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Acidic aqueous biphasic systems: a new paradigm for the ?one-pot? hydrometallurgical recovery of critical metals

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PURPOSE OF THE ABSTRACT

In recent years, ionic liquids (ILs) have attracted significant interest in the field of metal extraction as an alternative medium in solvent extraction processes. ILs are salts composed of asymmetric ions with disperse charge that are liquid at room temperature. Several factors currently limit the industrial application of ILs in solvent extraction processes, namely their viscosity and the incorporation of fluorinated moieties which increases their price, toxicity and solubility in inorganic acids. We recently demonstrated that many of these issues could be overcome through the application of acidic aqueous biphasic systems (AcABS) for metal extraction (doi: 10.1002/anie.201711068). Aqueous biphasic systems (ABS) represent a well-established alternative to solvent extraction for the separation and purification of target compounds. They are primarily composed of water and a water-soluble low-polarity solute, which upon addition, in the right proportions, of an inorganic salt partition to form a reversible biphasic system composed of a salt-rich phase and organic-rich phase. In the newly reported AcABS composed of an IL, an inorganic acid (HCl, HNO3 or H2SO4) and water, the inorganic salt is replaced by the acid used to leach the metals. The innovation of AcABS lies in its ability to extract metals directly from leachates just by adding a carefully selected ionic liquid, thereby allowing for a ?one-pot' approach to metal recovery which overcomes the traditional issues of IL-based ABS and liquid-liquid extraction.

In this work, we aim to summarise our findings to date and extend these to new systems for the recovery of metals and detoxification of various problematic waste streams including waste NiMH batteries. These new AcABS present a flexibility and tuneability which allows them to be applied to a range of recovery systems. The determinant structural factors for an IL's applicability in AcABS are identified. The tuneability of AcABS systems is demonstrated with the studied IL systems displaying a strong thermomorphic response with the presence of lower critical solution temperature. The ability to manipulate the formation of a biphasic system from a monophasic one and vice-versa simply by changing the temperature avoids the kinetic limitations related to the mass transfer between two-immiscible systems and extends the applicability of the reported AcABS to less acidic leachate solutions. In addition, the partition and separation of critical metals is studied across a range of conditions and compared to those in traditional ABS and mixt ABS-AcABS mixtures. Finally, as AcABS occurs in aqueous solutions, this allows for direct recovery of metals using precipitation or electrodeposition thereby avoiding the required stripping steps of liquid-liquid extraction processes. Taking advantage of this feature, we report a closed-loop process for the AcABS separation of (i) cobalt from other transition metals and the direct electrodeposition of cobalt from the IL-rich phase and (ii) cerium from other rare earth elements. These processes were directly applied for the recovery of these elements from NiMH battery waste.

FIGURES

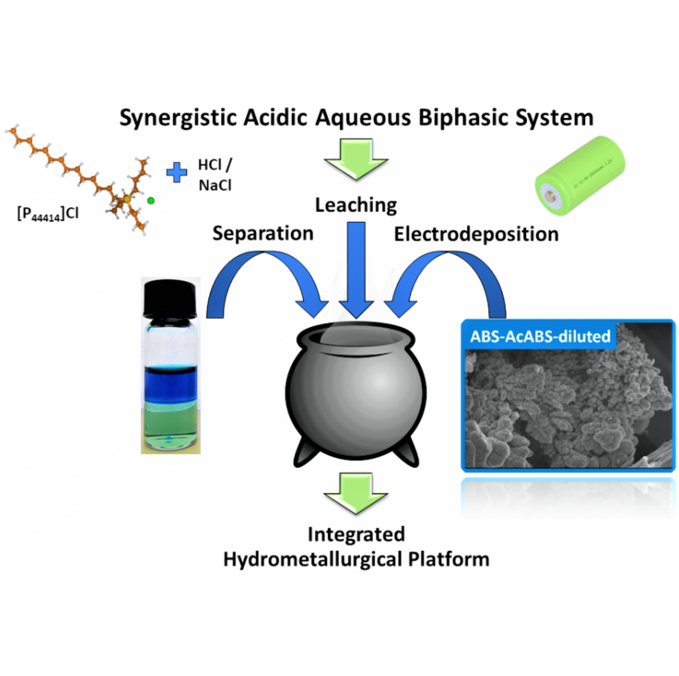

FIGURE 1

Graphical Abstract

Conceptual diagram of acidic aqueous biphasic system for the recovery of cobalt.

FIGURE 2

KEYWORDS

alternative solvents | critical metals | waste electrical and electronic equipment | integrated process

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