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Flotation separation of diaspore from kaolinite, pyrophyllite and illite using three cationic collectors

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ABSTRACT

The effect of cationic groups on performance of 12-carbon chain collectors in flotation separation of diaspore from kaolinite, pyrophyllite and illite has been investigated by flotation tests and explained by density functional computations. The flotation test results indicated that the separation of diaspore from these aluminosilicate minerals was feasible at strong alkaline conditions by using cationic collectors, dodecylamine chloride (DDAC), dodecyl trimethyl ammonium chloride (DTAC) or dodecylguanidine sulfate (DDGS), respectively. In strong alkaline conditions, these three collectors showed excellent selectivity against diaspore, however, DDGS returned superior collecting ability for aluminosilicate minerals compared with DDAC and DTAC. By using the density functional theory (DFT), we calculated some properties such as the H and N atomic charges and cationic group charges which are related to the reactive behavior of 12-carbon chain collectors at B3LYP/6-31G (D) level. The results of calculations indicated that the efficiencies of these three cationic collectors depend on the investigated parameters, and DDGS is better than DDAC and DTAC as a collector agent. The theoretically obtained results are consistent with the flotation tests.

1. Introduction

China has about 2500 million tonnes of bauxite reserves, and more than 98% of the bauxite is of the diasporic type. The gangue silicon minerals in diasporic bauxites are mainly kaolinite, pyrophyllite and illite. A unique undesirable feature of Chinese diasporic ores is their low Al_2O_3 to SiO_2 mass ratio, typically ranging from 4 to 6. Chinese diasporic ores have been processed mainly by the sintering process. It is known that high grade bauxite, with an Al_2O_3 to SiO_2 mass ratio greater than 10, can be processed directly by the Bayer process (Papanastassiou et al., 2002; Ma et al., 1996). Compared with sintering process, the Bayer process is environmentally friendly and low alumina production cost. Therefore, it is highly desirable to increase the Al_2O_3 to SiO_2 mass ratio of Chinese diasporic ores by a low cost physical separation process.

An effective processing method may be the reverse flotation, it is less collector consumption, less foaming product and less effect on metallurgy than direct flotation (Liu et al., 2007; Hu et al., 2000, 2001; Hu, 2003; Luo et al., 2001). The reverse flotation for aluminosilicates removal is to float out these minerals from diaspore (Jiang et al., 2001). Whereas, alkylguanidine as a collector agent for diasporic bauxite flotation has not been studies in the previous work and the effect of cationic groups on performance of 12-carbon chain collectors in flotation separation of diaspore from kaolinite, pyrophyllite and illite is also worthy of attention. In this paper, the reverse flotation separation of diaspore from kaolinite, pyrophyllite and illite is investigated by flotation tests using dodecylamine chloride (DDAC), dodecyl trimethyl ammonium chloride (DTAC) and dodecylguanidine sulfate (DDGS) as collectors, and the flotation results are further explained from the structure–reactivity relationship of collector by density functional computation at B3LYP/6-31G (D) level.

2. Experiments

2.1. Materials

The diaspore, pyrophyllite and illite samples used in the experiments were prepared from hand picked crystals obtained from Mianchi, Qingtian and Ohai deposits in China. Kaolinite sample was supplied from Geological Museum of China. All samples were over 92% in purity by mineralogical analysis, chemical analysis and X-ray diffraction.

All samples were ground in porcelain to pass 0.076 mm. The BET surface area was measured as 1.22 $m^2 g^{-1}$, 10.35 $m^2 g^{-1}$, 9.60 $m^2 g^{-1}$ and 11.20 $m^2 g^{-1}$ for diaspore, kaolinite, pyrophyllite and illite. The isoelectric point (IEP) of them in 1 mM KNO_3 solution exhibited at pH 5.4, 3.2, 2.3 and 2.9.

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The diasporic bauxite ore used in this bench-scale flotation tests was supplied from Zhengzhou in China. This sample with an Al_2O_3 head assay of 65.12% and 11.13% SiO_2 head assay was mainly composed of 67.57% diaspore, 10.8% kaolinite, 6.9% illite, 3.1% pyrophyllite and 0.7% chlorite by the X-ray diffraction analysis and mineralogical analysis, and the Al_2O_3 to SiO_2 mass ratio of it was 5.85.

DDAC and DTAC were supplied by Daochun Chemical Engineering and Technology Corporation in China, and DDGS was synthesized using *O*-methyl isourea sulfate with dodecylamine by our team. Solutions of HCl and NaOH were used to adjust the pH values in the system.

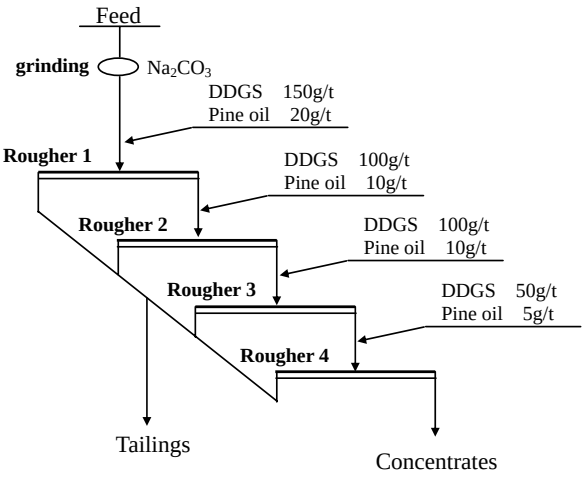

Fig. 1. The flowsheet of reverse flotation experiments.

