ГЕОЛОГІЧНІ НАУКИ

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TECHNOLOGY OF ORE ENRICHMENT WITH THE USE OF SODIUM CYANIDE AND ITS SUBSTITUTE REAGENT JINXIN

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The degree of the extraction of gold from ores by direct cyanidation, as well as by the combined method (flotation of the initial ore and pre-extraction of gold by cyanidation of the received flotation tails). The technology of enrichment of gold-containing ores under the new flotation-cyanidation method is established. This work was carried out to determine the leaching of gold from the gold-containing ores of the «Ishtamberdy» gold deposit by the cyanidation method, with use of sodium cyanide and its substitute reagent «Jinxin» for the following types of ores: ISH-1 oxidized; ISH-2 sulfide and ISH-3 mixed. The purpose of this work is to determine the degree of gold extraction from these ores by direct cyanidation method, and also by the combined method (flotation of the initial ore and pre-extraction of gold by cyanidation from the received flotation tails). Flotation experiments were carried out according to the scheme and regime used at concentrating factory. The main industrially valuable component of all three samples is gold.
Keywords: leaching, cyanidation, flotation, oxidized ore, sulphide ore, extraction.

Introduction. LLC «Full Gold Mining» is a gold mining company founded by the Chinese state corporation «Linbao Gold» in cooperation with the «China Road and Bridge Corporation», the investment company «Lin Xi» and and the Ministry of Transport and Communications of the Kyrgyz Republic and the State Committee for Industry, Energy and Mining of the Kyrgyz Republic, conduct underground development of the «Ishtamberdy» gold deposit on the basis of a bilateral agreement, located in Ala-Buka district of Jalal-Abad region of the Kyrgyz Republic.

«Ishtamberdy» gold deposit is located on the southern slope of the Chatkal ridge in the upper part of the Kassan river valley, on the left-hand board of the Ishtamberdy river in the area of its confluence in the Kassan river.

Administratively this area belongs to Chatkal district of Jalal-Abad region of the Kyrgyz Republic.

The main indicators for the development of the «Ishtamberdy» gold deposit:

· Useful ore reserves – 2619 th. t;
· Metal reserves (gold) – 19.197 kg;
· The volume of ore after deduction of loss and dilution – 2.635 th. t;
· Metal reserves (gold) – 16.396 kg;
· Metal reserves taking into account coefficient of complex extraction – 14.146 kg.

Purpose of the study. This work was carried out to determine the leaching of gold from the gold-containing ores of the «Ishtamberdy» gold deposit by the cyanidation method, with use of sodium cyanide and its substitute reagent «Jinxin» for the following types of ores:

Sample ISH-1 – Sulfide ores
Sample ISH-2 – Oxidized ores
Sample ISH-3 – Mixed ores

Samples ISH-1 and ISH-2 were delivered to the laboratory in a worn-out form, and the ISH-3 sample was delivered from the Ishtamberdy mine in a non-crushed state. The maximum grain size of the mixed ore was 50-70 mm.

* NaCN – Sodium cyanide, – sodium salt of a cyanhydric acid. NaCN is used for extraction of precious metals (gold, silver) from ores by selective leaching.

In industry, sodium cyanide is mainly produced by neutralizing hydrocyanic acid with sodium hydroxide NaOH

$NaCN+H2O \leftrightarrow HCN+NaOH$

* Reagent «Jiansin» as substitute represents the chemical mixture consisting of: sodium cyanate, sodium chloride, sodium carbonate, sodium thiosulfate, ammonium nitrate and calcium oxide in a percentage ratio:

NaCNO : NaCl : Na2CO3 : Na2S2O3 : NH4NO3 : : CaO = 55:15:15:5:5:5

The main component of the proposed lixivating agent is sodium cyanate, i.e. sodium cyanate with a formula NaCNO.

The chemical mixture (NaCNO, Na2S2O3, NH4NO3, NaCl, Na2CO3, CaO) contains substances that support the processes of intramolecular oxidation and reduction (NaCNO, Na2S2O3), on the basis of which sodium cyanide is formed, which is the main leaching reagent in the process of gold extraction from ores.

