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Influence of Fatty Acid Based Collector on The Flotation of Heavy Minerals from Alkali Feldspar Ores

ECE KILINC AKSAY*, ALI AKAR†, EROL KAYA† and ILKNUR COCEN†
Dokuz Eylul University, Torbali Vocational School of Higher Education, 35860 Izmir, Turkey
Fax: (90)(232)8531606; Tel: (90)(232)8531828
E-mail: ece.kilinc@deu.edu.tr

Turkey possesses large reserves of mainly albite feldspar ores in the western part. The principal discolouring impurities in these deposits are titanium and iron oxide, which reduce the quality and hence the revenue of the ore. Conventionally, the coloured gang minerals can be separated from albite through the use of reverse multi-stage flotation. The results of mineralogical investigation indicate that the albite ore samples of Mugla-Milas district contain mainly the high level of titanium and iron oxide minerals and small amount of mica minerals. This study showed that these main coloured impurities in the albite ore can be floated together in an alkali medium by single-stage flotation, using fatty acid based collector. It is found that Aero 704 collector achieves much superior results at 1000 g/t dosage and pH 9 compared to other anionic collectors. The results of bench scale flotation tests to evaluate the performance of this collector have been reported along with the elaboration of the mechanism of the collector action.

Key Words: Industrial mineral, Anionic collector, Feldspar, Flotation, Mineral processing.

INTRODUCTION

Feldspar consists essentially of aluminum silicates combined with varying percentage of potassium, sodium and calcium. Commercial feldspars minerals of albite ($NaAlSi_3O_8$) and orthoclase ($KAlSi_3O_8$) are primarily used as a flux in glass and ceramic industries due to their alkali and alumina content. In general, the gangue minerals associated with albite are mica minerals (muscovite and biotite), iron oxide, titanium minerals (rutile and sphene), tourmaline and hornblende[1,2]. In most cases, commercial quality of the feldspar can be increased by applying conventional concentration techniques, *i.e.* magnetic separation and flotation methods to remove these impurities from the feldspar ore[1-4]. However, while magnetic separators are usually used only in the removal of iron bearing minerals, flotation process is the most selective method used in the rejection of both mica and heavy minerals[1,2].

†Mining Engineering, Division of Mineral Processing, Dokuz Eylul University, 35160 Izmir, Turkey.

Conventionally, feldspar can be separated from the impurities through the use of multi-stage flotation. Mica firstly floated by amine (cationic) flotation at acidic pH (2.5-5)[2,3,5-8], followed by flotation of iron and titanium bearing (rutile) heavy minerals, using fatty acids in acidic medium (pH 4-6)[3,5,9,10] and basic conditions (pH 9)[11,12], petroleum sulfonates at pH 3.0-3.5 or fatty primary amine acetate at pH 2.5[13,14]. The use of alkyl succunamate together with petroleum sulfonate, increases the efficiency of flotation in the removal of heavy minerals[15-17]. The use of non-polar oils like fuel oil increases the selectivity of mica and heavy minerals flotation[15,18,19]. Furthermore, titanium minerals can be floated with hydroxamates at pH 6.5, oleoyl sarcosine at pH 7.7 and potassium oleate at pH 7.7[1,3,20]. In the flotation of titanium minerals containing sphene ($CaSiTiO_3$), oleic acid or its soaps[5,20] or various vegetable oil soaps are also successfully used[2,5,11]. Separation of associated quartz is also sometimes desired. In this case, feldspars are activated by hydrofluoric acid, then floated by amines at pH of 2.5-3.5[2-5,13].

Slime containing mostly clay and fine gangue minerals have been removed by classifiers, hydroseparators and cyclones, because it decreases the flotation recovery of feldspar and increases the reagent consumption[2,5,6,18,21]. Furthermore, after the flotation of mica minerals, the use of classifier or cyclone with the purpose of decreasing the effect of amine type reagents in water, increases the selectivity of anionic reagents used during heavy mineral flotation[2,18].

In this investigation, an albite concentrate was produced by a single-stage flotation of decolouring impurities. In this study, anionic type fatty acid (Aero 704 and 727) and hydroximate (Aero 6493) collectors have been tested to remove micaceous and heavy minerals from the albite ore of Mugla-Milas district in a single-stage. Bench scale flotation tests were conducted to evaluate the performance of three anionic collectors at the same conditions. Furthermore the effects of collector dosage and pH circuits were investigated by carrying out laboratory scale flotation tests.

