



Technical Note

The selective flotation of arsenopyrite from pyrite

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Abstract

Flotation tests were conducted to compare the arsenopyrite depressing effect of MAA with pH control, potassium permanganate and pre-aeration. The recovery and selectivity were optimised by varying the collector and depressant concentration, pH and the effect of copper sulphate addition. It was found that with MAA, depression of arsenopyrite was possible however, the recovery of pyrite was also adversely affected. To achieve the best separation, the pulp conditions were a pH of 8, 2.14×10^{-3} mol/l sodium ethyl xanthate and 250 mg/l of MAA depressant. These conditions resulted in an overall arsenopyrite recovery of 25.5% and a pyrite recovery of 62.1%, a decrease in recovery of 63.0% and 7.5%, respectively.

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1. Introduction

Separation of pyrite and arsenopyrite by flotation using xanthates presents difficulties due to the fact that xanthates adsorb onto both these minerals as dixanthogen, which is not cation selective. Therefore, a number of separation techniques have been employed by a number of authors to produce separate arsenopyrite and pyrite streams (Abeidu and Almahdy, 1980; Poling and Beattie, 1984). These techniques include varying the pH of the pulp, varying the oxidation of the mineral surface and the addition of sulphur dioxide which promotes the flotation of arsenopyrite. Some of these attempts have been made on an industrial scale, however there is a lack of recovery or the degree of selectivity is too difficult to control.

1.1. Magnesium–ammonium mixture (MAA) depressant

Yen and Tajadod (2000) studied the use of a magnesium–ammonium mixture as a depressant in the selective flotation of chalcopyrite (CuFeS_2) from enargite (Cu_3AsS_4). The authors determined the adsorption density of the potassium amyl xanthate (PAX) collector with respect to a change in MAA concentration and pH

and subsequently the recoveries of synthetic enargite, natural enargite and natural chalcopyrite. The results showed that the adsorption density on both synthetic and natural enargite decreases with increasing MAA concentration. On the other hand, the adsorption density on chalcopyrite does not vary at all with respect to MAA concentration, and only slightly decreases with respect to pH. The mechanism proposed for the effect of MAA was explained by the oxidisability of the enargite. The arsenic ion on the enargite surface forms a stable complex anion (AsO_4^{3-}) by oxidation by the dissolved oxygen in the pulp and it remains on the enargite surface through covalent bonding. Nishimura et al. (1988) explained that magnesium, which is present in the MAA depressant, has a high affinity for arsenates to form a hydrophilic compound, $\text{AsO}_4\text{NH}_4\text{Mg} \cdot 6\text{H}_2\text{O}$. This compound is formed on the enargite surface and effectively blocks the xanthate from being adsorbed.

The usefulness of the MAA depressant on the separation of arsenopyrite from pyrite has not been investigated. Because arsenopyrite has arsenic ions, it could be inferred that the same process could be followed allowing the depression of arsenopyrite, while maintaining the flotation characteristics of pyrite.

2. Experimental procedure

A sample of arsenopyrite ore from Coolgardie, Western Australia, was crushed to -2 mm. Eighty

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kilograms of sample were passed through rotary and riffle splitters to obtain 1 kg samples, which were then stored in a freezer to avoid oxidation of the sulphides. When the ore sample was required for flotation the 1 kg samples were ground to a p80 of 106 μm in a rod mill.

The flotation experiments were carried out using a 3 l Leeds flotation cell as a single stage rougher. The flotation collector used was sodium ethyl xanthate (SEX) and Interfroth 50 as frother.

A number of flotation tests were conducted to determine the optimal flotation conditions to ensure maximum selectivity and recovery. All tests were performed at a p80 of 106 μm , which was fine enough to ensure adequate mineral liberation. The parameters varied were the SEX concentration, MAA concentration and pH. Additional flotation tests examined the effect of copper sulphate, potassium permanganate and pre-aeration on the flotation of arsenopyrite.

The Magnesium Ammonium solution was prepared by adding 0.5 M $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, 2.0 M NH_4Cl and 1.5 M NH_4OH (10.65 ml of 25% NH_3) to 100 ml of distilled water while stirring.

The frother (Interfroth 50) concentration remained at 0.03 kg/t for each test. The pH was varied from the natural pH of the ore, which was 8.2, to the desired pH using sodium hydroxide or hydrochloric acid.

