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Cu diffusion in a basaltic melt

PENG NI[1],* AND YOUXUE ZHANG[1]

[1]Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, Michigan 48109-1005, U.S.A.

ABSTRACT

Recent studies suggest a potential role of diffusive transport of metals (e.g., Cu, Au, PGE) in the formation of magmatic sulfide deposits and porphyry-type deposits. However, diffusivities of these metals are poorly determined in natural silicate melts. In this study, diffusivities of copper in an anhydrous basaltic melt (<10 ppm H_2O) were measured at temperatures from 1298 to 1581 °C, and pressures of 0.5, 1, and 1.5 GPa. Copper diffusivities in anhydrous basaltic melt at 1 GPa can be described as:

$$D_{\text{Cu}}^{\text{basalt}} = \exp\left[-\left(14.12 \pm 0.50\right) - \frac{11813 \pm 838}{T}\right]$$

where $D_{\text{Cu}}^{\text{basalt}}$ is the diffusivity in m^2/s, T is the temperature in K, and errors are given at 1σ level. A fitting of all experimental data considering the pressure effect is:

$$D_{\text{Cu}}^{\text{basalt}} = \exp\left[-(13.59 \pm 0.81) - \frac{(12153 \pm 1229) + (620 \pm 241)P}{T}\right]$$

where P is the pressure in GPa, which corresponds to a pre-exponential factor $D_0 = (1.25 \times\div 2.2) \times 10^{-6}$ m^2/s, an activation energy $E_a = 101 \pm 10$ kJ/mol at $P = 0$, and an activation volume $V_a = (5.2 \pm 2.0) \times 10^{-6}$ m^3/mol.

The diffusivity of copper in basaltic melt is high compared to most other cations, similar to that of Na. The high copper diffusivity is consistent with the occurrence of copper mostly as Cu^+ in silicate melts at or below NNO. Compared to the volatile species, copper diffusivity is generally smaller than water diffusivity, but about one order of magnitude higher than sulfur and chlorine diffusivities. Hence, Cu partitioning between a growing sulfide liquid drop and the surrounding silicate melt is roughly in equilibrium, whereas that between a growing fluid bubble and the surrounding melt can be out of equilibrium if the fluid is nearly pure H_2O fluid. Our results are the first copper diffusion data in natural silicate melts, and can be applied to discuss natural processes such as copper transport and kinetic partitioning behavior in ore formation, as well as copper isotope fractionation caused by evaporation during tektite formation.

Keywords: Copper diffusivity, kinetics, kinetic fractionation, copper isotope fractionation