Lohawat howardite: trapped noble gases and nitrogen isotopic signature

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Howardites, the members of HED (howardite, eucrite and diogenite) family, are the mechanical mixtures of eucritic and diogenitic material cemented by fine dust, with various constituents like melt spherules, remnants of impactor and enriched in solar noble gases (Cartwright et al., 2014). Asteroid Vesta is linked to HEDs as their parent body (McSween et al., 2019). Howardites provide an important clue about the processes occurred in past at the asteroidal surface, such as solar wind implantation, characterization of impactors, regolith processing. Noble gases are useful trace elements as isotopic anomalies are detected due to their scarcity in solid materials. In eucrites and diogenites, trapped solar gases are absent (for neon: Jaiswal et. al., 2022). Howardites are enriched with trapped noble gases (Cartwright et al., 2014; Mahajan et al., 2019). Noble gas studies in different howardites and their constituents comprises solar noble gases, which indicates that these constituents, before agglomeration, resided at the very top of the Vestan regolith.

Lohawat howardite is a texturally heterogeneous breccia having a variety of lithic fragments and minerals (Sisodia et al., 2001). The noble gases and nitrogen were extracted from a single chip weighing 577.38 mg and light noble gases were discussed earlier (Sisodia et al., 2001), while here, nitrogen and Kr-Xe from the same sample are discussed. The measured concentration and isotopic ratios for N, Kr, and Xe are presented in Table 1. The values in Table 1 are corrected for blanks, interferences and mass spectrometric corrections.

The concentration of trapped $^{84}Kr_t$ is (9.92 ± 1.4) x 10^{-11} cm^3STP/g, and that of $^{132}Xe_t$ is (4.84 ± 0.69) x 10^{-11} cm^3STP/g. The elemental ratio $^{84}Kr_t/^{132}Xe_t$ for Lohawat is 2.05 ± 0.41 and is in agreement with the aliquots studied earlier, 1.09 ± 0.23 and 1.96 ± 0.36, L1 and L2, respectively (Mahajan et al., 2019). The Kr and Xe isotopic ratios in stepwise extractions (Table 1) span in the region of Q-SW-HL-GCR in respective plots (not show here).

The trapped nitrogen composition, $\delta^{15}N_t$ is estimated by adopting the systematics given by Hashizume and Sugiura (1995) and Mahajan et al. (2019). The trapped nitrogen in this sample is, $\delta^{15}N_t$ = +18.4 ± 0.4 ‰. Trapped nitrogen values of ($\delta^{15}N_t$ in ‰) L1 = -41.7 ± 2.2 and L2 = -51.4 ± 0.7 were reported in bulk aliquots of Lohawat (Mahajan et al., 2019). This indicates that trapped nitrogen in Lohawat howardite is highly heterogeneous. Isotopic composition of trapped nitrogen in bulk samples of eucrites ranges from -52.9 ‰ to +22.4 ‰ (Miura and Sugiura, 1993; Mahajan et al., 2019). The observed $\delta^{15}N_t$ in eucrites can be explained as heterogeneous isotopic characteristics in subsurface / lower crust material of Vesta. The composition in Lohawat howardite can be explained as either is manifestation of fragments of various eucrites possessing variety of N isotopic signatures or alternatively with one eucrite type signature mixed with impactors possessing various N signature.

Table 1. Measured noble gases and nitrogen in Lohawat howardite

Isotope	Temperature 400°C	Temperature 1000°C	Temperature 1600°C	Total
N (ppm)	0.43 ± 0.01	0.58 ± 0.03	0.12 ± 0.01	1.12 ± 0.06
$\delta^{15}N$	15.73 ± 1.55	100.23 ± 1.55	270.90 ± 2.73	85.49 ± 1.67
^{84}Kr cm^3STP/g, x 10^{-12}	4.96 ± 0.15	54.90 ± 0.05	55.64 ± 0.05	11.55 ± 3.78
$^{78}Kr/^{84}Kr$	0.0215 ± 0.0026	0.0471 ± 0.0007	0.0557 ± 0.009	0.0502 ± 0.0009
$^{80}Kr/^{84}Kr$	0.0348 ± 0.0136	0.1380 ± 0.0011	0.1602 ± 0.0011	0.1442 ± 0.0016
$^{82}Kr/^{84}Kr$	0.2327 ± 0.0005	0.3315 ± 0.0014	0.3699 ± 0.0008	0.3457 ± 0.0011
$^{83}Kr/^{84}Kr$	0.2297 ± 0.0002	0.3738 ± 0.0011	0.4307 ± 0.0008	0.3950 ± 0.0009
$^{86}Kr/^{84}Kr$	0.3084 ± 0.0006	0.3103 ± 0.0010	0.3019 ± 0.0013	0.3062 ± 0.0011
^{132}Xe cm^3STP/g, x 10^{-12}	2.50 ± 0.07	25.81 ± 0.02	22.02 ± 0.02	50.33 ± 0.16
$^{124}Xe/^{132}Xe$	0.0207 ± 0.0002	0.0228 ± 0.0002	0.0392 ± 0.0005	0.0298 ± 0.0004
$^{126}Xe/^{132}Xe$	0.0241 ± 0.0002	0.0374 ± 0.0006	0.0655 ± 0.0005	0.0490 ± 0.0005
$^{128}Xe/^{132}Xe$	0.0895 ± 0.0004	0.1204 ±0.0016	0.1530 ± 0.0009	0.1331 ± 0.0012
$^{129}Xe/^{132}Xe$	0.9275 ± 0.0032	1.1110 ± 0.0042	0.9627 ± 0.0072	1.0307 ± 0.0055
$^{130}Xe/^{132}Xe$	0.1658 ± 0.0003	0.1760 ± 0.0004	0.1811 ± 0.0025	0.1777 ± 0.0014
$^{131}Xe/^{132}Xe$	0.8239 ± 0.0008	0.8473 ± 0.0034	0.8854 ± 0.0053	0.8628 ± 0.0041
$^{134}Xe/^{132}Xe$	0.3721 ± 0.0008	0.4118 ± 0.0012	0.5036 ± 0.0012	0.4499 ± 0.0012
$^{136}Xe/^{132}Xe$	0.3254 ± 0.0014	0.3594 ± 0.0017	0.4642 ± 0.0021	0.4035 ± 0.0019

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