The oxidation state of iron in peridotite liquids and implications for planetary magma oceans

PAOLO A. SOSSI[1,2*], ANTONY D. BURNHAM[3], JAMES BADRO[1], ANTONIO LANZIROTTI[4], MATT NEWVILLE[4], HUGH ST.C. O'NEILL[3]

[1]Institut de Physique du Globe de Paris, Paris, France
[2]Institute of Geochemistry and Petrology, ETH Zürich, Zürich, Switzerland
[3]Research School of Earth Sciences, Australian National University, Canberra, Australia
[4] Center for Advanced Radiation Sources, University of Chicago, Chicago, USA
* email address: paolo.sossi@erdw.ethz.ch

Our knowledge of the relationship between oxygen fugacity (fO_2) and the redox state of iron dissolved in silicate melts comes almost exclusively from investigations of basaltic melts [1 – 3]. Although instructive for understanding mafic magmatism, the mantles of telluric bodies in the inner solar system are broadly peridotitic, not basaltic, in composition [4]. Because the valence of iron may be shifted not only by oxygen fugacity, but also by melt composition [5], understanding the mantle redox states of such bodies necessitates experimental investigation of peridotitic liquids.

In order to wholly fuse peridotite, powders of a synthetic fertile lherzolite composition based on KLB-1 were heated using a gas-mixing aerodynamic levitation furnace to 1900 °C for 30 s under varying Ar+CO_2-H_2 gas mixtures and pure O_2, yielding logfO_2s between 0 and -8. Here, we report Fe^{3+}/Fe^{2+} ratios in the quenched glasses calculated from Fe K-edge XANES spectra collected at the 13-IDE (GSECARS) beamline at APS, Chicago, Illinois.

Calculated $Fe^{3+}/\sum Fe$ ratios ranged from 0.01 at logfO_2 = -8 to 0.47 at logfO_2 = 0. Dependence of Fe^{3+}/Fe^{2+} on logfO_2 conforms to a slope within uncertainty of the ideal value (0.25) and the resultant equilibrium constant for the reaction $Fe^{2+}O(l) + \frac{1}{4}O_2 = Fe^{3+}O_{1.5}(l)$ is close to unity, indicative of ideal dissolution of both species in peridotite melt. Based on estimates for the FeO contents of planetary mantles [4], bodies in equilibrium with core-forming metal at low pressures should contain 1 – 2 % Fe^{3+} in their mantles. The 3.6 % present in Earth's mantle argues that it underwent additional and/or distinct processes during its accretion.

[1] Kress, V.C., & Carmichael, I.S.E. (1991), *CMP*, **108**, 82-92 [2] Cottrell, E. *et al*. (2009), *Chem. Geol.* **268**, 167-179 [3] Berry, A. J. *et al*. (2018) *EPSL*, **483**, 114-123 [4] Wanke, H. & Dreibus, G., (1988), *Phil.Trans.R.Soc. A.*, **325**, 545-557 [5] Borisov, A.A. *et al.* (2017), *CMP*, **172**, 34