The mechanism of reactions on the basis of the above-stated chemical mix:

$NaCNO + Na2S2O3 + 3NH4NO3 + NaCl + + Na2CO3 \rightarrow NaCN + Na2SO4 + 3NaNO3 + NH4Cl + + 2NH3\uparrow + CO2\uparrow + H2O + S\downarrow,$

This equation shows that NaCNO and Na2S2O3 undergo internal oxidation and reduction. Accordingly, products of the following type are formed: sodium cyanide, sodium sulfates and nitrates, ammonium chloride, and volatile gaseous substances – ammonia and carbon dioxide. Sulfur is precipitated.

Sodium cyanide in aqueous medium undergoes hydrolysis with the formation of hydrocyanic acid, respectively, calcium oxide in the chemical mixture plays a role of so-called «protective alkali», preventing the hydrolysis of NaCN and the release into the gas phase of highly toxic hydrogen cyanide HCN. Taking into account these provisions, the process of leaching gold from ores with reagent «Jinxin» must be carried out strictly in an alkaline condition (pH = 10.5-11) using CaO and/or NaOH.

Chemical composition of the reagent «Jiansin».

№	Name	Chemical formula	№ CAS	% of content
1	Sodium cyanate	CNNaO	917-61-3	55%
2	Sodium chloride	NaCI	7647-14-5	15%
3	Soda ash	Na 2SO3	497-19-8	15%
4	Sodium thiosulfate	Na 2S2O3	7772-98-7	5%
5	Ammonium nitrate	NH4NO3	6484-52-2	5%

The purpose of this work is to determine the degree of gold extraction from these ores by direct cyanidation method, and also by the combined method (flotation of the initial ore and pre-extraction of gold by cyanidation from the received flotation tails). Flotation experiments were carried out according to the scheme and regime used at concentrating factory.

The main industrially valuable component of all three samples is gold. Based on the results of the assay of the Central laboratory of the State committee of Industry, Energy and Mining use of the Kyrgyz Republic, on flotation products, the content of gold in the initial ore was: on the ISH-1 ore – 3.6 g/t; on the ISH-2 ore – 2,6 g/t and on the ISH-3 ore – 4,2 g/t. The content of silver in samples was determined by atomic absorption analysis: on the ISH-1 ore – 0.5 g/t; on the ISH-2 ore – 0.3 g/t and on the ISH-3 ore – 0.4 g/t.

Technology of ore enrichment with the use of sodium cyanide and its substitute reagent – Jiansin.

1. Cyanidation of ore.

Based on the results of the assay, it was found that in the initial provided samples, content of gold was: in the ISH-1 sample – 3.6 g/t; in the ISH-2 sample – 2.6 g/t and in the ISH-3 sample – 4.2 g/t.

Tests for direct cyanidation of the initial ore of all samples were carried out at a grain size of 80-82% class – 0.074 mm using a traditional reagent for leaching – sodium cyanide (NaCN) and its substitute reagent of the Chinese production, Jinxin.

Cyanidation of the initial samples was carried out:

A) at a concentration of cyanide solution NaCN = 0.05; 0.1; and 1.0 g/l;

B) at a concentration of jinxin;

in exactly the same as with sodium cyanide in the L:S = 3:1 mode (L:S – liquid-solid suspension). Cyanidation was conducted for duration of 48 hours, while in the intervals of time the kinetics of gold cyanidation was removed.

In order to make pH equal to 10.5-11.5, lime was used in the amount of 500-600 g/t. After the aeration process, sodium cyanide and jinxin in the required amount and activated carbon 15 grams per liter of pulp were added. Leaching was carried out by pulp agitation in 1 liter bottles with free air access at room temperature of 18 to 20° C for 48 hours.

The concentration of sodium cyanide, jinxin and pH of the pulp at predetermined levels were maintained throughout the leaching time.

After leaching, product was neutralized and washed from cyanide and alkali to the neutral medium through a filter and was dried. The dry residue was rubbed until the lumps disappeared, packed in marked bags, and then analyzed for gold content.

The results obtained from leaching of sulfide ore with the help of «Jinxin» reagent are shown in Figure 1.

