace and electrodeposition 999.9-degree gold sol. with 99.9% puritycan be obtained in the first phase

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