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Original scientific paper

DEPRESSION OF PYRITE MINERAL WITH CYANIDE AND FERROUS/FERRIC SALTS

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Abstract: This paper presents the results of the examination of depressing effect of cyanide salts type reagents (NaCN, $K_3[Fe(CN)_6]$ and $K_4[Fe(CN)_6]$), as well as ferrous/ferric salts ($FeSO_4$ and $Fe_2(SO_4)_3$) on the floatability of pyrite in the presence of xanthate as collector. The examinations show that all tested depressants reduce the collection ability of pyrite with K-butyl xanthate (KBX). Different combinations of reagents $FeSO_4$ and/or $Fe_2(SO_4)_3$ with NaCN showed the greatest depressing effect on the pyrite, while the complex cyanide salts showed much less depressing effect on mineral.

Key words: pyrite, depression, cyanides, iron salts

1. INTRODUCTION

In industrial practice of flotation of sulphide lead-zinc and copper ores, pyrite, as a constant presented mineral in these ores, depresses in the various stages of selective flotation or it separates in concentrate. This mineral is commonly collected with sulfhydryl anionic active collectors - xanthates. In practice of lead-zinc-pyritic ores flotation, pyrite depresses with the cyanide type reagents, and in practice of copper-pyritic ores flotation cyanides are not used, but pyrite depresses with OH^- ions (pH>11). The problem of pyrite depression with cyanide type reagents, alkaline cyanide (NaCN) and complex cyanide salts ($K_3[Fe(CN)_6]$ and $K_4[Fe(CN)_6]$) are treated in this paper (Kostović, 1989). Besides the examination about depressing effects of these reagents on pyrite, also, the depressing effect of reagent type of ferrous or ferric salts, or $FeSO_4$ and $Fe_2(SO_4)_3$, in combination with alkaline cyanide is tested. In the papers of many researchers, depressing effects of cyanide salts on pyrite were tested (Elgillani and Fuerstenau, 1968; Ball and Richard, 1976; Wet et al. 1997), while significant attention is not devoted to combination of alkaline cyanide salts with ferrous or ferric sulfate and its depressing effect, especially not to pyrite mineral. Depressing effect of these combination of reagents on zinc minerals was studied (Pavlica, 1983), and also applied in practice of lead-zinc ores flotation in many of our flotation plant (Pavlica et al. 1991; Pavlica et al. 2011).

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2. MINERAL, REAGENTS AND TEST METHODS

A pure pyrite mineral sample from lead-zinc ore body "Novo Brdo" was used in the examinations. Pyrite sample had a density of 4.999 g/cm^3 and contained 51.30% S and 46.91% Fe.

For these examinations a sample of pyrite, size class -0.210+0.149 mm, was used and prepared by manual grinding in porcelain mortar and screening on the appropriate screens. Pyrite floatability was determined by foamless flotation procedure in modified Hallimond cell, 90 ml in volume. The sample of mineral, weight of 1 g, was floated for 4 minutes at an air flow rate of 10 ml/min through the cell. Previously, the conditioning of solution of definite reagents and regulated pH was performed manually in a flask. The time of conditioning with xanthate and cyanide or ferrous/ferric sulfate was 1 min and 2 min, respectively.

K-butyl xanthate (KBX) was used as collector, and also reagents NaCN, $K_3[Fe(CN)_6]$, $K_4[Fe(CN)_6]$, $FeSO_4$ and $Fe_2(SO_4)_3$ were used. All reagents were of analytical purity. Tests were performed in distilled water at natural pH of solution (pH from 5.3 to 5.8).

3. RESULTS AND DISCUSSION

The aim of this examination was to determine the pyrite floatability in the presence of KBX collector (Figure 1), and also in the presence of various depressants (Figures 2-5). The results of pyrite floatability in solutions of various concentrations of KBX collector (from 1 mg/l to 15 mg/l) are shown on Figure 1. The results of pyrite floatability in the presence of KBX collector and different depressants are shown on Figures 2-5, as follows:

- single depressants at different concentrations (Figure 2),
- combination of reagents $FeSO_4$/NaCN for concentration ratios from 1:5 to 5:1 (Figure 3),
- combination of reagents $Fe_2(SO_4)_3/FeSO_4$/NaCN for concentration ratios of 1:1:1, 2:1:1, 3:1:1, 4:1:1 and 5:1:1, or 1:2:1, 1:3:1, 1:4:1 and 1:5:1 (Figure 4),
- combination of complex cyanide salts $K_3[Fe(CN)_6]/K_4[Fe(CN)_6]$ for concentration ratios from 1:5 to 5:1 (Figure 5).

The concentrations of depressants are varied from 5 mg/l to 25 mg/l.

The results of all tests are graphically presented as relations: recovery (R, %) - concentration of reagents (C, %).

According to the results presented on Figure 1, pyrite well floates ($R > 90\%$) in the presence of KBX collector at concentrations greater than 3 mg/l pyrite, while concentrations greater than 10 mg/l practically have no influence on the change of floatability, since the pyrite floates even 98% by weight.

