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PHYSICOCHEMICAL FOUNDATIONS OF THE CYANIDE PROCESS OF RARE METALS, GOLD AND SILVER AWKWARD STRUCTURE

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Annotation. This article presents the physicochemical foundations of the process of cyanining of ores for storing rare metals (gold and silver). Basic reactions of the process, the role of oxygen and cyanide ions, diffusion mechanisms, influence of temperature, concentration and ore composition are consulted. The electrochemical nature of cyanization, the formation of complex ions of gold and silver as well as difficulties in real industrial conditions (e.g. turbid ores, additional elements) are analyzed. The article suggests ways to improve the efficiency of the process, based on scientific experience and industry practice.

Keywords. Cyanidation process, gold and silver ores, physical and chemical foundations, electrochemical reactions, oxygen diffusion, complex ions, ore beneficiation, diffusion coefficient, temperature effect, turbid ores, tellurium and mercury additives, industrial technology.

One of the main methods for extraction of gold particles of smaller sizes is the cyanence process. The basic essence of the cyanide process is the smelting of rare metals using salts and oxygen formed by alkaline and alkaline earth metals.

In the process of cyanization, gold and silver are oxidized to Me^{+1} with the help of oxygen and pass into the solution as a complex anion (Fig.1). The overall chemical appearance of the process goes through the following 2 consecutive reactions:

$$2Me + 4CN^- + O_2 + 2\,H_2O = 2[Me(CN)_2]^- + 2OH^- + H_2O_2$$

$$2Me + 4CN^- + H_2O_2 = 2[Me(CN)_2]^- + 2OH^-$$

With gold, the first reaction often takes place, namely:

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

And for silver, the second reaction goes:

$$4Ag + 8CN^- + O_2 + 2H_2O = 4\,Ag[(CN)_2]^- + 4OH^-$$

Cyanence process is an electrochemical process. The main reason for the melting of gold is its formation of a complex ion $Au(CN)_2$ ($Ag(CN)_2$ for silver). Gold and silver have very high free energy which can form a complex ion in participation of cyan solutions. The free energy of formation of the $Au(CN)_2$ ion is ~277,875 kDj, while for silver, $Ag(CN)_2$ is ~289,100 kDj. Gold complex is formed due to the diffusion of cyan ions on a metal surface. They compress water

molecules and interact with the metal and as a result a golden anion complex is formed, and the gold is transferred to the solution:

$Au + 2CN^- = Au(CN)^{2-} + e$

Thus, the loss of the gold ion is explained by the release of the valent electron, the donation of electrons of gold, which forms a galvanic current in the microelement and turns into an anode. In the cathode section, oxygen returns and as a result a certain amount of hydrogen peroxide is formed.

$O_2 + 2H_2O + 4e = 4OH^-$, $\varphi = + 0{,}4B$

$O_2 + 2H_2O + 2e = H_2O_2 + 2OH^-$, $\varphi = - 0{,}15$ B

Among the reactions mentioned above, the slower one is the return of oxygen. With the help of silver, this process is also accelerated. The essence of this process is that oxygen in the form of a molecule is broken down (dissociated) and passes through atoms. Oxygen in its atomic state reacts with silver to form an oxide membrane. As a result, silver accelerates the dissociation of oxygen molecules and leads to the formation of hydrooxide ions.

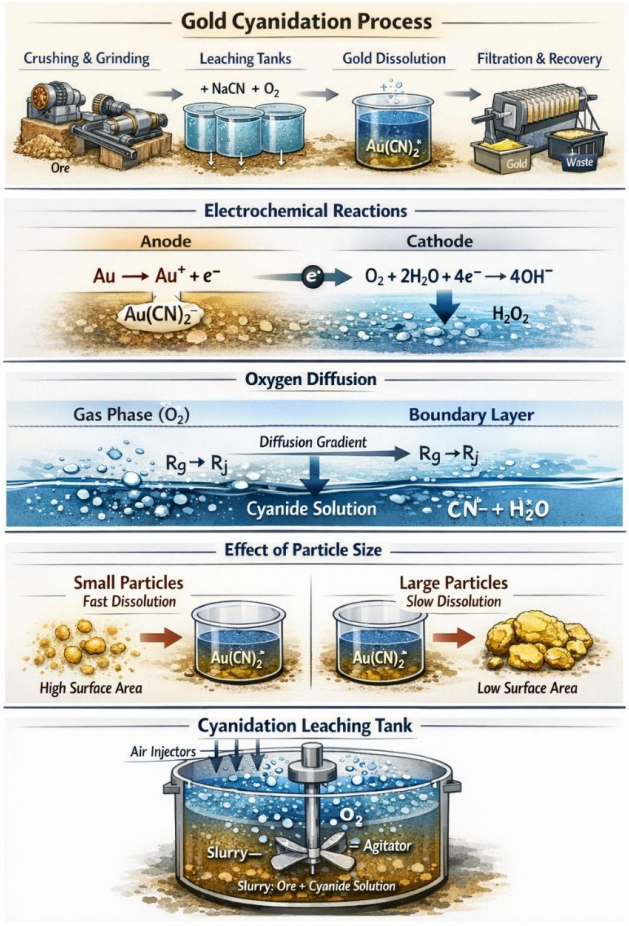


Figure 1. General technological scheme of the gold cyanidation process.

