

# Path-dependent Phase Selection in Compressed Cerium: Metastability and Microstructural Memory in an *f*-electron Metal

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Competing low-symmetry phases, sluggish kinetics, and strong hysteresis are recurring challenges in *f*-electron materials, yet they are often difficult to disentangle in chemically complex systems. Here we will show that cerium provides a particularly clean test case for how metastability and retained microstructure govern phase selection under pressure. Using neutron diffraction on large volumes of ultra-high-purity Ce, we tracked structural evolution during controlled pressure-temperature cycling between 85 and 295 K up to 8 GPa. The results reveal two distinct transformation pathways. Slow compression at 295 K produces a strongly textured orthorhombic  $\alpha'$  phase, whereas compression at 100–120 K stabilizes a pure monoclinic  $\alpha''$  phase. The  $\alpha''$  phase persists metastably to near room temperature but transforms irreversibly on heating above  $\sim 280$  K or after modest pressure cycling. At the same time, a remnant fraction of the lower-pressure  $\gamma$  phase remains trapped far beyond its expected stability field, indicating that inherited parent-phase microstructure helps bias nucleation of the high-pressure state. These findings resolve longstanding contradictions in the cerium literature and show that its phase behavior is governed not by equilibrium thermodynamics alone, but by kinetics, history, and microstructural memory. More broadly, they provide an experimentally accessible framework for understanding competing structures and path-dependent transformations in *f*-electron metals relevant to actinide science.