Chemical and physical characteristics of finely divided solids can be studied advantageously by measuring the adsorption of suitable gases and vapors. This paper is concerned with such experiments (utilizing a vacuum microbalance system) on lunar samples 12001, 12070, 14003, and 63341 (sieved fractions <1 mm). The adsorption-desorption isotherms of nitrogen, argon, carbon monoxide, and oxygen (all at 77 K) were measured after an initial outgassing (minimum of 16 hours to less than $10^{-5}$ torr). Results demonstrated that all of the samples had relatively low specific surface areas (all values were in the range of 0.3 to 0.6 m$^2$/g). In addition, the absence of hysteresis loops in the isotherms indicated that the samples were nonporous in the initial state. Adsorption energies, as reflected by the BET "c" constant, increased in the order $\text{CO} < \text{N}_2 < \text{Ar}$. This indicates that the adsorption is not determined solely by dispersion forces.

Results for the adsorption of water vapor were, as usual, quite different from those obtained with the preceding four gases. All of the samples exhibited a strong irreversible adsorption of water (water which could not be removed by evacuation at the isotherm temperature of 20 or 22°C). If the lunar sample is outgassed at an elevated temperature the irreversible adsorption of water is much larger than that required for a single monolayer of chemisorbed water. There was massive adsorption of water at relative pressures ( humidities) approaching saturation vapor pressure. Desorption from high relative pressures gave marked hysteresis and indicated the presence of a pore system extending down to, and including, two molecular diameters in size. Specific surface areas calculated from successive adsorption-desorption cycles with water vapor indicated a significantly progressive increase in surface area. The extensive interaction with water vapor which was first observed with a sample from the Apollo 11 mission has been confirmed with samples from the Apollo 12, 14, and 16 missions.

In order to ascertain if the changes indicated by water adsorption are permanent or specific and observable only with water vapor the adsorption isotherms of argon and nitrogen were measured after the water adsorption experiments. Results obtained with nitrogen and argon showed conclusively that the changes were real and permanent. This fact can be seen in the accompanying figure which shows a nitrogen adsorption isotherm for sample 12070 after outgassing at 500°C following the water adsorption experiments. More specifically the isotherm reveals the presence of a pore system spanning the size range from micro (widths less than 20Å) to transitional or intermediate (widths from 20 to 200Å) pores. The hysteresis between adsorption and desorption data at high pressures is indicative of pores in which capillary condensation hysteresis can occur. According to de Boer, this type of hysteresis loop results from open slit-shaped capillaries or capillaries with wide bodies and narrow short necks. One cannot decide between these two types of capillaries on the basis of adsorption data alone. At least equally important is the specific surface area resulting from a usual
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BET treatment\textsuperscript{3} of the data; 1.15 m\textsuperscript{2}/g as compared to the initial value of 0.56 m\textsuperscript{2}/g. The increased specific surface area and the pore system clearly indicate that the reaction with water vapor has caused drastic changes in this sample. These results are not unique to sample 12070. Experiments with argon, an adsorbate which does not have a quadrupole moment, confirmed the results obtained with nitrogen.

A tentative and logical explanation for the action of water vapor on lunar fines samples is that water vapor, at sufficiently high relative pressures, penetrates the severely radiation damaged surfaces of the particles and leaches out soluble material which recrystallizes on desorption of water. As a result of the leaching and recrystallization process the specific surface area increases and a pore system is created. Results with nitrogen and argon adsorption after outgassing at intermediate temperatures (less than the 500°C in the figure), coupled with the known effects of irreversibly adsorbed water on the adsorption of nitrogen and argon on microporous solids, substantiate this hypothesis.

The stability of the water induced pore system was investigated by measuring the adsorption of nitrogen (and argon) after outgassing the samples at increasingly higher temperatures. Temperatures of 700 to 900°C were sufficient to eliminate the water induced porosity. However, a significant specific surface area remained after heating the samples at 1000°C in vacuo. These results have obvious implications concerning the coupled temperature-humidity history of lunar samples. Details of the effect of experimental sequence (e.g. the effect of outgassing temperature on the extent of adsorption) will be discussed in the extended manuscript.

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\textsuperscript{6}e.g., R. B. Gammage, E. L. Fuller, Jr., and H. F. Holmes, "Adsorption on Porous Thorium Oxide Modified by Water," J. Colloid Interface Sci., 38 (1972) 118.
Adsorption of Nitrogen on 12070,218 at 77 °K, Sample Outgassed at 500 °C.