Slag Chemistry on the Moon

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ABSTRACT

The field of astrometallurgy is a growing area of study. This paper provides an overview of potential metallurgical processing methods for lunar conditions, emphasising the impact of lunar factors on slag chemistry. Metal production on the moon is expected to start in less than a decade as major space agencies plan the construction of habitats and bases on the lunar surface. Utilisation of regolith, deposited water in the polar regions, and scrap from previous missions are expected to be important in these developments. Lunar regolith is primarily composed of metal oxides close in chemistry to mineral deposits found on the earth but with a relatively large content of fine glassy material formed from meteorite impacts. The interaction between regolith and the extracted metals, as well as their impact on slag composition and refractory performance, are critical considerations in metal production. The initial research on lunar metallurgical technologies indicates that the primary byproducts of these process will be Fe-Si alloys, along with oxygen as the main product. The paper delves into the fundamental thermodynamics associated with the production of iron-silicon (Fe-Si) alloys under lunar conditions. Thermodynamic analysis indicates that the extreme vacuum on the moon will affect significantly the required operating temperature for smelting ferro-silicon, lowering the smelting temperature by approximately 500 K. Experimental studies using Mare regolith simulants suggest that Fe-Si alloys with up to 10 wt.% Si can be readily formed using carbothermic reduction, but this also promotes chromium and phosphorus in the metal. Minimising flux additions is a critical element, given the cost of transporting materials to the moon. The predicted results of “Lunar Steelmaking” using injected Oxygen to refine these alloys will be described, including an analysis of flux and refractory requirements in the context of the restrictions of operating in an isolated environment.