Polyacrylamides as co-depressant in hematite and quartz microflotation

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Abstract

In the present study, microflotation experiments were performed on pure minerals systems involving hematite and quartz in the presence of etherdiamine as collector. The influence of polyacrylamides as co-depressant was investigated in a blend with starch depressant. The results obtained demonstrated that all the polyacrylamides used were efficient in hematite depression, at different levels and following the order of effectiveness: cationic > non-ionic > anionic. The depressant power was proportional to the degree of ionicity and the molecular weight. It is proposed that the enhanced performance is due to the presence of two functional groups, the cationic group adsorbing by electrostatic interaction and the amide group $-C(=O)NH_2$ adsorbing by hydrogen bonding. Non-ionic polyacrylamides indicated similar performances for different molecular weights and the proposed adsorption mechanism is hydrogen bonding associated with the amide group. Electrostatic repulsion did not have deleterious action on the adsorption of anionic polymers on hematite, nevertheless the adsorption on quartz was impaired. Polyacrylamides adsorb on quartz, although at a weaker intensity than on hematite.

keywords: iron ore, flotation reagents, polyacrylamides.

1. Introduction

Flotation routes play an important role in iron ore concentration. The reverse cationic flotation is the most used technique in beneficiation of iron ore and the most commonly reagents are starch, as hematite depressant, and etheramine as quartz collector and frother. The use of collectors blends to improve metallurgical recovery has already been investigated and utilized (Araujo *et al*. 2005), but blending depressants is not a common practice.

The use of a combined reagent system could render the depressant action more selective and efficient, besides providing a higher recovery of fine particles, which impair the selectivity. Under this scenario, polyacrylamides are an option to be studied as a co-depressant in iron ore flotation.

The sequence of reagent addition is an important factor and previous studies (Weissenborn *et al*., 1994) indicated that starch is a more selective depressant than polyacrylamides, which when combined promote flocs formation with better selectivity. The sequence could promote the selective flocculation action of starch, and the previous formed flocs could enhance the polyacrylamide action, since Hogg (1999) states that large particles could receive more adsorption of flocculant polymer.

Turrer *et al*. (2007) ran bench scale iron ore cationic flotation experiments. Significant increases in the metallurgical recovery of 5.5% and 7.8% were achieved with cationic and non-ionic polymers, respectively.

Polyacrylamydes were also used as depressant in different flotation systems and promising results were achieved. Liu *et al*. (2007) studied the use of cationic polyacrylamides as diaspore depressant in reverse bauxite flotation. In the conditions tested the depressant action was strong and selective even at relative low dosages of polymer. It could be seen that the higher the cationic charge of polyacrylamide, the better the effectiveness of the separation. Anionic polyacrylamides reached good results in the direct flotation of kaolinite (Yuehua *et al*., 2004). The anionic polymers adsorb on some preferential plans via hydrogen bond minimizing the exposure of hydrophilic plans and providing a low interaction with the collector. The wide pH range of interaction confirmed that the adsorption mechanism is not electrostatic. Ding and Laskowski (2006) reported that the use of anionic polyacrylamides reduce the amine consumption and promote better results in coal flotation. They concluded that a low anionicity result in a low aggregation and better selectivity, which promote the gangue flotation. Moudgil (1983) also reached good results with non-ionic polyacrylamides as gangue depressant in coal flotation flotation and the depressive effect was attributed to the adsorption of the hydrophilic polymer molecules on the coal particles wich render the surface hydrophilic.

Castro and Laskowski (2015) study the depressing effect of polyacrylamide on molybdenite flotation. This study concluded that high-weight anionic polyacrylamides are strong flotation depressant of fine particles of molybdenite. Also could be concluded that shear degraded polymer products maintain a strong depressing effect on flotation of molybdenite.

The objective of this study was to evaluate how the addition of polyacrylamides at different concentrations affects hematite and quartz floatabilities in the presence of etherdiamine as collector and starch as depressant in microflotation tests.

2. Materials and methods

2.1 Mineral sample and characterization

Hematite and quartz mineral samples with high purity degrees were collected in the Iron Quadrangle MG, Brazil. After comminution and screening stages the fractions in the size range -150 + 75 µm were further purified in a Frantz Isodynamic Magnetic Separator.

