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Editorial

The Spark of Discovery: Charting Electrochemistry's Future with *eChem*

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Dear Colleagues, Researchers, and Visionaries of the Electrochemical World,

It is with immense enthusiasm and a profound sense of responsibility that we announce the launch of *eChem*, a new Gold Open Access, peer-reviewed journal dedicated to the vibrant and ever-expanding universe of electrochemical science and technology. Published quarterly online by Scilight Press, *eChem* is born from the recognition that electrochemical innovation stands at the very heart of addressing some of humanity's most pressing challenges: the transition to sustainable energy, the development of advanced materials, the creation of intelligent devices, and the remediation of our environment.

The past decade has witnessed nothing short of an electrochemical renaissance. Driven by the urgent need for decarbonization and technological advancement, research spanning fundamental charge transfer mechanisms to large-scale industrial applications has accelerated at an unprecedented pace. *eChem* emerges to serve as the premier, interdisciplinary platform for disseminating the most significant and transformative research across this vast landscape. Our scope is intentionally broad and inclusive, encompassing the full spectrum from electrocatalysis, nanoelectrochemistry, battery materials and electrochemical energies, bioelectrochemistry, and electroanalytical chemistry, to surface electrochemistry, computational electrochemistry, electronic devices, electrosynthesis, and environmental electrochemistry. We welcome original research articles, short communications, insightful reviews, forward-looking perspectives, and engaging editorials that push the boundaries of knowledge and application.

1. Celebrating Recent Triumphs: The Solved and the Understood

The global electrochemical community has made remarkable strides, solving critical problems and deepening our fundamental understanding:

1) Deciphering reaction mechanisms: Advanced *in situ* and *operando* spectroscopic and microscopic techniques (e.g., *in situ* Raman, X-ray absorption spectroscopy, transmission electron microscopy, electrochemical mass spectrometry) have revolutionized our understanding of complex electrocatalytic reactions. We now possess unprecedented atomic-level insights into pathways for the oxygen evolution reaction (OER) and oxygen reduction reaction (ORR), revealing the dynamic restructuring of catalysts under operating conditions and identifying true active sites beyond idealized surfaces [1]. Similar progress is being made for CO_2 reduction reaction (CO_2RR), elucidating selectivity determinants towards valuable C1 and C2+ products [2].
2) Beyond lithium-ion dominance: While lithium-ion batteries (LIBs) continue to mature, significant breakthroughs have been achieved in alternative chemistries. Sodium-ion batteries (SIBs) have transitioned from lab curiosities to near-commercial viability, driven by innovative cathode (e.g., layered oxides, polyanionics) and anode (e.g., hard carbon, alloying materials) designs, offering cost and sustainability advantages [3]. Solid-state batteries (SSBs), particularly using sulfide- or oxide-based electrolytes, have seen dramatic improvements in ionic conductivity and interfacial stability, promising enhanced the battery safety and energy density [4]. The understanding and mitigation of challenges in lithium-sulfur (Li-S) batteries (polysulfide shuttling) and zinc-based batteries (dendrite growth) have also advanced considerably.
3) The nano and bio revolutions: Nanoelectrochemistry has flourished, enabling ultrasensitive detection (nanoelectrochemical sensors, nanopores for single-molecule analysis), novel energy harvesting concepts

(nanodroplets), and the exploration of quantum effects at the nanoscale. In bioelectrochemistry, the mechanisms of extracellular electron transfer (EET) in electroactive microbes are being unraveled at the genetic and protein level, powering advances in biofuel cells and bioelectrochemical systems (BES) for waste treatment and electrosynthesis [5].

4) Computational power unleashed: Computational electrochemistry has become indispensable. Multiscale modeling, from density functional theory calculations of adsorption energies to continuum modeling of full devices, guides materials discovery, optimizes electrode architectures, and predicts system performance. Artificial intelligence (AI) and machine learning are rapidly accelerating materials screening, predicting degradation pathways, and optimizing electrochemical processes [6].
5) Electrosynthesis ascendant: Driven by the demand for sustainable chemical production, organic electrosynthesis has experienced a major revival, offering routes to valuable pharmaceuticals and fine chemicals with high atom economy and reduced waste. Significant progress has also been made in green ammonia (NH_3) and hydrogen peroxide (H_2O_2) electrosynthesis routes, challenging traditional energy-intensive processes [7,8].

2. Confronting Persistent Challenges: The Frontiers of Electrochemistry

Despite these impressive advances, formidable scientific and technological hurdles remain, demanding urgent and focused attention:

