Mechanisms for Incorporation of Hydrogen in and on the Lunar Surface

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Abstract

Absorption features near 3-microns that are diagnostic of OH/H_2O have been observed on many bodies in our solar system, including Mars, the Moon, and asteroids. We examine laboratory data that support ten different mechanisms by which OH/H_2O may be incorporated in or on a planetary surface, some of which may be appropriate for the Moon. These mechanisms can be broadly grouped in two categories: OH/H_2O in the interiors of minerals and glasses (#1-5 below), and OH/H_2O on their surfaces (#6-10). 1) Olivine, pyroxene, feldspar, and many other "nominally-anhydrous" silicates commonly incorporate OH, either during crystallization or through diffusion from a hydrous magma.2) Hydrous minerals, like amphiboles and clay minerals, contain structural OH. 3) Hydrated minerals such as zeolites contain structural H_2O. 4) Minerals that crystallize in water-rich environments may contain fluid inclusions of H_2O, indicating the presence of H during crystallization. 5) OH and/or H_2O may be dissolved in silicate glasses with variable speciation depending on crystallization history and composition. Recent SIMS analyses of lunar volcanic glasses shows the presence of H at ppm levels (Saal et al., 2009). Our work suggests OH may be present (near detection levels) in agglutinate glasses as well. Such OH/H_2O could represent either primary magmatic H or solar-wind H interacting with the melt on the surface. 6) Liquid water (H_2O) occurs at present only on the surface of Earth. 7) Surface ice (H_2O) occurs on the surfaces of many terrestrial planets, may exist only in the cold portions of the permanently-shadowed portions of the lunar polar craters (e.g., Spudis, 2003). 8) Water can adsorb onto a mineral surface and then dissociate to form OH (e.g., Lane et al., 2007). 9) H_2O may be physically adsorbed onto a mineral surface. 10) Interactions between solar wind particles and oxygen of mineral and/or glass surfaces may form OH (e.g., Zeller et al., 1970) with potential abundances on the order of a monolayer or a few layers. Detailed spectroscopic, crystal-chemical, and petrogenetic data are needed to distinguish between the above mechanisms; all of the above except #4 and #6 may well be viable on the Moon. Further laboratory work is needed to facilitate quantification of absorption features associated with these different mechanisms, as well as to constrain the mobility, stability, and possible dependence of OH/H_2O adsorption on mineral and glass composition and grain size.

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