CENTRAL ASIAN JOURNAL OF MEDICAL AND NATURAL SCIENCES

Volume: 04 Issue: 05 | Sep-Oct 2023 ISSN: 2660-4159

http://cajmns.centralasianstudies.org

Technological Processing of Gold-, Copper-Containing Ores of the Taror Deposit

[1]**Solekhova G.N.**, [1]**Samikhov Sh.R.**, [2]**Khakimov F.Kh.**, [2]**Ochilov D.Kh.**

Received 5th Aug 2023,
Accepted 3rd Sep 2023,
Online 16th Sep 2023

[1]*Tajik National University, Dushanbe, Tajikistan*
[2]*Samarkand State University named after Sh. Rashidova, Samarkand, Uzbekistan*
E-mail: firuz3515@gmail.com

Abstract: The paper deals with the problems of increasing the efficiency of processing gold-, copper-, arsenic-containing ores of the Taror deposit of the Republic of Tajikistan.

A scheme of flotation enrichment of the studied ores and a phase analysis of the flotation concentrate have been developed, the leaching of copper and gold from the concentrate of the studied deposit has been studied.

On the basis of scientific research, a schematic diagram of the processing of gold-, copper-bearing ores has been developed.

Key words: Ore, minerals, concentrates, technology, flotation, analysis, reagents .

1. Introduction

Minerals rich in disseminated ores occupy from 50 to 80% of the section area, which are distributed in the form of nest-like accumulations, individual phenocrysts, and less often small veinlets up to 3 mm in size.

Poor ores include carbonate rocks with rare (up to 5%) dissemination of small grains of arsenopyrite or chalcopyrite [1].

Aue M.T. together with colleagues describe the mineralogy of the gold-copper scrap-porphyry deposit Batu Khojau (Indonesia) [2].

The works described in the article are devoted to the most urgent problems of increasing the efficiency of processing gold ores, new technologies, and environmental aspects of using these technologies.

The technological basis for the processing of gold-copper-bearing ores remains relevant in the modern world for a number of reasons [3-5]:

- Gold and copper are valuable metals that are widely used in various industries.
- modern technologies for processing gold-copper-bearing ores make it possible to reduce the harmful impact on the environment associated with the extraction and processing of these ores. The use of new methods for extracting metals can reduce the amount of waste and emissions into the atmosphere, which is positively associated with the environmental situation.
- as the reserves of ores with high grades of gold and copper are declining, it is necessary to constantly develop new technologies for the extraction of these metals.

The technological scheme for processing gold-copper-bearing ores may include several stages and depends on the composition of the ore and its physical properties. Usually this technological scheme includes the following main stages: crushing, flotation, concentrate recovery, pyrometallurgical process, electrolysis, chemical process.

Thus, the technology for processing gold-copper-bearing ores includes several complex processes that require high precision and product quality control at all stages.

Experimental part. At the initial stage of the study, we carried out a trial analysis of the object under study, the data of which are shown in Table 1.

Table 1. Chemical composition of Tarorore, %

Components	Primary ores
SiO_2	52,0
Al_2O_3	2,6
Na_2O	3,2
K_2O	2,8
Fe_2O_3	8,2
FeO	2,5
TiO_2	0,47
MNO	0,14
CaO	1,8
MgO	2,7
As	0,83
Cu	1,3
Au, g/t	4,2
Ag, g/t	32,0

According to the results of chemical analysis, it can be concluded that the ore of the Taror deposit is a gold-bearing copper-arsenic ore.

To study the distribution of copper by ore size classes, a sieve analysis was carried out (Table 2).

Table 2. Results of sieve analysis of ore

Class, mm	Exit		Content Cu, %	Distribution Cu by class , %	Distribution Cu by class , total %
	G	%			
-2.0+1.0	28.1	28.1	0.86	20.2	20.2

-1.0+0.63	14.4	42.5	0.71	8.5	28.7
-0.63+0.315	18.9	61.4	0.82	12.9	41.6
-0.315+0.125	12,7	74,1	1,42	15,1	56,7
-0,125+0,063	10,3	84,4	1,71	14,7	71,4
-0,063	15,6	100,0	2,20	28,6	100,0
Ref. ore	100,0		1.3	100,0	

As can be seen from the table, the maximum output has a large class - "2,0 + 1,0 mm", its output is 28,1%.

