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Reverse flotation separation on diaspore and kaolinite in the presence of cationic polyacrylamide polymers①

LIU Guang-yi(刘广义), ZHONG Hong(钟 宏), LU Yi-ping(卢毅屏), FENG Qi-ming(冯其明)
(College of Chemistry and Chemical Engineering, Central South University, Changsha 410083, China)

Abstract: Based on the analyses of crystal structures and surface properties of diaspore and kaolinite, an effective diaspore depressant, CPAM(cationic polyacrylamide) polymers was discovered by single minerals tests, separation experiments of artificial mixed minerals, zetapotential and adsorption measurement. The reverse flotation separation on diaspore and kaolinite can be carried out using collector dodecylamine acetate and depressant CPAM under pH 5.5－8.5. On the surfaces of diaspore, there are a large amount of active aluminum atoms. They can bond with $-C(O)NH_2$ groups in CPAM and make the $-CH_2N^+(CH_3)_3$ groups in CPAM orient toward the outer surfaces of diaspore, which prevents a majority of the dodecylamine cations from adsorbing on diaspore, enhances hydrophilicity of diaspore, and depresses the floatability of diaspore. But for kaolinite, CPAM polymers have little effect on its floatability.

Key words: cationic polyacrylamide; reverse flotation; diaspore; kaolinite
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1 INTRODUCTION

China is rich in diaspore bauxite resources[1, 2] which possess special properties such as high grade of both Al_2O_3 and SiO_2 and low Fe content, but the Al/Si(mass ratio of Al_2O_3 to SiO_2) value is low. In order to treat the diaspore bauxite, united methods and sintering methods[3] are still applied although suffering from disadvantages including complex technology flow chart, high energy consumption, high production cost, and restraining further development of alumina industry. However, by improving bauxite Al/Si > 10, we can choose more advanced alumina production technology —Bayer Methods.

Froth flotation is one of the most widely used processes for benefication of ores containing valuable minerals. It is especially used for separating finely ground valuable minerals from the associated gangue or for separating valuable minerals from one another. For diaspore bauxites, the flotation technology is applied to get high quality material for Bayer technology by improving Al/Si values of bauxites.

The speciality of diaspore bauxites is that the grade of valuable mineral diaspore is high and the grade of associated gangue silicates such as kaolinite is low. If a routine flotation flow chart is used, the yield of diaspore concentrate is over 80%, but it still suffers from many disadvantages for commercial production. Aiming at overcoming those disadvantages, the reverse floatation[4－7], floating silicates such as kaolinite from diaspore bauxites, is applied in this study.

2 EXPERIMENTAL

2.1 Minerals

Diaspore was obtained from Mianchi Bauxites, Henan Province, China. Kaolinite was obtained from geological museum of China. They are 95% in purity by chemical and spectroscopical analyses. Diaspore and kaolinite were ground to particles with diameter ≤4 μm and BET 1.14 $m^2 \cdot g^{-1}$ for diaspore and 11.34 $m^2 \cdot g^{-1}$ for kaolinite.

2.2 Reagents and experimental apparatus

1) Reagents

Dodecylamine, acetic acid, hydrochloric acid and caustic soda are AR grade. CPAM-1 having about 10%, CPAM-2 having 20% and CPAM-3 having 35% cation by mass respectively are commercial purity.

2) Apparatus

pHS-3C pH meter, UV-3000 spectrometer, Zeta-plus electrophoresis instrument, XFD hanging-cell flotation machine.

2.3 Experimental methods

A 40 mL flotation cell was fed with 2 g sample

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Correspondence: LIU Guang-yi, Candidate for Doctor; Tel: +86-731-8830603; E-mail: Huangyi.Liu@163.com

of minerals and suitable amount of distilled water was added. The tests were carried out in hanging-cell flotation machine with procedures shown in Fig. 1.

