

HOW THE MOON MAKES WATER: A CONCEPTUAL VIEW.

Donald D. Bogard, Formerly NASA-JSC and LPI (retired). donbogard@comcast.net

Material surfaces can readily be chemically activated by various processes that break chemical bonds, such as physical breaking and irradiation by charged particles or high-energy photons. The typical Si-O bond is ~ 450 kJoule/mole, or ~ 2.4 eV/bond, which is substantially below the electron ionization energy of either element. In many silicates, the Si-O bond length is ~ 0.16 μm , and the lunar surface erosion rate produced by micro-particle impacts is $\sim 10^{-9}$ m/yr, or a few Si-O bonds/yr. Thus both surface erosion and impact breaking can produce active surfaces. In addition, solar wind protons, with an energy of ~ 1 keV and a flux at the Moon of $\sim 3 \times 10^8$ atoms/cm²-sec, are capable of breaking all Si-O bonds on a surface in a time period of less than a year. Thus the solar wind may activate surfaces on a rate comparable to that produced by surface erosion. Further, the flux of UV photons on the lunar surface is $\sim 10^{15}$ photon/cm²-s, far greater than the solar wind H flux. A UV photon with 300 nm wavelength has an energy of ~ 4 eV, or slightly above the Si-O bond energy. Thus, whereas far UV and X-ray photons are capable of breaking Si-O bonds, visible light is not. All of the above mechanisms likely contribute to producing chemically activated material surfaces on the Moon.

When such broken bonds are produced, there are limits to the degree they can be reformed internally through bond distortion. Such chemically activated surfaces can be strongly reactive toward other atoms brought into contact, and through chemisorption they can produce bonding whose strength approaches those of normal silicate bonds, or up to ~ 400 kJoule/mole. This chemisorption bonding occurs only in a monolayer and can have covalent or ionic character. In the lunar environment there are few volatile species

that can quickly neutralize these chemically active surfaces, and so they persist. Such chemically active surfaces do not persist on Earth, both because physical breaking to form new surfaces is the only common way to generate them (the atmosphere stops solar H and UV photons) and because the terrestrial environment has volatiles to quickly neutralize such active surfaces. For example, to neutralize active surfaces on 10 g of regolith consisting of grains of 10 μm diameter, probably would require only ~ 20 cm³ of terrestrial air at 50% humidity and STP, considering only chemisorption by water. It has proven to be difficult to generate such active surfaces in laboratory experiments and to preserve them long enough so as to measure their chemical activation properties.

The lunar surface is continually bombarded by solar wind H, and this H is capable of interacting with unsatisfied O bonds at material surfaces to produce an O-H bond. This process may be the most probable way in which unsatisfied O surface bonds are satisfied. The Deep Impact flyby of the Moon in June, 2009 spectrally detected the 2.8 μm O-H adsorption feature at middle latitudes on the Moon, where water ice cannot exist (Sunshine et al., 2009). Such O-H surface bonding may also incorporate through chemisorption a second H atom to produce a proto H₂O atom, which might be then released into the lunar atmosphere. However, such a process occurring repeatedly on a silicate surface would tend to deplete that surface in O and produce a charge imbalance that would retard the process. Nevertheless, continual generation of new chemically active material surfaces and their reaction with solar wind H is probably a continuous process by which the Moon produces water.