



Enhancing the sulfidation of smithsonite by superficial dissolution with a novel complexing agent



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ABSTRACT

Sodium sulfosalicylate was used for the first time to enhance the sulfidation–flotation of smithsonite. Sodium sulfosalicylate could facilitate the flotation of smithsonite, and increase the flotation recovery by ~28%. Inductively coupled plasma analysis indicated that the surface dissolution of the enhanced sulfurized smithsonite decreased significantly. X-ray photoelectron spectral analysis revealed that smithsonite can be sulfurized easily by using sodium sulfide with sodium sulfosalicylate. The effect of sodium sulfosalicylate on zinc-oxide ore flotation has been verified. Compared with the direct sulfidation–flotation of zinc-oxide ore, enhanced sulfidation–flotation can improve the concentrate grade by 3.83% and the concentrate recovery by 7.63%. Therefore, the addition of sodium sulfosalicylate played a significant role in smithsonite sulfidation, which improves the flotation performance.

1. Introduction

In nature, ores used for zinc recovery can be divided into zinc-sulfide and zinc-oxide ores (Rey, 1953). Zinc-oxide ores are an important part of zinc resources. Smithsonite is found commonly in zinc-oxide ores. The exploitation and use of zinc-oxide ore has become inevitable as a result of the increasing demand for zinc.

Sulfidation–flotation is used to concentrate zinc-oxide minerals from oxide ores. The process involves sulfurizing the oxide ore with sulfur dioxide, sulfide ions, or metabisulfite ions (Keqing et al., 2005), which allows for known sulfide collectors to concentrate the targeted base-metal oxide. Flotation of smithsonite by sulfidation has been a significant research topic in China and other countries (Bustamante and Shergold, 1983; Ejtemaei et al., 2011; Ejtemaei et al., 2014; Hales and Frost, 2008; Herrera-Urbina et al., 1998; Hosseini and Forssberg, 2006a, 2009; Irannajad et al., 2009; Kashani and Rashchi, 2008; Pereira and Peres, 2005; Rao and Finch, 2003; Shi et al., 2012; Wu et al., 2015c). Although amine or xanthate is used in smithsonite sulfidation–flotation (Ejtemaei et al., 2011; Hosseini and Forssberg, 2006a, 2006b, 2007, 2009; Irannajad et al., 2009; Önal et al., 2005), because these two methods have shortcomings, they are not used extensively in the industry. Moreover, sulfidation–amination flotation is difficult to achieve because this process is affected by slime, which requires

chemical treatment. Pre-desliming of sulfidation–amination flotation is necessary to obtain a stable production and to ensure a high recovery rate. However, pre-desliming causes substantial zinc loss (Hosseini and Forssberg, 2011; Kiersznicki et al., 1981). The surface of sulfurized smithsonite requires a more complete sulfidation–xanthate flotation process. However, it is difficult to achieve such a process on the sulfurized smithsonite surface. After sulfidation, sulfidation–xanthate flotation also requires copper-ion activation. Therefore, the recovery rate of smithsonite through sulfidation–xanthate flotation is lower than that through sulfidation–amination flotation. Previous research has shown that smithsonite recovery is 81.3% when using potassium amyl xanthate and the recovery of smithsonite is 94% when using dodecylamine, respectively (Hosseini and Forssberg, 2006a, 2006b). However, the influence of slime on sulfidation–xanthate flotation is much smaller than sulfidation–amination flotation. Thus, a xanthate collector was used in this study. We aimed to optimize the surface sulfidation of smithsonite, which is a key factor in improving the sulfidation–flotation of smithsonite.

In recent years, an increasing number of acids have been used to improve mineral floatability (Parapari et al., 2016). Surface dissolution is a method that has been used to modify mineral surfaces and create differences in their flotation behavior (Abeidu, 1974; Bulatovic and Wyslouzil, 1999; Liu et al., 2006; Torem et al., 1992; Zhu et al., 2011).

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Surface dissolution changes the distribution and states of elements on the mineral surface, which affects the surface properties of mineral (Parapari et al., 2016). To the best of our knowledge, a study that uses sodium sulfosalicylate as the complexing agent to improve smithsonite floatability has not been conducted. Sodium sulfosalicylate is an organic complexing agent that has been used because of its good water solubility, stability, non-toxicity, and strong coordination ability with transition and heavy metals. Metal-complexing compounds that are produced by sodium sulfosalicylate and metal ions usually have a higher stability and selectivity. Thus, sodium sulfosalicylate has been used extensively for chemical analysis. The water-soluble complexing compounds produced by sulfosalicylic acid and metal ions on the mineral surface can increase or accelerate the metal ion dissolution and promote the formation of multilayer collector absorption, which causes mineral activation. These dissolved sulfosalicylic acid ions will degrade the smithsonite and other oxidized ores to form $M(SSA)_2^{2+}$ (Wang et al., 2004a, 2004b; Wu et al., 2015a, 2015b). However, sulfidation causes these compounds to form MS more readily than through metal-oxide sulfidation, which results in more active sights for collector binding and improves the flotation performance.

