Rare Metal Materials and Engineering
Volume 45, Issue 11, November 2016
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: Rare Metal Materials and Engineering, 2016, 45(11): 2784-2789.

ARTICLE

Gold, Mercury, and Silver Extraction by Chemical and Physical Separation Methods

Yaser Olyaei[1], Sajjad Aghazadeh[1], Mahdi Gharabaghi[1], Hassan Mamghaderi[1], Jahanbakhsh Mansouri[2]

[1] University of Tehran, Tehran Iran; [2] Pouya Zarkan Aghdareh Gold Plant, Takab Iran

Abstract: An agitation leaching method was used for gold extraction from Aghdareh mine samples. Mineralogical study showed that 58% of the gold particles were finer than 10 μm. In addition 3% of the grade in the sample was related to refractory gold. Experiments results showed that at the optimum condition gold recovery was 91.8% and silver, and mercury recoveries were 41.5%, and 10.2%, respectively. After performing cyanidation tests for 6 different fractions, it was concluded that the most unleached gold particles exist in the fraction size finer than 25 μm and about 5% of gold particles in the fraction size larger than 25 μm was not leached. Therefore, further comminution was applied which increased by about 3.57% of gold recovery and about 5% of silver recovery. Further comminution did not affect the recovery of mercury. In order to increase the mercury recovery and prevent from amalgamation of gold by mercury particles, Knelson gravity concentrator was used. The tailing of gravity method was examined using cyanidation tests by considering the optimum conditions. According to the final results, using the combination of these methods, gold recovery is increased to 93.3% and the recovery of mercury increased to 42.1% while the recovery of silver is 42.17%, without noticeable change.

Key words: gold; silver; mercury; cyanidation; Knelson method

The recovery of gold can be accomplished via thorough leaching, gravity, flotation, bioleaching, high pressure oxidation, roasting or combination of these methods[1]. Each of these methods strongly depends on the chemical and physical properties of ore, and mineral occurrence state inside the ore[2]. Among these methods, cyanidation is the standard process for the recovery of gold and silver[3]. Cyanidation process due to its high efficiency and cost-effective matter has become the main leaching method for dissolution of gold[2]. The cyanidation reaction for gold and silver occurs according to Eqs.(1) and (2)[4]. Oxidation of gold is a prior process before dissolution of gold within alkaline medium. When gold is oxidized, gold cyano complex $[Au(CN)_2]^-$ is formed with the presence of cyanide[4, 5].

$$4Au + 8CN^- + O_2 + 2H_2O \rightarrow 4[Au(CN)_2]^- + 4OH^- \quad (1)$$

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

The rate of gold dissolution is controlled by a number of parameters including cyanide and oxygen concentration, pH/Eh, particle size, solid-liquid interface, and temperature. Some of the above mentioned factors were investigated in the present work.

Mercury is one the most poisonous elements and its metallic form cannot be removed by chemical reactions or changed into unharmed forms. Mercury is associated with gold mining, and release of mercury into the environment remain a concern due to its health effects on humans and other organisms[6]. Mercury is of paramount importance in the chemistry of gold extraction. Due to its natural occurrence in the form of pure or cinnabar mineral accompanied with gold ores, it is considered an important impurity in the gold cyanidation process. Metallic mercury is capable of adsorbing metallic gold which reduces gold recovery in cyanidation[3]. Mercury strongly follows the chemistry and mechanism of gold cyanidation. According to the Eq.3, in the presence of

Received date: November 14, 2015
Corresponding author: Mahdi Gharabaghi, School of Mining Engineering, College of Engineering, University of Tehran, Tehran Iran, Tel: 0098-21-82084556, Fax: 0098-21-88225384, E-mail: Gharabaghi@ut.ac.ir, m.gharabaghi@gmail.com

cyanide it is converted to di- or tetra-cyano mercury complex which is highly water soluble. Mercury cyanide complexes compete closely with gold cyanide complexes for adsorption on the active carbons and even can be replaced with some gold cyanide ions on the active carbon [6].

$$4Hg^{2+} + 6CN^- = Hg(CN)_2 + Hg(CN)_4^{2-} \quad (3)$$

Centrifugal separators are not limited to gold but research is also being carried out in coal and hematite processing, as well for processing fine material[7]. Due to the Knelson concentrator capability in the recovery of finer and lager particles of gold, it has been broadly used in the gold extraction industry. Also, it is considered to be a key factor contributing to environmental issues. In gold plants, the gravity method is applied as a pretreatment process which reduces cost of operations[8]. Knelson Concentrators are almost always placed in the grinding circuits [9].

