Effect of amine and starch dosages on the reverse cationic flotation of an iron ore

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ABSTRACT

In iron ore concentration, reverse cationic flotation of quartz has been successfully employed for particles below 150 µm previously deslimed. Amine and starch are used, respectively, as quartz collector and iron oxides depressant. Understanding the mechanisms of reagents interaction is relevant to improve the separation selectivity, especially for high amine dosages. The term clathrate was used to explain this interaction, meaning a molecular compound in which molecules of one species occupy the empty spaces in the lattice of the other species, resulting in the depression of hydrophobic minerals. Laboratory scale experiments were carried out with itabirite iron ore in three different size ranges. The clathrate formation between molecules of amine and starch may explain the increase of SiO_2 content in the concentrates of the coarse size range ($-150 + 45$ µm) due to an increase in amine dosage.

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1. Introduction

The flotation of iron ores is performed in circuits consisting of mechanical cells, columns, or a combination of both types of machine. The feed consists of particles in the size range between 10 µm and 150 µm. The slimes (fraction < 10 µm) is removed in hydrocyclones and the top size is limited to 5–10% > 150 µm. This wide range of particles size impairs the process selectivity due to possible differences in behaviour concerning properties such as hydrophobicity, specific surface area, and weight).

Oliveira (2006) stated that it is widespread in the technical literature the concept that the fast and disproportional collector consumption by fine particles, due to their higher specific surface area, causes a lower hydrophobic coverage on the coarser particles surface, decreasing the floatability of these particles. This concept was based originally on the investigations by Robinson (1975), in the system quartz–dodecylamine, and Glembotsky (1968), in the system pyrite–xanthate. In both systems higher reagents dosages were required to float larger particles.

According to Brandão (2005), the selectivity of iron ores reverse cationic flotation observed in laboratory and in plant practice is based on the quantitative aspects of collector and depressant adsorption, rather than on qualitative aspects. Starch adsorbs extensively on hematite and at lower intensity on quartz. The cationic collector alkyl etheramine adsorbs strongly on quartz and at lower amounts on hematite. Therefore, after the sequential conditioning of both reagents hematite remains hydrophilic and the quartz surface is rendered hydrophobic.

The interaction between collector and starch molecules has been reported by several researchers (Khosla et al., 1984; Somasundaran, 1969; Schulz and Cooke, 1953).

Some experimental observations by Somasundaran (1969) indicate that the mechanism of depression by starch is not by classical means of competitive adsorption. There seems to be some evidence of increase in adsorption of collector on the mineral surface in the presence of starch and of starch in the presence of collector. "The coadsorption of starch and oleate at the calcite-solution interface and the effects of such coadsorption are explained in terms of a clathrate formed between starch in its helical form and oleate held inside the starch helix. Such wrapping of oleate by starch helixes can explain why the resulting surface is not hydrophobic".

The interaction between a cationic polymer (acrylamidemethacrylamidopropyltrimethyl–ammonium chloride copolymer) and cationic and anionic surfactants (docylammonium chloride and dodecylsulphonate) on quartz was investigated by Somasundaran and Cleverdon (1985). A molecular model was proposed for the polymer – surfactant layer on the quartz particle, the massive polymer species masking the adsorbed amine imparting hydrophilic characteristics to the particle.

Experimental investigations of Khosla et al. (1984) clearly showed the complexity of the problem involving starch and collector interaction. This study corroborates earlier investigations (Partridge and Smith, 1971; Schulz and Cooke, 1953) showing that mutual or synergistic enhancement of starch and collector adsorption should not be taken as universal or unequivocal for all minerals, not even for calcite. Synergistic coadsorption on calcite takes place significantly only for amylose and, possibly, for high amylose content starches.

Potapova et al. (2012) investigated a way to restore the wettability of hydrophobized magnetite due to adsorption of flotation collector via surface modification with hydrophilic polymers, aiming at eliminating problems in the pelletization of concentrates. Cationic, anionic, and non-ionic polymers were tested. Only the anionic ammonium polyacrylate could be successfully used to improve the wettability of magnetite after adsorption of surfactants. Considering that no desorption of the surfactant was observed, it was suggested that "surface hydrophilicity was achieved due to shielding of the hydrophobic surfactant tails by hydrophobic polymer chains".

The targets of the present investigation were to evaluate the effects of particles size range ($-150 + 45 \mu m$, coarse fraction, $-45 \mu m$, fine fraction, and $-150 \mu m$, global fraction), starch and amine dosages, pH level, and rotor speed on the flotation performance of an iron ore, aiming at SiO_2 grade in the concentrate <1%, and to bring light to possible interactions between amine and starch.

