

## **Mechanism and kinetics of element and isotopic exchange mediated by a fluid phase**

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### **ABSTRACT**

We consider the fluid-mediated exchange of elements or isotopes between two mineral grains that are physically separated from each other in an analytical model. The process is found to depend on three non-dimensional parameters defined herein as  $\beta$ ,  $\gamma$ , and  $\delta$ . The behavior of a given system depends on only two of these ( $\gamma$  and  $\delta$ ), while the third ( $\beta$ ) determines the rate. This allows us to define a reaction mechanism map as a function of  $\gamma$  and  $\delta$ . These parameters can be calculated from independently measured or estimated thermodynamic, kinetic, and transport properties, thereby enabling a prediction of reaction mechanisms for the first time. It is found that at least six different reaction mechanisms are possible rather than just diffusion or interface control. Some of the more significant observations are that: (1) time scales of equilibration may be substantially greater than the diffusive time scale ( $x^2/D$ ); (2) rim compositions of zoned minerals may be out of equilibrium with each other and even with the adjacent fluid in some cases; and (3) solubility of the species of interest in the intergranular fluid plays a very important role in determining reaction behavior. We discuss case studies, selected from the literature, of garnet-biotite geothermometry and speedometry from granulite-facies metamorphic rocks in the light of the model to show that intergranular transport may be inefficient (rather than slow) in some cases. Finally, we consider the implications of these results for geothermometry, geospeedometry, and geochronometry.