Water solubility in forsterite and enstatite: implications for the secular evolution of mantle convection

I. KOVÁCS[1] J. HERMANN[1] AND H. ST. C. O`NEILL[1]

[1] Research School of Earth Sciences, The Australian National University; istvan.kovacs@anu.edu.au

The temperature dependence of solubility of H_2O in forsterite and enstatite has been studied experimentally using three different starting compositions in the system MgO-SiO_2-H_2O to produce the parageneses *per*+*fo*+*fluid*, *fo*+*en*+*fluid* and *en*+*melt*+*fluid* (*per* = MgO; *fo* = Mg_2SiO_4; *en* = $MgSiO_3$). All experiments were run at 2.5 GPa for >24 hours, with temperature varied from 1000 to 1400 ^oC. Recovered samples were examined for the types of H_2O substitution and their quantification by FTIR spectroscopy.

In the *per*-buffered experiments, peaks in *fo* at 3612, 3589, 3566, 3555, 3533 and 3480 cm^{-1} were identified, which are related to silica vacancies due to low silica activity [1, 2]. In the *en*-buffered experiments, the IR spectrum of *fo* shows two peaks at 3160 and 3220 cm^{-1} in addition to those present in the *per*-buffered experiments. These peaks indicate Mg vacancies [1]. Peak intensities decrease with increasing temperature in both the *per*- and *en*-buffered systems, showing that water solubility is inversely proportional to temperature in *fo*. For *en,* in both the *en*-buffered experiments and those at higher silica activity coexisting with hydrous melt, two peaks at 3360 and 3060 cm^{-1} were found. These peaks are close to the peaks in *fo* at 3160 and 3220 cm^{-1} that are associated with higher silica activity, suggesting that H_2O only substitutes in *en* by a Mg vacancy mechanism. The H_2O content of *en* increases with increasing silica activity, but, in contrast to *fo,* also increases with temperature.

The results imply that the partitioning of H_2O between olivine and orthopyroxene in the mantle is a very strong function of temperature. Because of their much higher H_2O contents, pyroxenes control the water budget of the upper mantle, but olivine controls its rheology. Cooling of the mantle will transfer H_2O from orthopyroxene (and presumably clinopyroxene) into olivine. We calculate that transfer from pyroxenes increases the H_2O content of olivine by a factor of 2.5 for a 100 ºC decrease in temperature. Since H_2O causes marked weakening in olivine [3], this increase in H_2O “dampens” the effect of decreasing temperature on mantle viscosity, so that the net effect of secular cooling on mantle convection may be much less than currently estimated.

References

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