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Selective flotation of scheelite from calcite and fluorite using a collector mixture

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ABSTRACT

Collector 733, a sodium soap ($C_{12-16}COONa$) is widely used industrially for scheelite flotation. Low selectivity of 733 collector is always observed. In this study, a collector mixture of 733 and MES (sodium fatty acid methyl ester sulfonate) demonstrated a high selectivity for the flotation of scheelite from calcite and fluorite. An optimal mass ratio 4:1 of 733:MES was found, producing a 65.76% WO_3 concentrate grade with a recovery of 66.04% from a feed material containing only 0.57% WO_3. In addition, the effect of water hardness and water glass addition were studied. The results indicated that the presence of Ca^{2+} or Mg^{2+} had little effect on the adsorption of the collector mixture at the scheelite surface. Addition of water glass for depressing calcite and fluorite had no significant effect on the adsorption of the collector mixture on the scheelite surface. The advantages of this new collector mixture (733+MES) include lower cost, low dosage, high tolerance against water hardness and high selectivity, and this collector mixture has great potential for industrial application.

1. Introduction

The flotation separation of scheelite from other calcium-containing minerals such as fluorite and calcite, is problematic, due to their similar solubility and the same active Ca^{2+} site for interaction with anionic collectors (Rai et al., 2011). Thus, using a single type of collector is unlikely to achieve selective flotation of scheelite from fluorite and calcite.

Collector 733, a sodium soap of fatty acids ($C_{12-16}COONa$) made from oxidized paraffin, is widely used industrially for scheelite flotation (Li et al., 2010; Huang et al., 2010; Meng et al., 2007). However, using 733 as collector, a large amount of water glass (WG), i.e. sodium silicate, must be added to depress the calcite and fluorite and to achieve selective separation. However, excessive WG in the pulp also reduces the floatability of scheelite, requiring an increase in the dosage of collector 733 to achieve a satisfactory concentrate grade and recovery.

A more selective collector, with low cost and dosage, is required for scheelite flotation. A collector mixture is a good choice for this purpose. Recent research showed that, the flotation separation efficiency of Ca minerals could be enhanced using a mixture of anionic collectors with nonionic reagents, and collector mixture demonstrated three synergetic effects, namely enhanced mineral recovery, improved adsorption behavior of the main collector on the target mineral surface, and enhanced adsorption selectivity (Filippov et al., 2012).

In this study, sodium fatty acid methyl ester sulfonate (MES), was considered as an assistant collector, as MES is a low cost, low irritation and low toxicity reagent with biodegradability and high tolerance against water hardness. An attempt to improve the selectivity for the flotation of scheelite from calcite and fluorite was made using a collector mixture of MES and collector 733. The mechanism of the selective separation was investigated through zeta potential measurement.

2. Materials and methods

2.1. Pure minerals and reagents

Pure fluorite and calcite were sourced from Fujian, China; and scheelite from Qinghai, China. X-ray powder diffraction data confirmed that the scheelite, fluorite and calcite samples were 95%, 99% and 99% pure, respectively. The −74 μm fraction was used in the flotation tests. Samples further ground to −5 μm in an agate mortar were used for zeta potential measurements.

The sources of flotation reagents were as follows: analytical grade MES ($RCH(SO_3Na)COOCH_3$, $R = C_{16-18}$) from Kemiou Chemical Research Institute, Tianjin, China; Technical grade 733 ($C_{12-16}COONa$) and WG ($Na_2O{\cdot}2.4SiO_2$) from the Zhuzhou Flotation Reagents Factory, Hunan, China. The pH was adjusted with NaOH or HCl stock

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solutions. Deionized water with a resistivity of more than 18 MΩ × cm was used for all experiments.

2.2. Flotation experiment

Single mineral flotation tests were carried out in an XFG flotation machine with a 40 mL plexiglass cell, at an impeller speed of 1800 rpm. The mineral suspension was prepared by adding 3.0 g of minerals to 40 mL of distilled water. The pH of the mineral suspensions was first adjusted by adding NaOH or HCl. Once the desired reagent was added, the suspension was agitated for 3 min and the pH measured before flotation. The flotation lasted for 4 min before the products were collected, dried, and weighed. The recovery was calculated based on the weights of the dry products obtained.

2.3. Zeta potential measurement

Zeta potential measurements were conducted at 20 °C using a Coulter Delsa-440SX zeta potential analyzer (Brookhaven Corporation, USA). Mineral suspensions containing 0.01% solids were conditioned in a beaker for 15 min at a given pH and a collector concentration in a 1×10^{-3} mol/L KNO_3 background electrolyte solution.

3. Results and discussions

3.1. Single mineral flotation experiment results

Firstly, the flotation separation using 733 or MES at a dosage of 50 mg/L were evaluated by single mineral test. Flotation results show that, the preferred pulp pH ranges using 733 and MES as individual collector for scheelite flotation are 9–11 and 8–11, respectively, as shown in Fig. 1. pH 10 was further used for all flotation tests.

