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Time-dependent freezing of water under shock and ramp loading[1]

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Understanding the high-pressure behavior of water remains an area of tremendous interest in physics, chemistry and biology – elucidation of both the kinetic and thermodynamic properties of water under compression has had impact on models for planetary formation and evolution, and even in the search for life. As laboratory drivers for dynamic compression continue to advance and allow for specific compression paths, we are increasingly confronted with the challenge of interpreting the data in the face of non-equilibrium effects. We present here a model for coupling phase transformation kinetics and hydrodynamics, directed toward the dynamic freezing of water. This theoretical model (based on nucleation and growth concepts) for solidification, constructed from multiple-shock and quasi-isentropic compression experiments as well as molecular dynamics simulations, presents one possible approach. It is found that the phase transition from liquid water to ice VII involves a transient nucleation regime and for which a strong explicit time-dependence enters into the nucleation rate. We conclude by highlighting some anomalies regarding dynamic solidification of water that remain unexplained and propose additional experimental concepts that could shed light on this complex behavior.

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