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The oxidation state of sulfur in lunar apatite

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Abstract

Lunar apatites contain hundreds to thousands of parts per million of sulfur. This is puzzling because lunar basalts are thought to form in low oxygen fugacity (f_{O_2}) conditions where sulfur can only exist in its reduced form (S^{2-}), a substitution not previously observed in natural apatite. We present measurements of the oxidation state of S in lunar apatites and associated mesostasis glass that show that lunar apatites and glass contain dominantly S^{2-}, whereas natural apatites from Earth are only known to contain S^{6+}. It is likely that many terrestrial and martian igneous rocks contain apatites with mixed sulfur oxidation states. The S^{6+}/S^{2-} ratios of such apatites could be used to quantify the f_{O_2} values at which they crystallized, given information on the portioning of S^{6+} and S^{2-} between apatite and melt and on the S^{6+}/S^{2-} ratios of melts as functions of f_{O_2} and melt composition. Such a well-calibrated oxybarometer based on this the oxidation state of S in apatite would have wide application.

Keywords: Moon, oxygen, apatite, sulfur