

Technical note

# Effect of iron content in sphalerite on flotation

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## Abstract

The effect of iron, substituted in the mineral lattice, on the froth flotation of sphalerite has been investigated at alkaline pH. It has been found that a critical copper sulphate concentration exists where sphalerite recovery is maximized, above which the recovery of sphalerite then decreases. The presence of iron in sphalerite is detrimental to the rate of sphalerite flotation and hence its recovery, with the coarser particles being more affected than the fines. The presence of iron reduces the activation of sphalerite by copper, which in turn results in a reduction in collector adsorption.

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## 1. Introduction

As xanthate collectors have a relatively low affinity for zinc ions, activation of sphalerite by copper ions is generally required to float sphalerite. The activation of sphalerite involves the exchange of zinc for copper ions, thus providing a surface receptive towards collector adsorption (Finkelstein, 1997). One of the main impurities present in sphalerite is iron, which substitutes for zinc atoms in the sphalerite lattice, thus reducing the number of zinc atoms available for exchange with copper. Previous studies investigating the effect of iron content in sphalerite on copper activation, collector adsorption and subsequent sphalerite flotation have produced conflicting results (Pomianowski et al., 1975; Mukherjee and Sen, 1976; Solecki et al., 1979; Nakahiro, 1980; Harris and Richter, 1985; Gigowski et al., 1991). For example, both an increase and decrease in copper activation, collector adsorption and froth flotation of

sphalerite have been reported with increasing iron content in sphalerite. The loss of sphalerite to tailings in flotation circuits as a result of inadequate particle surface hydrophobicity reduces the economic viability of the processing operation. Thus an understanding of the effect that iron in sphalerite has on the flotation behaviour of this mineral may allow us to maximise sphalerite recovery. In the present study, we have investigated the effect of iron content in sphalerite on sphalerite flotation as a function of particle size. These flotation results were correlated with the amount and type of copper and collector adsorbed on the sphalerite surface.

## 2. Experimental section

The chemical composition of the low iron content sphalerite sample, ZnS, (Carthage, TN, USA) was 66.7% Zn, 0.3% Fe and 32.7% S (0.06% Cu and 0.07% Pb) while that of the high iron content sphalerite sample, (Zn, Fe)S, (Broken Hill, New South Wales, Australia) was 53.2% Zn, 12.5% Fe and 32.7% S (0.47% Cu and 0.24% Pb). Scanning electron microscopy confirmed that the iron present in the sample was in fact

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incorporated in the sphalerite particles, and not present as individual pyrite inclusions. The collector, sodium iso-propyl xanthate (SIPX), was re-crystallised from ethanol.

ZnS and (Zn, Fe)S (250 g each) were ground in a Galigher mill with stainless steel rods and 0.3 dm<sup>3</sup> of demineralised water (pH 12.0) to produce a flotation feed with a  $d_{90}$  of 45  $\mu\text{m}$ . The sample was transferred to a 3.0 dm<sup>3</sup> Agitair flotation cell and conditioned at pH 11.0 with CuSO<sub>4</sub>, collector and then frother (Aerofroth 65) with each stage having a 2 min conditioning period. The concentrates were then collected for 0.5, 2, 4 and 8 min (for a total of 8 min) of flotation by bubbling air through the mineral pulp at 4 dm<sup>3</sup>/min. The  $-45 \mu\text{m}$  fraction of each concentrate and tail sample was passed through a pre-cyclone rig. The underflow was sized with a Warman cyclosizer (6 size fractions collected) whilst the overflow constituted the sub 4  $\mu\text{m}$  particle size fraction. All size fractions were analysed by ICP-MS (Amdel Pty. Ltd., Australia) for total zinc and iron, and the relative amounts of ZnS and (Zn, Fe)S in each of the size fractions determined.

A first order rate equation,  $R = R_{\text{max}}(1 - e^{-kt})$ , was used to fit the curves of flotation recovery,  $R$ , versus time,  $t$ , and to obtain the flotation rate constant,  $k$ , and maximum flotation recovery,  $R_{\text{max}}$  at each particle size.

