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Agitation Leaching of Gold with Thiourea and Cyanidation Methods

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In this study, preliminary laboratory test work to identify the relative agitation leaching response to cyanidation and thiourea leaching of an oxidized ore have been carried out. The ore deposits of Neishaboor area with gold grade of 4 ppm are rich enough for studies. The characterization studies shows that, the ore is oxidized and gold is present partly in the form of solution in quartz veins as well as in the form of free particles in iron hydroxide specially hematite which is the product of pyrite oxidation. Quartz, hematite, calcite and feldspar are the main minerals present in the order of abundances. Sieve analysis and distribution of gold particles in different sieve fractions shows gold particles are distributed below 2000 μ. Based on characterization studies, the potential of an alternative lixiviant like thiourea and cyanide leach have been determined and found that under optimized conditions thiourea leaching of the ore performs (extraction of 96.7 % after 16 h) better than cyanide leaching (extraction of 47.3 % after 16 h).

Key Words: Thiourea, Cyanidation, Mineralogy, Gold ores, Leaching, Extraction.

INTRODUCTION

Gold is usually associated with complex sulphide ores and conventional straight cyanidation method is used to extract gold if they present in the boundary of the mineral particle[1]. Therefore the characterization studies of an ore deposit and its mineral assemblages determine the mining methods, extraction and in particular, the performance of all beneficiation and chemical process involved in precious metals extraction. Consequently, a good understanding of the mineralogy of the matrix material (sample) is required to design or operate an extraction or optimum efficiency[2-5].

Cyanidation has been the standard process for gold recovery since cyanide was firstly applied as an optimum lixiviant for gold, nearly a century

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ago[1]. Although this method has been used commercially for the past years, there are refractory ores that are not amenable to cyanidation method. Many alternate lixiviants have been studied for extraction of gold, especially those of halogens, thiourea, thiosulfate and malononitrile, however only thiourea has found some industrial application. Table-1 shows some basic properties of lixiviants used for gold extraction[6].

TABLE-1
BASIC PROPERTIES OF LIXIVIANTS USED FOR GOLD EXTRACTION

Reagent	Type of oxidant	Type of Au complex in solution	Optimum pH
Alkaline system			
Cyanide	O_2	$Au(CN)^-$	> 10
Ammonium cyanide	O_2	$Au(CN)^{2-}$	> 10
Organic nitriles	O_2	$Au[CH(CN)_2]_2^-$	> 7
Calcium cyanoform	O_2	$Au[C(CH_3)_3]_2$	> 10
Neutral system			
Thiosulfate	O_2	$Au(S_2O_3)_2^{3-}$	>7
Bromocyanide	Br, CN	$Au(CN)_2$	7
Bromine	Br_2	$AuBr_4^-$	7
Acid system			
Chlorine	Cl_2	$AuCl_4^-$	< 2
Ferric chloride	Fe^{3+}	$AuCl_4^-$	< 2
Thiocyanate	Fe^{3+}, H_2O_2	$Au(SCN)_4^-$	< 3
Thiourea	Fe^{3+}, H_2O_2	$Au(CS(NH_2)_2)_2^+$	2-3

Thiourea leaching of Au and Ag was first reported by Reynolds[7] and has attracted the interest of many investigators[8]. Any consideration of thiourea usage must be take into account the relative costs *vis-a-vis* cyanide. Thiourea consumption is at least twice that of cyanide in the best of circumstances and costs at least four times as much. However, its main attraction could be its relative non-toxicity, its selectivity for the precious metals, specially Au, its superior kinetics and specific applicability in certain circumstances[8].

