Diffusive mineral dissolution or growth when diffusivity in the melt depends on concentration

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Mineral dissolution or growth is an essential process in magma evolution, and diffusion is a necessary step. When the diffusivity is concentration-independent, diffusive and convective mineral dissolution rate can be predicted from the diffusivity of the major equilibrium-determining component or the diffusion matrix, and the composition of the crystal and the farfield and interface melts (e.g., refs. 1-6). The interface melt composition can in principle be estimated from thermodynamic equilibrium and diffusion properties (e.g., refs. 1,5,7-8).

Under some conditions, such as the digestion of a quartz xenocryst or the growth of a quartz crystal under high degree of oversaturation, the diffusivity is concentration dependent. Because no analytical solution is available, I use numerical simulation to examine how to predict the dissolution or growth rate in the case of concentration-dependent diffusivity. Effective binary diffusion approach is used to simplify the complicated treatment. The simulations examine a linear dependence and an exponential dependence of diffusivity on concentration. The results are cast in the same equation as in the case of constant diffusivity by expressing the dissolution distance as:

$$L = 2\alpha\sqrt{D_{\text{eff}}t}\ ,$$

where L is the dissolution distance, α is related to the composition of the mineral and the farfield and interface melt (ref. 1), t is time, and D_{eff} is the effective diffusivity. Effeort is being made to derive a universal relation for the prediction of the effective diffusivity.

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