

# Selective flotation of scheelite from calcite: A novel reagent scheme



Yuesheng Gao, Zhiyong Gao\*, Wei Sun, Yuehua Hu\*

School of Minerals Processing and Bioengineering, Central South University, Changsha 410083, China

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## ABSTRACT

Sodium oleate (NaOl) has been widely used as a collector for the scheelite flotation. However, low selectivity of NaOl and large amount of sodium silicate (SS) needed remain tough problems. In this study, octyl hydroxamic acid (HXMA-8) was used as an associate collector with NaOl in scheelite flotation. The flotation tests showed that a novel reagent scheme, i.e., a lower dosage of SS (300 mg/L) and mixed collectors of HXMA-8 + NaOl (total concentration  $4.5 \times 10^{-4}$  mol/L, preferred mass ratio of 1:2) achieved the selective separation of scheelite from calcite. Zeta potential measurements indicated that the depressant, SS, adsorbed more strongly on calcite surface than on scheelite surface. HXMA-8 adsorbed significantly on scheelite surface either in the absence or presence of SS by chemical bonding between oxygens of HXMA-8 and surface metal ions. NaOl also adsorbed on both mineral surfaces by chemisorption, but the adsorption on calcite surface was influenced adversely by the presence of SS.

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## 1. Introduction

Scheelite, as an important tungsten-bearing mineral, is nowadays utilized mainly by flotation (Bo et al., 2015; Gao et al., 2015a, 2015b; Yin and Wang, 2014). In ore deposits, scheelite always coexists with other calcium-containing minerals such as calcite and fluorite. Owing to the same Ca active sites on their cleavage planes (Rai et al., 2002), the commonly used fatty acid anionic collector, such as sodium oleate, can strongly collect all of them and exhibit little selectivity. Cationic collectors, such as amine (Hiçyılmaz et al., 1993) and quarternary ammonium (Hu et al., 2011; Yang et al., 2015) and collector mixture (Gao et al., 2015a, 2015b) have been used to improve the scheelite flotation.

Moreover, hydroxamate collectors, such as benzohydroxamic acid (Xian et al., 2001; Yin and Wang, 2014), naphthenic hydroxamates (Zhao et al., 2013) and amide hydroxamate (Deng et al., 2016), were also used for scheelite flotation in recent years. In fact, alkyl hydroxamates have been proved to be the selective and effective collectors for various of minerals, such as cassiterite (Sreenivas and Padmanabhan, 2002), kaolin clay (Yoon et al., 1992), bastnaesite (Fuerstenau, 1983), mixed copper oxide and sulfide minerals (Lee et al., 2009; Lee et al., 1998). Those reports indicated that the -CONHOH group in hydroxamates exhibits a strong chelating ability with metal ions exposed on the mineral surfaces. Till now, however, few work has been focused on alkyl hydroxamate as a collector for scheelite flotation.

Recent work showed that, octyl hydroxamic acid (HXMA-8), one kind of alkyl hydroxamic acids, can achieve the separation of fluorite

from calcite and apatite with a higher selectivity compared with conventionally used oleate (Pradip et al., 2002; Pradip and Rai, 2003). In this work, HXMA-8 was considered as an associate collector with oleate to improve the selectivity of scheelite flotation from calcite. The mechanism of the selective separation was studied by zeta potential measurement.

## 2. Materials and methods

### 2.1. Experimental minerals and reagents

Pure scheelite crystals were obtained from Sichuan, China, and calcite from Fujian, China. XRD spectrums (showed in Fig. 1) confirmed that the scheelite and calcite samples were over 98% and 99% pure respectively. The +37–74 μm fraction was used for the flotation tests. Samples further ground to –5 μm in an agate mortar were used for zeta potential measurements.

Chemically pure reagents were obtained from the following sources: octyl hydroxamic acid (HXMA-8, C<sub>8</sub>H<sub>17</sub>NO<sub>2</sub>) from Jusheng Science and Technology Ltd., Hubei, China; sodium oleate (NaOl, C<sub>18</sub>H<sub>33</sub>O<sub>2</sub>Na) from Baisaiqin Chemical Technology co., Ltd., Shanghai, China; sodium silicate (SS, Na<sub>2</sub>SiO<sub>3</sub>·9H<sub>2</sub>O) from Zhuzhou Flotation Reagents Factory, Hunan, China. The molecular structures of HXMA-8 and NaOl are shown in Fig. 2. The pH was adjusted with NaOH or HCl stock solutions. Deionized water (18 mΩ × cm) was used for all experiments.

### 2.2. Flotation experiment

Pure mineral flotation tests were carried out in an XFG-type flotation machine (Fig. 3) with a 40 mL plexiglass cell, and the impeller speed

\* Corresponding authors.

E-mail addresses: [zhiyong.gao@csu.edu.cn](mailto:zhiyong.gao@csu.edu.cn) (Z. Gao), [hyh@csu.edu.cn](mailto:hyh@csu.edu.cn) (Y. Hu).

