1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

New deep eutectic solvents as carriers in polymer inclusion membranes for efficient metal ion separation.

1.1. Project golas

The project aims to develop a membrane system with specific transport and separation properties to recover strategic metal ions such as cobalt, nickel, cadmium, zinc, and indium. The goal includes chemometric design and synthesis of innovative deep eutectic solvents (DES), optimization of the composition of polymer inclusion membranes (PIM), determination of parameters influencing the efficiency of membrane transport, identification of changes in membrane morphology occurring during transport and development of a mathematical model of transport kinetics.

1.2. Outline

In the era of growing demand for strategic metals, developing ecological and effective methods for their recovery is becoming a priority for industry and environmental protection. Applying deep eutectic solvents (RGE) in membranes is an innovative approach that can revolutionize separation processes. RGE is a new class of ecological liquids that can replace traditional, often toxic solvents thanks to unique properties such as low vapor pressure, non-flammability, and stability.

One of the intensively developing research directions is the application of polymer inclusion membranes (PIMs) for the recovery and/or separation of metal ions from aqueous solutions. PIMs are obtained by slow evaporation of a volatile organic solvent from a polymer, carrier, and plasticizer solution. The carrier binds to the substance in the feed solution and enables (or facilitates) the transport through the membrane. One of the new research directions is the application of deep eutectic solvents (DESs) as carriers in PIMs. DESs are a new class of safe, efficient, simple, and low–cost solvents characterized by significant depressions in melting points compared to those of the neat constituent components. Compared to typical carriers, DESs possess many advantages, such as low vapor pressure, non-flammability, thermal and electrochemical stability, and the ability to dissolve organic and inorganic substances depending on the structure. Due to their properties, they can also be called "green solvents". The main advantage of DESs is the possibility of designing a compound with specific and desired properties through the appropriate selection of a hydrogen bond donor (HBD) and a hydrogen bond acceptor (HBA) forming the DES. The ease of synthesizing new DESs with unique properties makes it possible to use them in PIMs to recover metal ions from electroplating wastewater, electronic waste, sewage sludge, etc.

1.3. Work plan

The work plan includes several stages:

1. Chemometric design and synthesis of new, innovative deep eutectic solvents (4 months).
2. Preparation and optimization of the composition of polymer inclusion membranes (2 months).
3. Study of the membrane structure (measurement of contact angle, vibrational spectroscopy, atomic force microscopy, scanning electron microscopy) and determination of the effect of structure on transport efficiency (12 months).
4. Application of response surface analysis to optimize selectivity and transport efficiency (6 months).
5. Development of a mathematical model to describe the kinetics of membrane transport (2 months).
6. Application of optimized membranes for recovery and separation of metal ions from real wastewater and waste containing strategic metals (plating wastewater, e-waste) (10 months).

1.4. Literature *(max. 7 listed, as a suggestion for a PhD candidate preliminary study)*

[1] European Commission, Report on ad hoc working group on defining critical raw materials. Report on Critical Raw Materials for the EU, 2014, available at http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm.
[2] A. K. Dwamena, Separations 2019, 6, 9.
[3] Deep Eutectic Solvents, Y. Marcus, Springer Nature Switzerland AG, 2019.
[4] Deep Eutectic Solvents Synthesis, Properties, and Applications, D. J. Ramón, G. Guillena (Eds), Wiley-VCH Verlag GmbH & Co. KGaA, 2020.

1.5. Required initial knowledge and skills of the PhD candidate

Knowledge about general, physical, and polymer chemistry.
Self-discipline.
Motivation to achieve the goal (i.e. PhD degree).

1.6. Expected development of the PhD candidate's knowledge and skills

Ability to design deep eutectic solvents with desired properties.
A better understanding of the membrane transport physicochemistry.
Practical knowledge and skills in membrane morphology analysis.
The ability to work independently.
Gaining experience in analyzing according to principles of good laboratory practice (GLP).
The advanced ability to process data and perform statistical/chemometric analysis.