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# Method for extraction of gold and silver from technogenic pyrite raw materials

**V I Sachkov, R A Nefedov and R O Medvedev**

Innovation and Technology Center, National Research Tomsk State University, 36  
Lenin Street, Tomsk 634050, Russian Federation

E-mail: rodionmedvedev7@gmail.com

**Abstract.** The paper contains the results of hydrometallurgical processing of technogenic pyrite raw materials. The method is based on selective extraction of gold and silver from ore by solution, which contains sodium sulfite and sodium sulfate. The most promising results were obtained utilizing solution with sodium sulfite and sodium sulfate concentration of 25 g/L and leaching time – 1 hour. Under these conditions, the extraction of gold was 67%. The use of sodium sulphate and sodium sulfite allows to extract gold and partially silver from refractory sulfide ores.

## 1. Introduction

In connection with the depletion of reserves of rich and easily enriched gold-bearing ores, it is necessary to involve in the production technogenic pyrite raw materials, which are promising and easily available [1–3]. At the same time, complex processing of technogenic pyrite raw materials solves the problem of environmental hazards during storage in landfills [4–6]. The problem of waste disposal is acute for all of Russia's regions [7]. According to the data, the amount of nonrecycled waste in Russia is estimated at approximately 82 billion tons [8]. The gold and silver reaches are respectively 2.5 and 20 g/t [9]. The content of components is enough for their industrial extraction. Complex economical processing of technogenic deposits is possible with the creation of a rational environmentally processing technology [10]. The paper studies influence of the effect of time on the sulfate-sulfite leaching of gold and silver from technogenic pyrite raw materials.

## 2. Materials and methods

### 2.1. Ore

In the current work, we used a pyrite raw material from Sverdlovsk Region, Russia. Raw materials are tailings of flotation concentration of sulfide copper-zinc ores. Pyrite technogenic raw materials are light brown spherical odds agglomerates.

### 2.2. Leaching tests

The method was based on the leaching of raw materials using sodium sulfite and sodium sulfate. In this paper, the effect of time leaching on the target extraction components was studied. The concentration of sodium sulfate and sodium sulfite was 25 g/l. The time ranged from 1 to 122 hours. The masses of the studied samples were 100g. The mass ratio of solid: liquid = 1:2. The process was carried out in 1000 ml polyethylene agitators with constant stirring at room temperature. After leaching, filtration was



carried out with the suction filter. The solid residue was rinsed by the water on a suction filter. Then the precipitate was dried at 80 °C in the oven to constant weight. Next, we analyzed the content of gold and silver in the solid phase.

### 2.3. Use of analytical techniques

The elemental composition of the samples was investigated by the method of energy-dispersed X-ray spectroscopy using a Hitachi S-3400N electron microscope. The content of microimpurities in the solid phase was determined by inductively coupled plasma mass spectrometry using an ICAP 6200 Duo spectrometer. Particle size analysis was investigated by screen test.

## 3. Results and discussions

The mass and atomic content of technogenic pyrite raw materials obtained by elemental analysis are presented in table 1.

**Table 1.** The elemental composition of pyrite raw materials.

Element	Mass content, wt. %	Atomic content, atm. %
Iron (Fe)	41.2	23.3
Sulfur (S)	26.6	26.1
Oxygen (O)	17.7	35.2
Silicon (Si)	6.5	7.2
Calcium (Ca)	3.6	2.8
Aluminum (Al)	2.5	3.0
Magnesium (Mg)	1.8	2.3

The bulk of the pyrite raw material represented by compounds of iron oxides and iron sulfides. The raw materials contain significant amounts of silicon (Si), calcium (Ca), aluminum (Al), magnesium (Mg).

The results obtained by ICP - MS analysis of technogenic pyrite raw materials are presented in table 2.

**Table 2.** The results of the ICP - MS analysis of pyrite raw materials.

Element	Content, g/t
Gold (Au)	1.15
Silver (Ag)	13.6
Copper (Cu)	1200
Zinc (Zn)	1500
Arsenic (As)	1400
Barium (Ba)	3900
Antimony (Sb)	57
Lead (Pb)	380
Indium (In)	2
Germanium (Ge)	1.5
Selenium (Se)	110
Manganese (Mn)	110
Cobalt (Co)	120

The gold and silver content are 1.15 and 13.6 g/t respectively. Copper, zinc, arsenic and barium are found in raw materials in significant concentrations. The interfering components may be arsenic and

copper. Copper can be a catalyst for the oxidation of sodium sulfite. This affects to the consumption of sodium sulfite. Mercury can form complex compounds with the components of the leach solution, which will also lead to increase the consumption of sulfite and sodium sulfate.

