THE PROBLEM OF INCOMPLETE MIXING OF INTERSTELLAR COMPONENTS IN THE SOLAR NEBULA: VERY HIGH PRECISION ISOTOPIC MEASUREMENTS WITH ISOPROBES P AND T. S. B. Jacobsen[1], M. C. Ranen[1], M. I. Petaev[1,2] , M.I. Smoliar[1] and E. R. Adams[2], [1]Department of Earth and Planetary Sciences, Harvard University, 20 Oxford St., Cambridge, MA 02138 USA (Jacobsen@neodymium.harvard.edu) for first author, [2]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138.

Introduction: In order to investigate the possible relationships between bulk chemical compositions, isotopic anomalies and isotopic fractionation we are measuring the bulk chemical and isotopic compositions of carbonaceous chondrites and CAIs. This data will be used to improve our understanding of the evolution of solids in the Solar Nebula.

Bulk compositions of chondritic meteorites: There are well documented volatile element depletions in most primitive meteorites as well as in terrestrial planets. One of the major shortcomings of the equilibrium condensation model is its inability to account for the observed mineralogy of primitive meteorites. The very presence of high-temperature condensates in them requires an isolation of at least a portion of such condensates from further reactions with the residual nebular gas. To take into account effects of condensate isolation, the CWPI condensation model was developed [1]. The model assumes that as condensation proceeds, a specified fraction (*isolation degree* ξ) of condensed phases is steadily withdrawn from reactive contact with the residual nebular gas, presumably as a result of growth and aggregation of condensed mineral grains (*inert or coarse* dust), while the rest (*reactive or fine* dust) continues to react with the gas. It was also found that the segregation of coarse condensates from the fine dust and residual gas could result in volatility-based fractionation patterns similar to those observed in primitive meteorites. Here we used a newer version of the CWPI model [2] to test this effect quantitatively. Figure 1 shows our results for four elements of different volatilities (Al, Si, Cr, Mn) which condense from a gas of solar composition at different conditions. We assume that chondritic meteorites represent accreted coarse dust, while fine dust and the residulal gas were somehow lost. It is obvious that equilibrium condensation (red curve) fails to account for the bulk chemistry of most chondrites. Bulk chemistry of the CM, CO, CV, and CK carbonaceous chondrites, enriched in refractory elements, requires significant isolation of condensates (green curve corresponding to ξ = 0.7%) during condensation. It is interesting that bulk Earth plots very close to this curve. We note that chondritic meteorites with obvious metal/silicate fractionation (H, L, LL, CR and CH) have been shifted from the CV-CK-CO-CM-CI trend. On the other hand, enstatite chondrites, which are depleted in refractories, could have formed in residual systems, which then must have been reprocessed later. The curves for fine dust corresponding to ξ = 0.1-0.15 % show that the enstatite chondrites cannot be complementary to the coarse dust of the CV-CK-CO-CM-CI trend. Fine dust from ξ = 0.7% ends up with much higher Si/Al ratios (~70) and has not been identified in meteorites.

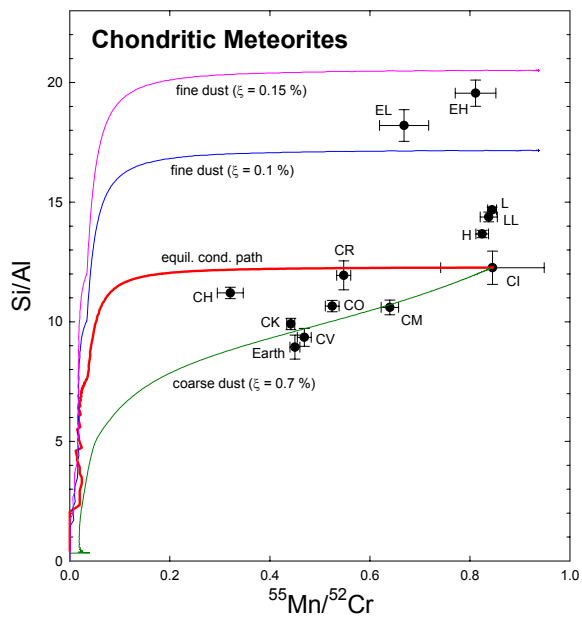

Figure 1.

