

Sulfur saturation limits in silicate melts and their implications for core formation scenarios for terrestrial planets

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ABSTRACT

This study explores the controls of temperature, pressure, and silicate melt composition on S solubility in silicate liquids. The solubility of S in FeO-containing silicate melts in equilibrium with metal sulfide increases significantly with increasing temperature but decreases with increasing pressure. The silicate melt structure also exercises a control on S solubility. Increasing the degree of polymerization of the silicate melt structure lowers the S solubility in the silicate liquid. The new set of experimental data is used to expand the model of Mavrogenes and O'Neill (1999) for S solubility in silicate liquids by incorporating the influence of the silicate melt structure. The expected S solubility in the ascending magma is calculated using the expanded model. Because the negative pressure dependence of S solubility is more influential than the positive temperature dependence, decompression and adiabatic ascent of a formerly S-saturated silicate magma will lead to S undersaturation. A primitive magma that is S-saturated in its source region will, therefore, become S-undersaturated as it ascends to shallower depth. In order to precipitate magmatic sulfides, the magma must first cool and undergo fractional crystallization to reach S saturation. The S content in a metallic liquid that is in equilibrium with a magma ocean that contains ~200 ppm S (i.e., Earth's bulk mantle S content) ranges from 5.5 to 12 wt% S. This range of S values encompasses the amount of S (9 to 12 wt%) that would be present in the outer core if S is the light element. Thus, the Earth's proto-mantle could be in equilibrium (in terms of the preserved S abundance) with a core-forming metallic phase.