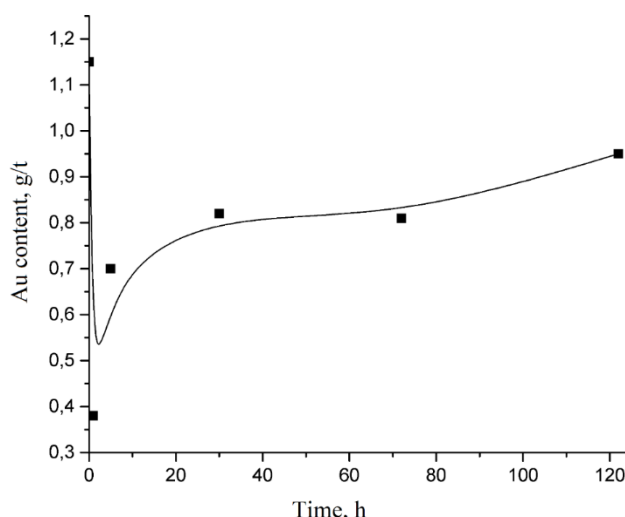
The granulometric composition is an important technical indicator for raw materials. Large particles of material will include particles of the target components. Particle size distribution of technogenic pyrite raw materials are presented in table 3.

**Table 3.** The results of the particle size analysis of pyrite raw materials.

Particle size, mm	Mass content, wt. %
>1	1.30
0.9 – 1	53.43
0.8 – 0.9	2.90
0.7 – 0.8	3.30
0.6 – 0.7	3.03
0.5 – 0.6	2.77
0.4 – 0.5	1.72
0.3 – 0.4	1.85
0.2 – 0.3	4.62
0.1 – 0.2	5.28
0.1 <	21.11

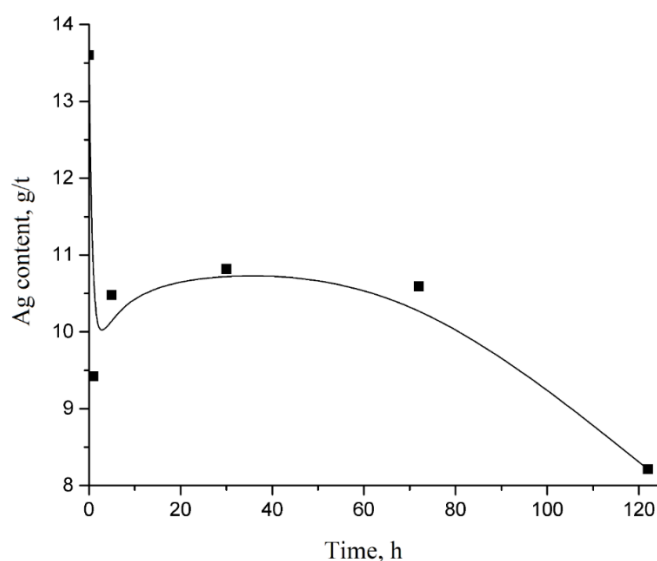
As the table 3 shows more than half of the particles had a particle size of 0.9-1 mm. Particles with a size of <0.1 mm in the raw material contained at the level of 20%.

The experiments results are shown in the graphs of concentration silver and gold in the solid phase from the interaction time when concentration of sodium sulfate and sodium sulfite is 25 g/l (figure 1,2).



**Figure 1.** The dependence of gold content in the solid phase from the leaching time.

Analysis of the experimental data showed that with increasing process time, gold extraction decreases. The lowest gold content in the solid phase was achieved in the raw material samples in the first hour of processing. The degree of gold extraction in the first hour of leaching is 53%. Further, the degree of extraction is reduced to 20%. Then the gold content began to increase which may indicate the presence of natural sorbents in the raw materials. It may also be due to the decomposition of complex gold compounds.



**Figure 2.** The dependence of silver content in the solid phase from the leaching time.

Figure 2 shows two pronounced extremums. According to the graph the silver content has a maximum in the point of 24 hours. In the first hour of the process there is a minimum on the graph (the silver content decreases rapidly). There is an upward trend of silver content from 5 to 24 hours. After 24 hours of processing, the silver content in the raw materials begins to decrease. The degree of silver extraction in the first hour of leaching is 26.5%, for 120 hours is 40%. Increasing the extraction time does not bring enough positive effect to the extraction of silver, to justify the increase in process time.

#### 4. Conclusion

Technogenic pyrite raw materials with gold content – 1.15 g/t, silver – 13.6 g/t is a promising to produce target components. The processing of raw materials can significantly increase the extraction of precious metals. Raw materials can be efficiently processed by a method based on the interaction of pyrite raw materials with a solution containing sodium sulfate and sodium sulfite. The maximum extraction of components in the first hour of leaching was achieved. It is expected that this is due to the instability of the complex or the presence of natural sorbents in the raw materials. But the degree of extraction is insufficient for industrial application of the method. In this regard, further studies are aimed at studying the effect of the component concentration, the medium acidity, and the choice of oxidizing agents.

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