NOBLE GASES AND NUCLEAR TRACKS IN THE NAKHLITE MIL 03346. S.V.S. Murty*, R.R. Mahajan, J.N. Goswami and N. Sinha, Planetary and Geosciences Division, Physical Research Laboratory, Ahmedabad 380 009, India (*E-mail: murty@prl.ernet.in)

Introduction: MIL 03346 is collected during the 2003-2004 field season and is the 7th nakhlite known in world collection [1]. We have analysed a set of near surface and interior samples from MIL 03346 for their noble gas and nuclear track records to delineate the cosmic ray exposure history of this meteorite and signatures of martian atmospheric and interior components in it.

Noble Gases : We have received splits (19, 33, 36,59) of about 100 mg for nuclear track studies and a split of about 500 mg (73) for both noble gas and track investigations. About 400 mg of the later split has been used for N and noble gas studies by stepwise heating following standard procedures [2]. After two low temperature (300^{o}C, 400^{o}C) combustion steps at 2 torr oxygen pressure, we continued pyrolysis at 600, 800, 1200 and melting temperatures (1600^{o}C). The data for He, Ne, Ar, Kr and Xe are presented in Table 1. Presence of radiogenic (^{4}He, ^{40}Ar) and trapped components (Kr, Xe), in addition to cosmogenic components (for He, Ne and Ar) is clearly seen. Cosmogenic amounts, production rates and the inferred exposure ages are given in Table 2.

Trapped Components:The trapped ratios ^{84}Kr/^{132}Xe (0.66) and ^{36}Ar/^{32}Xe (6.1) are much lower than the fractionated atmosphere generally found in Nakhlites ($\geq$ 3 and $\geq$ 60 respectively) [3] , but are similar to the values found in an interior component of Chassigny, Chassigny-E [4]. However ^{129}Xe/^{132}Xe ratios in all temperature steps are in the range 1.75-2.32 and clearly suggest the presence of martian atmospheric component. In a plot of ^{129}Xe/^{132}Xe versus elemental ratio ^{84}Kr/^{132}Xe, the data points of MIL 03346 fall further to the left than other nakhlites, suggesting a more severe elemental fractionation than hitherto observed in nakhlites.

Exposure age: Cosmogenic ^{3}He, ^{21}Ne and ^{38}Ar are given in Table 2. We take (^{36}Ar/^{38}Ar)$_t$ = 4.6 [5] for calculating the cosmogenic ^{38}Ar in view of the presence of martian atmospheric component indicated by ^{129}Xe/^{132}Xe ratios. The calculated production rates assume a chemical composition similar to Nakhla [6] and are based on the procedure suggested in [7]. (^{22}Ne/^{21}Ne)$_c$ = 1.185±0.002 is used as a shielding parameter and shielding dependence for nakhlites is taken to be the average of those for eucrites and howardites [8]. The production rate of cosmogenic ^{38}Ar is calculated following the method suggested by [9]. All the three exposure ages (in units of Ma) T$_3$ (9.6), T$_{21}$ (8.9) and T$_{38}$ (10.1) are in agreement within experimental uncertainities and we take the average value of 9.5±1.0 Ma as the exposure age for MIL 03346. This value is similar to that of other nakhlites [10,11], suggesting that all the nakhlites were ejected in a single event from Mars.

Gas retention ages: From radiogenic ^{4}He and U,Th contents of 52 and 198 ppm, respectively (of Nakhla), we derive a U,Th-^{4}He age (T$_4$) of 1.02±0.15 Ga. Since Mars atmospheric component is present we calculate the radiogenic ^{40}Ar after correcting for trapped ^{40}Ar, taking (^{40}Ar/^{36}Ar)$_t$ = 1800 [4]. If we use the K content of Nakhla (1079 ppm), we obtain a K-Ar age (T$_{40}$) of 1.75±.26 Ga. Within the uncertainties that can result from the assumed chemical composition etc., both T$_4$ and T$_{40}$ are consistent with the formation age of nakhlites, 1.3 Ga.

