METAL-SILICATE FRACTIONATION IN CHONDRITIC METEORITES: EXPERIMENTS UNDER MICROGRAVITY CONDITIONS. P.H. Benoit[1], M. Franzen[1,2], J. Czlapinski[1], R.D. Godsey[1], M.C. Meyer[1], A. Straughn[1], D.W.G. Sears[1]. [1]Arkansas-Oklahoma Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR 72701 USA. pbenoit@uark.edu, [2]Department of Chemistry, Loras College, Dubuque, Iowa, 52001.

Introduction. Unequilibrated chondrites consist of three major components, matrix, chondrules, and metal/sulfide grains. Chondrules and metal/sulfide grains exhibit restricted size distributions within major chondrite groups, a phenomenon referred to as "size sorting" [1], with average sizes ranging enough to serve as a guide to meteorite classification in some cases [2].

The process responsible for the "sorting" of chondrules and metal grains is largely unknown. The only major constraints are the average sizes, and the difference in average sizes of chondrules and grains and the composition of the materials. Possible processes can be divided into two major classes: Processes occurring in space (or the early solar nebula), and processes occurring on asteroidal bodies after accretion. Within "nebular" processes, some attribute restricted size distributions to restrictions in the chondrule and metal formation process, and others attribute them to magnetic separation or velocity-based separation [3]. Post-accretionary processes have attributed sorting to passage through an early "atmosphere", or to fluidization on degassing asteroidal bodies [4, 5].

The minimum gas velocity to fluidize a bed of particles of given grain diameter (d) is:

$$v_{mf} = d^2(\rho_s - \rho_g)g/(1650*\mu)$$

For Reynolds numbers <20, where ρ_s and ρ_g are density of the particles and gas, respectively, g is gravity, and μ is the viscosity of the gas [6]. The equation is empirical and largely based on observation at 1 g.

Unlike most other suggested sorting processes, fluidization is amenable to testing in the laboratory. We have previously examined possible sorting of "chondrite-like" mixes of metal at 1 g and found that metal grains are easily separated from chondrule-sized silicates and tend to be moved to the top of a particle bed [5]. We also examined the effect of gravity on fluidization separation in a previous experiment on the KC-135 aircraft [7]. In that experiment, the data collection consisted primarily of analysis of metal/sand separation *after* the end of the flight by visual inspection and by removal of samples at intervals in the columns, using magnetic separation to determine masses of iron and sand in each fraction. A system of plungers was used to "freeze" samples after each microgravity parabola. The data showed that (smaller) metal grains tended to be concentrated in the top of each column compared with sand grains but similar results were noted for columns that had not experienced gas flow, but had been allowed to move within their tubes during the course of the flight.

In this abstract, we discuss a set of experiments intended to further evaluate the influence of gravity on fluidization of "chondrite-like" mixture of metal and silicates.

Methods. Two 35 cm diameter plexiglass tubes were fitted with a bottom gas inlet and diffuser plate, several plates being used with different shapes and sizes of holes. The top of each cylinder was closed by a gas-permeable filter. Each cyclinder contained a bed of two liters of sorted sand grains (200 µm diameter), and sorted iron filings (50 µm diameter), the iron about 5% by volume. Two digital video cameras looked at the tubes from about 15 cm distance. The tubes were hooked to a compressed air tank, air flow being controlled by a valve. The entire unit was encased in a Lexan© shield.

The experiment was placed on NASA's KC-135 aircraft during the Summer 2001 student flight opportunity campaign. The experiment flew on two days, for 30 reduced gravity parabolas each day. On each day, a two member crew accompanied the experiment, opening the gas valve at the beginning of the flight, adjusting cameras during the experiment, and making observations on behavior of the beds during the flight. The beds were fully mixed at the beginning of each flight by bubbling the beds with a high flow rate of compressed air.

Data consisted of the video record and the data records of the crew.

Results. A variety of problems occurred during the experiment. Some records were lost due to errors in camera handling, glare from the reflected sunlight through the plane's windows obscured some of the video, and one crew member was incapacitated by nausea. Observation became more obscured over time, due to retention of grains on the side of the cylinders by static electricity. Despite these problems, a record of about 40 parabolas was collected over both flights.

During each parabola, results were similar (Fig. 1). Each parabola involved a period of 2 g gravity, a short (few seconds) transition period of tenths of gravity, a period of 20-25 seconds of microgravity gravity, then a rapid transition to 2 g gravity. During the 2 g period, only occasional bubbles were observed in the beds (Fig. 1a). During the transition, the bed expands (a requirement of fludization), and a layer with a higher concentration of dark metal grains forms on the top surface of the bed, with a few small "geysers" of sand rising through the surface (Fig. 1b; Fig. 2). The bed behaves as a fluid at this point, and, in the case of this example, a minor bump causes a portion of bed to slide up over the surface layer, resulting in apparently doubled layering (Fig. 1c). Continuing into microgravity, the bed exhibits increasing turbulence, until, when gravity shifts to negative gravity, the entire bed moves to the top of the cylinder (Fig. 1d). During the rapid transition to 2 g, the entire bed quickly falls to the bottom of the cylinder.

Interpretation. Our present experiment assists in interpretation of the previous results:

Point 1. Metal/silicate separation occurs easily and reproducibly in a micro-gravity environment by fluidization.

