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Preliminary Cyanidation of Gold Ore from Zavvarian

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Abstract*— Zavarian area is located about 60 km south-west of Qom city, Iran. Due to high potential of the region, representative sample was prepared and then several primary cyanidation experiments were carried out. Screening and assaying tests showed that there exists a considerable amount of gold within all size distribution ranges. The mean value of grade was measured about 1.9 g/t for this ore. Degree of freedom was found to be -74 micron by considering the fact that most gold particles existed within size distribution finer than 74 micron. According to chemical analysis, elements of Au, Ag, Hg, and As comprise 2 ppm, 13 ppm, 25 ppm, and 1600 ppm of the sample, respectively. Based on the microscopic studies (polished and thin sections), XRD, and XRF, the main minerals included quartz, and tourmaline and other minor minerals were feldspar, chlorite, muscovite, hydrous iron oxides/hydroxides, limonite, and goethite. Cyanidation tests were conducted in order to determine the optimum value of the effective parameters including particle size, pH, cyanide concentration and leaching time. The optimum condition for particle size, pH, cyanide concentration and leaching time were determined as 74 micron, 10.58, 3 kg/t and 24 hours, respectively. The results showed that gold recovery of 93.36% was achieved at the optimum condition.

Keywords: **Cyanidation, Gold, Zavvarian. pH.**

I. INTRODUCTION

Cyanidation is a common method in gold extraction industries due to its high efficiency, inexpensive operation, and easy accessibility [1,5]. The oxidation of gold is a prerequisite for dissolution in the alkaline cyanide lixivian [9]. In the presence of cyanide (CN), gold forms a cyano complex $[Au(CN)_2]^-$ when it is oxidized [9,8]. Elsner's equation (Eq. 1) shows the dissolution of gold in alkaline cyanide solution and the role of oxygen in gold cyanidation [5].

$$4Au + 8NaCN + O_2 + 2H_2O \quad (1)$$

Gold dissolution by cyanide was introduced since beginning of 19th century; however, it did not economically applied into practice until the late 1980. First cyanidation process was used for gold extraction from amalgamation method's residues. Then, it was applied for all gold-bearing ores due to its high productivity [2,7,6]. Sharafabad gold ore cyanidation showed that gold particles changes in the range of 65-250 micron. Also, the grade of gold were 5.7 g/t in the representative sample. The maximum recovery of gold in cyanidation experiments was obtained 96.76% under optimum conditions of d80=75micron, pH=11, and leaching time of 20 hours [3]. Tuzlar gold cyanidation showed that the sample includes 2 g/t gold inside. Cyanidation leaching, roll bottle, and column methods were carried out for gold dissolution whereby the recovery of gold were obtained 94%, 59%, and 70%, respectively. Also, gold recovery through active carbon and ion exchange by zinc foil was obtained 99.87% and 95.4%, respectively [4].

Zavvarian area is located about 60 km south-west of Qom city and about 5 km of Salafchegan. The study area includes 300 km2 of the region which ends from north to Salafchegan and Marvar village, from west to Koushk and Salehabad village, from south to Sakht Hesar Mountain, and from east to Sorkh Hesar Mountain. In the scope of this work, due to presence of 2 g/t gold in the ore, cyanidation experiments were carried out for Zavarian gold ore in order to examine gold leaching feasibility in this region and optimize the effective parameters including particle size, pH, chemical material consumption, and dissolution time.

II. MATERIAL AND METHODS

In order to perform cyanidation studies, four effective parameters were optimized in 4 levels through classic method (keeping constant 3 parameters and changing 1 parameter at the same time). Then, responses were examined for gold recovery and consumption amount of cyanide by titration using silver nitrate. Experiments were conducted for samples obtained through wet grinding stage by using ball mill. Solid percent of 33% was kept constant during all the experiments (1kg of sample with 2 lit of water). Due to the high influence of pH on the process, pH value was regularly controlled using pH meter. Hydrate lime and sulfuric acid (15%) were used for increasing and decreasing pH value, respectively. Sodium cyanide with industrial purity was used as dissolution agent of gold. Gold distribution in solid and liquid phases was determined by ICP method. After each test, pulp was filtered, and residue was washed with 2 lit water to extract the remained gold bearing solution from the residue. Finally, samples were separately taken from initial pregnant solution and pregnant solution produced from washing stage in order to measure the grade and recovery of gold for each section.

