Transformations at megabar pressures

Under megabar pressures solids can be strongly compressed: volume of solid hydrogen decreases in >20 times, even diamond is 1.5 fold compressed at achievable pressures of \( \sim 400 \) GPa. This dramatically changes interatomic distances in materials eventually leading to electrical conductivity, metallization and superconductivity in a number of presenting elements: B, Xe, nitrogen, Li. A special case is Na – simple metal – it becomes transparent at pressures of \( \sim 200 \) GPa transforming into ionic-electride-like state\(^1\). Ammonia transforms to ionic state\(^2\).

The main focus of the presentation is hydrogen. At ambient pressures and low temperatures hydrogen forms a molecular crystal which is expected to display metallic properties under megabar pressures. This metal is predicted to be superconducting with a very high critical temperature \( T_c \) of 200–400 K. The superconductor may potentially be recovered metastably at ambient pressures, and it may acquire a new quantum state as a metallic superfluid and a superconducting superfluid.

Previous experiments performed at low temperatures \( T <100 \) K showed that at record pressures of \( 300 \) GPa, hydrogen remains in the molecular state and is an insulator with a band gap of \( \sim 2 \) eV.

We have found that at room temperature and already at pressures >220 GPa, a new opaque and conductive phase IV appeared. Above 280 GPa, in the next phase V, hydrogen resistance is nearly temperature-independent over a wide temperature range, down to 30 K\(^3\). Our recent data and theoretical works further support the conclusions\(^3\) that hydrogen is semiconductor in phase IV and most likely metal (semimetal) in phase V. We will present new data on phase diagram of hydrogen determined in \( P, T \) domain up to 300 GPa and 350 K.