### 3. Results and discussion

The cumulative recoveries of ZnS and (Zn, Fe)S as a function of particle size, flotation time and CuSO<sub>4</sub> concentration are shown in Fig. 1. With no copper addition the total recoveries were too low for a size analysis of the concentrates. With CuSO<sub>4</sub>, flotation recovery increases sharply with particle size up to approximately 25  $\mu\text{m}$ , and then levels off or decreases for the coarser particles. This decrease in recoveries of the coarser particles is more pronounced at the higher CuSO<sub>4</sub> concentrations and for (Zn, Fe)S.

The flotation rate constant ( $k$ ) and maximum recovery ( $R_{\text{max}}$ ) obtained by fitting the recovery versus flotation time data with a first order rate equation are shown in Fig. 2 as a function of particle size. At the lower CuSO<sub>4</sub> concentration the flotation rate constant and maximum recovery of sphalerite are relatively unaffected by the presence of iron in the sphalerite lattice. The increase in flotation rate constant with increasing particle size is relatively well understood and is attributed to an increase in bubble-particle collision efficiency (e.g., Pyke et al., 2003). The increase in  $k$  and  $R_{\text{max}}$  values of the fine particles with an increase in CuSO<sub>4</sub> concentration to 2000 g/t is certainly related to an increase in bubble-particle attachment efficiency, and therefore surface hydrophobicity, as the conditions inside the flotation cell are unchanged. At 2000 g/t CuSO<sub>4</sub>, nearly all the

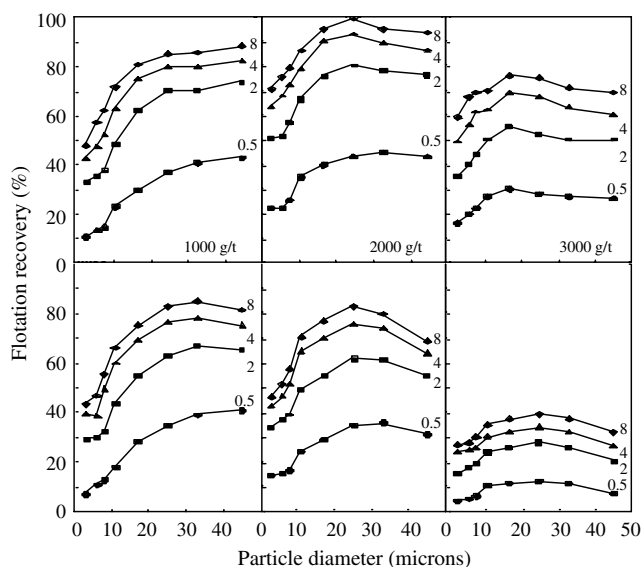


Fig. 1. (Top) ZnS and (bottom) (Zn, Fe)S flotation recovery as a function of particle size, flotation time (0.5, 2, 4 and 8 min) and copper sulphate concentration (from left to right: 1000, 2000 and 3000 g/t) in mixed mineral experiments at pH 11.0 in the presence of 150 g/t SIPX.

