

Actinide Colloidal Phases and their Impact on Nuclear Waste Management

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Actinide behavior in nuclear waste systems is commonly framed in terms of solubility limits and equilibrium speciation. However, a growing body of evidence demonstrates that actinides, particularly plutonium, readily form persistent colloidal phases under a wide range of chemical conditions relevant to both nuclear waste processing and long-term disposal. These colloidal phases occupy a critical length scale between dissolved species and bulk solids, strongly impacting their chemical reactivity.

This presentation examines the origins and stability of actinide colloidal phases, with a focus on plutonium as a paradigmatic example. After introducing the fundamental pathways of actinide hydrolysis, oligomerization, and nanophase formation, the talk highlights recent observations of plutonium colloid chemistry related to ongoing cleanup efforts in the high-level waste (HLW) tanks at the Hanford site, a former plutonium production site in the US. Under highly alkaline, radiolytic, and chemically complex conditions, plutonium persists in nanoparticulate and colloidal forms [1] that challenge traditional assumptions about the solubility of Pu species directly influencing waste treatment, separations efficiency, and safety considerations.

The discussion then extends to environmental transport at legacy nuclear sites and geological repositories, where evolving geochemical conditions promote the formation of both intrinsic actinide colloids and actinide association with mineral and organic colloids [2]. In these systems, colloid-facilitated transport can decouple actinide mobility from solubility constraints, complicating performance assessment and long-term risk predictions.

By linking near-field tank waste behavior with far-field repository processes, this presentation emphasizes that actinide colloids are not system-specific anomalies but a fundamental manifestation of actinide chemistry that needs to be recognized and incorporated into waste management strategies that rely on robust and chemically informed models across the nuclear waste lifecycle.

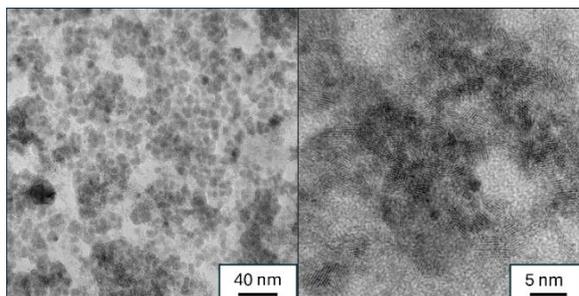


Figure 1: Hydrolytically synthesized PuO_2 Nanoparticles in Solution of NaOH at pH 10, representing similar chemical conditions that are encountered in HLW storage tanks at the Hanford Site.

[1] Delegard, C. H. et al., Chemical Disposition of Plutonium in Hanford Site Tank Wastes; Richland, Washington, PNNL-23468, Rev.1, 2015.

[2] Walther, C. and Denecke M.A. Actinide Colloids and Particles of Environmental Concern. Chemical Reviews 2013, 113.2, 995–1015.