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ACETIC ACID APPLICATION AS AN ACTIVATING REAGENT IN THE INTENSIVE CYANIDATION OF GRAVITY CONCENTRATES

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Summary. The well-known technology of intensive cyanide leaching of gravity concentrates, which allows introducing part of gold into commercial products with obtaining high-purity Dore alloy, requires the use of expensive reagents and a high temperature (80 °C) leaching. The article provides studies have been carried out on the intensive leaching of gold-containing gravity concentrate in a drum-type machine at low concentrations of sodium cyanide with a new activating reagent. The acetic acid is proposed to be used as an effective activator reagent at intensive cyanidation of enriched gravity concentrate. The efficiency of cyanide leaching grains by introducing activators into the reagent system as a result of dissolving passivating films on the surface of gold grains. The studies on the intensive leaching of gold in the aggregated laboratory tests have been accomplished. The results of the aggregated laboratory tests on the intensive cyanide leaching of the gravity concentrate using acetic acid as an activating reagent have totally confirmed the data of laboratory studies.

Key words: intensive leaching, gravity concentration, activating reagent, leaching, acetic acid, gold.

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ГРАВИТАЦИЯЛЫҚ КОНЦЕНТРАТТАРДЫ ҚАРҚЫНДЫ ШАЙМАЛАУ БАРЫСЫНДА РЕАГЕНТ-БЕЛСЕНДІРГІШ РЕТІНДЕ СІРКЕ ҚЫШҚЫЛЫН ҚОЛДАНУ

Түйіндеме. Аса жоғары тазалықты Доре қорытпасын алумен тауарлық өнімге алтынның аса құнды бөлігін өткізу мүмкіншілігі бар гравитациялық концентраттарды қарқынды цианирлі шаймалау белгілі технологиясы аса қымбат реагенттерді қолдану мен жоғары шаймалау температурасын (80 °С) қажет етеді. Алтынқұрамды гравитациялық концентратты барабан типтес аппаратта жаңа реагент-белсендіргіштің қосындысымен натрий цианидінің төмен концентрациясында қарқынды шаймалау бойынша зерттеу жұмыстары жүргізілді. Байытылған гравитациялық концентратты қарқынды цианирлеуді жүргізуде тиімді реагент-белсендіргіш ретінде сірке қышқылын қолдану ұсынылып отыр. Цианидті шаймалау үрдісінің тиімділігін арттыру жүйеге реагент-белсендіргіштерді қосу нәтижесінде алтын беттігіндегі пассивтеуші қабаттың еруі арқылы жүзеге асырылады. Алтынды қарқынды шаймалау іріленген-зертханалық зерттеу жұмыстарымен іске асырылды. Гравиоконцентраттарды реагент-белсендіргіш сірке қышқылының көмегі арқылы қарқынды цианирлі шаймалау бойынша жүргізілген іріленген-зертханалық зерттеу жұмыстарының нәтижелері зертханалық зерделеу жұмыстарының мәндерін толығымен растады.
Түйін сөздер: қарқынды цианирлеу, гравитациялық концентрат, реагент-активатор, шаймалау, сірке қышқылы, алтын.

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ПРИМЕНЕНИЕ УКСУСНОЙ КИСЛОТЫ В КАЧЕСТВЕ РЕАГЕНТА-АКТИВАТОРА ПРИ ИНТЕНСИВНОМ ЦИАНИРОВАНИИ ГРАВИТАЦИОННЫХ КОНЦЕНТРАТОВ

