LUNAR BRECCIA 14066: ^{81}Kr-^{83}Kr EXPOSURE AGE; EVIDENCE FOR FISSIO-GENIC Xe FROM ^{244}Pu; RATE OF PRODUCTION OF SPALLOGENIC ^{126}Xe, B. Srinivasan, Department of Physics, University of California, Berkeley, California 94720.

A preliminary rare gas survey of lunar breccia 14066 by Kaiser (1) revealed an unusual isotopic composition for spallogenic Xe and a simple irradiation history. Since such samples are ideal for determining the rate of production of spallogenic Xe from Ba and REE (rare earth elements), a reinvestigation of rare gases in 14066 has been carried out. Aliquots from saw dust 14066,31,1 and breccia clast 14066,21,2.01 were analyzed for Kr and Xe. The concentrations of Ba, REE, Sr, Y, Zr and U were determined on separate aliquots of these two samples by Laul et al. (2) and Maxwell (3).

KRYPTON is assumed to be a mixture of (a) isotopes 83-86 from spontaneous fission of ^{238}U (b) trapped Kr of atmospheric composition and (c) isotopes 78-84 from spallation. Using the U concentrations (2) and the ^{40}Ar-^{39}Ar age of (3.93±0.03) b.y. (4), the observed spectra were corrected consecutively for components (a) and (b). The residual spectra representing the spallogenic component is shown in Table 1. Note that the ratio $(^{78}$Kr$/^{83}$Kr$)_{sp}$ in 14066 is relatively high when compared to other Apollo 14 samples having similar proportions of target elements (Sr, Y and Zr).

Table 1. Spallogenic spectra for krypton (^{83}Kr$\equiv$1.000)

Sample	^{78}Kr	^{80}Kr	^{81}Kr	^{82}Kr	^{84}Kr	$[^{83}$Kr$]_{sp}$ $\times 10^{-12}$cc STP/g
14066,31,1	0.2306 ±.0035	0.5262 ±.0074	0.00698 ±.00029	0.767 ±.014	0.250 ±.036	98.3 ±5.4
14066,21,2.01	0.2341 ±.0018	0.5304 ±.0041	0.00699 ±.00013	0.7759 ±.0080	0.240 ±.010	99.6 ±5.6

^{81}Kr-^{83}Kr exposure age: Using the data for the radioactive isotope ^{81}Kr (Table 1) and following the method of Marti (5), the ^{81}Kr-^{83}Kr exposure ages are found to be (26.7±1.2) m.y. and (26.9±0.5) m.y. for 14066,31,1 and 14066,21,2.01, respectively, in excellent agreement with the exposure ages for other Apollo 14 samples which are believed to be ejecta from Cone Crater event (6,7).

XENON is assumed to be comprised of (a) isotopes 131-136 from spontaneous fission of ^{238}U (b) isotopes 131-136 from spontaneous fission of ^{244}Pu (c) trapped Xe of "Sucor" composition (8) and (d) isotopes 124-132 from spallation. The reaction ^{130}Ba(n,γ)$\rightarrow^{131}$Xe has been included in component (d).

Fissiogenic Xenon from ^{244}Pu: The observed amount of fissiogenic xenon could not be accounted for solely as a result of decay in situ of ^{238}U during the past 3.93 b.y. An additional source, probably ^{244}Pu, appears to be necessary. If ^{244}Pu is postulated as an additional source, the concentrations of fissiogenic Xe from sources (a) and (b) can be calculated and set out in Table 2.

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Table 2. Abundance of ^{136}Xe from spontaneous fission of ^{238}U and ^{244}Pu; inferred ^{244}Pu/^{238}U ratios.

Sample	(^{136}Xe)$_f$ × 10^{-12}cc STP/g from		^{244}Pu/^{238}U at	
	^{238}U	^{244}Pu	t = 3.93 b.y.	t = 4.56 b.y.
14066,31,1	8.3 ± 0.8	9.9 ± 4.1	(2.0 ± 0.9) × 10^{-4}	0.038 ± 0.016
14066,21,2.01	5.6 ± 0.6	8.1 ± 2.7	(2.5 ± 0.9) × 10^{-4}	0.046 ± 0.016

Assuming that both ^{238}U and ^{244}Pu have decayed in situ, the initial ^{244}Pu/^{238}U ratio is in the range 0.022 - 0.062 at t ⇒ 4.56 b.y. The initial ^{244}Pu/^{238}U ratio, although critically dependent on the age difference (4.56-3.93), appears to be at least twice the value for bulk St. Severin meteorite (9). It is likely that chemical fractionation is responsible for the increased Pu/U ratio in this lunar breccia. Nonetheless, the above exercise provides qualitative evidence for the contemporaneity of Moon and meteorites, as has been observed earlier by other workers (10-13).

Spallogenic xenon: The subtraction of fissiogenic and trapped components from the observed spectra yield the isotopic composition of spallogenic xenon shown in Table 3.

Table 3. Spallation spectra for xenon (^{126}Xe≡1.000)

Sample	^{124}Xe	^{128}Xe	^{129}Xe	^{130}Xe	^{131}Xe	^{132}Xe	[^{126}Xe]$_{sp}$ × 10^{-12}cc STP/g
14066,31,1	0.571 ±.011	1.462 ±.044	1.48 ±.38	0.898 ±.064	2.87 ±.31	0.68 ±.38	31.3 ±1.8
14066,21,2.01	0.577 ±.018	1.479 ±.050	1.42 ±.24	0.864 ±.048	2.75 ±.21	0.54 ±.24	32.2 ±2.1

The ratio (^{131}Xe/^{126}Xe)$_{sp}$ is a new low for lunar samples and is consistent with minimal exposure to secondary particles, mainly neutrons. The low (^{131}Xe/^{126}Xe)$_{sp}$ ratio and high (^{78}Kr/^{83}Kr)$_{sp}$ ratio have already been recognized as correlated indicators of minimal shielding during cosmic-ray exposure (14) and reveal a simple irradiation history for 14066 -- that is, burial at great depth until transport to the lunar surface at the time of Cone Crater event.

The rate of production of spallogenic ^{126}Xe in units of 10^{-9} cc STP/g/m.y. is equal to

$$(1.20 \pm 0.13) \times (g\ Ba/g) + (0.73 \pm 0.08) \times (g\ REE/g)$$

where REE signifies La + Ce + Pr. The relative production rates from Ba and

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REE have been inferred from Rudstam's systematics (15) as used by
Hohenberg et al. (16) for the Pasamonte meteorite, since Ba and REE appear
to be present in nearly the same proportions in Pasamonte and breccia 14066.
It is expected that the above equation will be useful in calculating the
"surface" exposure ages of lunar samples.

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