To determine the recoveries of arsenopyrite and pyrite in each of the tests, a Varian inductivity coupled plasma emission spectrometer (ICP), an X-ray diffractometer (XRD), and a LECO sulphur analyser were used. The ICP provided the amount of arsenopyrite and pyrite reporting to the concentrate from the arsenic percentage, while the LECO gave an initial indication of the sulphur content in the concentrate.

The XRD was used to confirm that the sample has only iron–arsenic compounds present, and no other metal sulphides in significant quantities.

3. Results and discussion

The effect of changing the concentration of MAA with respect to the recovery of arsenopyrite and pyrite is shown in Fig. 1. The selectivity index (pyrite recovery/arsenopyrite recovery ratio) is also given which indicates how well the two are being selectively floated. The greatest selectivity of 2.1 was found at a MAA concentration of 250 mg/l and hence this concentration was used in subsequent tests. This corresponds to a recovery of 22.9% and 48.5% for arsenopyrite and pyrite respectively. The decrease in recovery of arsenopyrite with an increase in depressant concentration was expected due to the greater thickness of the hydrophilic $\text{AsO}_4\text{NH}_4\text{Mg} \cdot 6\text{H}_2\text{O}$ layer being formed upon it, limiting the adsorption of xanthate and thus its floatability. The recovery of pyrite was relatively unaffected between

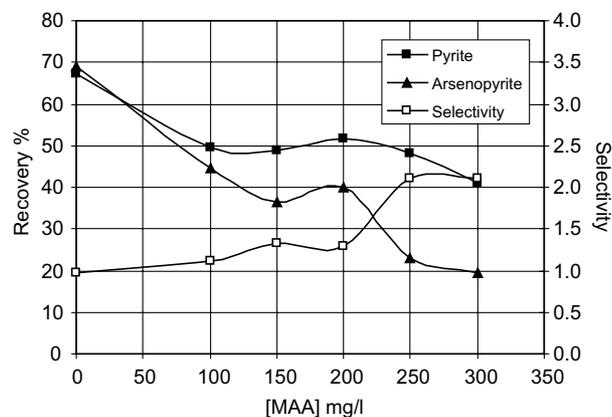


Fig. 1. Varying the MAA concentration with respect to the recovery of arsenopyrite and pyrite (pH 8, 2.14×10^{-3} mol/l SEX).

100–200 mg/l MAA, however the recovery began to decrease above this.

Comparing the recovery of these tests to the one with no MAA depressant, it can be observed that there was a decrease in recovery of both minerals. An hydrophilic layer cannot form on the pyrite surface as iron (II) and iron (III) species do not form stable arsenides. One explanation could be that when the arsenic sites on the arsenopyrite surface oxidise to AsO_4^{3-} , and consequently form the hydrophilic compound, the agitation within the cell may be enough to detach some of the compound from the arsenopyrite. This may attach to some of the pyrite in the cell which would inhibit the xanthate adsorption onto the pyrite surface, thus depressing it. This phenomenon would also explain the drop in recovery of pyrite at 300 mg/l. At this concentration, the compound may be too large for it to support itself on the arsenopyrite surface, thus more is ripped off resulting in a lower pyrite recovery.

3.1. Varying pH

The effect of varying the pH with respect to the recovery and selectivity of arsenopyrite and pyrite is shown in Fig. 2. It can be observed that very little selectivity has occurred over the tested pH range. However there has been a large drop in recovery of both minerals with an increasing pH which concurs with the results of Sirkeci (2000).

The highest recovery occurs when the pH of the pulp is 6. This is expected due to the formation of dixanthogen at lower pHs which is the main collecting species. At higher pHs, unstable dixanthogen is converted back to xanthate ions decreasing the collectors ability to float mineral particles.