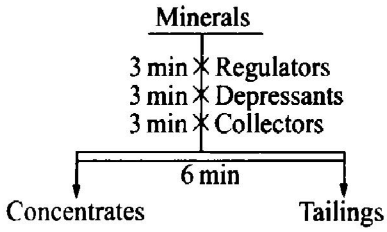

Fig. 1 Minerals flotation testing flow chart

3 RESULTS AND DISCUSSION

3.1 Single minerals flotation tests

3.1.1 pH value tests

Fig. 2 demonstrates that the floatabilities of diaspore and kaolinite are similar in whole pH range, with only a little difference under pH 2−6. Theoretically, the reverse flotation separation on them can partly be implemented under these pH values. But for industrial practice, an obvious disadvantage under acidity circumstances is that the processing equipments are easily corroded. In order to increase the floatability difference between diaspore and kaolinite and to improve the pulp pH values, regulators or depressants are very essential in this flotation system.

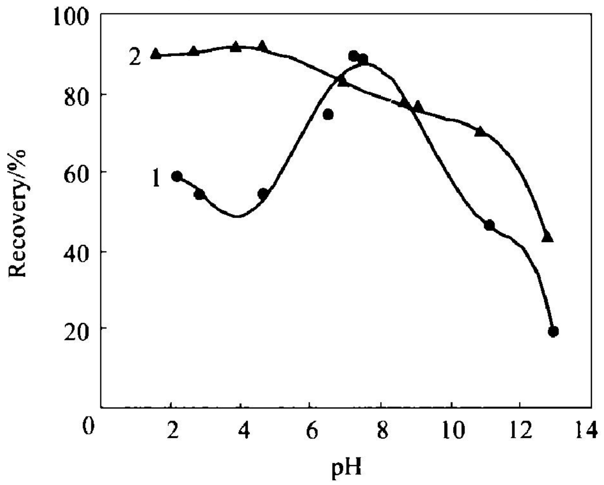

Fig. 2 Flotation recovery of diaspore and kaolinite under different pH values and using 4×10^{-4} mol·L^{-1} dodecylamine acetate
1—Diaspore; 2—Kaolinite

3.1.2 Dosage of CPAM

Fig. 3 shows that CPAM-1, CPAM-2 and CPAM-3 have little effect on the floatability of kaolinite, and efficiently reject diaspore being floated out. The rejection abilities of these CPAMs are followed as this sequence: CPAM-3 > CPAM-2 > CPAM-1, identical to their cationic contents: CPAM-3 > CPAM-2 > CPAM-1.

3.1.3 pH values tests in the presence of CPAM-3

Fig. 4 shows that kaolinite has excellent floatability under pH 4−10, but diaspore is effectively rejected by CPAM-3 in pH 5.5−8.5. So the reverse flotation separation on diaspore and kaolinite can be brought about under this pH value.

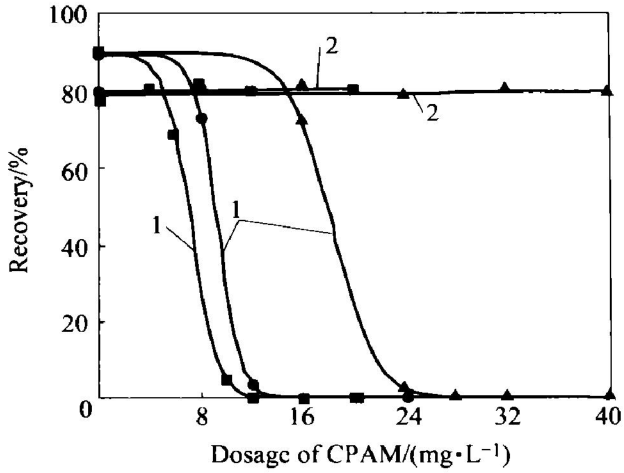

Fig. 3 Flotation recovery of diaspore and kaolinite as function of dosage of CPAM
1—Diaspore; 2—Kaolinite. ■—CPAM-3; ●—CPAM-2; ▲—CPAM-1; pH = 7.5; dodecylamine acetate: 4×10^{-4} mol·L^{-1}

