

# Flotation separation of diasporite from aluminosilicates using commercial oleic acids of different iodine values

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## ABSTRACT

A systematic study of diasporic bauxite flotation using commercial oleic acids with different iodine values as collector was conducted in this paper. Bench scale flotation tests for diasporic bauxite ore and micro-flotation tests for relevant pure minerals (including diasporite, pyrophyllite and kaolinite) were carried out at different conditions using commercial oleic acids with iodine values of 65, 121 and 131. The results suggest that an increase in the iodine value of oleic acid would lead to improved flotation separation of diasporite from aluminosilicates. Use of the commercial oleic acid with iodine value of 131 in closed-circuit flotation tests allowed us to obtain a concentrate with alumina-to-silica (A/S) ratio of 5.33 and alumina recovery of 85.56% from the feed ore (A/S ratio = 3.39). Chemical analyses of these commercial oleic acids found that an increase in the iodine value was associated with increased proportion of linoleic acid in the commercial oleic acids. To fundamentally understand the correlation between the iodine value of commercial oleic acids and the efficiency of flotation separation of diasporite from aluminosilicates, the computational studies of frontier molecular orbital energy of oleic and linoleic acid were done, and the results suggest that linoleic acid has higher chemical activity than oleic acid and its chemical adsorption on diasporite is more stable than that of oleic acid.

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## 1. Introduction

There are approximately 3.8 billion tonnes of bauxite reserves, predominantly composed of diasporic bauxite, in China. Compared with gibbsite-type bauxite, diasporic bauxite has features of high aluminum content (>55%  $\text{Al}_2\text{O}_3$ ), high silica content (5%–15%  $\text{SiO}_2$ ), low iron content (<15%  $\text{Fe}_2\text{O}_3$ ) and low  $\text{Al}_2\text{O}_3$ -to- $\text{SiO}_2$  (A/S) mass ratio, which make it uneconomical to directly feed the Bayer process. The dominant silica-bearing minerals in diasporic bauxite are pyrophyllite, kaolinite and illite. For the purpose of increasing the A/S mass ratio of diasporic bauxite, several physical separation methods have been extensively studied in China, including direct flotation of diasporic bauxite to recover diasporite by using anionic collectors (Lu et al., 2002; Smith, 2009; Jiang et al., 2010; Jiang et al., 2012), reverse flotation to remove silica from diasporic bauxite by using cationic collectors (Wang et al., 2004; Cao et al., 2004; Liu et al., 2007; Zhao et al., 2007; Xia et al., 2009; Xia et al., 2010; Yu et al., 2011), and selective flocculation of diasporite by using flocculants (Nasser and James, 2006; Wang et al., 2008; Lee et al., 2010). However, industrial practice shows that direct flotation of diasporic bauxite has good adaptability to different grade and types of diasporic bauxite and high flotation efficiency of diasporite, it has been commercially applied in China. On the contrary, the reverse flotation

of diasporic bauxite shows low flotation efficiency of fine silicate particles and poor adaptability to low grade diasporic bauxite due to the small amount of quartz but large amount of different types of silicates in diasporic bauxite, so the reverse flotation and selective flocculation technologies are still at the stage of laboratory or industrial trials (Xu et al., 2004; Wang et al., 2004; Massola et al., 2009; Huang et al., 2012). Besides, with the ever decreasing grade of diasporic bauxite grade, use of collectors with high selectivity is still necessary for effective direct flotation of diasporic bauxite.

Carboxylic acids, especially oleic acid, are widely used in the direct flotation of diasporic bauxite as collector. The common characteristics of them lie in the activated carboxylic acid group as the functional group, which can react with multivalent metal ions, such as  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Al}^{3+}$ , to generate precipitation. In industrial practice, oleic acids are made from a great variety of oils or fats of animals and plants. The purities of commercial oleic acids are often different, which can be classified by saponification value, acid value and iodine value. Especially, the iodine value is considered a possible indicator of the flotation collectability and selectivity of oleic acids. In our recent investigation, we found that linoleic acid component showed high selectivity for the flotation separation of diasporite from pyrophyllite, and linoleic acid is also easy to react with Al atom site on diasporite and shows better selectivity and collectability than oleic acid (Feng et al., 2016). It can be thought that commercial oleic acids with different iodine values may have different collecting capacity and selectivity for the flotation of diasporic

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**Table 1**  
Chemical components of the pure mineral samples (wt%).

Minerals	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	K <sub>2</sub> O	CaO	TiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	A/S ratio
Diaspore	78.17	0.62	0.58	0.060	0.20	0.85	126.08
Pyrophyllite	29.57	62.21	0.58	0.18	0.20	0.25	0.48
Kaolinite	38.11	46.05	0.11	0.1	2.19	0.59	0.83

bauxite. Here, the iodine value of a commercial oleic acid is defined as the mass in grams of iodine in the addition reaction with 100 g of the organic acid, which represents the degree of unsaturation (in the form of double bonds, which react with iodine compounds) of organic acid. Based on our previous work, the aim of the present work is to systematically investigate the effects of oleic acids with different iodine values on the flotation of diasporic bauxite.