However, copper is enriched in smaller classes. Here in the class – 0,063 mm, the copper content is 2,2%, and the metal in it is 28,6%.But copper is enriched with smaller grades. Here, in the class – 0,063 mm, the copper content is 2,2% and in which 28,6% of the metal is concentrated.

When determining the conditions and parameters of flotation processing of gold-copper ores, various factors influencing the flotation process were studied, such as: the degree of ore grinding before flotation and the reagent mode of flotation.

For further research, it was necessary to establish the required ore grinding fineness. For this purpose, ore weights were subjected to grinding at different times. In this case, the following conditions were observed: ore weight - 1000 grams, ratio T:L:SHAR - 1:0, 6:11. The grinding time varied from 10 to 20 minutes. For further studies, a minimum of 15 minutes was taken for grinding time, which corresponded to 96,34% of the "–0,074 mm" class.

One of the main features of displaced ores is the complexity of their mineral composition. The peculiarity of the quantitative composition of oxidized and mixed polymetallic ores requires careful control of the reagent regime during flotation [6–9].

A great variety of complex compositions of oxidized ores are their formations. Sulfides are replaced by sulfates, oxides and hydroxides, the latter, in turn, are replaced by carbonates, silicates, etc., which replace the most stable elements in an oxidizing atmosphere, such as iron, manganese, chromium, aluminum, with oxides and hydroxides. The variety of mineral forms of non-ferrous metals during the oxidation of ores predetermines the technological complexity of their processing. The most important methods of flotation of these ores are indicated in [10-13].

The main parameters of flotation enrichment of copper-gold-bearing ores were established: the optimal ore grinding size is 96% of class -0,074 mm (grinding time is 15 minutes), the reagent consumption of class Z -200 isopropylthionocarbamate collector is 60 g/t, the frother is pine oil 50 g/t. In the process of sulfide flotation, the pH of the pulp must be maintained within 8-10 units. At pH more than 10 units. the output of the foam product and, accordingly, the extraction of copper into the concentrate is reduced. Extraction of copper in the concentrate with these parameters is 40-42%.

Flotation studies were carried out according to the scheme (Fig. 1), which included the main and control flotation. The time of the main and control flotation was 10 minutes each.

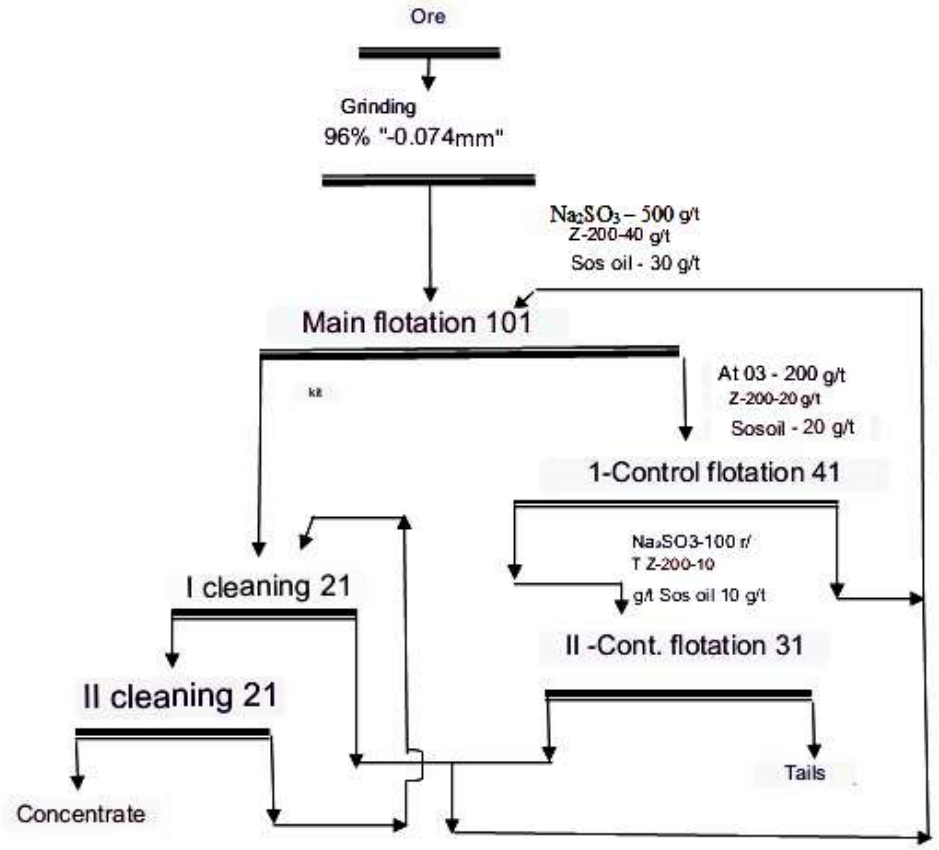


Figure 1. Flotation scheme of closed loop experiments

The results of experiments on flotation of the Taror deposit ore are presented in Table 3.

