We analyzed noble gases of the Julesburg L3.6, Tulia H4, Y-86789 thermally metamorphosed CM, and Allende CV3 chondrites by the stepped crushing method. All samples have released light noble gases with meteoritic isotopic compositions and heavy noble gases which are contaminated with air to various extents. Total amounts of crush-released noble gases of the four meteorites are estimated to be less than 1% of bulk [1,2,3,4,5]. Comparing with the results of crushing experiments on the Happy Canyon E6/7 chondrite [6], the above four meteorites released much smaller fractions of noble gases, suggesting that the four meteorites contain minor amounts of noble gases in places such as microbubbles.

A primitive achondrite Y-74063 has released large amounts of heavy trapped noble gases from dusty orthopyroxene containing tiny metal spherules and many voids. This fact suggests that microbubbles are the host phase that traps large amounts of noble gases [7]. In order to investigate whether other types of meteorites contain noble gases in microbubbles, we analyzed the Julesburg L3.6, Tulia H4, Y-86789 thermally metamorphosed CM, Allende CV3 chondrites by the stepped crushing method. A chip of sample (weighing ~70-280 mg) and a piece of magnetic stainless steel (weighing ~10g) were put together in the nonmagnetic stainless steel tube connected to the mass spectrometer and heated to about 190°C for about 20 hours in vacuum to reduce atmospheric noble gas contamination. The piece of magnetic stainless steel was lifted with two pieces of magnet and dropped to the sample repeatedly 50-300 times per one step. We analyzed noble gases extracted by one step from Allende, and those by two steps from other three meteorites.

The four meteorites released He and Ne being dominated by spallation-induced noble gases (Fig.1), although the amounts of the gases were very small, i.e., the ratios of crush-released 20Ne to bulk 20Ne are 1.2x10^3, 4.0x10^3, 1.7x10^3, and 4.5x10^4 for Julesburg, Tulia, Y-86789, and Allende, respectively. Y-86789 released three components of neon, spallation-induced Ne (Ne-S), Ne-E, and Ne-A by the stepwise heating analysis (Fig.1) [4]. Large fractions of Ne-S were released at low temperatures, 600°C and 800°C and Ne-E and Ne-A were released at higher temperatures. On the other hand, crush-released Ne was dominated by Ne-S. This appears to indicate that crushing releases Ne with low retentivity. The same tendency was observed in He-release from Y-86789. It was also observed in the experiments of Julesburg and Y-86789 that the amounts of crush-released He and Ne were proportional to the number of times of crushing. This suggests that large surface area is formed by extensive crushing and noble gases are released from the newly formed surfaces.
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Crush-released Xe from all samples has isotopic composition intermediate between Xe-Q and air Xe. This implies that crush-released Xe was contaminated with adsorbed air Xe. We corrected the air Xe which occupies from 22% to 66% of the total crush-released Xe using a $^{130}$Xe/$^{132}$Xe isotopic ratio in order to estimate the amounts of meteoritic Xe. Ratios of the crush-released meteoritic $^{132}$Xe to bulk $^{132}$Xe are 2.0x$10^{-3}$, 3.5x$10^{-3}$, 6.8x$10^{-4}$, and 2.6x$10^{-4}$ for Julesburg, Tulia, Y-86789, and Allende, respectively. These ratios are much smaller than the ratio obtained from the Happy Canyon E6/7 chondrite (1.2x$10^{-3}$) [6]. Therefore, it is concluded that the four meteorites contain very minor amounts of noble gases in phases such as microbubbles.


Fig. 1

- Solar
- Air
- Planetary (Ne-A)
- Ne-E
- Ne-S

- Julesburg (crush)
- Julesburg (bulk)
- Tulia (crush)
- Tulia (bulk)
- Y-86789 (crush)
- Y-86789 (stepwise heating)
- Allende (crush)
- Allende (bulk)

Temperature markers: 1850°C, 1500°C, 1200°C, 1000°C, 800°C, 600°C.