Duality in Diffusion – one element, one mineral, many diffusion coefficients

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Traditional descriptions of diffusion in minerals assign a single diffusion coefficient to the diffusion rate of an element in a mineral at a certain condition of pressure, temperature, composition and other intensive variables (e.g. oxygen fugacity). Recent technical developments have made it possible to use different methods to measure diffusion coefficients over a wider range of ambient conditions than has been possible in the past. In particular, the availability of methods to manipulate and measure concentration gradients on the nanoscale have extended experimental data to lower temperatures. With our improved understanding of diffusion mechanisms and point defects in minerals as a result of this (e.g. [1]), it is becoming clear that a single diffusion coefficient is too simplistic a description in many cases. Diffusion of one element in one mineral may proceed at different rates depending on a number of factors such as (a) simultaneous operation of two diffusion mechanisms (e.g. by vacancy and interstitial point defects), (b) occurrence of an element in two sites of a mineral (i.e. as constituents of two different thermodynamic components), and (c) the different manners of equilibration of point defects, leading to different kinds of compositional dependence of diffusion rates in different environments. The first case is exemplified by the diffusion of Li in olivine [2] and to some extent Fe-Mg in spinel [3], the second by the diffusion of Ca in garnet and the third by the diffusion of Mg in plagioclase. In all of these cases, well constrained experiments help to quantitatively characterize, and even predict, these processes. The resulting diffusion behavior may be complex and counterintuitive in some cases, but it is possible to quantitatively model these now to obtain better constrained timescales of thermal evolution. An important consequence of this aspect is that the concept of a single closure temperature for an element in a mineral needs to be re-thought. It has long been known that closure temperatures may vary depending on the circumstances under which diffusion takes place (e.g. nature of the surrounding medium). Now it is becoming clear that it may vary depending on the details of the diffusion process itself, even in the same environment in some cases.

[1] Dohmen R and Chakraborty S, *Phys. Chem. Mineral.* (2007) Doi 10.1007/s00269-007-0158-6; [2] Dohmen R *et al* (2010) *Geochim Cosmochim Acta* **74**:274-292 [3] Vogt K, Dohmen R and Chakraborty S, this session.