

Spinodal decomposition in ternary feldspar: Microstructure evolution during cooling

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Phase separation in a both binary and ternary feldspar systems is considered. The separation occurs by virtue of the spinodal decomposition mechanism and corresponds to a nonlinear uphill diffusion. The latter is described in terms of the generalized chemical potential that explicitly depends on component concentrations and therefore implicitly depends on space coordinates and time. In accord with general thermodynamic laws the chemical potential of each component becomes a uniform constant throughout the system as it evolves to an equilibrium state.

The region of unstable concentrations is found numerically on the ternary diagram together with the final characteristics of the decomposing phases. Realistic regions of temperatures and pressures are considered having in mind specific geologic applications for the feldspar system. Decomposition dynamics is described by corresponding multi-component generalization of the original equation of Cahn and Hilliard. A possible intrinsic anisotropy of the system is taken into account by considering anisotropic terms accounting for the surface energy contribution. Furthermore, such an anisotropy accounts for the formation of elongated lamellae. Multicomponent Cahn-Hilliard equations are solved numerically using finite elements routine. The results are in good qualitative correspondence with the actually observed patterns.

Various cooling scenarios are investigated to address the influence of cooling rate on the compositions of the exsolved phases. At slow cooling rates which are typical for regional metamorphism the compositions of the exsolved phases develop along the binodal curve down to temperatures lower than 300°C. Only at the high cooling rates typical for volcanic rocks, the compositions of the exsolved phases depart from the binodal curve and are “frozen in” at high temperature.

Secondary minerals in tungsten mine tailings: Mount Pleasant, New Brunswick, Canada

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Secondary minerals formed in tailings derived from a W-rich deposit were investigated in detail using transmission electron microscopy (TEM). The study focused on secondary minerals that formed in the vicinity of oxidized sphalerite [ZnS] and tennantite [Cu₁₀(Fe,Zn)₂As₄S₁₃] grains. Samples for TEM analysis were prepared directly from petrographic thin sections using a focused ion beam (FIB) instrument. This method insured that spatial relationships between primary grains, secondary minerals and the pore spaces were maintained. The results from this study indicate that the secondary coatings associated with sphalerite and tennantite are composed of several discrete phases. The phases identified in this study include an Fe–Zn–As–O phase, secondary sulfides, native Cu, an Fe–Si–O phase, an In–O phase, and wulfenite [PbMoO₄]. The Fe–Zn–As–O phase precipitates directly from the pore water and the nearby primary mineral grains act as a source for some of the elements (e.g., Zn from sphalerite, As from tennantite). Secondary Cu sulfides were found at the outer margins of sphalerite and roquesite [CuInS₂] grains. It is likely that these Cu sulfides form as a result of interactions between the primary grain and aqueous Cu(II) present in the pore water, similar to what occurs in supergene environments. A secondary sulfide that was composed of variable amounts of Cu, Zn, As, Fe, and S was also identified along the outer margins of tennantite. Native Cu was found in association with chalcocopyrite [CuFeS₂] inclusions present in one of the sphalerite grains and probably represents a low-temperature secondary phase. The oxidation of chalcocopyrite in the presence of aqueous Si leads to the formation of a nanocrystalline or amorphous Fe–Si–O phase. Roquesite oxidation leads to the formation of a crystalline In–O phase, which is likely dzhalindite [In(OH)₃]. Wulfenite was found in the interstitial voids present in the Fe–Zn–As–O phase suggesting that it forms by direct precipitation from the local pore water. The results from this study indicate that secondary coatings formed during sulfide oxidation are composed of complex nano-scale mixtures of phases. The TEM investigations reveal details regarding mineralogical sinks and sources that exist within the tailings.