

THERMAL DESORPTION PROPERTIES OF WATER ADSORBED ON MICRONIZED LUNAR SURROGATES JSC-1A AND ALBITE. M. J. Poston¹, A. B. Aleksandrov¹, G. A. Grieves¹, C. A. Hibbitts², M. D. Dyar³, T. M. Orlando¹, ¹School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, GA, 30332, michael.poston@gatech.edu. ²Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 20723. ³Mount Holyoke College, Dept. of Astronomy, South Hadley, MA, 01075.

Introduction: The existence of reservoirs of water-ice in the permanently shadowed regions at the lunar poles was first predicted by Watson et al. in 1961 [1]. The recent LCROSS impact experiment at Cabeus crater confirmed the presence of up to 6% concentration (by mass) of water and ice in the ejecta plume [2], yet the original source of this water is unknown. Three independent spacecraft observations also reported the presence of water (10-1000 ppm) and hydroxyl (OH) on the sunlit lunar surface [3-5]. These observations were unexpected because it was determined, based on isotopic analysis, that the water from lunar samples returned by the Apollo missions was due to terrestrial contamination [6]. However, the last 27 ppm of 675 ppm of water removed from lunar breccia 66095 was slightly deficient in deuterium, which may suggest a solar wind origin for some lunar water.

Water is an important resource for human exploration of the solar system, most importantly for sustaining the life of the astronauts, but also as a possible efficient source of hydrogen and oxygen for rocket fuel. Indeed, accessible sources of water may be the deciding factor in selecting targets for future human space exploration. Thus, the ability to predict locations of accessible water (and/or hydroxyl) will be a valuable tool for space agencies across the Earth. The work reported here seeks to build the experimental basis for modeling interactions of molecular water with the lunar regolith, regardless of the source of the water.

Experimental Methods: Temperature Program Desorption (TPD) experiments were performed under Ultra-High Vacuum (UHV) conditions. Mechanically-micronized JSC-1A was chosen to simulate the maria regions, while micronized albite was used to represent the lunar highlands. Details about the sample material mineralogy can be found in Hibbitts et. al. [7] and referenced cited therein. About 40-50 mg of powder was deposited on a gold-plated sample holder; sample pretreatment involved heating the samples to 750 K under UHV.

Results: *Varied Quantity of Exposure.* TPD experiments of JSC-1A exposed to water doses of 0.2 L up to 128 L at temperatures below 110 K were conducted, and up to 4 L exposure is shown in Figure 1. At low exposures (less than 1 L), only a broad peak is observed, ranging from 170 to ~400 K. This peak, which is assigned as molecular chemisorption,

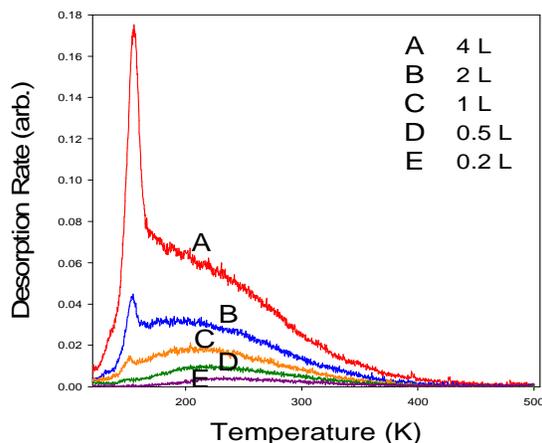


Figure 1: TPD spectra of micronized JSC-1A exposed to 0.2 to 128 L of water vapor.

increases in magnitude with continued exposure up to 64 L. Additionally, a narrow peak with onset at ~140 K grows in at 0.5 L and continues to triple in area each time the exposure is doubled. The maximum of this peak shifts to higher temperature as the peak grows, indicating zeroth-order desorption kinetics, and the peak is assigned as ice. Albite shows similar behavior with two important differences: 1) the broad peak from 170 to 400 K shows a more defined maximum centered at 220 K; and 2) the chemisorption feature does not saturate with increased water exposures of up to 256 L.

Calculations that employ the BET [8] surface area of the amount of powder used, the geometric surface area of the sample holder, and the water exposure required for saturation (assuming 512 L for albite) yield the total chemisorption sites on each material: ~14% for micronized JSC-1A and >43% for micronized albite. These values convert to maximum chemisorption concentrations of ~336 ppm and >2200 ppm water, by mass, on JSC-1A and albite, respectively.

Varied Temperature of Exposure. When considering a heterogeneous (glass plus crystals of different minerals) powder sample such as JSC-1A, a vast distribution of pores and defect sites is present, each with its own binding energy for chemisorbed water. Desorption peaks from a distribution of sites will overlap and sum to a broad peak, similar to those observed for both micronized powders. However, excessive re-adsorption as ice desorbs and travels from

the deeper particles within the powder film could also broaden narrow peaks. To differentiate between these two interpretations, water was dosed at elevated temperatures (140-340 K) (where little or no ice should form) and this procedure was followed by TPD from 110 K. The resulting spectra showed a clipping of the low temperature portions of each peak consistent with the dosing temperature, but the portions of the peak above the dosing temperature remained. This result supports the assignment of the broad peak in both samples as a distribution of chemisorption sites with varied desorption energies for adsorbed water.

Energies of the Adsorption Sites. Accurate modeling of water transport on the Moon requires knowledge of the desorption energies for water on regolith surfaces, which can be obtained from TPD experiments. Lunar regolith is composed of a distribution of grain sizes that are loosely-packed and irregularly-shaped, consisting of various minerals, breccias, glasses, and agglutinates. These materials will have many different types of desorption sites. Broad peaks in our TPD data, as well as the results described in the previous section, are consistent with the existence of a distribution of sites as would be found on the Moon. A numerical analysis method to quantify the desorption energies is therefore required. Our group has developed a program (in Labview 8.6) that fits an arbitrary number of overlapping Polanyi-Wigner desorption peaks to the TPD data, yielding a set of desorption energies and the relative coverage of each site. Both samples were found to have similar distributions of desorption sites, with desorption energies ranging from 0.4 to 1.2 eV. However, after multiplying these distributions by the maximum concentrations reported above, the albite clearly has the greater ability to chemisorb water.

Future work. Further work is needed to unravel the relative contributions of the mixed phases in JSC-1A, and work on materials more directly relevant to the Moon. TPD and desorption experiments on pure glasses with lunar compositions as well as olivine, pyroxene, and anorthite are also being undertaken. For those experiments, the water and hydroxyl contents of starting materials will be measured with FTIR before and after desorption to help constrain the role played by their loss from the interiors of these nominally-anhydrous starting materials.

Acknowledgments: We are grateful for support of this project from LASER grant #NNX08AZ01G and Lunar Science Institute grant #NNH08ZDA008C.

References: [1] Watson, K., et al. (1961) *JGR*, 66, 3033. [2] Colaprete, A., et al. (2010) *Science*, 330, 463-468. [3] Clark, R. N. (2009) *Science*, 326, 562-564. [4] Pieters, C. M., et al. (2009) *Science*, 326, 568-572. [5] Sunshine, J. M.,

et al. (2009) *Science*, 326, 565-568. [6] Epstein, S. and Taylor, H. P. (1973) *LPS IV*, 1559-1575. [7] Hibbitts, C. A., et al. (2011) *Icarus*, Submitted. [8] Brunauer, S., et al. (1938) *JACS*, 60, 309-319.