Table 3. The result of flotation of the ore from the Taror deposit

No.	Name of products	Exit		Content Cu, %	Recovery, %
		G	%		
1.	Copper concentrate	11,6	1,16	17,58	41,57
2.	Tails	988,4	98,84	0,29	58,43
3.	Ore source	1000,0	100,0	0,54	100,0

Flotation experiments with two pure concentrate flotations and control tailings flotation ensured the production of conditioned copper concentrate from the ore with a copper content of 17,6% with a copper recovery of 41,6%.

Copper concentrate and flotation tailings were produced according to the developed scheme using two concentrate recleanings for further research.

Chemical analyzes of the Taror flotation concentrate are shown in table 4.

Table 4. Chemical and assay analyzes of the concentrate

Components	Content, in %	Components	Content, in %
Cu	14,55	TiO_2	0,19
Fe	17,43	MnO	0,08
As	7,22	P_2O_5	0,14

S	17,11	CO_2	16,28
CaO	12,14	alkali metals	0,74
MgO	5,57	Gold, g/t	20,2
SiO_2	6,10	Silver, g/t	78,6
Al_2O_3	1,87		

As analyzes show, the Taror flotation concentrate is a sulfide gold-, copper-, arsenic product with a copper content of up to 14.5%.

Table 5 shows the distribution of gold and other components by sieve grade.

Table 5. Distribution of metals by concentrate classes

Size, MM	Exit, %	Content in source				Distribution of metals, %			
		g/t		%					
		Have	Ag	With	I would	Have	Ag	With	I would
+0.20	4.16	41.06	98.48	13.06	0.21	2.90	3.06	3.15	2.82
-0.20 + 0.10	12.67	43.17	113.60	12.26	0.21	9.28	10.74	9.00	8.65
-0.10 + 0.071	15.34	32,71	119,34	16,44	0,27	8,51	13,66	14,61	13,46
-0,071+0,063	8,39	50,62	110,47	16,76	0,26	7,20	6,91	8,15	7,09
-0,063 + 0,04	12,08	65,20	127,53	17,18	0,32	13,36	11,50	12,02	12,55
-0,04	47,36	73,14	153,16	19,34	0,36	58,75	54,13	53,07	55,43
Total	100,0	51,40	125,48	16,07	0,26	100,0	100,0	100,0	100,0

The results obtained indicate that gold is small in size and associated with sulfides.

The nature of gold dissemination in the mineral components of the concentrate is shown by phase analysis, the results of which are shown in Figure 2.

During the oxidation of sulfide minerals in an acidic environment, the formation of various chemical compounds is possible. The opening of gold-bearing sulfide concentrates containing arsenic, which is possibly carried out mainly by oxidative roasting. However, this is associated with the release of significant amounts of sulfur dioxide and arsenic-containing dust into the atmosphere, which is unacceptable from an environmental point of view [14, 15].

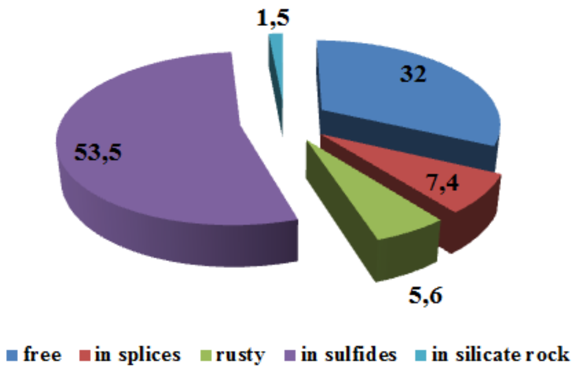


Figure 2. Phase analysis of fleet concentrate (%)

In connection with the above, special attention is paid to the development of technology for the hydrometallurgical processing of such concentrates.

