

NEAR INFRARED SPECTRA OF PURE ICES AND MIXTURES RELEVANT TO ICY SATELLITES. R. M. E. Mastrapa¹, M. P. Bernstein², and S. A. Sandford², ¹SETI Institute 515 N. Whisman Road Mountain View, CA 94043, ²NASA Ames Research Center MS 245-6, Moffett Field, CA 94035, rmastrapa@arc.nasa.gov.

Introduction: For decades, ices have been detected on the satellites and small bodies of the Solar System by spacecraft and ground-based telescopes. Meanwhile, laboratory measurements have lagged behind these discoveries. The few measurements made are often in the wrong wavelength range, temperature regime, or phase. The advantages of laboratory measurements include high signal to noise and spectral resolution. Bridging the gap between lab and Solar System spectra involves calculating the complex index of refraction of an ice, then using these values to create model spectra.

Infrared Spectroscopy: The primary application of infrared spectroscopy is remote detection of surface composition. To accomplish this we need to know the locations and relative strengths of an ice's absorptions in the infrared. For ices relevant to the Solar System, the absorptions in the 1-5 μm range are the result of molecular vibrations. An example of the vibrations seen in H_2O -ice is given in Figure 1.

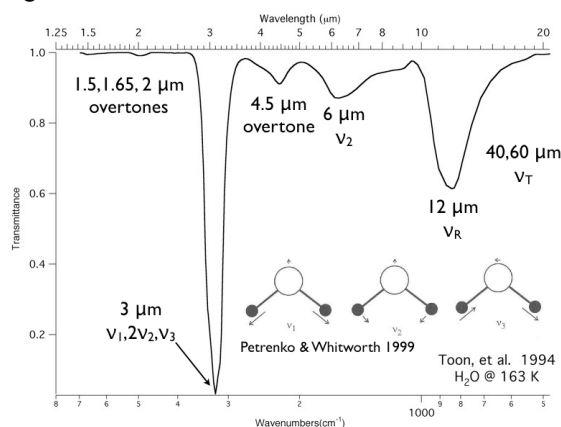


Figure 1. A model transmittance spectrum of a 1 μm thick slab of hexagonal H_2O -ice calculated from optical constants from Toon (1994) and Grundy and Schmitt (1998). Inset: the molecular vibrations of the H_2O molecule (Petrenko and Whitworth, 1999).

Beyond identifying composition, infrared spectra can be used to interpret the physical state of the surface materials. For example, the infrared features of H_2O -ice are temperature and phase dependent e.g. (Schmitt et al., 1998), Figure 2. Clark (1980) showed that the infrared spectrum of H_2O -ice is also dependent on grain size and amount of contamination by other materials. Band depth analysis can be used

to show these variations.

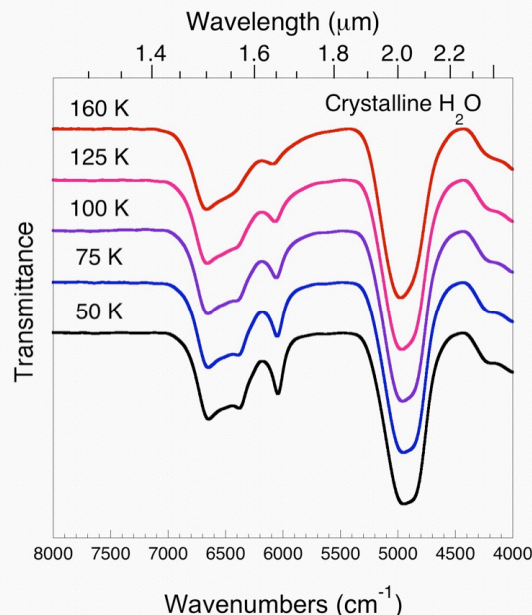


Figure 2. Transmittance spectra of crystalline H_2O -ice at 50, 75, 100, 125, and 160 K. The spectra are offset for clarity.

Lab Measurements: The vast majority of infrared measurements of ices were made for comparing to ISM observations. Therefore, they were made at low temperatures < 30 K and at > 2.5 μm . For the purposes of ground based observing, the visible and near infrared 0.5-2.5 microns are the most effective at seeing through the Earth's atmosphere. Spacecraft can make measurements at wavelengths longer than 3 μm , but H_2O -ice is usually saturated in this region, making the spectrum difficult to interpret. The wavelength range from 3-5 μm is still relevant since this is where the fundamental or strongest vibrations are for many ices.

Infrared lab measurements are made in transmission or reflection. Reflection is useful in identifying features, but is not easily converted to optical constants. Transmission needs to be done with thin samples either vapor deposited or in a closed cell. Closed cell measurements are limited by the fact that the sample is not under vacuum, and therefore cannot make metastable phases such as amorphous H_2O -ice. For spectra of H_2O -ice in the mid infrared (3-5 μm), ice samples only need to be a few microns thick for strong absorptions to appear. To see the relatively weak combination features in the 1-3 μm range, one needs to prepare a sample that

is on the order of tens of microns thick, saturating the fundamental at 3 μm . To see features shortward of 1.5 μm , a sample hundreds of microns thick is necessary, but cannot be made by thin film deposition since the sample begins to deviate from a flat surface into a mound. Thus, each individual ice composition presents a unique problem depending on the target wavelength range, phase, etc.

Scattering of icy surfaces is poorly understood. Scattering models are for particulate matter, but ices that can sublime and sinter together should not be treated as particles. Few scattering studies have been performed on thin films of ices, and it is unknown how this scattering can affect the infrared spectrum.

Mixtures: The presence of CO_2 and CH_4 in H_2O -ice create a spectrum that is not the same as a model mixture of the pure end members (Bernstein et al., 2005; Bernstein et al., 2006). The features are temperature and H_2O -ice phase dependent and could be used to interpret the state of mixing on an icy surface. Few studies have looked at the effect on features shortward of 3 μm .

Irradiation: Irradiation causes phase and chemistry changes, sputtering loss e.g. (Bernstein et al., 1995; Mastrapa and Brown, 2006). However, long term effects on the bulk structure, i.e porosity, density, scattering properties, are unknown. Laboratories are limited to specific particle types and energy ranges based on available equipment. Also, it is difficult to measure optical constants of irradiated samples because the ice thickness changes due to sputtering.

What is needed? Some pure substances have still not been measured. Some have been measured, but at the wrong temperature or spectral range. For what measurements there are, only few have been used to derive proper optical constants, and many of them are not appropriate for conversion. Very few mixtures have been investigated at temperatures or with compositions relevant to satellites. Scattering properties of ices are also poorly understood. In addition, the long-term effects of radiation and gardening are not well understood, nor are how they impact porosity, etc. Future laboratory work in these areas is critical to our ability to interpret current data sets.

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