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Circular Hydrometallurgical Process for Extraction of Beryllium from Beryl Ore

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ABSTRACT

Beryllium is a critical raw material in high-tech industries. The extraction of this metal from beryl ore faces environmental and economic challenges because the conventional methods such as sulfate fusion, chlorination, and fluorination operate at high temperatures (450–900 °C). In this paper, a circular hydrometallurgical process was designed for extraction of high-purity $Be(OH)_2$ and BeO from beryl with minimal environmental impact. The first step in the process is alkaline leaching in an autoclave, using 100% w/v NaOH. A beryllium recovery yield of over 99% is achieved under optimized conditions (S/L = 1/10 g mL^{-1}, 200 °C, 8 h, 1000 rpm). The next step is selective precipitation using a saturated $Ca(OH)_2$ solution at ambient temperature, leading to quantitative beryllium recovery and NaOH regeneration in a closed-loop system. Further, selective leaching of the crude $Be(OH)_2$ precipitate with 14 wt.% $NaHCO_3$ at ambient pressure yields 99% beryllium recovery (S/L = 1/10 g mL^{-1}, 50 °C, 2 h, 500 rpm), while minimizing codissolution of impurities (*i.e.* Ca, Si, and Al). Subsequent solvent extraction with water-saturated Aliquat 336 in its carbonate form, $[A336]_2[CO_3]$, yields over 99% beryllium extraction in a two-stage counter-current batch simulation (O/A = 3/1, 25 °C, 10 min, 800 rpm). The use of a 14 wt.% $NaHCO_3$ solution ensures beryllium purity exceeding 99.8% in the strip solution. Additionally, the stripping step regenerates the organic solvent. This circular hydrometallurgical process represent an eco-friendly method for the large-scale production of $Be(OH)_2$ and BeO from beryl ore.

KEYWORDS: *Alkaline leaching; Beryllium; Quaternary ammonium salts; Selective precipitation; Solvent extraction*