The chemical composition of the hematite sample was determined in the apparatus Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), from VARIAN, 725-ES model. The iron content was determined by a titrimetric method (Titration of the solution after tin(II) chloride reduction of ferric ion).

The high grade of the quartz sample was confirmed by x-ray diffratometry in the apparatus PANalytical, model Empyrean, Cu-Kα_1 (λ=1,5406 Å) irradiation, and 2θ=0-90º.

2.2 Microflotation tests

Microflotation experiments were performed in a modified Hallimond tube with addition of an extender between the base and top parts of the tube in order to reduce the effects of hydraulic entrainment. The internal volume of tube is 320 mL. The airflow rate was kept at 60 cm^3/min, value determined in previous tests to minimize the hydraulic entrainment. The mineral mass used in each test was 1.0 g with particle size between -150 + 75 µm. Both fractions (floated and non floated) were filtered, dried and weighed in analytical balance model Shimadzu AY220 (d=0,1mg) for determination of floatability.

The collector was etherdiamine partially neutralized with acetic acid, supplied by Clariant (20 mg/L for hematite and 5 mg/L for quartz) at a concentration of 1% w/v. The depressant was corn starch supplied by Ingredion. The solution was prepared by gelatinization with caustic soda, weight ratio starch/NaOH 5:1, at 1% w/v concentration. The used dosage was 10 mg/L for both minerals. Eight different types of polyacrylamide reagents were tested as a co-depressant (three cationic, three anionic and two non-ionic) and five different dosages were used (1, 3, 5, 8 and 10 mg/L). The cationic (C492 HMW, C498 HMW and C492 SUPERFLOC) and anionic (A110 HMW, A130 HMW and A130 V HMW) polymers were supplied by KEMIRA and the non-ionic (Magnafloc 351 and Magnafloc 333) were supplied by BASF CHEMICALS. The tested polymers are listed in Table 1. The solution concentration was 0.01%. Conditioning time was 3 min for polyacrylamides, 5 min for starch and 1 min for amine. The sequence of addition was starch, polyacrylamide, and amine. The flotation time was 1 min. Distilled water was used throughout the experiments.

Table 1 - Polyacrylamides used in the tests.

Polymer name	Degree of ionicity, %	Molecular Weight	Manufacturer
C492 HMW	10	Low	Kemira
C498 HMW	48	Low	Kemira
C492 Superfloc	10	Low	Kemira
A110 HMW	-20	High	Kemira
A130 HMW	-32	High	Kemira
A130V HMW	-34	High	Kemira
Magnafloc 351	-	High	BASF
Magnafloc 333	-	High	BASF

3. Results and discussion

Results of the chemical analysis of the hematite sample are presented in Table 2.

Table 2 - Chemical analysis of the hematite sample.

Fe_2O_3	Fe	SiO_2	Al_2O_3	P	LoI	Mn	CaO	MgO	TiO_2
98.11	68.34	0.3	0.39	0.03	0.35	0.024	0.112	0.12	0.033

Figure 1 shows the X-ray diffractogram of the quartz sample.