2.2. Flotation tests

Pure mineral particles (3 g) were placed in a plexiglass cell (40 ml), which was then filled with distilled water. After adding the desired amount of reagents, the suspension was agitated for 3 min and the pH was measured before flotation. The flotation was conducted for 8 min. The products were collected, dried, and weighed. The recovery was calculated based on the dry weights of the products obtained.

The ore sample (500 g crushed to −2 mm during sampling) with pH modifier sodium carbonate was ground to 75.5% passing 76 μm in a Φ200 × 400-mm XMB-type steel mill at a pulp density of 50% (by weight). The pulp was conditioned at 30% solids with the collector and frothing agent added in a 1.5 dm^3 XFD-type flotation machines. The ore flotation tests were conducted in accordance with the flowsheet shown in Fig. 1.

2.3. Computational methods

All calculations were made using the Gaussian03 (Frisch et al., 2003) and Chemoffice2005 programs and the energies were corrected by means of the full counterpoise technique. The initial molecular modeling of DDAC, DTAC and DDGS cations and dodecylamine (DDA) were optimized by MM2 and MP3 methods as implemented in Chemoffice2005. The obtained geometries

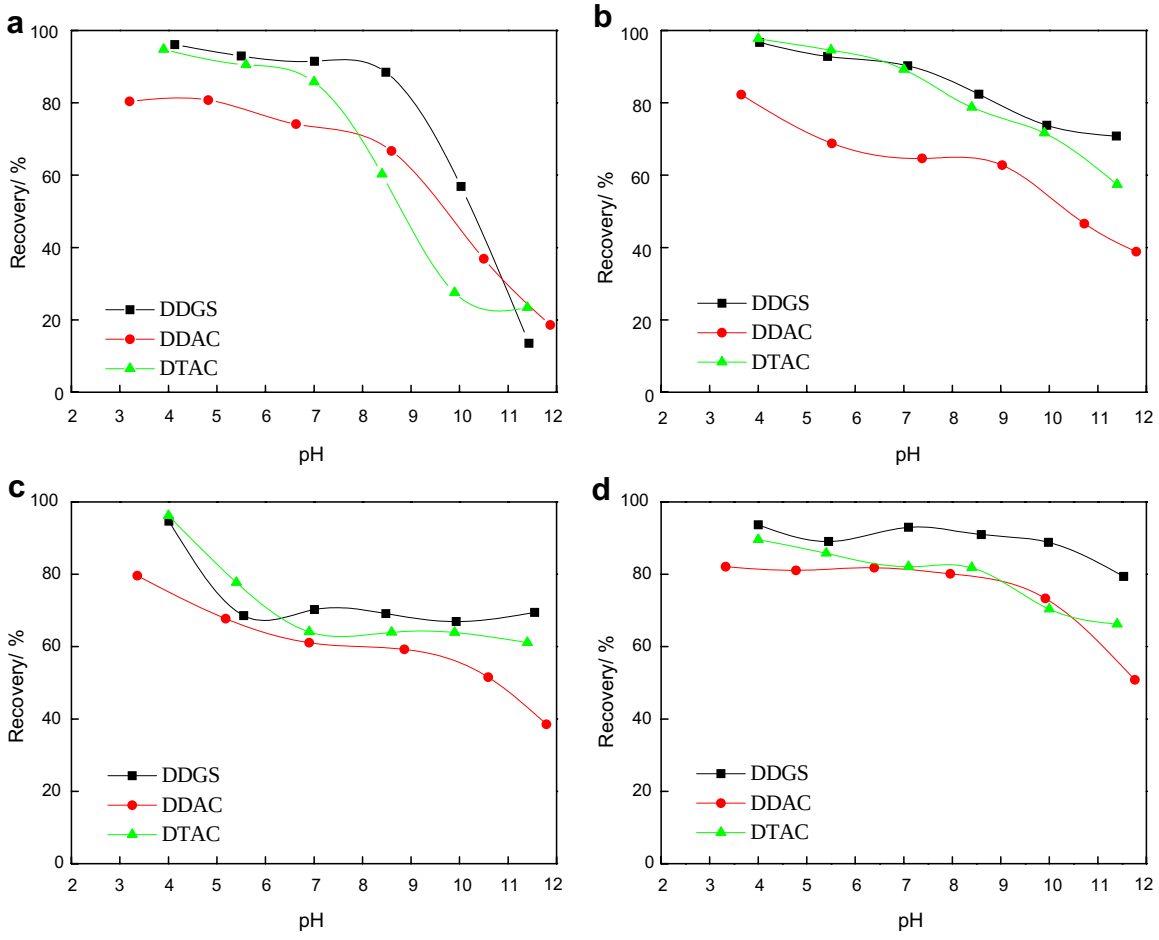

Fig. 2. Flotation recovery of single mineral as a function of pH using C_{12} cationic collectors [C] = 0.2 mM: (a) diaspore; (b) kaolinite; (c) illite; (d) pyrophyllite.