One of the promising tasks of opening refractory gold-sulfide concentrates is hydrosulfation in a solution of nitric acid [16, 17].

On an industrial scale, a nitric acid method for the decomposition of sulfides has been introduced at one of the plants for the decomposition of molybdenum concentrates [18].

The nitric acid method allows you to transfer arsenic, sulfur and iron into a solution in the form of arsenic and sulfuric acid, iron in the form of iron nitrate and sulfate.

The interaction of basic minerals (pyrite, arsenopyrite and chalcopyrite) with nitric acid can be accompanied by the formation of soluble, heavy and gaseous products, which follows from the reaction equations:

$$2FeS_2+8HNO_3(\text{diff.}) =Fe_2(SO_4)_3+S+ 8NO + 4H_2O \ (1)$$

$$2FeS_2+2HNO_3(\text{razor.}) +3H_2SO_4(\text{conc.})=Fe_2(SO_4)_3+ 2NO + 4S + 4H_2O \ (2)$$

$$FeS_2 + 4HNO_3 (\text{ diff.}) =Fe(NO_3)_3 +NO+2S+ 2H_2O \ (3)$$

$$FeS_2 + 8HNO_3 (\text{ razil.}) = Fe(NO_3)_3 +2H_2SO_4 +5NO+ 2H_2O \ (4)$$

$$2FeS_2 +3NO_2 + 3H_2SO_4 (\text{conc.})=Fe_2(SO_4)_3 +3NO + 4S + 3H_2O \ (5)$$

$$2FeAsS+ 4HNO_3 (\text{ dec. })+H_2SO_4 (\text{dec.})+4O_2 =Fe_2(SO_4)_3 +2H_3AsO_4 +4NO \ (6)$$

$$7FeAsS+ 29HNO_3 (\text{sc.})+8O_2 =7Fe(NO_3)_3 +8NO+7S+7H_3AsO_4 +4H_2O \ (7)$$

$$S + 2HNO_3 (\text{razb.}) = H_2SO_4 + 2NO \ (8)$$

$$3FeAsS+ 23HNO_3 (\text{dec.})=3Fe(NO_3)_3 +3H_3AsO_4 +3H_2SO_4 +14NO+4H_2O \ (9)$$

$$3FeAsS+ 17HNO_3 (\text{dec.})=3Fe(NO_3)_3 +3H_3AsO_4 +3S+8NO+4H_2O \ (10)$$

$$CuFeS_2 + 8HNO_3 (\text{conc.}) = CuSO_4 + FeSO_4 +4NO + 4NO_2 +4H_2O \ (11)$$

$$3CuFeS_2 + 16HNO_3(\text{razb.})=3Cu(NO_3)_2 + 3Fe(NO_3)_2 + 6S+ 4NO + 8H_2O \ (12)$$

The most probable reactions are: (1), (2), (4), (6) and (7).

Elemental sulfur, formed by the interaction of nitric acid with sulfides, is oxidized to sulfuric anhydride. Further, when the latter interacts with water, sulfuric acid is formed. The possibility of elemental sulfur formation decreases, and the degree of its oxidation to sulfuric anhydride increases with an increase in the concentration and consumption of nitric acid (reactions 3, 6, 7).

The studies were carried out with constant stirring.

The degree of extraction of components from flotation concentrates in all experiments was established on the basis of chemical analysis of the starting material and cake by leaching.

For the purpose of optimization, the influence of various factors in wide ranges of parameter changes on the recovery of the concentrate from the Taror deposit was studied. The chemical composition of the flotation gold-copper-arsenic concentrate of the Taror deposit, % (wt.): 52,4 g/t Au; 86,7 g/t Ag; 13,6 Cu. The studies used 60% nitric acid.

The dependence of the degree of copper extraction was studied at a process duration of up to 120 minutes, a temperature of 80 ^{0}C, a ratio of T:L = 1:5, and a concentration of nitric acid of 400 g/dm^3 (Table 6).

