

OXIDATION OF THE GIBEON IVA IRON METEORITE.

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Introduction: We continue our metal oxidation studies [1,2] in order to examine differences in oxidation products and kinetics between Gibeon iron meteorite metal and pure Fe metal.

Experimental Methods: As in [1], polished foils of Gibeon metal ($\text{Fe}_{92}\text{Ni}_{7.6}\text{Co}_{0.4}$) and pure Fe (99.994%) were heated in dry air at 700-900 °C. The reaction progress was followed gravimetrically by measuring mass gain and geometrically by measuring remnant metal and oxide layer thicknesses.

Results and Discussion: Reacted samples of Gibeon show layers of hematite and magnetite spinel overlaying the remnant metal [1]. The magnetite spinel ($\text{Ni}_x\text{Fe}_{3-x}\text{O}_4$) contains up to several percent Ni. Metal near the metal-oxide interface is enriched in Ni as Fe preferentially enters the oxides [3]. Pure Fe metal initially oxidizes to form multi-layered scales consisting primarily of wüstite in contact with metal, overlaid by thinner layers of magnetite and hematite. Once the metal is entirely consumed, wüstite is further oxidized to magnetite, which in turn oxidizes to hematite as the reaction nears completion.

Initially, oxidation of Gibeon metal follows linear kinetics (mass gain proportional to time) after which mass gain becomes proportional to $t^{0.5}$ (diffusion-controlled, parabolic kinetics). This parabolic stage is observed at all temperatures and reaction times up to ~21 days. Iron metal oxidation follows parabolic kinetics until all metal is consumed. Any linear stage is very short if present.

We find that iron metal oxidation is over two orders of magnitude faster than that of Gibeon metal at these temperatures, and our reaction rates and activation energies are consistent with literature data for pure Fe and Fe-Ni alloys [3,4]. Our 700-900 °C rate data should not be extrapolated to lower temperatures because the Arrhenius function is nonlinear over a large temperature range. Furthermore, our experiments are above the wüstite eutectoid temperature of 570 °C.

Differences in oxidation products and rates are apparently due to Ni in the meteoritic metal [1-3], which affects the oxidation process in several ways. Nickel enrichment at the metal-oxide interface introduces a barrier layer to Fe diffusion [3], slowing oxide formation. The Ni in the metal apparently suppresses wüstite formation [3,5,7] and magnetite forms instead. Iron self-diffusion in magnetite is several orders of magnitude slower than that in wüstite [6,7] so magnetite growth on Gibeon metal is slower than wüstite growth on pure Fe metal. The incorporation of Ni into magnetite also decreases Fe self-diffusion in magnetite [7] and further slows Gibeon metal oxidation.

References: [1] Visscher C.W. and Fegley B. (2001) *Meteorit. Planet. Sci.*, 36 A215. [2] Hong Y. and Fegley B (1998) *Meteorit. Planet. Sci.*, 33, 1101-1112. [3] Foley R. T. (1962) *J. Electrochem. Soc.*, 109, 1202-1206. [4] Sheasby, J.S., Boggs W.E. and Turkdogan, E.T. (1984) *Metal Science* 18, 127-136 [5] Brabers M.J. and Birchenall C.E. (1958) *Corrosion*, 14, 33-36. [6] Himmel L., Mehl R.F. and Birchenall C.E. (1953), *Trans. AIME*, 197, 827-843. [7] Condit R. H., Brabers M.J., and Birchenall C.E. (1960) *Trans. AIME*, 218, 768.

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