SOLAR, SPALLOGENIC AND RADIOGENIC RARE GASES IN APOLLO 17 SOILS AND BRECCIAS.

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Rare gas concentrations and isotopic composition of four Apollo 17 soils (72701/25, 74260/9, 75061/21 and 75081/72) and two breccias (79035/15 and 79135/32) have been determined mass spectrometrically. The results are given in Tab.1. In addition to our recently published analyses of different grain size fractions from orange soil 74220/47 and the reference soil 74241/24 (1) we have measured the rare gases of a suite of grain sizes from 74260/9, the second reference soil to 74220/47 (Tab.2) and from 75081/72.

The elemental rare gas ratios vary from soil to soil as a function of thermal-and irradiation history as well as their mineralogy. For trapped gases the ratio R(36)=Ar36/Kr84 is relatively constant ($\rho(36)=[R(36)max-R(36)min]$: R(36)min) = 0.47) compared to large variations of the ratios R(20)=Ne20/Kr84 and R(4)=He4/Kr84 ($\rho(20)=1.7$; $\rho(4)=4.4$). The variations of the relativ abundances of the light rare gases are caused to a large extend by diffusion losses. As a rule, samples with high TiO_2 contents (2) show large (He4/Kr84)-and (Ne20/Kr84)-ratios, reflecting the higher retentivity of ilmenite for light rare gases (1) (3).

The isotope ratios $(Ar36/Ar38)_{tr}$ and $(Ne20/Ne22)_{tr}$ are constant within $\pm 2\%$. The ratio $(Ar40/Ar36)_{SC}$ of the surface correlated argon isotopes, however, shows large variations between 0.77 in 75081/72 and 7.6 in 74241/24 and the ratio $(He4/He3)_{tr}$ varies also between 2740 and 3260 in the corresponding samples. Radiogenic Ar40 and He4 librated from lunar material and ad - sorbed on the highly damaged grain surfaces or incorporated by some other mechanism into them may explain the correlation between $(Ar40/Ar36)_{SC}$ and $(He4/He3)_{tr}$.

Of special interest are the two reference soils 74241/24 and 74260/9 to the orange soil 74220/47: Both exhibit high He4/He3 and Ar40/Ar36 ratios, their noble gas concentrations in bulk and grain size samples are very similar. From the grain size analyses we determined the radiogenic and spallogenic gas components (Tab.3). It follows that the exposure age of the reference soils with about 200 my is high compared to the

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Table 1: Rare gas concentrations in cm^3 STP/g in bulk material of fines and breccias from Apollo 17 mission.
Errors in isotope ratios 2%, errors in concentrations of He, Ne and Ar about 3%, of Kr and Xe about 10%.
Sample weights between 0.5 - 2.1 mg.

