THE Mo-Ru COSMIC CORRELATION: DECOUPLED PRESOLAR CARRIERS IN CARBONACEOUS-TYPE METEORITES. E.A. Worsham[1], C. Burkhardt[1], M. Fischer-Gödde[1], T. S. Kruijer[1] and T. Kleine[1], [1]University of Münster, Institut für Planetologie, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (worsham@uni-muenster.de).

Introduction: Parent body-specific isotope anomalies have been observed at the bulk meteorite scale for a variety of elements, including Mo [e.g., 1-2] and Ru [e.g., 3-4]. The isotopic variability in Mo and Ru between meteorite groups has been attributed to nucleosynthetic effects, which may have originated as a result of inhomogeneous mixing and/or thermal processing of isotopically diverse presolar materials [e.g., 5-6].

Both Mo and Ru consist of seven stable isotopes that are created by a combination of *p*-process, *s*-process, and *r*-process nucleosynthesis. It is this variety of nucleosynthetic processes represented in Mo and Ru isotopes that makes them ideal tracers of the relative proportions of diverse presolar carriers in solar system materials. For example, bulk meteorite anomalies in Mo and Ru have been attributed to variable deficits in an s-process component [e.g., 1-4]. Further, Mo and Ru isotope anomalies are correlated with one another, forming a "cosmic correlation" [e.g., 7]. It has been proposed that Mo and Ru *s*-process isotopes are correlated because they are hosted in the same or similar presolar carriers [e.g., 7]. By studying the extent to which this Mo-Ru correlation holds for a variety of cosmochemical materials, it may be possible to elucidate the natures of the presolar carriers of nucleosynthetic anomalies. Iron meteorites belonging to magmatic iron meteorite groups that are generally smaller and less well-characterized than the larger magmatic iron meteorite groups (i.e., IC, IIC, IID, IIF, IIIE, and IIIF) are the target of this study.

Experimental Methods: The digestion and chromatography methods for Mo and Ru analyses are similar to those of [2, 4]. Molybdenum and Ru isotope data were collected from separate digestions of iron meteorite pieces from the same sample mass. Platinum isotopes were used to monitor for cosmic ray exposure (CRE), which can modify the Mo and Ru isotopic compositions. Platinum isotope compositions were determined for adjacent pieces from each iron meteorite, such that the pieces had similar shielding conditions. The digestion and chromatographic methods for Pt are described in [8].

Isotopic compositions of Mo, Ru, and Pt were determined using a *Thermo-Fisher Neptune Plus* MC-ICP-MS at Münster. The Mo, Ru, and Pt isotopic compositions are reported in ε notation (parts-per-10^4 deviations from terrestrial standards). The data are normalized to $^{98}Mo/^{96}Mo$, $^{99}Ru/^{101}Ru$, and $^{198}Pt/^{195}Pt$. The external reproducibility (2SD) of the repeated analysis of terrestrial standards is ~ ± 37 ppm for $\varepsilon^{92}Mo$, 13 ppm for $\varepsilon^{100}Ru$, and 7 ppm for $\varepsilon^{196}Pt$, respectively.

Results: The new $\varepsilon^{92}Mo$ and $\varepsilon^{100}Ru$ isotopic compositions of IC, IIC, IID, IIF, IIIE, and IIIF irons are shown in Fig. 1a. Here, the Ru isotopic compositions are corrected for CRE and Mo is not. Molybdenum-97 is minimally affected by CRE, so it is shown in Fig. 1b as a point of comparison. Molybdenum and Ru literature data for other magmatic iron meteorite groups and chondrites are also shown in Fig. 1 [2-4, 9-10].

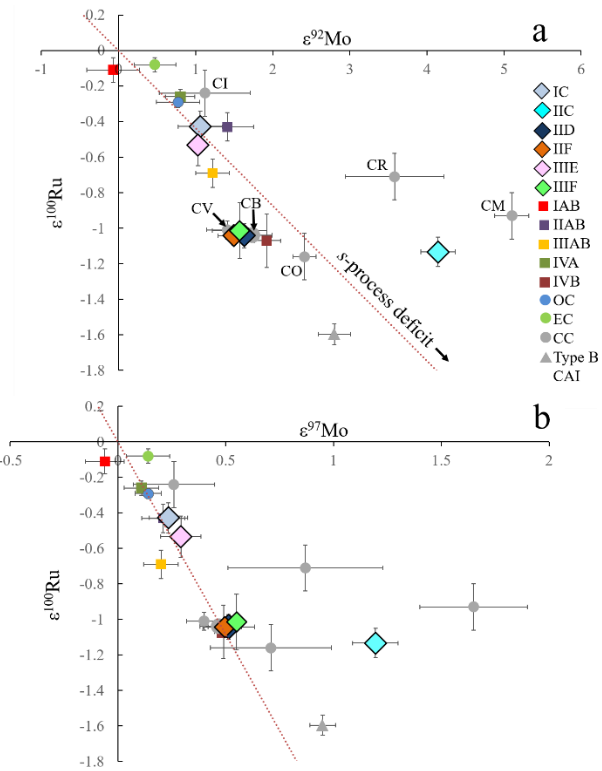

Fig. 1. $\varepsilon^{92}Mo$ vs. $\varepsilon^{100}Ru$ (a) and $\varepsilon^{97}Mo$ vs. $\varepsilon^{100}Ru$ (b) for iron meteorites and chondrites. The new data are shown with large diamond symbols. Uncertainties of each data point are the 2SE of samples with ≥ 4 analyses, or the 2SD long-term external reproducibility of standards for samples analyzed ≤ 3 times. Ruthenium data are corrected for CRE where necessary. Molybdenum and Ru data for other iron meteorite groups, chondrites, and type B CAIs are from [2-4, 9-10]. The red dotted line is a theoretical *s*-process mixing line as described in the text [7, 11].

