Titanium Isotope Compositions of Chondrites and Achondrites

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Titanium is an element of particular interest in planetary sciences as, (i) it is refractory and cannot easily be lost by impact-induced vaporization, (ii) it is lithophile meaning that core partitioning is irrelevant, and (iii) it is fluid immobile, meaning that it is immune to parent-body alteration. Thus, the range of processes susceptible of fractionating Ti isotope ratios is rather limited and involves primarily nebular and magmatic/metamorphic processes. For example, in terrestrial magmatic systems, the Ti isotope composition (expressed as δ49Ti; deviation in ‰ of the 49Ti/47Ti ratio relative the OL-Ti standard [1]) correlates positively with SiO2 concentration [2]. This observation was interpreted to reflect preferential incorporation of light Ti isotopes in Ti-oxides during fractional crystallization [2]. To evaluate if Ti isotopes can be used to trace nebular and magmatic processes in meteorites, we have measured the δ49Ti values of several chondrites, eucrites and aubrites using the protocol of [1].

The δ49Ti values of all ordinary and enstatite chondrites are indistinguishable within uncertainty, ranging from -0.027 ‰ (Bald Mountain, L4) to +0.027 ‰ (Blithfield, EL6) with an average of +0.004 (n=11). This δ49Ti value is identical to that proposed for the BSE [1, 2]. Eucrites have fractionated δ49Ti values that are both heavier and lighter compared to the chondritic average. δ49Ti values are positively correlated with indices of magmatic fractionation such as FeO/MgO ratios, similar to trends observed in terrestrial systems.

Preliminary results for aubrites indicate strongly fractionated δ49Ti values, ranging from around -0.1 to -0.25 ‰. The Ti isotope compositions correlate negatively with the MgO concentration. Core formation and magmatic differentiation on the aubrite parent body occurred under extremely low ΦO2, allowing Ti to be present in the Ti2+ and Ti4+ oxidation states. Thus, the highly variable δ49Ti in aubrites might be caused by crystallization of Ti2+-rich pyroxene or Ti-bearing sulfides.

These results demonstrate that Ti isotope systematics are a valuable tool in deciphering magmatic and crust-mantle differentiation processes on planetary bodies.