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What Lurks in the Martian Rocks and Soil? Investigations of Sulfates, Phosphates, and Perchlorates

Spectral properties of Ca-sulfates: Gypsum, bassanite, and anhydrite†

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Abstract

This study of the spectral properties of Ca-sulfates was initiated to support remote detection of these minerals on Mars. Gypsum, bassanite, and anhydrite are the currently known forms of Ca-sulfates. They are typically found in sedimentary evaporites on Earth, but can also form via reaction of acidic fluids associated with volcanic activity. Reflectance, emission, transmittance, and Raman spectra are discussed here for various sample forms. Gypsum and bassanite spectra exhibit characteristic and distinct triplet bands near 1.4–1.5 μm, a strong band near 1.93–1.94 μm, and multiple features near 2.1–2.3 μm attributed to H_2O. Anhydrite, bassanite, and gypsum all have SO_4 combination and overtone features from 4.2–5 μm that are present in reflectance spectra. The mid-IR region spectra exhibit strong SO_4 ν_3 and ν_4 vibrational bands near 1150–1200 and 600–680 cm^{-1} (~8.5 and 16 μm), respectively. Additional weaker features are observed near 1005–1015 cm^{-1} (~10 μm) for ν_1 and near 470–510 cm^{-1} (~20 μm) for ν_2. The mid-IR H_2O bending vibration occurs near 1623–1630 cm^{-1} (~6.2 μm). The visible/near-infrared region spectra are brighter for the finer-grained samples. In reflectance and emission spectra of the mid-IR region the ν_4 bands begin to invert for the finer-grained samples, and the ν_1 vibration occurs as a band instead of a peak and has the strongest intensity for the finer-grained samples. The ν_2 vibration is a sharp band for anhydrite and a broad peak for gypsum. The band center of the ν_1 vibration follows a trend of decreasing frequency (increasing wavelength) with increasing hydration of the sample in the transmittance, Raman, and reflectance spectra. Anhydrite forms at elevated temperatures compared to gypsum, and at lower temperature, salt concentration, and pH than bassanite. The relative humidity controls whether bassanite or gypsum is stable. Thus, distinguishing among gypsum, bassanite, and anhydrite via remote sensing can provide constraints on the geochemical environment.

Keywords: Gypsum, sulfate, reflectance spectra, emission spectra, infrared