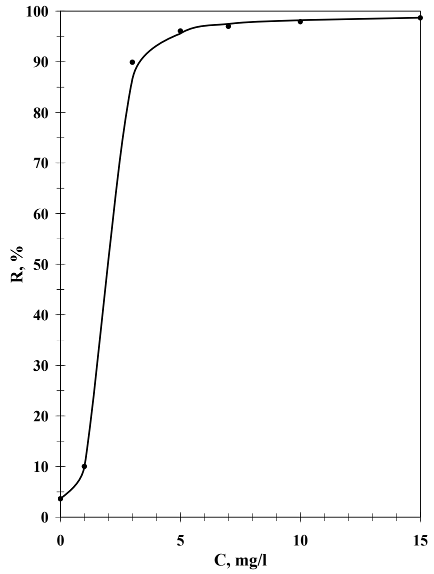

Figure 1 - Floatability of pyrite in the solutionsof different concentrations of KBX collector

The introduction of the depressants in the flotation system leads to the reducing of pyrite floatability, while various depressing effects were achieved with various depressants (Figures 2-5).

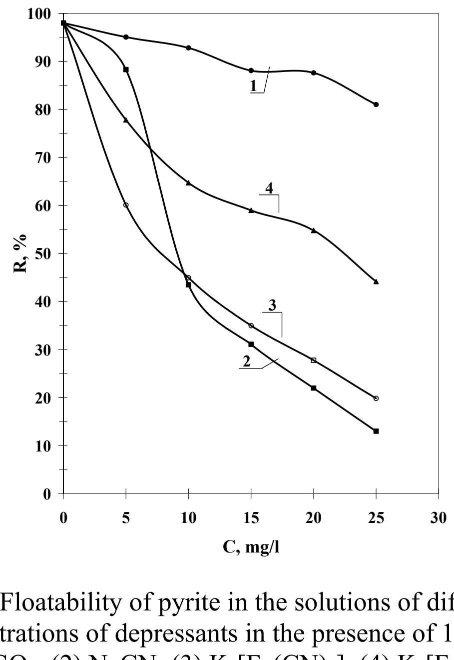

Figure 2 - Floatability of pyrite in the solutions of different types and concentrations of depressants in the presence of 10 mg/l KBX (1) $FeSO_4$; (2) NaCN; (3) $K_3[Fe(CN)_6]$; (4) $K_4[Fe(CN)_6]$

From Figure 2 it can be seen that single depressants significantly reduced the pyrite collection ability in the presence of 10 mg/l KBX. This effect is not so pronounced in the presence of $FeSO_4$, while pyrite still relatively well floates in the solution of this reagent (R = 82%). Used reagents could be classified in the following series by the efficiency of depressing effects:

$$NaCN > K_3\,[Fe(CN)_6] > K_4[Fe(CN)_6] > FeSO_4$$

When a combination of reagents $FeSO_4$/NaCN and $Fe_2(SO_4)_3$/$FeSO_4$/NaCN (Figures 3 and 4) were introduced in the flotation system at different concentration ratios, there is an effective prevention of pyrite collection with xanthate. The greatest depressing effect in solutions of combinations of reagents $FeSO_4$/NaCN and collector KBX is achieved in the presence of 5/15 mg/l and 15/5 mg/l $FeSO_4$/NaCN, when pyrite floates about 5-7% by weight. By further increasing the concentration of $FeSO_4$ and NaCN flotability of pyrite remains no variable. In addition, the advantage is certainly gives the used combination of reagents in 3:1 ratio of concentration, because of reduced cyanide consumption. Also, the combination of reagents $Fe_2(SO_4)_3$/$FeSO_4$/NaCN also leads to a successful pyrite depression. Most optimal concentrations of tested reagents are 5/10/5 mg/l or 1:2:1, when pyrite floats about 10% by weight.

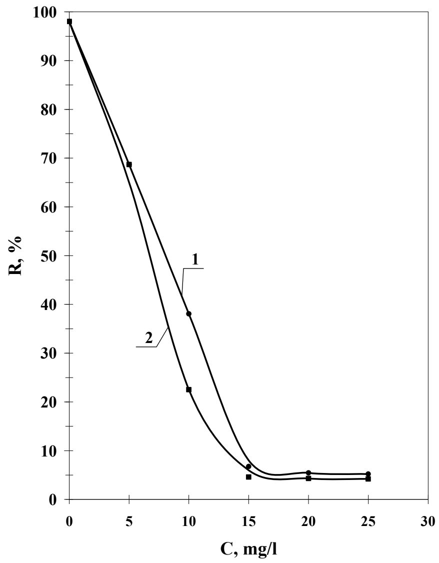

Figure 3 - Floatability of pyrite in the solutions of $FeSO_4$/NaCN of different concentration ratios in the presence of 10 mg/l KBX; (1) $FeSO_4$ variable, 5 mg/l NaCN, (2) 5 mg/l $FeSO_4$, NaCN variable

