Nitrogen, neon, and argon analysis of a single Ryugu grain by step-heating

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Introduction: Carbonaceous chondrites are primitive, volatile-rich meteorites, considered to originate from C-type asteroids, which may have contributed to Earth's volatile budget. Studying these objects is key to understand the origin of Earth's volatiles, but terrestrial weathering makes it difficult to distinguish between primary and secondary features. In December 2020, JAXA's Hayabusa2 mission returned to Earth 5.4 g of regolith collected on the C-type asteroid (162173) Ryugu, permitting the analysis of material not altered by terrestrial weathering [1]. The first analyses of noble gases and nitrogen were performed by the 'initial analysis volatile team' [2-3], providing key information about Ryugu, especially its formation, composition, and alteration history. Noble gases were found to be mainly of primordial and presolar origin, with variable contributions from solar wind and cosmogenic components. Nitrogen was present in lower abundances (700 to 900 ppm [2-3]) than in typical CI chondrites, with $\delta^{15}N$ values ranging from 0.0±0.4 ‰ [2] up to +43±4 ‰ [4], indicating sample heterogeneity and the presence of at least two carrier phases: a N-rich phase with $\delta^{15}N$ up to +70 ‰ and a N-depleted phase with $\delta^{15}N$ near 0 ‰.

Sample and experimental method: For this study, we targeted grain A-0164 (2.6 mg), which was sampled during the first touchdown on the asteroid and corresponds to surface material. The grain was analyzed at the Centre de Recherches Pétrographiques et Géochimiques (CRPG, Nancy, France) by step-heating with a CO_2 laser. By performing a large number of extraction steps, various components of nitrogen and noble gases, carried by different phases, can be distinguished. A total of 85 heating steps were performed at increasing laser power to successively analyze the different phases carrying nitrogen and noble gases. Nitrogen, neon, and argon abundances and isotope ratios were analyzed at each step using a Nu Instruments Noblesse HR mass spectrometer, a state-of-the-art instrument for multi-collection, high-precision, static-vacuum analysis.

Preliminary results:

Noble gases. Neon was mainly released at low temperature steps, whereas Ar was extracted over a wide temperature range. The sample presents a mainly solar wind-like isotopic composition for noble gases, as shown for neon in Figure 1. Step heating allowed us to identify other components, including primordial and presolar components (possibly phase Q and/or HL), as well as a minor cosmogenic contribution.

Nitrogen. Nitrogen is present in higher abundance (1219±113 ppm) than in previous studies, with a bulk $\delta^{15}N$ value of +24.4±0.1 ‰, with significant variations during successive extractions (+1.0±1.0 ‰ to +65.8±1.1 ‰), pointing to the presence of at least four N-carrier phases.

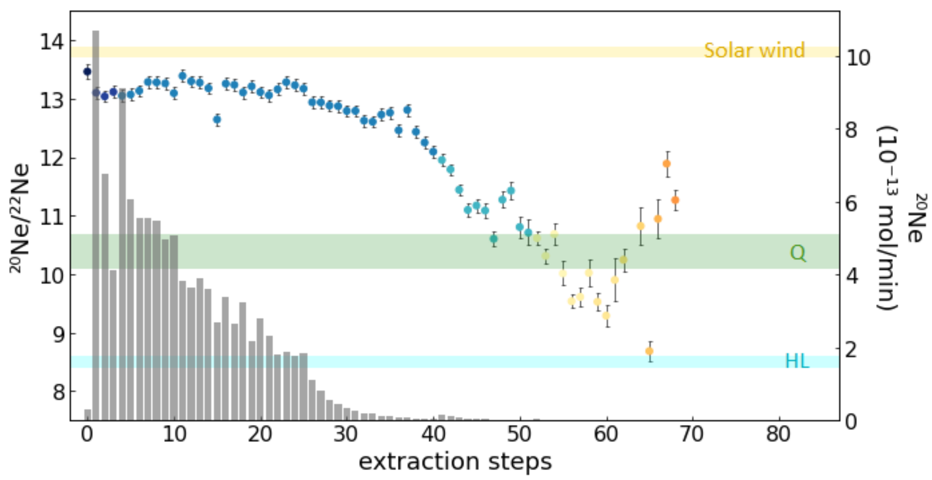

Figure 1. Ne ($^{20}Ne/^{22}Ne$) isotope ratio (colored circles) and ^{20}Ne abundance (gray histogram) measured for each of the 85 extraction steps at increasing laser power. The Ne isotopic compositions of the solar wind, Phase Q, and Ne-HL are shown for comparison.

References

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