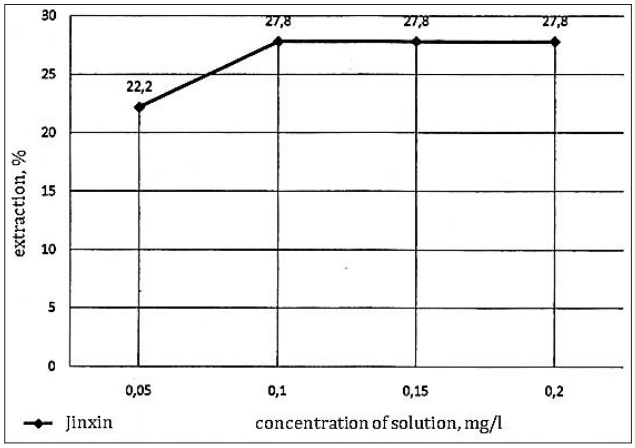

Fig. 1. Leaching of sulphide ore

On sulfide and mixed ore, direct leaching does not yield positive results, as evidenced by the results of leaching of gold, Figure 1.

At the same time, comparing the results of leaching of ores with the use of sodium cyanide and a new reagent – jinxin, it can be noted that the leaching of gold in the investigated ores is almost identical.

Thus, the use of jinxin allowed to obtain cakes of cyanide by the content of gold: on sulfide ore 2.8, 2.6 and 2.6 g/t; on oxidized ore 0.8, 0.3 and 0.3 g/t; on mixed ore 1.8, 1.4 and 1.4 g/t. The cyanidation tails with sodium cyanide were: on the ISH-1 ore – 2.8, 2.6 and 2.6 g/t; on the ISH-2 ore – 0,8, 0,3 and 0,3 g/t; on the ISH-3 ore – 1,8, 1,5 and 1,4 g/t, depending on the concentration of solutions.

* Cake is solid sediment of concentrate. In this case, the sediments formed on the tailings of the Ishtamberdy gold deposit.

Loss of gold in Cakes at a concentration of sodium cyanide and Jinxin, 48 hours.

Samples	Loss of NaCN			Loss of Jinxin		
	0,05 g/l	0,01 g/l	1,0 g/l	0,05 g/l	0,01 g/l	1,0 g/l
Ish-1 sulfide	77,8%	72,2%	72,2%	77,8%	72,2%	72,2%
Ish-2 oxidized	30,7%	10,6%	10,6%	30,7%	10,6%	10,6%
Ish-2 mixed	42,8%	38,0%	33,3%	42,8%	33,3%	33,3%

The gold content in cyanidation solutions when removing the kinetics of leaching also indicates

that cyanidation on the oxidized sample gives positive results on the leaching of gold. It is significant that with a small concentration of oxidants, cyanidation proceeds slowly, but with increasing cyanidation time, solutions in terms of gold content become richer. At a high concentration of cyanide and its substitute-jinxin, the dissolution of gold into the solution goes quite intensely, and by the end of the leaching time it slows down.

The maximum extraction of gold (89.4%) in the solution was obtained on oxidized ore (ISH-2) at 0.5 g/l and 1.0 g/l sodium cyanide and jinxin concentration. At the same time, gold losses with cyanide tails amounted to 10.6%, with a content of 0.3 g/t gold.

At the same concentration of sodium cyanide and jinxin, gold extraction on sulfide ore – ISH-1 amounted to only 27.8%, and cakes of cyanide contained 2.6 g/t gold, and gold losses with them amounted to 72.2%.

The maximum gold extraction in direct cyanidation of mixed ISH-3 ore was also obtained with a concentration of oxidants of 1.0 g/l and amounted to 66.7% (on sodium cyanide and jinxin). Gold losses in this case amounted to 33.3% with a gold content of 1.4 g/t in each cake.

2. Cyanidation of cakes. Pre-extraction of metal.

According to the above-mentioned results of laboratory studies, tailings obtained during flotation were subjected to cyanidation in order to extract gold. Cyanidation on tailings of flotation was carried out with the help of:

1) sodium cyanide;

2) new reagent (cyanide substitute) – Jinxin.