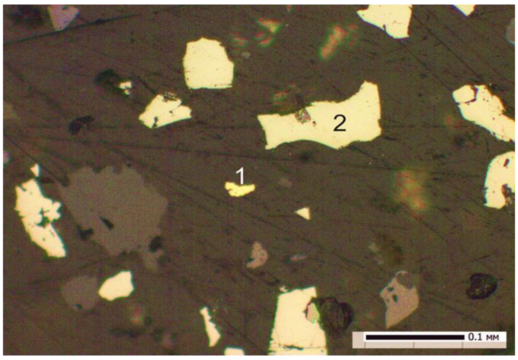
Резюме. Известная технология интенсивного цианидного выщелачивания гравитационных концентратов, позволяющая вывести часть золота в товарную продукцию с получением высокочистого сплава Доре, требует использования дорогостоящих реагентов и высокой температуры (80 °C) выщелачивания. В статье показаны проведенные исследования по интенсивному выщелачиванию золотосодержащего гравитационного концентрата в аппарате барабанного типа при пониженной концентрации цианида натрия с добавкой нового реагента-активатора. Предлагается в качестве эффективного реагента-активатора при интенсивном цианировании обогащенного гравитационного концентрата использовать уксусную кислоту. Повышение эффективности цианидного выщелачивания путем введения в систему реагентов активаторов достигается в результате растворения пассивирующих пленок на поверхности крупинок золота. Проведены исследования по интенсивному выщелачиванию золота в укрупненно-лабораторных испытаниях. Результаты укрупненно-лабораторных испытаний по интенсивному цианидному выщелачиванию гравиоконцентрата с применением в качестве реагента-активатора уксусной кислоты полностью подтвердили данные лабораторных исследований.
Ключевые слова: интенсивное выщелачивание, гравитационный концентрат, реагент-активатор, выщелачивание, уксусная кислота, золото.

Introduction. The process of intensive cyanidation is one of the effective treatments of gold containing gravity concentrates allowing reaching a high gold extraction over an appropriate process time. Within the process of intensive cyanidation the chemical additives are used as well apart from the high sodium cyanide concentrations destroying passivating films on the surface of gold grains are known. However, common activating reagents are used in the gold technology to stimulate cyanidation process contribute serious spending of sodium cyanide [1, 2].

With regard to the abovementioned, consequential and important technological challenge of gold production becomes detecting an effective activating reagent leading to the leaching process stimulation of gold out of gold containing raw material, significantly reducing the leaching process and enhancing the level of precious metal extraction into the gold containing solutions.

Experiments. The gold content in the gravity concentrate under study ranged within the limits of 77-92 g/t. Chemical analysis of gravity concentrate on the main component and sulfur showed the composition,%: Cu - 0.11; Zn - 0.025; Fe - 35.02; S total - 32.14; Sulfate. - 0.034; Sulphide. - 32,106 [3-5].

X-ray diffraction method by automatic diffractometer DRON-3 determined the concentrate composition of the following minerals, %: pyrite – 78.5, chalcopyrite - 5.5, potassium feldspar - 5.9, quartz - 10.0. Magnetite, covellin, and iron hydroxides are present in the small amounts [3-5]. Gold is in free form and dissolves well, which is consistent with the results of optical analysis (Figure 1).



1 – gold; 2 – pyrite

Figure 1 – Gravity concentrate micrograph

The process of gold dissolution is known to find difficulty by blocking the grains surface of the precious metal by sulphide ore minerals - chalcopyrite and pyrite, as well as generated compounds of their oxidation in alkaline cyanide environment [1, 6-8].

Both inorganic and organic compounds of various activating reagents are used to intensify the gold cyanidation process, by destroying insoluble films on the gold surface. The organic additives are valuable to reduce the consumption of sodium cyanide in the process of gold leaching [1, 9, 10]. Acetic acid is known to be actively interact with the metal compounds to form easily soluble acetates. It is also important that acetic acid is much cheaper

Table 1 – The results of thermodynamic calculations of probable reactions of the acetic acid interaction with the compounds passivating the gold surface

