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Sodium carbonate effects on the flotation separation of smithsonite from quartz using N,N′-dilauroyl ethylenediamine dipropionate as a collector

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ABSTRACT

To improve the flotation separation efficiency of smithsonite from quartz using N,N′-dilauroyl ethylenediamine dipropionate (DNET) as a collector, sodium carbonate was used as a regulator. Single-mineral flotation results indicated that more than 97.36% of smithsonite was floated when DNET was used as a collector at a concentration of 200 mg/L. However, artificially mixed minerals were poorly separated during the activation of quartz with Zn(II) due to smithsonite dissolution. Sodium carbonate could inhibit the dissolution of smithsonite and thus improve the flotation separation of smithsonite and quartz. The results of artificially mixed mineral separation showed that a concentrate with 89.7% Zn recovery and 36.6% Zn grade could be obtained when the DNET concentration was 50 mg/L at a slurry pH of 10.45. To clarify the action of sodium carbonate during the separation process, zeta potential measurements, Fourier transform infrared (FTIR) spectroscopic analysis, and zinc ion concentration measurements were carried out. In addition, the results indicated that sodium carbonate could inhibit the solubility of smithsonite, and thus, the activation of quartz was prevented during the interaction of CO_3^{2-} with dissolved Zn(II), thereby improving the separation results.

1. Introduction

Zinc metal holds an important status and value in modern industry (Feng et al., 2016; Jia et al., 2017; Shi et al., 2013). Zinc ores, which are classified into sulfide and non-sulfide ores, are the main source for zinc metal. Zinc sulfide ores are easily separated from gangue minerals and have been primary zinc sources for a long time. Currently, zinc oxide ores are attracting increasing interest from researchers as a means to meet the demand for zinc resources due to the over-exploitation of zinc sulfide ores (Liu et al., 2012; Shi et al., 2013). Froth flotation is one of the most effective processing methods to concentrate zinc oxide ores due to the limited leaching of low-grade zinc oxide (Hurşit et al., 2009; Zhang et al., 2013).

The gangue minerals in zinc oxide ores include quartz, dolomite, pyromorphite, and iron oxide (Ejtemaei et al., 2014). Quartz, as a primary gangue mineral in zinc oxide ores, exhibits favourable floatability whether the collector is a cationic or anionic surfactant. Cationic collectors can adsorb on quartz surfaces via electrostatic interaction, and anionic collectors can adsorb on activated quartz surfaces, which inhibits the flotation process (Abaka-Wood et al., 2017; Fuerstenau et al., 1985; Liu et al., 2018; Xu et al., 2018). Therefore, many studies have sought to eliminate the negative effects, for example, by the adjustment of slurry pH, adoption of different collectors, or addition of inhibitors (Li et al., 2017; Tian et al., 2017; Vidyadhar and Hanumantha, 2007). In addition, these studies have shown that flotation reagents have a vital impact on quartz separation.

In the flotation separation of smithsonite and quartz, the biggest challenge is the poor selectivity of the collector due to the adsorption of metal ions on the quartz surface. When using a primary amine as a collector to treat tailings and sodium hexametaphosphate as a quartz depressant, a concentrate with 70% zinc recovery and 40% zinc grade could be obtained (Kashani and Rashchi, 2008). M. Irannajad studied the effects of sodium hexametaphosphate and sodium silicate as depressants on the selective flotation of smithsonite and quartz. The results showed that the optimal inhibitory effect was obtained when the quantity of sodium hexametaphosphate was 1250 g/t and that of sodium silicate was 1500 g/t (Irannajad et al., 2009). To weaken the influence of metal ions, various reagents have been investigated to depress quartz. When using oleic acid as a collector to float quartz activated by Zn(II), sodium silicate, sodium fluoride, and starch cannot depress quartz effectively. In addition, quartz can be depressed by adding sodium sulfide, sodium hexametaphosphate, and CMC as depressants. Meanwhile, sodium sulfide and sodium hexametaphosphate cause a negative effect on the flotation of smithsonite, while CMC has little effect (Ejtemaei et al., 2012).

Both sodium carbonate and sodium hydroxide can serve as pH-

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Table 1
Chemical analysis of smithsonite and quartz (wt.%).

Sample	Composition					
	ZnO	TFe	Pb	SiO_2	Pb	CaO
Smithsonite	62.43	0.44	1.12	1.08	0.044	0.46
Quartz	—	< 0.01	—	99.36	—	0.004

adjusting reagents in conventional flotation. Rahimi discovered that sodium carbonate could enhance the selectivity of collectors in some cases; however, there are few reports about the effect of sodium carbonate during smithsonite flotation (Rahimi et al., 2017; Wang et al., 2016). In this paper, micro-flotation tests for pure and mixed minerals were conducted to investigate performance and behaviour when using DNET as a collector. Zeta potential measurements, FTIR analysis, and zinc ion concentration measurements were carried out to determine the inhibitory mechanism of sodium carbonate.

