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Light elements in planetary cores: a review

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Abstract

Planetary cores are mainly constituted of iron, however the presence of other elements could strongly affect its properties, such as melting temperature, liquid density and more generally phase diagrams. Each light elements commonly assessed, e.g. S, C, Si, O or H [1], must be considered individually, as their effects are highly different, and strongly depend on pressure, that is to say on the size of the planet considered. I will present here a review of the actual knowledge on light elements effects on iron properties, from the Moon's to exoplanets cores.

1. Introduction

From the nucleosynthesis sequence, iron is one the major non-volatile element during planetary accretion. Differentiation processes occurring for solar system planets extracted an iron-based core from a silicate-based mantle. Potential high pressure metal-silicate equilibration during magma ocean stage favors the presence of Si and O in planetary cores [2] (volatile-poor scenario), whereas the study of meteorites emphasize the presence of S and C in parent bodies of differentiated achondrites [3] (volatile-rich scenario).

However, each light elements would have strongly different impact on physical properties of the planetary core formed after the differentiation. On one hand, considering different types of mechanisms, volatile –rich or volatile-poor, the resulting properties of the planetary cores would be drastically different. On the other hand, integrated models of planetary interiors could help us to decipher what is the most probable core composition.

2. Experimental results

I will mainly discuss in this presentation Laser Heating Diamond Anvil Cell coupled with different diagnostics, such as diffraction, absorption, inelastic scattering but also chemical analysis of recovered samples. This global set of diagnostics for iron and iron alloys under high pressure and high temperature allows to have a large overview on how each light element affects the properties of iron, such as binary and ternary phase diagrams, but also density, sound velocity…

I will finally compare these results with ab initio calculations and dynamic compression experiments.

3. Implications for planetary cores

First, the hypothesis of a liquid outer core in the Moon constrains the presence of volatile elements, such as S or C, in its core. We recently proposed a structure for the Moon's core based on a recent dataset on Fe-S binary phase diagram [4], [5].

Secondly, the Earth's core composition derived from siderophile elements partitioning experiments imply the combined presence of Si and O in the Earth's core, from metal-silicate equilibrium [2]. However, present temperature at the Core-Mantle Boundary require the addition of volatile elements, such as C and S, to decrease metal crystallisation temperature [6].

Finally, binary and ternary phase diagrams will be discussed under extreme pressure, emphasizing the difference between different core composition and how it will affect the expected core properties, such as magnetic field generation.

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