

Liquid–liquid Phase Separation of Designer EF-hand Peptides for Selective and Enhanced Recovery of Rare Earth Elements

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Abstract

The sustainable and selective separation of rare earth elements (REEs) remains a pressing challenge owing to their nearly identical chemical properties. Despite the widespread adoption of liquid-liquid extraction, the method entails considerable reliance on organic solvents, thereby posing substantial environmental burdens. Here, we develop a bioinspired liquid–liquid phase separation (LLPS) system based on engineered EF-hand peptides, which enables highly efficient and selective recovery of REEs through a fully aqueous, green, and low-cost separation process. By incorporating a hydrophobic self-assembling Nap-FF motif, these peptides undergo rapid coacervation upon REE binding, forming dense liquid-like condensates. Remarkably, the LLPS platform enhances REE binding capacity by over 30 %, significantly outperforming conventional immobilization approaches. Moreover, the system achieves efficient separation of adjacent light REEs (Nd/Ce) with a separation factor exceeding 2.8 at pH 5.6, surpassing most reported liquid–liquid extraction systems. With excellent reusability, broad pH tolerance, and strong resistance to competing ions, this LLPS strategy provides a sustainable and efficient route for the selective recovery and enrichment of REEs.

Keywords

Rare Earth Elements, Liquid–liquid Phase Separation, Engineered EF-hand Peptides, Enhanced Recovery, Selective Separation