2. Materials and methods

2.1. Materials and reagents

Pure smithsonite and quartz ores were obtained from Guangxi Province and Liaoning Province, China, respectively. To obtain pure mineral samples, the ores were handpicked, crushed, ground and gravity separated. Then, the products were sieved to obtain the −100 μm +15 μm fraction for flotation tests. The chemical analysis (Table 1) shows that the content of smithsonite and quartz was 96.34 wt.% and 99.36 wt.%, respectively. The XRD results (Fig. 1) prove that the main minerals in the samples were smithsonite and quartz.

The activator zinc chloride ($ZnCl_2$) was purchased as chemically pure from Tianjin Kermil Chemical Reagents Development Centre and prepared as a 1 g/L solution. Chemically pure sodium hydroxide (NaOH), hydrochloric acid (HCl) and sodium carbonate (Na_2CO_3) were used to adjust the slurry pH. The collector was a Gemini surfactant, N,N′-dilauroylethylenediamine dipropionate (DNET), synthesized in a lab according to the literature (Hu-Jun et al., 2004). Deionized water was used in all experiments.

2.2. Micro-flotation experiments

Single-mineral flotation experiments were conducted in an XFG flotation machine at a rotating speed of 1992 rpm. In each test, 2.0 g pure mineral sample and 30 mL deionized water were added to a 40 mL cell. After 2 min conditioning, the suspension was adjusted to the desired pH for 2 min by 0.1 mol/L HCl, 0.1 mol/L NaOH, or 3g/L Na_2CO_3. Then, Zn(II) ions were added as the activator. After 2 min, the collector DNET was added, and flotation was conducted for 3 min. The froth products and tails were weighed after filtering and drying, and the recovery was calculated, with the largest standard deviation being 1.72%.

For flotation experiments using artificially mixed minerals, 4.25 g quartz and 0.75 g smithsonite samples were weighed and placed in a 40 mL cell with 30 mL deionized water, and the suspension was stirred for 2 min. After adding the HCl, NaOH or Na_2CO_3 solution to adjust the slurry pH, the slurry was stirred for 2 min. The collector was added into the cell and conditioned for 3 min. Flotation was carried out for 4 min, and the concentrate and tails were filtered, dried, and weighed. Finally, the grade was tested, and recovery was calculated. To ensure the validity and reliability of experimental flotation data, at least three individual measurements were performed, and the average recovery and grade were calculated. In addition, the results reported along with the standard deviation. The average standard deviation was 1.2%.

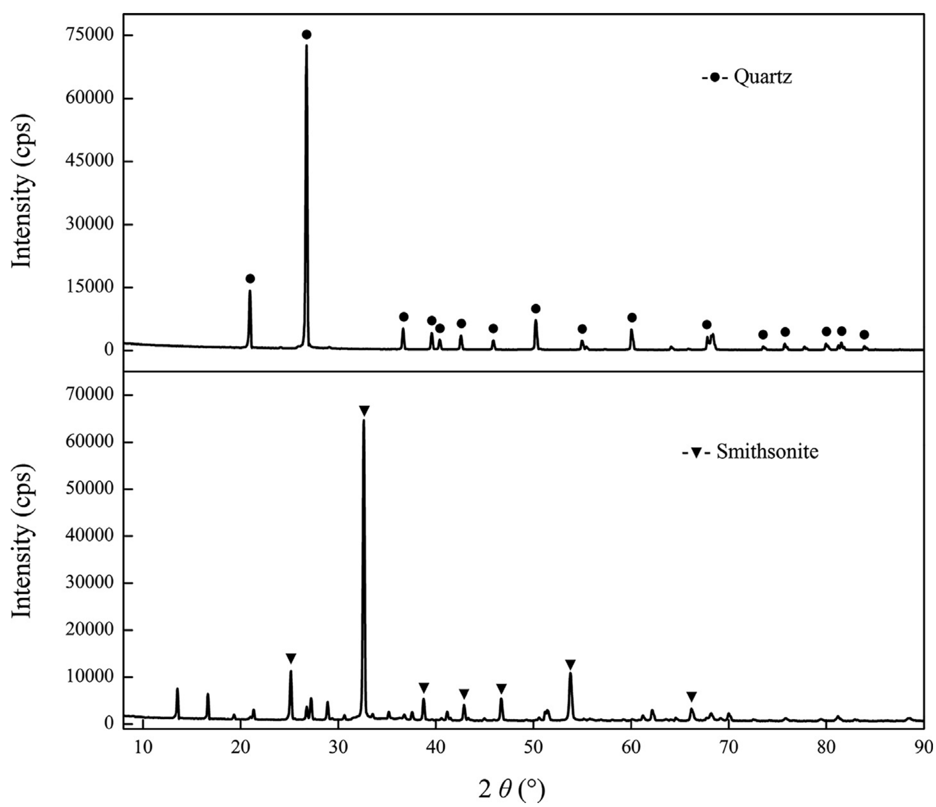

Fig. 1. X-ray diffraction patterns of smithsonite and quartz.