Reaction	ΔGт, kJ/mol			
	298 K	323 K	353 K	373 K
$2FeS_2+2NaOH+CH_3COOH+4{,}75O_{2(г)}=0{,}5Fe(CH_3COO)_2+Na_2SO_4+$ $+1{,}5H_2O+1{,}5S+1{,}5FeSO_4$	-1811,8	-1790,1	-1764,7	-1748,1
$2FeS_2+2NaOH+CH_3COOH+4{,}25O_{2(г)}=0{,}5Fe(CH_3COO)_2+Na_2SO_3+$ $+1{,}5H_2O+1{,}5S+1{,}5FeSO_4$	-1548,4	-1529,2	-1506,8	-1492,1
$FeS+NaOH+CH_3COOH+1{,}25O_{2(г)}=0{,}5Fe(CH_3COO)_2+0{,}5Na_2SO_4+$ $+0{,}5H_2O+0{,}5S+0{,}5Fe(OH)_2$	-543,37	-534,54	-524,48	-518,02
$1/3Fe(OH)_2+CH_3COOH+1/3NaOH=1/3Fe(CH_3COO)_2+1/3NaCH_3COO+H_2O$	-41,83	-39,64	-37,54	-36,37
$0{,}5CuFeS_2+2NaOH+CH_3COOH+1{,}5O_{2(г)}=0{,}5Fe(CH_3COO)_2+Na_2SO_3+$ $+H_2O+0{,}5Cu(OH)_2$	-594,35	-584,68	-573,64	-566,54
$0{,}25CuFeS_2+NaOH+CH_3COOH+0{,}75O_{2(г)}=0{,}25Cu(CH_3COO)_2+$ $+0{,}25Fe(CH_3COO)_2+0{,}5Na_2SO_3+H_2O$	-301,12	-294,95	-288,15	-283,89
$0{,}5CuO+CH_3COOH=0{,}5Cu(CH_3COO)_2+0{,}5H_2O$	-4,78	-1,68	1,43	3,23
$1/3Cu(OH)_2+CH_3COOH+1/3NaOH=1/3Cu(CH_3COO)_2+$ $+1/3NaCH_3COO+H_2O$	-35,73	-33,76	-31,97	-31,04

than the known activator reagents used in the industry and is an environmentally safe compound used even in the food industry [10, 11].

A thermodynamic analysis was performed of the probability of compounds dissolution that passivate the gold surface and the products of their decomposition with acetic acid solutions using the HSC Chemistry 8.0 thermodynamic calculation program of Outokumpu Technology Engineering Research in Satbayev University (table 1).

The probability of sylphide mineral films dissolution in the acetic acid in the alkaline medium with water soluble acetated salt is massive that is confirmed by the low values of Gibbs free enthalpy (below - 595 kJ/mol). The decomposition products of sulfide minerals are also able to interact with acetic acid to form soluble acetate salts.

Thus, based on the performed thermodynamic analysis, the probability of the acetic acid impact, even at room temperature, on the dissolution of compounds that passivate the gold surface was established.

A drum-type machine has been successfully used for intensive cyanidation of gravity concentrates [1, 2, 12]. The drum-type machine is distinguished by the simplicity of the device; the gills are embedded inside, intensifying the mass exchange. Laboratory and integrated laboratory tests of intensive cyanidation of gold-containing gravity concentrates were conducted.

The parameters of the laboratory facility of the drum type were as follows: the diameter of the drum was 98 mm; drum length - 214 mm; full volume - 1.6 dm^3; effective operating volume is 0.38 dm^3, the rotation speed of the agitator's drum is 4.25 rotations per minute. Arrangements for the experiments in a drum-type machine: gravity concentrate mass is 50 g; solid liquid ratio = 1:6; cyan-containing slurry volume - 0.3 dm^3; pH 10.50; NaCN - 1 g/dm^3 (0.1 %), the acetic acid consumption was maintained between 1.5 and 3.0 kg/t.

Integrated laboratory tests of intensive cyanidation of gold-containing gravity concentrates were carried out in a drum-type machine with the addition of an activating reagent under appropriate conditions. The integrated laboratory tests were carried out at the Branch office of the RSE "NC CPMS RK" State Scientific-Industrial Association of Industrial Ecology "Kazmekhanobr"

The drum-type machine for the integrated laboratory tests had the following characteristics: the drum diameter is 180 mm; drum length - 412 mm; the drum total volume is 10.48 dm^3; the effective operating volume of the drum is 3.15 dm^3; agitator's drum rotation speed - 4.5 rpm. The integrated laboratory tests conditions were as follows: gravity concentrate mass - 500 g, leach solution volume - 3 dm^3; solid liquid ratio=1:6; leaching time - 24 hours; sodium cyanide concentration - 1 g/dm^3 (0.1 %); acetic acid consumption - 1.5 kg/t. NaOH was added to maintain the required pH.

The results discussion. Table 2 provides the results of laboratory tests of intensive cyanidation of the gravity concentrate.