Nuclides and Ratios	72701,25	74220,47	74241,24	74260,9	75061,21	75081,72	79035,15	79135,32
^{3}He	$2.81 \cdot 10^{-5}$	$4.85 \cdot 10^{-6}$	$4.91 \cdot 10^{-5}$	$4.63 \cdot 10^{-5}$	$4.14 \cdot 10^{-5}$	$6.82 \cdot 10^{-5}$	$6.68 \cdot 10^{-5}$	$4.33 \cdot 10^{-5}$
^{4}He	$8.07 \cdot 10^{-2}$	$1.426 \cdot 10^{-2}$	$1.573 \cdot 10^{-1}$	$1.420 \cdot 10^{-1}$	$1.086 \cdot 10^{-1}$	$1.845 \cdot 10^{-1}$	$1.882 \cdot 10^{-1}$	$1.295 \cdot 10^{-1}$
^{20}Ne	$1.664 \cdot 10^{-3}$	$1.566 \cdot 10^{-4}$	$1.542 \cdot 10^{-3}$	$1.594 \cdot 10^{-3}$	$1.248 \cdot 10^{-3}$	$2.33 \cdot 10^{-3}$	$3.10 \cdot 10^{-3}$	$2.75 \cdot 10^{-3}$
^{21}Ne	$4.27 \cdot 10^{-6}$	$4.35 \cdot 10^{-7}$	$3.98 \cdot 10^{-6}$	$4.18 \cdot 10^{-6}$	$3.26 \cdot 10^{-6}$	$5.97 \cdot 10^{-6}$	$8.48 \cdot 10^{-6}$	$7.48 \cdot 10^{-6}$
^{22}Ne	$1.292 \cdot 10^{-4}$	$1.213 \cdot 10^{-5}$	$1.228 \cdot 10^{-4}$	$1.270 \cdot 10^{-4}$	$9.47 \cdot 10^{-5}$	$1.812 \cdot 10^{-4}$	$2.42 \cdot 10^{-4}$	$2.13 \cdot 10^{-4}$
^{36}Ar	$3.81 \cdot 10^{-4}$	$1.653 \cdot 10^{-5}$	$1.593 \cdot 10^{-4}$	$1.708 \cdot 10^{-4}$	$1.676 \cdot 10^{-4}$	$3.72 \cdot 10^{-4}$	$4.10 \cdot 10^{-4}$	$4.46 \cdot 10^{-4}$
^{38}Ar	$7.24 \cdot 10^{-5}$	$3.14 \cdot 10^{-6}$	$3.06 \cdot 10^{-5}$	$3.27 \cdot 10^{-5}$	$3.17 \cdot 10^{-5}$	$7.02 \cdot 10^{-5}$	$7.84 \cdot 10^{-5}$	$8.51 \cdot 10^{-5}$
^{40}Ar	$4.15 \cdot 10^{-4}$	$1.067 \cdot 10^{-4}$	$1.197 \cdot 10^{-3}$	$1.232 \cdot 10^{-3}$	$1.565 \cdot 10^{-4}$	$3.05 \cdot 10^{-4}$	$9.19 \cdot 10^{-4}$	$1.217 \cdot 10^{-3}$
^{84}Kr	$2.0 \cdot 10^{-7}$	$8.5 \cdot 10^{-9}$	$7.2 \cdot 10^{-8}$	$7.1 \cdot 10^{-8}$	$9.4 \cdot 10^{-8}$	$1.9 \cdot 10^{-7}$	$1.9 \cdot 10^{-7}$	$1.7 \cdot 10^{-7}$
^{132}Xe	$2.2 \cdot 10^{-8}$	$1.8 \cdot 10^{-9}$	$1.5 \cdot 10^{-8}$	$1.2 \cdot 10^{-8}$	$1.2 \cdot 10^{-8}$	$2.6 \cdot 10^{-8}$	$4.4 \cdot 10^{-8}$	$5.0 \cdot 10^{-8}$
$^{4}He/^{3}He$	2870	2940	3200	3070	2620	2710	2820	2990
$^{20}Ne/^{22}Ne$	12.88	12.91	12.56	12.55	13.18	12.86	12.92	12.91
$^{22}Ne/^{21}Ne$	30.3	27.9	30.9	30.4	29.0	30.4	28.5	28.5
$^{36}Ar/^{38}Ar$	5.26	5.26	5.21	5.22	5.29	5.30	5.22	5.24
$^{40}Ar/^{36}Ar$	1.089	6.45	7.51	7.21	0.934	0.820	2.24	2.73
$^{4}He/^{20}Ne$	48.5	91.1	102.0	89.1	87.0	79.2	60.7	47.1
$^{20}Ne/^{36}Ar$	4.37	9.47	9.68	9.33	7.45	6.26	7.56	6.17
$^{36}Ar/^{84}Kr$	1910	1940	2220	2410	1780	1960	2160	2620
$^{84}Kr/^{132}Xe$	9.1	4.7	4.7	5.9	8.1	7.3	4.3	3.4
number of aliquots	5	3	3	4	3	4	3	3
^{4}He-content max.	$8.96 \cdot 10^{-2}$	$1.458 \cdot 10^{-2}$	$1.615 \cdot 10^{-1}$	$1.442 \cdot 10^{-1}$	$1.408 \cdot 10^{-1}$	$2.02 \cdot 10^{-1}$	$2.04 \cdot 10^{-1}$	$1.712 \cdot 10^{-1}$
min.	$7.03 \cdot 10^{-2}$	$1.397 \cdot 10^{-2}$	$1.530 \cdot 10^{-1}$	$1.403 \cdot 10^{-1}$	$7.10 \cdot 10^{-2}$	$1.566 \cdot 10^{-1}$	$1.630 \cdot 10^{-1}$	$1.064 \cdot 10^{-1}$

Table 2: Rare gas concentrations in cm^3 STP/g in grain size fractions of fines from Apollo 17 sample 74260,9.
Errors in isotope ratios 2%, errors in concentrations of He, Ne and Ar about 3%, of Kr and Xe about 10%.
Sample weights between 0.5 - 2.9 mg.

