The solubility of Os and Ir in sulphide melts: Implications for Os heterogeneity in the Earth's mantle

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The concentration of Os into refractory, chemically inert, µm-sized Os-Ir alloys is significant for our understanding of the Os isotopic evolution of the terrestrial mantle and the preservation Os isotopic heterogeneities in mantle rocks over several Gy. However, despite this, not much is known about their origin. Some authors suggested desulfuration of the mantle or direct precipitation of metal as mechanisms responsible for the formation of Os-Ir alloys in the terrestrial mantle rocks.

We report the results of an experimental study on solubilities of Os and Ir in sulphide melts over a large range of fO_2, fS_2 at 1300ºC. Experiments were carried out in a vertical muffle tube furnace, equiped for gas mixing, with fO_2 and fS_2 controlled by mixing SO_2, CO and CO_2. Run products were analyzed by electron microprobe for major elements, and by LA-ICP-MS for trace elements.

The solubilities of Os and Ir in sulphide melts increase with increasing fS_2, with Os dissolving as Os^{2+} at high fS_2 and Os^0 at low fS_2; and Ir dissolving as Ir^{4+} at high fS_2 and Ir^0 at low fS_2. The effect of fO_2 on the solubility of Ir and Os is negligible. Although Os and Ir solubilities in the sulphide melt increases with fS_2, solubilities are low when compared to the solubilities of other HSE (e.g. Pt). The maximum Ir and Os solubilities obtained at $fS_2=10^{-1.6}$ and 1300ºC in a sulphide melt is ~2000 ppm and ~200 ppm respectively.

Assuming a relative fO_2 of QFM-1, and a fS_2 of $10^{-0.5}$ bars, the calculated $D_{Os}^{sul/sil}$ is ~10^6 and $D_{Ir}^{sul/sil}$ is ~10^5. The low solubilities of Ir and Os in sulphide melts, coupled with the high $D_i^{sul/sil}$, suggests that Os and Ir concentrate initially in the sulphide melt at >1200ºC. During partial melting of the mantle, the extraction of sulfides into silicate melt lead to a fS_2 decrease which likely triggers the exsolution of Or-Ir alloys from the refractory sulphide left in the residue. This mechanism is likely to be the most prevalent in the upper mantle of the Earth, with implications to the survival of Os heterogeneity of the terrestrial mantle.

P-T conditions in the reaction zone of basaltic-hosted mid-ocean ridge hydrothermal systems: Inferences from vent fluid Si and Cl concentrations

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The chemical composition of mid-ocean ridge hydrothermal vent fluids is thought to reflect conditions within a deep-seated reaction zone. Under the assumption that dissolved silica is controlled in the reaction zone by quartz solubility (a function of temperature, pressure, and chlorinity), and further that vapor-phase chlorinity is also a function of T and P, the intersection of Cl and Si solubility lines in P-T space can be used to infer reaction zone P and T when a vapor phase is present. Recently published experimental data on quartz solubility at super-critical conditions show significant differences from earlier solubility equations. We use this new quartz solubility equation to develop a model to infer reaction zone conditions using both Si and Cl concentrations in vapor-like vent fluids. We apply this model to various basaltic-hosted mid-ocean ridge sites. Little variation is observed in inferred temperatures which range from 410-440°C. This lends support to the fluxability model which assumes that upwelling plumes rise at temperatures that maximize the energy flux. Reaction zone pressures are site dependent and compare well with depth of magma chamber imaged by seismic studies. This suggests that vapors circulate close to magma chambers and is difficult to reconcile with models in which mid-ocean ridge hydrothermal circulation occurs in two layers with a substantial layer of convecting brine.