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Sulfur solubility in reduced mafic silicate melts: Implications for the speciation and distribution of sulfur on Mercury

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Chemical data from the MESSENGER spacecraft revealed that surface rocks on Mercury are unusually enriched in sulfur compared to samples from other terrestrial planets. In order to understand the speciation and distribution of sulfur on Mercury, we performed high temperature (1200-1750°C), low- to high-pressure (1 bar to 4 GPa) experiments on compositions representative of Mercurian lavas and on the silicate composition of an enstatite chondrite. We equilibrated silicate melts with sulfide and metallic melts under highly reducing conditions (IW-1.5 to IW-9.4; IW = iron-wüstite oxygen fugacity buffer). Under these oxygen fugacity conditions, sulfur dissolves in the silicate melt as S^{2-} and forms complexes with Fe^{2+}, Mg^{2+} and Ca^{2+}. The sulfur concentration in silicate melts at sulfide saturation (SCSS) increases significantly with increasing reducing conditions (from < 1 wt.% S at IW-2 to >10 wt.% S at IW-8) and with increasing temperature. At sulfide saturation, the composition of the sulfide melt is mainly composed of FeS at IW-2 to IW-6 whereas it also contains (Mg,Ca,Fe)S under more reducing conditions (< IW-6). Metallic melts have a low sulfur content which decreases from 3 wt.% at IW-2 to 0 wt.% at IW-9. Based on our new data and those from previous studies, we developed a parameterization to predict SCSS in Mercurian magmas as a function of melt composition, temperature, pressure and oxygen fugacity. Using physical constraints of the Mercurian mantle and magmas as well as our experimental results, we suggest that basalts on Mercury were free of sulfide globules when they erupted. The high sulfur contents revealed by MESSENGER result from the high sulfur solubility in silicate melt at reducing conditions. By combining our parameterization of SCSS with chemical data from MESSENGER, we constrain the oxygen fugacity of Mercury's interior to IW-5.4±0.4 when the lavas were produced in the mantle. We also estimate that the mantle of Mercury most probably contains 7-11 wt.% S and that the metallic core of the planet has little sulfur (< 1.5 wt.% S). The external part of the Mercurian core is likely to be made up of a thin (< 90 km) FeS layer.