Extraction and chromatographic studies on rare-earth elements (REEs) from their minerals: the prospect of REEs production in Indonesia?

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Abstract

Rare-earth elements, which are important materials in numerous high technology applications, are relatively abundant in Indonesia, but have not been exploited for optimal economic benefit. One of our research group’s objectives of the studies on REEs is to develop extraction and chromatographic method(s) to prepare both mixture of REEs (or concentrates) and single rare-earth elements with sufficient purity, using di-n-butyldithiocarbamic (DBDTC) and with di-n-butyldithiophosphoric (DBDTP) acids as chelate-forming ligands. The complex formation reaction between each element under investigation (i.e. the rare-earth elements commonly constituting the minerals monazite and xenotime: Nd, Y, Ce, La, Gd) and each of the acidic ligands was studied for the first time. To prepare REEs concentrates, REE mineral samples were digested with different oxidizing reagents and experimental conditions. In one of the procedures, a mineral sample was digested with sulphuric acid, to produce REEs in their ionic forms, which were then separated from both insoluble and soluble non REEs. The resulted REEs were precipitated from their solution as oxalates, which were converted into hydroxides. The REE hydroxides were then calcinated to result in REE oxides. Using DBDTC, five out of the six elements contained in the studied minerals could be extracted at a pH range of 2.0 - 7.0, with non polar organic solvents, resulting in extraction efficiencies ranging from 58-79%. During the extraction of the elements with DBDTP at a pH of 2.0, higher extraction efficiencies (80 to almost 100%) were resulted. Separation of Ce, Y, and Gd as single elements from the REEs mixture using the ligands at selected experimental conditions has been shown to be possible. Chromatographic separation of a mixture of Nd, Pr, Ce, and La as their complexes with DBDTC on a C18 column, with mobile phases of methanol-acetonitrile mixtures has been successful. Meanwhile, Ce has been well separated from its mixture with the other rare-earth elements in a monazite sample as its complex with DBDTP on the same column, using the same mobile phase system. Separation of rare earth elements on ion exchange chromatographic columns, including those prepared from cellulose fibers isolated from local banana stems, have been studied. The resulted separation method(s) are recommended for their adoption and further development to become the technology for the production of rare-earth elements of required purity for commercial purposes. But the idea of producing the REEs products must be aided by the business through co-operation, and supported or pushed by the government through its policy and regulations on the management of natural resources.

Keywords: Rare-earth elements, extraction, chromatography, di-n-butyldithiocarbamic acid, di-n-butyldithiophosphoric acid.

Introduction

Description of Rare-Earth Elements (REEs)

Rare-earth elements consist of 17 elements i.e. lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pr), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu), scandium (Sc), and yttrium (Y) (Prayitno, 2005). In spite of their given name, rare-earth elements, excepting promethium, are actually relatively abundant in the earth’s crust. Indeed, cerium for instance is among the most abundant elements. It’s a pity however, due to their geochemical properties, rare-earth elements are typically dispersed and rarely found in concentrated and economically exploitable forms, known as rare earth minerals (Mulyasih, 2009).

The Uses of REEs

The chemical, nuclear, and physical properties of rare-earth elements make them ideals for a lot of high technology applications. The elements are used in a number of modern technology such as permanent magnets, hybrid batteries, catalysts, generators, phones, computers, TVs, and fiber optics (Wikipedia). The elements are also used in the data transmission, touch screen, high definition and imaging devices that facilitate modern life. Other uses are: missile guidance systems, super