Also plotted is a theoretical mixing line between an endmember depleted in a pure *s*-process component and an endmember enriched in a pure *s*-process component [7, 11]. Iron meteorites from groups IC and IIIE have similar Mo and Ru isotopic compositions to IIAB iron meteorites (ε^{92}Mo ~ 1.0; ε^{100}Ru ~ -0.5). These meteorites generally plot along the theoretical *s*-process mixing line. Iron meteorites from groups IID, IIF, and IIIF have Mo and Ru isotopic compositions similar to IVB iron meteorites and some carbonaceous chondrites (ε^{92}Mo ~ 1.6; ε^{100}Ru ~ -1.0). This cluster of meteorites plots to the left of the mixing line on Fig. 1a (and when ε^{94}Mo is plotted), but on the mixing line in Fig. 1b (and when ε^{95}Mo is plotted). Finally, a IIC iron meteorite, Wiley, has an ε^{92}Mo = 4.14 ± 0.22 and an ε^{100}Ru = -1.13 ± 0.08. This meteorite plots considerably to the right of the mixing line in both plots.

Discussion: The Mo and Ru isotopic compositions of iron meteorites define a roughly linear relationship, in agreement with [7]. However, the carbonaceous chondrites and the IIC iron, Wiley, have Mo and Ru isotopic compositions that are not correlated with other meteorites. The deviation of carbonaceous chondrites from the correlation may be due to incomplete digestion of presolar grains in these meteorites. However, because Wiley is an iron meteorite, incomplete digestion cannot account for its deviation from the correlation.

Recent work has identified a dichotomy of Mo isotopic compositions between "carbonaceous" and "non-carbonaceous" meteorites [9, 12]. The carbonaceous suite is defined by an excess in ^{95}Mo, relative to ^{94}Mo. Included in this group are the IVB, IID, and IIIF iron meteorites. The results presented here indicate that the IIF irons likely also belong to this suite of meteorites. When the IVB and isotopically similar meteorites are considered along with Wiley and the carbonaceous chondrites, we observe that this subset of meteorites exhibits Mo isotopic compositions that are variable and ε^{100}Ru values that are more restricted. Previous work has also shown that the Mo and Ru isotopic compositions of leachates from Murchison are not correlated with one another [13]. Therefore, these results indicate that the Mo-Ru cosmic correlation may not apply to meteorite groups in the carbonaceous suite.

The observed deviations from the Mo-Ru correlation indicate that the presolar carriers of *s*-process Mo and Ru may have been decoupled in the precursor materials of the "carbonaceous" meteorites. This decoupling may have occurred through some thermal or chemical process which only affected the carbonaceous suite. One possibility is that the Mo-Ru *s*-process enriched presolar materials experienced oxidation, which may have generated volatile Mo oxides. This scenario has been invoked to account for Mo and W isotope systematics in Murchison leachates [14]. In this case, the ε^{92}Mo, for instance, of the residue would increase with little change in ε^{100}Ru. Complex re-condensation of the volatile *s*-process enriched Mo may account for the meteorite groups to the left of the *s*-process mixing line.

Alternately, addition of *r*-process enriched material may result in deviations from the Mo-Ru correlation. Type B calcium-aluminum-rich inclusions (CAIs) have Mo isotopic compositions that are indicative of an enrichment of *r*-process Mo isotopes [2]. These also plot to the left of the *s*-process mixing line on Fig. 1a. The presence of an offset between the IVB cluster and the *s*-process mixing line in Fig. 1a, vs. the lack thereof in Fig. 1b, is consistent with this interpretation. This is because the IVB cluster is offset on plots incorporating only *p*- and *s*-process Mo isotopes, but not on plots incorporating *s*- and *r*-process Mo isotopes. Therefore, addition of an *r*-process enriched component would affect the proportions of ^{92}Mo and ^{94}Mo, relative to ^{100}Ru, more than the proportions of ^{97}Mo and ^{95}Mo relative to ^{100}Ru. The addition of an *r*-process component has also been invoked to explain the Mo isotope carbonaceous/non-carbonaceous dichotomy [9, 12]. This and the above scenario are not mutually exclusive.

The results of this work further support the observation of an isotopic dichotomy between carbonaceous and non-carbonaceous meteorites. These results also suggest that the carbonaceous suite of meteorites experienced chemical/thermal processing and/or addition of *r*-process enriched material, whereas the precursor materials of the non-carbonaceous meteorites did not, either due to the time or location of their formation.

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