THE PRIMORDIALLY TRAPPED NOBLE GAS COMPONENT IN THE RUMURUTI PARENT BODY.

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Introduction: Models aiming to understand the accretion and evolution of the terrestrial planets often utilize known chondrite classes as precursor material [e.g., 1,2]. Knowledge of the primordially trapped noble gas content can be particularly diagnostic [3]. They can trace, e.g., volatile loss during differentiation or impact and late additions of volatile-rich material. However, these abundances are often difficult to determine, as many processes overprint the original, primordial signatures. These include parent body alterations, ingrowth of radiogenic and fissiogenic gases, exposure to solar wind in regolithic environments and to cosmic rays both on planetary surfaces and in space, and finally terrestrial weathering.

Here we discuss new noble gas data from the Rumuruti chondrites (RCs) Northwest Africa (NWA) 755 (type R3-5, brecciated-"br"), 830 (R5, br), 3364 (R3-5) and 4693 (R3-6) combined with literature data to determine the primordial noble gas concentrations in the RC parent body(ies). RCs are especially interesting as they have experienced more oxidizing conditions than, e.g., the ordinary chondrites and might originate from a larger heliocentric distance [4,5]. However, the lack of very primitive (type 3.0-3.3) gas-rich and unbrecciated material compromises this discussion.

Experimental: All isotopes were analyzed at ETH Zurich (see [6] for details). RCs with comparably little or no solar gases and various cosmic-ray exposure ages (10–27 Ma) sampling different source craters were selected [4,7]. NWA 3364 was studied in two lithologies (see table 1). Further small chips (typically 1 mg) were analyzed, irradiated and unirradiated, for Xe isotopes with the high-sensitivity resonance mass spectrometer RELAX in Manchester [8,9].

Results: The isotopic and element compositions in the newly measured RCs are generally in agreement with previous analyses [6,7,10-12] and given in Table 1. All available data (115 sets for 59 RCs) will be used here to estimate the trapped (tr) noble gases, corrected for possibly present radiogenic (rad), cosmogenic (cosm) and fissiogenic (fiss) components.

Discussion: Many RCs contain solar noble gases and are brecciated, consisting of various lithologies of type 3 to 6 [4], indicating their origin in the regolith of the RC parent body(ies). We assume that the exposure to the solar wind occurred "late", i.e. after the accretionary period in the solar system, which is generally assumed, but difficult to prove and not always warranted (see, e.g., [13]).

We identified 34 RCs void of solar gases (63 data sets). All RCs with <2100 x 10^{-8} cm^3/g ^{4}He are assumed to be solar wind free. All excluded RCs show at least in one data set ^{4}He >9500 x 10^{-8} cm^3/g ^{4}He.

Table 1 Noble gas concentrations and isotopic ratios in R chondrites*.

NWA, type *mass*	^{20}Ne 10^{-8} cm^3/g	$^{20}Ne/^{22}Ne$	$^{21}Ne/^{22}Ne$	^{84}Kr 10^{-10} cm^3/g
755 R3-5 br *101.42 mg*	3.063±0.009	0.870±0.004	0.9223±0.0027	39.8±0.6
830 R5 br *101.92 mg*	21.52±0.04	2.044±0.009	0.741±0.004	26.6±0.4
3364,3 R3-5 *70.84 mg*	19.96±0.05	2.634±0.013	0.656±0.004	46.5±0.9
3364,m *101.11 mg*	10.549±0.023	1.493±0.007	0.822±0.005	16.7±0.3
4693 R3-6 *26.45 mg*	5.25±0.04	1.417±0.006	0.8760±0.0021	8.63±0.12

*A re-extraction of NWA 755 at 1700ºC yielded <0.2% of the total He-Kr, and <0.7 % of the Xe and was neglected. All other samples were extracted in a single step. 3 = type 3 lithology, m = metamorphosed.