A. Optimum particle size

In this series of experiment we attempted to determine the optimum particle size based on d_{80} for cyanidation process. In order to determine optimum particle size, 4 cyanidation tests were performed in different particle sizes (-44, -53, -74, and -88 micron) and kept constant other parameters at the same

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time. To obtain optimum grinding time for each particle size based on d_{80}, 4 samples with each 2 kg weight were ground using ball mill in different times which finally 100, 85, 60, and 47 minutes were calculated for particle sizes of -44, -53, -74, and -88 micron, respectively. Cyanidation tests for optimum particle size were performed in conditions as follows: cyanidation leaching time of 24 hours, media pH of 11, sodium cyanide concentration of 1550 ppm, pulp solid percent of 33% (1 kg of sample with 2 lit of water), and stirring speed of 700 rpm.

B. pH

In this series of experiment, the effect of pH on gold recovery during cyanidation experiment was investigated. By conducting four cyanidation tests in different pH values of 9.5, 10, 10.5, and 11, optimum pH value was obtained for gold dissolution. Also, the consumption amount of lime required for pH adjustment during cyanidation process was measured. pH value was controlled during pH optimization experiments by sulfuric acid (15%). Cyanidation tests for optimum pH were carried out by keeping constant particle size (Obtained optimum particle size from previous test) and conditions as follows: sodium cyanide concentration of 1550 ppm, leaching time of 24 hours, pulp solid percent of 33% (1 kg of sample with 2 lit of water), and stirring speed of 700 rpm for predetermined pH values.

C. Cyanide concentration

In order to determine optimum cyanide concentration, experiments were carried out in four different values (1000, 1250, 1500, and 1750 ppm) of cyanide concentration. Particle size and pH value were kept constant based on their values obtained from previous optimum experiments. Leaching time of 24 hours, solid percent of 33% (1kg of sample with 2 lit of water), and stirring speed of 700 rpm were considered as experimental conditions.

D. Leaching time

To determine optimum leaching time, experiments were conducted in different leaching time of 2, 4, 6, 8, 12, 24, and 48 hours. Particle size, pH, and sodium cyanide concentration were kept constant during the experiment based on the values obtained from previous optimum experiments. Solid percent of 33 %(1 kg of sample and 2 lit of water) and stirring speed of 700 rpm were also considered as experimental conditions. The recovery of gold for each experiment was measured and plotted in different leaching times.

III. RESULTS AND DISCUSSION

A. Effect of particle size

According to the obtained results from cyanidation experiments in different particle sizes, the tends of gold recovery increase with decreasing feed particle size from -74 micron to -53 micron which is due to more liberation of gold particles. Further decrease in particle size from -53 micron to -44 micron caused the recovery of gold to decrease slightly. This trend can be argued by the small amount of clay minerals and also excessive amount of arsenic (1600 g/t) in the ore. Because excessive amount of arsenic in the ore, the possibility of gold dissolution with cyanide ion decreases in the leaching media. Taking into account the fact that reaching fine particle sizes of -44 and -55 micron requires much more comminution costs and also the liberation possibility of arsenic element in the ore increases, optimum particle size of -74 micron based on d_{80} (grinding time of 60 minutes) was chosen. The recovery of gold in different size fractions is presented in **Figure 1**.

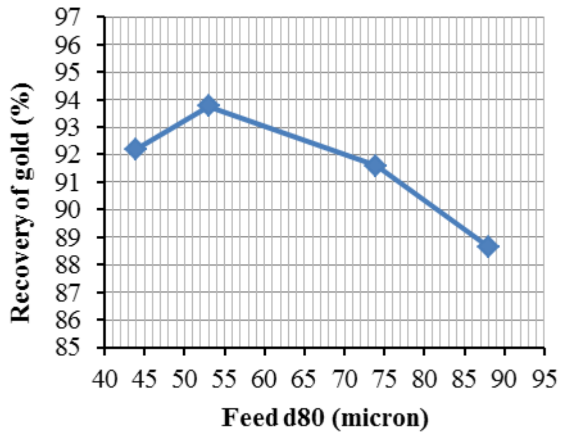

Fig 1. The recovery of gold in different size fractions [10].

B. Effect of pH

By increasing pH up to 10.58%, the recovery of gold increases; however, further increase of pH causes the recovery of gold to decrease as shown in **Figure 2**. The maximum gold recovery of 93.6% was achieved in pH value of 10.58. Therefore, pH=10.58 was chosen as optimum pH value.

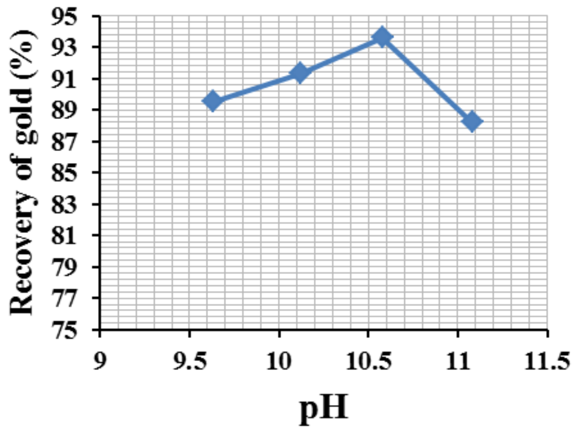

Fig 2. The recovery of gold in different pH values [10].

