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Development of a portable mass spectrometer for on-site analysis of helium isotope ratio of volcanic gas

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Helium isotope ratio ($^3He/^4He$) shows different values in geochemical reservoirs such as the atmosphere, crust, and mantle, depending on relative contributions of primordial and radiogenic helium. $^3He/^4He$ of volcanic gases in subduction zones vary between magmatic (up to 1.1×10^{-5}) and crustal (less than 1×10^{-7}) values. When magma becomes active, $^3He/^4He$ of volcanic gas may increase due to the increased contribution of magmatic helium. Therefore, $^3He/^4He$ of volcanic gas has the potential as a monitoring tool of volcanic activity. Although continuous analysis of volcanic gas is necessary to monitor volcanic activity, it is difficult to carry out because a large magnet-sector type mass spectrometer is currently used to analyze helium isotopes due to requirements for mass resolution and sensitivity.

In order to analyze helium isotopes with a portable instrument, we use a multi-turn time-of-flight mass spectrometer (MULTUM), which is small enough to be carried around and has high mass resolution [1]. However, the sensitivity of the original MULTUM was far below the level required to detect trace amounts of ^3He in natural samples. Therefore, we improved sensitivity of MULTUM by operating the instrument in the static mode and by processing the detector signals with the pulse-counting method. As a result, the sensitivity of 2.4×10^{-10} cm^3STP/cps was achieved, which is equivalent to the detection of 100 counts of ^3He in a 10-minute measurement of a 0.4-4 cm^3 volcanic gas sample. $^3He/^4He$ of volcanic gas samples and air, which were obtained with MULTUM using helium standard gas (HESJ) with a known $^3He/^4He$ [2] for calibration, were consistent with those measured with a magnet-sector type mass spectrometer within analytical errors.

As a simple preparation system in the field, we combined a helium extraction system using a hot quartz glass tube [3] with MULTUM. Based on the result of a helium permeation experiment at 700°C, it is possible to repeatedly measure the $^3He/^4He$ with 4% error per hour.

References: [1] Toyoda *et al.* (2003) *J. Mass Spectrom.* 38, 1125–1142. [2] Mishima *et al.* (2018) *G-cubed.* 19, 3995-4005. [3] Bajo *et al.* (2012) *Mass Spectrom.*, 1, 0009.