EXPERIMENTAL

Alkali feldspar ore sample used in the experiments was albite (Na-feldspar) ore from the Mugla-Milas region of Turkey. Chemical composition of the albite ore used in this investigation: 68.1 % SiO_2, 18.2 % Al_2O_3, 0.34 % TiO_2, 0.42 % Fe_2O_3, 1.06 % CaO, 0.65 % MgO, 9.95 % Na_2O, 0.76 % K_2O, 0.52 % LOI. The chemical and microscopic analysis, coupled with XRD determination, revealed that the ore contains albite with minor amounts of ortoclase, quartz, titanium minerals (rutile and minor amounts of sphene), iron oxide minerals and small quantities of mica minerals (muscovite and biotite) and weathered clay minerals.

Flotation test were conducted with different anionic reagents individually. Aero 704 promoter consists of various type of fatty acids is known as the straight tall oil fatty acid. As for Aero 727 that contains surfactants and other chemical coupling agents together with various types of fatty acids is defined as tall oil fatty acid. Aero 6493 promoter is alkyl hydroximate based collector and is specified to be a mixture of alkyl hydroxamic acids. These promoters were supplied by Cytec Industries Inc. (USA). In the flotation tests, the pH of the system was adjusted with H_2SO_4 and NaOH. These reagents are supplied by Merck, Germany.

Alkali feldspar ore was grinded to below 2 mm by a laboratory jaw and hammer crushers respectively and ground to below 0.3 mm by using a porcelain ball mill. A closed system was operated with 5 min intervals to separate the ground at 0.3 mm sieve size. Prior to flotation tests, the samples were deslimed at 40 µm with wet sieving. The amount of the material removed is 10 % by weight. All the flotation tests were conducted on 0.3 ± 0.040 mm fractions with 500 g samples.

The impurities from the samples were removed by reverse flotation method, *i.e.*, mica and heavy minerals were floated. A 2 L, self-aerated sub-A Denver flotation machine was used. Test conditions and the procedure followed for flotation tests are summarized in Table-1. For the removal of impurities by single-stage flotation, collectors were added into the cell in 4 steps. In flotation tests 20 g/t commercial pine oil was used as frother. All the flotation products (feed, slime, concentrate and tailings) were analyzed by XRF to determine the best performing collector.

TABLE-1
TESTING PARAMETERS FOR SINGLE-STAGE FLOTATION

Impeller speed (rpm)	Solid rate (%)	Conditioning time (min)	Flotation time (min)
1200	30	40*	20*

*Collectors added stage-wise.

RESULTS AND DISCUSSION

With flotation tests, all the impurities (mica and heavy minerals) were floated together in one-stage. Several anionic collectors were tested to measure their effectiveness for the removal of mica and heavy mineral impurities in single-flotation-stage. The results were explained on the basis of Fe_2O_3 and TiO_2 % recoveries in tailings (floated), Fe_2O_2 and TiO_2 % grades in albite concentrates (*i.e.* not floated or sink). Çelik *et al.*[3] found that Aero 6493 collector is effective at pH 6.5 for floating titanium impurities from albite. Besides they emphasized that the manufacturer recommended the use of hyroximate above pH 6.

Fig. 1 illustrates the results of flotation tests with various anionic collectors. These collectors were tested at pH 8 and added stage-wise, 300 g/t at each step, totaling 1200 g/t. Aero 727 promoter shows the less performance, as seen from the Fig. 1. The results showed that Aero 704 promoter was more effective than Aero 6493 type collector for the removal of both iron and titanium containing minerals at the same conditions.

These flotation tests were applied at pH 6, pH 7 and at pH 8. It was observed that 3 collectors failed because bubbles were not formed at acidic conditions. It is seen that the better performance is yielded for 3 collectors at pH 8 than pH 7.

