LABORATORY STUDIES OF PLANETARY MOLECULES AND ICES: THE CASE OF IO

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ABSTRACT. The techniques of low temperature spectroscopy are applied here to analyze infrared observational data of Io in the 2.0-5.0 μm range. The presence of solid H_2S and traces of H_2O in the SO_2-dominant surface ices are derived from this analysis and it is suggested that CO_2 clusters may as well be present near the surface of Io.

1. Introduction

Io, a satellite of Jupiter, is the reddest object in the solar system and the first body (beyond Earth) where active volcanism has been observed. Io spectra show several features in the IR. While SO_2 frost responsible for the prominent absorption features in this range, is one of the major surface components, the other components which are responsible for the weaker spectral features had been unidentified. We have focused our attention on the 2.0-2.5 and 2.9-5.3 μm regions. Originally unidentified bands falling at 2.97 μm, 3.15 μm, 3.85 μm, and 3.91 μm [1] and 2.1253 μm [2, 3], were found in Io spectra. All the features, except the 2.1253 μm band, show strong temporal and longitudinal variations. In this paper, we present the result of comparative studies between observational data on Io [1, 2] and detailed laboratory studies of plausible surface ices [1, 3].

2. Results

Among the unidentified features of the Io spectrum, the 3.91 μm and 3.85 μm bands fall close to *but not at* the position expected for the S-H stretching vibrations of pure H_2S frost; the 3.15 and 2.97 μm pair fall close to those expected for the O-H stretching vibrational modes of H_2O, and the 2.1253 μm band falls close to, *but not at* the position of an overtone of the asymmetric stretching vibration of solid CO_2. Laboratory simulations [1,3] were then performed on pure H_2S, pure H_2O, pure CO_2 and pure SO_2 frosts and their mixtures (mixed molecular ices and layered ices) in order to determine how the solid state interactions as well as temperature variations (from 9 K to 130 K) and UV irradiation would affect the spectra. These comparative studies of spectra of Io with laboratory absorption spectra allow us to draw *several main conclusions* about the composition and physical nature of the surface material on Io.

1- The good match between the laboratory spectra and the spectra of Io strongly suggests that *hydrogen sulfide is mixed in the surface material of the satellite* [1]. An upper limit of about 3% for the amount of H_2S relative to SO_2 in the surface material is indicated at the cold patches (~ 100 K). The 3.91 μm and 3.85 μm bands in the spectra of Io (Fig.1) indicate that

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H_2S is present as clusters and isolated molecules in a matrix of SO_2. The laboratory experiments show that the infrared spectrum of H_2S embedded in an SO_2 ice is largely unaffected by thermal variations below 100 K and prolonged VUV irradiation, implying that H_2S can survive the harsh conditions on Io which is in Jupiter's radiation belt. Also, only mixed molecular ices (i.e, SO_2 matrices containing H_2S) can explain the observed band shifts and splitting and can account for the fact that solid H_2S is observed in the surface material of Io under temperature and pressure conditions well above the sublimation point of pure H_2S.

2- The relatively more complicated case of the variable bands of Io at 2.97 µm and 3.15 µm indicates that *traces of water are suspended in the mixtures of H_2S and SO_2*. An upper limit of about 0.1% for the amount of H_2O relative to SO_2 is implied [1]. The spatial and temporal variability of the H_2O bands appears correlated with the volcanic activity on Io.

3- The experiments also suggest that the newly discovered band at 2.1253 µm [2] may be due to *the formation of CO_2 clusters in the atmosphere of Io*. An upper limit of about 1% for the amount of CO_2 relative to SO_2 is derived and much of the CO_2 is estimated to be contained in the cold (~ 100 K) polar regions of the satellite [3].

This study stresses the importance of studying mixed ices (matrices) in carrying out laboratory simulations of the "dirty" ices covering the surfaces of satellites and planets in the solar system. Previous studies have only considered pure materials and neglected the importance of molecular interactions.

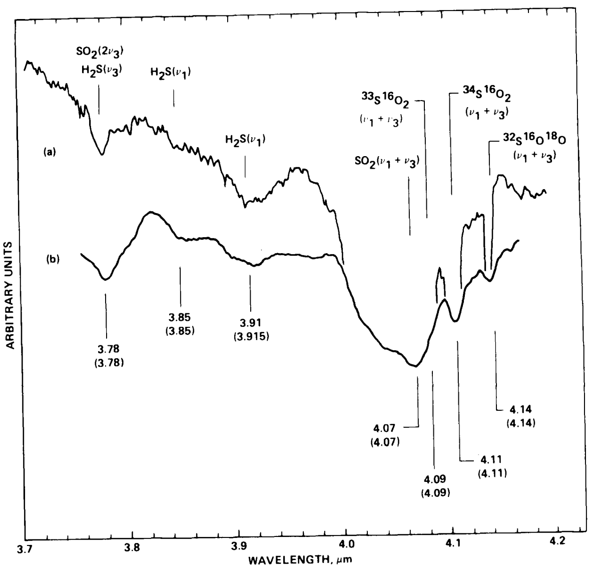

Figure 1: Comparison between (a) the IR absorption spectrum of an H_2S:SO_2 (3:100) ice grown on a 100K surface [1] and (b) the reflectivity of Io at $\Phi = 70^o$ measured by Howell et al (Icarus 78, 27-37, 1989).

References:

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