

## Enhancing Metal Recovery from Lithium-Ion Battery Cathodes: Optimization of Leaching and Reactor Configuration

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### Abstract:

This study explores the application of hydrometallurgy for recycling lithium-ion batteries (LIBs), focusing on optimizing leaching processes to recover valuable metals. Conventional methods often require high acid concentrations, resulting in increased reagent consumption and environmental concerns. Typically, the leaching process is carried out in a batch reactor, where the solid material, acid, and reductant agent are loaded at the initial time. In contrast, this research study the use of a semi-batch reactor, where the acid is continuously fed to the system to maintain constant the reactant concentrations.

Experimental results demonstrate that the semi-batch configuration offers significant advantages over traditional batch reactors, including faster dissolution rates and higher extraction efficiencies. Optimizing the initial concentrations of HCl and H<sub>2</sub>O<sub>2</sub> was critical in enhancing metal recovery while maintaining low reagent consumption. Specifically, the study found that high H<sub>2</sub>O<sub>2</sub> concentrations improved reaction selectivity and extraction rates, reducing Co<sup>3+</sup> to soluble Co<sup>2+</sup>, whereas low HCl concentrations favored selectivity without significantly compromising the overall yield. The introduction of a double semi-batch system further optimized reactant use, achieving extraction efficiencies of up to 93% for lithium and 91% for cobalt, while reducing H<sub>2</sub>O<sub>2</sub> consumption by 30%.

These findings highlight the potential of semi-batch reactors to improve both economic and environmental sustainability in LIB recycling processes. The proposed method could be integrated into existing industrial systems with minimal investment, offering a scalable solution for advancing the circular economy. Future work will explore the application of this approach to other LIB materials on a larger scale.

**Keywords:** Lithium-ion battery, recycling, hydrometallurgy, leaching, reactor configuration,

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