A solution of 0.02-0.05% of cyanide solution is used in the cyanide process. Gold without a complex dissolves and penetrates into solution, one of the main components of which is oxygen. It is also possible to use other oxidants instead of oxygen. For example: sodium peroxide, barium peroxide, and ozone.

Any reduction in one of the substances described above will lead to a slowing down of the process. Excess concentration of oxygen and cyanide gives a negative result, since the solution of oxygen and cyanide will dissolve the additional metals contained in the solution, which makes gold extraction difficult. The cylication process is carried out at conducting temperature 20-45$^{\circ C}$ °C. At higher temperatures, evaporation of cyanide substance occurs.

The diffusion of oxygen towards dissolving a metal is primarily due to the transition of the diffusion from the gaseous state to the liquid state. It is a boundary between gas and liquid phases, this boundary consists of 2 layers - gas and liquid, which resists the transfer of gas into the solution. 1 layer of diffusion occurs due to the concentration difference of the two lateral layers. The diffusion of the liquid boundary layer is due to the concentration difference at the surface of the gases, being out of the boundary layer where the entire mass of the liquid is. The transition of a gas from a gaseous state to a liquid state justifies the first stage of the melting of a gas in a liquid. This state change depends on the membrane resistance of the boundary layer and the diffusion rate. The dissolution of oxygen manifests itself in the form of a difficult soluble gas The resistance is determined in the liquid boundary layer.

The dissolution of oxygen in water or weak sian salts causes the motive force to diffusion of the gas in the boundary layer, to which it is proportional to the difference in concentration of oxygen at the gas and liquid surfaces on the basis of:

$R_D = K_g(R_g - R_j)$,

wherein K_g is the diffusion coefficient of the gas layer; R_D is the gas concentration in the gas phase, or the partial pressure of the gas, at; R_j is the oxygen concentration in the gas boundary layer, or the partial pressure of oxygen, at.

The diffusion caller of the liquid fluid related to the same force,

$R_D = K_j(C_g - C_j)$,

wherein K_j is the diffusion coefficient of the liquid layer membrane; C_g – the concentration of dissolved oxygen at the boundary of the liquid layer, g/cm^3; C_j is also in the fluid phase.

When the motive force of the diffusion is rten in the gas-liquid boundary layer, then $R_g - R_j$, or

$Kg(R_g - R_j) = R_D = K_j(C_g - C_j)$.

We look at the conditions under which oxygen is absorbed from the air into water at 18°C and the total pressure is 1°C. Saturation of water with oxygen, the concentration of pure oxygen in the atmosphere is equal to 0.0000457 g/sm^3 in the final solution. The concentration of oxygen without Shubha can be from 0.0000457 g/cm^3 to 0.

If the total air pressure is equal to 1 at, the portial pressure of oxygen is equal to 0.2096at. We conditionally assume $K_g = K_j$, and get:

$R_j = 0.2096 - (C_g - C_j)$

By focusing more on the value (C_g- C_j), it can reach 0.0000457, we can assume the value of R_g as equal to the value of R_j. Thus, the deciding factor for the concentration of oxygen in the solution is considered pressure, and according to Henry's law (C_j= kP), the concentration of oxygen is directly proportional to its porsional pressure in the atmosphere.

Each of these processes has its own individual velocity, and in turn, each is the lowest moving reaction, determining the course of the process and can be considered decisive in gold in general.

I.A. Kakovsky and Yu.B. With the rotary disc method, Holmansky studied the melting rate of silver under various variables—precipitation and oxygen concentrations—and temperature variations. In the experiment, where the disc surface (R=2.0cm.) was kept unchanged, the change in sinic concentration was not taken into account because it was small, the kinetic curves would consist of a regular function.

Smelting gold in hydrochloric salts in industrial conditions is extremely difficult. The form of the gold metal used in the experiment will only be under experimental conditions. Hydrocyanine solutions used in real conditions are not clean, there are various additives in them that have a great effect on reactions. Under real conditions, too many minerals are involved in the solution, influencing processes. But in any case, scientific experiments confirm that the melting process is a diffusion process. Therefore, based on scientific experience, diffusion can be considered as an efficient progress, the efficient course of the gold melting process.

At the same time, it is necessary to ensure a reliable course of diffusion of dissolved oxygen. For the most favorable conditions, the diffusion rate of the CN and O_2 needs to be doubled.

