LIBRARY OF MINERAL AND ROCK SPECTRA IN THE THERMAL- INFRARED (2.1-25.0 μm): IMPLICATIONS FOR OBSERVATIONS OF FINE PARTICULATE PLANETARY SURFACES


All the major rock-forming minerals display molecular vibration bands in the thermal-infrared region of the spectrum (2.1-25.0 μm) that can be used for compositional remote sensing. However, most currently available thermal-infrared laboratory spectra for minerals and rocks were recorded in transmittance mode and cannot be used to predict spectral emittance, because the spectra do not include the effects of scattering (1, and references therein). Also, many mineral and rock samples used in past spectral measurements were not adequately characterized, either mineralogically or chemically. We have begun compiling a library of mineral and rock spectra in the thermal infrared that will eliminate both these deficiencies. To provide spectra that can be used to interpret both laboratory and remote-sensing data, measurements are made under a variety of experimental conditions, including reflectance of three different particle-size ranges and transmittance in KBr. Characterization of the hand-picked mineral phases is accomplished using a petrographic microscope, an X-ray diffractometer, and an electron microprobe. Thus, all minerals are being well documented both mineralogically and chemically. Similar efforts are also made to fully characterize rock samples.

In accordance with previous work, we find that the fundamental molecular vibration bands of minerals in the 8-14 μm region of the spectrum have greatly diminished spectral contrast for fine particles (in our library these spectra are for particles having diameters less than 74 μm). Thus, assuming Kirchhoff's Law (E=1-R, where E is total emittance and R is total reflectance), the so-called "reststrahlen" bands associated with these fundamentals should be virtually undetectable in spectral emittance of a fine particulate regolith, especially a regolith composed of dark material. However, fine particulate minerals and rocks typically display other spectral features that can be compositionally diagnostic. One feature is a reflectance minimum (emittance peak) associated with the principal Christiansen frequency (2). This emittance peak occurs because of anomalous dispersion of the refractive index at a slightly shorter wavelength than the major absorption band. A refractive index occurs that approaches 1 and results in a minimum of scattering at a wavelength where absorption is relatively low, causing a maximum in emittance. A second compositionally significant spectral feature of fine particulate materials occurs in a region of high transparency between the fundamental stretching and bending vibrational bands. Minerals are essentially opaque in these fundamental vibration bands and hence display peaks in reflectance at these wavelengths due to first surface (Fresnel) reflections. These peaks diminish in intensity as particle size is reduced (3). However, the low absorption coefficient between these strong bands results in the opposite reflectance behavior related to particle size. Thus, as particle size is reduced, a reflectance peak (emittance trough) appears in the interband region. Just as the reststrahlen bands generally migrate to longer wavelength with increasing average oxygen coordination number and changing mineral composition (4), so too does the transparency feature.

The principal spectral features found in the 3-5 μm spectral region are associated with the fundamental O-H stretching vibration. Unlike the reststrahlen bands, these features typically increase in spectral contrast as particle size is reduced (5), and thus should be readily detectable in emittance or reflectance, provided that one or the other dominates the radiance received from a planetary surface.

Other spectral features found in the 3-5 μm region are due to overtones and combination tones of the fundamental molecular vibrations at longer wavelength.
Prominent here are bands due to carbonates and sulfates, but some silicates also have spectral features in this region. Like the O-H stretch, these bands tend to increase in spectral contrast as particle size is reduced. Further, they often occur in the longer wavelength portion of the 3-5 μm region so that confusion between reflectance and emittance is less severe, because emittance tends to dominate.

When observations are possible outside the Earth's atmosphere and, thus, not confined to the 3-5 μm and 8-14 μm atmospheric windows, the availability of many additional spectral features shown in our library should facilitate reliable compositional analysis of planetary surfaces.

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References


