Ordinary chondrites: nitrogen systematics

Ramakant R. Mahajan[1]

[1]*Physical Research Laboratory, Ahmedabad, Gujarat, 380009, India (email: ramakant@prl.res.in)*

Introduction: The N isotopic anomalies observed in primitive meteorites are likely to be originated from the nucleosynthetic processes in the stellar evolution. Alternatively, to explain the anomalies, processes such as self-shielding and low-temperature ion-molecule reactions inside the protoplanetary disk can be considered. These anomalies should be erased in post-accretionary processes such as thermal and aqueous alterations that occurred in the asteroids. In thermally and aqueously altered object, creation of a new N component, with distinct signature than the original, is expected. Ordinary chondrites (OC's) offer a possibility for studying the composition obtained from the nebula and new component derived from the post-accretionary processed in the asteroids. OC's are actually important candidates, possibly linking between the carbonaceous chondrites and the differentiated objects. In order to improve the understanding of the nitrogen isotopic evolution and constrain the N component, here the nitrogen signature of the ordinary chondrites is investigated. Also, how much extent, the original nebular N signature is retained and that carried forward, is need to examine.

Experimental: Gas extraction has been carried out by stepwise heating. Nitrogen and noble gases have been analysed by standard procedures (most recently given in Mahajan et al., 2019), and the measurements were in the same aliquot. Noble gas composition was reported elsewhere (Bhandari et al., 2005, 2008; Dhingra et al., 2004; Ghosh et al., 2002), here, the nitrogen composition is presented.

Nitrogen: The measured data of N in the ordinary chondrites is presented in Table 1 ('-' in table 1 indicates that experiment not conducts at this temperature). The N concentration in the OC's is span between 1.34 to 11.1 ppm, and is within the range of ordinary chondrites. The two aliquots of Kendrapara, A and B are from different locations of the main mass (Dhingra et al., 2004). It is observed from measurements in the two aliquot that, there is variation of nitrogen composition in intra-meteorite. Interestingly, the two aliquots do not show heterogeneity in the noble gas systematics.

Table 1. Nitrogen composition, T is temperature in ^{o}C.

T	Ararki (L5)		Bhawad (LL6)		Sabrum (LL6)		Kendrapara-A (H5)		Kendrapara-B (H5)	
	N ppm	δ^{15}N ‰	N ppm	δ^{15}N ‰	N ppm	δ^{15}N ‰	N ppm	δ^{15}N ‰	N ppm	δ^{15}N ‰
400	0.79	11.0 ± 0.2	0.30	17.3 ± 0.2	0.70	5.17 ± 0.12	0.36	13.6 ± 0.4	0.58	17.7 ± 0.7
800	0.28	14.8 ± 0.8	-	-	-	-	-	-	-	-
1000	-	-	1.10	17.0 ± 0.1	-	-	0.72	6.8 ± 0.4	0.75	23.8 ± 0.2
1200	0.20	15.4 ± 1.0	-	-	-	-	0.06	17.9 ± 0.5	0.13	15.1 ± 0.4
1600	0.25	11.4 ± 1.5	0.28	43.0 ± 0.2	-	-	0.19	-0.7 ± 1.0	0.29	23.5 ± 0.4
1700	-	-	-	-	10.4	10.9 ± 0.2	-	-	-	-
Total	1.52	12.3 ± 0.6	1.67	21.4 ± 0.1	11.1	10.6 ± 0.2	1.34	8.1 ± 0.5	1.75	21.1 ± 0.4

Trapped Nitrogen: The trapped $\delta^{15}N_t$ is obtained by the subtracting cosmogenic N from the measured, adopting the systematics of Hashizume and Sugiura (1995). The estimated $\delta^{15}N_t$ is, -0.71 ± 0.10 ‰, +1.72 ± 0.24 ‰, +3.64 ± 0.52 ‰, +0.91 ± 0.14 ‰ and 15.01 ± 2.14 ‰, in the chondrites, Ararki (L5), Bhawad (LL6), Sabrum (LL6), Kendrapara-A (H5) and Kendrapara-B (H5), respectively. These values of $\delta^{15}N_t$ are comparable to and extend the range values reported previously (Bonino et al., 2001; Hashizume and Sugiura, 1995; Mahajan et al., 2016, 2018; Mahajan, 2017, 2020a; Ray et al., 2017; Sugiura et al., 1998). The potential sources for N_2 are SW, HL and Q-phase. The signature of trapped N in the ordinary chondrites studied here and reported in the literature is enriched in heavier isotope and differ than the solar wind (SW), HL and Q-phase. Can this observation be considered as an indicator of a common source for heavier N? The heavier $\delta^{15}N_t$ suggest any or combination of this: (1) the SW is not a main component in OC's, (2) the meteoroids derived from inner regions of the parent body and were not exposed to SW, (3) carriers of anomalous N are easily destroyed by post-accretionary processes, (4) anomalous N phases are minor components, (5) gas from the Q-carrier is not present in OC's. However, the (5) argument may not be true, since OC's has noble gas signature similar to the Q-component. Therefore, the trapped $\delta^{15}N_t$ in OC's can be explained by (i) a mixture of heavy N gas with Q-gas or (ii) the signature is derived due to loss of N in post-accretionary process occurred in the parent body or (iii) it was derived from the self-shielding in nebula. All these cases can be responsible as viable processes for derivation and/or modification of N in the OC's.

