3636

FORMATION OF IRON METAL AND GRAIN COAGULATION IN THE SOLAR NEBULA, Joseph A. Nuth III and Otto Berg, Astrochemistry Branch, Code 691, NASA-Goddard Space Flight Center, Greenbelt, MD 20771

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 particles[3] and have shown that the enhancement in the effective interaction distance (R) between two magnetic dipoles can be approximated by

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

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, μ is the magnetic permeability, n_o is the initial number density of iron grains and V_o is their average relative velocity. For $a = 30$ nm, $m_1 = m_2 = 5 \times 10^{-4}$ esu, $M = 7 \times 10^{-17}$ g, $\mu = 1$, $n_o = 10^6$ cm^{-3} and $V_o = 1$ cm/sec, equation (1) predicts an effective interaction length of ~ 2.5 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 ($\alpha\ n_o{}^{1/6}$). 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 remanance 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.

References 1. Cassen, P. and A. Boss (1988) in Meteorites and the Early Solar System 015=/8=/01(J0. Kerridge and M. Mathews, eds.) pp 304-328 (Univ. Ariz. Pres., Tucson). 2. Nuth, J. (1989) Earth, Moon and Planets 47, 33-50. 3. Nuth, J., O. Berg, J. Faris and P. Wasilewski (1993) Icarus (in press). 4. Beckwith, S. and A. Sargent (1991) Ap. J. 381, 250-28.