NOBLE GASES OF EIGHT HAYABUSA2 SAMPLES FROM THE ASTEROID RYUGU.

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Introduction: Noble gas analysis of the Ryugu samples [1] has shown that primordial components, Ne-Q (P1) and Ne-HL (in presolar diamonds) are the dominant Ne components, while a couple of particles contain high concentrations of solar wind Ne. The weighted means of cosmogenic ^{21}Ne are 5.0 and 4.6×10^{-9} cm^{3}STP/g for the Chambers A (except for A0105-15) and C samples, respectively. The Xe analysis for A0105-05 [2] found that the Xe concentration is higher than those of CI chondrites, dominated with Xe-Q isotope signature. Excesses of ^{129}Xe and $^{134,\,136}$Xe compared with the Xe-Q isotopic composition were detected for this sample [2].

Eight Hayabusa2 samples are being studied to investigate cosmic ray exposure condition for each sample on the asteroid Ryugu by comparing radionuclides, e.g., ^{10}Be, ^{26}Al, ^{36}Cl, and ^{41}Ca, and stable noble gas nuclides, e.g., ^{3}He and ^{21}Ne, that formed on the Ryugu surface through cosmic ray irradiation [3]. Based on the ^{10}Be and ^{26}Al concentrations obtained to date it has been found that Chamber A samples from the 1st touchdown (TD) were exposed to cosmic rays more than 4 Myr at a shielding depth of 5–15 g/cm^2 and that Chamber C samples C0002 and C0106 from the 2nd TD site, close to the artificial crater, were ejected from shielding depths of 90–160 and 125–150 g/cm^2, respectively [3]. These Chamber C samples are likely to be ejected from the lower portion of the crater which has an estimated depth of 1.7 m [3]. We report here the noble gas isotopic compositions of these samples.

Experimental: Allocated samples were from Chamber A (A0105-19 and -20) and Chamber C (C0106-09, -10, -11, -12, C0002-V01 and -V02). All the samples were gently crushed and divided: one fraction for radionuclides (AMS analysis) and the other for noble gases [3]. Sample weights for noble gas analysis were 0.0812–0.1071 mg (A0105-19, -20 and C0106-09, -10, -11), 0.7464 mg (C0106-12), 0.0178 mg (C0002-V01), and 0.0039 mg (C0002-V02). All sample preparation procedures were conducted under clean atmospheric conditions. Noble gases were measured at Kyushu University using the analytical methods reported in [1]. Noble gases were extracted using step-wise pyrolysis at 200, 900, and 1700°C, except for the largest sample C0106-12, which permitted 5 steps at 200, 600, 900, 1200, and 1700°C, and for the very small samples C0002-V01 and V02, 2 step pyrolysis at 200 and 1700°C was applied.

Results and discussion: High concentrations of ^{4}He, $(0.3–1.8)\times10^{-4}$ cm^{3}STP/g with ^{3}He/^{4}He ratio of $(4.0–5.3)\times10^{-4}$ and ^{4}He/^{20}Ne of 190–250 strongly indicate a presence of implanted noble gases of solar wind origin. The He isotopic ratio showed at most small deviations from the ^{3}He/^{4}He = 4.64×10^{-4} for solar wind [5], and the concentrations of cosmogenic ^{3}He were difficult to be obtained. The ^{4}He/^{20}Ne ratios of Chamber A samples are ≈250, higher than those in Chamber C samples, 190–240. The low values of the Chamber C samples may reflect their larger shielding depths than for the Chamber A samples, or selective escape of He due to the crater forming impact shock.

Neon isotopic compositions show a small contribution of solar wind at the lowest release temperature of 200°C for all the samples. Solar wind particles are implanted on the surfaces of grains and weakly retained, so lighter particles, like He, might not be quantitatively retained. Neon isotopic compositions released at higher heating temperatures are a mixture of several primitive components, e.g., P1 (Ne-Q), P3 (presolar diamond), and Ne-E(H) (SiC) [5], to which a small contribution of cosmogenic ^{21}Ne, $(1.8–7.8)\times10^{-9}$ cm^{3}STP/g, was detected. To estimate a cosmic ray exposure age, the cosmogenic ^{21}Ne production rate from galactic cosmic rays was calculated using the MCNP Code System [6] assuming a body having a 2π geometry with Ryugu's chemical compositions [7]. Production rates calculated for the Chamber A (shielding depth 5–15 g/cm^2) and the Chamber C (120–150 g/cm^2) samples were (1.01–1.18) and $(1.06–1.22)\times10^{-9}$ cm^{3}STP/g/Myr, respectively. These production rates yield cosmic ray exposure ages of (6.5–7.3), (6.5–7.5), (1.5–1.7), (2.9–3.4), (4.2–4.8), and (5.4–6.2) Myr for A0105-19, -20, and C0106-09, -10, -11, and -12, respectively. Concentrations of ^{21}Ne for the samples C0002-V01 and -V02 could not be determined because of their small sample sizes. These cosmic ray exposure ages (1.5–7.5 Myr) of the grains are compatible with those obtained from cosmogenic radionuclides [3]. We also note that isotopic compositions of Ar, Kr and Xe of all the analyzed samples are similar to those of CI chondrites.

References: [1] Okazaki R. et al., (2022) *LPS LIII*, Abstract #1348. [2] Byrne D. J. et al. (2022) *LPS LIII*, Abstract #2096. [3] Nishiizumi K. et al. (2022) *LPS LIII*, Abstract #1777. [4] Heber V. S. et al. (2009) *Geochim. Cosmochim. Acta* 73: 7414-7432. [5] Ott U. (2002) *Noble gases in Geochem. and Cosmochem., Rev. in Mineral. Geochem.* 47: 71–100. [6] Masarik J. and Reedy R. C. (1994) *Geochim. Cosmochim. Acta* 58: 5307–5317. [7] Yokoyama et al. (2022) *Science (in revision)*.