The aims of the present study are to investigate the effective parameters in the cyanidation process, increasing the amount of mercury as a minor product by Knelson concentrator, and finally increasing the recovery of gold.

1 Experiment

The sample was taken from Aghdare mine which is located Takab, Iran. Ore samples with different grades were collected and then mixed with a specific ratio to produce a mean feed grade. This measured value was about 1.5 g/t for Aghdare gold plant. Data show that 150g/t mercury exists in the form of cinnabar mineral inside the ore. Due to the presence of mercury, large portion of gold was lost. Sample size was reduced using cone and cylindrical crushers and ball mill. After comminution stage, 2 kg of homogeneous sample was prepared for leaching tests. Also, some amount of initial sample were taken to do further experiments with Knelson concentrator equipment.

Leaching tests were carried out using a mechanical agitator (Ika-RW20, Germany) within ambient pressure and temperature, inside a 3 liter container with 1 kg ground sample by Denver ball mill. During all experiments, pH of solution was adjusted with pH meter (744 Metrohm) to keep constant value of 10.5. Hydrated lime for increasing pH solution and sodium cyanide for dissolution of gold were selected which are currently used in Aghdare gold complex with industrial purity. At the end of each test, pulp was filtered and washed with distilled water. Solution and filter cake were analyzed by atomic adsorption spectrometry and yields were calculated. The most effective parameters on the cyanidation process were identified and optimized including feed size distribution, solid percent, cyanide concentration and time (changing one parameter and keeping constant other parameters at the same time). Finally, response values for gold, silver and mercury recoveries were carefully examined.

Gold and silver particle sizes were in submicroscopic level in Aghdare mine which prevented using of centrifugal method for recovering these metals. Taking into account this fact, Knelson concentrator method for the recovery of cinnabar mineral (density of 8.1 g/cm^3) was chosen. Gravity tests with Knelson concentrator equipment in the laboratory scale (KC-MD-2") were conducted with the bowl capacity of 1 L pulp feed rate of 1 kg/min, and d_{80}=500 μm for feed input (with regard to cinnabar mineral's degree of freedom).

Optical mineralogy (using the prepared polished and thin sections) and X-ray diffraction (XRD) studies were performed to define the main and the trace minerals and their interlocking.

2 Results and Discussion

2.1 Sample characterization and deportment of gold

2.1.1 Sample mineralogy

Main minerals are quartz, Muscovite, calcite, dolomite, and smectite as seen in Table 1. The result of optical mineralogy shows that Aghdare gold particles are mostly distributed as native gold (Fig.1). Amalgamation or electrum grains (gold, mercury, and silver alloys) rarely can be observed inside the ore (Fig.2). It is also found that gold particles are submicroscopic (Fig.3).

Chemical analysis was carried out using atomic absorption spectrometry (AAS). Based on the obtained results, the grades of gold, silver, and mercury in the sample are 1.5, 7.5, and 160 g/t, respectively.

Table 1 Constituents of Aghdare gold ore mine and its gold percentage

Mineral	Formula	Amount/wt%
Quartz	SiO_2	25.7
Muscovite	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	10.4
Smectite	$(Ca,Na)_7(AlFeMg)_4[(SiAl)_8O_{20}](OH)_4.nH_2O$	8.6
Kaolinite	$Al_2Si_2O_5(OH)_4$	5.6
Other silicates	-	2.7
Calcite	$CaCO_3$	21.0
Dolomite	$CaMg(CO_3)_2$	9.6
Barite	$BaSO_4$	3.1
Jarosite	$KFe_3(SO_4)_2(OH)_6$	2.0
Lead and iron arsenates	-	2.2
Goethite	FeOOH	3.7
Hematite	Fe_2O_3	1.0
Magnetite	Fe_3O_4	0.3
Pyrolusite	MnO_2	2.5
Anatase-Rutile	TiO_2	0.2
Cinnabar	HgS	0.02
Liberated gold	Au	(226)
Electrum gold	Au<80%+Ag>20%	(8)
Amalgamated gold	Au<80%, Ag+Hg>20%	(9)
Carbonaceous material	C_{org}	0.1

Note: Values inside parenthesis are numbered particles in microscope.