Experimental data on the Tschermak substitution in Fe-chlorite

TEDDY PARRA,1,* OLIVIER Vidal,2 AND THOMAS THEYE3

1Laboratoire de Géologie, UMR 8538, Ecole Normale Supérieure, 24 rue Lhomond, F-75231 Paris Cedex 05, France
2LGCA, UMR 5025, 1381, rue de la Piscine, BP 53, F-38041 Grenoble Cedex 09, France
3Institut für Mineralogie und Kristallchemie, Universität Stuttgart, Azenbergrasse 18, D-70174 Stuttgart, Germany

ABSTRACT

Iron chlorite with compositions intermediate between the two end-members daphnite [Fe3AlSi3O10(OH)8] and Fe-amesite [Fe4Al4Si2O10(OH)8] were synthesized from gels, under fO2 conditions defined by the solid oxygen buffer Fe-FeO. The unit-cell parameters and volume of chlorite with Si-content ranging from 2.3 to 2.7 were calculated. A least-squares fit of these data yields VFe-ames = 213.06 cm3 and VFe-daph = 216.50 cm3. The molar volume of daphnite is similar to that estimated by Vidal et al. (2001), but the volume difference between Fe-amesite and daphnite is too low. The experimental data were also fitted for reasonable values of VFe-ames and VFe-daph, with linear (ideal) or non-ideal volume models involving a positive excess volume. With these models we obtain VFe-ames between 216 cm3 and 217.49 cm3, and VFe-daph between 209 and 211.35 cm3.

Equilibration experiments involving chlorite with almandine-hercynite/fayalite or chloritoid-hercynite/fayalite provide data on the chlorite composition as a function of T and P at temperatures between 420 and 520 °C and pressures between 3 and 20 kbar, at fO2 buffered by the assembly Fe-FeO. Initial Si-rich and Si-poor chlorite compositions converged in most cases toward an equilibrium composition during the experiments. The results show that the Si-content of chlorite is sensitive to temperature for the various divariant assemblages. The most definitive results, obtained for the assemblage chlorite-almandine-fayalite, were used to estimate HfFe-amesite and the Al-Fe Margules parameter for the various sets of daphnite and Fe-amesite molar volumes constrained from the synthetic chlorites. The results indicate that HfFe-amesite = −7616 ± 3 kJ and WAlFe ∼ −10 kJ.

INTRODUCTION

Chlorites are widespread in metabasites and metapelites, and they are stable over a wide range of pressure (P) and temperature (T) conditions. Moreover, reactions involving chlorite delineate important isograds of prograde metamorphism, such as the breakdown of chlorite-quartz at conditions close to the greenschist-amphibolite facies boundary (e.g., Massonne 1989). The main compositional variations of chlorite result from the three following substitutions: FeMg–1, di/trioctahedral (DT): VIAl VIAl (Fig. 1). The extent of substitutions depend on pressure, temperature (Vidal et al. 2001), the fluid, and bulk-rock composition. Chlorite is therefore a good candidate for the estimation of intensive variables in various geological contexts, but accurate thermodynamic data for the end-members and solution models are required.

Most experimental studies dealing with chlorite have been conducted in the MgO-Al2O3-SiO2-H2O system (Staudigel and Schreyer 1977; Jenkins and Chernosky 1986; Bryndzia and Scott 1987; Massonne 1989; Saccoccia and Seyfried 1994; Baker and Holland 1996). These experimental data provide constraints on the stability of Mg-chlorite near clinochlore composition as well as the P-T dependency of the TK substitution in the Mg system (for abbreviations see Table 1). In contrast, very few experimental data are available in the FeO-Al2O3-SiO2-H2O (FASH) system (Turnock 1960; Hsu 1968; James et al. 1976). This is due to technical difficulties inherent to experiments in the FASH system, such as the persistence of metastable phases (e.g., 7 Å chlorite), difficulties in maintaining buffered fO2 during the run, and difficulties in analyzing fine-grained run products. Turnock (1960) first determined the upper thermal stability of synthetic Fe-chlorite, with Si = 2.2 apfu (atoms per formula unit, normalized on four tetrahedral cations). According to his unreversed data, the stability limit lies near 600 °C at oxygen fugacity conditions defined by the Mt-Wu buffer and pressure conditions between 1 and 3 kbars. James et al. (1976) concluded that the maximum temperature stability of Fe chlorite was bracketed at approximately 550 °C at 2 kbar, under fO2 defined by the Ni-NiO buffer. These authors assumed that the Si-contents of their synthetic starting chlorite were around 2.8 ± 0.2 and 2.2 ± 0.2 apfu, respectively, and remained constant during the bracketing runs. However, significant uncertainties attend the compositions of Fe-chlorite in run products and starting materials (syntheses produced quartz, fayalite, magnetite, and hercynite).

At present, no experimental data obtained in the FASH system constrain the P and T dependency of the TK substitution in Fe-chlorite, and only few data are available on the compositional dependence of unit-cell parameters for the daphnite-Fe-amesite binary (McOnie et al. 1975; James et al. 1976). The aim of the present study is to provide these missing data.