

Diffusion compensation for argon, hydrogen, lead, and strontium in minerals: Empirical relationships to crystal chemistry

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ABSTRACT

Inspection of available experimental data reveals log-linear compensation effects between activation energies and pre-exponential factors for Ar, H, Pb, and Sr diffusion in a wide array of minerals. As a result, diffusion of Ar, H, Pb, and Sr converges to the same rates, respectively, at isokinetic temperatures in these minerals. Ionic porosity, Z , defined as the fraction of the unit-cell volume in a mineral not occupied by ions, is a measure of atomic packing density in silicate, carbonate, and phosphate minerals. Experimental diffusion parameters exhibit first-order correlations with ionic porosity, which proxies for mean metal-oxygen bond length/strength in minerals. An empirical kinetics-porosity model systematizes Ar, H, Pb, and Sr diffusion in minerals for which experimental diffusion data exist. For Ar and H diffusion, linear correlations are documented between activation energy and total ionic porosity. Combination of these correlations with diffusional compensation effects, which are also documented, yields empirical relationships among elemental diffusivity, total ionic porosity, and temperature. Linear correlations are also observed between experimental diffusion coefficients for Pb and Sr at given temperatures and calculated ionic porosities. For most minerals, the empirical predictions are remarkably consistent with experimental data, which strengthens the link between crystal chemistry and diffusion kinetics.

Keywords: Diffusion kinetics, compensation effect, ionic porosity, crystal chemistry, geochronology, geothermometry, geospeedometry