Chemical Engineering Colloquium

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Goddard Hall, Room 227

12:00 PM – 1:00 PM

Taming the Transient: Mn(III) and Cu(I) Intermediates and the Path to Durable Aqueous Grid-Scale Batteries

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Meeting the growing demands of the power grid requires battery technologies that are cost-effective and inherently safe at scale. Lithium-ion batteries dominate today's markets, but their flammable organic electrolytes present real safety challenges for large-format, grid-connected deployment. Aqueous electrolyte batteries offer a compelling alternative: inherently safer operation, lower material costs, and simpler manufacturing. However, they face a fundamental constraint: the narrow electrochemical stability window of water limits achievable voltage and, with it, energy density.

One route around this limitation is to use high-capacity two-electron conversion reactions to compensate for lower cell voltage, potentially reaching commercially relevant energy density with an aqueous chemistry. This approach introduces its own instability, however: two-electron transfer typically proceeds through a transient intermediate oxidation state and managing that intermediate is often the key to maintaining cycling stability. In alkaline MnO_2 cathodes that intermediate is Mn(III); with CuO cathodes, it is Cu(I). In both cases, the intermediate can nucleate inactive or resistive phases that accumulate irreversibly over cycling, and the electrode's long-term fate is determined as much by the nature of the intermediate (its stability, crystal structure, morphology, solubility, and mobility) as by the overall reaction thermodynamics.

This talk traces this theme across two cathode systems developed over more than a decade of work, from early studies at City College of New York (CCNY) through current work at Northeastern University. These are the rechargeable alkaline MnO_2 electrode (for Zn-MnO_2 batteries) and the rechargeable CuO cathode (for Zn-CuO batteries). In both, cycling stability turns is inseparable from the evolving microstructure and morphology of the electrode, and controlling the intermediate is the common mechanistic thread connecting cathode chemistry, electrode engineering, and the prospects for durable, low-cost aqueous batteries at grid scale.