

OXYGEN SOLUBILITY IN IRON MELTS AT HIGH PRESSURES AND TEMPERATURES: EXPERIMENTAL CONSTRAINTS ON TERRESTRIAL PLANETARY CORE FORMATION.

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Introduction: It has been determined from seismic data that the density of the Earth's core is significantly lower than that of pure iron, indicating that the Earth's core must contain several wt% of one or several light elements in addition to Fe-Ni alloy [1]. Oxygen and Sulfur are favorite candidates among the proposed light elements because of their high abundance in the solar system.

The scope of this study is to further constrain the enigma of 'the light component in the core'. This has major consequences for core formation models during accretion of terrestrial planets, in particular for the very initial stage when the metallic fraction is molten but the silicate fraction still solid. Understanding eutectic compositions and temperatures at that stage allows to model the beginning of core segregation. The core composition has also direct implications for the temperature estimates of the Earth's interior.

Using high-pressure multi-anvil devices, we have investigated the Fe-rich portion of the Fe-FeO binary and the Fe-O-S ternary systems at 15 and 23 GPa. The Fe-S eutectic has been investigated as a function of oxygen concentration. With a stepwise addition of oxygen (0.5 wt% oxygen/step), we follow the compositional and temperature evolution of this eutectic until saturation in a FeO-phase is achieved.

Experimental procedure: Starting materials were prepared from mechanical mixtures of pure iron, FeO powder and pure sulfur. The starting materials were packed into Al_2O_3 capsule surrounded by MgO sleeves and then brought to pressure at room temperature. Experiments were conducted at ETH Zurich in a Walker-type multi-anvil. Octahedron edge and cube truncation lengths were 14 and 8mm at 15 GPa and 10 and 3.5 mm at 23 GPa, respectively. After reaching experimental pressures, samples were heated at 100 °C/min to the desired temperatures, where they were held for 10 to 20 min. Temperatures were measured using W-Re type C thermocouples. After quenching, melting relations were determined using a JEOL JXA-8200 electron microprobe, based on quench textures and chemical composition analyses.

Results: The melting relations of the Fe-rich portion of the Fe-FeO system have been determined at 15 and 23 GPa. The occurrence of melting is easily recognized by a change of texture. During quench oxygen migrates towards the boundary of the charge causing precipitation of crystalline metallic iron. Growth of metallic iron crystals prevents further diffusion of oxygen. The residual liquid, close to the Fe-O eutectic, crystallizes within the interstices to form fine intergrowths of metallic iron and feathery FeO precipitates (Fig1). Our results indicate that the Fe-FeO eutectic composition at 15 GPa occurs at a temperature of 1625°C with 10±2wt% FeO (Fig2) and around 1820°C 12±2 wt% FeO at 23 GPa. The solubility of oxygen in metallic thus increases with increasing pressure. Our results can be used to evaluate the incorporation of oxygen into planetary cores and its distribution between inner and outer cores.

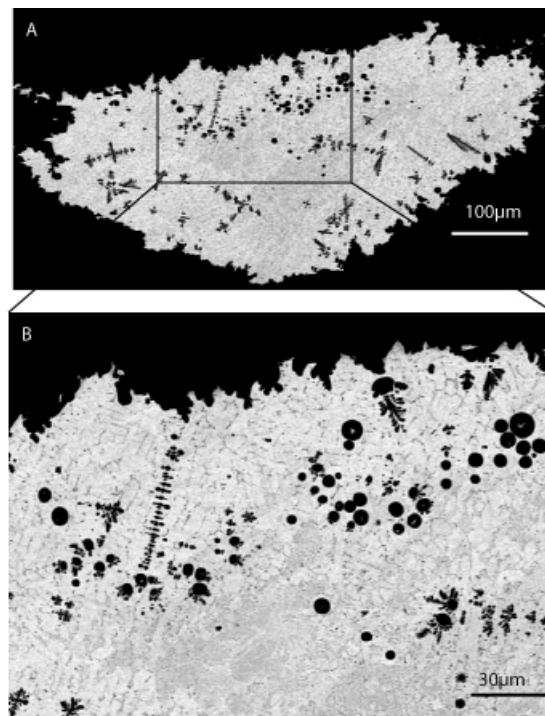


Fig 1: A: BSE images of run JL14b at 15GPa and 1700°C.
B: Detail of run JL14b showing FeO blobs and dendrites (black), FeO precipitates (grey) and metallic iron crystals (clear).

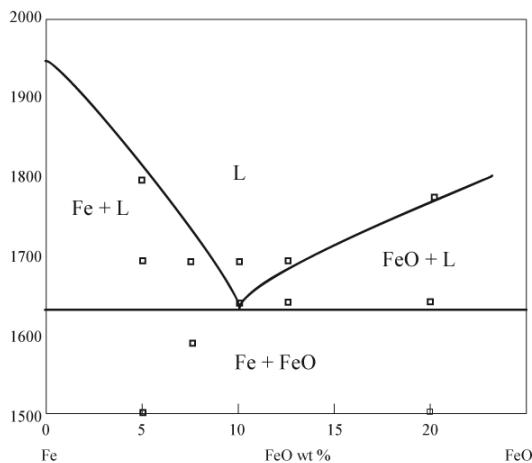


Fig2: The Fe-FeO eutectic as determined by our experiments. The eutectic is located at 10 wt% FeO (2.2 wt% O) near 1625 °C.

We also conducted experiments in the Fe-O-S system. Preliminary data indicate that iron with 8 wt% O and 8 wt% S forms one miscible liquid at 15 GPa and 2000 °C.

Discussion and implications: The measured eutectic melting temperature in the Fe-FeO system is 270 °C lower than the melting point of pure iron at 15 GPa with a content of 10 ± 2 wt% of FeO. Our results are consistent with those from Ringwood and Hibberson [2] who found the Fe-FeO eutectic to locate at 10 wt% FeO and to be 275 °C lower than the melting temperature of pure iron. A previous abstract reported a eutectic at a lesser oxygen content. Nakayama and Takahashi [3], using other textural criteria, they found that the solubility of FeO in molten Fe liquid is less than 10 mol% (0.14 wt%) in the temperature of 2000 -2300 °C at 15 GPa, which is also suggested by Tsuno et al. [4]. All of the studies (and equally those at the FeO-rich of the eutectic) suffer from the non-quenchability of the system which invariably leads to a central zone with oxygen-rich blobs in a Fe-rich matrix and a rim with less blobs and oxygen in the liquid. The analysis and subsequent calculation of bulk oxygen content in the liquid is thus due to some interpretation, and is most likely the major reason for the discrepancies between various studies. We consider that the blobs, dendrites and FeO intergrowth have originally dissolved in a homogeneous metallic liquid and exsolved during quenching. In our study, defocused electron beam sizes up to 40 μm were used for the analysis of the quenched liquid to avoid analytical problems related to the quench texture.

Our results are consistent with a geochemical model for the core containing 5.8 wt% oxygen and 1.9 wt % sulfur as proposed by McDonough and Sun (1995) [5].

- References:**
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