As shown in Fig. 2(a), using 733 alone as collector and WG as depressant, selective scheelite flotation could be achieved when the WG concentration is higher than 3×10^{-3} mol/L. However, the scheelite recovery is only about 40%. Fig. 2(b) shows that MES+WG cannot achieve selective separation of the three minerals from each other, but a scheelite recovery of above 60% is possible when WG concentration is below about 3×10^{-3} mol/L. A WG concentration of 3×10^{-3} mol/L was subsequently used for all flotation tests.

From Fig. 2(a) and (b), it can be noted that scheelite has better floatability with MES+WG than 733+WG, indicating that MES is a better collector for scheelite than 733. Also, 733+WG shows better selectivity for scheelite than MES+WG.

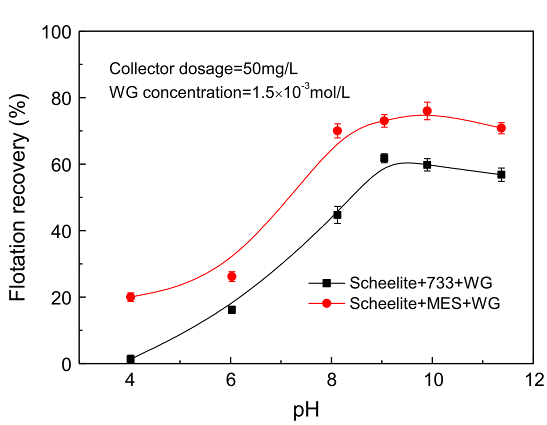

Fig. 1. Effect of pulp pH on scheelite flotation using 733 or MES as collector and WG as depressant.

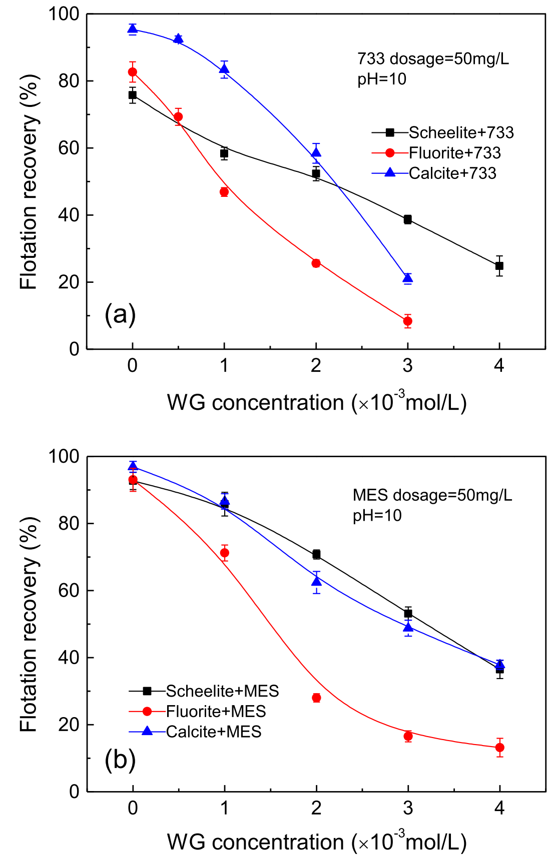

Fig. 2. Effect of WG dosage on flotation behavior of three minerals using 733 (a) or MES (b) as collector.

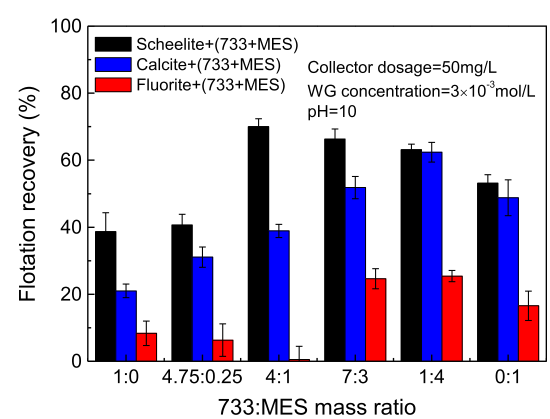

Fig. 3. Effect of mass ratio of 733+MES on flotation behavior of scheelite, fluorite and calcite.

The flotation behavior of scheelite, fluorite and calcite individually using a collector mixture of 733 and MES at different mass ratio was investigated. A series of flotation results demonstrate that the collector mixture of 733 and MES at a mass ratio of 4:1 achieves the best flotation separation performance, as shown in Fig. 3. Scheelite has a favorable recovery of 70%. However, the recovery of calcite and fluorite are 39% and 1%, respectively. Compared with the results using 733 collector as shown in Fig. 2(a), marked differences in the recovery of three minerals implies that the flotation separation performance is improved using 4:1 collector mixture 733+MES.