American Mineralogist, Volume 92, pages 139–150, 2007

Reversed phase equilibrium constraints on the stability of Mg-Fe-Al biotite

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ABSTRACT

The stability of Mg-Fe-Al biotite has been investigated with reversed phase-equilibrium experiments on four equilibria. Experimental brackets in pure H_2O and H_2O-CO_2 mixtures for the equilibrium:

phlogopite + 3 quartz = enstatite + sanidine + H_2O (1)

are in good agreement with previous experiments in mixed-volatile fluids (Bohlen et al. 1983) and H_2O-KCl solutions (Aranovich and Newton 1998), while indicating a reduced stability field for phlogopite compared to previous data in pure H_2O (Wood 1976; Peterson and Newton 1989). Aluminum solubility in biotite has been determined in the Fe-, Mg-, and Fe-Mg systems from reversed phase-equilibrium data for the equilibria:

3 eastonite + 6 quartz = 2 phlogopite + 3 sillimanite + sanidine + H_2O (2)

3 siderophyllite + 6 quartz = 2 annite + 3 sillimanite + sanidine + H_2O (3)

over the *P-T* range ~600–750 °C and 1.1–3.4 kbar. Over the investigated temperatures, the brackets define nominal Al saturation levels of 1.60 ± 0.04 in Mg-biotite, 2.08 ± 0.05 in Fe-biotite, and 1.81 ± 0.03 in biotite with Fe/(Fe + Mg) = 0.43–0.44. The slight decrease in Al with increasing *T* and decreasing *P* suggested by the data is less than experimental uncertainties.

Compared to biotite on the Phl–Ann join, Al-saturated biotites have a markedly larger stability field, particularly in the Fe-system. This effect has been quantified in the Fe-system with one reversal between 691–709 °C at 2.4 kbar for the equilibrium:

biotite + sillimanite + quartz = almandine + sanidine + H_2O (4)

The combined experimental results place tight constraints on the thermodynamic properties of phlogopite, annite, eastonite, and siderophyllite. The resulting nonzero (ΔH_{298} = –9.4 kJ/mol, with $\Delta S = \Delta V = 0$) energetics for the internal equilibrium:

Eastonite + 2/3 Annite = 2/3 Phlogopite + Siderophyllite (5)

reflect strong Fe-Al affinity in biotite, which has a marked effect on thermobarometers involving biotite.

Keywords: Biotite, phase equilibria, experimental petrology, mixing properties, annite, phlogopite, siderophyllite, eastonite