Mobility and fluid/melt partitioning of heavy metals in silicate liquids: Implications for magma degassing

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The volatilization of Cd, Re, Tl, Pb, Sb and Te from melts in the system $CaO\text{-}MgO\text{-}Al_2O_3\text{-}SiO_2$ has been investigated at 0.1 MPa and 1200-1350°C. Analysis of quenched glasses normal to the melt/gas interface produced concentration profiles for Cd, Re, Tl, Pb, Sb and Te to which a semi-infinite one-dimensional diffusion model could be applied to extract diffusion coefficients (D). At 1300°C, the fastest diffusing element was Cd having a $\log D_{Cd} = -6.5 \pm 0.2$. The slowest element was Re with $\log D_{Re} = -7.5 \pm 0.3$. Diffusivities of Sb, Te, Pb and Tl have intermediate values where $\log D_{Sb} = -7.1 \pm 0.1$, $\log D_{Te} = -7.2 \pm 0.3$, $\log D_{Pb} = -7.1 \pm 0.2$, $\log D_{Tl} = -7.0 \pm 0.2$ cm^2/sec.

Fluid/melt partitioning was also measured in the system $CaO\text{-}MgO\text{-}Al_2O_3\text{-}SiO_2\text{-}H_2O\text{-}Cl$ between 1200 and 1400°C at 1GPa. Mass balance calculations were used to calculate $Kd^{fluid/melt}$. In experiments where the fluid was only H_2O, $Kd^{fluid/melt}$ for Re and Mo were 3.6 and 7.6 respectively. Addition of Cl greatly increased metal partitioning into the fluid where all Re and Mo partitioned into the fluid which, by using the detection limit in the glass as a lower limit, yields a minimum $Kd^{fluid/melt}$ for Re and Mo that exceeds 400. Pb, Tl and W also partitioned into the fluid when Cl was present having $Kd^{fluid/melt}$ of ~10, 8 and 4 respectively. Experiments have also been carried out to determine any dependence or $Kd^{fluid/melt}$ on the fluid composition.

Differences in diffusivity of volatile heavy metal ions to a melt-gas interface lead to significant fractionation between these metals in magmas during degassing. Given the observed differences in Cd, Re and Sb diffusivities, our modelling predicts an increase in the normalized Cd/Re and Cd/Sb ratio in the gas phase with increasing bubble growth rate and during pre-eruptive degassing. Natural data from Kilauea support our model. Monitoring of the Cd/Re or Cd/Sb ratios in aerosols from degassing volcanoes may provide a tool for predicting volcanic eruption.

Scanning transmission x-ray microscopy (STXM) in biogeochemical environments

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In natural environments bacteria cell walls and extracellular structures transform the bacteria – solution interface into a highly heterogeneous environment that can promote mineral formation inside, outside or even some distance away from the cell surface. Understanding how microbes influence the nucleation of minerals and amorphous precipitates is important to understanding the cycling of trace elements in low-temperature environments. In addition, the nucleation of minerals at the cell surface can lead to entombment and eventual fossilization of the cell. Thus, understanding how microbes affect nucleation processes is also important in astrobiology.

In order to determine sites of nucleation associated with bacteria cells direct observations of the chemistry of the cell-mineral interface is required. Scanning transmission X-ray microscopy (STXM) combines the chemical contrast and chemical sensitivity of NEXAFS with a high spatial resolution X-ray microscopy to provide a way to investigate the chemistry of microbial cells to identify sites of mineral precipitation. In this study, STXM is used to investigate the role of biogenic structures in the nucleation of precipitates in biogeochemical systems.