## 2. Materials and methods

### 2.1. Pure minerals

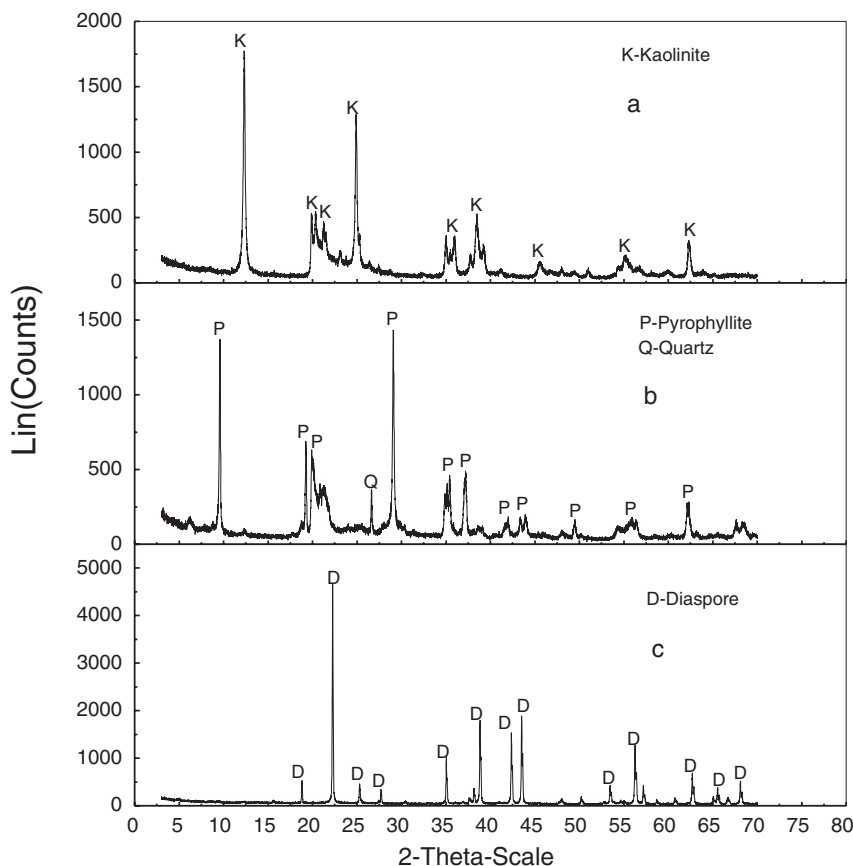
Bulk samples of diasporic, pyrophyllite and kaolinite were collected from XiaoGuan Mine located in Henan Province, China. These samples were hammered and hand-picked to remove a small proportion of impurity minerals, ground in a porcelain mill loaded with agate balls, and sieved with stainless steel screens in ultra-pure water to an appropriate particle size. The samples with the size fraction of  $-0.075$  mm were then filtered, vacuum-dried and stored in glass bottles for use in micro-flotation tests. The purities of these three mineral samples were above 90% based on mineralogical, X-ray diffraction and chemical analyses. The chemical components of these samples are presented in Table 1, and the x-ray diffraction spectra of the samples are shown in Fig. 1.

### 2.2. Diasporic bauxite ore

A diasporic bauxite sample was also gathered from the XiaoGuan Mine. The ore was crushed to 0–3 mm using a jaw crusher and a roll crusher. The chemical components of the ore are given in Table 2. The mass ratio of Al<sub>2</sub>O<sub>3</sub> to SiO<sub>2</sub> of this ore was 3.43, which was much lower than that of the commercial diasporic bauxite (A/S = 5–6) in China. Fig. 2 shows the X-ray diffraction pattern of the ore. Based on the chemical and X-ray diffraction analyses, the mineral components of the ore were quantified as 60.8% diasporic, 25.8% pyrophyllite, 4.8% kaolinite, and 2.1% anatase by the software of Jade 6.0. Because pyrophyllite has relatively higher contact angle and natural hydrophobicity in distilled water than diasporic and kaolinite (Wang et al., 2003), so a high proportion of pyrophyllite in the feed is expected to impair the grade of diasporic concentrate for the direct flotation process. Hence, reagent scheme with high selectivity, including collector, depressant and regulator, is required for achieving satisfactory flotation of this kind of diasporic bauxite.

### 2.3. Reagents

Hydrochloric acid and sodium carbonate of analytical grade were used as pH modifier, and analytical sodium hexametaphosphate (SHP) was used as dispersant and depressant for the silicate gangue (Chen et al., 2005). Commercial oleic acids with different iodine values of 65, 121 and 131 (Sanyuan Grease Corporation of Jiangsu, China) were used as collector. Ultra-pure water (18.25 MΩ·cm) was used in micro-flotation and component analysis of commercial oleic acid, and Changsha city tap-water was used in bench flotation tests.



**Fig. 1.** XRD diffraction spectra of pure mineral samples: a) kaolinite, b) pyrophyllite, and c) diasporic.

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