Chemical Engineering

Fall 2023 Seminar Series

Unlocking Molecular Selectivity in Electrochemical Separations

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66-110
3:00-4:00pm
2:45pm Reception

Electrification of separation processes offers a sustainable pathway to decarbonization and lower chemical footprint. Control of the redox electron-transfer at electrochemical interfaces allows for reversible binding and release of target molecules. However, most liquid-phase electrosorption studies have focused on simple inorganic species in aqueous media, with limited translation to industrially-relevant, multicomponent contexts. Here, we present a mechanistically guided approach for electrochemical separations design, to expand their scope to new applications requiring high precision and structural discrimination.

First, we elucidate the underlying mechanisms in redox-mediated electrosorption and establish molecular design principles. We unravel the importance of solvation and copolymer design as a route for unlocking different modes of interfacial selectivity. Uniquely, our lab exploits the supramolecular effects arising from the complex structure of copolymer systems to amplify selectivity beyond single-site interactions. These principles are translated into the development of new electrochemical separation schemes, including towards critical element recovery, the recycling of homogeneous catalysts, and even enantioselective purification. Next, we discuss how these molecularly selective redox electrodes can tackle emerging environmental challenges such as the remediation of short-chain PFAS and the upcycling of nitrate to ammonia. By coupling reaction and separations at bifunctional redox interfaces, we overcome the mass transfer limitations of dilute pollutant streams and dramatically enhance electrocatalytic efficiency.

Finally, we present new directions in engineering continuous redox-mediated multicomponent separations, and highlight the generalizability of electrochemical design beyond adsorption-based approaches.

http://cheme.mit.edu/seminar-series/