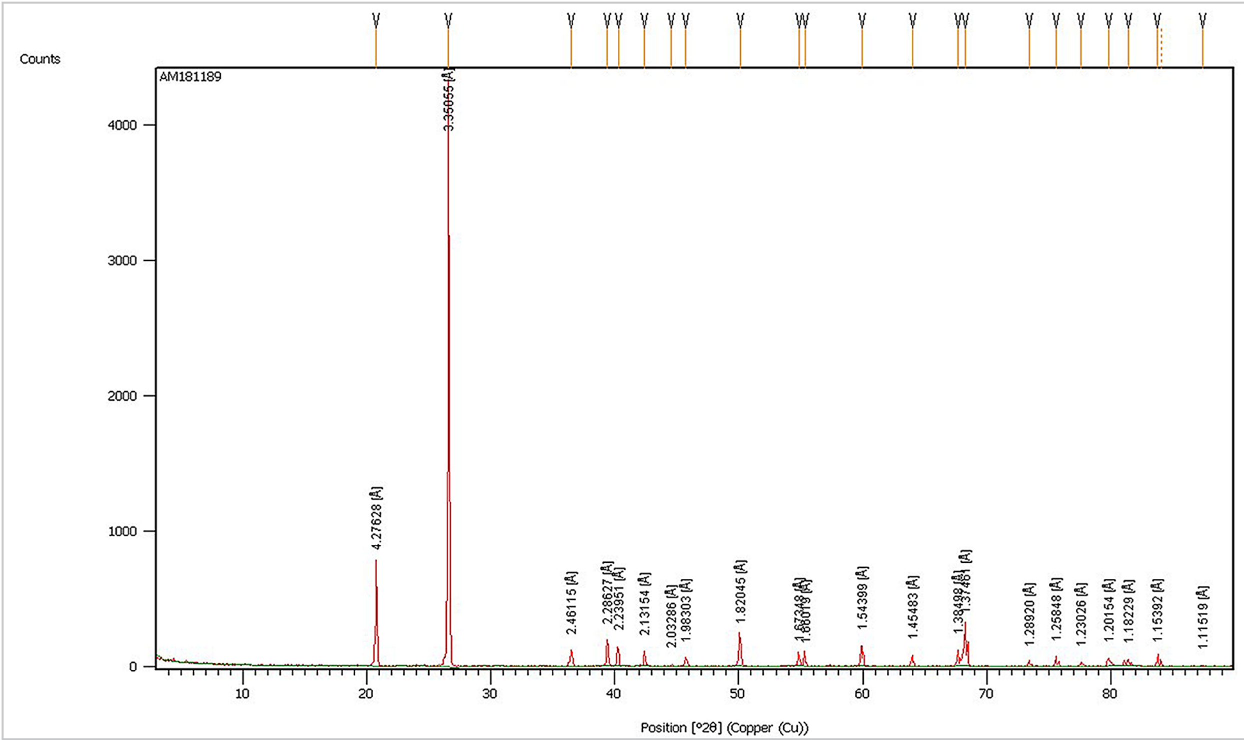

Figure 1 - X-ray diffractogram of the quartz sample (λkα Cu=1,54060 A).

Results of microflotation experiments with hematite and quartz, at pH 10.5, in the presence of three different cationic polyacrylamides, as a function of polymer dosage are presented in Figures 2a and 2b.

The lowest average hematite floatability was 0.296 % for C498 HMW, 2.010% for C492 HMW and 9.353 % for C492 Superfloc, all results considering the dosage of 3 mg/L. The hematite floatability for the dosage of 3 mg/L were approximately 98%, 90% and 52% lower than those of the standard test in which the achieved floatability value was 19.890%.

It was observed that the floatability is determined to first decrease and then increase with larger amounts of the polymer added. This can be associated with some physicochemical modification of the system (Moudgil, 1987).

Cationic polyacrylamide was effective on the quartz sample, although the effect was comparatively weaker than that on hematite, as expected. The minor effect of the cationic polyacrylamide on quartz does not impair significantly the selectivity.

It was observed that the hematite and quartz floatability is dependent on the cationic charge density and molecular weight. The good flotation results using cationic polyacrylamides could be associated with the two kinds of functional groups in this polymer as indicated by Gebhardt and Fuerstenau (1983). The cationic group $-CH_2N{+}(CH_3)_3$ can adsorb on the negative mineral surface via electrostatic interaction. The amide group $-C(=O)NH_2$ is able to adsorb on MOH or MOH_2^+ sites by hydrogen bonding through –N-H atoms.