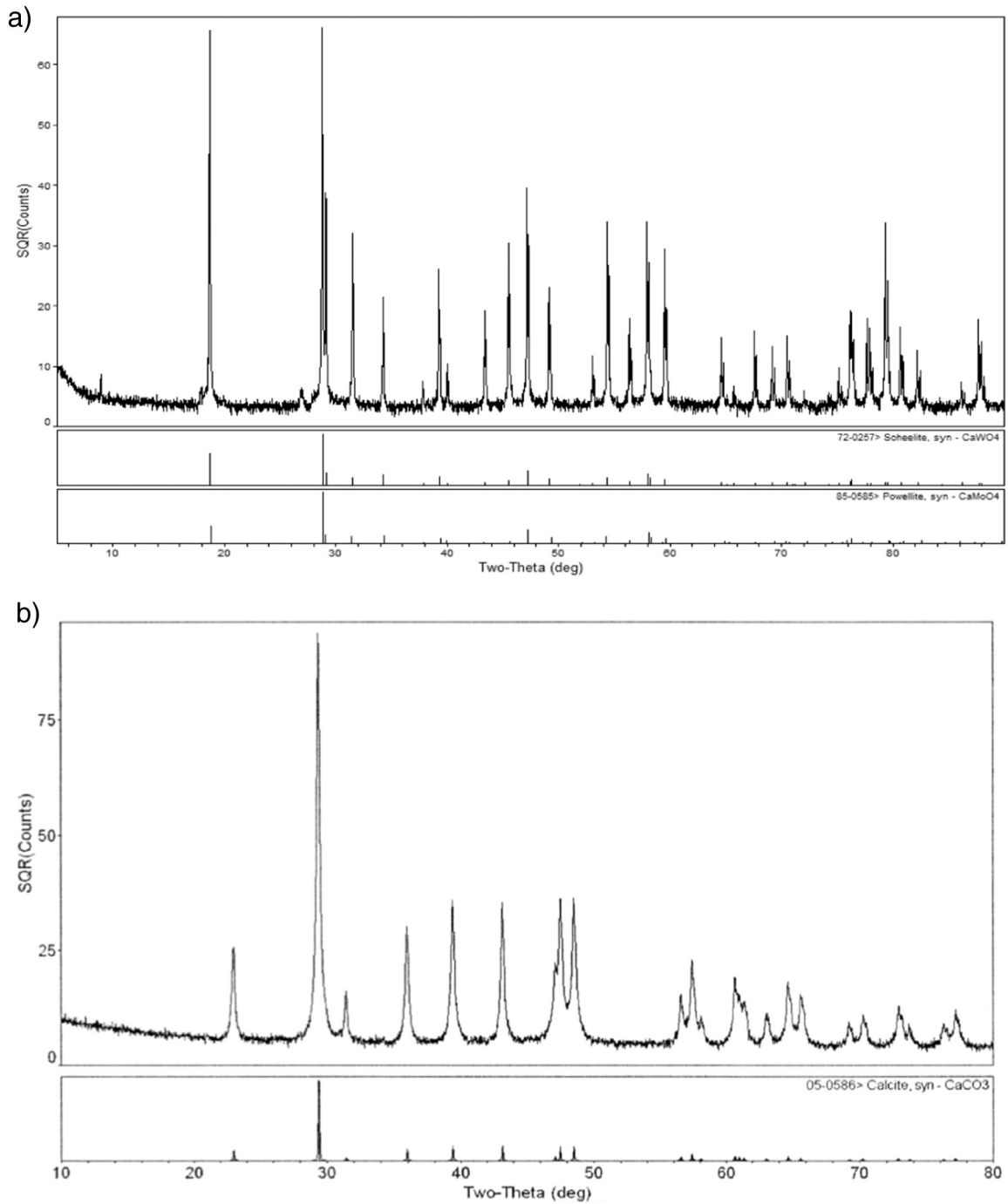


Fig. 1. XRD spectrums of the scheelite (a) and calcite samples (b) used for flotation tests.

was set to 1400 rpm. The procedure of pure mineral flotation tests is as follows: (1) adding 2.0 g minerals and 35 mL deionized water to the plexiglass cell and agitating for 1 min to obtain mineral suspension; (2) adjusting pulp pH by adding pH regulators and agitating for 2 min; (3) adding depressant and agitating for 3 min; (4) adding collector (for collector mixture, adding HXMA-8 and NaOI successively) and agitating for 3 min; (5) collecting floated products for 3 min; (6) filtering, drying, and weighing the products to calculate the recovery. The flowsheet of single mineral flotation test is presented in Fig. 4.

### 2.3. Zeta potential measurement

Zeta potential measurements were conducted at 20 °C using a zeta potential analyzer (ZetaPlus, Bruker, Germany). Mineral suspensions

containing 0.02 g of solids and 40 mL KCl (0.01 mol/L) background electrolyte were prepared in a beaker at a given pH and a collector concentration. After settling for 5 min, the supernatant liquor was used for zeta potential measurement.

## 3. Results and discussions

### 3.1. Single mineral flotation experiments

Single mineral flotation tests were conducted using HXMA-8 as the single collector at pH 8.3 (natural pH of scheelite suspension) in the absence and presence of 200 mg/L regulator SS. The results are shown in Fig. 5. In the absence of SS, scheelite recovery steadily increases with increasing HXMA-8 dosage till up to  $1.5 \times 10^{-4}$  mol/L where it reaches a

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