



## Recovery of zinc from cyanide tailings by flotation



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### ABSTRACT

The present research investigates sodium hypochlorite, hydrogen peroxide, sodium metabisulfite and copper sulfate as activators to lessen the depressant effect of cyanide. The results indicate that the zinc recovery exceeded 93%, 90%, 85% and 95% at the dosages: sodium hypochlorite 1.5 ml/L, hydrogen peroxide 2 ml/L, sodium metabisulfite  $1.67 \times 10^{-3}$  mol/L and copper sulfate  $2 \times 10^{-3}$  mol/L, respectively. According to the results of FTIR spectrum and zeta potential, it is suggested that the studied marmatite was depressed due to the adsorption of  $CN^-$  on the surfaces of marmatite by chemical bonds, and moreover the afore enhanced activators can present  $Zn-C\equiv N$  bonds on the surfaces of depressed marmatite by oxidation or ionic adsorption, respectively, and hence activate the depressed marmatite for flotation.

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### 1. Introduction

Cyanidation tailings are produced from gold plants that use sodium cyanide as solvent to extract gold (Lv et al., 2015; Zhang et al., 2013b). The gold industry in China has developed rapidly due to an increasing gold demand. China produced 451.799 tons of gold in 2014, up 5.52% over last year. Chinese gold production has been the highest globally for eight consecutive years. Meanwhile, it is estimated that more than 2.45 million tons of cyanide tailings are dumped into tailing ponds every year (Li et al., 2010b; Lv et al., 2015; Wang et al., 2015; Zhang et al., 2013a, 2012). Therefore, about 300 million tons of cyanide tailings have been stockpiled in China, which causes serious environmental pollution, and even death to wildlife (Adams and Lloyd, 2008; Donato et al., 2007; Hewitt et al., 2012; Velásquez-López et al., 2011; Stephen et al., 2009; Zagury et al., 2004). These residues occupy much land, and tailings storage facilities increase production costs of gold enterprises (Donato et al., 2007). In addition, these residues contain many valuable elements, such as zinc, lead, copper and sulfide. For example, cyanide tailings from Gaoyao Hetai Gold Plant (Guangdong Province, China) contains 2.5% Cu, 0.31% Pb, 0.23% Zn and 15.36% Fe (Shi, 2008) and that from Tianshui Gold Plant (Gansu Province, China) contains 1.94% Cu, 5.96% Pb, 0.27% Zn and 24.62% Fe. Therefore cyanidation tailings have been concerned as a secondary resource rather than waste, not only on the

requirements of environmental protection, but also on economic requirements.

Mineral compositions differ across different gold plants, but the total iron content in most cyanide tailings is relatively high. These tailings can be readily recycled using: magnetizing roasting–magnetic separation (Li et al., 2010a; Yang et al., 2011), direct reduction–magnetic separation (Liu et al., 2009; Mawaja et al., 2009) and reduction roasting–water leaching followed by magnetic separation (Zhang et al., 2012). However, due to the depression of cyanide, the other minerals, containing metals such as zinc, lead and copper, are difficult to recycle from cyanide tailings. So the elimination of depressant remaining from initial processing or surface species formed during initial processing which will cause further depression on re-processing is critical for the recovery of these valuable minerals.

This work focuses on the recovery of zinc which mainly exists in the form of marmatite in cyanide tailings. Currently the depression mechanism is not well understood. Some researchers believe that the marmatite surface become coated with an insoluble hydrophilic  $Zn(CN)_2$  compound (Sutherland and Wark, 1955). Other researchers suggest that the formation of  $Zn(CN)_2$  remains in the solution rather than at the marmatite surface due to weak affinities between metal cyanide complexes and the parent mineral. Zinc xanthate complexes are suggested to be responsible for the hydrophobicity of marmatite in the flotation with xanthate (Zhu and Zhu, 1996). It is clear that cyanide can depress the flotation of marmatite. Therefore, in order to recycle zinc from cyanide tailings, it is necessary to eliminate the depressive effect of cyanide.

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In this study, depressed fully liberated marmatite was chosen as the feed to investigate the elimination of depression using the specified activators at different dosages, including sodium hypochlorite, hydrogen peroxide, sodium metabisulfite and copper sulfate. Moreover, the activation mechanisms were investigated by FTIR measurements and zeta potential measurements.

## 2. Experimental

### 2.1. Materials

All reagents used in this study were of analytical grade and locally procured. Pure marmatite was obtained from Zijin Mining Industry Co., Ltd. in Fujian Province, China. The chemical composition of the marmatite is shown in Table 1, and the XRD spectrum is shown in Fig. 1.

Marmatite depressed by free cyanide was made in the laboratory by simulating the gold cyanide leaching process. Marmatite and sodium cyanide 0.4% were added into sealed beaker and stirred at the speed of 1000 r/min at a pH value of 12 for 36 h. After filtration and drying, the obtained residues, termed depressed marmatite, were prepared for subsequent experiments. The depressed marmatite was difficult to float and the recovery was only 4% ( $\pm 1\%$ ) under the conditions: butyl xanthate =  $5.32 \times 10^{-5}$  mol/L, copper sulfate =  $8.01 \times 10^{-5}$  mol/L, 2# oil = 10 mg/L and pH = 10. 2# oil as frother is a kind of compound higher alcohols.