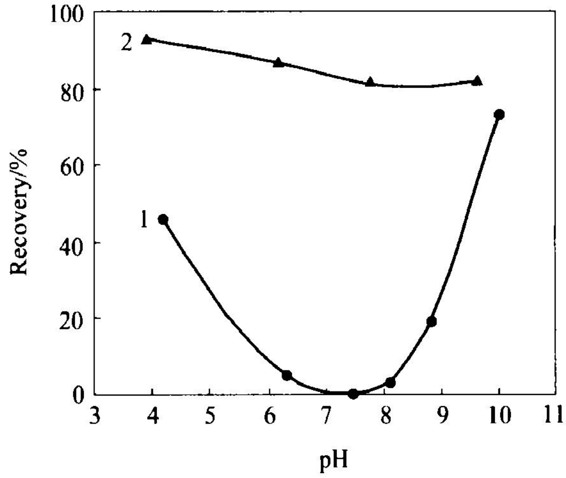

Fig. 4 Recovery of diaspore and kaolinite as function of pH value in the presence of CPAM-3
1—Diaspore; 2—Kaolinite. CPAM-3: 12 mg·L^{-1}; dodecylamine acetate: 4×10^{-4} mol·L^{-1}

3.2 Separation tests of artificial mixed minerals

Based on the results of single minerals tests, separation tests of artificial mixed minerals were conducted employing mass ratio 1:1 of diaspore to kaolinite. The results obtained was plotted in Fig. 5. It shows that the reverse flotation separation on diaspore and kaolinite succeed under such conditions as pH = 7.5, dosage of dodecylamine acetate 4×10^{-4} mol·L^{-1}, and CPAM-3 over 4 mg·L^{-1} at an excellent diaspore rejection.

3.3 Zeta potential

3.3.1 pH value

Fig. 6 demonstrates that the point of zero charge is at pH 5.3 and pH 3.1 for diaspore and kaolinite,

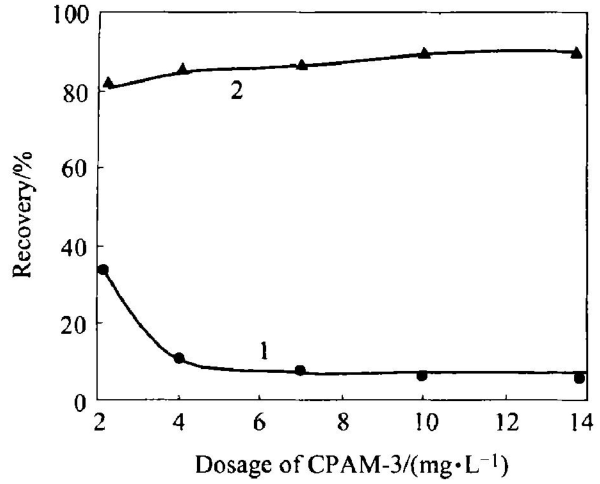

Fig. 5 Results for separation experiments of artificial mixed minerals
1 —Diaspore; 2 —Kaolinite. dodecylamine acetate: 4×10^{-4} mol·L^{-1}; pH= 7.5