2. Materials and methods

The sample utilized is an itabirite iron ore from the Iron Quadrangle, Minas Gerais, Brazil. The characterisation stages were chemical analysis (global and by size range) and size distribution determination. After desliming, the sample was screened to produce two size ranges ($-150 + 45 \mu m$, coarse fraction, and $-45 \mu m$, fine fraction), to be used in laboratory scale flotation tests under different reagents (starch and amine) dosages and at different pH levels. The results obtained with the split samples were compared with those achieved with the global sample.

The flotation tests conditions were:

  i. *collector:* etheramine 30% neutralisation, solution concentration 2% in weight;
  ii. *depressant:* gelatinised corn starch, solution concentration 2% in weight;
  iii. *flotation pH modulator:* sodium hydroxide, solution concentration 5% in weight;
  iv. *solids concentration in the pulp:* 50% in weight.

The levels of variables used in the flotation tests of each size fraction are presented in Table 1. These levels were selected following preliminary tests with the goal of achieving SiO_2 contents in the concentrate <1%. These preliminary tests indicated that higher amine dosages were required for the coarse fraction than for the other fractions. The best starch dosage suggested by the preliminary tests was 500 g/t for the three size fractions. In addition, this work intended to evaluate the effect of different dosages (starch dosage increased to 1000 g/t), pH values, and rotor speed during conditioning on the flotation performance. Furthermore, the effects of pH and rotor speed during conditioning on the amine and starch molecules interaction was evaluated.

Table 1
Levels of variables used in the flotation tests.

Variable	Fraction $-150 \mu m$	Fraction $-150 + 45 \mu m$	Fraction $-45 \mu m$
pH	9.5 and 10.7	9.5 and 10.7	9.5 and 10.7
Amine (g/t_{SiO2})	60 and 100	150 and 250	120 and 200
Starch (g/t_{feed})	500 and 1000	500 and 1000	500 and 1000
Rotor speed during conditioning (rpm)	1400 and 2000	1400 and 2000	1400 and 2000

Flotation tests were carried out using a Denver laboratory scale tests (2.6 L vessel volume). Specific surface areas (BSA) of the particles (10 g samples) were measured using a blaine permeability apparatus.

Chemical analyses of SiO_2 were performed by X-ray fluorescence and of Fe by titrimetric method after chloride reduction.

Residual amine was determined using the colorimetric bromocresol green methodology (Araujo et al., 2007), after filtering of the samples using a specific paper as cloth. The readings of absorbance were done on a spectrophotometer Merck – SQ118, with wave length of 405 nm. This analytical procedure is widely used by Brazilian iron ore processing companies and provides reliable and consistent results such as those reported by Batisteli and Peres (2008).

The mineralogical characterisation was carried out using reflected light optical microscopy.

3. Results and discussion

The results of the weight partition and chemical analyses of the three size fractions used in the flotation tests are presented in Table 2. The mineralogical analysis showed that quartz is the only significant source of SiO_2 in all size fractions. Specular hematite is the main iron mineral. Hematite and quartz particles are fully liberated.

The size distributions of the global and coarse fractions are illustrated in Fig. 1. The global fraction presented approximately 60% passing 45 μm and the coarse fraction presented 6% passing 45 μm and 5% retention in 150 μm.

Table 3 presents the results of the effects of amine dosage and pH (at starch dosage 500 g/t) on iron recovery and SiO_2 content in the concentrate and iron grade in the reject fraction for the three size fractions. An unexpected result was observed in the case of the coarse fraction. At pH 9.5 the silica grade in the concentrate increased from 1.18 to 3.81 as a consequence of amine dosage increase from 150 g/t_{SiO_2} to 250 g/t_{SiO_2}.

Table 4 presents the results of the effects of amine dosage and pH (at starch dosage 1000 g/t) on iron recovery and SiO_2 content in the concentrate and iron grade in the reject fraction for the three size fractions. Again, at pH 9.5 a sharp increase in silica grade in the concentrate from 1.17 to 4.70 was observed as a consequence of amine dosage increase from 150 g/t_{SiO_2} to 250 g/t_{SiO_2}.

Increasing the amine dosage caused increase in the SiO_2 content in the concentrate in the case of the coarse fraction. On the other hand, in the case of the fractions $-150 \mu m$ (global) and $-45 \mu m$ (fine) no increase of SiO_2 content in the concentrate was observed.

Table 5 illustrates the SiO_2 distribution in the concentrate for the coarse fraction under different amine and starch dosages and pH levels.

The results in Table 5 indicate increase in quartz depression with the increase in amine dosage, the effect being more significant for pH 9.5 and starch dosage 1000 g/t.

The increase in the SiO_2 content in the concentrate with increase in the amine dosage, observed in the case of the coarse fraction can be an indication of the interaction between starch and

Table 2
Weight partition and chemical analyses of the three size fractions, global, coarse, and fine.

Fraction (μm)	Partition (%)	Chemical analysis (%)	
		Fe	SiO_2
-150	100.00	46.00	32.90
$-150 + 45$	42.20	30.03	55.52
-45	57.80	57.67	16.38