FORMATION OF IRON METAL AND GRAIN COAGULATION IN THE
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The interstellar grain population in the giant molecular cloud from which the sun
formed contained little or no iron metal.1 However, thermal processing of individual
interstellar silicates in the solar nebula is likely to result in the formation of a population of
very small iron metal grains.2 If such grains are exposed to even transient magnetic fields,
each will become a tiny dipole magnet capable of interacting with other such dipoles over
spatial scales orders of magnitude larger than the radii of individual grains.3 Such
interactions will greatly increase the coagulation cross-section for this grain population.
Furthermore, the magnetic attraction between two iron dipoles will significantly increase
both the collisional sticking coefficient and the strength of the interparticle binding energy
for iron aggregates. Formation of iron metal may therefore be a key step in the aggregation
of planetesimals in a protoplanetary nebula. Such aggregates may have already been
observed in protoplanetary systems.4

Experimental studies have demonstrated the enormous increase in the coagulation
efficiency of magnetized iron particles3 and have shown that the enhancement in the
effective interaction distance (R) between two magnetic dipoles can be approximated by

\[ R = a \left[ 1 + 2 \left( \frac{4\pi}{3} \right)^{1/3} \frac{m_1 m_2}{M \mu} \frac{n_0}{V_0^2} \right]^{1/2} \]  

(1)

where \( a \) is the average particle radius, \( m_1 \) and \( m_2 \) are the magnetic pole strengths, \( M \) is the
reduced mass of the interacting particles, \( \mu \) is the magnetic permeability, \( n_0 \) is the initial
number density of iron grains and \( V_0 \) is their average relative velocity. For
\( a = 30 \text{ nm}, m_1 = m_2 = 5 \times 10^{-4} \text{ esu}, M = 7 \times 10^{-17} \text{ g}, \mu = 1, n_0 = 10^6 \text{ cm}^{-3} \) and \( V_0 = 1 \text{ cm/sec} \), equation (1) predicts an effective interaction length of \( \sim 2.5 \text{ cm} \), an enhancement
over the geometric radius by a factor of nearly 10^6.

The enhancement is directly proportional to the strength of the magnetic dipoles and
inversely proportional to the relative velocity. It is less sensitive to the reduced mass of the
interacting particles (\( \alpha M^{-1/2} \)) and almost insensitive to the initial number density of
magnetic dipoles (\( \alpha n_0^{1/6} \)). We are in the process of measuring the degree of coagulation
in our condensation flow apparatus as a function of applied magnetic field and correlating
these results by means of magnetic remanance acquisition measurements on our iron grains
with the strength of the magnetic field to which the grains are exposed. Results of the
magnetic remanence acquisition measurements and the magnetic-induced coagulation study
will be presented as well as an estimate of the importance of such processes near the
nebular midplane.

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