

On-site analysis of helium isotope ratios of volcanic gases using a multi-turn time-of-flight mass spectrometer

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The helium isotope ratio ($^3\text{He}/^4\text{He}$) varies among the geochemical reservoirs, such as the atmosphere, crust, and mantle, depending on the ratio of the primordial component trapped in the Earth during its formation to the radiogenic component produced by radioactive decay of U and Th. Since volcanic gases are derived from magma and released to the earth's surface through various processes, the $^3\text{He}/^4\text{He}$ of volcanic gases reflect the mixing ratios of components originating from each reservoir. Because the mixing ratio may change before an eruption due to increased magmatic activity, the $^3\text{He}/^4\text{He}$ of volcanic gas is expected to be a new tool for volcano monitoring. For the $^3\text{He}/^4\text{He}$ measurement, a magnetic field mass spectrometer with a total weight of more than 1 ton has been used due to the requirement for sensitivity and mass resolution to detect trace amounts of ^3He (generally less than 0.1 ppb) with separation from HD^+ . In addition, a vacuum line for purification and separation of noble gases is also needed, so the $^3\text{He}/^4\text{He}$ measurements can only be performed in a laboratory. Therefore, real-time monitoring, essential for volcanic observation, is difficult for the $^3\text{He}/^4\text{He}$ of volcanic gas.

To make on-site, real-time $^3\text{He}/^4\text{He}$ measurement of volcanic gases possible, we are developing a method for on-site analysis using a portable mass spectrometer and a compact helium extraction system. We adopt a portable multi-turn time-of-flight mass spectrometer (MULTUM), which is small enough to carry around and has a high mass resolution to discriminate $^3\text{He}^+$ from HD^+ . As a result of several improvements in the sensitivity of MULTUM, it is possible to measure the $^3\text{He}/^4\text{He}$ of about 25 cm^3 of volcanic gas with an accuracy of about 10%.

MULTUM has already been operated on board the ship during the YK23-16S cruise of YOKOSUKA, JAMSTEC, at the Okinawa Trough to analyze seafloor hydrothermal water collected by the Shinkai 6500 submersible. Since only active gases were removed from the gas extracted from the hydrothermal water using a simplified gas purification line, the relatively high argon pressure hampered precise $^3\text{He}/^4\text{He}$ determination. Nevertheless, significant magmatic helium contributions were successfully identified for some low $^{40}\text{Ar}/^4\text{He}$ samples.