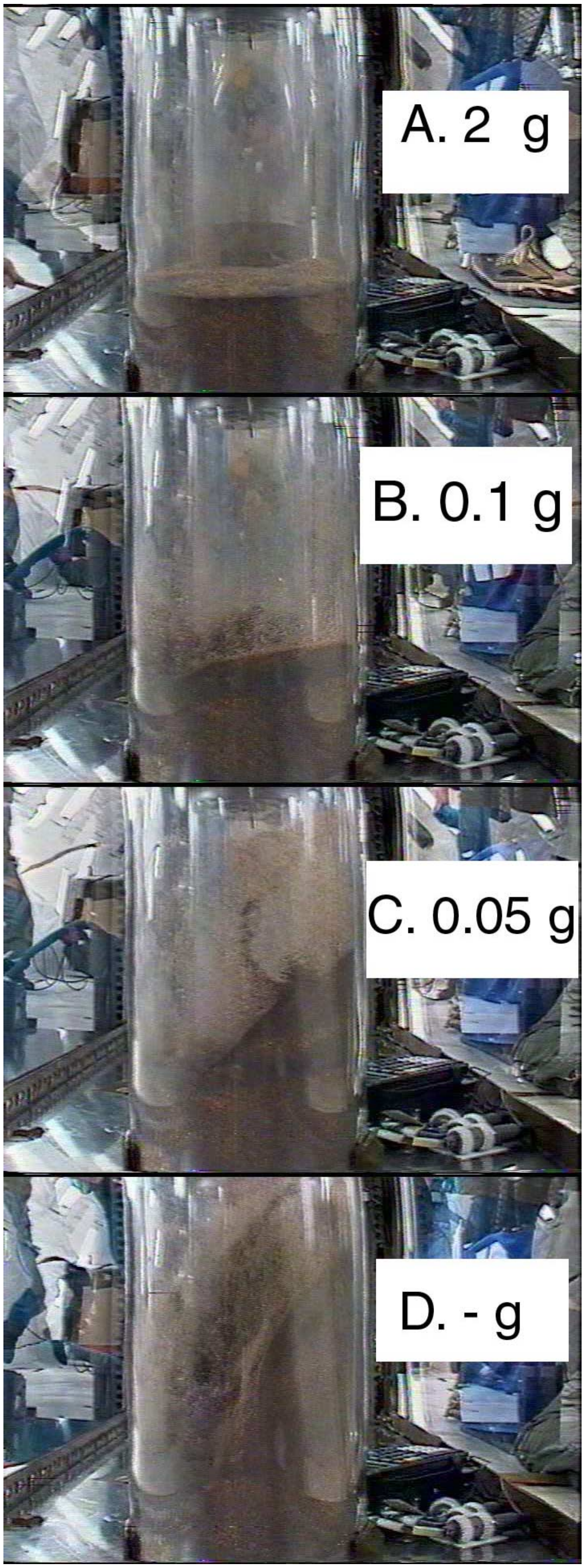

Fig. 1 Series of pictures showing results of one flight parabola with gas flow entering from the bottom of the tube. A. 2 g; B. ~0.1 g C. ~0.05 g D. Initialization of negative gravity.

Point 2. Separation is not complete, in accord with observed chondrites, which consist of mixes of metals and silicate.

Point 3. Metal grains tend to be transported to the top surface of the column. However, the present data do not allow us to make a quantitative assessment of gas flow needed for fluidization verses gravity.

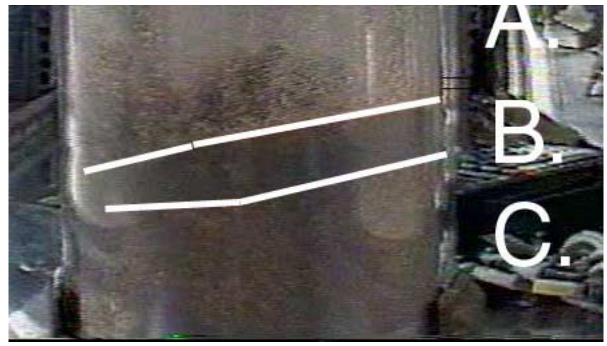

Fig. 2. Detail of Fig. 1B, showing grain separation with gas flow in reduced gravity. Dark grains are iron metal, light gray grains are quartz sand. Three grain zones are noted: A. A thin surface zone, dominated by sand, mostly carried by channels ("geysers") from zone C to the surface; B. A ~1 cm thick zone dominated by metal; C. A bottom layer of mixed sand and metal.

Conclusions. The apparent sorting within fluidized tubes in our first experiment [7] probably did reflect metal/silicate separation via fluidization. However, the separation was not as well expressed in those data than in the video of the present experiment, probably reflecting the influence of mixing and turbulence during the negative gravity portion of the parabola, an experimental artifact.

The sorting observed in the unfluidized tubes in our previous experiment probably reflects a combination of density separation and separation by mechanical vibration during the positive to negative gravity cycles. Again, this is probably largely an artifact of the experiment.

The present experiment, while not quantitative, does indicate that incorporating gravity as a factor in fluidization does not invalidate the idea, and, in fact, requires lower gas flow rates, as expected from the empirical relationship based on 1 g experiments.

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