Timing of the bulk chemical fractionation of planetary bodies

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Planetary formation processes can perturb the major elemental and stable isotopic compositions of planetary bodies compared to the primordial composition of the solar nebula as recorded by chondrites. For instance, magnesium, the sixth most abundant element in the sun and one of the primary rock-forming components of planetary bodies in the inner solar system, is depleted in Earth by ~ 20% relative to more refractory elements such as Al when compared to chondritic meteorites [1]. Moreover, recent data show that Earth, Mars and eucrite parent bodies all share the same Mg stable isotopic compositions, with a δ^{25}Mg which is ~ 0.020‰ (± ~ 0.006‰) heavier than chondrites [2]. The relatively heavy Mg stable isotopic composition of differentiated bodies was attributed to fractionation between silicate vapour and silicate melt followed by vapour loss. This process was inferred to have occurred early in accretion history both empirically, since the isotopically heavy Mg is observed in material from Vesta and conceptually because of the difficulty to silicate vapour escape from bodies larger than about Mars size.

We use the ^{26}Al-^{26}Mg systematics (half life of 0.72 Myr) to better constrain the timing of this chemical and isotopic fractionation, by measuring at high precision (~ ± 3ppm, 2se) the Mg isotopic compositions of a suite of bulk chondrites (ordinary chondrites and enstatite chondrites), Martian meteorites and Earth. The set of data allows a comparison between planetary bodies and undifferentiated chondrites. Assumptions have to be made regarding the starting composition from which the planetary bodies formed, as well as regarding how the chemical change was made (e.g. instantaneously or linearly). In the case of the Earth, an instantaneous fractionation increasing the ^{27}Al/^{24}Mg ratio from ~ 0.085 (the average composition of enstatite chondrites or ordinary chondrites) to 0.122 (Earth's composition) should have occurred after ~ 1.5 ^{26}Al half-life. Otherwise, the Earth would be too radiogenic in its Mg mass-independent composition compared to what is measured.

References: [1] Palme H. and O'Neill H.S.C. (2003) In: *The Mantle and Core*, Carlson R.W. (Ed). [2] Hin R.C., Lai Y.J., Coath C.D., Eliott, T. (2015), Abstract V23D-06 presented at 2015 Fall Meeting, AGU, San Francisco, Calif.