Ultra-high precision isotopic ratio measurements: Recently we have acquired a new GV Instruments Isoprobe-P (a multicollector ICP-MS) and a new GV Instruments Isoprobe-T (a multicollector TI-MS). These instruments have considerable advantages over previous generations of similar instrumentation in that they both have a wide flight tube that allow for ion beams with 20 % dispersion in mass to be measured in static mode. For example, all Ca isotopes can be measured in static mode. Also, the Isoprobe-P has both a hexapole and a continuously variable mass resolution (up to 10000) in multicollecton mode capable of eliminating or resolving molecular interferences. Our goal is to obtain a resolution of ~1 ppm in our isotopic ratio measurements. Figure 2 compares the results for the Nd isotope composition and ^{142}Nd enriched standards obtained by three different TIMS instruments: the Finnigan MAT 262 and the Isoprobe-T at Harvard and the

Finnigan TRITON at Thermo Electron's demo laboratoriy in Bremen. The results obtained so far demonstrate that all three instruments yield the same $^{142}Nd/^{144}Nd$, $^{143}Nd/^{144}Nd$ and $^{145}Nd/^{144}Nd$ isotopic ratios to within a few ppm, while $^{148}Nd/^{144}Nd$ and $^{150}Nd/^{144}Nd$ ratios agree to within 10-20 ppm, with all ratios normalized to $^{146}Nd/^{144}Nd$ using the exponential law to correct for instrumental mass fractionation. The results for the enriched standards (Figures 3 and 4) show that the Isoprobe-T can yield data that are accurate to within ~3 ppm or better. Similar work done with the Isoprobe–P suggests that it can yield data that are accurate to within ~ 5 ppm or better.

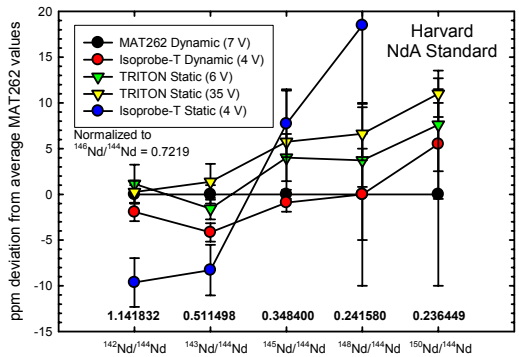

Figure 2.

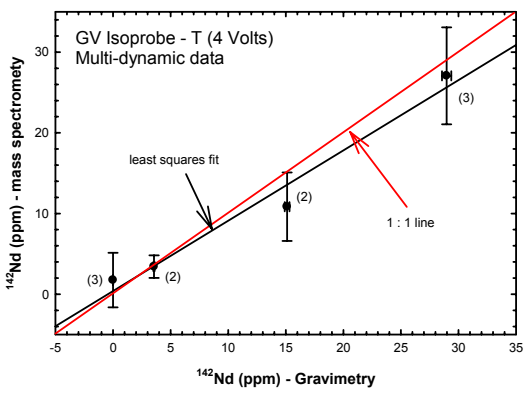

Figure 3.

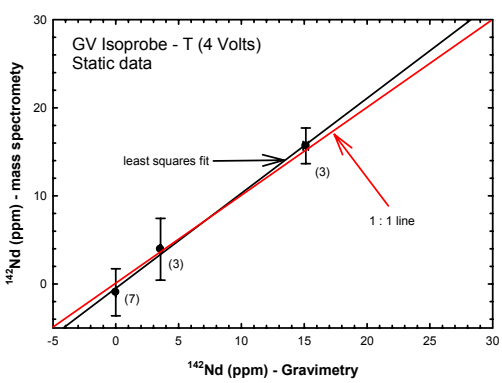

Figure 4.

Isotopic Heterogeneity of the Solar Nebula: Variations in the isotopic composition of primitive meteorites demonstrate that the presolar material aggregating to make the chondrite parent bodies and the terrestrial planets was not completely homogenized, nor was it processed at temperatures high enough to erase signatures of diverse presolar stellar sources. This is in accord with astronomical observations, which indicate that accretion disks of young stellar objects are at relatively low temperatures. The data of [3,4,5] show that the ^{53}Cr isotope variations (and $^{55}Mn/^{52}Cr$) in C-chondrites (except for CH) correlate with ^{54}Cr isotope variations. The ^{54}Cr anomalies are most likely of nucleosynthetic origin and result from incomplete homogenization of the material that formed the C-chondrites. If these meteorites represent successive coarse dust fractions as suggested in Figure 1, then it points to the addition of a new material of different Cr isotopic composition to the Solar Nebula as condensation was proceeding in the C-chondrite formation region. Also, Yin et al. [6] showed that the isotopic composition of Mo in bulk CM and CV carbonaceous chondrites is distinctly different from what is considered to be the average solar isotopic composition. Bulk CI chondrites appear to be normal in Mo isotopes [7].

Ca, Nd, Sm, Ba, Os and Sr isotopes variations in bulk chondrites and CAIs: R-process excess anomalies in Ba, Nd and Sm isotopes are well-known from studies of the highly anomalous "FUN" CAI EK1-4-1 [8], but most CAIs have much smaller effects (1-2 ε-units or less). Bulk carbonaceous chondrites have anomalies in Ba and Nd that are < 50 ppm. We now have the tools for reinvigorating the measurements of isotopic anomalies in carbonaceous chondrites and their components for a large variety elements.

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