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Metastability of sillimanite relative to corundum and quartz in the kyanite stability field: Competition between stable and metastable reactions

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Abstract

The formation of sillimanite, under metastable conditions, relative to corundum and quartz has been defined experimentally, approximately 700 to 800 MPa inside the kyanite stability field thereby allowing for the approximate location of the metastable Sil = Cnd + Qtz equilibrium to be outlined in *P-T* space from 600 to 800 °C. Experiments involved using a NaCl assembly with a graphite furnace in a two-piston-cylinder apparatus. The thermocouple tip was in direct contact with the flat-lying, folded Pt capsule thereby minimizing thermal gradients to <5 °C. Charges consisted of equimolar amounts of gem-quality sillimanite, corundum, and quartz, plus H_2O as a flux, placed in a 1.3 cm long Pt capsule that was arc-welded shut and folded. During the course of the experiment, the metastability of the assemblage Sil-Cnd-Qtz implies that Sil ↔ Cnd + Qtz is, at some point, in direct competition with Cnd + Qtz → Ky and Sil → Ky. Early during the experiment it may be assumed that a steady state between dissolution and growth rates is established. However, due to the sluggish nucleation of kyanite, there is a *P-T* dependent induction period during which Cnd + Qtz → Sil is the controlling reaction. Once kyanite does appear, the reaction proceeds very fast to kyanite via reactions Cnd + Qtz → Ky and Sil → Ky. The kyanite surface area is probably a major factor in controlling the overall reaction rates. Under constant *P* and *T*, the system evolves from metastable sillimanite formation to sillimanite consumption, which is only dependent on the kyanite surface area. Similar competition between stable and metastable reactions could occur during contact metamorphism where metastable mineral growth is observed. The relative sluggishness of all three reactions under relatively dry conditions could help to explain the persistence of metastable corundum + quartz ± Al_2SiO_5 assemblages in nature.

Keywords: Sillimanite, kyanite, corundum, quartz, rate of reaction, experimental petrology, Rietveld refinement, aluminosilicates