Solubility of andradite, $Ca_3Fe_2Si_3O_{12}$, in a 10 mol% NaCl solution at 800 °C and 10 kbar: Implications for the metasomatic origin of grandite garnet in calc-silicate granulites

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ABSTRACT

The solubility of andradite garnet was determined at 800 °C and 10 kbar in a solution of 10 mol% NaCl and 90 mol% H_2O. Experiments were syntheses carried out with high-purity natural wollastonite, reagent hematite or natural specular hematite containing ~1 wt% TiO_2, and fluid. All experiments were performed with Mn_2O_3-Mn_3O_4 or Fe_2O_3-Fe_3O_4 oxygen buffers in a piston-cylinder apparatus with NaCl pressure media for 1–3 days. Andradite saturation was determined by the presence or absence of garnet in quenched charges.

Andradite dissolves incongruently to hematite and fluid with $CaSiO_3$ molality (m_{CS}) of 0.0838 ± 0.0015 for the reagent hematite and both buffers. Slightly higher m_{CS} of 0.0895 ± 0.0005 for the natural hematite and Mn-oxide f_{O_2} buffer is interpreted as due to incomplete equilibration and/or ~9 mol% Ti in the run-product andradite. Dissolved Fe molality could be determined only approximately, but must be at least ten times lower than m_{CS}. Quenched fluids were very basic (pH 11–12). The solubility of Fe_2O_3 in andradite-saturated H_2O-NaCl fluids is lower than that of Al_2O_3 at grossular saturation at the same pressure (P), temperature (T), and fluid composition.

The results permit a test of a model of $CaSiO_3$ dissolution in NaCl solutions to three dominant aqueous species: $CaCl^+$, OH^-, and H_3NaSiO_4. Combination of the $CaSiO_3$ molality at andradite saturation with wollastonite solubility at the same conditions (0.1253 ± 0.0047 molal; Newton and Manning 2006) leads to a Gibbs free energy change of the reaction 3 wollastonite + hematite = andradite at 800 °C and 10 kbar of -32.21 ± 2.45 kJ. The good agreement between this value and that derived from previous studies supports the dissolution model of $CaSiO_3$ in NaCl solutions. The low solubility of the Fe_2O_3 component of andradite contrasts with the high solubility of magnetite and of Fe in pelitic and granitic mineral assemblages measured in acidic chloride solutions by previous workers at lower P and T. The results imply that Fe_2O_3 is conserved during metasomatic processes affecting calc-silicates at high metamorphic grades.

Keywords: Experimental petrology, thermodynamics, fluid, crystal growth, metasomatism