EVIDENCE FOR CARBON-14 IN THE SOLAR WIND

E. L. Fireman, J. D'Amico, and J. DeFelice
Center for Astrophysics
Cambridge, Massachusetts 02138

Solar wind is implanted in material on the lunar surface. The abundances of the stable isotopes of hydrogen, carbon, nitrogen, oxygen, and the rare gases in the solar wind have been obtained by heat extraction studies on lunar soil. Radioactivities, manufactured by nuclear processes in the solar atmosphere, could be measurable in the solar wind. Two radioactivities of prime significance are tritium and carbon-14. An upper limit of 2×10^{-11} for the $^3H/^1H$ ratio in the solar wind has been obtained (1) by measurements on Surveyor 3 material. Carbon-14, because of its longer half-life, could have a higher solar wind abundance than tritium. We present evidence for a $^{14}C/^1H$ ratio in solar wind of approximately 3×10^{-11}.

The carbon in lunar soil is mainly of solar wind origin (2),(3),(4),(5) and is released from lunar fines by heating above 400°C and below melting temperature. (6) (7) We extract the carbon by vacuum heatings of the sample in a molybdenum crucible for approximately 4 hours at 400°C, 600°C, 800°C, 1000°C with resistance heating and above melting temperature by induction heating. The released gases are collected and passed over CuO at 650°C converting the carbon compounds to CO_2. The CO_2 is condensed in a trap at -196°C, recovered from the trap at -78°C, and measured. To purify the CO_2 from radon, the CO_2 is converted to CO over Zn at 300°C. The gases which condense from CO at -196°C are removed. The purified CO is reconverted to CO_2. On the basis of stoichiometry, no carbon is lost in the Zn purification.

Since lunar rocks are often covered with a dust layer that is removed by handling, we study lunar soils. We are mainly analyzing samples from a trench sequence: 73221 (0 to 0.5cm depth), 73241 (0 to 5cm depth), 73261 (5 to 10cm depth). We also analyzed a sample of 10084.20, the first Apollo 11 grab sample, because the ^{14}C in equivalent material had been measured (8). Although cosmogenic ^{14}C should be in all the samples, solar wind ^{14}C should be present only in samples having recent solar wind (implanted during the past 30,000 years). The ^{14}C activity is identified by its energy spectrum and by its chemistry; solar wind ^{14}C is distinguished by its heat release pattern and by its depth correlation. Solar wind ^{14}C should be totally extracted at temperatures below melting, cosmogenic ^{14}C, which is imbedded within the silicates, is difficult to extract even by melting.

Our small ($\sim 0.7 cm^3$ volume) low-level proportional counters used for ^{37}Ar and ^{39}Ar measurements operate well with 1 1/2 atmospheres of CO_2 and

Ar if the CO_2 pressure is less than 1 atmosphere. The counter backgrounds, obtained with identical pressure of CO_2 from a petroleum source, are approximately 3 counts per day when the counter efficiency for ^{14}C is between 25 and 30%.

Table 1 gives the amounts of CO_2 obtained from samples 73241, 73261, and 10084 and the ^{14}C activities for 73241 and 10084. The ^{14}C counting for 73261 is in progress.

Table 1. Amounts of CO_2 and ^{14}C

Sample	73241.23		73261.15 & .3		10084.20	
Weight	2.01g		2.17g		0.52g	
Temp. (°C)	Volume (cm^3STP)	^{14}C (ct.day^{-1})	Volume (cm^3STP)	^{14}C (ct.day^{-1})	Volume (cm^3STP)	^{14}C (ct.day^{-1})
400	0.48	-0.1±0.6	0.14	*	1.42	—
600	0.58	5.5±0.5	0.11	*	0.22	2.6±0.4
800	0.34	1.2±0.4	0.18	*	0.25	1.7±0.4
1000	0.24	4.5±0.5	0.29	*	0.12	-0.5±0.5
Melt	0.35	3.1±0.5	1.64	*	0.40	2.9±0.4

*Measurement is in progress.

The amounts of CO_2 obtained above 400°C and below melting were 0.58, 0.27, and 1.14cm^3STP/g corresponding to 290, 140, and 570ppm of C for samples 73241, 73261, and 10084 respectively. At 400°C the carbon is largely from sample contamination. Above melting temperatures the walls of the molybdenum crucible contribute carbon. No ^{14}C activity was observed at 400°C. The temperature release pattern of the ^{14}C activity is bimodal. The total ^{14}C activity for 73241.23 is 18.5±3.5dpm/kg and for 10084.20 is 35±6 dpm/kg. The ^{14}C in 10084.18 had been measured [8] to be 39±5dpm/kg. Although the solar wind ^{14}C should be completely extracted by the heatings, the cosmogenic ^{14}C may not by extracted completely. We plan to test whether the ^{14}C extraction is complete by remelting the sample with flux and by ^{11}C activation studies.

If we attribute the ^{14}C released at 600 and 800°C to solar wind, the $^{14}C/^{1}H$ ratio of the solar wind is $(3\pm1)\times10^{-11}$.

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