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Amphibole equilibria in mantle rocks: Determining values of mantle a_{H_2O} and implications for mantle H_2O contents

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ABSTRACT

H_2O can affect the thermophysical properties of the mantle, and nominally anhydrous mantle minerals, such as olivine, pyroxenes, and garnet, may be an important reservoir of mantle H_2O. However, the H_2O content of nominally anhydrous mantle minerals now at the Earth's surface may not always reflect mantle values. It is, therefore, desirable to develop different techniques to estimate mantle H_2O contents, or values of the activity of H_2O (a_{H_2O}) at the conditions of equilibration in the mantle. To examine the potential of amphibole equilibria to determine values of mantle a_{H_2O}, the chemical compositions of co-existing amphibole, olivine, two-pyroxenes, and spinel from a mantle xenolith, sample DH101E of McGuire et al. (1991), were used to estimate values of pressure (P), temperature (T), and a_{H_2O}.

A value of a_{H_2O} was estimated from pargasite dehydration equilibria using chemical compositions of minerals as the basis for estimating activities of end-members in the natural phases (e.g., the activity of forsterite in olivine). These calculations were performed with the THERMOCALC software package and, at an estimated maximum T and P of 900 °C and 20 kbar, they yield an estimated value of $a_{H_2O} \approx 0.02$ for sample DH101E. The application of oxy-amphibole equilibrium, as described by Popp et al. (2006a, 2006b), using the composition of the amphibole in DH101E yields a value of the log of the hydrogen fugacity (f_{H_2}) of –1.37. This value of f_{H_2} together with the estimated log f_{O_2} of –9.9 yields a value of $a_{H_2O} \approx 0.0005$ for sample DH101E. The lower estimated a_{H_2O} compared to that estimated from dehydration equilibria may reflect a slight loss of H from amphibole in the post-formation environment, but both types of amphibole equilibria are consistent with a low value of a_{H_2O}.

Values of mantle a_{H_2O} can be used to predict the H_2O content of mantle olivines. At 900 °C and 20 kbar, the olivine in a sample that equilibrates at a_{H_2O} <0.04, as estimated for sample DH101E, should contain <10 wt ppm H_2O. This value is consistent with the lower end of the range of measured H_2O contents of mantle olivines (≈4–400 wt ppm). Thus, estimates of values of a_{H_2O} from amphibole equilibria can produce useful predictions of both the activity of H_2O as well as the H_2O content of nominally anhydrous mantle minerals.

Keywords: Amphibole, mantle H_2O activity, H_2O in mantle, amphibole equilibria, phase equilibria, mantle a_{H_2O}, thermobarometry, thermodynamics