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Leaching behaviors of iron and aluminum elements of ion-absorbed-rare-earth ore with a new impurity depressant

Ting-sheng QIU[1], Xi-hui FANG[1], Hong-qiang WU[2], Qing-hua ZENG[1,3], Dong-mei ZHU[1]

1. Faculty of Resource and Environmental Engineering, Jiangxi University of Science and Technology, Ganzhou 341000, China;
2. Ma'anshan Institute of Mining Research, Sino-Steel Group, Ma'anshan 243000, China;
3. School of Computing, Engineering and Mathematics, University of Western Sydney, Penrith, NSW 2751, Australia

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Abstract: Ion-absorbed rare-earth ore is an important mineral resource which is widely extracted by in-situ leaching process. And such process generates a significant amount of impurities such as aluminum and iron ions in leaching solution simultaneously. The surface characteristics and interactions by infrared spectroscopy and X-ray diffraction were studied to optimize the leaching conditions. It is found that the environment-friendly depressant LG-01 can react with the impurity ions through the formation of a new complex on the surface of leaching residues. Thus, it reduces significantly the concentration of impurity ions in leaching solution and improves the leaching rate of rare-earth ore. Moreover, a leaching rate of 95.6% and an impurity removal rate of 92% have been achieved under the optimized conditions.

Key words: ion-absorbed-type rare-earth ore; leaching; depression mechanism; aluminum and iron impurity

1 Introduction

Ion-absorbed-type rare-earth ore is a unique mineral resource which was first discovered in Jiangxi Province, China. With further exploration, such rare-earth ore has also been found in other provinces mainly located in Southeast of China, including Fujian, Guangdong, Hunan, Guangxi and Zhejiang. Most of such rare-earth ore deposits are associated with granite, mixed rocks, and other igneous rocks [1−3]. Ion-absorbed-type rare-earth ore is formed through a series of geological processes. Initially, granite and igneous rocks containing rare-earth minerals are subjected to biological and chemical reactions under humid conditions and changed into clay minerals. Meanwhile, rare-earth minerals (e.g., fluoro-carbonate, gadolinite) associated with the rocks are weathered and form rare-earth hydroxyl aqueous ions. Then, such rare-earth ions are absorbed onto clay minerals during the infiltration process, and form ion-absorbed-type rare-earth ores [4−6].

At present, electrolyte leaching is widely used to leach ion-absorbed-type rare-earth ore, which leads to the leaching of impurity ions (e.g., aluminum and iron) into leaching solution [7−9]. Such impurity ions can influence the quality of rare-earth precipitation and increase the cost toward impurity elimination. More importantly, the crystal form of carbonated rare-earth may not be able to form due to the presence of such impurities [10,11]. The main impurities in leaching solution of ion-absorbed-type rare-earth ore are related to the nature of rare-earth ore, leaching process, operating conditions, and kinds of leaching agents. The main chemical composition in leaching solution is shown in Table 1 [12], which indicates that the main impurities are aluminum and iron ions. Thus, such impurities must be removed before the precipitation of leaching solution, which would further increase the production cost. In the past, some studies have been done to inhibit the impurities and leach ion-absorbed-type rare-earth ore [13−15]. Yet, the depressants used have adverse impacts on environment and human being. Moreover, a further understanding and exploration should be done about the mechanisms of the reaction between the impurities (e.g.,

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Corresponding author: Ting-sheng QIU; Tel: +86-79-78312008; E-mail: qiutingsheng@163.com
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Table 1 Main chemical composition in leaching solution of typical ion-absorbed-type rare-earth ore [12]

Composition	Mass concentration/ ($mg \cdot L^{-1}$)	Molar concentration/ ($mmol \cdot L^{-1}$)
K_2O	156	0.8−1.5
Mg	16.80	0.2−0.4
Ca	83.3	0.3−0.6
Al	9.1	4−7
Fe	1.73	0.01−0.03
Mn	5.95	0.03−0.05
Pb	5.85	0.03
Zn	0.48	0. 01
Si	11.5	0.8−1.2
$(NH_4)_2SO_4$	4.95	0. 04
REO	2150	4−6

REO is rare-earth oxide

aluminum and ferric ions) and impurity depressant.

