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Introduction: The objective of this work is to develop a safe, efficient, and recyclable method for oxygen and/or metals extraction from lunar regolith, in support of establishing a manned lunar outpost. The approach is to solubilize the oxides that comprise lunar regolith in media consisting of ionic liquids (ILs) and/or their mixtures at temperatures at or below 300ºC. Once in solution, electrolysis can be performed in-situ to generate oxygen at the anode and hydrogen and/or metals (silicon, iron, aluminum, titanium, etc.) at the cathode. Alternatively, the water that is generated during the solubilization process can be distilled out and condensed into a separate IL and then electrolysized to produce hydrogen and oxygen. In the case of lunar regolith, this method could theoretically produce 44g oxygen per 100g of regolith. The oxygen can be used for human life support and/or as an oxidizer for rocket fuels, and the metals can be used as raw materials for construction and/or device fabrication. Moreover, the hydrogen produced can be used to re-generate the acidic medium, which can then be used to process additional regolith, thereby making the materials recyclable and limiting up-mass requirements. An important advantage of IL acid systems is that they are much "greener" and safer than conventional materials used for regolith processing, such as sulfuric or hydrochloric acids. They have very low vapor pressures, which means that they contain virtually no toxic and/or flammable volatile content. Additionally, they are relatively non-corrosive, and they can exhibit good stability in harsh environments (extreme temperatures, hard vacuum, etc.). Furthermore, regolith processing can be achieved at lower temperatures than other processes such as molten oxide electrolysis or hydrogen reduction, thereby reducing initial power requirements.

Results and Current Experiments:
Initial results using JSC-1 lunar simulant show that ILs appear extremely promising for solubilizing lunar simulant. Results from preliminary water extraction experiments show that over 75% of the oxygen from the simulant can be harvested as water. This is for solubilization at only 150°C-160^{o}C. The water is produced from the reaction of the metal oxides in the simulant with hydrogen supplied by the IL. Electrolysis was used to split the water and produce liquid oxygen. Electrolysis efficiency, based on hydrogen and oxygen gas collected, was greater than 98%; and the efficiency of oxygen liquefaction is around 80%. This set-up also included a portable mass spectrometer for the identification of gases released from electrolysis cells. Recyclability of the IL is a critical factor in limiting up mass and making the process economically viable. Regeneration of the spent ILs through re-protonation on an ion exchange column was also demonstrated. Four sequential regenerations of an IL following solubilization of simulant took place with 97-98% efficiency, and showed no significant decrease in the amount of simulant dissolved. Hydrogen collected from the water electrolysis step can also be used for re-protonation. These experiments are in progress. We have begun a series of experiments to determine the reduction potentials and the electrochemical windows of our electrolytes. Knowledge of the reduction potentials allows us to electro-refine metals from the lunar regolith.

Solubilization of actual lunar material should depend on mineralogy. Owing to the lack of actual Apollo lunar samples, we have started small scale experiments on lunar meteorites. A small sample of Dar al Gani 400 was dissolved using our IL acid. These techniques can be extended to Martian regolith. Solubility of the Martian meteorite Sayh al Uhaymir 05 (SaU 05) has also been studied.