

Solubility of Carbon and Hydrogen in Melts at High Pressures and Reduced Conditions

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Important characteristics of the Earth's mantle, such as the temperature of its solidus at a given depth and the compositions of mantle-derived magmas (e.g. silica-saturated vs. silica-undersaturated), are dependent on the prevailing oxidation state and the solubilities of volatile species. In particular, C-H-O species are known to have large effects on mantle solidus temperatures and magma compositions. Magmas on the Earth's surface are generally oxidized ($fO_2 \sim$ FMQ) and CO_2 -bearing. However, the source region of these magmas - the convecting upper mantle - is likely to be significantly reduced at depth, probably \sim FMQ-2 to FMQ-3 log units for basalt source regions and $<$ FMQ-3 log units for kimberlite source regions. The stable C-H-O volatile phase under these fO_2 conditions will be a CH_4 - H_2 \pm H_2O fluid, rather than CO_2 - H_2O . Calculations suggest that upper mantle fO_2 may decrease by as much as 0.6 log fO_2 units per GPa (relative to FMQ). The question arises as to how oxidized magmas can be extracted from a reduced source.

In order to tackle this question, we have undertaken an investigation into the role of C-H-O volatile species and their interaction with silicate melts. Initial experiments have been conducted at 2.8 GPa with silicate melts in the system forsterite-nepheline-quartz (Fo-Ne-Qz), which represents a simple analogue to natural basalts and peridotite melting. Experiments were first conducted in order to locate the olivine-orthopyroxene two-phase boundary in the system Fo-Ne-Qz+ CH_4 - H_2O fluid. Increasing pressure shifts this boundary to increasingly silica-poor compositions, but pure H_2O and CH_4 fluids have the opposite effect and produce increasingly silica-rich compositions. CH_4 - H_2O fluids significantly lower the 2.8 GPa olivine-orthopyroxene cotectic (\sim 1260°C compared to \sim 1490°C under volatile-free conditions) but have little effect on the cotectic composition. Jadeite glass was then saturated at 2.8 GPa and 1240°C with CH_4 - H_2O fluid. The glass was analysed by FTIR spectroscopy to determine the solubility of C-H-O volatiles. The volatile solubility of CH_4 - H_2O fluid in equilibrium with Jadeite-Ferrosilite ($Jd_{50}Fs_{50}$) melt was compared at 0.5 and 2.8 GPa and 1240°C. Measured and calculated fluid species ratios generally agree at 2.8 GPa. CO_2/CO_2+H_2O ratios show a marked increase at 0.5 GPa compared to 2.8 GPa, with Fe^{3+}/Fe^{2+} ratios mirroring this increase. The experiments demonstrate an important redox exchange equilibrium by which degassing of carbon-rich fluids containing small CH_4 contents increase Fe^{3+}/Fe^{2+} in the decompressing melt.