Effect of galvanic contact on the flotability of galena in the presence and absence of a collector

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ABSTRACT

In this paper, the effect of various electrochemical environments in the galena flotation is investigated. The electrochemical environments consisted of a ball mill for grinding of galena ore and a Denver flotation cell for flotation of galena in the laboratory scale. In order to achieve the maximum recovery with sodium hyposulfite, the concentrations of 0.06 and 0.12 M of air and nitrogen gases have been used to control the pulp potential in the Denver flotation cell. The galena sample was from the "Era mine" which is located in the Kiyasar area, north of Iran. This mine contains: Galena (PbS) at least 22%, Fluorite (CaF_2) 73.37%, Quartz (SiO_2) 2.54% and other minerals such as Cerussite ($PbCO_3$) and Kaolinite ($Al_2Si_2O_5(OH)_4$). Flotation of Galena was conducted in a 0.12 M of sodium hyposulfite solution. It was found that the amount of recovery by this process was 85% and 63% in the presence and absence of potassium amyl xanthate (KAX) and at an estimated potential of 280 to 350 mV respectively while the recovery was 70% and 52% at an approximate potential of 175 to 210 mV in water in the presence and absence of collector (KAX).

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1. Introduction

Any sulfide mineral has a different rest potential and even the same mineral from different regions would have different potentials [1]. The medium of steel grinding, with respect to sulfide mineral has a lower potential [2]. The galvanic contact between the sulfide minerals or grinding media and sulfide minerals would affect the flotation characteristics of such minerals [3]. Given the fact that rest potential of sulfide minerals is greater than that of steel grinding medium, sulfide minerals act as the cathode and steel grinding medium acts as the anode. During grinding process, minerals and steel grinding medium are continuously in contact with each other and thus a galvanic current between these two will occur [4]. The presence of oxygen in pulp will lead to more noble rest potentials [5].

In mineral-mineral interactions, a mineral with higher rest potential acts as the cathode while a mineral with lower rest potential acts as the anode [6]. For multiple mineral-steel grinding medium systems, the galvanic interactions become more complex than two-component systems. These effects are the results of mixed potential [7]. The presence of oxygen also increases the galvanic interactions [8]. The primary cycle of galena oxidation is as follows [9]:

$$PbS \rightarrow Pb^{2+} + S^0 + 2e^- \tag{1}$$

The reaction of galena in an alkaline solution can be expressed as [10,11]

$$PbS + 2H_2O \rightarrow Pb(OH)_2 + S^0 + 2H^+ + 2e^- \tag{2}$$
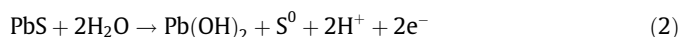
where $Pb(OH)_2$ is as the passive layer on the galena surface.

To minimize galvanic interaction, it is necessary to choose the inert atmosphere grinding such as ceramic or stainless steel mill and balls, nitrogen aeration, grinding minerals separately and an exact combination of the above immediately before flotation [2].

This research investigates the effect of various electrochemical environments in the flotation of galena. The electrochemical environments contained consisted of a ball mill for grinding of the lead bearing sample and a Denver flotation cell for flotation of galena in the laboratory scale.

2. Experimental

2.1. Chemical and mineralogy composition of lead bearing ore

In this investigation, galena bearing sample was provided from the Era mine which is located near the Kiyasar city in the Mazandaran province, north of Iran. The chemical composition of the sample was determined by the XRF method. In addition, the

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mineralogical study was conducted quantitatively and qualitatively by the grain counting method. The results are summarized in Table 1. The results of XRD method showed that the sample consisted of galena (PbS) approximately 22%, Fluorite (CaF_2) 73.37%, Quartz (SiO_2) 2.54%, as the main minerals and other trace minerals such as cerussite ($PbCO_3$) and Kaolinite ($Al_2Si_2O_5(OH)_4$).

2.2. Conditioning and flotation test procedure

The representative sample of ore was ground in steel mill and its size decreased to 100 meshes (150 microns). Flotation tests were carried out with the sample 1 kg in weight and −150 micron in size fraction which was conditioned in 2 liters water in the Denver cell. Consequently, 0.06 and 0.12 M of Sodium hyposulfite ($Na_2S_2O_4$) solution was used to control the pulp potential. It was prepared before each experiment. Potassium Amyl Xanthate (KAX) was used in flotation tests as a collector. This collector was crystallized twice from acetone and kept in cool place. The optimum concentration of collector was 1000 g/t of mineral in each experiment. In addition, Pine oil was used as a frother in the flotation tests. Sodium bicarbonate (Na_2CO_3) and sulfuric acid (H_2SO_4) were used to stabilize and control the pH in the flotation medium. The gases that were used in the flotation experiments were air and nitrogen. A platinum electrode E_h meter was used to monitor the pulp potential during the conditioning stages and the flotation tests. The error was ±20 mV for control of pulp potential in oxidizing or reducing potential. The flotation recovery was calculated either by weighing of the concentrate and waste or by metallurgical calculations.