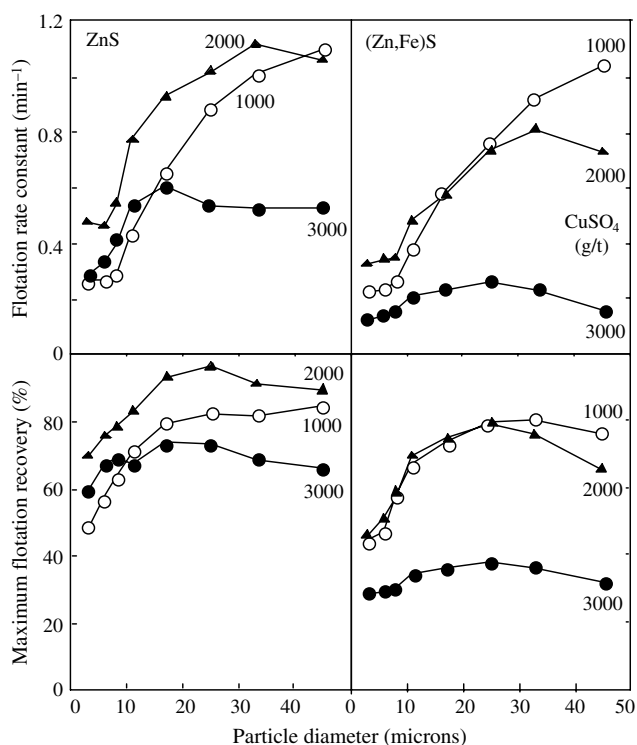


Fig. 2. Flotation rate constant (top) and maximum recovery (bottom) for ZnS and (Zn, Fe)S as a function of particle size and copper sulphate concentration in mixed mineral experiments at pH 11.0 in the presence of 150 g/t SIPX.

intermediate size ZnS particles can float ( $R_{\text{max}}$  close to 100%). The lower flotation rate constants and maximum recoveries of the coarser particles are mainly attributed

to the increased detachment of these particles from bubbles in the regions of high turbulence inside the flotation cell (e.g., Pyke et al., 2003). Because this detachment is also dependent on particle hydrophobicity or the lack of it, an increase in  $\text{CuSO}_4$  concentration decreases surface hydrophobicity (higher coverage by  $\text{Cu}(\text{OH})_2$ , Clarke et al., 1995) and therefore the flotation rate constant and maximum recovery of the coarser particles.

At 3000 g/t  $\text{CuSO}_4$ , the sphalerite flotation rate constant and maximum recovery decrease across the entire particle size range, with the decrease being more pronounced for the coarse particles than for the fine particles and for  $(\text{Zn}, \text{Fe})\text{S}$  than for  $\text{ZnS}$ . This larger decrease in flotation observed for the coarser particles is not necessarily linked to a higher coverage of their surface with copper hydroxide, but is certainly related to the larger effect that coarse particles have on their detachment from bubbles at a constant surface hydrophobicity (Pyke et al., 2003).

In alkaline pH domains, the activation of sphalerite is believed to firstly involve precipitation of copper hydroxides, followed by exchange of zinc atoms for copper atoms on the sphalerite surface (Ralston and Healy, 1980; Laskowski et al., 1997). Hence the presence of iron in sphalerite results in a decrease in the number of copper atoms that could be incorporated in the sphalerite lattice. Indeed, this is what we have found at a pH value of 5.0 with no increase in iron detected in solution (Boulton, 2002). UV-visible and infrared studies on individual  $\text{ZnS}$  and  $(\text{Zn}, \text{Fe})\text{S}$  samples of similar surface area have shown that without prior activation of sphalerite with  $\text{CuSO}_4$  the uptake of xanthate at pH 11.0 was close to zero. This indicates that SIPX does not interact with zinc or ferric species on the sphalerite surface, in agreement with the flotation results showing low flotation recoveries in the absence of  $\text{CuSO}_4$ . With  $\text{CuSO}_4$ , the adsorption of xanthate on  $\text{ZnS}$  is double than on  $(\text{Zn}, \text{Fe})\text{S}$ , with maximum adsorption occurring at around 10 min. Copper(I) xanthate was the only surface xanthate species detected (Boulton, 2002).

#### 4. Conclusions

Copper sulphate concentration is critical in controlling sphalerite recovery at alkaline pH. A critical level of copper sulphate concentration exists where sphalerite recovery is maximized, above which the recovery of sphalerite decreases as a result of excess copper hydroxide on the sphalerite surface.

The presence of iron in the sphalerite lattice has a detrimental effect on the flotation of sphalerite because cop-

per activation is reduced, which in turn results in a reduction of xanthate adsorption as copper(I) xanthate.

Most of the non-floating sphalerite particles are fine particles, because of their low collision efficiency with bubbles. The coarser particles are more affected than the fines by the presence of iron in sphalerite and by excess addition of copper sulphate.

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