ASSESSING THE EXTENT OF MASS-DEPENDENT TUNGSTEN ISOTOPE VARIATIONS IN SOLAR SYSTEM MATERIALS.

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Introduction: Stable isotope variations in meteorites and their components are powerful tools to study the processes and conditions of planetary accretion and differentiation [1-4]. So far, W stable isotopes have received little attention and W isotope studies have primarily focused on applications of the short-lived ^{182}Hf-^{182}W chronometer. However, W stable isotopes hold great potential to examine a variety of processes operating in the early solar system, including evaporation/condensation, metal-silicate fractionation and magmatic differentiation. Moreover, the measurement of W stable isotope compositions may help to assess the significance of Hf-W ages, such as the Hf-W age of core formation in the Earth. The latter is strongly dependent on the assumed degree of metal-silicate equilibration during accretion, and W stable isotopes can potentially provide the necessary constraint to assess the magnitude of equilibration. In this study we aim to assess the magnitude and origin of W stable isotope variations among terrestrial and extraterrestrial materials using a new W double spike. Here we present W stable isotope data for several terrestrial standards, chondrites, achondrites, and iron meteorites.

Methods: All samples were spiked with a ^{180}W-^{183}W double spike prior to digestion and dissolved in HF-HNO_3-$HClO_4$. After purification of W by anion exchange chromatography, W isotope measurements were performed using a Neptune *Plus* MC-ICPMS at Münster. The double spike inversion used the *Double Spike Toolbox* [5], and all data are reported in $\delta^{184/183}$W as the permil deviation from the NIST 3163 W standard.

Results: The terrestrial rock standards reveal a narrow range in $\delta^{184/183}$W of ~+0.01 and ~+0.05 ‰ for multiple analyses. Only the NIST 129C high-S steel exhibits a heavier $\delta^{184/183}$W of ~+0.19, a signature that may have been induced during industrial production of the steel. Iron meteorites and chondrites show a narrow range in $\delta^{184/183}$W and are indistinguishable from the terrestrial rocks. However, the basaltic achondrites analyzed thus far display variable $\delta^{184/183}$W and most of them are isotopically heavy compared to the chondrites and iron meteorites.

Discussion: In bulk meteorites, W stable isotope fractionations seem to be restricted to basaltic achondrites, i.e., to samples derived from the crust of small differentiated protoplanets. This obversation is not surprising, because as a siderophile element W preferentially partitioned into the metal core of such bodies, meaning that the major portion of W is hosted in the core. Consequently, the W stable isotope composition of iron meteorites, which presumably are samples of protoplanetary cores, should reflect that of the bulk undifferentiated body. This is consistent with our finding of indistinguishable W stable isotope compositions for iron meteorites and chondrites. Nevertheless, compared to the chondrites, the iron meteorites exhibit slightly more, albeit barely resolved, scatter in $\delta^{184/183}$W. The scatter among the iron meteorites most likely reflects small isotope fractionations induced by fractional crystallization of their parental cores. Within each group of irons, later crystallized samples tend to have slightly heavier W isotope compositions, although these effects are barely resolvable. Another potential source of scatter in the iron meteorite data is the modification of W isotope compositions through secondary neutron capture induced during cosmic ray exposure of the iron meteoroids. Such effects have been shown to significantly alter ^{182}W/^{184}W (internally normalized to ^{186}W/^{184}W) in iron meteorites. However, we analyzed two of the most strongly irradiated irons (Carbo and Ainsworth), but their W stable isotope compositions do not show evidence for significant effects from neutron capture.

All of the investigated achondrites (four basaltic eucrites and one angrite) exhibit a heavy W isotopic composition. This signature could in principle result from W isotope fractionation between metal and silicate during core formation. This process is expected to lead to heavier W isotopic compositions in the silicates, consistent with the compositions measured for the eucrites. However, the variable $\delta^{184/183}$W values observed among the eucrites are unlikely to be the result of core formation, which is expected to induce an uniform $\delta^{184/183}$W signature. Thus, the heavy W stable isotope composition of the eucrites must at least in part reflect other processes than core formation, most likely magmatic differentiation during the genesis of the eucrite lavas.

The W stable isotope compositions of all terrestrial rocks analyzed thus far are indistinguishable from those of the chondrites and iron meteorites. Thus, if the heavy W isotope signatures observed for the eucrites are representative for the composition of the silicate poritions of differentiated protoplanets, then these results imply efficient re-equilibration of W isotopes during accretion of such bodies onto Earth. However, additional data for a more comprehensive set of samples derived from the silicate portion of differentiated bodies are needed to arrive at this conclusion.

References: [1] Georg R. B. et al. 2007. *Nature* 447:1102-1106. [2] Hin R. et al. 2013. *EPSL* 379:38-48. [3] Moynier F. et al. 2011. *Science* 331:1417-1420. [4] Burkhardt C. et al. 2014. *EPSL* 391:201-211. [5] Rudge J. et al. 2009. *Chem. Geol.* 265:420-431.