Development of a system for Ne isotope measurement using permeable membrane to separate Ne from Ar for future Mars exploration

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The current Mars has a thin atmosphere with dry and cold climate. However, as inferred from geologic evidences observed by past Mars missions such as NASA's MSL and MRO, ancient Mars may have been wetter and warmer with thick atmosphere. Reason why such drastic change has been occurred is still an open question. In order to reveal them, it is important to investigate the present Martian atmosphere in detail as well as origin and evolution scenario of the atmosphere. Noble gases are chemically inert so that they must be useful tracers to study physical processes like degassing from interior and escape into space. Because Ne is sensitive to mass fractionation for its light mass (relative mass difference between isotopes is large), isotopic compositions of Ne are expected to provide us valuable constraints on history of the atmosphere.

The isotopic composition of Ne in Martian atmosphere, however, has not been measured directly by the former missions. Conventional mass spectrometers onboad, e.g., quadrupole mass spectrometers with m/Δm ~ 100, cannot separate $^{20}Ne^{+}$ ions from $^{40}Ar^{++}$ ions in mass spectrometry (m/Δm of 1778 is required). The $^{20}Ne/^{22}Ne$ ratios estimated from Martian meteorites show a wide variation due to relatively large contribution of other components such as cosmogenic Ne and contaminated terrestrial Ne. Therefore, in order to achieve on-site measurements of the Ne isotopes in a future Mars mission, we develop a system of Ne isotopic measurement equipped with a permeable membrane for Ne-Ar separation, which has an advantage from the point of view of light weight and simple structure. Neon must more permeate than Ar through a membrane and thereby Ne can be selectively introduced into the mass spectrometer. In this study, (i) the differences in permeability between Ne and Ar for polyimide sheets and Viton sheets are experimentally investigated, (ii) the results are compared with theoretical values calculated by diffusion coefficients of the materials, and (iii) applicability at Martian atmospheric condition is discussed.

The results indicate that a polyimide sheet with 125 μm in thickness and a Viton sheet with 1 mm in thickness increased the abundance ratio of Ne to Ar from the terrestrial atmospheric value of ~10^{-3} to ~100 and ~1, respectively. These results are consistent with the calculated values based on the reported diffusion coefficients and formulas of permeation (Fick' s first law and second law) within uncertainties. Appropriate duration time of the permeation is several tens of minutes. According to the results, a polyimide sheet with about 100 μm in thickness is currently the best candidate for Ne-Ar separation. The Ne/Ar ratio can be increased up to ~1 using the polyimide sheet under Martian atmospheric condition (assuming the total atmospheric pressure of 700 Pa and $^{20}Ne/^{40}Ar$ of 10^{-4}). The polyimide sheet of ~50 cm^2 in the effective area is needed at the present experimental conditions, which is mainly constrained by the detection limit of the mass spectrometer and the blank level (mostly degas from the Viton O-rings that we used as vacuum seal for the polyimide sheet). The improvement of them can reduce the size of the membrane. The results in this study suggest that the measurement of Ne isotopic ratios in the Martian atmosphere can be achieved with this approach.

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