Tailings of flotation were cyanated at the initial size, which were obtained after flotation of the ore. The pulp density for cyanidation was 50% for the solid. The leaching was carried out by pulp agitation in 1 liter bottles with free air access at room temperature of 18 to 20° C with the addition of activated carbon (15 grams per liter of pulp) for 24 hours at a pH of 10.5-11.5.

Cyanidation was carried out:

A) at a concentration of cyanide solution NaCN 0.05; 0.1; and 1.0%;

B) at a concentration of jinxin, at the same concentration as with sodium cyanide.

The concentration of sodium cyanide, jinxin and the pH of the pulp were maintained at predetermined levels throughout the leaching time. At the same time, the kinetics of gold cyanidation was continuously removed in the intervals of time.

After leaching products were washed from cyanide and alkali residues through a filter, and then were dried and weighed. The dry residue was rubbed until the lumps disappeared, and then analyzed by assay method for gold content.

The results of flotation tailings cyanidation are presented in Table 1.

From the results in Table 1, it can be noted that cyanidation of flotation tailings gives positive results on gold leaching. The cyanidation of flotation tailings with a gold content of 1.5 g/t made it possible to transfer gold into the solution from the operation: a) using sodium cyanide, 33.4%, 60.0% and 66.7%; b) with the use of jinxin – 46.6%, 66.7% and 66.7% or respectively of ore: a) using sodium cyanide * 9.0%, 16.0% and 17.8%; b) using jinxin – 12.5%, 17.8% and 17.8%, depending on the concentration of oxidants.

According to the assay analysis, the gold content in cakes after leaching became:

A) with the use of sodium cyanide – 1.0; 0.6 and 0.5 g/t;

B) with the use of jinxin – 0,8; 0.5 and 0.5 g/t.

It was noted that cyanide cakes with a minimum gold content of 0.5 g/t were obtained at concentration of oxidants of 1.0 g/t. In the tailings of cyanidation, 33.4% of unleached gold or 9.0% of ore remains from the operation.

The results on the leaching of gold from tailings of flotation show that the dissolution (Table 2) of gold with the use of sodium cyanide and jinxin occurs almost identically. At the same

Table 1

Results of cyanidation of flotation tailings obtained after flotation of mixed ore

Concentration of solutions, g/l	Mixed									
	NaCN					Jinxin				
	Extraction from (%)		Content in			Extraction from (%)		Content in		
	operation	ore	cakes	Solution, h/s		operation	ore	cakes	Solution, h/s	
				hour	Mg/l				hour	Mg/l
0,05	33,4	9,0	1,0	6	0,299	46,7	12,5	0,8	6	0,324
				12	0,323				12	0,305
				18	0,365				18	0,300
				24	0,628				24	0,421
				48	0,655				48	0,466
ОД	60,0	16,0	0,6	6	0,456	66,7	17,8	0,5	6	0,412
				12	0,396				12	0,400
				18	0,278				18	0,352
				24	0,200				24	0,201
				48	0,198				48	0,188
1,0	66,7	17,8	0,5	6	0,412	66,7	17,8	0,5	6	0,456
				12	0,400				12	0,396
				18	0,352				18	0,278
				24	0,201				24	0,200
				48	0,188				48	0,198

time, cross-cutting extraction of gold on mixed ore (ISH-3) according to the flotation-cyanidation scheme was 91.1% (73.3% – by flotation and 17.8% by cyanidation).

The main indicators of technological tests from the sample of mixed ore ISH-3.

Flotation technology. Flotation of the ore was carried out with a content of 80-82% of the class – 0.074 mm in the flotation feed. The flotation was carried out in one stage, with the use of the main and control flotation, where the concentrate of control flotation is returned to the beginning of the main flotation, and the concentrate of the main flotation is the final flotation concentrate. The total flotation time is 31 minutes.

In the flotation, sodium amyl xanthate (SAX) and aeroflot were used as collectors, turpentine oil was used as a foaming agent.