At higher pHs, the oxidation of the arsenopyrite and pyrite particles is strongly favoured over xanthate oxidation. This results in the formation of an oxidation

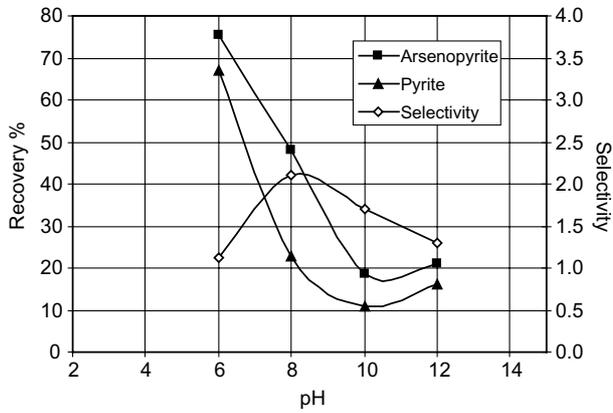


Fig. 2. Varying pH with respect to arsenopyrite and pyrite recoveries ([MAA] = 250 mg/l, [SEX] = 2.14×10^{-3} mol/l).

product on the mineral’s surface, reducing the chemisorption of the collector onto the mineral particle. Based on these series of tests, the pH which best suited the separation was 8. Although the selectivity was poor, it is thought that xanthate species predominate at a pH value between 8 and 9 and are adsorbed selectively on the pyrite surface (Abeidu and Almahdy, 1980).

3.2. Varying collector concentration

The effect of the concentration of the collector (sodium ethyl xanthate) with respect to the recovery and selectivity of arsenopyrite and pyrite is shown in Fig. 3.

The increase in recovery of both sulphide minerals with an increase in collector dosage is expected, as there are more xanthate ions in solution to be adsorbed and converted to dixanthogen, which is the collecting species for the two sulphides. However, above 3.21×10^{-3} mol/l SEX there appears to be a drop in recovery of both minerals. The greatest selectivity occurred at a collector concentration of 2.14×10^{-3} mol/l and hence subsequent tests were conducted at this concentration.

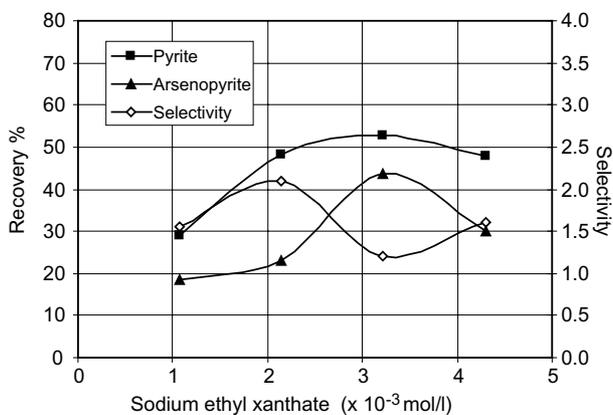


Fig. 3. Varying SEX concentration with respect to arsenopyrite and pyrite recoveries ([MAA] = 250 mg/l, pH = 8).

3.3. Optimal condition test

By establishing the optimal pH, MAA concentration and SEX concentration of 8, 250 mg/l and 2.14×10^{-3} mol/l, respectively, tests were conducted to see how well arsenopyrite and pyrite could be selectively floated under these conditions. The results show a drop in recovery from 69.0% to 26.9% for arsenopyrite and from 67.1% to 62.6% for pyrite in the concentrate.

The arsenopyrite is depressed with the addition of the MAA depressant and although the pyrite recovery is also depressed it is not to the same extent as arsenopyrite, giving rise to a higher selectivity compared to the blank test (no MAA present).

3.4. Copper sulphate addition

The activator copper sulphate was added at a dosage of 0.05 kg/t to test if the flotation characteristics of pyrite could be improved resulting in greater recovery. To determine whether the activating effect of the copper sulphate was greater than the depressing effect of the MAA, the reagents are added in different sequence. Fig. 4 summarises these results compared to the flotation test with optimal reagent conditions.

As shown in the MAA–CuSO₄ test, the recovery and selectivity of both minerals has decreased. An explanation for the depression of arsenopyrite is that the copper ions in solution selectively adsorbs onto arsenic sites as Cu₂As₃. This is then easily oxidised with the dissolved oxygen in the pulp to form AsO₄³⁻, which is covalently bonded onto the mineral. The AsO₄³⁻ then combines with the magnesia mixture in the depressant to form the hydrophilic compound. An explanation for the depression of pyrite could be that because more of the hydrophilic compound is being produced on the surface of arsenopyrite, some may be ripped off and adsorb onto

