D/H ratio and water partitioning into the protoplanetary interior

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Analysis of Baffin volcanic rock samples, which are thought to have originated from the Earth's deep mantle, shows that the D/H ratio (~ 1.2×10^{-4}) is lower than that of water on the Earth's surface (e. g., Hallis et al., 2015). Furthermore, the Pb-Pb analysis suggests that the magma source region of the sample is formed between 4.45-4.55 billion years ago, which corresponds with the formation stage of Earth (Jackson et al., 2010). This indicates that this source region has not experienced recycling between the surface and interior. Therefore, the low D/H ratio of this sample probably reflects the value of the primordial water. The solar nebula gas is expected to be contributed to decreasing in the D/H ratio of primordial water.

Our resent paper, Saito & Kuramoto (2020), focused on the rapid planetary accretion suggested by Hf-W chronology studies and analyzed the thermal structure of a hybrid-type proto-atmosphere where the solar nebula component dominates the upper layer, and the degassed component dominates the lower layer, by developing a 1D radiative-equilibrium model. Our calculation implies Mars-sized proto-planets keep a hybrid-type proto-atmosphere and the D/H ratio of the lower atmosphere resembles that of the building blocks. Conversely, when the mass is larger than Mars, the compositional stratification is collapsed by convective mixing of the solar nebula component with the degassed component, and the D/H ratio approaches that of the solar nebula. The D/H ratio of the mixed proto-atmosphere readily reaches the value of primordial terrestrial water when planetary mass grows up to two times the Mars mass.

In this presentation, we will discuss the conditions under which protoplanets with low D/H ratios are formed such as the atmospheric pressure, composition, and the amount of water and other volatiles partitioned into the planetary interior.

Keywords: D/H ratio, proto-planet, proto-atmosphere, proto-Earth