MAGNETIC FRACTIONATION IN THE EARLY SOLAR SYSTEM

D.W. Strangway and N. Sugiura

Over the past few years there have been a number of studies of the remanent magnetization carried by meteorites. These have almost invariably showed that there is a magnetic field recorded by various samples. These have been recorded by a number of authors including Brecher and Arrhenius (1974), Banerjee and Hargreaves (1972), Butler (1972), Stacey et al. (1961), Sugiura et al (1979), Strangway and Sugiura (1983), Funaki et al, (1981), Nagata and Funaki (1983). Sonnett (1978) reviews data measured by Russian investigators. The picture that emerges from these studies is one of strong magnetic fields, typically 1.1-5 oersted that were present when the samples became magnetized, whether they are carbonaceous chondrites, ordinary chondrites or enstalite chondrites.

Our studies have shown that chondrules contain a stable component of magnetization which remains randomly oriented. (Sugiura and Strangway, 1983, Sugiura and Strangway, in press) in spite of accretion and other subsequent heating events. This high temperature component in chondrules suggests the presence of early fields subsequently unmodified. The matrix also appears to carry a component which in Allende is quite uniform in direction over much of the meteorite and was acquired at 320°C or less. It is not clear whether this records a heating event in the presence of a magnetic field (e.g. accretion or later metamorphism) or whether it records a chemical event (e.g. sulfidization) in the presence of a field (Wasilewski and Saralkar, 1981). In either case, the matrix also appears to record fields present in the early solar system.

Models for the accretion of the solar system include those of Alfven (1954) and Alfven and Arrhenius (1970a, b) which used the presence of strong magnetic fields to cause strong element fractionation depending upon the presence of ionized gases in the solar nebula. The resulting chemistry would be determined by the ionization potential. Dodd (1981) reviews various models and points out that the chemistry of the solar system is not consistent with a model based on ionization potentials. Current models of solar system chemistry involve accretion from a high temperature gas cloud in which there are no charged particles (Dodd, 1981). These models have been remarkably successful at explaining the chemistry of meteorites and planets. Larimer and Ander (1970) however indicate that there remains a difficulty in explaining a major fractionation between selicates and metals. They review the evidence from a chemical point of view and suggest that this fractionation took place between 1050°K and 680°K. Dodd states that "at present magnetic fractionation is the only strong candidate in a very narrow field."

The view builds on the model proposed by Harris and Tozer (1967) where they suggest that single domain particles could stick together by magnetostatic action and thereby cause the initial clumping of fine iron particles. Bonerjee (1967) remainds us that single domain particles of iron are restricted to the range from approx. 150°A to aproximately 3300°A. Below this size range, no remanence is present to cause the clumping and above this multidomains sharply reduce the magnetic moment.

In this paper, we propose a separate mechanism for the fractionation. Magnetic particles can be separated in the presence of magnetic fields and magnetic field gradients as a result of conventional magnetostatic effects

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based on the susceptibility. The meteorite magnetism shows that there were significant fields present and we suggest that as the particles grew, the more magnetic or iron-rich ones were separated by the action of these fields after the temperatures had fallen to the Curie point.

There has been much speculation on the source of such a field. Levy and Sonnett (1978) consider that the cause was either a strong solar dipole spread into the solar wind, associated with the early sun and a T-Tauri stage or with a hydromagnetic dynamo associated with the solar nebula itself. Ip (1984) suggests a further possiblity which depends upon enhancement of a field associated with an intense solar wind of charged particles interacting with the solar nebula.

The presence of a widespread magnetic field together with the presence of iron-rich particles (150°A or perhaps less due to superparamagnetion could lead to metal-silicate fractionation once the dust particle temperature is below the Curie point of iron (approx. 1050°C).

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