THE ROLE OF S IN THE EVOLUTION OF IRON METEORITE PARENT MELTS,
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Abundance of S in iron meteorites and their parent melts

The mean S abundances in iron meteorite groups are characterized by: (1) a narrow range uncorrelated with the wide ranges of elements such as Ge, having similar nebular volatilities; and (2) a large depletion relative to solar abundances even in groups in which abundances of other volatiles are solar. Even the low amounts of S found in most iron meteorites are greater than those expected from equilibrium solution in the solid during core crystallization and seem to reflect the presence of trapped liquid. Since S is nearly insoluble in the solid, it will become enriched in the melt during fractional crystallization until FeS begins to crystallize. In a core containing Fe, Ni, and S in solar proportions, this should happen after about 30% solidification. The extent of fractional solidification, g, represented by any one iron meteorite group can be inferred from the trace element behavior through the Rayleigh equation, but the change of partition coefficients with increasing S content of the melt (Narayan and Goldstein, 1980; Drake and Jones, 1981) makes this uncertain. The trends on log refractory element - log Ni diagrams are expected to change sharply in slope when FeS becomes liquidus.

The weight fraction of the core already solid when FeS begins to crystallize will be designated g here. The large trace element fractionations in group IIAB (Ir varies from 60 to 0.01 μg/g) indicate that the high-Ni, low-Ir extreme of this group corresponds to g > 0.65, at variance with g < 0.3 expected if S, like the moderately volatile siderophiles, had been present in solar abundance in the parent melt. In group IIIAB, based on its similarity to H group chondrites (Wasson and Wai, 1976), the S/Ni ratio should be lower than in group IIAB by a factor of about 4.5, and this makes it more difficult to detect any discrepancies between the g value inferred from the high-Ni, low-Ir extreme of the group and g based on its expected S abundance. However, if the estimated initial S content of the IIIAB parent magmas of 14 μg/g by Esbensen et al. (1982) is correct, this group is deficient in S by at least a factor of 6. The parent magma of group IVA was presumably still lower in S content.

Is the S deficiency real?

The trace element patterns in group IIAB indicate that either S was deficient in this group, or if it was present it did not lead to the expected discontinuities on log X - log Ni (X=trace element) diagrams. We have explored several alternative models to account for that:

A. Loss of S through volatilization. It does not appear possible to outgas S from the parent body in the absence of appreciable H-containing compounds. The nearly solar abundances of volatile siderophiles in group IIAB suggest, however, that the parent body may originally have resembled CI or CM chondrites, containing sufficient organic matter to form volatile S-compounds.

B. Liquid immiscibility. Although liquid Fe and liquid FeS are miscible in all proportions, minor elements such as P or Cr could induce immiscibility (Vogel, 1961). Solar abundances of these elements are significantly lower than that of S, but the relevant 4-component systems are not known well enough to rule out that the IIAB core was saturated with a second, S-rich liquid when it began crystallizing. Even if immiscibility commenced during formation of the IIAB suite, it need not lead to the discontinuities on log X-log Ni diagrams expected for precipitation of solid FeS if the initial amount of S-rich liquid formed were very small.

C. Organized liquid. It is possible that through a fortuitous combination of thermodynamic parameters the discontinuities on log X-log Ni diagrams
are not nearly as prominent as predicted by the Rayleigh equation, and given the scatter of data points are unnoticeable in the actually observed suite of IIAB irons. This model requires a strong unmixing tendency for liquid into metallic and sulfidic portions, relating it to the 2-liquid model (B) above, and we therefore refer to it as the "organized liquid model."

D. Metastable liquid layers by episodic melting. The first melt forming at \( \sim 1250K \) contains some 15% metal and 85% sulfide. If this melt drains to the center of the parent body, no further melting of Fe,Ni will occur until the temperature is some 500K higher. Core formation is thus likely to occur in two discrete episodes. Based on the discussion by Huppert and Sparks (1980) we expect only limited mixing to take place between the two magmas, and suggest that metastable liquid layers may have persisted in differentiated parent bodies for times comparable to their crystallization lifetimes.

Not all of these models are equally plausible, especially when the depletion of S in group IIIAB is taken into account. The presence of organic matter is unlikely in the IIAB body, and there certainly has not been enough S present to postulate liquid immiscibility at the onset of crystallization. On balance, we consider it more likely that S depletion in both the IIAB and IIIAB parent magmas was real, and that in these as well as other well-sampled groups, the high-Ni, low-Ir extreme corresponds to FeS-saturation, i.e. \( g = g_E \). The scarcity of sulfide meteorites

Even if S was depleted on most or all iron meteorite parent bodies, some material must have been formed after FeS saturation. Such material would contain \( > 80\% \) sulfide by weight (\( > 90\% \) by volume). If S was not outgassed from the parent body, but present as (immiscible or metastable) S-rich liquid, crystallization of this liquid should have produced many more sulfide meteorites. The scarcity of S-rich meteorites in our collections can be attributed to a lower resistance of sulfide meteorites to attrition in space, their lower melting point and hence higher probability of total melting during atmospheric passage, and their tendency to weather rapidly. These mechanisms do not preclude the survival of metal, without most of its sulfide complement, from post-saturation material. Its recovery probability depends mostly on its size, i.e., the grain size of the original, presumably eutectic, texture. The composition of such metal depends in part on whether fractional crystallization continues after FeS saturation. Some very small Ni-rich iron meteorites with unusual trace elements contents are possible candidates. Experimental investigation of the pertinent partition coefficients in a S-saturated Fe,Ni melt would enable us to predict the composition of post-saturation material from the composition of the high-Ni, low-Ir extremes of established groups, and that way possibly relate some unusual ungrouped meteorites to the well-sampled major groups of irons.


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