Elucidating Surfactant–Solvent interactions in dilute regimes to control Nanostructured Fluids features

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Surfactant-driven self-assembly underpins the formation of a broad class of complex fluids that are essential for applications ranging from drug delivery to conservation science.[1,2] However, the development of nanostructured fluids with targeted properties remains largely empirical, as formulation strategies still rely on iterative and time-intensive trial-and-error approaches. Advancing beyond this paradigm requires molecular-level insight into how surfactant structure and solvent environment collectively determine mesoscale organization and macroscopic behaviour.[3]

Here, we propose a systematic and experimentally accessible approach to probe surfactant–solvent interactions in dilute regimes.[4] A library of bio-derived polyethylene glycol (PEG) surfactants bearing distinct terminal functionalities was selected as a model system. Structural characteristics and translational dynamics were quantified in dilute aqueous and organic solutions using size-exclusion chromatography and nuclear magnetic resonance spectroscopy (NMR). These molecular descriptors were subsequently linked to the formation and evolution of micellar nanostructures through combined NMR and small-angle X-ray scattering analyses.

The study reveals well-defined relationships between surfactant molecular parameters, including molar mass, end-group chemistry, and hydrophilic–hydrophobic balance (logP), and the size, internal organization, and dynamic properties of the resulting micellar assemblies. In addition, the introduction of water-miscible organic solvents emerges as an effective strategy to tune micellar dimensions, internal solvation, and solvent encapsulation efficiency.

Taken together, these findings establish a coherent structure–property framework for the rational design of sustainable, bio-derived soft matter systems. The methodology presented here provides a foundation for the predictive engineering of tailored micellar fluids, offering new opportunities for performance optimization across a wide spectrum of soft-matter-based technologies.

References:

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