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CHEMICAL ENGINEERING ON THE MOON

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In discussing the possible industrialization of space it should be recognized that a major economic problem will be the difficulty of chemical process engineering. It is obvious that extracting desired elements and compounds from lunar material will present many novel challenges. However, two fundamental problems might be termed the entropy problem and that of waste heat disposal.

The entropy problem has four aspects each of which has implications for the other:

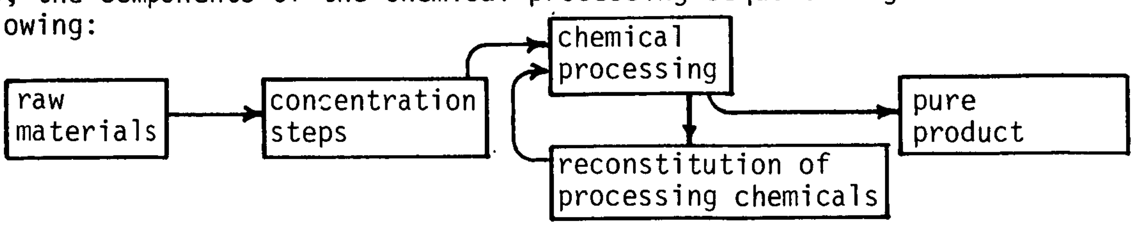
1) The relatively homogeneous nature of lunar material requires that steps be taken to concentrate species wanted for chemical processing. On the earth this has already been done by various geological processes so that enriched ores and sources for the necessary processing chemicals are available.

2) The cost of making processing chemicals from lunar materials or of importing them from the earth requires that they be re-used.

3) We will need to achieve necessary purities of the product materials without at any time being able to use large amounts of cheap, pure cleaning agent in the way that we are able to use water on earth. Purity of the product will be necessary to meet performance standards for the material and to avoid wasteful entrainment of precious processing chemicals.

4) We will need to avoid contamination of moon's atmosphere or space with gaseous or solid debris.

Thus, the components of the chemical processing sequence might be the following:



Conventional chemical engineering cycles normally include additional input and output paths such as disposable wash water. It is very hard to devise a closed cycle such as the above where the processing chemicals are reused with only slight loss. The degree of re-purification can be equated to energy by the formula, $E = -k \ln W$, where E is the energy per mole of material, k is Boltzmann's constant, and W is the fraction of the species of interest in the material. The work to increase the concentration from 9 to 90% is the same as that to decrease the impurities from 1 to 0.1% by this formula. The energy may be expended to run a distillation column, electrical energy to disassociate some compound used for cleanup, etc. The reconstitution loop would include many sub-loops for purification and in

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turn for purifying the purifying chemicals, and each would require energy input. At this stage in the study of possible space industrialization we should propose some likely production processes and examine them in detail from the foregoing point of view.

Waste heat disposal is a problem familiar to the space community but not to the chemical engineering community under the restrictions relevant to operations on the moon or in space. Radiation to space is the only method available on a long term basis. In chemical operations such as distillation, for example, it is necessary to remove thermal energy at the condensation stage. This may still be hot in which case radiation cooling is practical, but if it is too cool, it will be necessary to use refrigeration systems to pump the heat to the necessary temperature for radiation. If one takes the option of selecting chemical operations where the low temperature point is still hot enough for radiative dissipation of heat, the system tends to suffer from corrosion problems. For any scheme, large radiative surfaces will be necessary.

The entropy problem and the heat disposal problem play on each other, because each sub-loop in the reconstitution of processing chemicals consumes energy which must eventually be radiated away as heat. Also, pumping efficiencies are not typically high in moving materials or in refrigeration processes. Therefore, the total energy costs for chemical processing might be high enough to make a significant economic impact on the proposal for space industrialization.

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