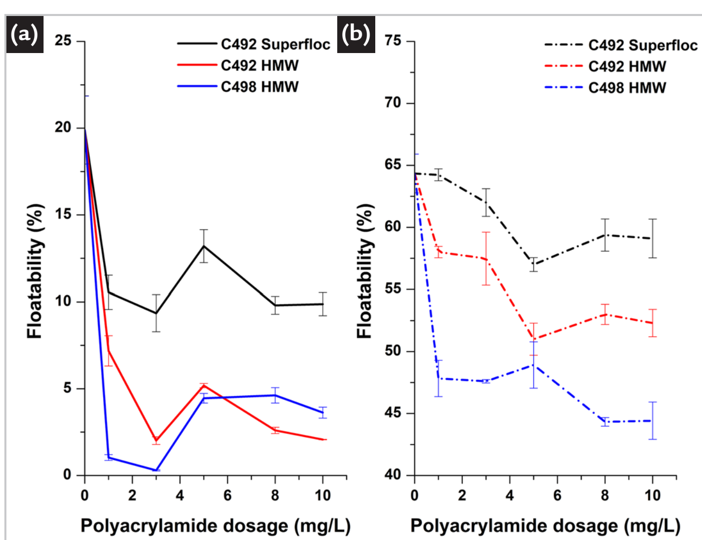

Figure 2 - Hematite (a) and quartz (b) floatability as a function of cationic polyacrylamide dosage, pH 10.5.

Results of hematite and quartz floatability, at pH 10.5, in the presence of three different anionic polyacrylamides, as a function of polymer dosage, are presented in Figures 3a and 3b.

The lowest average hematite floatability was 9.341% for A110 HMW, 8.017 % for A130 HMW and 14.192 % for A130V HMW, all results considering the dosage of 10 mg/L. The hematite floatability in the dosage of 10 mg/L were respectively 53%, 60% and 29% lower than those of the standard test in which the achieved floatability value was 19.890 %. A130V HMW, the most anionic charged and with the higher molecular weight polyacrylamide, achieved the worst hematite depressing results. It could be associated with the strong electrostatic repulsion between the negative charged hematite surface and A130V HMW polyacrylamide (Nasser and James, 2006).

As expected, in the case of quartz the depressant action of anionic polyacrylamides was weaker than on hematite. The minor effect of the anionic polyacrylamide on quartz does not impair significantly the selectivity.

The anionic polyacrylamides were effective in hematite and quartz depression. According to Jin *et al.* (1987), electrostatic forces do not play a relevant role in the adsorption of polymers on mineral surfaces and chemisorption responds for adsorption on hematite. Electrostatic repulsion probably impairs the adsorption of anionic polyacrylamides on quartz. Similar results were obtained by Bagster and Mcilvenny (1985).

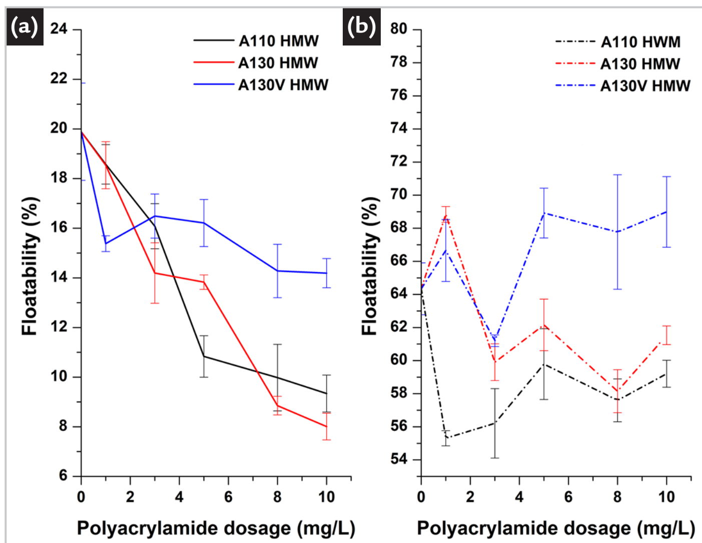

Figure 3 - Hematite (a) and quartz (b) floatability as a function of anionic polyacrylamide dosage, pH 10.5.

Floatability results in the presence of two different non-ionic polyacrylamides presented in Figure 4a and 4b for hematite and quartz, indicate similar performances. Strong depression of hematite was achieved even at low dosages.

The lowest average hematite floatability was 0.868 % for Magnafloc 333 at the dosage of 1 mg/L and 0.701 % for Magnafloc 351 for the dosage of 10 mg/L. These values represent a floatability approximately 95.64 and 96.48 % lower than the standard.

