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A novel surfactant 2-amino-6-decanamidohexanoic acid: Flotation performance and adsorption mechanism to diaspore

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ABSTRACT

In this paper, a novel surfactant, 2-amino-6-decanamidohexanoic acid (AHA-10) was synthesized and used as a collector for flotation separation of diaspore and aluminosilicate minerals. The adsorption mechanism of AHA-10 onto diaspore was also evaluated by FTIR spectra, zeta potential, XPS and solution chemistry. The flotation results demonstrated that AHA-10 exhibited superior collecting power to diaspore and good selectivity against kaolinite and illite, and could effectively recover diaspore from bauxite ores contained aluminosilicate minerals at pH around 10. The analyses of FTIR spectra, zeta potential and solution chemistry inferred that at pH around 10, AHA-10 might chemisorb on diaspore surfaces by formation of Al—O and Al—N bonds. AHA-10's unique properties, such as characteristic bond model to Al atoms on diaspore surfaces, double hydrophobic groups and intermolecular hydrogen bonds between neighboring AHA-10 molecules coated on diaspore surfaces, rendering a weakening surface energy and enhancing hydrophobicity of diaspore particles.

1. Introduction

Bauxite is an economically important mineral used in the extraction of aluminum and in the manufacture of ceramics and refractories. In China, bauxites are generally diasporic resources with a low Al_2O_3 to SiO_2 (A/S) mass ratio ranging from 4 to 6, which are processed uneconomically by Bayer process in alumina technology unless their A/S mass ratio is over 10 (Zhong et al., 2008). Flotation is an effective method to prepare Bayer process feed with high A/S mass ratio by removing part aluminosilicate minerals such as kaolinite and illite from diasporic ores. Various surfactants (known as collectors) have been evaluated to separate aluminosilicate minerals from diasporic ores by flotation process (Xu et al., 2014; Jiang et al., 2001, 2010a, 2010b, 2010c, 2012, 2014; Zhang et al., 2001; Xia et al., 2009; Li et al., 2001; Sun et al., 2010; Huang et al., 2012). Among them, oleic acid has been proved to be an effective collector for flotation desilication (Yin et al., 2009). Carboxyl hydroxamic acids also exhibited strong collecting power to diaspore and weak response against kaolinite and illite (Jiang et al., 2010a, 2010b, 2010c, 2012). Recently, amide hydroxamic acids such as N-(6-(hydroxyamino)-6-oxohexyl)decanamide were introduced as flotation collectors and displayed superior affinity to diaspore and selectivity against aluminosilicate minerals (Deng et al., 2015).

Amino acids are of important raw materials for biocompatible system, and have been established as natural building blocks for surfactants. The amino and carboxyl groups of amino acids are active sites for synthesizing anionic, cationic, and amphoteric surfactants (Bordes and Holmberg, 2015). Ferlin et al. (2010) prepared amide carboxylate or hydroxamate surfactants by coupling octyl D-glucopyranosiduronic acid with glycine, aspartic acid, or glutamic acid methyl ester, and then with alkali or hydroxylamine. Among the natural amino acids, lysine is a low-cost amino acid with one carboxylic group and two amino groups in its molecule. In addition, lysine is a potential tridentate ligand for metal ions (Chen et al., 2011; García-Martín et al., 2008; Yang et al., 2009) and also possesses hydrogen bond sites. The metal-lysine complexes such as its Cu(II) (García-Martín et al., 2008; Sadler et al., 1994), Ni(II) (Sadler et al., 1994), Al (Sadler et al., 1994), Co (Constantino et al., 2008) and Zn(II) (Srinivas and Harohally, 2012) chelates have been reported. Thus, a surfactant contains lysine fragment and hydrophobic chain might possess superior affinity to metal ions and be used as a flotation collector for hydrophobization of metal oxide minerals.

One purpose of this paper is to develop new surfactants as flotation collectors and to investigate the structure-activity relationship of collector molecule. As we know, the cost for collectors in the

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mineral processing only takes a very small part in the whole production cost, and the value created by a collector is far higher than its cost. So, we think that it might be worthy to develop expensive collectors. Herein, a modified carboxylate surfactant, 2-amino-6-decanamidohexanoic acid (AHA-10), which contains amide, amino and carboxyl groups, was first introduced as a flotation collector. Its flotation performances for diaspore, kaolinite and illite were evaluated by single and bench-scale flotation tests. Its adsorption mechanism to diaspore was also investigated by FTIR spectra and zeta potential. The understanding of the role of amide, amino and carboxyl groups in flotation separation of diaspore from kaolinite and illite provided a new insight into the structure-property relationship of flotation collectors.

2. Experimental section

2.1. Minerals and reagents

Hand-picked diaspore (Mianchi, Henan province), kaolinite and illite (Qingtian and Ouhai, Zhejiang province) were obtained from the Geological Museum of China (Beijing). The X-ray diffraction of diaspore, kaolinite and illite was listed in Fig. 1a, b and c respectively. They were 90% pure based on X-ray diffraction and chemical analysis. Their chemical analysis was were listed in Table 1, which was reported in the previous investigation (Deng et al., 2015).

