

NOBLE GASES IN BULK AND MINERAL SEPARATES FROM THE MIL 03346 NAKHLITE.

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Introduction: MIL 03346 is classified as nakhlite, which was found by a field party from the U.S. Antarctic Search for Meteorites program (ANSMET) on Dec. 15, 2003, on an ice field in the Miller Range of the Transantarctic Mountains. The collected mass was 715.2 g. It is composed of 74 (78) % of augite, 22% (19%) of mesostasis and 4 (2) % of olivine (Fe-rich olivine; Fa₅₅₋₉₂) and some alteration products [1, 2]. The mesostasis is composed of Si-rich feldspathic glass with Ti-magnetite, Ca phosphate and silica [1].

Nakhlites are cumulates [3] and consist of mostly magnesian augite, microcrystalline mesostasis and smaller amounts of Fe-rich olivine. Parent magma for nakhlites may be different from shergottites, because nakhlites have high volatile contents, in contrast to shergottites, but are LREE-enriched [4]. Moreover, nakhlites have essentially no feature for shock, whilst shergottites, chassignites and ALH 84001 have heavily shocked. Nakhlites have the evidence for aqueous alteration on Mars. Iddingsite is an alteration product of olivine with aqueous fluid at the lower temperature than 150°C [5, 6]. ¹²⁹Xe/¹³²Xe value of iddingsite in the Lafayette was 2.04 ± 0.28 , while the value of ⁸⁴Kr/¹³²Xe is as low as 6 ± 3 [7]. They concluded that high ¹²⁹Xe/¹³²Xe ratio in iddingsite was due to the trapped Martian atmosphere during aqueous alteration on the surface of Mars. Therefore, nakhlites have Martian atmosphere with this aqueous mechanism, instead of shock mechanism. Focusing on secondary alteration in MIL 03346 should be important for understanding aqueous process on Mars. We report noble gas compositions of bulk sample and mineral separates (Olivine, Pyroxene and Plagioclase).

Experimental method: Noble gas elemental and isotopic compositions were analyzed using a noble gas mass spectrometer (modified-VG5400/MS-II) at the University of Tokyo, which is equipped with a noble gas extraction furnace (using a molybdenum (Mo) crucible), purification line and standard gas system. Sensitivities and mass discrimination correction factors for noble gases were determined by measuring a known amount of atmosphere (e.g., 5×10^{-4} cm³ STP). Mass discrimination for ³He/⁴He ratio was determined using a ³He and ⁴He mixture with ³He/⁴He = 1.71×10^{-4} .

Total melting and stepwise heating methods (15 steps from 400 to 1800°C) were applied to 35.2 mg and 87.5 mg bulk samples. Grains of 100-200 mesh weighing 127 mg were separated into three fractions,

plagioclase+mesostasis, pyroxene and olivine. Stepwise heating (8 steps from 400 to 1800°C) was applied to the plagioclase (14.9 mg) and the pyroxene (71.6 mg) and that of 4 steps (from 600 to 1800°C) to the olivine (0.8 mg). However, the 1800°C extractions for the mineral separates gave meaningless results due to small amounts of extracted noble gases, which were comparable with blank levels.

Results and discussion: Most of He and radiogenic ⁴⁰Ar in bulk sample were released at low temperatures (600-900°C), while release peak of Kr and Xe was at 1000°C. Neon was mostly cosmogenic and was released at higher temperatures from 1000 to 1400°C. About half of total He content in the plagioclase separate was released at the lowest temperature (400°C), which indicates low retentivity of He in the plagioclase and/or mesostasis.

Characteristic noble gas signature for this meteorite was observed as shown in Fig. 1. Results for the bulk sample by stepwise heating method showed high ¹²⁹Xe/¹³²Xe and very low ⁸⁴Kr/¹³²Xe (<1) ratios, and the high ¹²⁹Xe/¹³²Xe ratios were observed in both lower temperatures (400°C and 500°C fractions: ¹²⁹Xe/¹³²Xe ~2.1) and high temperatures (1400°C and 1500°C fractions: ¹²⁹Xe/¹³²Xe = 2.2). The low ⁸⁴Kr/¹³²Xe ratios indicate strong elemental fractionation of Martian atmosphere, much more than the reported Nakhla data [8]. Similar trend has already been reported for the MIL 03346 [9].

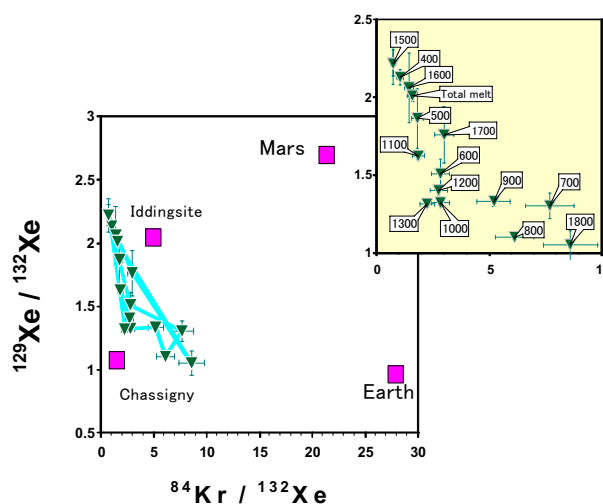


Fig. 1. Plot of ¹²⁹Xe/¹³²Xe versus ⁸⁴Kr/¹³²Xe for bulk sample of MIL 03346 nakhlite.

