Stable Isotope Records of Nebular and Planetary Processes

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Stable isotope variations (O, Mg, Si, K, Ca, Ti, Cr, Fe) in primitive chondritic meteorites provide important constraints on the formation and evolution of the early Solar System. It is well established that they show very large mass-dependent and mass-independent O isotopic variations, only enstatite chondrites exhibit O isotopic characteristics similar to the Earth. In contrast the other major planet components Mg, Si and Fe exhibit very similar isotopic compositions for all chondritic meteorites and the Earth. There is ~1‰ $\delta^{44/40}$Ca variation within chondrites that is comparable to that reported for terrestrial silicate rocks [1]. ^{48}Ca variations of several ε-units measured in carbonaceous chondrites and differentiated meteorites correlate with ^{17}O, ^{50}Ti and ^{54}Cr anomalies. The Earth and enstatite chondrites share almost the same Ca isotopic signatures. They may have originated from the same parental nebular reservoir but experienced different chemical evolution. The relationship between mass-independent O isotopic variations and ^{48}Ca (& ^{50}Ti, ^{54}Cr) nucleosynthetic anomalies suggests that the Δ^{17}O variations within the Solar System may have a nucleosynthetic origin rather than result from the CO self-shielding process. Ca isotopes also show that CAIs cannot be considered as representative of the initial isotopic compositions of refractory elements for the Earth–Moon system. The Earth–Moon system has unique chemical and isotopic signatures compared to other planetary bodies. The Moon is substantially depleted in volatile elements such as potassium relative to the Earth. New high-precision potassium isotope data for the Earth, the Moon and chondritic meteorites show that the lunar rocks are significantly enriched in the heavy isotopes of potassium compared to the Earth and chondrites (by ~0.4 permil) [2]. The enrichment of the heavy isotope of potassium in lunar rocks relative to the Earth and chondrites can be best explained as the result of the incomplete condensation of a bulk silicate Earth vapor in the protolunar disk at an ambient pressure that is higher than 10 bar. This supports the new high-energy, high-angular-momentum giant impact model [3] for the origin of the Moon.

References: [1] Huang & Jacobsen (2017) GCA 201: 364–376. [2] Wang & Jacobsen (2016) Nature 538: 487-490. [3] Lock et al. (2016) LPSC #2881.