On the mass independent fractionations of O, Hg, Si, Mg and Cd during open-system evaporation or thermal decomposition

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Many experiments in which an element or a mineral is evaporated or thermally decomposed under vacuum are known to consistently display unexpected behaviors. These include too low rates of evaporation, smaller (i.e. closer to 1) than predicted fractionation factors, and an inconsistent behavior of the stable isotope ratios of a given element (i.e. mass-independent fractionation). This applies to many elements including O, Hg, Si, Mg and Cd.

We present interpretations for a series of earlier observations, including experiments by Miller *et al.* (2002) in which mass-independent O isotope fractionations are produced during thermal decomposition of carbonates [1], and the finding of Estrade *et al.* (2009) showing an unexpected slope in a plot of Δ^{199}Hg vs Δ^{201}Hg (close to 1.2 instead of 2.4) during open-system evaporation of Hg [2].

These and related results can be explained if a fraction (usually a few to several tens of percent) of the evaporated compounds actually forms (or re-equilibrate) under conditions of isotope equilibrium, the remaining fraction obeying kinetic fractionation of its stable isotopes. This is the mixing of the that results in the appearance of mass-independence, rather than the action of a novel isotope effect having non-cannonical mass law.

[1] Miller M.F. *et al.* (2002) *PNAS* **99**, 10988–10993. [2] Estrade N. *et al.* (2009) *Geochim. Cosmochim. Acta* **73**, 2693-2711.

Howardite noble gases as indicators of asteroid surface processing

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Introduction and Research Objective:

The HED (Howardite, Eucrite and Diogenite) group meteorites likely originate from the Asteroid 4 Vesta [1] - one of two asteroid targets of NASA's Dawn mission [2]. Whilst Howardites are polymict breccias of eucritic and diogenitic material that often contain "regolithic" petrological features, neither their exact regolithic nature nor their formation processes are well defined [3-4]. As the Solar Wind (SW) noble gas component is implanted onto surfaces of solar system bodies, noble gas analyses of Howardites provides a key indicator of regolithic origin. In addition to SW, previous work by [5] suggested that restricted Ni (300-1200 μg/g) and Al_2O_3 (8-9 wt%) contents may indicate an ancient well-mixed regolith. Our research combines petrological, compositional and noble gas analyses to help improve understanding of asteroid regolith formation processes, which will play an intergral part in the interpretation of Dawn mission data.

Methodology:

Following compositional and petrological analyses [4,6], we developed a regolith grading scheme for our sample set of 30 Howardites and polymict Eucrites [4]. In order to test the regolith indicators suggested by [5], our 8 selected samples exhibited a range of Ni, Al_2O_3 contents and regolithic grades. Noble gas analyses were performed using furnace step-heating on our MAP 215-50 noble gas mass spectrometer.

Discussion of Results:

Of our 8 howardites, only 3 showed evidence of SW noble gases (e.g approaching ^{20}Ne/^{22}Ne ~ 13.75, ^{21}Ne/^{22}Ne ~ 0.033 [7]). As these samples display low regolithic grades and a range of Ni and Al_2O_3 contents, so far we are unable to find any correlation between these indicators and "regolithic" origin. These results have a number of implications for both Howardite and Vesta formation, and may suggest complex surface stratigraphies and surface-gardening processes.

[1] Drake M.J. (2001) *MAPS* **36**:501-513. [2] Rayman, M.D. *et al.* (2006) *Acta Astronautica* **58**:605-616. [3] Mittlefehldt, D.W. *et al.* (1998) *Rev. Min.* **36**: 4.1-4.195. [4] Cartwright, J.A. *et al.* (2011) *LPSC XLII* (abs. # 2655). [5] Warren, P.H. *et al.* (2009) *GCA* **73**:5918-5943. [6] Mittlefehldt, D.W. *et al.* (2010) *LPSC XLI* (abs. #2655). [7] Grimberg, A. *et al.* (2008) *GCA* **72**:626-645.