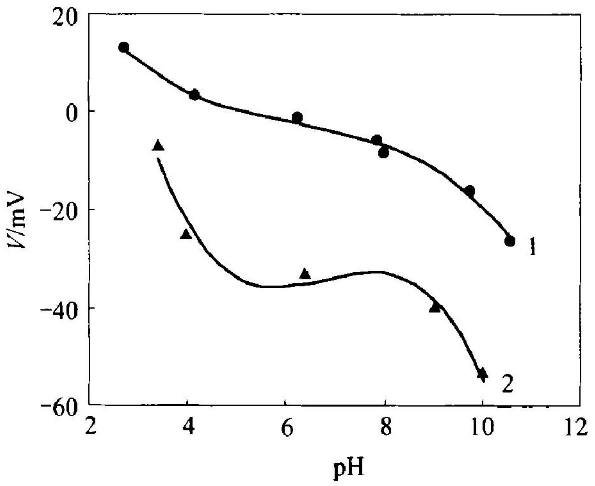

Fig. 6 Zeta potential as function of pH value
1 —Diaspore; 2 —Kaolinite

respectively. When pH value is over 5.5, the surfaces of diaspore and kaolinite show negative charge and both of them can be floated out using cationic collector dodecylamine. The Zeta potential of diaspore is more positive than that of kaolinite at the same pH value. i.e., the amount of aluminum atoms on diaspore surfaces is much more than that on kaolinite surfaces.

3.3.2 Dodecylamine acetate

Fig. 7 shows that the Zeta potential of diaspore and kaolinite increases with increasing dosage of dodecylamine acetate, which indicates that cationic dodecylamine can adsorb on the surfaces of both minerals and the amount of adsorption increases with increasing concentration of dodecylamine acetate. Fig. 7 also demonstrates that collector dodecylamine acetate shows multilayer physical adsorption on the surfaces of both minerals when its concentration is higher.

3.3.3 CPAM-3

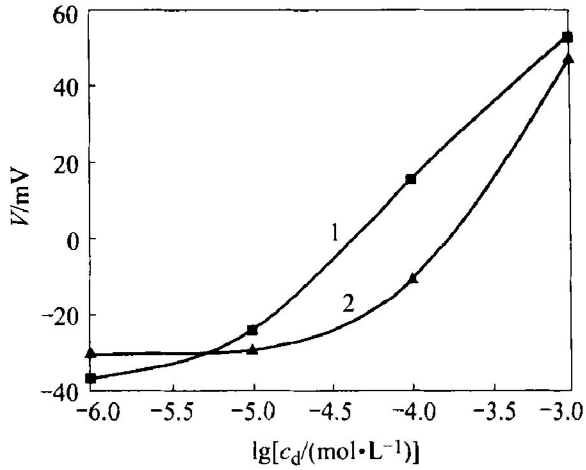

Fig. 7 Zeta potential as function of dosage of dodecylamine acetate(c_d)
1 —Diaspore; 2 —Kaolinite. pH= 7.5 − 7.8

Fig. 8 shows that the Zeta potential of diaspore increases and the Zeta potential of kaolinite decreases with increasing dosage of CPAM-3 in the presence of dodecylamine acetate of 10^{-4} mol·L^{-1}. On the surfaces of diaspore, there are a large number of active aluminum atoms. They can bond with —C(O)NH_2 groups in CPAM and make —$CH_2N^+(CH_3)_3$ groups in CPAM orient to the outer surfaces of diaspore, which enhances its Zeta potential. But for kaolinite, CPAM-3 polymers adsorb on its surfaces mainly by —$CH_2N^+(CH_3)_3$ groups in CPAM. On one hand, the competition adsorption between —$CH_2N^+(CH_3)_3$ groups and dodecylamine cation maybe decrease the adsorption capacity of dodecylamine on the surfaces of kaolinite. On the other hand, —C(O)NH_2 groups orient to the outer surfaces of kaolinite. These decrease the Zeta potential of kaolinite.

