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HELIUM-3 INVENTORY OF LUNAR SAMPLES: A POTENTIAL FUTURE ENERGY RESOURCE FOR MANKIND?

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Solar wind is the principal source for the volatile elements (H, C, N, and noble gases) in the lunar samples, which are enriched in the finest fraction of the Moon's comminuted regolith (1, 2). Some of these volatiles (H, N, He, and C) are regarded as potential lunar resources that can support the inhabitants of a lunar base and provide fuels for transportation (3). Various studies indicated that these volatiles may be extracted by heating the lunar soils to approximately 700°C. At this temperature near quantitative release of hydrogen and helium, and approximately 20-30% of the release of nitrogen and carbon and their compounds occurs (4).

It is recognized that the global fossil fuel resources could not provide even half the energy requirement of the world in the 21st century (5). Recent public concern over the safety, cost, and environmental impact of the worldwide fission reactors has focused the attention of scientists and engineers towards perfecting fusion technology because it promises a much more environmentally acceptable "clean" energy supply (6, 7). Among the three fusion reactions considered, namely the $^{2}D + {}^{2}D$, $^{2}D + {}^{3}T$, and $^{2}D + {}^{3}He$, the reaction: $^{2}D + {}^{3}He \rightarrow p\ (14.7\ MeV) + {}^{4}He\ (3.6\ MeV)$ has long been recognized as an ideal candidate for producing commercially "safer and cleaner" fusion power (5, 6, 7, 8).

Unfortunately, the scarcity of naturally occuring ^{3}He on earth is the chief impediment to consider this fuel on a commercial scale, aside from plasma physics issues (5, 8). Most of the helium on earth is essentially ^{4}He produced by the radioactive decay of U and Th, and the ^{3}He known to be contained in terrestrial natural gas deposits could not power a modest-sized electrical power plant of 500 MW for more than few months. Lunar regolith is a potential ore for ^{3}He because the high ^{3}He in solar wind (apparently due to the nuclear reaction $^{2}D\ (p,\gamma)\ {}^{3}He$, which occurs in the high gravitational field of the sun) has been implanted in the lunar regolith for $>4 \times 10^{9}$ years, along with other volatile species (1, 2). Considering the cost of mining the lunar soil, degassing, isotopic separation, and transportation to earth, the energy payback ratio for ^{3}He is estimated to be ~250 (5). This payback ratio is highly favorable compared to that for ^{235}U production for nuclear fuel (~20) and coal mining (~16) on earth. More importantly, ^{3}He from the Moon results in an environmentally "clean" energy to mankind for the next few centuries (5, 8).

We have compiled data on the contents of various volatile elements including ^{3}He, TiO_2, and the maturity index (I_s/FeO) for all the lunar soils for which measurements have been reported (9). Our study indicates that the helium content of lunar soils varies from 1 to 63 ppm and the helium-3 abundance of these soils ranges from 0.4 to 15 ppb (Table 1). The helium abundance in lunar soils is dependent not only on the maturity of soils (I_s/FeO) but also on their mineralogy (Figs. 1 and 2). The titanium-rich (ilmenite) lunar soils are important repositories for volatiles, which may be released by heating these soils up to ~700°C. We estimate that per tonne of ^{3}He extracted from the lunar regolith at this temperature, ~6300 tonnes of H, ~700 tonnes of N, and ~1600

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tonnes of C (as CO and CO_2) will be released as byproducts that are also essential to sustain a permanent lunar base (2).

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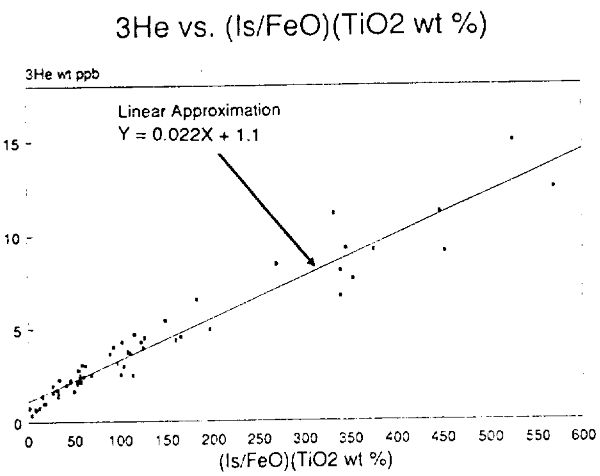
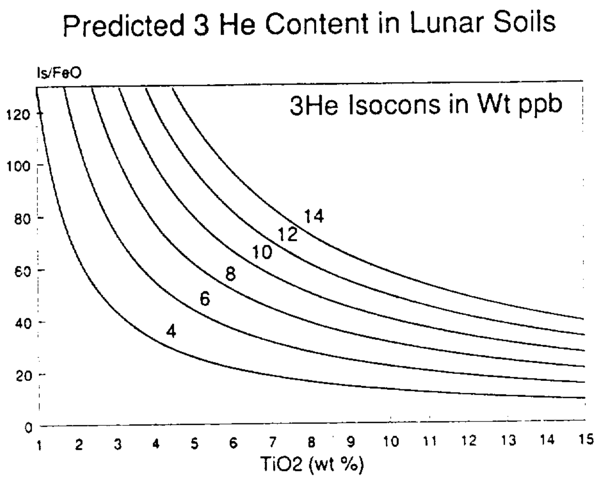
Table 1. Lunar Volatile Elements of Significance to Resource Utilization (9)

Element	**Measured range (ppm)**	**Origin**
H	0.1-211	Solar wind
He (^{3}He)	1-63 (0.4-15 ppb)	Solar wind
N	13-153	Solar wind
C	10-280	Solar wind
S	20-1330	Indigenous
H_2O	0-20	Terrestrial Contamination (?)



3He vs. (Is/FeO)(TiO2 wt %)

Fig. 1



Predicted 3 He Content in Lunar Soils

Fig. 2