NEAR-IR (0.8-2.5 μm) OPTICAL CONSTANTS OF WATER ICE AT 100K, T.L. Roush,
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Water ice is an abundant constituent on surfaces throughout the outer solar system [1-6]. Warren [7] provides a compilation of the optical constants of water ice (T=269K) from the UV to the thermal-IR. Bertie et al. [8] present the optical constants of water ice (T=173K) that include part of the near-IR (λ=1.25-2.5 μm). While both of these data are useful in modeling the interaction of incident solar energy with icy bodies [e.g. 9-11], these temperatures are too warm for application in the outer solar system where temperatures are generally below 150K [e.g. 12]. Ockman [13] grew thick crystals of water ice at temperatures of ~266K and then measured the transmission of these samples at temperatures near 100K. These data can be used to estimate the optical constants of hexagonal water ice at temperatures appropriate for the outer solar system.

Absorption coefficients (α) determined from the transmission of two crystals grown by Ockman [13] were digitized. These data included separate measurements polarized along each crystallographic axis of the ice crystal. Because there are only minor differences between these oriented measurements, the data from both were averaged and the results are shown as the data points in Figures 1a and 1b for the long and short wavelength regions, respectively. An initial continuum, representing scattering within the crystal, was estimated for each region and is shown as the solid lines in Figures 1a and 1b. The value of the continuum, 1.58 and 21.4 for the short and long wavelength regions, respectively, was subtracted from the digitized absorption coefficients. It is assumed that the thicker crystal (1.05 cm) provides a more accurate α value near 1.25 μm so no other adjustments were made to the short wavelength region. The region of overlap between the two data sets was used to adjust the continuum of the long wavelength region so that the α's agree with the short wavelength region yielding a new continuum value of 20.2. This adjustment has the strongest effect in the weaker interband regions and very little effect within the strong bands. The absorption coefficients are used to calculate the imaginary indices of refraction (k=αλ/4π). These values are compared to the data of [7] and [8] in Figure 2a. Using the derived imaginary indices of refraction and combining them with the imaginary indices of refraction at longer wavelengths from [8], a Kramers-Kronig analysis was performed to determine the real index of refraction (n) (using n=1.3097 @ 0.589 μm) [8] and the results are shown in Figure 2b.

As temperature decreases several trends are illustrated in Figure 2a. Firstly, the band near 1.65 μm becomes readily pronounced. This band has been reported previously [14] and has been observed in spectra of icy bodies in the outer solar system [1-6,14]. Additionally, the bands near 1.5 and 2.02 μm become narrower and the center positions shift to longer wavelengths with decreasing temperature. Transmission studies of thin films [15], used to determine the optical constants at longer wavelengths, also exhibit a narrowing of bands and apparent shift of bands to longer wavelengths at lower temperatures.

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Figure 1. Absorption coefficients (cm$^{-1}$) of water ice derived from [13]. (a) crystal thickness 1.05 cm. (b) crystal thickness 0.358 cm.

Figure 2. Optical constants of water ice from [7] (dotted line), [8] (dashed line), and derived from [13] (solid line). (a) Imaginary and (b) real indices of refraction.