Phase Changes in Dynamically Compressed Water

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Extreme conditions are ubiquitous in nature. Much of the matter in the universe exists under high pressures and temperatures. Of interest, are the planetary interiors of the icy giants, Uranus and Neptune. Which have particularly complex magnetic fields [1].

To understand these complex magnetic fields the conditions and composition of icy giant planetary interiors need to be determined. The interiors of these planets are understood to contain mixtures of water, ammonia and hydrocarbons [2].

Under compression the phase diagram of ice is rather complex. With several phases determined and predicted under high pressure and temperature conditions [3]. High pressure ice above ~1500K and 50 GPa is predicted to undergo a superionic transition, where the hydrogen atoms diffuse into the oxygen sub-lattice [4,5]. These superionic phases are a possible source of the complex magnetic fields of both Uranus and Neptune.

Several high-pressure phases of water have been observed in the superionic region of the phase diagram. A body-centred cubic (bcc) phase, which if superionic would be analogous to ice X structure and with increasing pressure a phase transition to a face centred cubic (fcc) phase has been reported [5].

Experiments carried out at the MEC end station at the LCLS XFEL in December 2020, utilised reverberating shocks to compress water into Off-Hugoniot states within the superionic region of the ice phase diagram [6]. Liquid water samples were confined between a diamond ablator and a rear window, reaching P-T states ranging from ~40 GPa and 1200K to ~200 GPa and 4000K.

The bcc phase of ice has been observed from ~50 GPa and ~1200 K. A mixed phase region starting at ~90 GPa and ~2500 K, has been of observed with the bcc phase and a second phase. With increasing pressure the second phase becomes more prominent with the loss of the initial bcc phase.

The higher-pressure ice initially appears to be the fcc phase as described by *Millot et al*. However, further examination of the diffraction revealed misfits to the fcc lattice and a lack of refinement has suggested that that this may in fact be a different structure. The structure of this phase has yet to be determined. However, several candidates are proposed from predicted high pressure ices [7].

Ongoing work aims to determine these structures of ice under superionic P-T conditions and with comparison with simulation, understand the magnetic field behaviour of icy giant type planets.

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