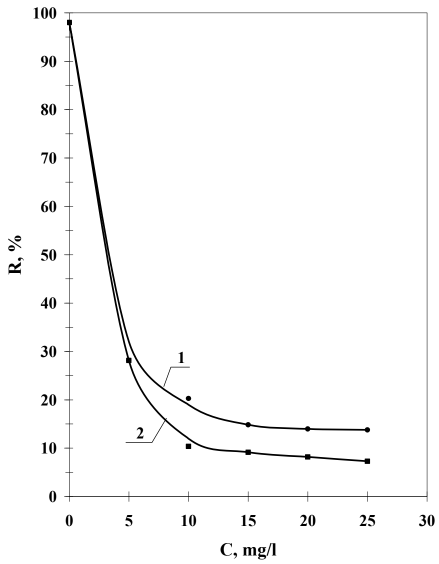

Figure 4 - Floatability of pyrite in the solutions of $Fe_2(SO_4)_3$/$FeSO_4$/NaCN of different concentration ratios in the presence of 10 mg/l KBX;
(1) $Fe_2(SO_4)_3$ variable, 5 mg/l $FeSO_4$, 5 mg/l NaCN;
(2) 5 mg/l $Fe_2(SO_4)_3$, $FeSO_4$ variable, 5 mg/l NaCN

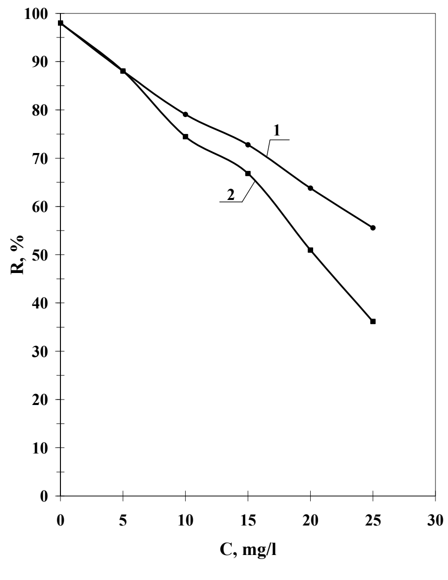

Figure 5 - Floatability of pyrite in the solutions of $K_3[Fe(CN)_6]$/$K_4[Fe(CN)_6]$ of different concentration ratios in the presence of 10 mg/l KBX;
(1) 5 mg/l $K_3[Fe(CN)_6]$, $K_4[Fe(CN)_6]$ variable
(2) $K_3[Fe(CN)_6]$ variable, 5 mg/l $K_4[Fe(CN)_6]$

Introducing the combinations of complex cyanide salts $K_3[Fe(CN)_6]/K_4[Fe(CN)_6]$ in the flotation system (Figure 5) does not lead to a complete stop of pyrite flotation, since pyrite well floates in the presence of KBX collector. The lowest floatability of this mineral from 35.15% and 55.57% is achieved in the presence of 25/5 mg/l 5/25 mg/l $K_3[Fe(CN)_6]/K_4[Fe(CN)_6]$. In addition, by comparing these combination of reagents with the same single used reagents, it can be concluded that complex cyanide salts are most efficient as depressants when they are used individually, not as a combination.

Used reagents could be classified in the following series by the efficiency of reducing collection ability of pyrite in the presence of xanthate collector at natural pH of solution:

$$FeSO_4/NaCN > Fe_2(SO_4)_3/FeSO_4/NaCN > K_3[Fe(CN)_6]/K_4[Fe(CN)_6]$$

4. CONCLUSION

Based upon the experimental tests we can conclude the following:

- Mineral pyrite in solution of K-butyl xanthate (KBX) at natural pH of solution, shows good collection ability with this collector.
- The floatability of this mineral is decreased when different depressants were introduced in the flotation system, single and in combinations at different concentrations and ratios.
- All single tested reagents of cyanide type (NaCN, $K_3[Fe(CN)_6]$ and $K_4[Fe(CN)_6]$) significantly affect the collection ability of this mineral with KBX. In addition, NaCN showed greater depressing effect when compare with complex cyanide salts. Reagent $FeSO_4$ does not affects significantly on the pyrite depression.
- The depressing effect of a combination of complex cyanide salts, without the presence of NaCN, is smaller than for the case when the combination of reagents $FeSO_4/NaCN$ and $Fe_2(SO_4)_3/FeSO_4/NaCN$ are introduced in the flotation system in the presence of xanthate collector. In addition, the combination of reagents $FeSO_4/NaCN$ can be considered the most effective depressants among all tested reagents.
- All tested depressants could be classified into the following series by the depressing effect on pyrite mineral:

$$FeSO_4/NaCN > Fe_2(SO_4)_3/FeSO_4/NaCN > NaCN > K_3[Fe(CN)_6] >$$
$$> K_4[Fe(CN)_6] > K_3[Fe(CN)_6]/K_4[Fe(CN)_6] > FeSO_4$$

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