Critical Metals:
Essential development of novel extraction methods

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Depletion of critical metals is a major issue in Europe. Cobalt, antimony, indium, germanium, and gallium are scarce yet high in demand; alternative sources must be utilised. Ioanna Maria Pateli is second year PhD student in the Department of Chemistry working on a project that aims to determine "green" ways of extracting precious and scarce critical metals from low metal containing industrial residues using deep eutectic solvents (DESs).

Critical metals in Europe

Mobile phones, smart TVs, cars, and solar panels. Other than being essential to our everyday living, what do these devices have in common? They each consist of a plethora of metals, including common metals such as iron, zinc, copper, and aluminium, as well as rarer metals such as germanium, gallium, cobalt, antimony, and indium. Aside from being less well known, these metals are not commonly found in Europe's crust surface, and for that reason, they are identified as critical metals.

Critical metals are in high demand, which consequently leads to their depletion from the few known reserves. Europe faces a serious challenge in supplying the demand of critical metals, as there are not enough natural sources available and all the major ores are located outside Europe in China and Africa. Though it may seem like a dead end for Europe's production of these rarer metals, there is, fortunately, still hope.

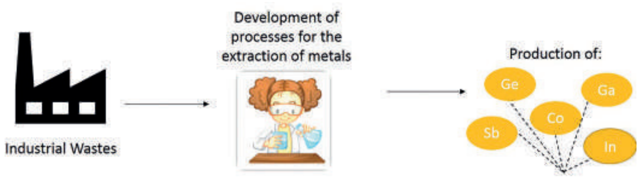
> "Depletion of critical metals is a major issue in Europe"

Europe's metal industries are producing thousands of tonnes of waste residue which contains small amounts of metal daily. Within these industrial residues, a wide variety of critical and economically important industrial and precious metals are present. Though the concentration of these metals in the waste is low, the additional waste produced is significantly higher. This fuels Europe's pursuit in researching processes considered efficient and eco-friendly for the extraction of these targeted metals. Such a solution would have considerable impact on Europe's economy by limiting the reliance on foreign producers to meet the supply demands for critical metals.

Fe - rich industrial waste called Jarosite; containing Fe, Ni, Co, In, Ge, Pb, Zn.

State of the art metal extraction processes

There are two main approaches to metal extraction, hydrometallurgy and pyrometallurgy. Hydrometallurgy is a methodology that utilises aqueous basic or acidic solutions to dissolve the targeted metals, whereas pyrometallurgy employs extremely high temperatures in order to reduce metal ions to a metallic state. Both of these well-established methods result in the production of high purity metals. However, both methods of extraction have a significant environmental impact. Pyrometallurgy consumes extreme amounts of energy and produces greenhouse gasses (e.g., carbon dioxide, carbon monoxide, methane, nitrous oxide, and sulphur dioxide), while hydrometallurgy requires the disposal of a vast amount of aqueous wastes and the use of toxic additives such as cyanide for the extraction of the metals.



Ionometallurgy – an alternative approach to the current processes

Presently, researchers are focused on the development of ionometallurgy, a new science that encloses all the processes of metal extraction with the use of ionic liquids or deep eutectic solvents. These solvents, first introduced in the literature by Prof Andy P. Abbott and his group at the University of Leicester in 2001, have attracted much global scientific interest in extractive metallurgy and chemistry. Deep eutectic solvents consist of eutectic mixtures of quaternary ammonium salts and hydrogen bond-donors, such as amides. The two components prior to mixture exhibit high melting points, which decrease drastically after their combination. These solvents exhibit a "green" behaviour, as they are non-flammable and not toxic, with low vapour pressure, thermal and chemical stability, biodegradability

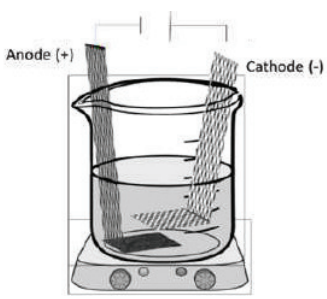
Paint casting, innovative process for conducting electrochemical experiments.

ABBOTT, A. P., BEVAN, F., BAEUERLE, M., HARRIS, R. C. & JENKIN, G. R. 2017. Paint casting: A facile method of studying mineral electrochemistry. Electrochemistry Communications, 76, 20-23.

and in addition, their production process is cheap and very straightforward. One of the most important things, is that their components are readily available in bulk amounts. For example, one of the most common deep eutectic solvent is Ethaline 200, which is a mixture of choline chloride and ethylene glycol. Choline chloride is common in chicken feed as it is a vitamin B supplement and ethylene glycol is routinely used in anti-freeze.

Focused on "Zero Waste Society"

At present, the question is, can we use these green solvents to extract critical metals from industrial residues? The SOCRATES Innovative Training Network, funded under the Horizon 2020 EU Research and Innovation programme, seeks new ways of achieving a zero-waste society. My research as part of SOCRATES explores the ways in which green solvents can be used to extract critical metals from industrial residues, by valorising the solid waste from industrial production, with hope that society can look to a greener future.



Cell of electrochemical dissolution of industrial wastes in Deep eutectic solvents designed by the Abbott research group at University of Leicester.