Fe-Mg-Mn Exchange between Olivine and Melt and an Oxybarometer for Basaltic Systems

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Fe-Mg and Mn-Mg exchange coefficients between olivine and basaltic melt have been determined experimentally over a wide range of pressure, temperature and fO_2 to explore the effect of redox state and dissolved H_2O. Run product glasses were analysed by synchrotron source Mössbauer spectroscopy to determine accurately $Fe^{3+}/\Sigma Fe$, which is found to be well described by the recent formulation of Borisov et al. [1]. $Kd_{Fe\text{-}Mg}$, expressed using total Fe in both olivine and melt, decreses linearly with increasing $Fe^{3+}/\Sigma Fe$, as expected if olivine incorporates negligible Fe^{3+}. Regression of the data to $Fe^{3+}/\Sigma Fe = 0$ recovers the 'canonical' $Kd_{Fe\text{-}Mg}$, i.e., in the absence of any Fe^{3+}. Melt and olivine composition, temperature and pressure have negligible effect on $Kd_{Fe\text{-}Mg}$ for the conditions studied. In contrast, $Kd_{Mn\text{-}Mg}$, is independent of $Fe^{3+}/\Sigma Fe$, but varies with olivine composition only, in a fashion consistent with the lattice strain model (LSM) [2].

Our results provide a means to determine $Fe^{3+}/\Sigma Fe$ of basaltic systems simply from the deviation of measured olivine-melt $Kd_{Fe\text{-}Mg}$ from the canonical value. The algorithm of Borisov et al [1] can then be used to recover fO_2. We show that this method provides an estimate of fO_2 to ±0.4 log units in the range NNO-3 to +5, provided (i) $Kd_{Fe\text{-}Mg}$ is precisely determined (±0.005) and (ii) temperature is known to ±50 °C.

The redox-sensitive nature of $Kd_{Fe\text{-}Mg}$ makes it unsuitable for correction of post-entrapment crystallisation (PEC) of olivine-hosted melt inclusions. Instead, $Kd_{Mn\text{-}Mg}$ is predicted with sufficient precision by LSM to be used to quantify PEC. $Fe^{3+}/\Sigma Fe$ and fO_2 can, in turn, be recovered from the deviation of PEC-corrected $Kd_{Fe\text{-}Mg}$ from the canonical value, providing a simple, but powerful, tool to estimate magmatic fO_2 in basaltic systems over a wide range of conditions.

[1] Borisov *et al*. (2018) *Contrib Mineral Petrol* **173**:98
[2] Blundy & Wood (1994) *Nature* **372**:452-454