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Cradle-to-cradle recycling of spent NMC batteries with emphasis on novel Co²⁺/Ni²⁺ separation from HCl leached solution and synthesis of new ternary precursor

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Abstract:

Herein, a cradle-to-cradle recycling of post-consumer NMC batteries has been demonstrated with a focused separation of cobalt over nickel by applying the ionic liquid, trihexyl(tetradecyl)phosphonium bis-2,4,4-(trimethylpentyl)phosphinate. At the optimized condition of: 0.8 mol.L⁻¹ ionic liquid, 3.0 mol.L⁻¹ Cl⁻ ions, equilibrium pH value similar to 5.0, and organic-to-aqueous ratio 2/3, > 99% cobalt was extracted in the organic phase with a separation factor of 1097. Approximately 99% cobalt from the loaded organic was stripped back in 2.0 mol.L⁻¹ HCl solution, yielding high-pure CoCl₂ center dot xH₂O crystals after crystallizing the stripped solution. Subsequently, similar to 99% of nickel from the Co-depleted raffinate was extracted over lithium using 0.32 mol.L⁻¹ acetophenone at an organic-to-aqueous ratio of 1 and equilibrium pH similar to 5.3. Nickel stripped in 2.0 mol.L⁻¹ H₂SO₄ was crystallized to yield high-pure NiSO₄ center dot 6H₂O crystals. Further, Li-bearing raffinate was subjected to carbonate precipitation at a higher pH (similar to 12) and CO₃²⁻:Li⁺ ratio of 1.2. All the recycled products were further employed to the stepwise synthesis of a new ternary precursor, exhibiting similar electrochemical behaviour (with 149 mAh.g⁻¹)