Student questions: Dan Shim colloquium on "Hydrogen in Planets"

9/2/20

Regarding the hydrogen and iron reactions, what are "water rich conditions" and how do these reactions work?
The definition I used was that water-rich conditions are where you have more volume fraction of water than the volume fraction of rocks. The definition can vary.

How accurate are these pressure experiments with lasers, and how do we know that the effects of pressure/temperature during the short time the laser is on the material is the same as what's going on in a planet over a much longer duration?
Yes, this time scale is the major issue. Ultimately we want to heat longer at that temperature, but it is impossible technically for now. However, it is worth noting that our results with pulse heating at low temperatures match very well with existing results with long heating duration experiments.

What causes the pores in the H_2O-$MgSiO_4$ reaction in the diamond cell?
The pores were created because MgO in $MgSiO_4$ dissolves in H_2O liquid.

How can water survive the conditions such as high Pressure and Temperature to react with Magnesium in the depth, and how can it sustain such conditions and not evaporate?
Because they are confined into that space by pressure.

How can scientists determine whether or not a planet has a core, especially in the case of gas giants like Jupiter and Uranus?
The density of planet, in short. The size (and therefore volume) and the mass of planets are very well known. Those planets' density is still bit higher than pure H or H_2O. But because we do not have as much geophysical data for those planets, we do not know the size and composition of those cores.

When SiO_2-H_2O is subjected to high pressure and temperature, why does the d-spacing increase implying that the SiO_2 lattice is expanding, instead of forming high-pressure polymorphs like coesite and stishovite?
The peaks also defined which type of phase we have from the synthesis. So we know exactly what phase we have and therefore what volume we must have if the sample is dry. We also have direct measurements of OH vibration which is the direct evidence for OH bonded to the crystal structure. The information, however, does not tell you how much. So we use H_2O induced volume expansion for water content.

Is there any techniques in development to study the inner layers of Jupiter directly?
Yes. But they cannot still reach the pressure conditions of the deepest part of Jupiter. With shock wave method, you can rich about 10 Mbar. However, you would need more than 20 to 30 Mbar to reach the pressure conditions expected for the deepest part of Jupiter.

Are these the only elements that you work with in your studies, or are there others that can be mixed under pressure to produce the results you are looking for?
I wish I would have had more time to present our Mg, Si mixing with H results. Yes, we do have.

Does octahedral placement of hydrogen in the iron lattice preclude tetrahedral placement, or can both be present at the same time?
They can exist together according to our density functional theory calculations.

What types of data from exoplanets do we take/analyze that help us develop/support these models for gas giants? I'm interested because it was said that gravitational field measurements from the close-encounter mission Juno gave us the information we needed to develop new models.
Juno level of data would be impossible to measure for exoplanets anytime soon. But current effort of making measurements on radius and mass of those exoplanets would still be very useful combined with our new data to model the interiors of gas giants better.

I know you talked about the role iron and magnesium plays when it comes to site substitutions in water under immense pressures and temperatures -- what is the largest cation substitution you've seen or hypothesize is possible in gas giants like Jupiter - for example, could a much larger cation like uranium possibly substitute in?
I am not sure what controls the solubility of different combinations of ions. I think size is one but not all. Yes, U would be an interesting case for heat producing elements.

How do you heat the substance without heat transfer to the diamond?
We use lasers with wavelengths which can avoid absorption by diamond.

In one of your last slides, you showed a diagram of mixing Magnesium with liquid water (I think it was the second to last slide). On the left figure, it shows ice instead of liquid water. Does the mixing of Magnesium with water prevent it from becoming cold enough to become ice, or is the water still in solid ice on the left figure?
We actually do not know exact state of H2O in those planets. In our experiments, we still see mixing when H2O is in solid even though it is bit lower in solubility.

In regards to the high pressure interaction between silica and water, are there any experimental tests to determine exactly how much hydroxide is present in the high pressured SiO2, or is it simply not possible at all?
It is matter of recovering good quality crystals to 1 bar where high precision H2O measurements are possible. Such recovery is not impossible but difficult.