American Mineralogist, Volume 105, pages 1695–1703, 2020

Vanadium micro-XANES determination of oxygen fugacity in olivine-hosted glass inclusion and groundmass glasses of martian primitive shergottite Yamato 980459

Ryoichi Nakada[1,2,*], Tomohiro Usui[2,†], Masashi Ushioda[3], and Yoshio Takahashi[4]

[1]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Monobe 200, Nankoku, Kochi 783-8502, Japan
[2]Earth-Life Science Institute, Tokyo Institute of Technology, Meguro, Tokyo 152-8550, Japan
[3]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan
[4]Department of Earth and Planetary Science, The University of Tokyo, Hongo 7-3-1, Bunkyo, Tokyo 113-0033, Japan

Abstract

The redox condition of magma determines the stability and composition of crystallizing and volatile phases in martian meteorites, reflecting the evolution of the martian interior. In the current study, direct analyses on the oxidation states of V, Cr, and Fe were performed based on the X-ray absorption near-edge structure (XANES) measurements equipped with a micro-sized X-ray beam. We first applied the micro-XANES (μ-XANES) technique to the olivine-hosted glass inclusion and groundmass glass of martian meteorite Yamato 980459 (Y98), which is interpreted as representing a primary melt composition. Mass-balance calculations and XANES spectra comparisons indicated that, while chromite and pyroxene affected Cr and Fe *K*-edge XANES spectra, the contribution of these minerals was minimal for V. The pre-edge peak intensity of V *K*-edge XANES enabled the estimation of the oxygen fugacity for inclusion and groundmass glasses. The calculated oxygen fugacity (f_{O_2}) of the glass inclusions was near the Iron-Wüstite (IW) buffer (IW-0.07 ± 0.32) for the glass inclusion, whereas it was 0.9 log units more oxidized (IW+0.93 ± 0.56) for the groundmass glasses. This result suggests that the redox condition of the parent magma of Y98 evolved during magma ascent and emplacement. Since Y98 is interpreted to have evolved in a closed system, our finding suggests that fractional crystallization and/or ascent of magma potentially induces the f_{O_2} increase. This study shows that the μ-XANES technique enables us to determine the f_{O_2} by only measuring a single phase of glassy compounds, and thus, it is useful to discuss the redox condition of volcanic rocks even if they do not crystallize out several equilibrium phases of minerals.

Keywords: μ-XANES, oxidation states, oxygen fugacity, Yamato 980459, shergottite