EXPERIMENTAL

A part of bulk sample (1000 kg) received, was subjected to size reduction carefully in a jaw and followed by roll crushers in closed circuit with a single deck screen to give a crushed product of -6 mesh (ASTM) fraction. The sampling techniques like Jones riffles and coning and quartering methods adopted and representative samples prepared for further studies. Table-2 shows the results of chemical analysis. It indicates that quartz may be the main gangue mineral present in the sample. The mineralogical analysis and modal percentage of grain size of the constituent minerals is shown in Table-3. The results show that the ore is oxidized and gold is present partly in the form of solution in quartz veins as well as in the form of free particles in iron hydroxides specially, hematite which is the product of pyrite oxidation. Fig. 1 shows the results of size fraction analysis and distribution of gold particles in different sieve fractions. The results of sink and float tests is also shown in Table-4. The studies clearly shows that most of the gold particles are distributed in the sizes 500 to 2000 μ and it is supplemented with petrographic investigation.

TABLE-2
CHEMICAL ANALYSIS OF GOLD SAMPLE

Constituents	Weight (%)	Constituents	Weight (%)
SiO_2	84.50	Na_2O	0.0900
Al_2O_3	5.20	K_2O	0.1700
Fe_2O_3	5.00	Au	0.0004
CaO	0.98	Others	3.3600
MgO	0.16	**Total**	**100**

TABLE-3
MODAL ANALYSIS AND GRAIN SIZE OF
THE CONSTITUENT MINERALS

Mineral	Modal (%)	Grain size (μ)
Quartz	84	5-500
Hematite	4	30-80
Calcite	3	70-90
feldespar	3	5-400

TABLE-4
SINK AND FLOAT TESTS ON DIFFERENT SIZE FRACTIONS

Separation densities (g/cm^3)	Weight (%)	Gold (%)	Distribution (%)	Cum. distribution (%)
-2.6	2.5	0.5×10^{-4}	0.34	0.34
2.6-2.7	25.0	0.5×10^{-4}	3.48	3.82
2.7-2.8	39.0	0.8×10^{-4}	8.80	12.62
2.8-2.9	7.5	3×10^{-4}	6.27	18.89
2.9-3.0	10.0	8×10^{-4}	22.29	41.18
3.0-3.1	7.5	10×10^{-4}	20.90	62.08
+3.1	8.0	17×10^{-4}	37.92	100.00
Total	100	3.588×10^{-4}	100	

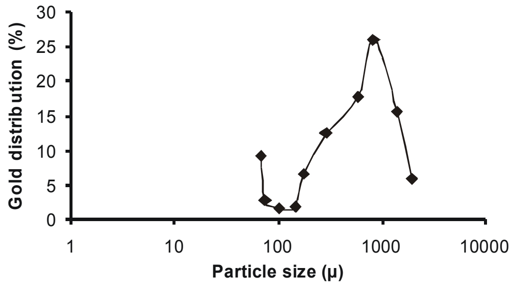

Fig. 1. Distribution of gold particles in different sieve fractions

Standard tests: Sodium cyanide, lime, hydrogen peroxide, thiourea, ferric sulphate and sulfuric acid were all chemicals of reagent grade and the liquid media was distilled water. Before starting the leaching tests, a standard 24 h cyanidation and thiourea leaching were carried out in a reactor stirred at 200 rpm. Leaching was carried out with 1 kg of ore grined to -74 μ using 1 kg/t NaCN with oxidizing agent 1.5 kg/t and run for 24 h at pH 11 per cent solid by weight was 35. The thiourea leaching was carried out with 20 kg/t reagent and ferric sulphate (10 kg/t) and sulphuric acid to ensure an operating pH range of 1.5-2 for 24 h. All the solutions were assayed by conventional atomic absorption spectrophotometry while the residues were fire-assayed. The results indicate that thiourea leaching performs (96.5 % extraction at 16 h) better than (96 % extraction at 24 h) cyanidation.

Leaching experiments: The tests were made with ore crushed carefully to -74 μ at the pH of desired level. Then the cyanide and thiourea were added along with oxidizing agents. Number of parameters like concentration of reagent, pH and oxidizing agent varied separately. All the solutions were assayed by conventional atomic absorption spectrophotometry while the residues were fire-assayed. The optimized results were obtained are shown in Tables 5 and 6 and illustrated graphically in Figs. 2 and 3.

