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Acid leaching pretreatment on two-stage roasting pyrite cinder for gold extraction and co-precipitation of arsenic with iron

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ABSTRACT

The leaching recovery of gold is low caused by the arsenic inclusion and gold encapsulation in the two-stage roasting pyrite cinder. It is necessary to pretreat the cinder to improve the recovery of gold. In this study, sulfuric acid was employed to remove arsenic and iron from the cinder, and then the arsenic was transferred to precipitates from the leaching solution by ferric ion precipitation for harmless disposal. The vast majority of the arsenic and iron were leached into the solution at 80 °C under atmospheric pressure. The recovery rate of gold in residue after non-cyanide extraction was greatly improved, and the gold content in residue decreased from 11.2 g/t to 3.8 g/t. The leached iron was partly precipitated by controlling the additive amount of hydrogen peroxide and pH value to precipitate the arsenic. The arsenic concentration in the solution was reduced to about 5 mg/L after 1 h of precipitation. The size of the precipitates was increased to > 100 μm when the pH value was > 5.69. In addition, the precipitates had a strong adsorption capacity to absorb many other impurity ions such as ammonium. This study indicates that the removal of arsenic and iron from cinder is beneficial to increase the recovery of gold, and it is effective to remove the arsenic from the leaching solution through co-precipitation with ferric ion.

1. Introduction

Gold-bearing ores ordinarily contain variable types of arsenic compounds that will interfere with gold extraction efficiency (Eisler, 2004). It is necessary to remove arsenic prior to cyanide leaching, and the most appropriate method is two-stage roasting (Dang et al., 2016). Most of the arsenic in the gold concentrate enters the furnace gas during first-stage roasting, and then it is washed into acid sludge, waste water and sulfuric acid. However, a small amount of arsenic remains in the pyrite cinder (Teofilo et al., 2011.). In addition, the ferric oxide produced during the roasting process may encapsulate ultrafine gold again, and the nonferrous-metal may also affect the leaching efficiency of gold (Dang et al., 2016; Xue and Yu, 2008). Therefore, the cinder is usually pretreated by the chemical methods before the cyanide leaching (Li et al., 2013a, 2013b; Chang et al., 2015). The pretreatment can remove most of the arsenic and harmful elements, but the gold encapsulation can not be opened (Dang et al., 2016). However, the gold grade in cyanide residue is too high with average grade > 4 g/t after cyanide leaching. This high gold cyanide residue as an important secondary resource has been widely studied using the methods of magnetic roasting, chlorination roasting, and so on (Ding et al., 2017; Liu et al., 2013; Wei et al., 2003). Most of these methods are energy consumption and may create new environmental problems. The present work aims to pretreat the two-stage roasted slag using acid leaching method to remove the arsenic and iron in order to open the gold encapsulation.

Acid leaching is one of the methods to pretreat the pyrite cinder, and the arsenic will be leached into solution (Dang et al., 2016; Li et al., 2013a, 2013b). Because the arsenic is a toxic substance that may produce potential risks to environmental and human health for long-term storage, it is necessary to extract arsenic from the solution and do harmless treatment. Arsenic into the water can be treated in various ways including chemical precipitation, adsorption, ion exchange and so on (Kaartinen et al., 2017; Dutré and Vandecasteele, 1995; Müller et al., 2010; Wickramasinghe et al., 2004). The co-precipitation of arsenic with ferric ion is one of the most commonly used methods through neutralization in the form of poorly-crystalline (Müller et al., 2010; Ladeira and Ciminelli, 2004). The adsorption of arsenate ions on the surface of the ferrihydrite is also the importance of arsenic removal by ferric ion (Le Berre et al., 2007). Because the precipitated As (V) is more stable than As (III), it is required to pre-oxidize As (III) to As (V) (Selvin et al., 2002). In general, the co-precipitation with Fe/As molar ratio greater than three under certain pH ranges can provide effective

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Table 1
Chemical composition of the pyrite cinders.

Component	Cu	Zn	Pb	Fe	As	Au(g/t)	Ag(g/t)	S
wt%	0.09	0.05	0.02	18.75	1.52	20.55	18.12	0.24

removal of arsenic in the water (Twidwell et al., 2005; Wang et al., 2017). In this present study, both of arsenic and iron were dissolved into the solution when the pyrite cinder was leached by sulfuric acid. Therefore, the ferric ion in the leaching solution rather than other ferric salts was used to precipitate the arsenic. Batch experiments have been conducted to investigate the precipitation conditions of arsenic from the solution, and the precipitates properties were also studied with a variety of analytical methods.

2. Materials and experimental

2.1. Materials

The pyrite cinder obtained by two-stage roasting process used for this study was collected from one gold smelter in Xinjiang province, China. The chemical composition of valuable elements in this material was determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, optima 8000) and Atomic Absorption Spectroscopy (AAS, WFX-130A), as the results were presented in Table 1.The main chemical compositions of the cinder were determined by X-ray diffraction (XRD, X'Pert PRO MPD) as shown in Fig. 1. According to the analysis results, the main component of the cinder was quartz (SiO_2) and hematite (Fe_2O_3), almost no magnetite (Fe_3O_4). This indicated that this cinder was not easily leached by sulfuric acid because the hematite is not easily leached (Zhang and Zheng, 2006). The arsenic in the cinder mainly existed in the form of arsenic trioxide (As_2O_3) and arsenate (AsO_4^{3-}). Particle size analysis of the cinder was determined by laser particle size analyzer (LS13-320) with the results indicating that 89.3% of the cinder finer than 76 μm.

