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By-product recovery of critical elements from ores and concentrates using deep eutectic solvent ionic liquids: *BRIO*

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Many ore deposit types, and concentrates produced from them, often contain high enrichments of scarce or critical elements such as Te, Bi, and Sb alongside the primary commodity being extracted. However, there are currently few financial incentives for a company to recover these accompanying elements. They may be lost to tailings or roasted off (and so become an environmental liability), or can incur smelter penalties. Sometimes a smelter will recover these by-product elements, but little or none of the value may be returned to the producer.

Ionic liquids are anhydrous salts that are liquid at low temperature. They are powerful solvents and electrolytes with potential for high selectivity in both dissolution and recovery. Deep eutectic solvents (DES) are a form of ionic liquid that are mixtures of salts such as choline chloride with hydrogen-bond donors such as urea. DESs are environmentally benign, yet chemically stable and, furthermore, the components are already produced in large quantities at low cost [1].

Using a microleach technique employing an optical profiler we show that gold, as electrum, dissolves rapidly by oxidation with I_2 in DES at 50°C (at least 80x the maximum cyanidation rate at 25°C). Recovery of the gold by electrodeposition has been demonstrated [2]. In itself this is a potential environmentally-benign alternative to cyanidation for gold recovery. In addition, hessite (Ag_2Te) dissolves as rapidly as electrum, whilst native tellurium, altaite (PbTe), tellurobismuthite (Bi_2Te_3) and stibnite (Sb_2S_3) also dissolve. Base metal sulfides such as galena and chalcopyrite dissolve relatively slowly, whereas pyrite and sphalerite are insoluble. Thus there is good mineralogically-based discrimination in dissolution rate between the base metal sulfides/pyrite gangue and the Au, Ag, Te, Bi and Sb minerals, suggesting the potential to recover *all* these elements from gold ores.

Pyrite, and many other sulphides, are soluble by electrolysis in DES. Thus inclusions of gold and other target minerals locked within pyrite could potentially be liberated by electrolysis for subsequent dissolution by oxidation.

In many deposit types elements such as Te, Bi, Sb form discrete mineral phases that are present in small volumes. Since the leaching by ionic liquids is mineral-specific this presents the opportunity to target particular phases for extraction from existing concentrates (or even to generate new concentrates specifically for extraction of by-products) a process we have coined ***BRIO***: **B**y-product **R**ecovery by **I**onometallurgy of **O**re. Recovery of rare and critical elements as by-products direct from concentrates and returning the full value to the producer would incentivize producers to optimize recovery, secure supply of critical elements, and represent a more environmentally efficient use of Earth resources.

References:

[1] Jenkin GRT et al. (2015) Min Eng 87:18-24
[2] Abbott AP et al. (2015) Green Chem 17: 2172-2179