THE MELTING OF METALLIC FeO TO OVER 100 GPa: IMPLICATIONS FOR CORE TEMPERATURE AND COMPOSITION. Elise Knittle and Raymond Jeanloz, Department of Geology and Geophysics, University of California, Berkeley, CA 94720.

Oxygen has been proposed by Ringwood to be the primary alloying element of the Earth's core based on geochemical arguments (1,2). According to this hypothesis, oxygen is incorporated into the outer core by the dissolution of iron oxide into the liquid iron which comprises the bulk of the core. However, Fe and FeO liquids are immiscible at ambient conditions; to become miscible at high pressure and temperature, FeO must undergo a substantial change in its chemical properties. Specifically, Ringwood has invoked the metallization of FeO under extreme conditions of pressure and temperature to remove this miscibility gap.

Recently, we have studied the high-pressure, high-temperature properties of FeO using electrical conductivity measurements in both the diamond-anvil cell and in shock-wave experiments (3,4). Maximum pressures of 155 GPa and temperatures of ~ 4000 K were achieved, and Figure 1 summarizes the results of our studies. Both electrical conductivity and equation of state measurements (5,6) constrain this high-pressure, high-temperature phase diagram for FeO. In particular, we have proven that a metallic phase of FeO exists above 70 GPa, but only at temperatures exceeding 1000 K. The evidence that FeO becomes metallic at simultaneously high pressures and temperatures is substantiated both by diamond cell and shock wave experiments. Therefore, we find strong support for Ringwood's hypothesis that Fe and FeO are miscible under core conditions. Further support of the presence of oxygen in the Earth's core is provided by our experimental observation that molten iron and iron alloys chemically react with solid oxides at the conditions of the core-mantle boundary (4,7).

In view of these results, we have measured the melting temperature of FeO to ~ 100 GPa. These experiments are intended to help constrain the temperature of the outer core, assuming that it consists mainly of iron and oxygen. That is, we evaluate the effect of oxygen as the core-alloying component on the melting temperature of pure iron at high pressure (7). A diamond-anvil cell was used to achieve pressures of over 100 GPa, and the FeO samples were heated using a cw Nd:YAG laser. The samples were contained in steel gaskets and were embedded in a ruby matrix which isolates the samples both chemically and thermally from the diamond anvils. Also, the ruby is used to measure the pressure accurately across the FeO surface by means of the ruby fluorescence technique (8,9). The temperatures and the gradients of temperature across the sample were measured spectroradiometrically and thermally induced relaxation of pressure was taken into consideration (10).

At all pressures above 5 GPa, the melting temperature of FeO is higher than that of pure Fe (7). For example, at approximately 100 GPa the melting temperature of FeO exceeds 5000 K, almost 1000 K higher than that of iron at the same pressure. Thus, our results indicate that the addition of a light alloying component does not necessarily lower the melting temperature of the outer core relative to that of iron. Indeed, if Fe and FeO form a solid solution at elevated pressures, and if oxygen is the alloying constituent involved, our measurements imply that the core could be at a temperature above that required to melt pure iron.

Our experimental observation that liquid iron and iron alloys such as FeO react readily with oxides, suggests that the interface between the core and mantle is a chemical reaction zone and hence that the Earth's core must contain substantial oxygen. We suggest that the seismically anomolous D" zone at the core- mantle boundary may be associated with such a reaction layer. We also note that these chemical reactions must take place at high enough pressure that the oxygen does not form an immiscible phase once it reacts with the liquid iron of the core. From our experiments we have determined this pressure to be ~ 70 GPa. This pressure indicates that oxygen did not become a primary constituent of the Earth's core until the Earth had substantially accreted: for 30% of the Earth (by mass) to be at pressures greater than 70 GPa, the accreting Earth's radius must be ~ 4500 km. These results also allow us to speculate that the core of Mars probably does not contain oxygen since the central pressure of the planet (3398 km in radius) is barely above 70 GPa. Similarly, the possibility of Mercury having substantial amounts of oxygen in its large core seems unlikely. However, a large region of the interior of Venus is at pressures high enough to incorporate oxygen into its core. There may be a reaction zone at the core-mantle boundary of Venus, similar to D" in the Earth and from which oxygen dissolves into the core.

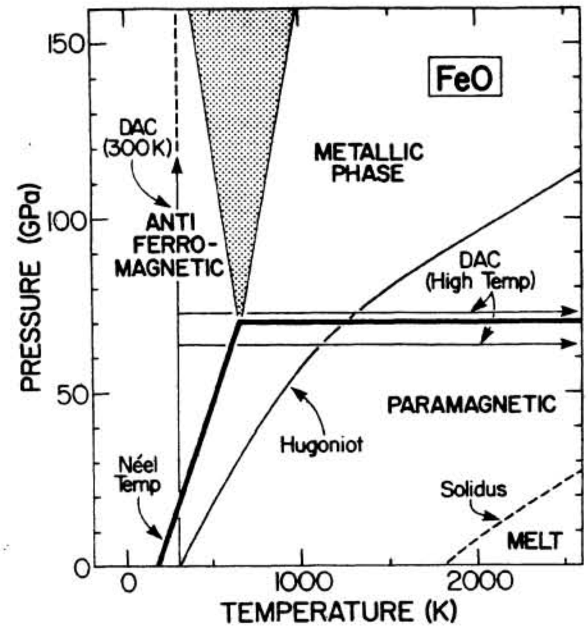


*Figure 1.* Phase diagram of FeO as determined by electrical conductivity results and equation of state experiments (from (4)). Also indicated are the pressure-temperature paths for experiments conducted in the unheated diamond-anvil cell (DAC, 300 K), in the laser-heated diamond-anvil cell (DAC, high temperature), and by shock-wave techniques (Hugoniot).

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