AHA-10 was synthesized in our laboratory, and its structure was confirmed by IR, ^{1}H NMR and LC–MS. IR spectra were recorded through a thin neat film on an AVATAR360 FTIR instrument (Nicolet, USA). ^{1}H NMR spectra were measured on Bruker AvanceIII (Switzerland). LC–MS spectra were recorded on Agilent 6000 LC/MS. Dilute HCl and NaOH solutions were used for adjusting the pH values of the system and distilled water was used in the all experiments.

Table 1
Elemental contents of three pure minerals (wt%).

Composition	Diaspore	Kaolinite	Illite
Al_2O_3	77.87	37.66	32.93
SiO_2	1.61	44.22	50.86
Fe	0.44	0.54	0.29
TiO_2	3.28	0.22	0.36
CaO	0.83	0.074	0.80
MgO	0.099	0.093	0.30
K_2O	0.013	0.064	7.52
Na_2O	0.014	0.049	0.18
Others	15.84	17.08	6.76
Total	100.00	100.00	100.00

2.2. Flotation tests

2.2.1. Micro-flotation

Micro-flotation tests were carried out by using a XFG5-35 flotation machine (mechanical agitation) (Fig. 2) with a 40 mL plexiglass cell (Huang et al., 2014), and its impeller speed was fixed at 1650 r/min. The mineral samples were dryly ground by using an agate mortar and pestle. After sieving, the fraction with a particle size ranging from −76 to +37 μm was used for micro-flotation tests. In each test, 2.0 g of −0.076 mm pure mineral samples were dispersed in the cell with 30 mL distilled water. The required pH values were adjusted by dilute HCl or NaOH solutions. Then a given collector was introduced and the pulp was stirred for 2 min. After that, the flotation was conducted and the froth product was collected for 5 min. The froth products and tailings were weighed separately after filtration and drying. The results were given in recovery (i.e. weight percentage) of the mineral samples floated. Each test was repeated three times. The average recovery of three

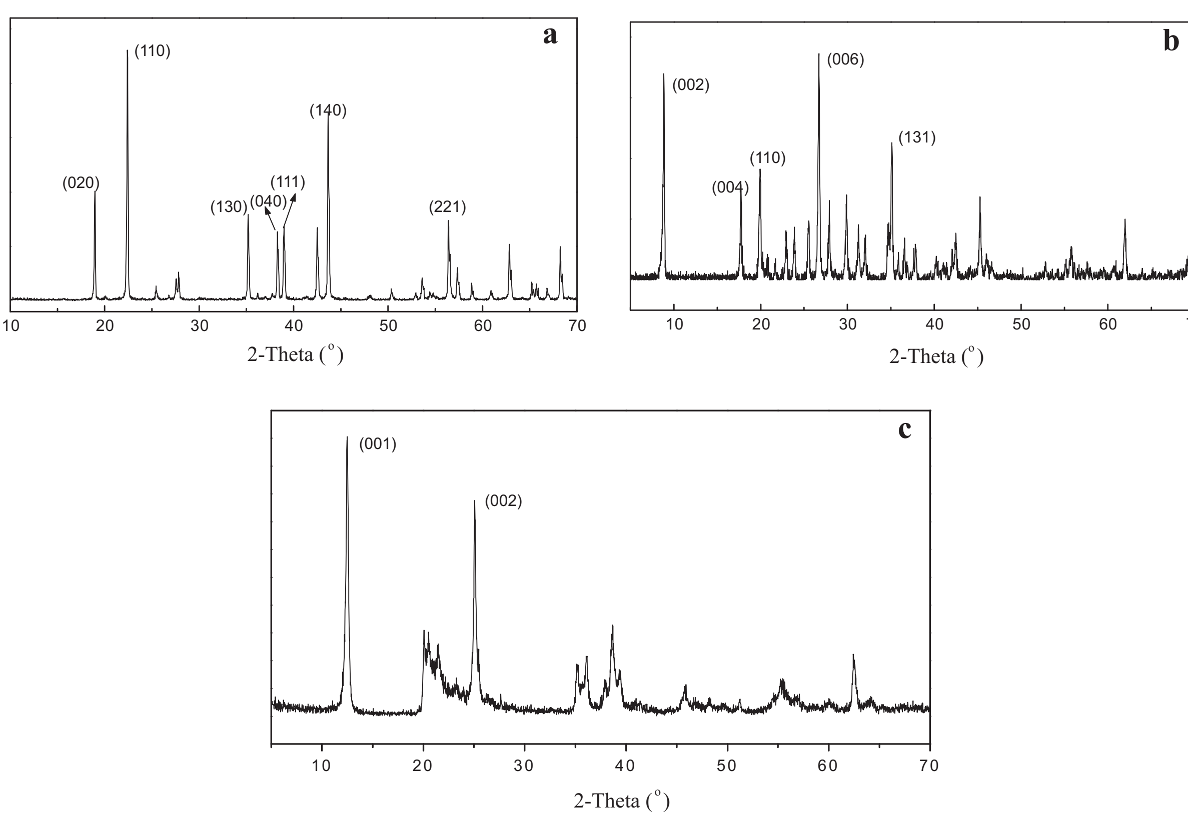

Fig. 1. XRD spectrum of diaspore (a), kaolinite (b) and illite (c).