The good flotation results using non-ionic polyacrylamides could be associated with the amide group $-C(=O)NH_2$ that are able to adsorbs on the MOH or MOH_2^+ sites by hydrogen bonding through –N-H atoms.

Non-ionic polyacrylamide was effective on the quartz sample although the effect was comparatively weaker than that on hematite, as expected. The minor effect of the anionic polyacrylamide on quartz does not impair significantly the selectivity.

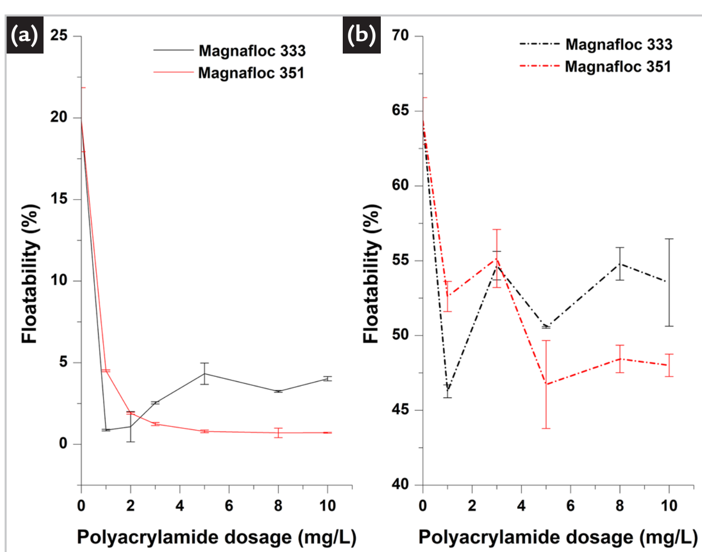

Figure 4 - Hematite (a) and quartz (b) floatability as a function of non-ionic polyacrylamide dosage, pH 10.5.

The figure 5 presents a summary of the better hematite and quartz microflotation results as previous discussion.

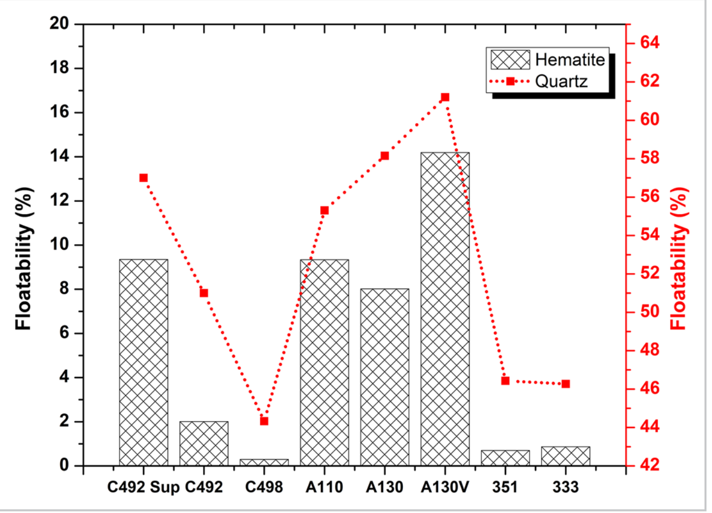

Figure 5. Better hematite and quartz floatability results.

4. Conclusions

Microflotation tests conducted to study the influence of polyacrylamides as co-depressant in a blend with starch depressant of hematite and quartz showed that:

• Hematite and quartz floatability is affected by the use of cationic polyacrylamide as co-depressant. It was observed that the floatability is dependent on the cationic charge density and molecular weight.

• The good flotation results using cationic polyacrylamides as co-depressant could be associated with the two kinds of functional groups, the cationic group associated with the electrostatics interactions and the amide group, associated with bonding interactions.

• The anionic polyacrylamides were effective in hematite and quartz depression. Electrostatic forces do not play a relevant role in the adsorption of polymers on mineral surfaces and chemisorption responds to adsorption on hematite. Electrostatic repulsion impairs the adsorption of anionic polyacrylamides on quartz

• Non-ionic polyacrylamides were effective for hematite and quartz depression, indicating similar performances for different molecular weights. Strong depression of hematite was achieved even at low dosages.

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