What sulfides exist on Mercury? Mainly CaS and FeS

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Introduction: The planet Mercury is more hellish than anticipated, with brimstone in addition to fire (i.e., maximum daytime temperatures over 400°C): elemental measurements of Mercury by X-ray and gamma-ray spectrometers aboard the MESSENGER spacecraft indicate ~2 wt. % sulfur in the regolith on average with up to 4 wt. % sulfur [1-3].

In what phase(s) is this ~2 wt. % sulfur present?
• Not in micron-thick coatings: [S]XRS ~ [S]GRS [3].
• Not in quenched silicate melts: low S solubility in silicate melt at low T, and exsolution rapid (~10^2 s timescales) [4].
• Not in nominally ansulfurous silicates: no evidence for wt. % levels of S in enstatite chondrite or achondrite silicates.
• Not in elemental sulfur: average Mercury daytime temperatures of 500 K exceed the melting point of elemental sulfur.
• Not in sulfates: Mercury’s surface is enstatite achondrite-like [1,3], evidently too reduced and O-poor for sulfates.
• Most S is present in sulfides (by process of elimination).

What sulfides exist on Mercury?
• Likely FeS; however, the Fe/S wt. ratio of Mercury’s regolith is ~0.8, whereas the Fe/S ratio of FeS is ~1.8. Sulfides besides FeS thus exist on Mercury.
• Minor elements like Cu, Zn, and Cr seem not to be present in sufficient abundance [1] to account for much sulfur.
• Lithophile elements such as Ca and Mg may pick up the slack, forming lithophile sulfides like CaS and MgS known in enstatite chondrites [5] and enstatite achondrites.
• Which lithophile sulfides occur on Mercury: CaS or MgS?

Based on thermochemical and experimental evidence, we suggest that CaS is the major lithophile sulfide.

Thermochemical evidence for abundant CaS:
At 1500 K and 1 bar, the activity of CaS in a silicate melt with [CaO] ~ [MgO] is 10^6 greater than MgS [6]:
\[ 2\text{CaO} + \text{S}_2 = 2\text{CaS} + \text{O}_2; \log K_{\text{Ca}} = -5.9 \]
\[ 2\text{MgO} + \text{S}_2 = 2\text{MgS} + \text{O}_2; \log K_{\text{Mg}} = -11.9 \]

Experimental evidence for abundant CaS:
A sulfur-rich, iron-poor Mercury regolith composition (from flare #5 of [1]) was prepared. The composition was packed in a graphite capsule, sealed in a platinum envelope, held at 1200°C for 2 hours, then cooled from 1200°C to 900°C over 3 hours. The oxygen fugacity was buffered at IW-2 by the graphite capsule. X-ray maps of the run product (top right) show FeS and CaS, but no MgS (with minor NaCrS_2).

Spectroscopic implications of CaS: Major mercurian silicates (probably enstatite, labradorite, and albite [7]) are featureless at UV-vis wavelengths. In contrast, CaS (and MgS) have prominent absorption features in the UV-vis (right). It should be possible to spot these spectral features on Mercury (though see [8]).

Petrologic implications of CaS: The sulfidation of CaO to CaS lowers the activity of CaO in mercurian magmas. Crystalizing plagioclase will be sodium-rich, as observed [3,7]. Lithophile sulfides link sulfide and silicate phase equilibria on Mercury.