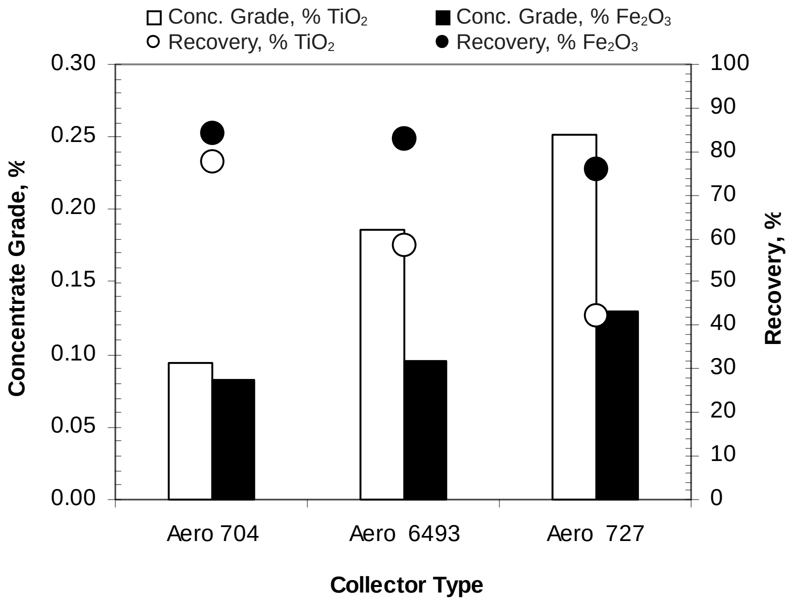

Fig. 1. Effect of different anionic collectors on the removal of both mica and heavy minerals in single stage

Aero 704 collector gave better results in the removal of iron and titanium bearing minerals. Albite concentrate was produced with 0.094 % TiO_2 and 0.082 % Fe_2O_3 grades. The recoveries of TiO_2 and Fe_2O_3 in tailings were 77.88 and 84.38 %, respectively.

The effect of pH in basic circuits for the removal of mica and heavy minerals were investigated using Aero 704 collector with single-stage flotation and the results are shown in Fig. 2. The coloured impurities in albite ore were floated stage-wise with 1200 g/t Aero 704 promoter. The results were evaluated on the basis of TiO_2 and Fe_2O_3 grades in the albite concentrate and recoveries of the coloured impurities from the albite ore.

As clearly seen in Fig. 2, with the increasing of pH in basic circuits, the recoveries of coloured impurities in albite concentrate are increased and the best quality concentrate was obtained. The tests performed in the presence of Aero 704 promoter at pH 10 gave closer results containing the recoveries and grades of impurities with pH 9. Based on the bulk flotation results shown in Fig. 2, Aero 704 promoter exhibited the best performance at pH 9. The albite concentrate contains 0.067 % Fe_2O_3 and 0.083 % TiO_2 grades with the removal of coloured impurities of 87.08 % Fe_2O_3 and 80.23 % TiO_2.

The performance of Aero 704 collector was tested with various collector dosages at pH 9. Aero 704 promoter added stage-wise at flotation tests. The results of the flotation tests were presented in Fig. 3.

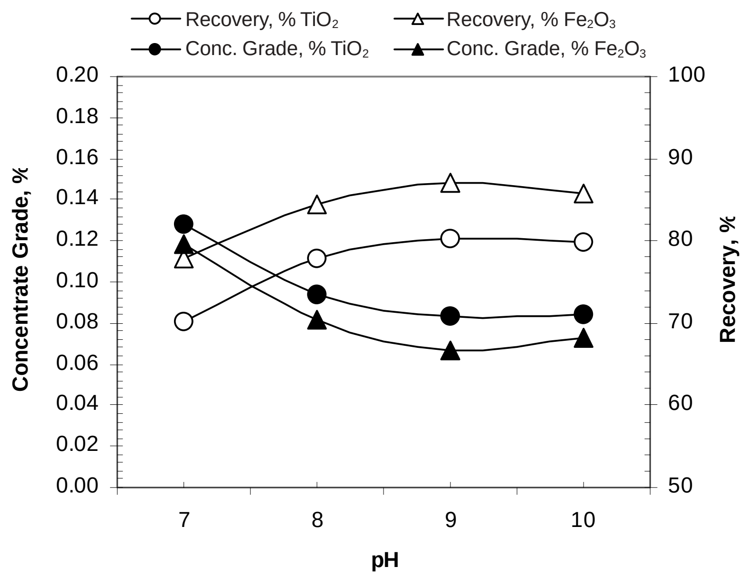

Fig. 2. Effect of pH in basic circuits using Aero 704 for the removal of mica and heavy minerals in single stage

