S-PROCESS NOBLE GAS ENRICHMENTS IN THE ALLENDE FINE–GRAINED CAIs: CASE FOR A PRESOLAR SiC CARRIER.

O. Pravdivtseva[1], F. L. H. Tissot[2], N. Dauphas[3], & S. Amari[1], [1]McDonnell Center for the Space Sciences, Washington University, Saint Louis, MO 63130 (olga@physics.wustl.edu); [2]The Isotoparium, Caltech, Pasadena, CA 91125; [3]Origines Laboratory, University of Chicago, Chicago, Il 60637.

Introduction: The mineralogy of CAIs closely approaches that predicted by equilibrium calculations for condensation from hot solar gas upon cooling [1]. However, many CAIs have experienced such severe reprocessing that all morphological or textural evidence of condensation has been obliterated. It is widely accepted that presolar grains would not have survived the violent CAI formation conditions [2] and they are thus thought to only be present in the matrix of the meteorites. Presolar SiC grains contain highly anomalous Si, C and N [3,4], as well as Xe-G, Kr-G and Ne-G noble gas components [5,6]. They were first discovered in the CM Murchison sample, etched to remove the carrier of the dominant trapped Xe component so the unique Xe isotopic signature corresponding to *s*-process nucleosynthesis (Xe-G) could be detected [7].

Type A fine-grained CAIs appear to preserve their condensate origin to some degree. They are known to be depleted in volatiles including Xe. The trapped Xe component in CV3 Allende CAIs is ~ 10^{-10} cm^3 STP/g of ^{132}Xe [8], thus eliminating the need for a chemical treatment in the search for potential *s*-process enrichments.

Results: The Xe isotopic composition was measured by step-wise pyrolysis in five fine-grained CV3 Allende CAIs neutron-irradiated for I-Xe dating. All are characterized by group II REE fractionation pattern [9], indicating condensation from the nebula after loss of an ultra-refractory component [10]. When presented on three-isotope plots as ^{124}Xe/^{130}Xe versus ^{126}Xe/^{130}Xe, 4–6 σ ^{130}Xe excesses, consistent with *s*-process enrichments were observed in 3 studied CAIs. The degree of these enrichments could be masked by spallation contribution on ^{124,126}Xe. In the neutron irradiated samples correction for spallation on REE and Ba is not possible, because of a contribution from the ^{130}Ba(n,γ)^{131}Xe reaction. To investigate the source and degree of ^{130}Xe enrichment, we measured the isotopic compositions of Xe, Kr, Ar and Ne in the unirradiated CAI *Curious Marie* from this set of samples, following the step-wise extraction experimental protocol described in [11].

Xenon in *Curious Marie* is a mixture of trapped Q, radiogenic, ^{244}Pu fission, Xe-G, and spallation components (Fig.1). The radiogenic ^{129*}Xe due to decay of ^{129}I ($T_{1/2}$=16 Ma) correlates with an excess of cosmogenic ^{128}Xe produced by natural neutron capture (from cosmic ray secondary neutrons) on ^{127}I (Fig.1a). Although a small *s*-process contribution to ^{128}Xe is expected if SiC carrier is present, it cannot be resolved here, since neither the parent nuclei ^{127}I concentration nor natural neutron flux and fluence are known.