The data acquired say the extraction of gold from a gold-containing gravity concentrate at the equal concentrations of sodium cyanide with the addition of an activating reagent-acetic acid reached more than 95 %, and without an additive less than

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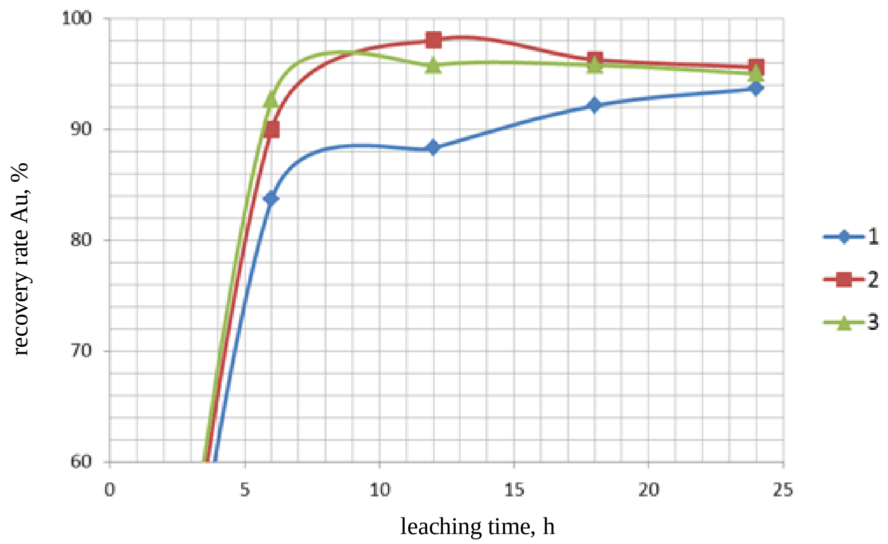
Table 2 – The results of intensive cyanidation of a gold-containing gravity concentrate in a drum-type machine

Parameters and indexes	Leaching indicators			
CH_3COOH consumption, kg/t	–	–	1,5	3,0
Au content in the liquid phase of the pulp, mg/dm^3	12,2	12,3	13,7	12,4
Au content in the solid phase of tailings, g/t	4,33	4,35	3,80	3,90
Estimated content of Au in the concentrate, g/t	77,53	78,15	86,00	78,30
Au dissolution degree, %	94,42	94,43	95,58	95,02



1 – non activating reagent ; 2 – with activating reagent 1,5 kg / t;
3 – with activating reagent 3,0 kg / t

Figure 2 - Dependence of gold extraction ratio from the gravity concentrate on the leaching process time

94.5 %. The gold content in the tails of intensive cyanidation using acetic acid is reduced to 3.80-3.90 g/t, and without the activating reagent it was 4.33-4.35 g/t.

Figure 2 provides the dependence of the gold extraction rate of the process time.

The gold is worth marking to be well intensively leaching with the activating reagent, the process time takes 12 hours until total gold dissolution, which make the process contracted twice comparing to the concentrate leaching without the reagent.

Table 3 gives the results of two tests in the integrated lab scale.

The results of the integrated laboratory tests on the intensive cyanide leaching of the gravity concentrate using acetic acid as an activating reagent were fully confirmed by the data obtained earlier in the laboratory. The gold extraction ratio was 95.53-95.79 %, the gold content in the tailings was 3.65-3.80 g/t.

Table 3 – The results of the integrated lab tests of intensive cyanidation of gravity concentrate, conducted in the drum-type machine.

Parameters and indexes	Leaching indicators	
	1st test	2nd test
Au content in the liquid phase of the pulp, mg / dm^3	14,4	13,0
Au content in the solid phase of tailings, g/t	3,80	3,65
Estimated content of Au in the concentrate, g/t	90,20	81,65
Au extraction degree,%	95,79	95,53

Conclusions. The acetic acid as an activating reagent is extensively stimulates the gold leaching process and reduces the gold loss with tailings was demonstrated by tests. The proposed method of processing gold-containing concentrates using acetic acid as an activating reagent for intensive cyanidation of gold will be of great interest for the industrial production of gold-containing concentrates.

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