Helium Diffusion in Periclase

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Helium isotope distributions in basalts can be used to trace heterogeneities in the Earth's mantle. With typically rapid diffusivities, He can be particularly useful for constraining length scales of these heterogeneities. Studying He diffusion in minerals relevant to the lower mantle and development of experimental and theoretical approaches for determining activation volume are of importance in assessing the minimum length scales for $^3He/^4He$ anomalies. Helium diffusion in periclase may be especially relevant to exchange between the core, a potential reservoir for primordial ^3He, and the mantle, at the base of which a layer enriched in (Mg,Fe)O may have formed by precipitation from the core [1], or dissolution of more soluble silica from the mantle (e.g. [2]).

In this work, we report measurements of He diffusion in end-member periclase using two experimental approaches. One set of experiments used ion implantation to introduce ^3He into polished MgO, with ^3He distributions in MgO samples measured with Nuclear Reaction Analysis using the reaction $^3He(d,p)^4He$. This method has been used previously in He diffusion studies, including measurements of diffusion in olivine up to 2.7 GPa [3]. In addition to these experiments, step heating experiments were conducted, measuring outgassing of ^3He produced in situ by proton irradiation of MgO. Initial experiments were at 1-atm, but work is in progress on higher-pressure experiments. In addition to end-member MgO, experiments were run on Ga-doped (3000ppm Ga) MgO to explore the effects of altervalent cation substitution and associated cation vacancy formation on He diffusion. For the ion implantation experiments, we obtain this Arrhenius relation for end-member MgO:

$$D = 2.8\text{x}10^{-7} \exp(-165 \pm 9 \text{ kJmol}^{-1}/RT) \text{ m}^2\text{s}^{-1}$$

Diffusivities for Ga-doped MgO agree within experimental uncertainty. This work complements recent theoretical studies of He diffusion in MgO using density functional theory [4].

[1] O'Rourke & Stevenson (2016) *Nature* **529**, 387–389. [2] Takafuji et al. (2005) *GRL*, L06313. [3] Cherniak & Watson (2012) *GCA* **84**, 269-279. [4] Song et al. (2018) *Phys. Chem. Minerals*, 1-14.