An experimental study of permeable membrane for Ne isotope measurement aiming for future Mars mission.

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Present Mars has cold and dry climate with a very thin atmosphere. However, early Mars may have possessed warm and wet climate with a large amount of atmosphere. One possible cause for such drastic change in climate and atmospheric mass on Mars is escape of atmosphere to space, but actual process of such possible atmospheric loss has not been understood well yet. One of the reasons for this uncertainty comes from the lack of our knowledge on how much Martian atmosphere has been lost. Noble gases, which are chemically inactive, are important for estimating the degree of the atmospheric loss. The non-thermal escape, such as pick-up ion sputtering, induces isotopic fractionation because lighter isotopes are selectively lost, resulting isotopic compositions in the atmosphere to be heavier. Since light noble gases, such as Ne, are sensitive to such a mass fractionation process, its isotopic ratios are useful for constraining the degree of the atmospheric loss. Thus, isotopic ratios of Ne are important in understanding the evolution of Martian atmosphere.
However, the Ne isotopic composition of Martian atmosphere has not been measured directly either by Viking or Curiosity. A typical lightweight mass spectrometer with moderate mass resolution ($m/\Delta m$ ~ 100) , such as a quadrupole mass spectrometer (QMS), cannot distinguish $^{40}Ar^{++}$ from $^{20}Ne^{+}$ signal because the difference in their mass/charge ratios is very small ($m/\Delta m = 1777$). Thus, Ar needs to be removed from sample gas before mass spectrometric measurements.
In order to achieve direct measurements of the Ne isotopic ratio with a future Mars lander, we are developing a gas measurement system with a permeable membrane. In this study, we experimentally investigate the difference in permeability of Viton sheets between Ar and Ne. Our experimental results indicate that a Viton sheet with 1 mm in thickness can increase the abundance ratio of Ne to Ar from the atmospheric value of ~10^{-3} to ~1. We also measured the ratio of $^{40}Ar^{++}$ to $^{40}Ar^{+}$ using a QMS with a typical ionization voltage (70V). The results show that the amount of $^{40}Ar^{++}$ produced during the ionization process in the QMS is about 10% of that of $^{40}Ar^{+}$. Thus, gas sample permeated through the Viton sheet would have $^{40}Ar^{++}$ contribution about 10% of $^{20}Ne^{+}$ contribution. These results suggest that the Ne isotope measurements can be achieved with uncertainty better than 10% after correcting for the contribution of $^{40}Ar^{++}$. Since Martian atmospheric pressure is about two orders of magnitude lower and $^{20}Ne/^{40}Ar$ ratio is about one order of magnitude lower in Martian atmosphere, the separation efficiency could decrease compared to that at the terrestrial atmospheric condition. However, it has a room for significant improvement by optimization for various parameters, such as materials, thickness, and duration of permeation. These results suggest that measurements of Ne isotopic ratio in Martian atmosphere may be achieved with this approach after optimization.

Keywords: Martian atmosphere, Ne measurement, Mars mission, mass spectrometer, instrument development