1) The catalysis conundrum: activity, stability, and scalability
   - Ubiquitous precious metals: Replacing scarce and expensive precious metals (e.g., Pt, Ir, Ru) in ORR, OER, and HER with earth-abundant, highly active, and durable alternatives remains a paramount challenge, especially for acidic environments (e.g., proton exchange membrane electrolyzers, fuel cells). Stability under harsh operating conditions (e.g., high potentials, variable pH, impurities) is often the Achilles' heel of promising non-precious catalysts.
   - Complex reactions and selectivity: Achieving high selectivity and activity for multi-electron/proton transfer reactions like CO_2RR to valuable fuels/chemicals beyond CO/formate, nitrate reduction to ammonia, and urea oxidation requires catalysts with exquisite control over reaction pathways, often hampered by competing reactions (HER) and complex reaction networks. Understanding and mitigating catalyst reconstruction during operation is critical.
   - Scaling fundamentals: Bridging the gap between exceptional lab-scale catalyst performance and scalable, cost-effective manufacturing of electrodes and devices with maintained activity and longevity is a major translational bottleneck.
2) Battery frontiers: pushing limits and enabling new paradigms
   - Energy density ceiling: Breaking the practical energy density limits of current LIBs requires new chemistries (e.g., Li-air batteries, solid-state Li-metal batteries) overcoming fundamental challenges like uncontrolled interfacial reactions, dendrite growth, and electrolyte decomposition.
   - Ultra-fast charging and extreme conditions: Developing batteries capable of extreme fast charging (XFC) without compromising safety or cycle life, and operating reliably under extreme temperatures (−40 °C to +60 °C), remains difficult.
   - Sustainability and Circularity: Truly sustainable batteries demand breakthroughs in recycling complex multi-material systems, designing for direct recycling, utilizing bio-derived or highly abundant materials, and minimizing environmental footprint across the entire lifecycle. Reducing reliance on critical minerals like Co and Ni is essential.
3) Fundamental understanding across scales
   - Dynamic interfaces: Achieving a holistic, real-time understanding of the complex and dynamic processes occurring at electrode-electrolyte interfaces (e.g., electric double layer, ion solvation/desolvation, SEI/CEI formation and evolution) across all relevant time and length scales is still incomplete.
   - Multi-phase and complex systems: Modeling and understanding charge transfer and mass transport in complex systems involving gases (e.g., batteries, fuel cells, CO_2RR), solids (e.g., SSBs), porous structures, and biological matrices (e.g., bioelectrochemistry, biosensors) requires new theoretical and experimental frameworks.
   - Degradation mysteries: Predicting and mitigating degradation mechanisms (e.g., corrosion, particle cracking, gas evolution, crossover) in complex electrochemical systems over long operational lifetimes remains a significant challenge, requiring advanced diagnostics and modeling.

4) Integration and system complexity
   - Beyond the half cells: Progress often occurs in isolated half-cell studies. Integrating optimized components (cathodes, anodes, electrolytes, separators, and current collectors) into functional, efficient, and durable full devices (e.g., batteries, electrolyzers, fuel cells) introduces new complexities and failure modes that are poorly understood.
   - AI integration: While promising, effectively integrating AI into the entire electrochemical R&D cycle—from discovery and synthesis to diagnostics and control—requires overcoming data scarcity, ensuring model interpretability and robustness, and developing standardized protocols.
   - Bridging bio-electro: Fully harnessing the potential of bioelectrochemical systems requires a deeper understanding and control of microbe-electrode interactions, extracellular electron transfer pathways beyond known cytochromes, and engineering robust, scalable reactor designs.

3. *eChem*: Your Catalyst for Electrochemical Discovery

In this landscape of immense opportunity and persistent challenge, *eChem* is conceived as more than just another publication outlet. It aspires to be the central nervous system of the global electrochemical community. Here's how we will contribute to tackling these critical questions:

1) Interdisciplinary nexus: *eChem*'s uniquely broad scope explicitly encourages cross-pollination of ideas. We believe solutions to complex problems like catalyst stability or battery degradation often lie at the intersection of traditional sub-disciplines. A paper on *in situ* characterization of electrocatalyst surfaces (surface electrochemistry) can inspire new diagnostics for battery interfaces (battery materials). Insights from nanoelectrochemistry can revolutionize biosensor design. Computational models developed for electrolyte properties can inform environmental electrochemistry processes. *eChem* provides the platform for this essential dialogue.
2) Emphasis on fundamental mechanistic insight: While applied results are crucial, *eChem* places a premium on research that provides deep, fundamental understanding. We seek studies that uncover *why* materials behave as they do, *how* reactions proceed at the molecular level, and *what* governs stability and degradation. This foundational knowledge is the bedrock upon which transformative technologies are built. Advanced characterization, rigorous theory, and insightful modeling are key pillars.
3) Championing novelty and practical relevance: We are dedicated to publishing truly original research that pushes boundaries—novel materials, unprecedented reaction pathways, innovative device architectures, and groundbreaking computational approaches. Simultaneously, we value research that addresses scalability, sustainability, cost, and real-world performance, bridging the gap between fundamental discovery and application.
4) Open access for global impact: As a Gold Open Access journal, *eChem* ensures that the latest breakthroughs are immediately and freely available to researchers, engineers, policymakers, and innovators worldwide, without barriers. This maximizes enhances visibility, accelerates collaboration, and democratizes access to cutting-edge knowledge, essential for tackling global challenges.
5) Rigorous and constructive peer review: The foundation of *eChem*'s credibility is a rigorous, fair, and constructive peer review process conducted by leading experts. We aim for timely decisions that provide authors with valuable feedback to strengthen their work, ensuring the highest scientific standards.
6) Platform for emerging fields: *eChem* is committed to providing visibility for rapidly growing fields like microbial electrosynthesis, electrochemical environmental remediation, flexible wearable sensors, optoelectronic neuromorphic devices, and the application of AI in electrochemistry, where many of the most exciting future solutions may emerge.

4. A Call to Action

The launch of *eChem* coincides with a pivotal moment for electrochemical science. The challenges are significant, but the potential rewards—a sustainable energy future, advanced healthcare diagnostics, cleaner environments, and revolutionary materials and devices—are monumental. We cannot achieve this alone. We invite you, the brilliant minds driving this electrochemical revolution, to join us. Submit your most impactful original research, your insightful reviews, and your visionary perspectives to *eChem*.

Together, through open access to groundbreaking research and fostering deep interdisciplinary connections, *eChem* will be a powerful catalyst, illuminating the pathways and providing the fundamental understanding needed to solve the critical electrochemical challenges of our time and power a sustainable, electrified future.

Welcome to *eChem*. Let the discoveries begin.

Sincerely,
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Conflicts of Interest

The author declares no conflict of interest.

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