TABLE-5
OPTIMIZED RESULTS OBTAINED USING CYANIDE REAGENT

Recovery after washing (%)	Recovery (%)	$KMnO_4$ (kg/t)	pH	Size of the particle (mm)	NaCN (kg/t)	Leaching time (h)
-	33.4	0.5	11	-74	0. 8	8
-	47.3		11	-74	0. 8	16
-	74.6		11	-74	0. 8	24
96.2	84.1		11	-74	0. 8	28

TABLE-6
OPTIMIZED RESULTS OBTAINED WITH THIOUREA

Recovery after washing (%)	Recovery (%)	Ferric sulphate (kg/t)	pH	Thiourea (kg/t)	Leaching time (h)
–	18.6	10	2	20	240
–	75.1	10	2	20	480
96.4	82.4	10	2	20	720

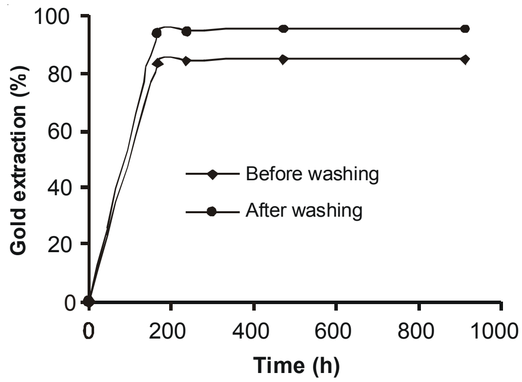

Fig. 2. Conditions of optimized results obtained using cyanide reagent

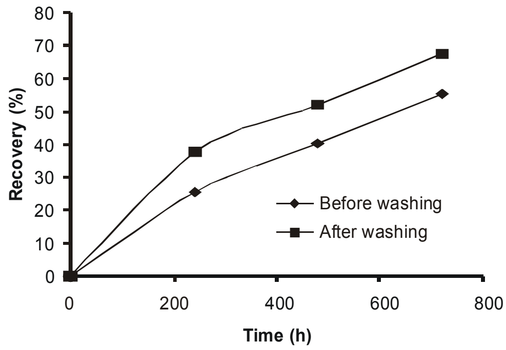

Fig. 3. Conditions of optimized results using thiourea

RESULTS AND DISCUSSION

Table-2 presents high percentage of SiO_2 and petrographic investigation confirms that quartz is the main gangue mineral, in which the gold particles present partly in the form of solution. However some gold particles are also present as inclusions in hematite which is the product of pyrite oxidation. This investigation shows that the ore is not refractory in nature, but is partly in the free state. With reference to Table-4 and Fig. 1 though the most of the gold particles are distributed below 2000 μ, but for comparative studies the ore were ground to -74 μ. Figs. 2 and 3 show that cyanide gave a low yield in compare to thiourea. The tests showed that the best conditions resulted in a gold extraction rate of 96.7 % after 16 h and thiourea consumption of 20 kg/t. The main reason for this performance was related to high leaching kinetics of thiourea[2].

An examination of Fig. 2 indicates that, in an experimental approach at low cyanide content, the leaching kinetics are really poor (47.3 % after 16 h however the 96.2 % of extraction were obtained after 28 h).

The experimental approach used in this part is in agreement with other investigators[2,8].

Conclusion

The authors have drawn the following conclusions: The gold deposits of Neishaboor area of Iran was subjected to characterization and leaching experiments and found that: (i) the ore is oxidized and gold is present partly in quartz as well as in the form of free particles in hematite which is the product of pyrite oxidation (ii) most of the gold particles are distributed in sizes between 500 to 2000 μ for comparative studies the ore were ground to -74 μ (iii) standard tests on samples grind to -74 μ clearly shows that thiourea leaching performs better than cyanidation (iv) agitation leaching on samples ground to -74 μ clearly shows that thiourea performs better than cyanide leaching, which confirms the standard tests.

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