

## The systematics of Cr<sup>3+</sup> and Cr<sup>2+</sup> partitioning between olivine and liquid in the presence of spinel

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### ABSTRACT

The partitioning behavior of Cr into olivine in basaltic systems has been parameterized and can now be modeled over a wide range of redox conditions and liquid compositions. The Cr<sup>2+</sup>/Cr<sup>3+</sup> in spinel-saturated experimental systems can be estimated based on a simple model of Cr solubility in basalt. Fe<sup>3+</sup> appears to suppress the presence of Cr<sup>2+</sup> in basaltic systems. We predict that, in Fe-free systems, all Cr is trivalent at log  $f_{\text{O}_2} = -3$  (i.e., QFM+3 to QFM+4), whereas all Cr is trivalent at approximately Ni-NiO(QFM+1) in Fe-bearing systems. Cr<sup>2+</sup> predominates under redox conditions <IW-1 in both Fe-bearing and Fe-free systems.

$D_{\text{Cr}^{2+}}$  and  $D_{\text{Cr}^{3+}}$  (olivine/liquid) have been determined in various liquid compositions and temperatures.  $D_{\text{Cr}^{3+}}$  (i.e.,  $f_{\text{O}_2} \geq \text{QFM}$ , appropriate for most terrestrial or martian basalts) strongly covaries with the ratio of non-bridging oxygens to tetrahedrally coordinated cations (NBO/T) (Mysen 1983) and can be estimated using the equation

$$D_{\text{Cr}^{3+}}^{(\text{ol}/\text{liq})} = -0.39 \cdot \frac{\text{NBO}}{\text{T}} + 1.29.$$

This relationship appears to be valid over the entire pressure range of olivine stability, from 1 atm to 15 GPa.

$D_{\text{Cr}^{2+}}$  (i.e.,  $\leq \text{IW-1}$ , appropriate for lunar and some asteroidal basalts) is sensitive to liquid composition and temperature and can be estimated using either

$$D_{\text{Cr}^{2+}}^{(\text{ol}/\text{liq})} = 0.24 \cdot D_{\text{Mg}}^{(\text{ol}/\text{liq})} - 0.07$$

or

$$D_{\text{Cr}^{2+}}^{(\text{ol}/\text{liq})} = 0.66 \cdot \left[ \frac{10,000}{\text{T(K)}} \right] - 4.48.$$

The  $1/T$  equation is probably only valid at 1 atm pressure, but the  $D_{\text{Mg}}$  equation may be useful at higher pressures as well. The Cr content of spinel-saturated liquids is a function of temperature, composition, and  $f_{\text{O}_2}$ . However, the Cr content of spinel-saturated liquids is buffered by spinel and is insensitive to the bulk Cr content of the system (e.g., Roeder and Reynolds 1991). Therefore, the Cr content of a crystallizing, spinel-saturated basalt cannot be modeled using Raleigh fractionation models.