Table 6. Teaching results copper and gold from the concentrates of the Taror deposit

No. p/n	Duration, min.	Ratio W:W	Temperature, ^{0}C	HNO_3 concentration, g/dm3	Concentration in solution, mg/dm^3		Degree of extraction into solution, %	
					Cu	Au	Cu	Au
1	120	1:5	25	400	10771,2	0,026	39,6	0,2
2	-	-	30	-	13763,2	0,010	50,6	0,1
3	-	-	40	-	16945,6	0,031	62,3	0,3
4	-	-	60	-	23228,8	0,062	85,4	0,6
5	-	-	80	-	26030,4	0,089	95,7	0,8
6	30	1:5	80	400	14796,8	0,000	54,4	0,0
7	60	-	-	-	19393,6	0,010	71,3	0,1
8	100	-	-	-	24371,2	0,026	89,6	0,2
9	120	-	-	-	25948,8	0,042	95,4	0,4
10	160	-	-	-	26057,6	0,062	95,8	0,6
11	120	1:5	80	100	9846,4	0,010	36,2	0,1
12	-	-	-	200	16836,8	0,000	61,9	0,0
13	-	-	-	300	21868,8	0,061	80,4	0,6
14	-	-	-	350	25187,2	0,083	92,6	0,8
15	-	-	-	400	25948,8	0,104	95,4	1,0
16	120	1:3	80	400	13545,6	0,026	49,8	0,2
17	-	1:4	-	-	20563,2	0,032	75,6	0,3
18	-	1:5	-	-	25840,0	0,073	95,0	0,7
19	-	1:6	-	-	25459,2	0,031	93,6	0,3

The maximum leaching of copper was observed at a process duration of 120 minutes, a temperature of 800C, a ratio of T:L=1:5, and a concentration of nitric acid of 400 g/dm^3.

Table 7 presents the results of studies at various flow rates of nitric acid, from which it can be seen that at a concentration of nitric acid of 400 g/dm^3, a satisfactory opening of the flotation concentrate is observed.

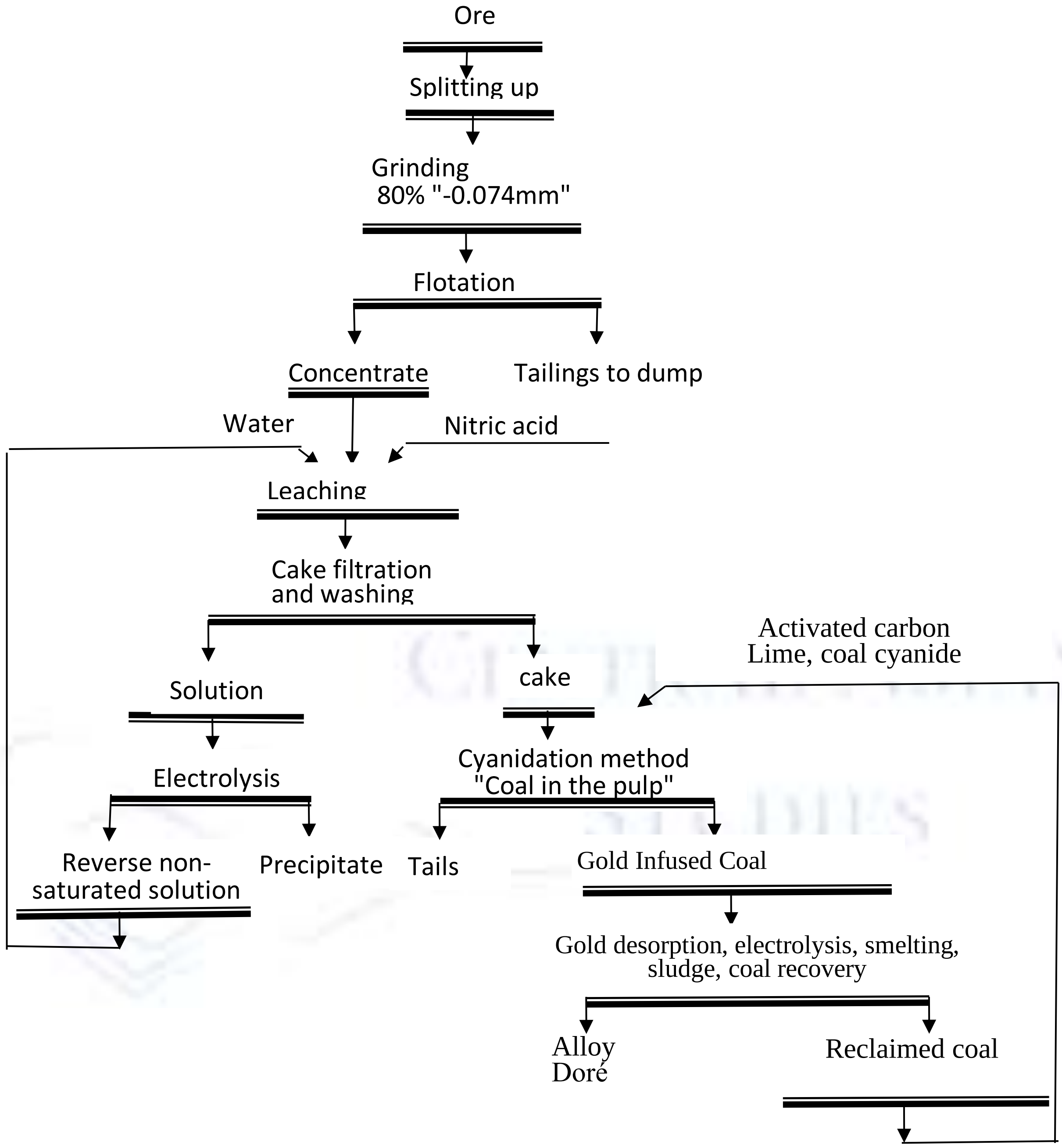
Table 7. Results of nitric acid leaching of concentrates

