30 – Chemistry

SUMMARY

Sure, the Moon has the elements needed to support settlement. But are they in their right chemical form. Unfortunately, no. So, there are organic and inorganic chemical processes that need to be done to transform them into the most useful chemical forms.

The focus of chemistry on the Moon is to produce materials from local resources (ISRU) so that less mass must be shipped from Earth. This reduces shipping costs and moves us towards increasing levels of self-reliance.

ORGANIC & INORGANIC CHEMISTRY

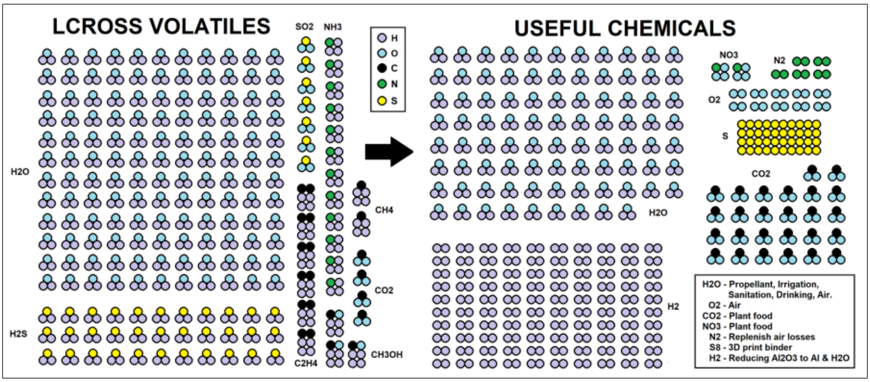
Like chemistry on Earth, chemistry on the Moon can best be divided between organic and inorganic chemistry. This is relevant not only to living things but also because the elements in organic chemistry tend to be volatiles and so it turns out that the volatiles are quite different between the Moon and Mars. In a sentence, volatiles are limited (but sufficiently present) on the Moon, but they are readily available on Mars. For this reason, locally produced objects on the Moon will want to use metals whereas on Mars, organics such as plastics will be commonly used.

SOURCES OF ELEMENTS ON THE MOON

Volatiles

Chapter 28 describes how volatiles such a water and nitrogen and carbon-containing molecules are trapped in permanently shadowed regions (PSRs) around the lunar poles. For lunar bases and settlements that recycle their chemicals, these organics are more than sufficient to support the needs of growing settlements. There are also volatiles embedded by the solar wind into sunlit regolith. But the concentration is so far below that of the volatiles in the PSRs it hardly makes sense to even think about those as a source of volatiles.

Those of us in the Space Development Network have done some preliminary work on how the chemical make-up of the LCROSS results could be chemically transformed into more useful chemicals. Here is a stoichiometric look at how the LCROSS volatiles could be transformed.



METALS

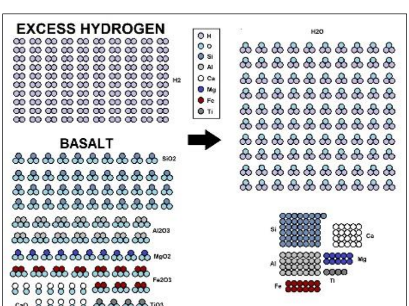
Iron & Steel

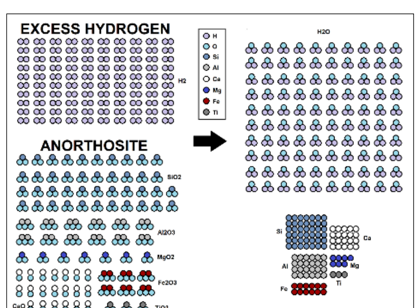
Iron can be extracted from iron-rich minerals such as FeTi)2 found in the common lunar rock, ilmenite. Using hydrogen reduction and carbonyl iron refining. Although energy intense, molten regolith electrolysis can also be used to produce high-purity iron.

Steel uses carbon, which is one of the volatiles found in the 2009 LCROSS results. But, given the relative rarity of carbon, high-carbon steel should be used only where it is essential.

Other Metals

The following stoichiometric diagram shows how the excess hydrogen from the previous diagram could be used to extract metals from different rocks.

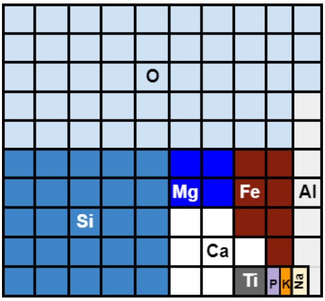




OTHER ELEMENTS

Micronutrients

Micronutrients tend to be in the regolith in the form of metal oxides. Certain single-celled organisms and plants have the biochemistry necessary to incorporate those elements into themselves in a bioavailable form. So, this will be the main way in which the crew will get those micronutrients from local resources.



