Tailored Separation of Light Rare Earth Elements using Combined Oxidative Precipitation and Multi-Stage Solvent Extraction Techniques

Hossein Salehi*, Samane Maroufi, Rasoul Khayyam Nekouei, Veena Sahajwalla

Centre for Sustainable Materials Research and Technology, SMaRT@UNSW, School of Materials Science and Engineering, UNSW Sydney, NSW 2052, Australia

Abstract

The remarkably similar chemical properties of rare earth elements (REEs) and their closely matched ionic radii present a significant challenge in the separation of these elements to produce individual REE products. This research focuses on the selective separation of La, Ce, didymium (Nd and Pr), and Sm from a pure mixed REE oxide sample derived from waste NiMH batteries, dissolved in an HCl solution. Initially, Ce was separated from the REE solution via an oxidative precipitation process, achieving a precipitation efficiency exceeding 99.8% for Ce with minimal co-precipitation of other elements. Subsequent separations of the remaining REEs (i.e., La, didymium, and Sm) were performed using solvent extraction, where the organic phase consisted of Cyanex 572 as the extractant and TBP as the phase modifier. The experimental parameters, such as pH, organic to aqueous phase ratio, and the composition of the organic phase, were meticulously optimized. Initially, Sm was separated from the solution using an organic phase containing 0.5 M Cyanex 572 and 0.25 M TBP at an initial pH of 1.5. This stage achieved over 45% extraction efficiency for Sm with less than 3% co-extraction of other elements in a single stage. Following this, the separation of didymium from La was performed at an initial pH of 2.0, using an organic phase composed of 1 M Cyanex 572 and 1 M TBP. This process resulted in over 40% extraction efficiency for didymium in a single stage, with no co-extraction of La. Multi-stage solvent extraction-stripping experiments were conducted, resulting in individual REE solutions. This study not only demonstrates an effective method for separating adjacent light REEs from their mixtures but also paves the way for more efficient and sustainable separation processes for these critical elements in future applications.

Keywords: Solvent extraction, rare earth elements, individual separation, Ni-MH batteries, extraction mechanism

*Corresponding author: h.salehi@unsw.edu.au

Abbreviations: RE, REE: rare earth elements; LREE: light rare earth element; REO: rare earth element oxide