

EVIDENCE FOR AMMONIUM-BEARING MINERALS ON CERES; T. V. V. King, R. N. Clark, W. M. Calvin, D. M. Sherman, G. A. Swayze (U.S. Geological Survey, Denver), and R. H. Brown (J.P.L., Pasadena)

Spectra of 1 Ceres has an absorption feature centered at $3.07\text{ }\mu\text{m}$ which we attribute to the presence of an NH_4 -bearing species on the surface of Ceres. This absorption feature was first reported by Lebofsky et al. (1) to be centered at $3.1\text{ }\mu\text{m}$ and was interpreted to be due to water ice. The wavelength position and width of the $3.07\text{-}\mu\text{m}$ absorption on Ceres are very similar to a NH_4 absorption in naturally occurring and synthetically produced NH_4 -bearing materials. This interpretation is based on four nights of observations from NASA's Mauna Kea IRTF using the CGAS detector and the Mars grating with a resolution of $0.013\text{ }\mu\text{m}$.

Prior to analysis, the Ceres spectra from all the observations had the thermal component removed. This was accomplished by determining the overall disk temperature and then by adjusting the wavelength independent emissivity(ϵ) and normalization constant (n) from the standard thermal model of Lebofsky et al. (2) to match the geometric albedo of Ceres reported by Feierberg et al. (3). The integrated disk temperature for Ceres used in this study is 243.7 K . The thermally-corrected spectrum of Ceres was compared to spectra from the USGS digital spectral library. After extensive research, we found that the $3.07\text{-}\mu\text{m}$ absorption feature can not be attributed to OH, H_2O , CO_3 , SO_4 , or other ions in geologically significant minerals.

The composite Ceres spectrum was compared to NH_4 -bearing mineral species including naturally occurring buddingtonite and a NH_4 -bearing illite/smectite, as well as laboratory samples including a NH_4 -substituted dioctahedral nontronite (Ng-1), a Ca/Na montmorillonite (SWy-1), a ferruginous smectite (SWa-1), and a trioctahedral saponite (SAPCa-1). The phyllosilicates used in the cation exchange process are standards of the Clay Mineral Repository (see Clark et al. (4) for additional discussion). The NH_4 -bearing saponite provides the best spectral comparison to Ceres. Comparison of the ammoniated-saponite and neat-saponite (nothing done to the clay) show that the NH_4 fundamental vibration matches the $3.07\text{-}\mu\text{m}$ feature and is stronger than the fundamental OH-absorption which occurs near $2.7\text{ }\mu\text{m}$.

The high resolution telescopic spectra indicate that the center of the NH_4 absorption on Ceres occurs at $3.07 \pm 0.02\text{ }\mu\text{m}$ vs. $3.05\text{ }\mu\text{m}$ for our laboratory samples. The width of the Ceres absorption is $0.127 \pm .08\text{ }\mu\text{m}$ vs. $0.145\text{ }\mu\text{m}$ for the laboratory sample. The depth of the $3.07\text{-}\mu\text{m}$ feature on Ceres is approximately 10%.

Lebofsky et al. (1) and Jones (5) have attributed a $3.1\text{-}\mu\text{m}$ absorption feature on Ceres to the presence of water ice. However, theoretical calculations of water ice spectrum at many grain sizes, shows that the $3.07\text{-}\mu\text{m}$ Ceres absorption is much too narrow to be caused by the presence of water ice. The spectrum of water ice at grain sizes of $1\text{ }\mu\text{m}$ indicate that the width of the feature is greater than 3.5 times the width of the $3.07\text{-}\mu\text{m}$ absorption on Ceres. Water ice at larger grain sizes would have greater widths because the absorption band is saturated.

To better understand the physio-chemical origins of the Ceres spectrum, we completed two laboratory studies in which we theoretically computed and physically mixed components that mimicked the spectrum of Ceres. We computed a spectrum using the derived optical constants of ammoniated-saponite, a black (low albedo mixture) and a gray (medium albedo) mixture. The best spectral agreement was achieved using a mixture of 7 wt. % ammoniated-saponite (grain size of $2\text{ }\mu\text{m}$), plus 52 wt. % of the black component (grain size of $5\text{ }\mu\text{m}$), and 41 wt. % of the gray material (grain size of $10\text{ }\mu\text{m}$). This produced a $3.07\text{-}\mu\text{m}$ absorption feature of 12 % versus 10 % for Ceres. The reflectance level of the calculated spectrum was less than 1 % lower than the reflectance level of the Ceres spectrum (~ 0.04 at $3.0\text{ }\mu\text{m}$). We also calculated the spectrum of a mixture which maintained the same proportions and grain sizes, but in

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which water ice was substituted for ammoniated-saponite. The resulting spectrum produced an absorption feature which was dominated by a very broad water ice absorption which extended from approximately 2.85 to 3.4 μm . The water ice dominated spectrum does not in any way resemble the Ceres spectrum. The band shape, depth and width are significantly different. A recent work by Calvin and Clark (6) indicates that increasing or decreasing the grain size of the water ice component would not produce a spectrum which could be confused with the spectrum of Ceres. The laboratory computed spectrum that includes the ammoniated-saponite component is a good spectral comparison to the high-resolution data of Ceres published by Lebofsky et al. (1).

A physical mixture of ammoniated-saponite and carbon black (8 wt. %) produced a spectrum which resembles the features in 3.07- μm wavelength region of Ceres. However, the reflectance level of the laboratory mixture is too low compared to Ceres when the strength of the 3.07- μm feature is correct. This suggests that the ammoniated-laboratory mixture contains more NH_4 than Ceres. The presence of additional absorption features in this Ceres data set, which have yet to be verified, may provide additional insight to the exact mineralogical association resulting in the 3.07- μm NH_4 absorption.

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