
Gallium, Ga, and Ir are the most widely used trace elements in iron meteorite taxonomy. It is usually assumed that they are completely siderophilic, at least in iron meteorite parent bodies [1]. This assumption and considerations of volatility and fractionation behavior lead to the prediction that no "magmatic" (core-derived) iron meteorites should exist that have Ge/Ga ratios greater than about 5. Although this is true for most irons, there are a few exceptions (e.g., group IIF, Eagle Station pallasites). The high Ge/Ga ratios in these meteorites may in part be due to non-siderophilic behavior of Ga [2].

In some irons, Ga is also enriched in chromite. Based on element correlations among bulk samples of Cape York troilite nodules, which contain variable amounts of chromite inclusions, it has been suspected that about 130 ppm Ga is present in chromite [3], a more than 6-fold enrichment over bulk metal.

In this study, we present proton microprobe (PIXE) data on chromite and some associated phases in the IIIA irons Cape York and Henbury, and two highly metamorphic silicate assemblages, Uden (LL7) and the Allan Hills A77081 winonaite. The PIXE data shown in Table 1 are preliminary results. Reported standard deviations are statistical uncertainties calculated by the peak fitting routine. All concentrations are normalized to Fe, and the uncertainty in the Fe determination is not included in the standard deviation.

Our analyses confirm the high Ga concentration of Cape York chromite. One might expect that this enrichment has little effect on the Ga concentration of other phases, because chromite is so rare. However, in order to explain the negative Cr-Ni correlation in most iron meteorite groups, it has been suggested [4] that chromite was a liquidus phase during the core's crystallization history. In this case the modal abundance of chromite present in iron meteorites may not reflect the actual amount of chromite that crystallized in equilibrium with metal. Chromite may have floated during solidification of the core, forming a cumulate layer at the core/mantle boundary, and this process may also have removed some Ga from the core.

Table 1. Gallium of Ge contents of chromite and associated phases in four meteorites. Data taken from the literature are identified by letters in square brackets, indicating the source reference. All other data by PIXE from this study (preliminary data).

<table>
<thead>
<tr>
<th></th>
<th>Ga</th>
<th>Ge</th>
<th>other</th>
<th>Ga</th>
<th>Ge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cape York</td>
<td>115±8</td>
<td>12±5</td>
<td>19.2[a]</td>
<td>36.0[a]</td>
<td></td>
</tr>
<tr>
<td>Henbury</td>
<td>18±7</td>
<td>11±6</td>
<td>17.7[a]</td>
<td>33.7[a]</td>
<td></td>
</tr>
<tr>
<td>A77081</td>
<td>93±7</td>
<td>&lt;7</td>
<td>52±16</td>
<td>249±14</td>
<td></td>
</tr>
<tr>
<td>Uden</td>
<td>25±7</td>
<td></td>
<td>38.3±1.9 [b]</td>
<td>330±70[b]</td>
<td></td>
</tr>
</tbody>
</table>

[a] I/RNAA [1]; [b] INAA (Schultz et al. (1982) EPSL 61, 23)
Unfortunately, the behavior of Cr during core formation is difficult to predict. Models for major and minor element behavior during differentiation of achondrite parent bodies usually assume that Cr behaves mostly lithophile [5,6], but the actual partitioning is poorly constrained. For example, in the eucrite parent body, anywhere from 0 to 65% of the total Cr may reside in phases associated with the core [5].

Core formation in a uniformly heated body may involve either one or two melting events: eutectic melting around 1230 K, and melting of metal around 1800 K [7]. The first step may not lead to segregation if the amount of S in the parent material is too low to produce a sufficient amount of eutectic melt. The second step may not take place if heating does not reach the higher temperature [8]. If eutectic melting is important, it could transport a substantial amount of Cr into the core, since Cr partitions strongly into S-rich melts [9].

From these considerations, an upper limit for the amount of Ga associated with core-derived chromite can be calculated. Assume a parent body with IIAAB-like abundances of trace elements, and a cosmic Cr/Ni ratio. If 50% of the Cr complement is fractioned into metal and sulfide liquids, the Cr concentration of the core would be close to 1% by weight. If all of this Cr forms chromite with an average Ga concentration of 115 ppm, this process would still remove only 13% of the total Ga. It thus appears that even a very drastic redistribution of Cr would have only a minor effect on Ga. This is also born out by the fact that Ga behavior can be successfully simulated with a fractional crystallization model based on laboratory partitioning data [10], without taking chromite removal into account.

There are several reasons why it is unlikely that the Ga deficit of a typical iron meteorite parent core would even come close to this upper limit. First, core segregation probably extracts less than 50% of total Cr. Second, a high extraction efficiency requires, as argued above, large amounts of sulfur. Sulfides forming in an S-rich core will take up substantial amounts of Cr, and this will decrease the amount of Cr available for chromite formation. Troilite nodules in Cape York contain about 1300 ppm Cr [3], but practically no Ga (unpublished INAA and PIXE data).

Third, even if the hypothetical chromite saturation of the core liquid is real, this chromite may not be as enriched in Ga as has been assumed in the above calculation. Table 1 shows that chromite in Henbury contains much less Ga than chromite in the otherwise very similar Cape York iron. The difference between chromite in Cape York and Henbury is that the former is associated with a large troilite nodule and presumably formed at a low temperature, whereas Henbury chromite is associated with a shock vein. For much of the core's crystallization history, temperatures of chromite formation were higher than they were in Cape York, and thus Ga may not fractionate as strongly into chromite as assumed in the above calculation.

Thus, removal of chromite during core crystallization cannot explain the high Ge/Ga ratios in some irons. However, the association of Ge with chromite, and the apparent differences in partitioning behavior in similar meteorites suggest that further study of Ga and Cr fractionations may lead to important insights into core formation and evolution.

References