C. Effect of cyanide concentration

By increasing cyanide concentration form 1000 ppm to 1750 ppm, free cyanide ions tend to increase in the leaching media which causes the recovery of gold to increase from 86% to 94.1%. Due to the fact that more concentrated solution

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did not affect the rate of gold extraction and also mechanical and chemical waste of more concentrated cyanide solutions are considerable, therefore it is reasonable to keep cyanide concentration at its minimum value. So, considering the required free cyanide amount in the leaching media (between 500-1000 ppm), 1500 ppm (3kg/ton) was chosen as optimum cyanide concentration. The recovery of gold in different cyanide concentrations is presented in **Figure 3**.

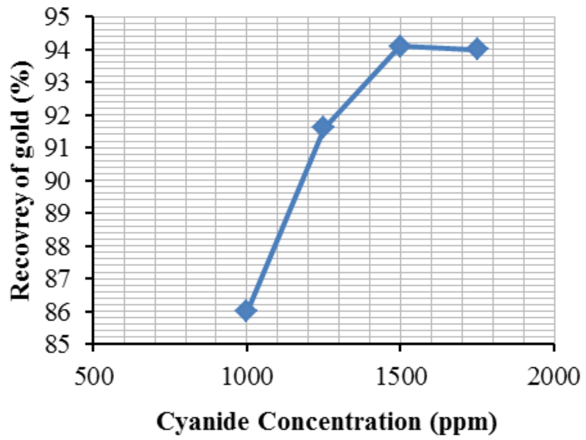

Fig 3. The recovery of gold in different cyanide concentrations [10].

D. Cyanidation kinetics

Based on the obtained results, diagram of gold recovery versus time was plotted as shown in **Figure 4**. Gold dissolution kinetic is very high during 12 hours of leaching time, as the recovery of gold reaches 90.36%. High kinetic of gold dissolution implies that gold particles are liberated and fine which cause them to be easily dissolved. For cyanidation experiment with more time, the recovery variation was very small where the recovery of gold increased 4.028% from 12 hours to 48 hours. Based on the obtained results and satisfactory recovery more than 90%, 24 hours was chosen as optimum leaching time which gives the gold recovery of 93.5%.

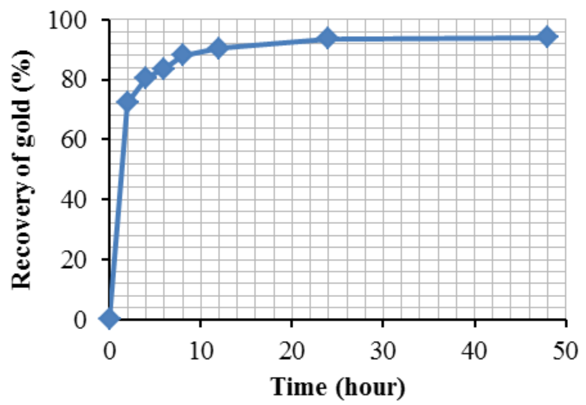

Fig 4. The recovery of gold in different leaching time [10].

IV. CONCLUSION

Based on the results obtained from gold distribution in different particle size, mean grade was measured about 1.9 g/t. With regard to high distribution of gold particles in particle size finer than 74 micron, degree of freedom was determined 74 micron. Taking into account results obtained from mineralogical studies by XRD and XRF, main minerals in the ore included quarts, tourmaline, and iron oxides. Applying chemistry analysis on the representative sample demonstrated that sample contains about 2 ppm gold inside. Polished and thin section studies along with rock and crushed samples characterized ore as oxide and main gangue mineral was quartz. Polished section studies showed that more than 90% contains transparent minerals such as silicates (i.e. quarts, tourmaline, chlorite, feldspar, and muscovite) and about 10% contains opaque minerals such as iron oxides/hydroxides. Also, no evidence of gold existence was detected in mineralogical studies. Optimum conditions for cyanidation experiment were determined as follows: feed d_{80}= 74 micron (grinding time of 60 minutes in ball mill), pH of 10.58, sodium cyanide concentration of 1500 ppm, and leaching time of 24 hours. Under The mentioned conditions, the recovery of gold was obtained 93.5%. Also, optimum consumption of cyanide and lime were 1.7 kg/t and 1/1kg/t, respectively. The future enhancement are adsorption investigation and the cyanidation investigation of silver and mercury.

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