Heavy noble gas in eucrites and diogenites: An attempt to understand the trapped components

Satvika Jaiswal[1*,] , Ramakant R. Mahajan[2#,] Mamata Ngangom[1]
[1]Banasthali Vidyapith, Rajasthan, 304022, India; [2]Physical Research Laboratory, Ahmedabad, 380009, India.
Emails: *jaswalsatvika@gmail.com, #ramakant@prl.res.in

Introduction: Eucrites and diogenites are achondrite meteorites originated from differentiated parent body and they are the products of igneous proceses [1-2]. Eucrites are mafic igneous rocks of pyroxene-plagioclase rich. They are likely derived from subsurface [2]. Diogenites are coarse-grained monomict orthopyroxene-rich cumulates that likely formed from a fractionally crystallising magma. Their clear plutonic features are indicative of an deeper region origin [1-2]. Planetary bodies in inner solar system such as Earth, Moon, Mars are differentiated and we don't have direct samples from their interior. Therefore the achondrites eucrites and diogenites are best suited for comparison and understanding various processes in planetology.

Achondrites are known of which eucrites and diogenites have been studied by noble gas mass spectroscopy in the past. Nonetheless, our knowledge of their trapped component remained rather sketchy.

Studying HED clan provide unique opportunity into the processes involved in volatile evolution of the early solar system processes. Howardite are studied by [3-5] in details. Here we sutdied the cases of eucrites and diogenites. In this work, we present a data set of Ar, Kr, Xe elemental composition of eucrites and diogenites, complied from literature to understand the trapped components in the HED parent body.

Data set and methodology: We took the data from literature (full list of references and data set is available with authors upon request). The present study, which has been carried out to assess the abundance and isotopic composition of heavy noble gases in the Eucrites based on bulk samples on a wide variety of measurements from the literature data. The main problem addressed are centered around the identification of the trapped component with the help of heavy noble gases: Argon, Krypton and Xenon. In the following discussion 't' denotes the trapped value. We use the methodology given in [5] for calculating the concentrations of trapped gases.

We considered only the 'total' gas concentrations in the samples. We determined the abundances of trapped gases, ^{36}Ar, ^{84}Kr and ^{132}Xe in eucrites and diogenites using concentrations in the bulk sample measurements. The ranges and average concentrations of trapped gases ^{36}Ar, ^{84}Kr and ^{132}Xe are given in Table 1 for eucrites, diogenites and howardites. For howardites use use the data set given in references [3-5].

Discussion: The average abundances of trapped gases ^{36}Ar, ^{84}Kr and ^{132}Xe in eucritics are: $2.49 \text{x} 10^{-9}$ cm^{3}STP/g, $4.98 \text{x} 10^{-11}$ cm^{3}STP/g and $1.63 \text{x} 10^{-10}$ cm^{3}STP/g, respectively. The average abundances of ^{36}Ar, ^{84}Kr and ^{132}Xe in diogenites are: 8.23×10^{-10} cm^{3}STP/g, 1.21×10^{-10} cm^{3}STP/g and 7.83×10^{-12} cm^{3}STP/g, respectively.

Table 1. Concentrations of the trapped noble gases (Ar, Kr and Xe) in eucrites, diogenites and howardites. Concentrations of noble gases are in cm^{3}STP/g,

Element	Eucrites	Diogenites	Howardites
^{36} Ar$_{min}$	2.26×10^{-11}	6.50×10^{-11}	1.28×10^{-9}
^{36} Ar$_{max}$	7.41×10^{-09}	2.10×10^{-09}	3.68×10^{-7}
^{36} Ar$_{average}$	2.49×10^{-09}	8.23×10^{-10}	5.42×10^{-08}
^{84}Kr$_{min}$	7.87×10^{-12}	1.72×10^{-11}	1.99×10^{-11}
^{84}Kr$_{max}$	2.66×10^{-10}	3.05×10^{-10}	3.67×10^{-09}
^{84}Kr$_{average}$	4.98×10^{-11}	1.21×10^{-10}	3.18×10^{-10}
^{132}Xe$_{min}$	5.92×10^{-12}	2.79×10^{-13}	1.14×10^{-11}
^{132}Xe$_{max}$	6.77×10^{-10}	1.90×10^{-11}	3.99×10^{-09}
^{132}Xe$_{average}$	1.63×10^{-10}	7.83×10^{-12}	3.11×10^{-10}
References	This work	This work	[3-5, 12]

The ranges of concentrations of ^{36}Ar, ^{84}Kr and ^{132}Xe in the eucrites and diogenties are differ to the howardites (Table 1) [3-5].

