Tungsten isotopes and oxidation in early planetary mantles

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The partitioning of W between silicate and metallic liquids is strongly dependent on the degree of oxidation of protoplanetary mantles. Recently there have been two, effectively opposite, suggestions for how the silicate Earth may have changed its degree of oxidation through time. The first (Halliday, 2004) is based on the initial W isotopic composition of the Moon and the evidence from O isotopes that the Earth and Moon were derived from a similar mix of inner solar system materials. On this basis, it can be argued that the protoEarth or components of it may have had a relatively oxidised mantle more like that found in Mars. The second (Wood and Halliday, 2005) is based on the potential for the Earth's mantle to have self-oxidised as a result of the high proportion of ferric iron in perovskite, which could have resulted in residual metal being transferred to the core. How reducing the earliest mantle would have been is unclear but must depend in part on the amount of nebular H gas that was present and incorporated into the growing Earth. Using the same accretion model deployed in Halliday (2004), it is possible to explore the effects on W isotopic composition resulting from changes in mantle oxidation, core relative mass and the fraction of the mantle in chemical equilibrium with newly formed segregating metal. Any model must satisfy the contraints that the present day silicate Earth has Hf/W15 and $\epsilon^{182}W = 0$. With constant full mantle equilibration and present day core proportions the effect of changing the partitioning exponentially as a function of mass has a negligible effect on W isotopes relative to maintaining Hf/W15 throughout. More reducing conditions early on lead to slightly slower accretion rates from W isotopes but whether the early Earth started with $^{180}Hf/^{184}W$ of 5 or 2000, the Earth's calculated Hf-W mean life varies by only 3 Myr. Increasing the proportional size of the core during accretion serves to protract calculated acretion timescales still further. There is evidence from siderophile elements that iron meteorite parent bodies may have had relatively small cores. Increasing the proportional core size at rates consistent with independent constraints from other bodies and increasing the bulk metal / silicate liquid distribution coefficient for W during accretion generates bulk silicate Earth Hf/W and W isotopic compositions that are consistent with independent constraints on the age of the Moon.

References

Halliday, A.N., 2004. *Nature* **427**, 505–509.
Wood, B.J., Halliday, A.N., 2005. *Nature* **437**, 1345–1348.