N	Loading HNO_3 g/m^3	Cake yield, %	Content in keke		Degree of extraction in cake, %		Cyanidated gold, %	
			Au, g/t	Cu, %	Au, g/t	Cu, %	Before showdown	After opening
1	500	46	88	0,23	99,2	1,9	42	97,6
2	450	48	80	0,31	99,4	2,6	46	97,2
3	400	51	78	0,29	98,9	2,3	48	96,2
4	300	60	67	0,35	98,6	3,2	51	88,6
5	200	61	61	0,42	98,9	3,6	52	82,3

The cake obtained after the process was subjected to cyanidation. The table shows that the recovery of gold after nitric acid leaching was 82.3-97.6%.

Based on the studies carried out, a technological scheme for processing arsenic-containing ore from the Taror deposit was developed (Fig. 5). The developed scheme includes crushing, ore grinding to 80% of the “-0.074 mm” class, flotation to obtain a high-quality concentrate, followed by autoclave-free nitric acid leaching.

Figure 5. Principal technological scheme of processing gold - copper-bearing ore of the Taror deposit



After leaching, the concentrate is filtered and washed. The filtrate is sent to electrolysis to obtain copper. The unsaturated solution is returned to the nitric acid leaching process. The leaching cake enriched in precious metals is sent for cyanidation to produce doré.

We also carried out studies on the production of copper by electrolysis from saturated solutions of nitric acid leaching. The main component of the electrolyte for copper refining was the solution after nitric acid leaching of the concentrate. The electrolyte was poured into a special bath at pH-2, temperature 25 ^{0}C, current strength 0,5 A.

Thus, in the conditions of the Republic of Tajikistan, the use of nitric acid technology for processing gold-arsenic concentrates can provide a significant economic effect and be useful for the development of other arsenic-containing ores in the country.

Conclusions

1. On the basis of the conducted studies, the optimal conditions for nitric acid opening of the concentrate were obtained: temperature 80^0C, process duration 120 min, ratio T:L = 1:5 and concentration of nitric acid (60%) 350-400 g/dm^3.

2. In pyrometallurgical processing by electrolysis, blister copper is burned as the final refining step. Electrolytic refining provides almost complete purification of blister copper from harmful impurities and allows you to extract a number of valuable components (Au, Ag, Se, Te) from it.

3. During hydrometallurgical processing, copper is transferred into a nitric acid solution from the original ore, followed by treatment with the same solution. Copper is extracted from the resulting solution by the electrolytic method. In this case, a high-purity cathode metal is formed [19].

