LUNAR OXYGEN PRODUCTION THROUGH HYDROGEN REDUCTION AT HIGH TEMPERATURES

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Introduction: A typical spacecraft at launch stores 85% by weight of oxygen for the combustion reaction during takeoff. [1] Lunar oxygen produced from lunar metals would jumpstart advanced development of a space transportation system. It is also suggested that because of the abundance of oxygen found in lunar soil, lunar oxygen can become a very important economic export. This would enable missions to use the moon as a 'refueling hub' for deep space exploration. Lunar oxygen, if able to be created, can be condensed into a liquid state and stored in tanks to give commercial/military spacecraft the extra fuel to fly into deeper space or back onto Earth.

Oxygen production experiments have been carried out on natural and synthetic material before. Lunar basalt, mare soil and volcanic glass have been tested on its nature to produce oxygen. The NASA Johnson Space Center Group has studied the release of oxygen through reduction of hydrogen gas at high temperature. This chemical reaction will initiate the conversion from FeO within the lunar material to iron metal and the release of oxygen. Ilmenite (a mixture of iron, titanium, oxygen and magnesium) and volcanic glass can be found freely on the lunar surface and is comprised of considerable oxygen. Therefore, both will become the focus of this discussion. [2]

Ilmenite Hydrogen Reduction:
The experiments use powdered lunar specimens and reacted it in flowing hydrogen ($122 cm^3/min$) in a microbalance furnace at temperatures between 900 and 1100 degree Celsius.

$$FeTiO_3 + H_2 \rightarrow Fe + TiO_2 + H_2O$$

The purpose of the hydrogen flow is to separate ilmenite into its primary constituents. This produces iron, rutile and water. After reacting the material in this manner for 2 to 3 hours, the resulting surface and internal textures of the material were examined by scanning electron microscopy (SEM).The oxidation states and relative abundances of iron metal and oxides were determined by iron Mossbauer spectroscopy (FeMS). [3] The NASA Group found that the amount of oxygen in an ilmenite specimen is independent on the ilmenite content. The availability of oxygen is controlled by TiO_2. From the experiment, the predicted maximum oxygen yield is approximately 20% of the TiO_2 abundance. Further reduction release from TiO_2 to Ti_4O_7 produces another 5% of oxygen. [4] These results are found to be independent on temperature, though experiments have found that FeO in ilmenite is completely reduced between the temperature of 900 and 1050 Celsius.

Synthetic Glass Hydrogen Reduction:
For comparison purposes, the same methodology was applied to synthetic glasses with similar elemental composition of lunar volcanic glass. The reduction experiment used synthetic glass powder at a temperature range of 1000 - 1100 degree Celsius to demonstrate oxygen yield. The results shown that using glass as a starting material also yield a large percentage of oxygen from reacting FeO. Other glasses with similar composition to Apollo volcanic glass samples have also been tested with similar results in terms of oxygen yield. [5] The difference between the synthetic glass is that the yielding oxygen is dependent on both composition AND temperature.

Conclusion: High temperature hydrogen reduction experiments have shown that it is feasible to produce oxygen using lunar ilmenite and volcanic glass. Both have confirmed results that would yield an acceptable amount of oxygen.

Further Research: Although the process is a feasible method of extracting oxygen from lunar material. Further research should focus on defining efficient mineral extraction methods to identify high grade ilmenite. Instrumentation to control and monitor the chemical process and report on the experimental results must be investigated. From a social and economical point of view, an economic model for lunar oxygen business must be developed and analyzed.

References:
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