American Mineralogist, Volume 110, pages 1209–1225, 2025

Discriminating ionic mobility between diffusivity and electrical conductivity experiments on Earth's silicate materials

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Abstract

Ionic diffusivity and electrical conductivity are two important transport properties of Earth's silicate materials (melts and minerals) and are widely used to constrain many chemical and physical aspects of Earth's interior. Both transport properties are related to the mobility of ionic species, and a genetic link between them has long been assumed, which implies similarity or comparability between their relevant transport nature and parameters. I examine the activation energy, anisotropy behaviors, and diffusivity and conductivity values of three well-documented ionic species (Na, F, and H) in a series of Earth's typical silicate materials and demonstrate that there are profound differences between the two transport properties. I have evaluated the theory that is commonly used to link the two transport properties of relatively simple and ideal materials in physics and materials science. It turns out that the theoretical model may not always be applicable to silicate materials in the Earth's interior, because their compositions and the bonding and interactions between their constitutive species are both much more complicated. A further assessment of the experimental studies on the diffusivity and conductivity of silicate materials reveals critical differences in the samples and analytical methods. In diffusion experiments, the sample is heterogeneous in composition (for producing the measurable diffusion profile): chemical or isotopic potential gradients are exclusively present, and during the runs, there is a net transfer of the charged species. In conduction experiments, the sample is usually homogeneous in composition: no potential gradients are involved, and there is no net transfer of the charged species (e.g., for analyses using impedance spectroscopy, which is necessary for Earth's silicate materials). The contrasting patterns of transport behaviors and parameters between the diffusivity and electrical conductivity of Earth's silicate materials, as experimentally observed, are more likely caused by discrepancies in the theoretical basis and laboratory work. The ionic mobility of a charged species between diffusion and conduction experiments on a silicate sample is, in fact, strikingly different. I suggest that the experimentally yielded diffusivity and conductivity of Earth's silicate materials cannot be simply compared or correlated with each other. The possible circumstances where a link between the two transport properties might be established are also briefly discussed.

Keywords: Ionic mobility, ionic diffusivity, electrical conductivity, Earth's silicate materials, experimental studies