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Shock Compression of Liquid Noble Gases to Multi-Mbar Pressures

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The high pressure – high temperature behavior of noble gases is of considerable interest because of their use in z-pinch liners for fusion studies and for understanding astrophysical and planetary evolution. However, our understanding of the equation of state (EOS) of the noble gases at extreme conditions is limited. A prime example of this is the liquid xenon Hugoniot. Previous EOS models rapidly diverged on the Hugoniot above 1 Mbar because of differences in the treatment of the electronic contribution to the free energy. Similar divergences are observed for krypton EOS. Combining shock compression experiments and density functional theory (DFT) simulations, we can determine the thermo-physical behavior of matter under extreme conditions. The experimental and DFT results have been instrumental to recent developments in planetary astrophysics and inertial confinement fusion. Shock compression experiments are performed using Sandia's Z-Accelerator to determine the Hugoniot of liquid xenon and krypton in the Mbar regime. Under strong pressure, krypton and xenon undergo an insulator to metal transition. In the metallic state, the shock front becomes reflective allowing for a direct measurement of the sample's shock velocity using laser interferometry. The Hugoniot state is determined using a Monte Carlo analysis method that accounts for systematic error in the standards and for correlations. DFT simulations at these extreme conditions show good agreement with the experimental data – demonstrating the attention to detail required for dealing with elements with relativistic core states and d-state electrons. The results from shock compression experiments and DFT simulations are presented for liquid xenon to 840 GPa and for liquid krypton to 800 GPa, decidedly increasing the range of known behavior of both gases. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Company, for the U. S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.