Table 1 continued

NWA	^{4}He 10^{-8} cm^3/g	$^{3}He/^{4}He$ x 10000	^{36}Ar 10^{-8} cm^3/g	$^{36}Ar/^{38}Ar$	$^{40}Ar/^{36}Ar$
755	1094±4	117.85±0.22	5.14±0.17	3.81±0.14	785±26
830	1052±4	282.2±0.5	10.2±0.3	3.66±0.14	465±15
3364,3	1482±5	68.65±0.21	11.7±0.3	3.82±0.14	165±5
3364,m	1005±4	137.15±0.24	1.95±0.06	1.99±0.08	2057±69
4693	1131±4	104.6±1.0	6.90±0.23	4.23±0.16	383±13

Helium is corrected for $^{4}He_{cosm}$ assuming $^{3}He_{total}$ = $^{3}He_{cosm}$ and $^{4}He/^{3}He$ = 5.25 [14]. The average $^{4}He_{rad}$ in RCs is ~910 x 10^{-8} cm^3/g based on R4 NWA053 with negligible $^{4}He_{cosm}$ (0.1%), and Sahara 99527 and NWA 830 (both R5), assuming that primordially $^{4}He_{tr}$ is entirely lost. $^{4}He_{tr}$ in the most primitive type 3 RCs analysed, NWA 4615 and 4360 (R3.4 and R3.6) and DaG 13 (R3.5-6), is in average 330 x 10^{-8} cm^3/g. The maximum in type 3 RCs is 1080 x 10^{-8} cm^3/g (Rumuruti R3.8-6). The upper limit of $^{3}He_{tr}$ (0.17 x 10^{-8} cm^3/g) can only be roughly estimated by adopting the ^{3}He in NWA 053, as its exposure age of 0.17 Ma is remarkably small [11]. However, this ^{3}He must at least partially be produced in space during its transfer to Earth.

Neon in most RCs is entirely cosmogenic; 22 meteorites show $^{20}Ne/^{22}Ne$ ratios of <0.9, where Ne_{tr} is generally not detectable. From these 32 data points we determined three average endmember compositions to cover the whole range of $(^{21}Ne/^{22}Ne)_{cosm}$, which depends on shielding and chemistry. We used Ne_{HL} and Ne_{Q} as trapped endmembers. None of the Ne isotope data indicate solar Ne, in agreement with the exclusion of solar wind gas-rich RCs based on ^{4}He.

There is no correlation between petrographic classification and bulk Ne_{tr} content: NWA 3364 (R3-5), 830

(R5) (2 measurements each) and Rumuruti show the largest Ne_{tr} concentrations of 12 to 17 x 10^{-8} cm^3/g, whereas of the three possibly most primitive RCs (see He) only DaG 13 (R3.5-6) contains detectable Ne_{tr} of 0.5 x 10^{-8} cm^3/g. This is probably due to the brecciation common for most RCs.

Table 1 continued

NWA	^{78}Kr	^{80}Kr	^{82}Kr	^{83}Kr	^{86}Kr
			$^{84}Kr\equiv100$		
755	0.602±0.012	4.08±0.06	20.22±0.19	20.00±0.14	30.15±0.26
830	0.601±0.013	5.12±0.08	20.16±0.25	19.94±0.23	29.8±0.4
3364,3	0.611±0.015	4.00±0.08	20.3±0.3	19.89±0.28	29.8±0.5
3364,m	0.574±0.015	4.14±0.08	19.3±0.4	18.94±0.29	28.2±0.5
4693	0.613±0.015	5.25±0.09	20.65±0.26	20.05±0.21	31.1±0.4

Table 1 continued

NWA	^{132}Xe	^{124}Xe	^{126}Xe	^{128}Xe
	10^{-10} cm^3/g		$^{132}Xe\equiv100$	
755	11.06±0.24	0.374±0.005	0.354±0.005	7.39±0.06
830	7.64±0.20	0.424±0.009	0.397±0.007	8.39±0.15
3364,3	12.70±0.28	0.417±0.005	0.383±0.006	7.84±0.06
3364,m	4.86±0.10	0.387±0.007	0.374±0.006	7.47±0.07
4693	8.25±0.19	0.440±0.008	0.407±0.007	8.24±0.10