The high $^{129}\text{Xe}/^{132}\text{Xe}$ ratios in the lower temperature is probably due to the weathering products from accessory minerals or iddingsite, because crystallizations of these kind of weathered minerals are weak and easily be decomposed even by weak heating. The high $^{129}\text{Xe}/^{132}\text{Xe}$ ratios from higher temperatures (1400°C and 1500°C fractions) are probably released from the clinopyroxenes, which might trap Martian atmosphere during its formation. Otherwise, these high temperature fractions may infer the unknown Martian reservoir, which is distinct from Martian atmosphere and Martian interior observed in Chassigny.

Fig. 2. is a plot of $^{129}\text{Xe}/^{132}\text{Xe}$ versus $^{84}\text{Kr}/^{132}\text{Xe}$ for the mineral separates from MIL 03346. All the samples show low $^{129}\text{Xe}/^{132}\text{Xe}$ ratios (<1.4) at the low temperatures, and the $^{129}\text{Xe}/^{132}\text{Xe}$ ratios increase at higher temperatures with maximum at 1000°C for pyroxene and plagioclase and at 1400°C for olivine. The maximum $^{129}\text{Xe}/^{132}\text{Xe}$ values for the three samples are identical at about 2.2, and are similar to the value for bulk sample.

In contrast to the bulk samples, the mineral separates do not show high $^{129}\text{Xe}/^{132}\text{Xe}$ ratios (~2) at the low extraction temperatures (< 800°C). Moreover, the extraction temperatures showing high $^{129}\text{Xe}/^{132}\text{Xe}$ ratios are clearly different among them, i.e., the bulk sample releases high $^{129}\text{Xe}/^{132}\text{Xe}$ at 1500 and 1600°C, while the plagioclase and the pyroxene at 1000°C. The $^{129}\text{Xe}/^{132}\text{Xe}$ values for the bulk sample were 1.3-1.7 at the medium temperatures from 1000 to 1300°C. The olivine sample, however, shows high value at 1400°C, which may be due to high retentivity of olivine crystal for noble gases.

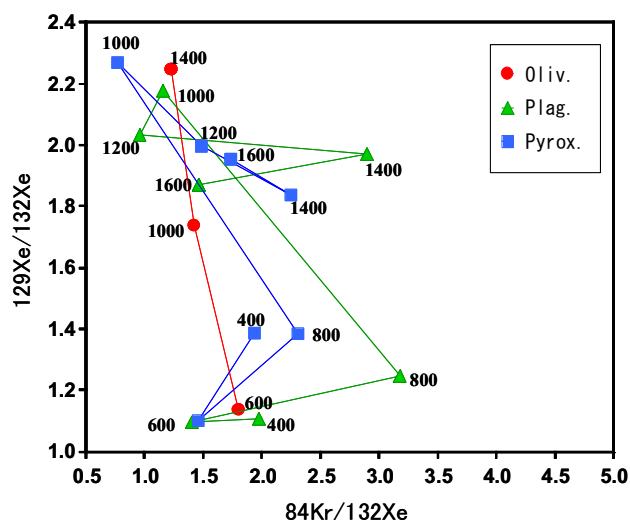


Fig. 2. Plot of $^{129}\text{Xe}/^{132}\text{Xe}$ versus $^{84}\text{Kr}/^{132}\text{Xe}$ for mineral separates from the MIL 03346 nakhilite. Numerical figures indicate extraction temperatures

The disappearance of high $^{129}\text{Xe}/^{132}\text{Xe}$ ratios for the mineral separates at low extraction temperatures would be caused by a removal of fragile weathering products which would contain the fractionated Martian atmospheric noble gas component released from the bulk sample at low temperatures. Such materials may be in finer grains (<100 mesh) and be separated by sieving prior to the mineral separation. Because the fine grained material is reserved, it will be measured for noble gases to examine the possibility. On the other hand, the difference between the higher release temperatures for high $^{129}\text{Xe}/^{132}\text{Xe}$ ratios from the bulk and the mineral separates is difficult to explain. Possible explanations may be different mineral assemblages of the samples, or heterogeneous distribution of trapped noble gases in the MIL 03346 nakhilite.

Acknowledgments: We thank the Meteorite Working Group for the MIL 03346 sample. This work was partly supported by Grant-in-Aid for Scientific Research (#19540512 to K.N.).

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