American Mineralogist, Volume 83, pages 669–684, 1998

The systematics of Cr^{3+} and Cr^{2+} 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^{2+}/Cr^{3+} in spinel-saturated experimental systems can be estimated based on a simple model of Cr solubility in basalt. Fe^{3+} appears to suppress the presence of Cr^{2+} in basaltic systems. We predict that, in Fe-free systems, all Cr is trivalent at log $f_{O_2} = -3$ (i.e., QFM+3 to QFM+4), whereas all Cr is trivalent at approximately Ni-NiO(QFM+1) in Fe-bearing systems. Cr^{2+} predominates under redox conditions <IW-1 in both Fe-bearing and Fe-free systems.

$D_{Cr^{2+}}$ and $D_{Cr^{3+}}$ (olivine/liquid) have been determined in various liquid compositions and temperatures. $D_{Cr^{3+}}$ (i.e., $f_{O_2} \geq$ 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

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

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

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

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

or

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

The $1/T$ equation is probably only valid at 1 atm pressure, but the D_{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_{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.