EPSC Abstracts
Vol. 10, EPSC2015-208, 2015
European Planetary Science Congress 2015

On the Chemical Evolution of the Impact-Generated Protolunar Disk

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Abstract

We investigate the evolution of the protolunar disk's chemical composition, which is assumed to have formed from a collision between the early Earth and a Mars-sized object. We use a two-phase model (solid and gas) for the silicate-dominated composition of the disk, based on the minimization of the Gibbs free energy, and that includes a chemical network with hundreds of chemical reactions. A thorough study of the parameters space of our model allows us to propose several observational tests that may trace back the thermodynamic evolution of the impact-generated disk.

1. Introduction

The giant impact theory suggests that the Moon was formed as a result of the collision between the planet Earth and a Mars-sized object, named Theia, about 30-50 million years after condensation of the first solids in the solar system. This collision is supposed to have formed a silicate-rich disk with both materials from the impactor and Earth's mantle, which led to the formation of the Moon after thermodynamic and chemical evolution.

2. Model and Methods

In this work, we used a two-phase model for the silicate disk, consisting of a melt layer surrounded by a vapor atmosphere, in order to investigate the evolution of the disk's chemical composition in previously set thermodynamic conditions. This model allows phase changes of the species as well as the formation and dissociation of new chemical species, and does not take into account the disk's dynamic evolution since the time needed to reach chemical equilibrium is negligible in comparison to the dynamic time of the system. Our initial conditions are those proposed by [1]: for a temperature range between 1800 K and 4200 K, the saturation vapor pressure values derive from [2], and the chemical elements used in the model are O, Na, Mg, Al, Si, K, Ca, Ti, Fe and Zn. Formed with these ten elements, 83 chemical species are selected to appear in the disk, whose initial composition is taken close to the Earth's mantle composition because of the collision.

In order to compute the disk's equilibrium composition, we utilized the commercial software *HSC Chemistry*, which is widely used in the fields of geophysics and planetary science. When comparing our equilibrium calculations against those made by [1], we found that both set of results are very close in the temperature range explored by these authors (i.e. 1800-4200 K) : the gas phase of the disk is dominated by Na, SiO, Fe, O_2 and O in this temperature range. One of their conclusions was that the high abundances of O and O_2 could be the direct signature of impact-generated disks.

3. Results and Conclusions

After validating our model against the results of [1], we decided to go further in our study of the protolunar disk. Because recent models suggest that the silicate disk's temperature range could be more extended, we investigated the disk's chemical composition in the 1000 K to 4500 K range. The first observation we make with these new temperature ranges is the strong decrease of O and O_2 abundances at $T < 1500$ K, which immediately shows that the conclusions made by [1] cannot be extrapolated outside the temperature range they chose. In contrast to this previous study, we find that species like Zn and K, whose abundances were magnitude orders below those of O and O_2 at T > 1800 K, become predominant at lower temperatures. We have thus obtained more accurate conclusions on the characteristics of the chemical composition at equilibrium of an impact-generated disk.

Figure 1 shows the partition of all elements found both in vapor and melt phases as a function of temperature in the 1000-4500 K range. This simulation shows that volatile elements in the disk essentially remain in solid phase, except in the 2000-4500 K range where their abundances increase in the gaseous phase. The trend is particularly true for species constituted from Na and K, the only ones for which the gas phase abundances exceed the solid abundances in the 2000-4500 K range. Our calculations show that the investigation of the gaseous abondances of Na and K should also be useful to trace back the thermodynamic evolution of an impact-generated disk.

4. Figures

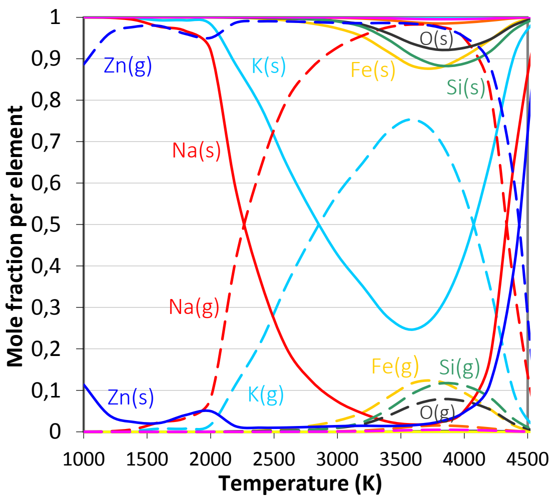

Figure 1: Distribution of elements in the two phases - solid (s) and gas (g) - of the protolunar disk as a function of temperature. For each element, the sum of mole fractions in solid and gaseous phases is normalized to the unity. In the temperature range 1000-2000 K, the abundances of all elements (except Zn) in the solid phase converge towards 1 (i.e. gaseous phase is negligible). In the 2000-4500 K range, the abundances of solids decrease in favor of those of gases.

References

[1] Visscher, C. & Fegley, B. Jr. 2013. *Chemistry of Impact-generated Silicate Melt-vapor Debris Disks*. The Astrophysical Journal 767, L12.

[2] O'Neill, H. St. C. 1991. *The Origin of the Moon and the early History of the Earth – A chemical Model*. Geochimica et Cosmochimica Acta 55, 1135.