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A PLANETARY REFRACTORY COMPOSITION MODEL FOR SOLAR TERRESTRIAL PLANETS

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Abstract

In planetary modeling studies, thermochemical equilibrium is an approach which has long been in use to calculate gas and grain chemistry inside the circumstellar disks [1]. These calculations show a general agreement with solar meteorite and planetary observations, which makes the equilibrium studies reliable to apply to other systems as well [1].
In this study, presuming that rocky composition is a product of the distance to the Sun; the formation conditions of refractory species, which build up the basic constituents of terrestrial planets, are examined under certain thermodynamic conditions with the chemical equilibrium assumption. Results are inferred in order to propose bulk compositions of inner planets depending on their formation locations within the Solar Disk.

1. Methodology

The treatment for the refractory part of the generic planetary compositions holds some similarities to the studies of Carter-Bond et al. (2012) [2] and Bond et al. (2010) [3], with an equilibrium assumption for the chemical composition of the disks, where planetesimals are formed and accrete into larger planetary "embryos". Equilibrium condensation assumption is already supported by various analyses of early chondritic meteorites [1, 3, 4, 5]. A quiescent disk profile is drawn in order to minimize the complications and focus on the relations between chemical composition and basic disk properties.
The Solar compositional data has been fully measured by Asplund et al. (2009) [6]. It is assumed that the Solar composition corresponds also to that of the Solar Disk, standing also for protosolar values. The solid phases, silicate and metal compounds formed in the disk under equilibrium composition are calculated with the software HSC Chemistry 7.1. The largest possible list of 1225 species is constituted using the entire combinations found in the code's database for the universally most abundant and essential refractory-forming elements of Al, C, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, N, Na, Ni, O, P, S, Sc, Si, Sr, Ti, V, Zn, along with H and He. The Temperature is taken within the range of 100 to 2000 K, and pressure is kept fixed at 10^{-4} bar, a traditional value for the Solar Disk studies due to being the characteristic total pressure at or around 1 AU from the Sun [2, 7, 8].

2. Results

An approach is introduced on the basis of in-situ formation assumption for the refractory bulk composition of solar planets, as it is believed that planetary locations are essential to determine their compositions [5]. This assumption is confident for the terrestrial planets as their orbits are thought to have been stable since they were formed.
Firstly, estimated bulk compositions for the solar planets are collected from previous works, and the temperature value which offers the closest ratios of the due species is taken as a reference to the birthplace temperature for the mentioned planet. Since refractory phases of the planetary bulks are not known in detail, the ratio, or at least the existence of a characteristic species is considered as a parameter to determine the formation location temperature and to trace other species in the neighborhood.

3. Figures

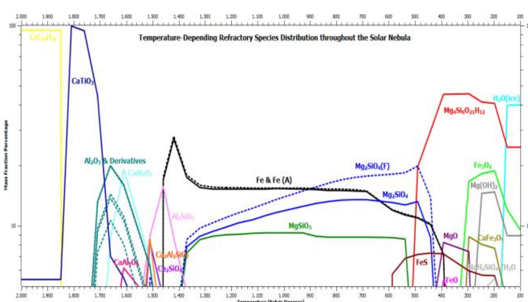

Fig. 1: The leading species of expected refractory composition in the Solar Disk on the basis of temperature. Dashed lines stand for alternative molecular combinations of species with a curve of the same color.

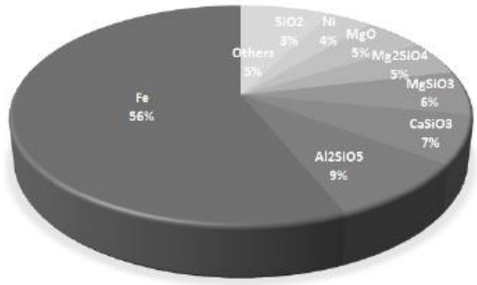

Fig. 2. Suggestion for Mercury's refractory composition calculated for the temperature of 1420 K where elemental iron is found at maximum abundance.

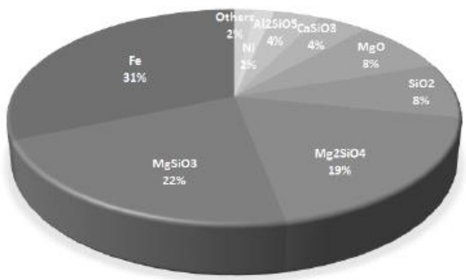

Fig. 3. Suggestion for Earth's refractory composition calculated for the temperature of 1318 K where elemental nickel is found at estimated abundance.

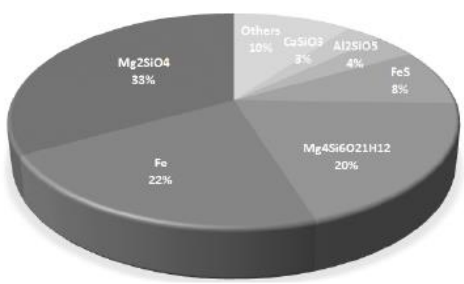

Fig. 4. Suggestion for Mars' refractory composition calculated for the temperature of 392 K where FeS is found at maximum abundance.

4. Conclusions

Restricting the formation of Mercury's iron core to a temperature of 1400 K, and to its current solar distance; and relying on the disk parameters calculated by Hueso and Guillot (2005) [9], it could be said that Mercury's core as imagined today can be traced back to 200.000 years after the beginning of the Solar Disk evolution.

1318 K, the temperature zone which provides the estimated nickel abundance for Earth, is well in line with the results provided by Bond et al. (2010) [4] who calculated the temperature for the formation zone of the Earth to be within 1352 to 1305 K. The Solar Disk age for when the temperature was 1318 K around the Earth's current orbital distance is 150,000 years according to Hueso and Guillot (2005) [9]. This age can also be taken into account for Venus.
According to Hueso and Guillot (2005) [9], the Solar Disk age estimated for when the temperature was about 490 K around Mars' current orbital distance is 200,000 years. The birth date of the Moon is scaled to a range of disk age 100,000 to 300,000 years after the formation of the Sun [10], and the terrestrial embryos about 100,000 years after [11]. Therefore, the planetary solid phase formation ages found here, at least for the formation of cores, are well in agreement with the earlier estimations.

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