Noble Gas Study of the Hamlet Meteorite (LL4).

Sachiko Amari[1], Yukie Sabe[2], Tomokazu Shiraishi[2] and Jun-ichi Matsuda[2], [1]McDonnell Center for the Space Sciences and the Physics Department, Washington University, St. Louis, MO 63130, USA, [2]Department of Earth and Space Science, Osaka University, Osaka, 560-0043, Japan.

Introduction:

Heavy noble gases in primitive meteorites are contained in a very small portion (< 1 %) of meteorites [1]. This phase was dubbed Q for quintessence [1]. It is most likely carbonaceous matter [2, 3] but the exact nature of Q remains enigmatic.

In a continued effort to better understand Q [4-7], we separated an HF-HCl residue from Hamlet (LL4) and analyzed noble gases in the residue and the bulk meteorite. It has been shown that the more thermal metamorphism meteorites experienced, the more SiC, diamond, and Q were destroyed, and that Q is most resistant among the three phases [8]. Thus, Hamlet may still contain Q, but not SiC and diamond. Since Q and diamond are hard to separate from each other, a sole presence of Q would help us study characteristics of Q in Hamlet.

Experimental:

The separation was carried out at Washington University in St. Louis, USA. Fragments that weighed 3.47 g were treated alternately with HF-HCl and HCl to dissolve silicates. Elemental sulfur was removed with CS_2. The residue comprised 1.11 % of the starting material.

Noble gases in the bulk meteorites and the HF-HCl residue were analyzed by step-wise heating at Osaka University, Japan. The temperature steps were 600, 800, 1000, 1200, 1400 and 1600°C for both samples. Since the noble gas concentrations in the 1600°C fraction in the HF-HCl residue were so low, only element abundances were determined.

Results and Discussion:

The ^{84}Kr and ^{132}Xe concentrations in our bulk sample are 1.24×10^{-9} and 1.40×10^{-9} cm^{3}STP/g, respectively. They are 2.2 and 2.8 times higher than those of the same meteorite by Alaerts et al. [9]. However, ^{4}He, ^{22}Ne and ^{36}Ar concentrations are comparable in the two studies, indicating Q is more abundant in our bulk sample. We concluded that the difference was due to heterogeneity in the meteorites. Such substantial differences in samples from the same meteorite are not uncommon: the ^{132}Xe concentration of an HF-HCl residue from the Ornans meteorite (CO3.3) was 1.18×10^{-6} cm^{3}STP/g by Srinivasan et al. [10], but that by Alaerts et al. [11] was 4.62×10^{-7} cm^{3}STP/g, significantly lower than the former.

The ^{132}Xe concentration of the HF-HCl residue is 9.24×10^{-8} cm^{3}STP/g, indicating that Q was enriched 66 times from the bulk sample. The mass balance calculation indicates that 73 percent of the Xe in the bulk sample remains in the HF-HCl residue.

In a ^{134}Xe/^{132}Xe – ^{136}Xe/^{132}Xe plot, the Xe in the residue were shown with that of Q (=P1) [8, 12] and air (Fig. 1). All data points except that of the 1400°C fraction plot around Q. Diamond carries Xe-HL, which has high ^{134}Xe/^{132}Xe and ^{136}Xe/^{132}Xe ratios (0.6361 and 0.7, respectively) [13] and plots outside of the figure. Thus, the HF-HCl residue contains only Q but not diamond.

The Ne in both bulk sample and HF-HCl residue show an overwhelming presence of cosmogenic Ne (Fig. 2). The total Ne in the bulk sample plots very close to a typical cosmogenic Ne [14]. Even after removing silicates, the HF-HCl residue still contains a significant amount of cosmogenic Ne. The Ne data points lie on a straight line, which is explained by a two-component mixture, Hamlet Ne-Q and cosmogenic Ne. Interestingly, the mixing line does not go through the typical cosmogenic Ne: the cosmogenic component in the HF-HCl residue contains less ^{21}Ne than the typical cosmogenic Ne. This may be due to the difference of mineral compositions in the bulk sample and the HF-HCl residue. In the former, silicates are dominant, thus Mg and Si are target elements. In the latter, where all silicates are removed, oxides must be a significant component.

In order to determine the ^{20}Ne/^{22}Ne ratio of the other end member, Hamlet Ne-Q, we needed to assume what the ^{21}Ne/^{22}Ne ratio of Hamlet Ne-Q would be. We took 0.029 as the ratio. It was because ^{21}Ne/^{22}Ne ratios of Ne-Q from many meteorites are ~ 0.029 [7, 12]. The ^{20}Ne/^{22}Ne of Hamlet Ne-Q was determined to be 11.0 ± 0.5.