Nuclear Tracks: Two near surface samples (MIL 03346, 36 and 59) from within 0.5 cm from the fusion crust (FC)/recovered surface and one interior chip (,73) sampled ≥1 cm below FC were analysed to study nuclear track records in olivines and pyroxenes following standard procedures [12]. A few olivine grains were found in the interior sample (,73) and they have well developed tracks with track densities of ~ 10^6 cm^{-2}. The other two samples taken from near the FC/recovered surface are devoid of olivines. Tracks were observed in pyroxenes in both the samples. However, the development of tracks suggest possible annealing effect in some of the pyroxene grains. The

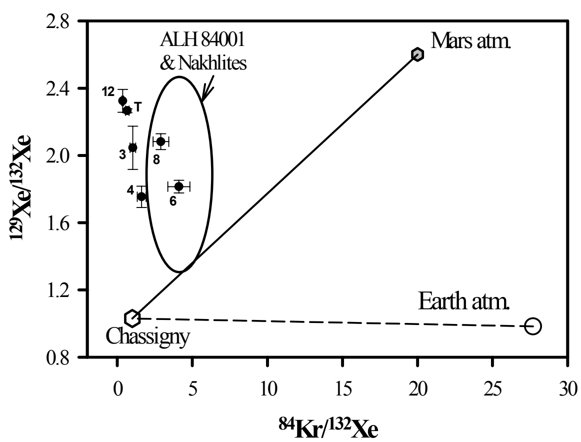

Fig. 1 Plot of ^{129}Xe/^{132}Xe Vs ^{84}Kr/^{132}Xe for different temperature fractions of MIL03346. Number beside the point indicates temperature in 100's of ^{o}C. Most data points fall outside the range of nakhlites, suggesting a more severe elemental fractionation.

etching behaviour of the olivines and the well developed tracks seen in them suggest that MIL 03346 suffered much lower shock effects than most other martian meteorites. If we consider MIL 03346 to be a single fall, the recovered mass of 715.2g and the deduced cosmic ray exposure age of ~10 Ma allow us to infer the shielding depths of the analyzed samples following [13]. The shielding depth of the interior sample (,73) is ~4 cm. This data combined with the preliminary data for the two other samples suggest an average atmospheric ablation of ≤3cm and a preatmospheric radius of ~6 cm for MIL 03346. This would imply a mass ablation of ≤75% for this Nakhlite which is towards the higher end of values for martian meteorites [10] but lower than for meteorites of asteroidal origin.

Discussion: The cosmic ray exposure history of MIL 03346 is similar to other nakhlites . The relatively low atmospheric mass ablation also suggest a low atmospheric entry velocity typical of martian meteorites. The high $^{129}Xe/^{132}Xe$ ratios clearly indicate the presence of martian atmospheric component in it. The significantly low elemental ratios of $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ for the trapped component suggest that either the primary process responsible for incorporation of martian atmospheric component or partial loss of trapped martian atmospheric gases in a later event caused a more severe elemental fractionation in MIL 03346 than in other nakhlites. If the former is true, MIL 03346 provides a more faithful signature of the process that caused the elemental fractionation of the trapped component. However, if the later is true, the partial gas loss could not have occurred during the interplanetary sojourn of MIL 03346, as indicated by its matching exposure age with other nakhlites. Further, the gas retention ages (T_4, T_{40}) that are also similar to other nakhlites suggest that the gas loss must have occurred soon after trapping the martian atmospheric component.

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Table -1. Noble gas data for MIL 03346, 73 (concentrations in cm^3STPg^{-1} units)

4	22	36	3/4	20/22	21/22	38/36	40/36	84	132	129/132
10^{-8}			$(x10^4)$					10^{-12}	10^{-12}	
1387	2.38	0.99	108.6 ±9.2	1.214 .006	0.8081 .0017	1.465 .005	1174 9	37.9	57.6	2.265 0.012

Errors in concentrations are ±10%. Isotopic ratios represent 95% C.L;

Table -2. Cosmogenic components, production rates and exposure ages

Sample	Cosmogenic amounts			Prod. Rates			Exp. Ages (Ma)		
	^3He	^{21}Ne	^{38}Ar	P_3	P_{21}	P_{38}	T_3	T_{21}	T_{38}
	$10^{-8}cm^{-3}STPg^{-1}$			$10^{-10}cm^{-3}STP(g\ Ma)^{-1}$					
, 73	15.1	1.91	1.63	157.5	21.5	16.1	9.6	8.9	10.1