Correlation with noble gases: Trapped He and Ne are negligible in all the four OC's. Only trapped Ar, Kr, Xe, are identified. Therefore, the carriers of noble gases mostly contain Ar, Kr, and Xe. By looking at the correlation between the elemental ratio $^{14}N/^{36}Ar_t$ and $\delta^{15}N_t$, it is possible to understand nitrogen carriers in OC's. Trapped noble gases in OC's are mixture of HL and Q components. N composition of OC's indicate a different trend, which cannot be explained by mixing of HL, Q or SW. The $N/^{36}Ar$ ratio in the bulk OC's are distinct (Mahajan 2020b) than the SW, HL, and Q. Nitrogen seems to be governed by different processes than argon (i.e. noble gases), and in different phases.

Conclusions: Trapped $\delta^{15}N_t$ signature in OC's suggest that, they derived their nitrogen from different mechanisms, and not obtained solely from the reservoirs, SW, Q or HL. Nitrogen composition in OC's could be derived from combination of progressions. Post-accretionary processes in asteroids such as thermal processing can be thought of controlling the final composition of N in them.

References:

Bhandari N., Murty S. V. S., Shukla P. N., Mahajan R. R., Shukla A. D., Suthar K. M., Parathasarathy G., and Paliwal B. S., Bhawad LL6 chondrite: chemistry, petrology, noble gases, nuclear tracks, and cosmogenic radionuclides. Meteoritics & Planetary Science. 40, 1015-1021, 2005.

Bhandari N, Murty S. V. S., Shukla P. N., Mahajan R. R., Shukla A. D., Lashkari G., Sisodia M. S., Tripathi R. P., Parthasarathy G., Verma H. C., and Franchi I. A., Ararki (L5) chondrite: the first meteorite find in Thar desert of India. Meteoritics & Planetary Science, 43, 761-770, 2008.

Bonino G., Bhandari N., Murty S. V. S., Mahajan R. R., Suthar K. M., Shukla A. D., Shukla P. N., Cini Castagnoli G., and Tarico C., Solar and galactic cosmic-ray records of the Fermo (H) chondrite regolith breccia. Meteoritics & Planetary Science. 36, 831-839, 2001.

Dhingra D., Bhandari N., Shukla P. N., Murty S. V. S., Ballabh G. M., Lashkari G., Shukla A. D., and Parthasarathy G., Spectacular fall of the Kendrapara H5 chondrite. Meteoritics & Planetary Science. 39, A121-132, 2004.

Ghosh S., Murty S. V. S., Shukla P. N., Shukla A. D., Mahajan R. R., Bhandari N., Pant N. C., Bhosh J. B., and Shome S., Gall, classification and cosmogenic records of the Sanrum (LL6) chondrite. Meteoritics & Planetary Science. 37, 439-448, 2002.

Hashizume K., and Sugiura N., Nitrogen isotopes in bulk ordinary chondrites. Geochimica et Cosmochimica Acta. 59, 4057-4069, 1995.

Mahajan R. R., Noble gases, nitrogen and cosmic ray exposure age of the Sulagiri chondrite. Geoscience Frontiers. 8, 205-210, 2017.

Mahajan R. R., Exposure ages, noble gases and nitrogen in the ordinary chondrite Karimati (L5). Earth, Moon, and Planets. 124, 3-13, 2020a.

Mahajan R. R., Noble gases and nitrogen in metal from the ordinary chondrites Katol (L6), Itawa Bhopji (L305) and Portales Valley. Astrophysics and Space Science. 365, 130, 2020b.

Mahajan R. R., Varela M. E., and Joron J. L., Santa Lucia (2008) (L6) chondrite, a recent fall: composition, noble gases, nitrogen and cosmic ray exposure history. Earth, Moon and Planets. 117, 65-76, 2016.

Mahajan R. R., Neija L. O, Ray D., and Naik S., Noble gases, nitrogen, cosmic ray exposure history and mineralogy of Beni M'hira (L6) chondrite. Planetary and Space Science. 152, 136-141, 2018.

Mahajan R. R., Sarbadhikari A. B. and Sisodia M. S., Noble gases, nitrogen composition and cosmic ray exposure history of two eucrites Vissannapeta, Piplia Kalan and one howardite Lohawat. Planetary and Space Science. 165, 23-30, 2019.

Ray D., Mahajan R. R., Shukla A. D., Goswami T. K., and Chakraborty S., Petrology, classification, oxygen isotopes, noble gases, and cosmogenic records of Kamargoan (L6) meteorite: the latest fall in India. Meteoritics & Planetary Science. 52, 1744-1753, 2017.

Sugiura N., Kiyota K., and Hashizume K., Nitrogen components in primitive ordinary chondrites. Meteoritics & Planetary Science. 33, 463-482, 1998.