To gain insights in the understanding of the trapped components present in samples, we have plotted Fig.1, which is a three element plot of trapped $(^{36}\text{Ar}/^{132}\text{Xe})_t$ and $(^{84}\text{Kr}/^{132}\text{Xe})_t$ ratio for the samples.

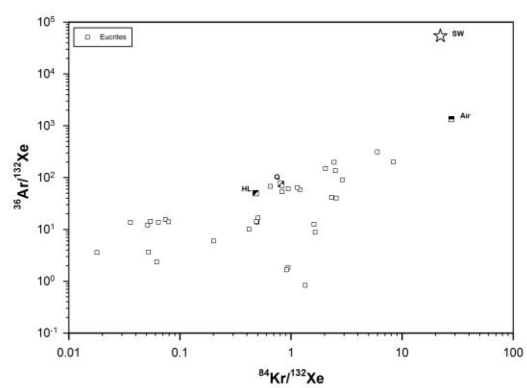

Fig. 1: Plot of $(^{36}\text{Ar}/^{132}\text{Xe})_t$ and $(^{84}\text{Kr}/^{132}\text{Xe})_t$ ratio for the eucrites.

Also plotted the components such as solar wind (SW) [9], Q component [10], HL component [11] and air (EA) [8] in Fig. 1, for the comparison.

The plot shows that Q-gas is the one of the component present in the eucrites. Majority of the sample data points fall below the Q–Air line on $^{36}Ar/^{132}Xe$ axis. Some samples fall towards lest of Q-gas on $^{84}Kr/^{132}Xe$ axis.

Elemental ratios of $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ are distinct in most of the eucritic samples compared to Q-Air mixing and hence cannot be explained by a mixture of phase Q type and atmospheric gases.
The data set do not show evidence for presence of solar wind gases in eucrites.

Part of the data of elemental ratios of $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ in eucrites can be explained by elemental fractionation, but not for all the data set.

Here we have used the concentrations of trapped gases, Ar, Kr and Xe in eucrites and diogenites and compared them with different reservoir of the solar system. The concentrations of trapped noble gases in Chassigny, carbonaceous chondrites and Mid Ocean Ridge Basalt (MORB) are given in Table 2.

Table 2. Concentrations of the trapped noble gases (Ar, Kr and Xe) in Chassiginy, carbonaceous chondrites, MORB. Concentrations of noble gases are in cm^3STP/g.

Reservoir	^{36}Ar	^{84}Kr	^{132}Xe	References
Chassigny	2.02×10^{-9}	8.27×10^{-11}	4.6×10^{-11}	[6]
Carbonceous Chondrites	6.82×10^{-7}	0.64×10^{-8}	0.46×10^{-8}	[7]
MORB	0.57×10^{-9}	14×10^{-12}	2×10^{-12}	[8]

We compare the concentrations of trapped noble gases with Chassigny, a representative of interior of Mars, carbonaceous chondrites, the accretating material of the parent bodies and MORB, the representative of interior of Earth. The concentrations of ^{36}Ar, ^{84}Kr and ^{132}Xe in eucrites and diogenites clearly shows depletion with respect to the carbonaceous chondrites. The depletion is result of loss of noble gases because of degassing occured during the melting of the HED parent body. The gases were lost to space and hence leads to the depletion in interior of HED parent body.

The concentrations of ^{36}Ar, ^{84}Kr and ^{132}Xe in eucrites and diogenites are similar to that of Chassigny and MORB. This indicates the similarity of loss or retention of noble gases in interiors of HED parent body compared with the interiors of Mars and Earth. The conentrations of ^{36}Ar, ^{84}Kr and ^{132}Xe in eucrites and diogenites are order than the lunar meteorites [13]. The lunar meteorites are rich in the gases derived either from SW implantation or through the contamination from impacted materials.

Conclusions: Trapped noble gases (Ar, Kr and Xe) indicates that depleted amounts of gases are present in eucrite and diogenites compared to carbonaceous chondrites. The elemental ratios of $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ in the eucrites differs than SW and air.

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