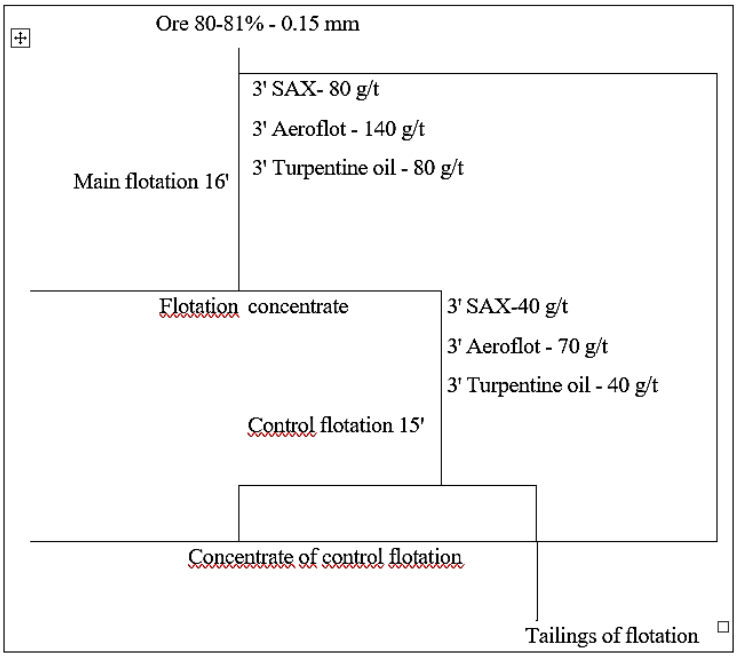

Fig. 2. Scheme and reagent flotation regime of the concentrating factory

* SAX – sodium amylic xantogenate – chemical formula – CH3CH2CH2CH2CH2OCSSNa. Sodium xanthate – amyl is a strong collector with a high selectivity, it is used as a collector reagent for the flotation of ores of heavy non-ferrous metals, and also oxide minerals, for example: gold-bearing pyrites, oxidized sulphides, copper lead ores.

Flotation experiments were carried out on weights of 1.0 kg in laboratory machines of the brand FM-1M with a capacity of 3 liters. The reagents were fed into the process in the form of aqueous solutions and emulsions with the consideration of their activity.

Before conducting the flotation tests, experiments were conducted to determine the influence of the grinding time on the yield of grade – 0.15 mm and – 0.074 mm in flotation.

To achieve grinding (80.0% of the class – 0.074 mm), a grinding time of 60 minutes is required.

Flotation tests were conducted under the following conditions:

1. content of the class – 0.074 mm in the flotation feed – 80-82%;

2. pulp density in flotation feed – 41%;

The consumption of reagents in the main and control flotation:

a. collector SAX in the amount of 80-40 g/t;

b. collector aeroflot in the amount of 140-70 g/t;

c. coaming agent – turpentine oil in the amount of 80-40 g/t.

The scheme and the reagent regime of flotation experiments are shown in Figure 2, the results of testing – in Tables 1, 2 and 3.

According to the flotation scheme in a closed loop that contains one basic and one control flotation, using the provided reagents (Fig. 2), on a mixed sample ISH-3 with a gold content of 4.2 g/t (according to assay analysis), the concentrate of the main flotation is obtained, into which 73.3%

Table 2

Name of test indicators	Units of measurement	Indicators with the use of	
		NaCN	Jinxin
Content of gold in the intial ore	g/t	4,2	4,2
Content of gold in cakes of direct cyanidation of the intial ore	g/t	1,4	1,4
Gold extraction in direct cyanidation of the intial ore	%	66,7	66,7
Yield of the concentrate	%	23,3	23,3
Content of gold in the flotation concentrate	g/t	13,7	13,7
Gold extraction during flotation	%	73,3	73,3
Content of gold in tailings of flotation	g/t	1,5	1,5
Content of gold in the cakes of cyanide tailings flotation	g/t	0,5	0,49
Gold extraction during cyanidation of flotation tailings from ore	%	17,8	17,8
Cross-cutting extraction of gold from ore according to the flotation-cyanidation scheme	%	91,1	91,1

Table 3

Name of the products	Yield %	Gold		Silver	
		Content, g/t	Extraction, %	Content, g/t	Extraction, %
Flotation concentrate of the main flotation	23,3	13,7	73,3		
Tailings of flotation	76,7	1,5.	26,7		
Ore	100	4,35	100		

of gold is extracted. Concentrate was obtained with a content of 13.7 g/t gold, and its yield was 23.3%.