	<20µm	<20µm	20 - 25µm	25 - 35µm	35 - 54µm	75 - 120µm	120 - 200µm	200 - 300µm
^{3}He	$5.88 \cdot 10^{-5}$	$5.80 \cdot 10^{-5}$	$1.580 \cdot 10^{-5}$	$1.364 \cdot 10^{-5}$	$7.48 \cdot 10^{-6}$	$5.93 \cdot 10^{-6}$	$2.46 \cdot 10^{-6}$	$6.91 \cdot 10^{-6}$
^{4}He	$1.759 \cdot 10^{-1}$	$1.745 \cdot 10^{-1}$	$4.42 \cdot 10^{-2}$	$3.86 \cdot 10^{-2}$	$1.840 \cdot 10^{-2}$	$1.454 \cdot 10^{-2}$	$4.76 \cdot 10^{-3}$	$1.997 \cdot 10^{-2}$
^{20}Ne	$2.05 \cdot 10^{-3}$	$2.10 \cdot 10^{-3}$	$6.04 \cdot 10^{-4}$	$4.84 \cdot 10^{-4}$	$2.69 \cdot 10^{-4}$	$1.626 \cdot 10^{-4}$	$7.10 \cdot 10^{-5}$	$2.22 \cdot 10^{-4}$
^{21}Ne	$5.45 \cdot 10^{-6}$	$5.40 \cdot 10^{-6}$	$1.811 \cdot 10^{-6}$	$1.531 \cdot 10^{-6}$	$1.004 \cdot 10^{-6}$	$7.24 \cdot 10^{-7}$	$5.12 \cdot 10^{-7}$	$8.20 \cdot 10^{-7}$
^{22}Ne	$1.643 \cdot 10^{-4}$	$1.688 \cdot 10^{-4}$	$4.98 \cdot 10^{-5}$	$4.04 \cdot 10^{-5}$	$2.24 \cdot 10^{-5}$	$1.364 \cdot 10^{-5}$	$6.30 \cdot 10^{-6}$	$1.905 \cdot 10^{-5}$
^{36}Ar	$2.05 \cdot 10^{-4}$	$2.25 \cdot 10^{-4}$	$4.95 \cdot 10^{-5}$	$4.66 \cdot 10^{-5}$	$2.59 \cdot 10^{-5}$	$1.727 \cdot 10^{-5}$	$1.107 \cdot 10^{-5}$	$2.90 \cdot 10^{-5}$
^{38}Ar	$3.87 \cdot 10^{-5}$	$4.34 \cdot 10^{-5}$	$9.68 \cdot 10^{-6}$	$9.16 \cdot 10^{-6}$	$5.23 \cdot 10^{-6}$	$3.55 \cdot 10^{-6}$	$2.37 \cdot 10^{-6}$	$5.66 \cdot 10^{-6}$
^{40}Ar	$1.367 \cdot 10^{-3}$	$1.588 \cdot 10^{-3}$	$3.03 \cdot 10^{-4}$	$3.08 \cdot 10^{-4}$	$1.698 \cdot 10^{-4}$	$1.353 \cdot 10^{-4}$	$8.72 \cdot 10^{-5}$	$2.29 \cdot 10^{-4}$
^{84}Kr	$8.7 \cdot 10^{-8}$	$8.8 \cdot 10^{-8}$	$2.0 \cdot 10^{-8}$	$1.9 \cdot 10^{-8}$	$1.0 \cdot 10^{-8}$	$6.4 \cdot 10^{-9}$	$4.2 \cdot 10^{-9}$	$1.3 \cdot 10^{-8}$
^{132}Xe	$1.5 \cdot 10^{-8}$	$1.7 \cdot 10^{-8}$	$3.7 \cdot 10^{-9}$	$2.3 \cdot 10^{-9}$	$2.1 \cdot 10^{-9}$	$1.2 \cdot 10^{-9}$	$1.1 \cdot 10^{-9}$	$2.2 \cdot 10^{-9}$
$^{4}He/^{3}He$	2990	3010	2800	2830	2460	2450	1935	2890
$^{20}Ne/^{22}Ne$	12.48	12.44	12.13	11.98	12.01	11.92	11.27	11.65
$^{22}Ne/^{21}Ne$	30.1	31.3	27.5	26.4	22.3	18.84	12.30	23.2
$^{36}Ar/^{38}Ar$	5.30	5.18	5.11	5.09	4.95	4.86	4.67	5.12
$^{40}Ar/^{36}Ar$	6.67	7.06	6.12	6.61	6.56	7.83	7.88	7.90
$^{4}He/^{20}Ne$	85.8	83.1	73.2	79.8	68.4	89.4	67.0	90.0
$^{20}Ne/^{36}Ar$	10.00	9.33	12.20	10.39	10.39	9.42	6.41	7.66
$^{36}Ar/^{84}Kr$	2350	2550	2540	2410	2560	2720	2640	2250
$^{84}Kr/^{132}Xe$	6.0	5.2	5.3	8.2	4.9	5.3	3.9	5.8