In all flotation tests, the Denver flotation machine was used. The potential (reduction-oxidization (Redox)) values were monitored using an E_h/pH meter and also pH was measured with the same electrode which is connected to the double purpose unit. The pulp potential was low in the grinding circuit because it was in the reduction condition. Therefore, pulp potential increased with aeration during flotation. The potentials between anode and cathode were adjusted with aeration of nitrogen or using sodium hyposulfite, respectively. As an example, Fig. 1 shows the pulp potential measurements in the conditioning stages and the flotation test which included 10 stages as follows:

Stage 1. The pulp potential was 233 mV after 7 min of grinding times and 2 minutes of agitation in the Denver flotation cell.
Stage 2. The pH of the pulp was adjusted to pH = 8.5 by sodium bicarbonate for 5 minutes and the conditioning potential reached 189 mV.
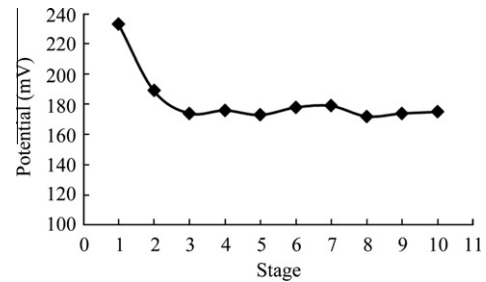
Table 1
Chemical and mineralogical compositions of the galena bearing sample.

Method	Composition	Quantity (%)
XRF	Al_2O_3	0.49
	SiO_2	2.57
	Fe_2O_3	0.26
	NaO_2	0.19
	MgO	0.27
	LOI	0.24
	Ca	37.35
	F	35.46
	Pb	20.15
	S	3.02
	Total	100
XRD	Galena (PbS)	22.03
	Fluorine (CaF_2)	73.37
	Quartz (SiO_2)	2.54
	Cerussite & kaolinite ($PbCO_3$, $Al_2Si_2O_5(OH)_4$)	2.06
	Total	100

Fig. 1. Pulp potential in the flotation test during conditioning stages.

Stage 3. Sodium silicate (Na_2SiO_3) was added as dispersant in dosage 500 g/t. The conditioning time was 7 min and the pulp potential reached 175 mV.
Stage 4. Potassium amyl xanthate (KAX) was used as a collector in dosage 250 g/t and the conditioning time was 2 min and the pulp potential was 176 mV.
Stage 5. Adding 100 g/t of pine oil as a frother to pulp and conditioning time was 1 min in this stage and also in the beginning of aeration, potential was 173 mV.
Stages 6 to 10 include froth gathering process.

3. Results and discussion

3.1. Electrochemical processes in electrolyte and in the galena surface

Most of the metals and minerals will be corroded severely when they get in galvanic contact with an electrolyte. This corrosion is attributed to the surface of minerals or metals interested to galvanic interaction. Electrolyte compound, minerals environment, current velocity, concentration of dissolved gases and many of factors affect on the potential. Therefore, the electrochemical potential changed over the surface of the mineral [1].

The potentials for the sulfite-sulfate and hyposulfite-sulfate systems can be determined from the Nernst equations as given below [2]:
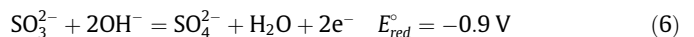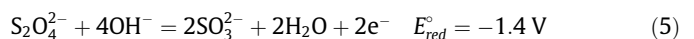
(a) Hyposulfite-sulfate system:

$$E_h = +0.252 - \frac{0.059}{2} \log \frac{[S_2O_4^=]}{[SO_2^=]^2} - 2(0.059)\text{pH} \tag{3}$$

b) Sulfite-sulfate system:

$$E_h = -0.074 - \frac{0.059}{2} \log \frac{[SO_3^=]}{[SO_4^=]} - 0.059\text{pH} \tag{4}$$

In such systems, the following chemical reactions may occur in the platinum electrode [11]:

$$S_2O_4^{2-} + 4OH^- = 2SO_3^{2-} + 2H_2O + 2e^- \quad E_{red}^\circ = -1.4\,\text{V} \tag{5}$$

$$SO_3^{2-} + 2OH^- = SO_4^{2-} + H_2O + 2e^- \quad E_{red}^\circ = -0.9\,\text{V} \tag{6}$$

Processes that occur on the surface of mineral in the electrolyte are such that in the anodic parts, which have electronegative potential, free electrons, are transferred from anode to cathode. On the surface of cathode, the electrons are collected by means of a reducing factor [2]. In general porosities, cracks, scratches, course of the surface and finally small parts of the mineral surface are anodic [9].

The reaction on the surface of galena in a steel-galena medium depends on the galvanic contact in the grinding circuit. On the galena surface (as a cathode) the absorbed oxygen is reduced according to Reaction 7 [10]:

$$O_2 + 2H_2O + 4e \rightarrow 4OH^- \tag{7}$$