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The Uranium Isotopic Composition of the Earth and the Solar System

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Recent high-precision mass spectrometric studies of the uranium isotopic composition of terrestrial material [1], meteorites [2] and standards [3] have shown significant variation in the $^{238}U/^{235}U$ ratio, which was previously assumed to be invariant (=137.88). In this study, we investigated 26 bulk meteorite samples from different groups and types, including carbonaceous and ordinary (H-, L-, and LL-) chondrites, as well as achondrites (angrites and eucrites) in order to constrain the degree of U isotopic heterogeneity of $^{238}U/^{235}U$ in the solar system.

The investigated meteorites show U isotope variation between 137.71 and 137.89 (1.3‰). However, 21 of 26 meteorites overlap with the range observed for terrestrial basalts (137.78 – 137.81; combining data from [1] and this study), within analytical uncertainties. Two notable exceptions among the ordinary chondrites are Richardton-H5 (137.711±0.01) and Elenovka-L5 (137.891±0.025), displaying the lowest and highest $^{238}U/^{235}U$ of all investigated meteorites, respectively. It is possible that these larger U isotope variations represent local isotopic heterogeneities generated by low-temperature alteration (e.g. redox) processes in the parent bodys. The observed U isotope variations in this study do not correlate with Th/U or LREE/U ratios (used as indicators for Cm/U), indicating that they cannot be attributed to the decay of extant ^{247}Cm in the early solar system. The average $^{238}U/^{235}U$ of all investigated meteorites (137.80) agrees with that of terrestrial basalts (137.80; combining data from [1] and this study), which are likely the best representatives for the U isotope composition of the Earth.

The following conclusions can be drawn from the findings of this study: (1) The Solar System, has a homogeneous U isotope composition with only a few exceptions, i.e. live ^{247}Cm in the early solar system had only a limited effect on the bulk meteorite scales (likely due to low Cm/U fractionation), and (2) no detectable U isotope fractionation occurred during accretion and planetary differentiation, i.e. the Earth, achondrites and chondrites have indistinguishable U isotope compositions. The average $^{238}U/^{235}U$ of the investigated meteorites, combined with that of terrestrial basalts may represent the best estimate for the U isotope composition of the Earth and the solar system, which is ≈137.80. This refined value may be used for U-Pb dating of terrestrial rocks and meteorites, if the precise U isotope composition of the sample is unknown. Depending on age, it results in an age adjustment for U/Pb ages, that where determined with the old value for $^{238}U/^{235}U$ (137.88), of 0.8 to 1.5 Ma.

[1] Weyer et al. (2008) Geochim. et Cosmochim. Acta, 72: 345-359 [2] Brennecka et al. (2010) Science, 327: 449-451 [3] Richter et al. (2010) Int. J. of Mass Spectrometry 295: 94-97.