

Superconducting hydrogen?

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Physicists have long wondered whether hydrogen, the most abundant element in the universe, could be transformed into a metal and possibly even a superconductor -- the elusive state in which electrons can flow without resistance. They have speculated that under certain pressure and temperature conditions hydrogen could be squeezed into a metal and possibly even a superconductor, but proving it experimentally has been difficult.

High-pressure researchers, including Carnegie's Ho-kwang (Dave) Mao, have now modeled three hydrogen-dense [metal alloys](#) and found there are pressure and temperature trends associated with the superconducting state—a huge boost in the understanding of how this abundant material could be harnessed. The study is published in the January 25, 2010, early, on-line edition of the [Proceedings of the National Academy of Sciences](#).

All known materials have to be cooled below a very low, so-called, transition temperature to become superconducting, making them impractical for widespread application. Scientists have found that in addition to chemical manipulation to raise the transition temperature, superconductivity can also be induced by high pressure. Theoretical modeling is very helpful in defining the characteristics and pressures that can lead to high transition temperatures. In this study, the scientists modeled basic properties from first principles—the study of behavior at the atomic level—of three metal hydrides under specific temperature, pressure, and composition scenarios. Metal hydrides are compounds in which metals bind to an abundance of [hydrogen](#) in a lattice structure.

The compounds were scandium trihydride (ScH_3), yttrium trihydride (YH_3) and lanthanum trihydride (LaH_3).

"We found that superconductivity set in at pressures between roughly 100,000 to 200,000 times atmospheric [pressure](#) at sea level (10 to 20 GPa), which is an order of magnitude lower than the pressures for related compounds that bind with four hydrogens instead of three," remarked Mao, of Carnegie's Geophysical Laboratory. Lanthanum trihydride stabilized at about 100,000 atmospheres and a transition temperature of -423°F (20 Kelvin), while the other two stabilized at about 200,000 atmospheres and temperatures of -427°F (18 K) and -387°F (40 K) for ScH_3 and YH_3 respectively.

The researchers also found that two of the compounds, LaH_3 and YH_3 , had more similar distributions of vibrational energy to each other than to ScH_3 at the superconducting threshold and that the [transition temperature](#) was highest at the point when a structural transformation occurred in all three. This result suggests that the superconducting state comes from the interaction of electrons with vibrational energy through the lattice. At pressures higher than 350,000 atmospheres (35 GPa) superconductivity disappeared and all three compounds became normal metals. In yttrium trihydride, the superconductivity state reappeared at about 500,000 atmospheres, but not in the others. The scientists attributed that effect to its different mass.

"The fact that the models predicted distinctive trends in the behavior for these three related compounds at similar temperatures and pressures is very exciting for the field," commented Mao. "Previous to this study, the focus has been on [compounds](#) with four hydrogens. The fact that superconductivity is induced at lower pressures in the trihydrides makes them potentially more promising materials with which to work. The temperature and pressures ranges are easily attainable in the lab and we hope to see a flurry of experiments to bear out these results." The team

at Carnegie has embarked on their own experiments on this class of trihydrides to test these models.

Provided by Carnegie Institution

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