Table 1 continued

NWA	^{129}Xe	^{130}Xe	^{131}Xe	^{134}Xe	^{136}Xe
			$^{132}Xe\equiv100$		
755	126.0±1.5	15.07±0.12	78.9±0.6	38.38±0.29	32.8±0.3
830	143.8±2.6	15.86±0.26	81.4±1.3	39.1±0.7	33.3±0.6
3364,3	128.0±1.1	15.71±0.11	81.2±0.6	39.0±0.3	33.07±0.28
3364,m	134.7±1.3	15.24±0.10	79.4±0.5	38.3±0.3	32.88±0.28
4693	150±3	15.79±0.18	81.4±0.8	38.2±0.5	32.2±0.4

Argon is a mixture of Ar_{tr}, Ar_{cosm}, Ar_{rad} and inevitably terrestrial Ar (note that all but two of the RCs studied for noble gases originate from hot deserts and most are weathered [4]). We used the rough correlation of $^{3}He/^{38}Ar$ with $^{36}Ar/^{38}Ar$ shown by most RCs to determine an average RC $(^{3}He/^{38}Ar)_{cosm}$ of ~44 for $(^{36}Ar/^{38}Ar)_{cosm}$ = 0.65. Assuming $^{3}He_{total}$ = $^{3}He_{cosm}$, the maximum $^{36}Ar_{tr}$ scatters around 25 x 10^{-8} cm^3/g, found in all types. Again, a decreasing $^{36}Ar_{tr}$ with increasing petrographic type cannot be observed. However, overprinting contributions from air are evident, as those RC with large $^{40}Ar/^{36}Ar$ (>950), indicating little loss of $^{40}Ar_{rad}$ and little air contamination, show consistently low $^{36}Ar_{tr}$ values between 0.8 and 4.3 x 10^{-8} cm^3/g. These values are found in 18 meteorites, including the least weathered NWA 753 and 2198, the Antarctic Y-793575 and the only fall Rumuruti, and hence are more representative for $^{36}Ar_{tr}$.Type 3 and 4 show the same average and range for $^{36}Ar_{tr}$.

Krypton and Xenon are, similar to Ar, strongly affected by weathering. This severely increases the heavy noble gas concentrations and overprints the isotope signatures. Best indicators for weathering and terrestrial contamination are the weathering index "W" [4] and the $^{129}Xe/^{132}Xe$ ratio. All RCs examined so far show an excess of ^{129}Xe due to decay of the short-lived radionuclide ^{129}I. We used only RCs from the literature with W<2 and unclassified meteorites, which show all low $^{84}Kr/^{132}Xe$ ratios, and RCs with $^{129}Xe/^{132}Xe$ ratios >1.85, implying that the trapped Kr and Xe cannot be entirely due to terrestrial components. These criteria yield a range of 0.4 to 12 x 10^{-10} cm^3/g $^{84}Kr_{tr}$ and 0.4 to 9 x 10^{-10} cm^3/g $^{132}Xe_{tr}$. It's not possible to verify a dependence of the concentrations from the metamorphic history due to the small statistics. However, the only R5 among the 18 RCs shows the lowest concentrations in ^{84}Kr and ^{132}Xe, around 7-9 times lower than the average concentrations of the type R3 and R4 meteorites. The question whether the small abundances of Kr and Xe are isotopically of Q type or solar will be addressed in detail at the meeting. The Kr and Xe concentrations are at the lower end of what is usually observed in ordinary chondrites. Particularly type 3 RCs show 1-2 orders of magnitude lower concentrations than, e.g., the LL chondrites [15]. This is most likely the result of the mixing of more degassed, metamorphosed fragments into the type 3 RCs but could also reflect the oxidation that may have occurred prior to lithification of the RC parent body(ies) [5], which could have destroyed some phase Q [6]. These processes might also be responsible for the apparent absence of presolar grains and their noble gas components.

The effect of metamorphism can be seen in NWA 3364. A type 3 and a metamorphosed (probably type 5) lithology have been separately examined. The concentrations of the primordially trapped gases decreased by factor of 7.9 ($^{4}He_{tr}$) to 2.6 (^{132}Xe), the radiogenic and cosmogenic components are much less affected. These differences are not discernible in bulk measurements. The petrographic type of each RC fragment has to be classified prior to the trapped noble gas analysis.

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