Literature

1. Zalesov M. V., Grigoryeva V. A., Trubilov V. S., Baudouin A. Ya.Development of technical solutions to improve the efficiency of processing high-copper gold-bearing ore //Mining industry. – 2021. – No. 5. - P. 51-56.
2. Origin and Characteristics of the Shwetagun Deposit , Modi _ _ The Taung-Nankwe Gold District and the Kunzeik and Zibyaung Deposits, Kyaikhto Gold District, Mergui Belt, Myanmar: Implications for Fluid Source and Orogenic Gold Mineralization //Frontiers in Earth Science. - 2021. - V. 9. - P.
3. Epiforov A. V., Nabiulin R. N., Balikov S. V. Low-temperature autoclave oxidation of refractory sulfide gold-copper flotation concentrates followed by sulfite leaching of precious metals from oxidized cakes. Izvestiya vuzov. Applied chemistry and biotechnology. – 2014. – no. 3 (8). - P. 31-38.
4. Mukhina T. N., Marchevskaya V. V. Cooperation of the Mining Institute of the Kola Scientific Center of the Russian Academy of Sciences with other organizations in the development of new technologies // Bulletin of the Kola Scientific Center of the Russian Academy of Sciences. – 2016. – no. 4 (27). - P. 51-61.
5. Chekushina T.V. , Skvartsova E.S. Ecological aspects of the introduction of technology for processing dump cake leaching of gold-bearing concentrate // Tula State University. Earth science. - 2020. - No. 4. – P. 79-85.
6. Abramov A. Flotation enrichment methods. – Literes, 2022.
7. Gorlova O. E., Yun A. B., Sinyanskaya O. M., Medyanik N. L. Development and pilot testing of a combined technology for processing a dump of refractory mixed copper ores at the Taskora deposit // Non-ferrous metals. – 2018. – No. 12. - P. 14-20.
8. Chanturia V. A., Vaisberg L. A., Kozlov A. P. Priority areas of research in the field of processing mineral raw materials // Enrichment of ore. – 2014. – no. 2. - P. 3-9.
9. Samikhov SR, Zinchenko ZA Methods of persistent gold containing ore processing of chore deposit //Applied and Fundamental Studies. - 2012. - P. 284-290.
10. Ren H., Wang Z., Hu L., Ji F., Zhang Y., Huang T. Flotation performance measurement and the DFT study of salicylhydroxamic acid as a collector in niobite flotation //Advances in Energy and Environment Research: Proceedings of the International Conference on Advances in Energy and Environment Research (ICAEER2016), Guangzhou City, China, August 12-14, 2016. – CRC Press, 2017. – P. 147.
11. Sabanova MN The use of selective collectors in the flotation of copper slags // Mining Information and Analytical Bulletin (scientific and technical journal). – 2015. – No. 4. - P. 415-418.

12. Akhmedov Kh. A., Kunbazarov A. K. Hydrosulfatization of gold-bearing sulfide-arsenic concentrates // In the collection “Materials of the meeting on the study of endogenous deposits of Central Asia.” – Tashkent: Izd. SAIGIMS. - 1975. - P. 78-80.
13. Yun A. B., Sinyanskaya O. M., Gorlova O. E. Substantiation of the parameters of the combined technology for processing mixed copper ores from dumps // Combined geotechnology: transition to a new technological order / ed. VN Kalmykova, MV Rylnikova//Materials. - 2019. - P. 160.
14. Kazakova, N.A. Physico-chemical and technological studies of mineral processing processes. – M.: Nauka, 1973. – 380 p.
15. Zinchenko Z. A., Samikhov Sh. R. Processing of refractory gold ores in Tajikistan // Mining Journal. – 2014. – No. 4. - P. 97-98.
16. Obidov Z. R., Samikhov Sh. R., Zinchenko Z. A., Kholov Kh. I. Nitric acid technology for opening refractory gold-, copper-, arsenic concentrates of the Taror deposit // Metallurgy va masoleshinosi. - 2016. - V. 4. - No. 36. - P. 26.
17. Mamatov E. D., Usmanova U. Kh., Nazarov Sh. B., Kurbonbekov A., Mirsaidov U. M. Features of the process of hydrochloric acid decomposition of boron-aluminum-containing raw materials in Tajikistan // Proceedings of the Academy of Sciences of the Republic of Tajikistan. Department of physical and mathematical, chemical, geological and technical sciences. – 2012. – No. 4. - P. 51-55.
18. Sotnikov V.I. Copper-molybdenum-porphyry ore formation: nature, problem of volume and boundaries //Geology and geophysics. - 2006. - V. 47. - No. 3. - P. 355-363.
19. Igumnov M.S., Drobot D.V., Chernyshov V.I. New milestones in applied electrochemistry of rare and noble metals //Ros. chem. magazine - 2001. - V. 45. - P. 64-71.