# NOBLE GAS ELEMENTAL RATIOS OF GHUBARA, REVEALED BY STEPWISE COMBUSTION AND CRUSHING METHODS.

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**Introduction:** The Ghubara meteorite (L5, S4, W1) contains significant concentrations of extraterrestrial trapped gases (mostly of solar origin) related to voids of high temperature phases [1,2]. As a next step, we conducted a combined noble gas, nitrogen, and carbon stepwise crushing and combustion study for different lithologies (host, xenolith, impact melt inclusion) of this L chondrite. The information on the petrography and mineralogy of these samples is available in [1]. Here we report the results on noble gas elemental ratios of analysed samples.

**Results and discussion:** The amounts of $^{36}$Ar obtained by total extraction are (7-43)×$10^{-8}$ cm$^3$ STP/g and are comparable with these reported in literature (7-79)×$10^{-8}$ cm$^3$ STP/g [3]. However, our data for $^{4}$He (326-1207) and $^{20}$Ne (10-40) show higher concentrations than published values: $^{4}$He (1-201) and $^{20}$Ne (0.08-11) [3], in units ×$10^{-6}$ cm$^3$ STP/g. The $^{4}$He/$^{36}$Ar (755-2772 for crushing and 3146-5536 for combustion) and $^{4}$He/$^{20}$Ne (8-27 for crushing and 27-41 for combustion) ratios are strongly fractionated relative to the SW composition [4] as usual showing deficit of He, but in much lesser extent than previously measured [3]. The $^{20}$Ne/$^{36}$Ar ratios of the analyzed samples are very unusual for meteorites: $^{20}$Ne is enriched relative to $^{36}$Ar compared to the SW composition. The $^{20}$Ne/$^{36}$Ar ratios in individual steps of crushed material and the totals obtained by both techniques show rather similar values (86-152). Individual combustion steps can be affected by diffusional fractionation upon stepwise heating extractions. But in the host sample Ne and Ar are released during stepped combustion simultaneously at 1200°C, and the $^{20}$Ne/$^{36}$Ar ratio of this step remains identical to the totals. Along with that, the lower than solar $^{20}$Ne/$^{36}$Ar ratios have been reported in all the Ghubara analyses before [3]. We, however, do not see any reasons to think that the measured high $^{20}$Ne/$^{36}$Ar ratios observed in the present study are related to an analytical artifact. The variations of noble gas elemental compositions and contents are rather related to the heterogeneity of the Ghubara breccia that is evident from a wide range of $^{20}$Ne/$^{22}$Ne ratio variations (1.61-13.75) in different specimens [3]. Although the deficit of light noble gases is common for stone material of the solar system, excess of light noble gases (particularly helium) is also observed: in terrestrial basalt glasses, due to higher solubility and vesicle-melt partitioning [5-7] and rarely in meteorites where high $^{20}$Ne/$^{36}$Ar ratios are not related to high abundance of cosmogenic $^{20}$Ne [8-10]. The elemental ratios of the total cosmogenic $^{21}$Ne and $^{38}$Ar released by crushing (($^{21}$Ne/$^{38}$Ar)$_{cos}$=4-8) are unfractionated compared to the production rate ratios for these isotopes (($^{21}$Ne/$^{38}$Ar)$_{cos}$=7-9) evaluated using [11] for the L-chondrite major element composition and the meteoroid radius of 85 cm defined for Ghubara by [12]. The "normal" ($^{21}$Ne/$^{38}$Ar)$_{cos}$ ratios and $^{21}$Ne$_{cos}$ concentrations ((3.3-6.4)×$10^{-8}$ cm$^3$ STP/g) identical to the literature ones ((3.20-5.36)×$10^{-8}$ cm$^3$ STP/g; [12]) give additional evidences of the correctness for the unusually high ($^{20}$Ne/$^{36}$Ar)$_{trapped}$ ratios.

The genesis of trapped Ar with isotopic composition different from primordial/solar/terrestrial in samples of asteroidal origin is considered to be linked with the mobilization of solar, cosmogenic or radiogenic Ar components during thermal processing leading to their redistribution into voids [13]. Similar scenario for the origin of the trapped noble gases has been suggested by [14] based on the crushing experiments with enstatite chondrites. Inter alia, the presence of trapped gases in Ghubara is obviously related with the major impact event that resulted in the last total reset of K-Ar system 470 Ma ago for most L chondrites [1] and induced extensive degassing of the parent body asteroid. Two mechanisms of gas redistribution during thermal process seem to be possible: i) diffusional redistribution of accumulated gases within the rock, ii) trapping of gases released from surrounding rocks (e.g., gases released from deeper hot rocks are trapped by shallow cooling rocks). The latter mechanism could explain the enhanced Ne/Ar ratios and higher light noble gas contents compared to the published results in the analysed Ghubara samples, if the neighboring rocks lost light noble gases preferentially over the heavy ones. Helium could be subsequently lost during solar heating and/or late mild impacts resulted in reduction of the $^{4}$He/$^{20}$Ne and $^{4}$He/$^{36}$Ar ratios to the values below solar. Although it could escape in large extent during the process of gas redistribution at 470 Ma event.

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