Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.17558

Densities of Fe^{2+}- and Fe^{3+}-bearing silicate glasses and the redox state of deep magma oceans

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The investigation of iron in silicate glasses, as analogues of melts, is fundamental to understanding the redox state of magma oceans and thus the evolution of planetary interiors and atmospheres through time. However, the variation of fO_2 in silicate magmas at lower mantle pressures is still poorly known, largely because of a lack of experimental constraints on compositions relevant to the Earth's deep interior. To evaluate the change in fO_2 with depth in magma oceans, we performed in-situ diamond anvil cell synchrotron X-Ray attenuation measurements on ^{57}Fe-enriched- peridotitic and basaltic glasses, synthesised at different fO_2 and compressed up to 118 GPa at ambient temperature. The X-ray attenuation (I/I_0) through the sample permits measurement of the linear absorbance (μ_{HP}), which is directly correlated to the density (ρ) of the material through the relationship $\rho_{HP}/\mu_{HP} = \rho_0/\mu_0$. Our results show that, at low pressure, the density of peridotitic glass with 68% Fe^{3+} is slightly lower than that of peridotitic glass with 100% Fe^{2+}. However, the density of the oxidised sample increases more rapidly with pressure, such that its density is higher than that of the reduced counterpart above 10 GPa. This indicates a higher compressibility of the Fe^{3+}-rich glass at high pressures, as also inferred from iron force constants [1]. Hence, the fO_2 (relative to IW) of a peridotitic liquid with constant Fe^{3+}/Fe^{2+} is expected to decrease with pressure in magma oceans, in accord with previous studies [2, 3]. Therefore, core formation occurring at higher pressures, all else being equal, will result in higher fO_2 at the planetary surface, potentially explaining the oxidised nature of the Earth's mantle (~IW + 3.5) relative to those of smaller telluric bodies (IW-1 to -2), and giving rise to an early atmosphere rich in oxidised species [e.g., 4].

[1] Ni et al. (2021), *GRL*, 49, e2022GL098451. [2] Armstrong et al. (2019), *Science*, 365, 903-906. [3] Deng et al. (2020), *Nature Comms.* 11, 2007. [4] Sossi et al. (2020), *Sci. Adv.* 6, eabd1387.