### 2.2. Experimental procedure

All experiments were carried out in a flotation machine equipped with a mechanical stirrer and 40 ml flotation cell. A schematic of the reactor is shown in Fig. 2. For each experiment 10 g of depressed marmatite and 20 ml of distilled water were put into the beaker and then dispersed ultrasonically for 5 min. The sample was left to stand for 10 min before the liquid phase was removed and then the solid phase was diverted into flotation cell. The regulator, activator, collector and frother were added in order. After stirring for 4 min at the speed of 1992 r/min, introduction of air to the cell was made via a hollow standpipe surrounding the impeller shaft, and then the air stream was sheared into fine bubbles by the impeller, these bubbles then rose through the pulp to the surface, where any particles picked up were removed as a mineralized froth. The mineralized froths were scraped by mechanical scraper into the breaker while the pulp remaining in the flotation cell was filtered, dried and weighed. The zinc content was analyzed by ICP-AES.

The recovery of zinc was calculated, as follows:

$$x\% = \frac{m_1 \times x_1}{m_0 \times x_0} \times 100 \quad (1)$$

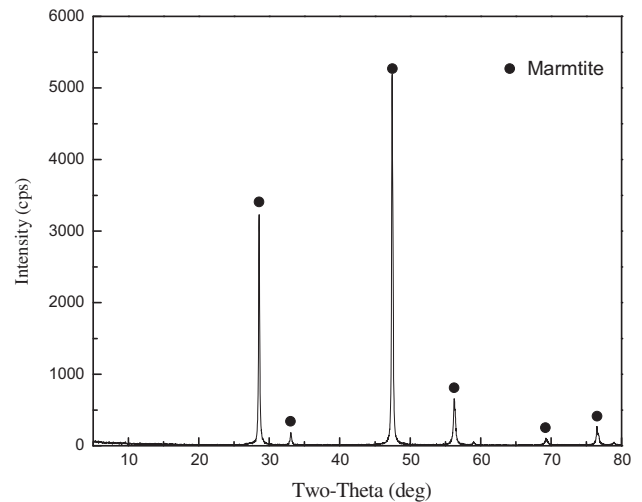
where  $x$  is the recovery of zinc,  $m_1$  is the mass of froth product,  $x_1$  is the fraction of zinc in the mineralized froths product,  $m_0$  is the original mass of depressed marmatite, and  $x_0$  is the fraction of zinc in the original depressed marmatite.

### 2.3. Analysis

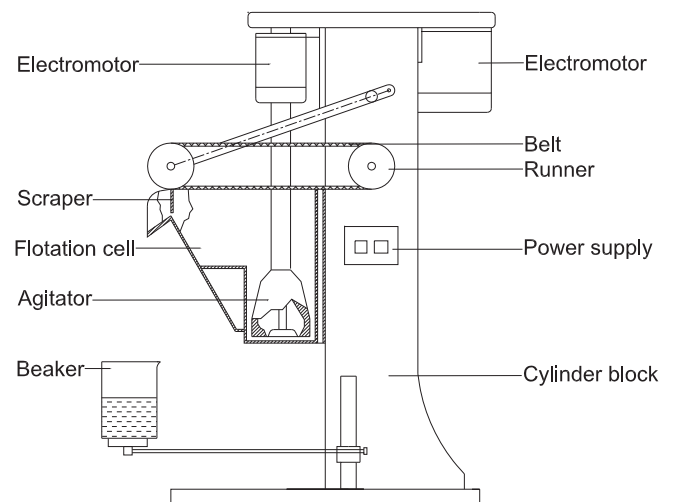
To examine the purity of the monomineral, the sample was analyzed using a Philips X-ray diffractometry with Cu K $\alpha$  radiation generated at 40 kV and 150 mA, X-ray diffraction spectra were obtained over a 5–90°  $2\theta$  range and the diffraction patterns obtained were compared with the JCPDS archives in the PDXL software program. To determine the mechanism of depression, the FTIR spectra of the samples were recorded in the range from 400 to 4000  $\text{cm}^{-1}$  with Thermo Electron Co. Chemical composition

**Table 1**  
Chemical composition of the marmatite (wt.%).

Zn	Fe	S	Purity
53.55	11.03	34.46	99.05



**Fig. 1.** XRD spectrum of the marmatite.



**Fig. 2.** Schematic representation of the reactor.

was analyzed by inductively coupled plasma-atomic emission spectroscopy.

## 3. Results and discussion

Four activators, including sodium hypochlorite, hydrogen peroxide, sodium metabisulfite and copper sulfate, were used to activate depressed marmatite. These reagents were expected to alter the chemical nature of depressed marmatite surfaces so that they became hydrophobic due to the action of the collector.

### 3.1. Effect of sodium hypochlorite on zinc recovery in the flotation process

The effect of sodium hypochlorite on zinc recovery was tested using sodium hydroxide as regulator to make the pH of pulp

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