3.4 Adsorption measurement

The results of adsorption measurement obtain-

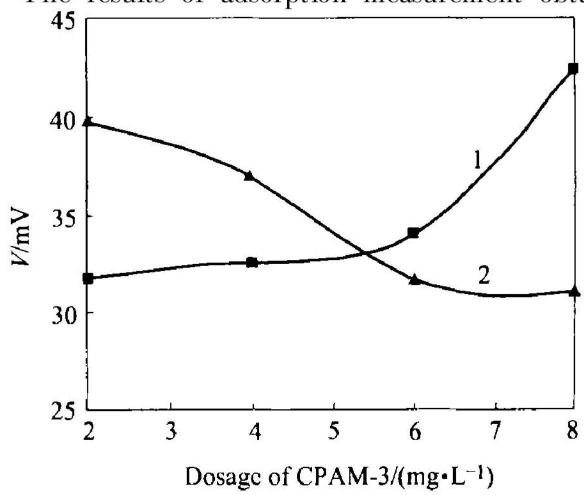

Fig. 8 Zeta potential as function of dosage of CPAM-3 in the presence of dodecylamine acetate
1 —Diaspore; 2 —Kaolinite. dodecylamine acetate: 10^{-4} mol·L^{-1}; pH= 7.5 − 7.8

ed is listed in Table 1. It shows that the amount of dodecylamine acetate adsorbed on the surfaces of diaspore decreases by 68.5% in the presence of CPAM-3. Under the same circumstances, the amount of dodecylamine acetate adsorbed on the surfaces of kaolinite only decreases by 0.4%. The results of adsorption capacity measurement indicates that CPAM-3 polymers have little effect on the amount of dodecylamine acetate adsorbed on the surfaces of kaolinite, whereas greatly decrease the amount of dodecylamine acetate adsorbed on the surfaces of diaspore. During reverse flotation processing, the use of depressant CPAM-3 can remarkably increase the difference of floatability between diaspore and kaolinite, which is of great advantage to minerals separation.

Table 1 Relation of adsorptive capacity on surfaces of minerals and CPAM-3

CPAM-3	Adsorptive capacity/ (10^{-6} mol·m^{-2})		Conditions
	Diaspore	Kaolinite	
0	7.30	1.240	Dodecylamine acetate: 4×10^{-4} mol·L^{-1}
20 mg·L^{-1}	2.30	1.235	pH= 7.5 - 7.8

3.5 Discussion

Solution chemistry of dodecylamine[8] shows that dodecylamine is mainly present in the form of $C_{12}H_{25}NH_3^+$ in aqueous solution under pH 5.5 - 8.5. So dodecylamine easily adsorbs on the surfaces of both diaspore and kaolinite whose Zeta potential is negative.

Chemical formula of diaspore is $Al_2O_3 \cdot H_2O$ or α-AlOOH. Diaspore belongs to rhombic crystal series and has the crystal structure of diaspore. When diaspore is ground to finer particles, the bond of Al—O is broken, which exposes a large number of active aluminum atoms on the surfaces of diaspore and enhances positive charge of diaspore in aqueous solution. The PZC of diaspore is high[1, 9, 10].

Chemical formula of kaolinite is $Al_4(Si_4O_{10})(OH)_6$. Kaolinite belongs to triclinic minerals and is a typical aluminum silicate ratio of 1∶1 layer structure. While kaolinite is ground to finer particles, the interlayer hydrogen bond is easily broken, but the bond of Al—O and Si—O is difficultly broken. The number of active aluminum atoms on the surfaces of kaolinite is small and its PZC is low.

—C(O)NH_2 groups in CPAM polymers can bond with the active aluminum on the surfaces of diaspore and kaolinite. On the surfaces of diaspore, there are a large amount of active aluminum atoms. They can bond with —C(O)NH_2 groups and make —$CH_2N^+(CH_3)_3$ groups in CPAM orient to the outer surfaces of diaspore, which prevents a majority of dodecylamine cations from adsorbing on diaspore, enhances hydrophilicity of diaspore, and rejects diaspore floated out. Both —C(O)NH_2 groups and —$CH_2N^+(CH_3)_3$ groups in CPAM polymers can adsorb on the surfaces of kaolinite. The —$CH_2N+(CH_3)_3$ groups do not orient to the outer surfaces of kaolinite. Dodecylamine cation adsorbs more easily on kaolinite than —$CH_2N^+(CH_3)_3$ groups do, which limit the accessibility of the nitrogen to participate in attachment to the negatively charged surfaces of kaolinite. CPAM-3 polymers have little effect on the floatability of kaolinite using collector dodecylamine cation.

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