Liquid Immiscibility in the Fe-O System: Implications for the Light Element in the Earths Core

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The Earth's core is known to contain of the order of 10% of a light alloying element or elements, with O, S or Si being the most likely candidates. Identifying the conditions at which a particular light element could have entered the core is important not only for ascertaining the likely composition of the core but also for developing an understanding of the conditions during planetary differentiation. The Fe-FeO system is the simplest in which the oxygen content of liquid Fe metal can be examined. At room pressure a large miscibility gap exists between metallic Fe-rich and ionic FeO-rich liquids but this gap closes with increasing temperature. In this study multianvil experiments on the oxygen contents of coexisting immiscible metallic and ionic liquids in the Fe-FeO system have been used to extract thermodynamic properties that describe oxygen solubility and FeO activities in Fe metal as a function of pressure and temperature. These properties are used to independently calculate oxygen partitioning in the Fe-Mg-O system. Mixtures of FeO and Fe with varying Fe/O ratios were employed as starting materials. Samples were melted for a few minutes at 2100-2200°C then rapidly quenched. Experiments were performed between 12-25 GPa. In agreement with some previous studies we found that the Fe-FeO compositional gap closes with increasing pressure. At 24 GPa 2200°C a 10 mole % difference in oxygen concentration was observed between Fe-rich and FeO-rich liquids. A thermodynamic model was developed that employs Fe and FeO liquid components that mix in a non-ideal fashion. The experimental data on the closure of the miscibility gap with pressure were used to refine excess volume terms for the Fe-FeO liquid. The properties of FeO liquid at high pressure were refined using published data on the FeO melting curve. Thermodynamic mixing properties for magnesiowüstite were also taken from the literature. Using the resulting model the partitioning of oxygen between magnesiowüstite and Fe-rich metal could be calculated as a function of pressure and temperature. The calculation was found to be in excellent agreement with multianvil and diamond anvil cell results on such partitioning. The model indicates that while oxygen partitioning is independent of composition at low temperature it becomes a strong function of composition at high temperature and pressure once the miscibility gap has closed and Fe-FeO mixing becomes more ideal.

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