It has been known that ^{20}Ne/^{22}Ne ratios of Ne-Q vary in different meteorites and that they can be divided into two groups [8, 12]. The first group has ^{20}Ne/^{22}Ne ratios of 10.11 ± 0.04 and the second group has those of 10.57 ± 0.19 [12]. The meteorites of the first group include Lnacé (CO3.4), and Cold Bokkeveld (CM2), and those of the second group include Allende (CV3), Chainpur (LL3.4), Grosnaja (CV3) and Murchison (CM2). Hamlet Ne-Q obviously falls into the second group.

References:

[1] Lewis R. S. et al. (1975) *Science*, 190, 1251-1262. [2] Reynolds J. H. et al. (1978) *Geochim. Cosmochim. Acta*, 42, 1775-1797. [3] Ott U. et al. (1981) *Geochim. Cosmochim. Acta*, 45, 1751-1788. [4] Amari S. et al. (2003) *Geochim. Cosmochim. Acta*, 67, 4665-4677. [5] Matsuda J. et al. (2009) *Geochemical J.*, 43, 323-329. [6] Matsuda J. et al.

(2010) *Geochem. Cosmochim. Acta*, 74, 5398-5409. [7] Matsuda J. et al. (2010) *Meteorit. Planet. Sci.*, 45, 361-372. [8] Huss G. R. et al. (1996) *Geochim. Cosmochim. Acta*, 60, 3311-3340. [9] Alaerts L. et al. (1979) *Geochim. Cosmochim. Acta*, 43, 1399-1415. [10] Srinivasan B. et al. (1977) *J. Geophys. Res.*, 82, 762-778. [11] Alaerts L. et al. (1979) *Geochim. Cosmochim. Acta*, 43, 1421-1432. [12] Busemann H. et al. (2000) *Meteorit. Planet. Sci.*, 35, 949-973. [13] Huss G. R. and Lewis R. S. (1994) *Meteoritics*, 29, 791-810. [14] Ozima M. and Podosek F. A. (1983) Noble Gas Geochemistry, Cambridge University Press, pp. 357.

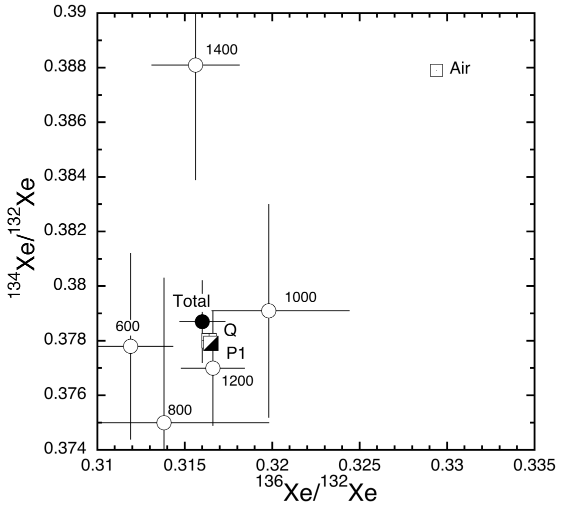

Fig. 1. $^{134}Xe/^{132}Xe$ vs. $^{136}Xe/^{132}Xe$ plot for the HF-HCl residue. The numbers indicate temperatures of the steps.

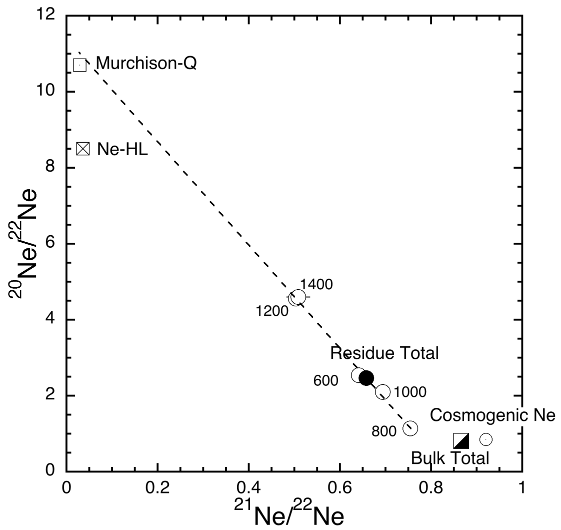

Fig. 2. Ne three-isotope plot for the HF-HCl residue. The data points form all temperature steps lie on a straight line, indicating the Ne in the residue is a two-component mixture.