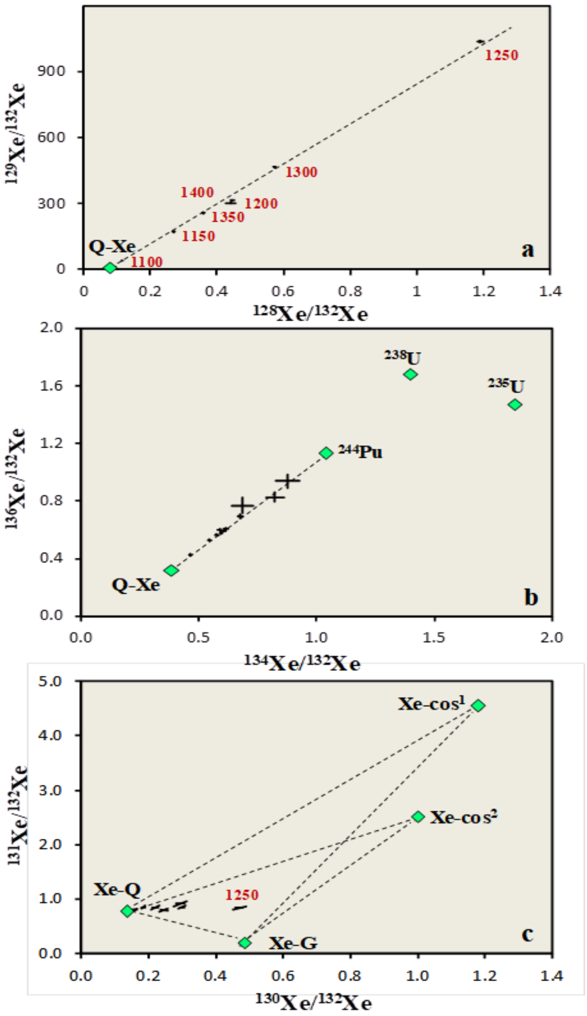

Figure 1. Xe isotopic composition of *Curious Marie*.

After the ^{244}Pu contribution is subtracted, Xe can be described as a mixture of trapped, cosmogenic and Xe-G (Fig.1c). A three components decomposition was done for two possible spallation Xe endmembers [12,13]. The resulting concentration of ^{132}Xe-G, obtained as an average of the two calculations, was ~10×10^{-12} cm^3 STP/g.

All Kr isotopes are nominally produced by the *s*-process but ^{82,83,84}Kr are not affected by flux and temperature-dependent branchings. The Kr isotopic composition of *Curious Marie* is dominated by a mixture of trapped and natural radiogenic components, resulting in correlated ^{80,82}Kr contributions from cosmogenic neutron-capture on ^{79,81}Br (Fig.2b). ^{83,84}Kr are a mixture of Kr-G, cosmogenic and Kr-Q, but shifted out of three-component mixing area by addition of ^{81}Br-derived ^{82*}Kr. ^{86}Kr *s*-process contributions do not correlate with Kr release but with ^{130}Xe-G at 1200-1300°C, consistent with a presolar SiC carrier.

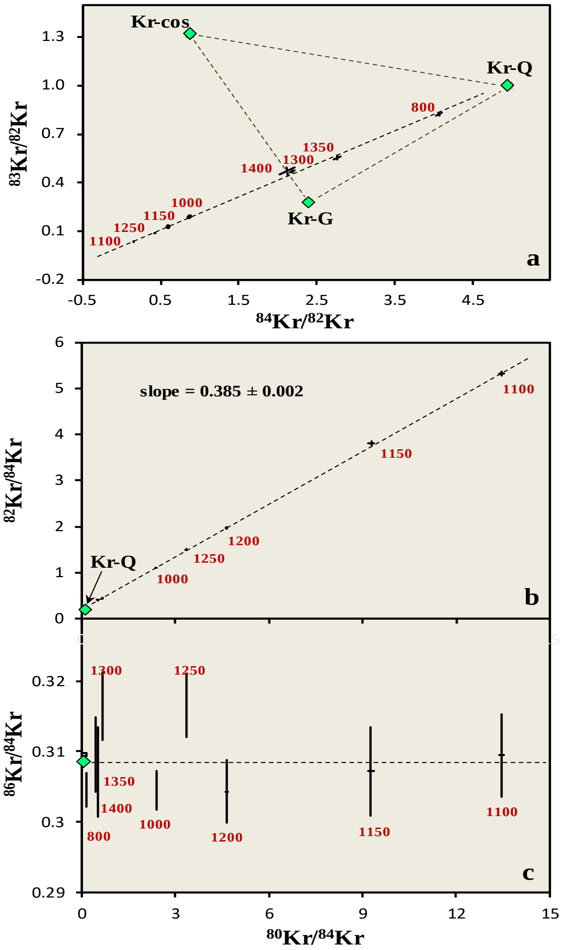

Figure 2. Kr isotopic composition of *Curious Marie*.