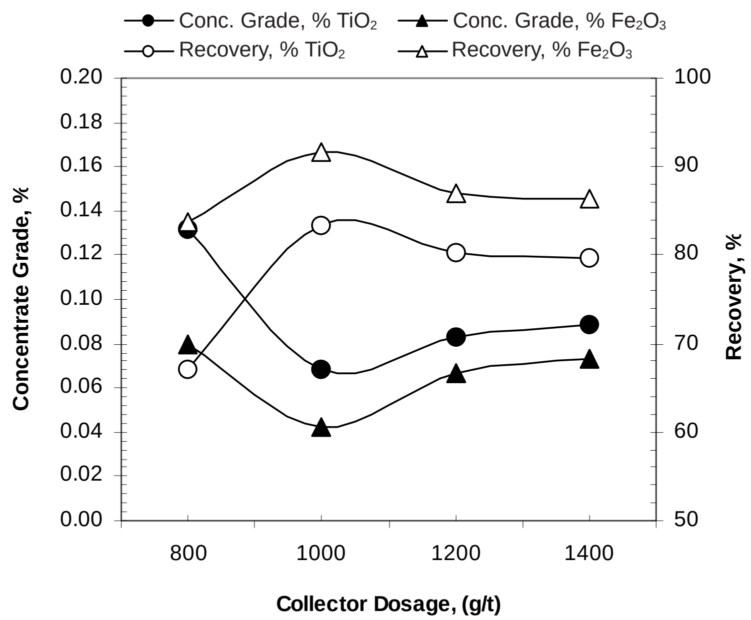

Fig. 3. Effect of Aero 704 collector dosage for the removal of mica and heavy minerals

As shown in Fig. 3, optimum dosage has been provided with the use of 1000 g/t Aero 704 promoter at pH 9. The performance of Aero 704 has decreased slightly at over the optimum dosage. Albite concentrate with 0.068 % TiO_2 and 0.042 % Fe_2O_3

grades was produced while mica and heavy minerals were removed from the albite ore with the recoveries of 83.40 % TiO_2 and 91.70 % Fe_2O_3 at the optimum conditions.

The fatty acid collector is normally used in neutral and basic circuits with best effectiveness in most nonmetallic mineral circuits[6]. Aero 704 is a straight tall oil fatty acid promoter with varying acid values, rosin acid content and per cent fatty acid[22]. It has been noted that this fatty acid-based promoter is most widely used for alkaline circuit flotation of iron ores and iron bearing mineral impurities especially from glass sands.

While albite has an i_{ep} of around 1.5[3,23], rutile is the major titanium mineral in albite and the reported i_{ep} of natural rutile varies from 3.5 to 5.5[24]. Fatty acids are the most common collectors used for the removal of coloured impurities from feldspar ores[3]. Rutile can easily be floated with unsaturated fatty acids at pH 4-6 but the extend of floatability decreases depending on the fatty acids which contains oleic, linoleic and linolenic acids, respectively[5,10]. The greater the number of double bonds in the hydrocarbon chain of a fatty acid, the lower the maximum value of pH at which rutile flotation is possible[25]. Fatty acid soaps and sodium dodecyl sulphate collectors in rutile flotation are determined to have strong collecting power for rutile[10]. Oleic acid or oleate adsorption on salt-type minerals such as fluorite and calcite is obtained in chemisorption ways and has been covered in several comprehensive reviews[26-28]. Chemical adsorption of oleic acid on fluorite was reported to increase with pH and maximum pH of 9. Similar results have been obtained with barite and calcite minerals[29]. Similarly, the adsorption mechanism of oleate on titanium minerals such as rutile is also regarded as chemisorption with titanium[3]. Purcell *et al.*[9] the rutile pzc value is obtained at pH 6.7 but rutile flotation is determined to be more dependent on Na-oleate concentration than that of pzc. At 10^{-6} M and 10^{-7} M Na-oleate concentrations, rutile flotation is obtained below rutile pzc values, whereas higher concentration of Na-oleate in rutile flotation is obtained at higher pH values above the pzc.

Conclusion

The results of bench flotation tests studies for the removal of micaceous and heavy minerals from an albite ore received from the Mugla-Milas region in Turkey are presented below: (i) The ore contains albite, orthoclase, quartz, rutile, minor amounts of sphene, iron oxide minerals, small quantities of muscovite and biotite and weathered clay minerals. Chemical analysis of the ore reveals 9.95 % Na_2O, 0.76 % K_2O, 68.1 % SiO_2, 18.2 % Al_2O_3, 0.42 % Fe_2O_3, 0.34 % TiO_2, 1.06 % CaO, 0.65 % MgO, 0.52 % LOI grade values. (ii) The use of Aero 704 promoter was proved to be effective in the removal of coloured impurities (micaceous and heavy minerals) in an alkali pH in single-stage. It also provides easy control of operations due to a one-stage flotation system. (iii) Superior concentrate product was obtained at conditions of 1000 g/t dosage of Aero 704 promoter and pH 9 by a single-stage flotation. Under these conditions, albite concentrate with 0.068 % TiO_2 and 0.042 % Fe_2O_3 grades was produced and mica and heavy minerals were removed from the ore with the recoveries of 83.4 % TiO_2 and 91.7 % Fe_2O_3.

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