2.2. Leaching experiment

The pyrite cinder and sulfuric acid with certain concentration were put into a 250 mL erlenmeyer flask heated in a water bath pot at a specific temperature. After stirring for a certain time, the pulp was filtered through a vacuum suction filter. Then, the residue was dried and its composition was determined by XRD, ICP-OES, AAS and SEM-EDS (JSM-7001F + INCA-MAX). The leaching solution was collected for arsenic-removal experiments.

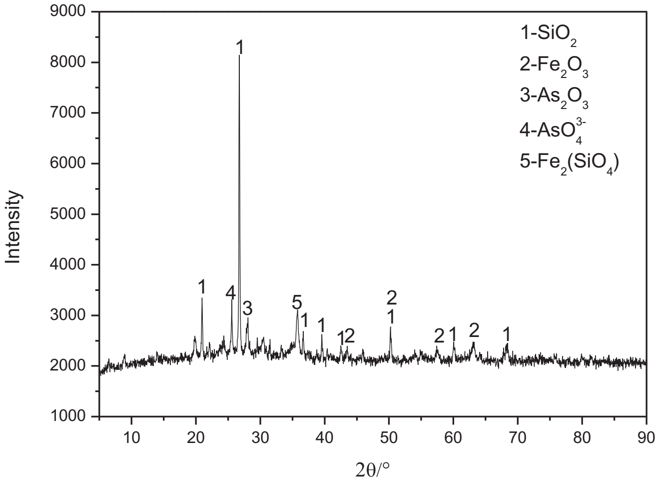

Fig. 1. XRD pattern of the pyrite cinders.

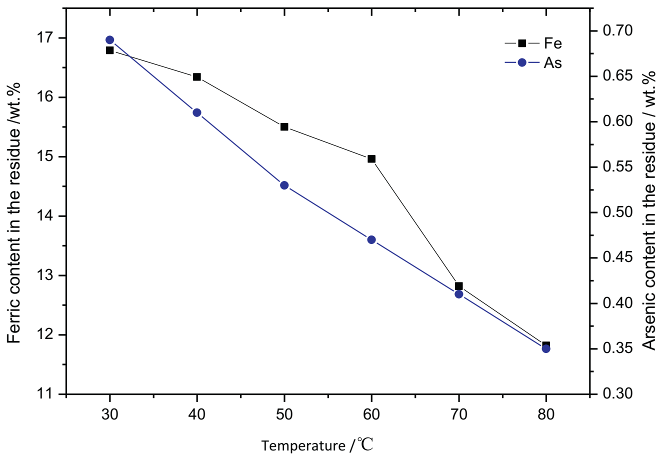

Fig. 2. Effect of temperature on arsenic and iron leaching.

2.3. Arsenic-removal experiment

A specific amount of mixed liquid adjusted pH using ammonia at the temperature of 30 °Cwas taken in an erlenmeyer flask, and put iron power to react with Fe^{3+} and Cu^{2+} at 45 °C. After 6 h, the solid in the solution was filtrated out and the desired pH value was adjusted by adding ammonia. Then, the hydrogen peroxide was added according to the concentration of arsenic and ferric in the solution determined by ICP-OES and AAS for a sure time. After the precipitation, the pulp was filtrated. The concentration of arsenic in the filtrate was determined by ICP-OES, and the leaching residue was analyzed by XRD and SEM-EDS.

3. Results and discussion

3.1. Acid leaching

3.1.1. Effect of temperature on arsenic and iron leached from pyrite cinders

The experimental results shown in Fig. 2 were obtained under different temperatures including 30, 40, 50, 60, 70 and 80 °C. The experimental conditions were kept at 10 vol% H_2SO_4, S:L = 1:5 (solid to liquid ratio), 6 h. The results showed that the iron content of the leaching residue decreased as the temperature increased. The residue still contained 11.8 wt% of iron at 80 °Cafter 6 h leaching. This indicated that the leaching efficiency was not so well because of the lower reactivity of hematite. While the arsenic content in the residue decreased proximately linearly with the temperature increasing, and the content was reduced to 0.35 wt%. Therefore, increasing the temperature is beneficial to the removal of arsenic and iron.

3.1.2. Effect of acid concentration on arsenic and iron leached from pyrite cinders

The effect of acid concentration between 5 and 20 wt% was studied under the conditions of S/L = 1:5, 80 °C, 6 h of leaching time, and the results were presented in Fig. 3. It can be seen that the arsenic and iron content in the residue both decreased as the acid concentration increased. After 6 h leaching, the contents of arsenic and iron were reduced to 0.18 wt% and 4.29 wt%, respectively. Therefore, the concentration of sulfuric acid has a significantly effect on the leaching of iron.

3.1.3. Effect of solid to liquid ratio on arsenic and iron leached from pyrite cinders

To investigate the influence of solid to liquid ratio, leaching tests were performed with the solid to liquid ratio between 1:3 and 1:10, as shown in Fig. 4. While the other conditions were kept at constant: 20 vol% H_2SO_4, 80 °C, 6 h of leaching time. When the S:L was below