In this study, infrared (IR) spectrometry and X-ray diffraction (XRD) are used to analyze the behaviors of exchange between rare-earth ion and leaching agent as well as the exchange between impurity ions (i.e., aluminum, iron) and leaching agent during the leaching process of ion-absorbed-type rare-earth ore. Then, leaching experiments are conducted using an impurity depressant called LG-01 and the effects of LG-01 on aluminum and iron ions are examined.

2 Experimental

2.1 Ore samples and chemicals

Rare-earth ore samples were obtained from a rare-earth mine in Xunwu of Jiangxi Province, China. The samples contained 0.22% ion-phase rare-earth, 71% SiO_2, 12% Al_2O_3, and 2% Fe_2O_3. In our experiments, tap water was used in leaching experiments and deionized water was used in chemical analysis. The agents in experiment such as $(NH_4)_2SO_4$, environment-friendly depressant LG-01 (the agents were organic agents containing hydroxyl and carboxyl groups), NH_4F, $NH_4 \cdot H_2O$ and Na_2S were analytically pure.

2.2 Methods

Leaching experiments were conducted in a leaching system which consists of a *d*10 cm leaching column, volumetric flasks, beakers, and dosing device. In the process, depressant and leaching agents were dissolved into the water together and then the leaching experiments were carried out. Leach liquor was collected by specialized device. Leaching residue should be dried naturally and used in follow-up study after the end of leaching experiment. IR and XRD techniques were used to analyze the surface properties of ion-absorbed-type rare-earth ore and the interaction mechanisms between leaching agents and minerals as well as depressant and impurity ions.

3 Results and discussion

3.1 IR spectrum analysis

IR analysis has been done on the rare-earth ore and leaching residues in the absence and presence of impurity depressant. Prior to IR test, the samples were dried naturally and placed in a mortar to crush them. Figure 1(a) shows the IR spectrum of rare-earth metal ore in which the characteristic peaks include 3000−4000 cm^{-1} from hydroxyl single bond or stretching vibration in water molecules, 1600−1660 cm^{-1} from bending vibration of water molecules, 960−1140 cm^{-1} from stretching vibration of phosphate polyhedron, and 830−1000 cm^{-1} from stretching vibration of silicon−oxygen single bond. The rare-earth leaching residue in the absence of depressant (Fig. 1(b)) has similar IR spectrum as that of rare-earth ore, which further confirms that there is no new substance formed and no significant change on the mineral surface.

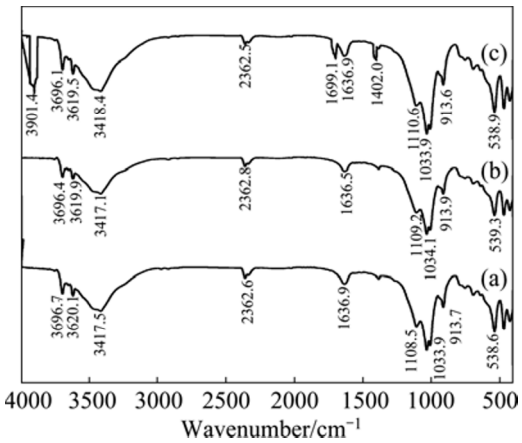

Fig. 1 IR spectra of rare-earth ore (a), rare-earth ore after leaching in the absence of impurity depressant (b), rare-earth ore after leaching in the presence of impurity depressant (c)

However, the IR spectrum of leaching residue obtained in the presence of depressant (Fig. 1(c)) has some new characteristic absorption peaks, including 3901.4 cm^{-1} from stretching vibration of hydrogen−oxygen single bond, 1699.1 cm^{-1} form stretching vibration of carbon−oxygen double bonds, and 1402.0 cm^{-1} from bending vibration of carbon−hydrogen−oxygen single bond. Depressants contain hydrogen−oxygen single bond, the carbon−oxygen double bonds and carbon−hydrogen−oxygen single bond groups. The results indicate that the presence of depressant may lead