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exposure age of the orange soil (~30 my). On the opposite, the gas retention ages of the reference soils are <500 my, small in any case compared to the gas retention age of the orange soil (3.5 ± .3) (1). One can assume that during an event which reduces the radiogenic Ar40 by a considerable amount, the trapped gases are lost or at least strongly depleted. Thus, the low gas retention age indicates that the trapped gases in the reference soils are the result of a relative recent solar wind irradiation. The high Ar40/Ar36 and He4/He3 ratios can, therefore not be attributed to a solar irradiation at a very early date (4).

Both analysed breccias appear as lithified soils because the matrix of these stones is matured with trapped solar wind rare gases.

Literature:

(1) Hintenberger H. and H.W.Weber (1973) Proc.Fourth Lunar Science Conf.,Geochim.Cosmochim.Acta Suppl.IV (in press)

(2) Lunar Sample Information Catalog Apollo 17, LRC, 1973

(3) Eugster O,N.Grögler,M.D.Mendia, P.Eberhardt and J.Geiss (1973) Geochim.Cosmochim.Acta 37, 1991

(4) Kirsten T., P.Korn, D.Heymann, W.Hübner and D.Storzer (1973) EOS 54, 595.

Table 3: Concentrations (cm^3 STP/g) and isotope ratios of trapped, spallogenic and radiogenic rare gas nuclides of lunar fines.

	$({}^{4}He/{}^{3}He)_{tr}$	$({}^{20}Ne/{}^{21}Ne)_{tr}$	$({}^{22}Ne/{}^{21}Ne)_{tr}$	$({}^{36}Ar/{}^{38}Ar)_{tr}$	$({}^{40}Ar/{}^{36}Ar)_{tr}$	${}^{3}He_{sp}$	${}^{21}Ne_{sp}$	${}^{38}Ar_{sp}$	${}^{40}Ar_{rad}$
						(10^{-8} cm^3 STP/g)			
74220,47	2970 ±40	399 ±4	30.8 ±0.3	5.26 ±0.06	5.0 ±0.2	15 ±2	4.2 ±0.2	2.3 ±1.1	2600 ±300
74241,24	3260 ±50	411 ±4	32.8 ±0.4	5.20 ±0.04	7.6 ±0.1	120 ±21	25 ±2	24 ±5	120 ±90
74260,9	3090 ±50	411 ±5	32.7 ±0.4	5.27 ±0.03	7.1 ±0.1	100 ±30	31 ±3	27 ±3	~8
75081,72	2740 ±30	418 ± 3	32,8 ± ,7	5,33 ±,02	0,77 ±,01	120 ±70	39 ±6	36 ±17	1500 ±300