A Sustainable Circular Approach to Lithium-Ion Battery Recycling: Optimizing Innocuous Acetic Acid Lixiviation for Exclusive Zinc Recovery From Simulated Black Mass

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With the rapid expansion of lithium-ion batteries (LIBs) to EV cars and modern-day electronics, battery waste is projected to reach 8 million tons by 2040. Current recycling approaches, encompassing pyrometallurgical and hydrometallurgic processes, amplify environmental degradation and anthropogenic effluence, while being expensive, time-consuming, and incommensurate. To address these gaps, four systems (A-D) were synthesized, utilizing acetic acid as the basal leachant whilst systematically incorporating ascorbic acid, citric acid, and hydrogen peroxide to determine which system harnessed the most effective synergistic properties to exclusively lixiviate zinc. Via gravimetric analysis, zinc was sequestrated from a simulated black mass-acid system using sodium carbonate for induced zinc carbonate precipitation. Quantitative percent recovery trends showed that System A (acetic acid) displayed a 42.0% recovery, while System D (four-component) increased to 95.33% recovery, revealing that mean zinc recovery scaled with acid complexity. The chromaticity analysis revealed that increased oxidative potential inversely correlated with selectivity as System D's slightly-green tinted precipitate indicated iron carbonate contamination. These results verify that amplified H+ concentrations and redox potential accelerate metal ion dispersion, although requiring precise refinement to prevent undesired co-precipitation. Industrial shifts from inorganic mineral reagents toward custom-engineered organic acid systems can significantly remediate the carbon footprint and ecological damage derived from traditional mining and destructive extraction processes. These green leaching systems function as a viable technique to produce a circular economy in battery production and renewable energy.

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