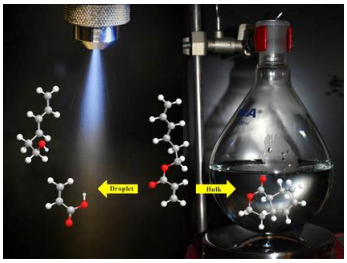
Chemical Wizardry of Microdroplets: Transforming Chemistry and Clinics



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Micron-sized droplets, seemingly simple and familiar, are now at the heart of one of the most exciting developments in modern chemistry and laboratory medicine. Over the past decade, studies have revealed that chemical reactions at the air–water interface of microdroplets can proceed along entirely new pathways or occur millions of times faster than in bulk solutions. This "chemical wizardry" is driven by unique interfacial properties and often attributed to interfacial charges and extreme local electric fields, partial solvation of reactants, molecular orientation, and confinement effects within the droplet. In recent years, sprayed microdroplets have enabled numerous chemical reactions to proceed without the need for catalysts or harsh conditions, paving the way for sustainable developments. This presentation will showcase the unusual physicochemical behavior of microdroplets, highlighting our pioneering contributions. These include the first demonstration of molecular transformations proceeding through unconventional reaction pathways within microdroplets; the spontaneous activation of nitrogen and argon at the air–water interface leading to the formation of their corresponding oxides and hydroxides; the cleavage of some of the strongest organic bonds in aqueous microdroplets; in-droplet phase separation of water isotopologues; the synthesis of pharmacophore and platform chemicals within microdroplets; and the stabilization of highly reactive intermediates (e.g., carbocations and carbanions) at the air–water interface. Beyond chemical transformation, we are leveraging propelled microdroplets to extract biomolecules directly from tissues and blood, enabling rapid, information-rich mass spectrometric analysis for probing molecular aberrations in diseases such as cancer, paving the way for next-generation point-of-care diagnostics. Overall, this talk will share our journey from the serendipitous discovery of unusual droplet chemistry to its growing role in sustainable synthesis, environmental applications, and clinical diagnostics, highlighting how these tiny droplets are making a big impact in both chemistry and medicine.

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