Excessive increase of cynyl CN concentration does not increase the dissolving process. Experiments show that when the portial pressure of oxygen is 0.21 atm., the limited concentration of saline solution should be 0.02-0.1%. These magnitudes correspond to the indicators of gold-sorting factories and plants. If it is easy to capture the omicron concentration of saline solution, then for oxygen this work is a commodity. Under natural conditions, the composition of ore used in industry can include minerals that are fast oxidizing. In this case, a small fraction of oxygen will be wasted on the course of the surrounding reactions. If the mixing of the solution is not sufficient, the oxide contained in it will be a small amount in relation to the temperature and particle pressure under the current conditions.

Having learned the melting pathways of gold and silver in the finite, its melting rate kinetics can also be controlled. It is also worth mentioning that one of the main ways to increase the efficiency of the process is by increasing the concentration of oxygen dissolved in solution. Since the dissolution of oxygen is in direct proportion to the porous pressure on the solution, it is necessary to increase the rate of melting of both cyanine and gold in the solution. The experience of scientists such as I.N. Plaksin shows that the melting rate of gold increases at a high concentration of sayanic solution, the pressure of oxygen and the melting rate. Experiments with various ores have shown that when the porous pressure of oxygen is increased, the rate at which gold melts also increases. Studies have shown that temperature increases lead to an acceleration of melting reactions. However, with an increase in temperature, other minerals in the ore also dissolve, creating various difficulties. Under increased temperature, hydrolysis occurs and ant acid is decomposed:

$CN + 2H_2O = NH_2 + HCOO$

Therefore, in factories based on this technology, they do not increase the temperature much, and in winter they try to bring it to about 15-20%.

The diffusion rate will depend on the intensity of the chemical reactions, the mineral surface area, the surface where the diffusion occurs. Therefore – the size and surface of the rare metals minerals indicate the intensity of their melting. Since the specific surface area of small particles is larger and larger than adults, their melting is faster. The full melting life of large grain particles can be 3-4 times higher than that of coarse grains. This can cause large particles to abandon the process of dissolving in hydrophenic solutions. In the milling of gold ores, the metal particles are not crushed too much, therefore, these particles are trapped by gravitation, amalgamation before grinding and smelting. Extremely fine 1-5 μm. Grinding ore particles and "opening" the surface of minerals is much more difficult work. Given the high energy consumption of electrolyte energy in the crushing of such extremely fine particulate ores, such ores are a component of unstable ores that are hard to beneficiate. The specific surface area also depends on the shape of these minerals. The gold form has a direct effect on framing melting. The sagging form surface of the same size-weight is smaller than the cube-shaped surface, and the cube is smaller than the flat-shaped surface. During the leaching melt, the surface of the metal decreases continuously, and its melting rate decreases gradually in unit of time. Sometimes the rate at which a mineral (metal) ore dissolves (vkraplennost) in its composition can also be different.

The ore particles are milled by mixing it with water in mills. The resulting viscosity (Q:S ratio) depends on its diffusion coefficient. Extremely fine micron ore particles form a muddy (slurry). And the muddy is amorphous, and the gold in it melts very poorly.

The mudflows are two-staged. The mudflows in the 1st stage are kaolinized (Al_2O_3 x $2SiO_2$ x $2H_2O$), and they form muddy ores. Another secondary type of gold ores mixed with muddies are sedimentary ores. In these ores there is a lot of yellow, which is mainly in the case of iron 3-oxide: Fe_2O_3 x nH_2O. Because of the high viscosity of these ores the rate of melting gold is slow. For this reason, such a body is dissolved in several times diluted. Botanical dilution leads to an increase in the volume and volume of machine tools and excessive consumption of reagents.

The turbidity of these ores also impairs subsequent processes: consolidation, filtration. Therefore, turbid ores are classified as hard-to-beneficiate ores. The transition of gold into the solution also depends on the ligature composition of the rare metals contained in the ore (which form, what amount, its chemical compounds, etc.) and the presence of electrically conductive minerals in it. Usually pure gold, silver companion, dissolves well in solutions of missinil. Therefore, its presence creates some difficulties in smelting gold.

Another additional element that poses a great challenge in the smelting of gold is tellurium. It greatly slows down the melting of gold. To activate the process, it is necessary to finely grind gold ore and increase the concentration of alkali in the solution. The interaction of tellurides with gold in saline solution is as follows:

$2AuTe_2 + 4CN + 6OH + 4{,}5O_2 = 2Au(CN)_2 + 4TeO_3 + 3H_2O$

If the ore contains innate pure platinum, it does not dissolve and directly passes into the waste. It melts slowly with excessive styrene, whereas it forms a hard solution with gold and silver. If the

waste of gravity and amalgamation is dissolved by sedimentation, mercury is another element in the stain. Mercury dissolved sparsely.

Alkaline metal sins used in the selective smelting of gold ores are cyanic salts and strong alkalinants (KOH, NaOH, $Ca(OH)_2$) of the hydrocyanic acid HCN, which is actually toxic. Therefore, when they are dissolved in water, they are lightly dissociated, and hydrolyzed by hydrolyzed hydrolyzed of hydrocynium ions CN, paving the way for alkali ions OH:

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