MOLYBDENUM IN PRESOLAR SILICON CARBIDE GRAINS REVEAL DETAILS OF *s*-, *r*-, AND *p*-PROCESS NUCLEOSYNTHESIS.

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Introduction: The isotopic information stored in presolar grains, which formed around dying stars, reflects a combination of three distinct sources: (1) the initial abundances in the parent stars of the grains, providing compositional snapshots of the times and locations where the stars formed; (2) matter newly synthesized by nuclear reactions within those stars; and (3) matter with solar isotopic composition from the protosolar cloud, the host meteorite's parent body, or contamination in the laboratory. Solar System material is itself a complex, and often slightly variable, mixture of matter formed in various nucleosynthetic processes.

Molybdenum is a favorable element for studying nucleosynthesis, because of the variety of sources represented in solar composition and in presolar grains, and, from an experimental perspective, because all of its stable isotopes have the same solar abundances within a factor of less than three, which makes measurements easier. Molybdenum has seven stable isotopes: *p*-process ^{92}Mo and ^{94}Mo; mixed *s*- and *r*-process ^{95}Mo, ^{97}Mo, and ^{98}Mo; *s*-process-only ^{96}Mo; and *r*-process-only ^{100}Mo.

Methods: Recent studies with RIMS (resonance ionization mass spectrometry) using CHILI (the Chicago Instrument for Laser Ionization) [1] provided high-precision Mo isotope data for single presolar mainstream [2,3] and types AB1 [4], AB2 [2,3], Y [5], and Z [5] SiC grains. Others have used MC-ICPMS (multicollector inductively coupled plasma mass spectrometry) to analyze Mo in bulk samples and leachates of primitive meteorites [6–10].

Results: RIMS data of presolar SiC mainstream grains show mixing lines in three-isotope plots of ^{i}Mo/^{96}Mo vs. ^{92}Mo/^{96}Mo between two endmember compositions, one indistinguishable from solar, the other pointing towards pure *s*-process Mo. These measurements provide the best estimate to date for *s*-process Mo made in low-mass AGB (asymptotic giant branch) stars [2]. Variability in individual grain data reflects variability of conditions (neutron density, temperature, timescale) during *s*-process nucleosynthesis in the grains' parent stars [2]. Other presolar SiC grain types including AB1, AB2, Y, and Z show trends in Mo isotopes that are all consistent with mainstream grain three-isotope plot mixing lines [2–5]. Furthermore, these mixing lines are also consistent with MC-ICPMS data for bulk samples and leachates of primitive meteorites showing depletions in *s*-process Mo isotopes relative to solar [6–10].

Discussion: Presolar mainstream, Y, and Z SiC grains, which all come from low-mass AGB stars, should show mixtures of *s*-process Mo produced in those stars with Mo from the unprocessed stellar envelopes and perhaps from solar contributions. In order to explain the linear mixing lines in Mo three-isotope plots for such grains as a result of three-component mixing, unprocessed Mo from each of the grains' parent stars must itself plot along those mixing lines defined by *s*-process and solar. This suggests that the ratio between *p*- and *r*-process Mo in presolar SiC from many low-mass AGB stars is $Mo_p/Mo_r = 0.767$ [2], a value that was inferred for the Solar System from *s*-process and solar endmembers of the mixing lines. The same is true for AB1 and AB2 grains, whose stellar origins are still a matter of debate and include J-type carbon stars, born-again AGB stars, and Type II supernovae.

It is important to emphasize that a constant Mo_s/Mo_{r+p} ratio is not required to explain the mixing lines observed for presolar SiC grains, as changing this ratio would move data points only along those lines. Depletions in *s*-process Mo as observed in bulk samples and leachates of primitive meteorites, which are consistent with $Mo_p/Mo_r = 0.767$, reflect some heterogeneity of Mo_s/Mo_{r+p} in the early Solar System. However, the carriers of the *s*-process-depleted Mo have not been identified so far. Presolar SiC X grains, which are attributed to Type II supernovae, could not be that carrier. Although they show indeed enrichments of mixed *s*- and *r*-process isotopes ^{95}Mo and ^{97}Mo, equivalent enrichment in *r*-process-only ^{100}Mo and in *p*-process isotopes have not been observed [11]. Also, a dichotomy, as observed between carbonaceous and noncarbonaceous meteorites [9], was not detected in SiC.

Conclusions: The constant ratio between *p*- and *r*-process Mo in presolar SiC, primitive meteorites, and the Solar System shows that *r*- and *p*-processes must be strongly correlated over time and perhaps space in the Galaxy.

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