Potassium and Phosphorus

There is a special case for two elements -- potassium and phosphorus. There is a specific layer of the Moon's crust which tends to concentrate these two elements (along with Thorium) more than in other rocks. Certain areas of the Moon and certain craters tend to be elevated in this type of rock. This rock has been given the name KREEP to indicate potassium (K), rare Earth elements (REE), and phosphorus (P). There is even one such KREEP rock which fell to Earth as a meteorite whose location has been localized to a specific crater (LaLande Crater) on the Earth-facing side of the Moon. This crater has one of the highest KREEP concentrations on the Moon and may be a mining site in the future. For agriculture potassium and phosphorus make up two of the three important elements in plant fertilizer (NPK).

Shipping Certain Elements

It may be that there will be certain circumstances in which it will be more cost-effective to simply ship certain elements to the Moon rather than try to extract them from low-concentration sources. An example of this may be copper which is in relatively low concentrations in the Apollo rock samples. We also don't believe that there were ever geologic processes which may have concentrated copper in a manner which has happened on Earth. In that case, the element could simply be shipped as an large payloads thereby meeting the needs for that element for a growing base or settlement for years to come.

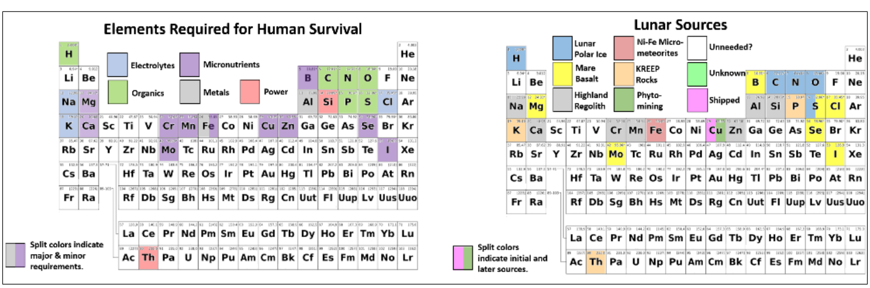
An analogy which might give some idea is that each home on Earth has an average of 50 kg of copper in its wiring. So, a 100 metric ton copper payload would provide the equivalent of the copper needed for 2,000 homes. And we know from renovations that copper wiring tends to last more than a century. But it should be acknowledged that this is an imperfect analogy because there are alternative metals for wiring yet probably a greater need for copper per lunar settler given all of the life support systems needed.

The Elements Needed for Human Survival

Finally, it is commonly stated by Mars advocates that only Mars has all of the resources needed to support a large and ultimately a completely Earth independent civilization. This is not true.

Not all elements are needed for human survival. For example, we like gold and it has many uses. But many human tribes have existed for centuries without working gold mines. It is neither a necessary metal nor a micronutrient. And there are plenty of other elements which are not essential.

The Network investigated this question of what elements exactly are needed for human survival and where they are known to exist on the Moon. As a result, we have produced two periodic tables of the elements which you can see here:



As you can see, every needed element has a known source on the Moon. The challenge then is to identify the processes necessary to transform these elements from their native form into a form usable to the lunar settlers and how they can be recycled in order to reduce the amount that needs to be harvested / mined.

CHEMISTRY IN THE INITIAL BASE

We envision the Initial Crew of eight having one team member who is the official Chemist with another (perhaps the Geologist) who is cross-trained to do the chemistry. The Chemist would receive the organic chemical residue distilled and separated from the water from the ice harvesting operations. This residue would be transported telerobotically from the field distiller to the Initial Base. She would take this organic stew and use an approach (perhaps further distillation) to separate the chemical species from each other. She would then employ a set of chemistry protocols to transform those organic chemicals into more useful forms. She would also produce excess hydrogen in the process and could receive hydrogen from the propellant electrolysis process. Working with the Geologist and the Metallurgist, they would conduct the inorganic chemistry protocols to use the excess hydrogen and electrolysis to extract metals from certain rocks.

The Chemist would routinely make news as she succeeded in demonstrating the production of one chemical after another. Undoubtedly, the Chemist would develop a following by a particular set of young people on Earth who would be inspired by her example to pursue careers in chemical engineering.

CHEMISTRY IN THE INTERNATIONAL BASE

As the International Lunar Base is established and grows, certain chemicals would be needed in increasing quantities. So, a ChemHab would be needed to produce the chemicals needed on an industrial scale. Since chemistry at this level tends to be fairly energy intensive, we would imagine that the chemistry would be conducted at the lunar poles near the Peaks of Eternal Light and then, in their refined form, would be transported to colonies and settlements in other parts of the Moon via automated transport. In this way, all parts of the Moon would have equal access to the water, oxygen, propellant, organic chemicals, and metals as any other part of the Moon.