

## Technical Note

## Electrokinetic behavior and flotation of kaolinite in CTAB solution

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**Abstract**

The electrokinetics and flotation behavior of kaolinite in cetyltrimethylammonium bromide (CTAB) solution were studied. The point of zero charge (PZC) of kaolinite is 4.3. The possible mode of CTAB adsorption on kaolinite is due to Coulombic and Van der Waals forces revealed by zeta-potential and FTIR measurements. The negative zeta potential of kaolinite and the adsorption of cationic collectors on kaolinite were higher in alkaline media than in acidic media. However, the flotation tests show that the kaolinite exhibited much better floatability in the acid range than in the basic pH range in the  $2 \times 10^{-4}$  M CTAB solution. The surface charge of the basal plane is negative and that of the edge is positive in the acid pH range. The aggregation occurs possibly by electrostatic interaction between particles because of different charged based plane and edges, and makes floatability of kaolinite better in an acid pH range.

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**Keywords:** Flotation collector; Froth flotation**1. Introduction**

Alkyl ammonium salts are widely used as collectors for oxide and silicate minerals. Usually, the amine flotation of oxide and silicate minerals is better at  $\text{pH} > \text{PZC}$  where the mineral surfaces are negatively charged (Smith and Akhtar, 1976). The individual ion electrostatic adsorption, ion–molecule dimeric complex adsorption and the coadsorption of ion and molecule have ever been proposed to be responsible for the mechanism of amine flotation (Somasundaran, 1976; Smith and Scott, 1990; Qin et al., 2001). In the reverse flotation of diasporic-bauxite, which is very important for aluminum oxide production in China, kaolinite is the main gangue to be removed. Although there is much research on the layer charge, cation-retention capacity, adsorption, hydrophilicity and hydrophobicity related to the adsorption about the aluminosilicate minerals (Saada et al., 1995; Hussain et al., 1996; Mermut and Lagaly, 2001) and there are a few reports on the flotation of kaolinite (Hu et al., 2001, Cao et al., 2001),

the cationic flotation mechanism of kaolinite is unclear, especially flotation of kaolinite from the bauxite deposits.

**2. Experimental**

Hard kaolinite, taken from Ping ding Shan, He-nan province in China, was hand picked then crushed and ground in a porcelain mill. The  $-0.098$  mm fraction was used in flotation. The samples were further ground in an agate mortar. The  $-5$   $\mu\text{m}$  fraction was used in zeta-potential and transmittance measurements. Cetyltrimethylammonium bromide (CTAB) of analytical quality was used as a collector. HCl and NaOH were used as pH modifiers.

Flotation tests were conducted in a lab. microflotation cell. Zeta potential was measured by using a Brookhaven Zeta plus zeta meter (USA). The transmittance of the suspension was measured on the 756 MC UV–VIS spectrometer. The FTIR spectra were obtained with a Nicolet spectrometer. The diffuse reflectance infrared (DRI) spectra were measured on the air-dried  $-5$   $\mu\text{m}$  powder after treating with CTAB. The sample was not mixed with KBr. The untreated kaolinite powder was used as reference. The DRI Nicolet accessory was utilized.

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### 3. Results and discussions

#### 3.1. Electrokinetic and flotation behavior of kaolinite

The variation of zeta-potential and flotation recovery of kaolinite with pH is shown in Fig. 1. At low pH values, a positive zeta potential is observed. The point of zero charge (PZC) of the kaolinite occurs at pH 4.3. Above pH 4.3, the kaolinite is negatively charged, and there is an increase in the negative potential with increasing pH.

In  $2 \times 10^{-4}$  mol/l CTAB solution, the kaolinite exhibited a better floatability in an acidic region, and the flotation of kaolinite decreased with the increase of pH. Similar results have been obtained for DDA/kaolinite system.

#### 3.2. Adsorption of CTAB on kaolinite

The FTIR spectra of the kaolinite treated with solution CTAB ( $2 \times 10^{-4}$  mol/l) respectively at pH 2, pH 5 and pH 9 were obtained. The two stronger absorbance bands in the  $3000\text{--}2800\text{ cm}^{-1}$  region of the spectra were selected and shown in Fig. 2. The peaks at  $\sim 2928$  and  $\sim 2855\text{ cm}^{-1}$ , are due to the anti-symmetric and symmetric  $\text{CH}_2$ -stretch vibration of the carbon chains, respectively. The increasing absorbencies in the C–H stretch region spectra of DDA and CTAB indicated the increased uptake of DDA and CTAB from pH 2 to pH 9. Similar results have been obtained for DDA/kaolinite system. Compared with Fig. 1, it can be seen that the adsorption of CTAB on kaolinite was increased with the increase of the negative zeta potential of kaolinite and pH values. This suggests that electrostatic interaction is the dominant adsorption mechanism for cation collector-kaolinite system.

