emc²⁰¹²
2 – 6 September
european mineralogical conference
frankfurt / main · germany

Redox control on iron isotope variations in magmas determined by nuclear resonant vibrational spectroscopy

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Non-traditional stable isotope variations can shed light on the major petrogenetic and geochemical processes that have shaped planetary reservoirs. During the last decade, significant Fe isotopes variations were measured in materials produced in high temperature environments such as planetary mantles. In this respect, previous studies have suggested that iron isotopes could be good tracers of redox conditions during melting [*e.g.*, 1]. However, we lack a reliable database of equilibrium fractionation factors between melts and igneous minerals such as olivine to interpret the rock record [2]. Iron equilibrium fractionation factors (or more specifically reduced partition function ratios β) can be derived from Nuclear Resonant Inelastic X-ray Scattering (NRIXS) experiments at a synchrotron facility [3, 4], through the determination of the mean force constant of the iron bonds. This method is insensitive to kinetic and thermal effects, contrasting with conventional experimental approaches that can be fundamentally flawed by such effects [5]. This technique was used to determine the β-factors of synthetic ^{57}Fe-labelled olivine prepared in piston-cynders and silicate glasses synthesized at different oxygen fugacities in a gas mixing furnace.

At a given Fe^{3+}/Fe^{2+} ratio, the force constants of tholeiitic, basaltic, andesitic, and dacitic glasses are almost identical, whereas the force constant of rhyolitic glass is higher. For all samples, the force constant increases linearly with Fe^{3+}/Fe_{tot}. Thus, for mafic melts, there is little structural control on iron isotopic fractionation; redox effects seem to dominate. The force constants of Fe^{2+} and Fe^{3+} are then estimated by interpolating the data to $Fe^{3+}/Fe_{tot}=0$ and $Fe^{3+}/Fe_{tot}=1$. At 1100 ˚C, the equilibrium δ^{56}Fe fractionation between the two oxidation states of iron in mafic magmas is +0.25‰ . The olivine-melt and melt Fe^{2+}-Fe^{3+} iron isotopic fractionations derived from NRIXS data may explain the heavy iron isotopic compositions measured in MORBs.

This study provides a solid reference for interpreting Fe isotopic variations in igneous rocks. Specifically, it reveals the potential of using Fe isotopes to trace redox variations and magmatic differentiation processes in planets.

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