Hydrothermal breakdown reactions of grossular and pyrope garnets in MgCl₂ and CaCl₂ solutions at 2 kbar and 550 and 750°C.

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Abstract: The hydrothermal reactions of grossular and pyrope garnet were been studied at 2 kbar and 550°C and 750°C in MgCl₂ and CaCl₂ solutions at concentrations of 0.2 to 2.0 molal. The reaction mechanism is of dissolution-precipitation type; reactant garnets typically show isotropic dissolution textures and products either crystallize as large idiomorphic crystals (cordierite, forsterite, anorthite) or clusters of minute crystals (chlorite, spinel, clintonite). Metastable intermediate assemblages precede the formation of the final (equilibrium) assemblages, in accordance with the Ostwald step rule, provided the latter is regarded in terms of reaction path and metastable assemblages rather than single phases. The dominant factor controlling the final mineral assemblage is the bulk Mg/Ca ratio with the cation fractionation being characterized by a strong partitioning of Ca²⁺ into the solution phase. Cordierite + forsterite + spinel is interpreted to be the stable product assemblage at 750°C and high Mg/Ca (Mg/Ca≥1.8), and anorthite + forsterite + spinel the stable product at lower ratios. At 550°C chlorite is the major run product along with anorthite at low Mg/Ca bulk ratios and quartz at higher ratios. The kinetics of the breakdown reaction of the garnets are shown to be strongly dependent on the solution concentration, and occur an order of magnitude faster at high concentrations (1 and 2 molal) compared to reaction in dilute solutions (0.2 molal or in water). Ionic solutions may therefore have a marked influence on the kinetics of dehydration and hydration reactions of garnet in nature.

Key-words: grossular, pyrope, dissolution-precipitation mechanism, reaction path, Ostwald step rule, kinetics.

1. Introduction

Although generally a minor modal component of metamorphic mineral assemblages, garnet occupy an important place in metamorphic petrology. Their continuous cation exchange reactions with biotite, pyroxenes, hornblendes, olivine and plagioclases have been calibrated to provide a number of successful geothermometers and geobarometers (eg. Ghent, 1976; Ferry & Spear, 1978; O'Neill & Wood, 1979; Bohlen et al., 1983; Blundy & Holland, 1990). The appearance of garnet by dehydration reactions occurring at the expense of chlorite marks one of the classic zonal changes in pelitic metamorphic rocks. Correspondingly, the hydration breakdown reaction of garnet to chlorite during the exhumation of metabasic eclogites or blueschists is a characteristic feature of the transformation to green­schists in alpine collision terrains (eg. Schliestedt & Matthews, 1987a; Okay, 1989).

Experimental research on garnets has largely concentrated on the derivation of equilibrium thermodynamic properties (Ganguly & Kennedy, 1974; Hensen et al., 1975; Haselton & Newton, 1980; Kawasaki & Matsui, 1983; Perkins, 1983). Less attention has been paid to the kinetics and mechanisms of their hydrothermal reactions in