Gold losses with flotation tailings amounted to 26.7%, with a gold content of 1.5 g/t (Table 3).

The results of flotation enrichment of mixed ore of sample ISH-3, according to the scheme and reagent regime of the concentrating factory In the concentrate of the main flotation 73.3% of gold was extracted. Concentrate was obtained with a content of 13.7 g/t. Flotation tailings were obtained with a gold content of 1.5 g/t and gold losses with tailings of 26.7%.

Conclusions. After laboratory studies of the use of substitute reagent «Jinxin» proposed by Chinese side LLC «Full Gold Mining» (China), to increase gold extraction on Ishtamberdy gold deposit, in laboratory tests, vital signs of gold enrichment technology of sample mixed ores (ISH-3) and analyzing the results, it can be noted that the sample of mixed ore ISH-3 of Ishtamberdy gold deposit at the applied technological scheme flotation-cyanidation with the use of reagent substitute Jinxin, we got the results of gold extraction up to 73.3% for ore, and up to 26.7% in the flotation tails (in cakes).

In connection with the above, reagent «Jinxin» shows a high degree of production performance not only for gold extraction, but also it is safe in the application of industrial safety of the mine and for the ecological environment of the Ishtamberdy gold deposit.

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ТЕХНОЛОГІЯ ЗБАГАЧЕННЯ РУД З ЗАСТОСУВАННЯМ ЦІАНІСТОГО НАТРІЮ І ЙОГО ЗАМІННИКА РЕАГЕНТУ ЦЗИНЬСИНЬ

Анотація
Визначення ступеня вилучення золота з руд за методом прямого ціанування, а так само з комбінованого методу (проведенням флотації вихідної руди і вилученням золота ціанування з отриманих хвостів флотації). Встановлена технологія збагачення золотовмісних руд при новому методі флотація – ціанування. Дана робота проводилася з метою визначення вилуговування золота з представлених золотовмісних руд родовища «Иштамберди» методом ціанування, із застосуванням ціаністого натрію і його замінника реагенту Цзиньсинь» за наступними типами руд: ІШ-1 окислений; ІШ-2 сульфідний і ІШ-3 змішаний. Метою даної роботи є визначення ступеня вилучення золота з цих руд методом прямого ціанування, а також з комбінованого методу (проведенням флотації вихідної руди і вилученням золота ціанування з отриманих хвостів флотації). Флотаційні досліди проводилися за схемою і режиму, застосовуються на збагачувальній фабриці. Основний промислово-цінний компонент для всіх трьох проб золото.

Ключові слова: вилуговування, ціанування, флотація, окислена руда, сульфідна руда, витяг.

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ТЕХНОЛОГИЯ ОБОГАЩЕНИЯ РУД С ПРИМЕНЕНИЕМ ЦИАНИСТОГО НАТРИЯ И ЕГО ЗАМЕНИТЕЛЯ РЕАГЕНТА ЦЗИНЬСИНЬ

Аннотация
Определение степени извлечения золота из руд методом прямого цианирования, а так же по комбинированному методу (проведением флотации исходной руды и доизвлечением золота цианированием из полученных хвостов флотации). Установлена технология обогащения золотосодержащих руд при новом методе флотация – цианирование. Данная работа проводилась с целью определения выщелачивание золота из представленных золотосодержащих руд месторождения «Иштамберди» методом цианирования, с применением цианистого натрия и его заменителя реагента «Цзиньсинь» по следующим типам руд: ИШ-1 окисленный; ИШ-2 сульфидный и ИШ-3 смешанный. Целью данной работы является определение степени извлечения золота из этих руд методом прямого цианирования, а также по комбинированному методу (проведением флотации исходной руды и доизвлечением золота цианированием из полученных хвостов флотации). Флотационные опыты проводились по схеме и режиму, применяемые на обогатительной фабрике. Основной промышленно-ценный компонент всех трех проб золото.
Ключевые слова: выщелачивание, цианирования, флотация, окисленная руда, сульфидная руда, извлечение.