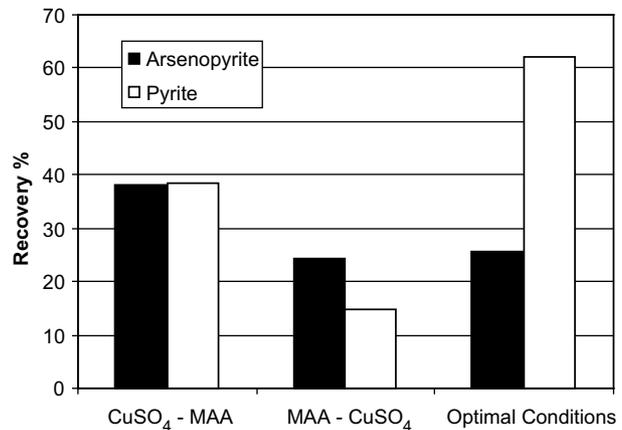


Fig. 4. Effect of copper sulphate addition on flotation recovery relative to optimal conditions [CuSO₄] = 0.05 kg/t, [SEX] = 2.14×10^{-3} mol/l, [MAA] = 250 mg/l, pH = 8.

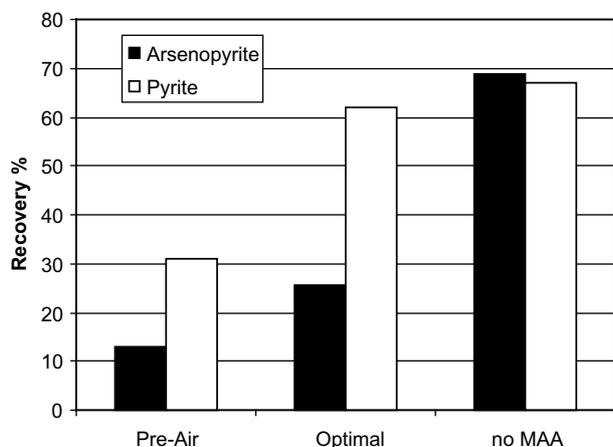


Fig. 5. Effect of pre-aeration of the pulp relative to the blank test. 7 l/min air for 10 min, $SEX = 2.14 \times 10^{-3}$ mol/l, $[MAA] = 250$ mg/l, pH = 8.

the pyrite, thus decreasing its floatability. The MAA– $CuSO_4$ test suggests that the hydrophilic layer initially produced on the arsenopyrite surface remains intact, decreasing the activating effect of the copper sulphate on the material.

3.5. Pre-aeration of the pulp

By agitating the pulp for 10 min with approximately 7 l/min of air, the following results were obtained (Fig. 5). This particular test resulted in a decrease in the recovery of arsenopyrite and pyrite by a further 49.4% and 50.1%, respectively from the optimal conditions. The decreased recovery can be explained by the increased oxidation of both mineral surfaces. The drop in recovery of pyrite is similar to the percentage drop in recovery for arsenopyrite. This is explained by the relative ease of oxidation of both minerals.

This test implies that further depression of arsenopyrite is indeed possible however due to the subsequent depression of pyrite, this technique is not recommended when selective depression is desired.

3.6. Potassium permanganate addition

The effect of potassium permanganate addition on the recovery of pyrite and arsenopyrite suggest that potassium permanganate is depressing both minerals with less than 9% of the two sulphides being recovered as the minerals' surface is being severely oxidised. By

conducting a test with only potassium permanganate, it was observed that the addition of MAA has a negligible effect on the recovery. This suggests that MAA is a much weaker depressant, which is obvious when compared to the test under optimal conditions. This test has succeeded in depressing arsenopyrite, but has failed with respect to selectivity.

4. Conclusion

A number of tests were conducted to determine the effect of MAA on arsenopyrite depression and the optimal conditions needed for the best separation from pyrite. The optimal conditions were found to be 250 mg/l MAA, pH 8 and 2.14×10^{-3} mol/l of sodium ethyl xanthate collector.

These conditions resulted in a pyrite and arsenopyrite recovery of 62.1% and 25.5%, respectively. Relating these results to the blank test where no MAA was added, a drop in arsenopyrite recovery of 63.0% was observed whereas a drop of only 7.5% was observed for pyrite.

Other tests were conducted to observe any differences in selectivity or recovery. These were pre-aerating the pulp, potassium permanganate addition and the use of an activator, copper sulphate. However it was found that the recovery of both minerals decreased resulting in a smaller selectivity.

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