UREILITE ATMOSPHERICS: COMING UP FOR ‘AIR’ ON A PARENT BODY.
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Introduction: The ureilite group is unusual. Petrographically, ureilites appear to be samples of a coherent suite that differentiated on a single parent body. The oxygen isotope ratios of the ureilites vary along a mass-independent fractionation (MIF) trend rather than the mass-dependent trend typical of most differentiated asteroids sample suites. The individual ureilites cannot be linked to one another by mass dependent fractionation of oxygen isotopes. Isolated lithic clasts in an individual polymict ureilite cannot be linked to a common process, by mass-dependent fractionation yet they are, by definition, samples of the same parent body. The MIF trend for oxygen is as fundamental property of ureilites, as the intense redox exchange products visible in all samples. While mixing of heterogeneous precursors might explain the variation of ureilite oxygen isotope ratios, it is implausible that such variation would survive the very high temperature processes implicit in ureilite petrography.

The petrographic/experimental evidence suggests that a “smelting” process may be responsible forming ureilites (e.g. Walker and Grove, 1993; Singletary and Grove, 2003). The smelting reaction can be written as: Fe$_2$SiO$_4$ + C $\rightarrow$ FeSiO$_3$ + CO + Fe. (A comparable reaction exists for CO$_2$). The reaction consumes graphite to reduce silicate FeO to Fe metal with CO/CO$_2$ as a by-product. The assumption is made that graphite is the reactant and CO gas, the product, even though both graphite/diamond and metal are present in most ureilites. The reaction, as stated, implies that the only mechanism, affecting the oxygen isotope ratios, is mass dependent fractionation. It provides no explicit explanation for the mass independent effects that are so characteristic of ureilites. However, if the CO acts as an oxidizing agent, in reaction with metal, and is reduced back to graphite, then the gas phase reactions can be exploited.

CO or CO$_2$ may provide oxygen in a form that enables symmetry dependent gas phase reactions to produce mass-independent enrichment of $^{16}$O relative to $^{17}$O and $^{18}$O (Theimens 1996). The reaction of such mass independent effects interacts with the solid fraction (ureilite matrix) to produce variable amounts of isotopically heavy olivine and pyroxene as well as a C-polymorph. Alternately if the process occurs in communication with the parent body surface, the presence of a transient CO atmosphere would permit photochemical disequilibrium in the form of self-shielding reactions (Clayton, 2005). In this case, the heat source for ureilite melting and the cause of the CO-photolysis reactions is likely the same – intense solar radiation +/- inductive coupling to magnetic fluctuations both associated with X-wind processing. Accretion and differentiation of a ureilite parent asteroid, should be intimately associated with at least partial mass-independent fractionation of oxygen in the parent body ‘atmosphere’. Interaction of the oxygen fugacity buffering reactions and oxygen isotopic signatures of the final lithic fragments seen in the meteorites is an inevitable consequence.

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