THE LIFE AND DEATH OF IRON-60.

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Introduction: There is controversy over the initial abundance of $^{60}Fe/^{56}Fe$ in the early Solar System. While bulk analysis methods infer a low $^{60}Fe/^{56}Fe$ of $(1.01\pm0.27)\times10^{-8}$ [1], in-situ secondary ion mass spectrometry (SIMS) analyses inferred initial ratios of up $(3.8\pm0.8)\times10^{-7}$ [2] or $(7.8\pm3.7)\times10^{-7}$ [3]. While a low $^{60}Fe/^{56}Fe$ ratio is consistent with the estimated galactic background at the start of the Solar System, the high initial $^{60}Fe/^{56}Fe$ requires a supernova injection of live ^{60}Fe into the solar nebula. Using resonance ionization mass spectrometry (RIMS), we reanalyzed Semarkona (LL3.0) chondrule DAP1 [2], one of the samples with high inferred $^{60}Fe/^{56}Fe$, for its Ni isotopic composition.

Methods: Using the Chicago Instrument for Laser Ionization (CHILI) RIMS instrument at the University of Chicago [4], we analyzed a total of 29 spots on DAP1 for their Ni isotopes. Thirteen of these spots are on the surface of the sample, while the other 16 measurements were done inside the previously analyzed SIMS craters. While we could not determine the elemental Fe/Ni ratio in these samples using RIMS, previous SIMS measurements [2] determined this elemental ratio for the pits. Compared to the SIMS pits, which have diameters of ~20 μm, RIMS measurements were done using a 351 nm desorption laser with a spot size of ~1 μm [4]. We used four lasers to resonantly ionize Ni and one laser to nonresonantly ionize Fe isotopes, resulting in much higher sensitivity for Ni than for Fe. This way, all Ni isotopes could be measured, because we could correct ^{58}Ni for nonresonant ^{58}Fe contribution with high accuracy assuming a terrestrial $^{58}Fe/^{56}Fe$ ratio.

Results: There was a maximum contribution of <1‰ to the ^{58}Ni signal from nonresonantly ionized ^{58}Fe. In addition, we collected off-resonance spectra, which showed that our Ni isotope measurements did not suffer from any other interference. On DAP1, the Ni isotopic measurements show a slight mass-dependent fractionation, varying from spot to spot. To remove the mass-dependent fractionation effects from the measurement and look for actual excesses in the $^{60}Ni/^{58}Ni$ ratios from ^{60}Fe decay, we internally normalized our measurements to the terrestrial $^{62}Ni/^{58}Ni$ ratio using an exponential mass fractionation law (see, e.g., [5]). Using the fractionation-corrected $^{60}Ni/^{58}Ni$ ratio, given as $\Delta^{60}Ni^*$ in ‰, and the elemental Fe/Ni ratio as determined by SIMS, we calculated an isochron with an initial $^{60}Fe/^{56}Fe$ ratio of $(4.2\pm7.6)\times10^{-8}$ (2σ, MSWD = 1.15) using an error-weighted regression [6]. This isochron is in good agreement with the low initial $^{60}Fe/^{56}Fe$ ratio by bulk methods [1]. The RIMS measurements were done on the same sample for which SIMS analysis previously showed excesses in $\Delta^{60}Ni^*$. High $^{60}Ni/^{58}Ni$ should have been readily found since the anomaly found by SIMS in $\Delta^{60}Ni^*$ is ~60‰ for the highest Fe/Ni elemental ratio reported by SIMS [2]. Our new measurements do not show any significant difference from zero, i.e., we found no excess in $\Delta^{60}Ni^*$.

Conclusion & Outlook: We analyzed the Semarkona DAP1 chondrule using RIMS, a sample that was previously analyzed by SIMS [2]. We found a slight mass-dependent fractionation of Ni isotopes in the sample. Correcting for this fractionation and using the Fe/Ni ratios determined previously by SIMS, results in a RIMS-determined initial $^{60}Fe/^{56}Fe$ of $(4.2\pm7.6)\times10^{-8}$. SIMS data for the same spots regressed in the same way give $(3.8\pm7.1)\times10^{-8}$, with MSWD of 15.8. Currently, we cannot determine the Fe/Ni ratio using RIMS since laser-desorbing atoms from the surface severely fractionates Fe/Ni ratios. In future analyses, we will use an ion gun or a femtosecond laser for sample removal. These techniques in combination with matrix-matched standards will ultimately allow us to determine the Fe/Ni ratio along with the isotopic composition of Ni isotopes in individual samples and further constrain the initial $^{60}Fe/^{56}Fe$ in the early Solar System.

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