We aimed to prove this theory and investigate the effect of sodium sulfosalicylate on smithsonite sulfidation and flotation using microflotation, inductively coupled plasma (ICP) analysis, zeta potential measurements, and X-ray photoelectron spectroscopy (XPS).

2. Materials and methods

2.1. Materials and reagents

Smithsonite and zinc-oxide mineral samples were from Yunnan, China. The smithsonite sample was ground in an agate mortar. The coarse fraction ($-74 \mu\text{m} + 19 \mu\text{m}$) was used in the microflotation experiments. Mineralogical analysis of the smithsonite sample was conducted using a Rigaku D/max 2550VB + 18 kW powder diffractometer with a $\text{Cu}/\text{K}\alpha$ X-ray source at 40 kV and 40 mA with the results as shown in Fig. 1. The ore sample consisted of smithsonite and calcite. The chemical composition of smithsonite is presented in Table 1. Phase analysis is a method that uses different solvents to allow various phases to achieve selective separation, and we use chemical or physical methods to determine the composition or structure. The multielement chemical and zinc-phase analyses indicated that the zinc-oxide ore contained 6.5% Zn and the main associated minerals of smithsonite were calcite and quartz. The multielement chemical and zinc-phase analyses are shown in Tables 2 and 3, respectively.

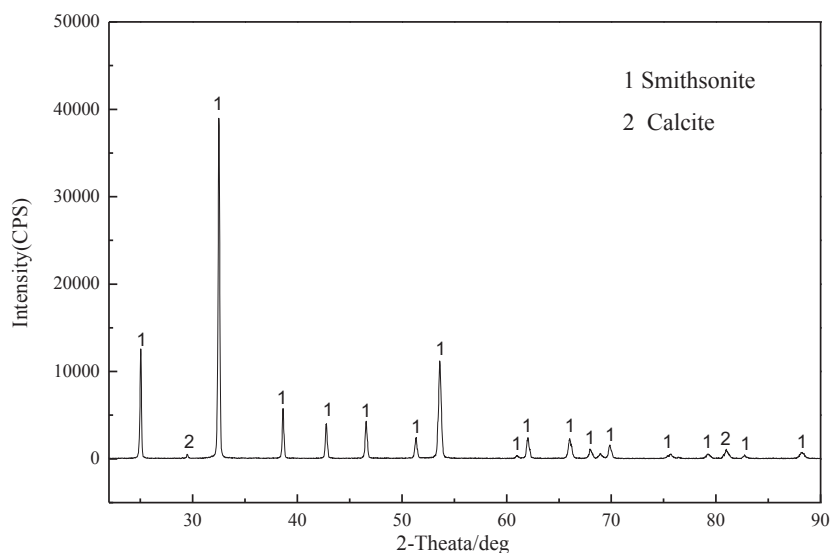


Fig. 1. X-ray diffraction pattern of the original smithsonite.

Table 1
Chemical composition of the pure smithsonite used in experiments.

Element	Zn	Fe	CaO	Al ₂ O ₃	Pb	Cd	SiO ₂
Content (%)	49.42	0.24	1.14	0.17	0.34	0.75	0.54

Table 2
Multielement chemical analysis of the zinc oxide ore.

Element	Zn	S	Pb	Fe	CaO	Al ₂ O ₃	Cd	SiO ₂
Content (%)	6.50	2.53	0.48	7.27	9.86	4.50	0.15	38.54

Table 3
Chemical analysis of zinc phase.

Phase	Smithsonite	Willemite	Sphalerite	Others	Zinc total
Content (%)	3.74	0.61	2.13	0.02	6.50
Distributive law (%)	57.54	9.38	32.77	0.31	100

Sodium sulfosalicylate was selected as the complexing agent. $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ was added as a sulfidizing agent, $\text{CuSO}_4\cdot 5\text{H}_2\text{O}$ was added as an activator, and commercial-grade sodium isoamylxanthate was used as the collector. All reagents, except for sodium isoamylxanthate were of analytical grade. Deionized water was used throughout.

2.2. Microflotation tests

Microflotation experiments were conducted under mechanical agitation in a 50-mL flotation cell. The mineral suspension was prepared by adding 5.0 g of pure smithsonite to 40 mL solutions. The desired amounts of sodium sulfosalicylate solution of various concentrations were added into the pulp solution for 5 min. Freshly prepared $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ solution was added to sulfurize the smithsonite surface for 5 min. The pulp pH was adjusted to 10.5. $\text{CuSO}_4\cdot 5\text{H}_2\text{O}$ solution was added into the pulp solution for 3 min. The pulp was conditioned with sodium isoamylxanthate (NaIX) for 3 min and floated for 5 min. After the flotation tests, the concentrate and tailings were filtered and dried before weighing. The flotation recovery was calculated based on the solid mass distribution between the two products. Microflotation tests were conducted in duplicate. Error bars on figures show standard error between duplicate tests.

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