The concentration of ^{22}Ne-G was estimated based on 800°–1250 °C temperature extractions, although with high uncertainties. Assuming a three component mixture of solar, cosmogenic Ne and Ne-G, the concentration of ^{22}Ne-G is 0.7×10^{-8} cm^3 STP/g.

The most detailed noble gas study of presolar SiC was conducted on Murchison KJ and LQ 92–97 % pure SiC samples that were separated according to the size of the grains [13]. Noble gas analyses of the KJ SiC size fractions revealed a decrease of the Xe-G concentration with an increase in grain size, characteristic of low-energy ion implantation [14]. It was also demonstrated that the ^{22}Ne/^{130}Xe and ^{86}Kr/^{82}Kr ratios increase with average grain size of the Murchison SiC KJ separates [14]. For *Curious Marie* (^{22}Ne/^{130}Xe)$_G$ is ~ 600 (Fig.3), suggesting the presence of finer-grained SiC grains that are typical for the Murchison KJ separate [14] but closer to the size range of astronomically observed grains [15] and consistent with [16].

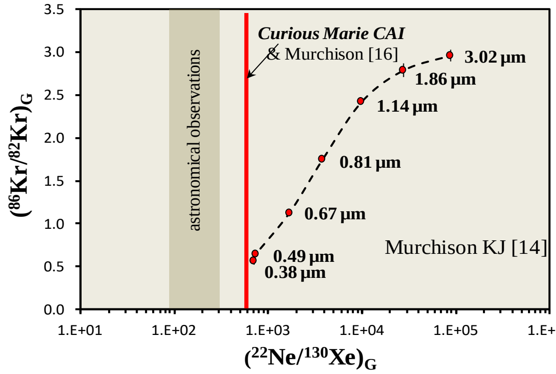

Figure 3. SiC grain size *in Curious Marie* CAI.

Based on (^{22}Ne/^{130}Xe)$_{G,}$ the SiC grains in *Curious Marie* are smaller than 0.4 µm. Concentration of ^{132}Xe-G normalized to 100% SiC could be estimated for the *Curious Marie* grains of this size based on the Murchison KJ data [14]; it is ~4×10^{-7} cm^3 STP/g, corresponding to ~20 ppm of SiC. Variation in SiC grain sizes between meteorites of different types and within the same type was previously reported [17], with CV3 having the lowest mean SiC sizes. Although estimated with high uncertainty, the abundance of SiC in *Curious Marie* is higher than that determined for bulk Allende [18] suggesting loss of fine grains during chemical processing. Independent of the SiC sizes in CV3s, the fact that they are present in some fine-grained CAIs places constrains on the conditions of CAIs condensation in the early Solar System.

References: [1] Grossman L. (1972) *GCA* 36, 597–619. [2] MacPherson G.J. & Grossman L. (1984) *GCA* 48, 29–46. [3] Tang M. et al. (1989) Nature 339, 351–354. [4] Zinner E. et al. (1989) *GCA* 53, 3273–3290. [5] Ott U. et al. (1988) *Nature* 332, 700–702. [6] Lewis R.S. et al. (1990) *Nature* 348, 293–298. [7] Srinivasan B. & Anders E. (1978) *Science* 201, 51–56. [8] Pravdivtseva O. et al. (2003) *GCA* 67, 5011–5026. [9] Tissot F.L.H. et al. (2016) *Sci. Advances* 2. [10] Boynton W.V. (1975) GCA 39, 569–584. [11] Pravdivtseva O. et al. (2018) LPS XLIX, Abstract 2959. [12] Kim J. & Marti K. (1992) *LPS XXII*, 145–151. [13] Hohenberg C.M. et al. (1981) *GCA* 45, 1909–1915. [14] Lewis R.S. et al. (1994) *GCA* 58, 471–494. [15] Mathis J.S. (1977) *Astrophis. J.* 217, 425–433. [16] Ott U. & Merchel S. *LPS LI*, Abstract 1356. [17] Davidson J. et al. (2014) *GCA* 139, 248–266. [18] Huss G.R. et al. (2003) *GCA* 67, 4823–4848.