#### 3.3. Flotation mechanism of kaolinite

It is unusual that the floatability of kaolinite decreased with the increase of pH, while the negative zeta

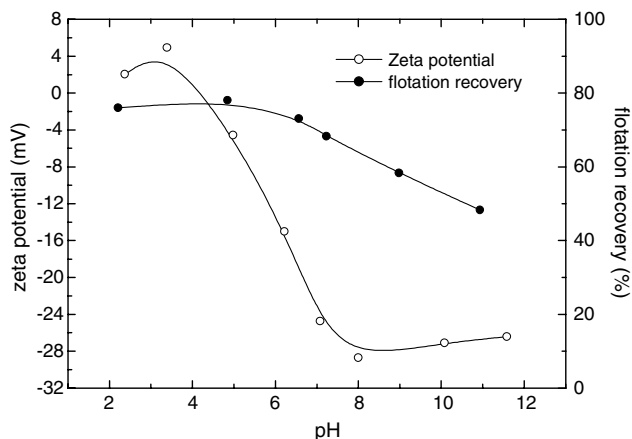


Fig. 1. Zeta potential of kaolinite in pure water and flotation recovery of kaolinite using CTAB (0.2 mM) as a collector as a function of pH.

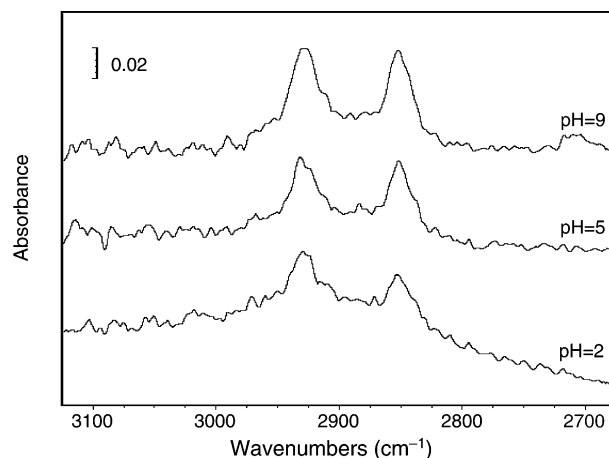


Fig. 2. Selected DRIFT spectra of kaolinite after treatment with the CTAB (0.2 mM) solution.

potential and the adsorption of collector are increased as seen from Figs. 1 and 2. It is different from the flotation behavior of quartz, diaspore and other oxide minerals using cationic collector which have a maximum flotation recovery in the basic pH range (Smith and Scott, 1990; Ravishankar and Yoon, 1997; Qin et al., 2001). A possible reason is that in the acid region, the surface charge of the basal plane and the lattice edges of kaolinite are different. Kaolinite particles interact in edge-to-face modes and form a “card-house” structure in aqueous media (Rand and Melton, 1977). The structure makes the aggregation of kaolinite particles take place between different charged surfaces and the floatability of kaolinite is enhanced. However, in the basic pH region, the basal plane and lattice edges of kaolinite are both negatively charged. The high negative zeta potential in the basic pH region makes the kaolinites completely disperse in the aqueous solution and hydrophilicity increases. The aggregation/dispersion of kaolinite suspension results were demonstrated in Fig. 3,

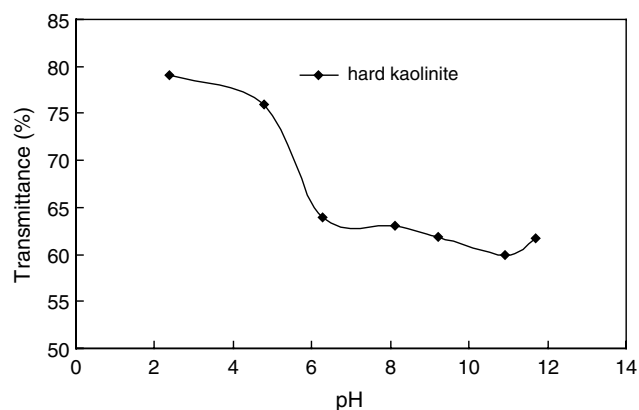


Fig. 3. The transmittance of kaolinite suspension as a function of pH.

which showed the same tendency with the flotation results in Fig. 1.

#### 4. Conclusion

The PZC of kaolinite is pH 4.3. The negative zeta potential of kaolinite is increased with the increase of pH. The adsorption of CTAB on kaolinite is governed mainly by electrostatic interaction. Although the negative zeta potential of kaolinite and the adsorption of cationic collectors on kaolinite are higher at alkaline pH region, kaolinite exhibited a better floatability in the acidic pH region and the floatability of kaolinite decreased with the increasing pH. The anomalous cationic flotation behavior of kaolinite may be attributed to the aggregation or dispersion behavior of kaolinite in various pH range due to the difference in the charged nature of basal planes and edges of kaolinite.

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