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Element fractionation in the early solar system: The role of nebular captured H_2-envelopes

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Abstract

The composition of the solar nebula, in which proto-Earth and proto-Venus formed, can be derived by the analysis of different families of chondrites. Compositional variations between those chondrites and the chemical abundances of the terrestrial planets provide evidence that some sort of elemental and isotopic fractionation should have taken place early in the history of the solar system. Some of those fractionations can be explained via atmospheric loss [1] and the collisional erosion of the early differentiated crust [2], whereas others remained poorly understood. An additional mechanism for the early fractionation of elements and isotopes at the terrestrial planets will thus be described for the first time within this presentation.

1. Introduction

During the disk-embedded phase, early in the evolutionary history of the solar system, protoplanetary cores are believed to accumulate hydrogen gas and to form thin planetary H_2-envelopes. According to the “Grant-Tack” scenario [3], those protoplanetary cores (proto-Earth and proto-Venus) should have accumulated a size of 0.5-0.75 Earth- and Venus-masses, respectively until the solar nebular evaporated and a short H_2-“boil-off” phase should have taken place. After the evaporation of the solar nebula, the accumulated H_2-atmosphere contracted and EUV-driven hydrodynamic escape started to slowly erode the H_2-envelope. In addition, constant bombardment of impacting material, delivered further material to growing proto-Earth and -Venus. Most of this impacting material got evaporated due to high impact velocities and the high pressure-related temperature of the H_2-envelope. This presentation shows how the evaporated material can be dragged away via hydrodynamic escape, adding up to the observed elemental and isotopical fractionation at the terrestrial planets.

2. Fractionation of K, ^{36}Ar, ^{20}Ne and others

Lighter elements, such as potassium (K) compared to uranium (U), as well as isotopes, as for example ^{36}Ar compared to ^{38}Ar, or ^{20}Ne compared to ^{22}Ne can escape easier from proto-Earth and proto-Venus due to H-drag from a nebula-captures H_2-envelope compared to a magma ocean related outgassed steam atmosphere, whereas heavier elements and isotopes cannot be dragged away that easily. Our simulations of this fractionation phase show that this effect can explain some of the initial compositional variations between the terrestrial planets and the original solar nebula as derived via data from chondrites. Our solutions of these nebula based fractionations are also supporting the Grant-Tack scenario.

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