



ALUMINUM MOBILITY IN CRUSTAL FLUIDS: THE ROLE OF Al-Si COMPLEXING

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The low solubility of Al in pure H₂O at crustal metamorphic conditions has led to the common assumption that this element is immobile during fluid flow; however, Al-rich minerals in metamorphic veins and segregations suggest otherwise. High fluid fluxes are typically not supported by other data, and alternatives such as H⁺ metasomatism or complexing with alkalis or halides require special conditions if they are to provide a general explanation for this apparent inconsistency. A more plausible explanation is Al complexing with SiO₂ because of its high concentrations in metamorphic pore fluids present in a wide range of crustal lithologies. We investigated this hypothesis via rapid-quench, hydrothermal piston-cylinder experiments on corundum solubility in SiO₂-bearing H₂O at 700-950°C and 0.5-1.5 GPa. Three sets of runs were conducted at fixed P and T: 1 GPa & 700°C, 1 GPa & 800°C, and 1.5 GPa & 800°C. Corundum solubility increases with SiO₂ concentration in each case, signaling Al-Si complexing. Quartz-saturated experiments at 1.5 GPa, 800-950°C, and at 800°C, 0.5-1.5 GPa, show that (1) both Al and Si solubility are enhanced in the presence of corundum+quartz relative to that expected for saturation in a single oxide mineral, and (2) Al and Si solubility enhancements increase with P and T, indicating progressively higher concentrations of Al-Si complexes. The nature of the Al-Si complex(es) can be determined from the solubility patterns. At 800°C, 1 GPa, the predominant Al and Si aqueous species are the neutral Al monomer (AlO_{1.5(m)}) and Si monomer (SiO_{2(m)}) and dimer (Si₂O_{4(d)}). Adopting a standard state of unit activity of one mole of the species and assuming ideal mixing, mass balance relations can be coupled with thermodynamic properties of equilibrium between SiO_{2(m)} and Si₂O_{4(d)} to obtain the stoichiometry and thermodynamic properties of the homogeneous reaction AlO_{1.5(m)} + nSiO_{2(m)} = AlSi_nO_{2n+1.5}. We obtain $n = 2.01$ and $\log K = 5.1 \pm 0.4$ (1σ). Average deviation from the experimental measurements is 17%. That the best fit value for n corresponds almost exactly to an integer reaction coefficient of 2 strongly suggests that the mechanism for Al interaction with Si is formation of a simple trimer complex at this P and T. In addition, we find that Si > Al at all conditions measured. The results show that, by forming polymeric clusters with silica in solution, Al is readily mobilized in metamorphic fluids simply by H₂O equilibration with the major minerals of the crust: quartz, feldspars and micas. Al mobility should thus be expected during fluid-rock interaction in deep crustal settings.