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# Stoichiometry in Environmental Redox Processes: Approaches and Implications

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Redox processes play a critical role in environmental chemistry, governing the transformation and degradation of contaminants. Understanding the stoichiometry of these processes provides essential insights into reaction efficiency, electron transfer mechanisms, and the fate of reactive intermediates. This study investigates key stoichiometric aspects of various redox-driven approaches, including sulfate radical-mediated oxidation and nanoscale zero-valent iron (NZVI)-based reduction, focusing on reaction efficiency, electron transfer mechanisms, and transformation pathways.

Persulfate activation by NZVI enables efficient sulfate radical generation, where controlled $Fe^{2+}$ release minimizes radical scavenging and enhances oxidation efficiency [1]. A detailed electron balance reveals that sulfate radical production in the persulfate/NZVI system is more than twice that of homogeneous $Fe^{2+}$ activation, contributing to sustained contaminant degradation. In heat-activated persulfate systems, sulfate radical stoichiometry is influenced by temperature, shifting reactivity toward persulfate oxidation at higher temperatures [2]. This mechanism reduces bromate formation by altering bromide oxidation pathways, highlighting the temperature-dependent competition between radical generation and secondary reactions.

In NZVI-based reduction, stoichiometric analysis demonstrates that electron transfer efficiency depends on competing oxidation pathways, particularly interactions with nitrate and dissolved oxygen [3]. The transformation of NZVI follows a core-shell model, where an evolving iron oxide shell influences redox cycling and long-term reactivity. These findings provide insights into optimizing NZVI application for groundwater remediation by controlling iron speciation and reaction pathways.

By evaluating stoichiometric efficiencies across different redox systems, this study advances the understanding of reaction dynamics and informs strategies for enhancing contaminant degradation while mitigating secondary effects. A precise balance of oxidant activation, radical yield, and electron transfer efficiency is crucial for designing effective and sustainable environmental remediation technologies.

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[2] Oxidation of bromide by heat-activated persulfate–Effects of temperature and the organic matter surrogate phenol on kinetics and stoichiometry, Kim et al. (2022), *Chemical Engineering Journal* 433, 133533

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