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(Laboratory Infrared Studies Relevant to Io, A Satellite of the Planet Jupiter)

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This report summarizes initial work devoted to identifying spectral features in the thermal spectrum of Io, as obtained by the Voyager infrared spectrometer experiment in March, 1979.

Background and Work Performed

1) From ground based observations: identification of Na, K and S in the 'Torus' surrounding Io (Brown, 1974; Trafton, et al., 1974; Trafton, 1975; Kupo, et al., 1976); observation of shortlived transient brightnings (Witteborn, et al., 1976); assignment of a strong absorption feature at 4.1μ to solid SO_2 on Io's surface (Fanale, et al., 1979).

2) From Voyager observations: Identification of 9 volcanic plumes (Smith, et al., 1979) and evidence of sulfur flows (Morabito, et al., 1979, Sagan, 1979); association of hot spots (250-600 K) with plume sources and other local regions, identification of gaseous SO_2 and the establishment of very low limits on gases containing C, N and H (Hanel, et al., 1979, Pearl, et al., 1979); direct detection of ionized sulfur, oxygen, sodium and possibly SO_2 in the torus of Io (Broadfoot, et al., 1979; Bridge, et al., 1979; Krimigis, et al., 1979; Vogt, et al., 1979). Together, these suggested a sulfur rich chemistry for Io's surface, with participation of several metallic ions.

To explain the unidentified spectral features in Io's thermal infrared spectrum (Figure 1) we measured the infrared absorption spectra of a number of stable sulfur and oxygen compounds available in our laboratory. The following materials were investigated:

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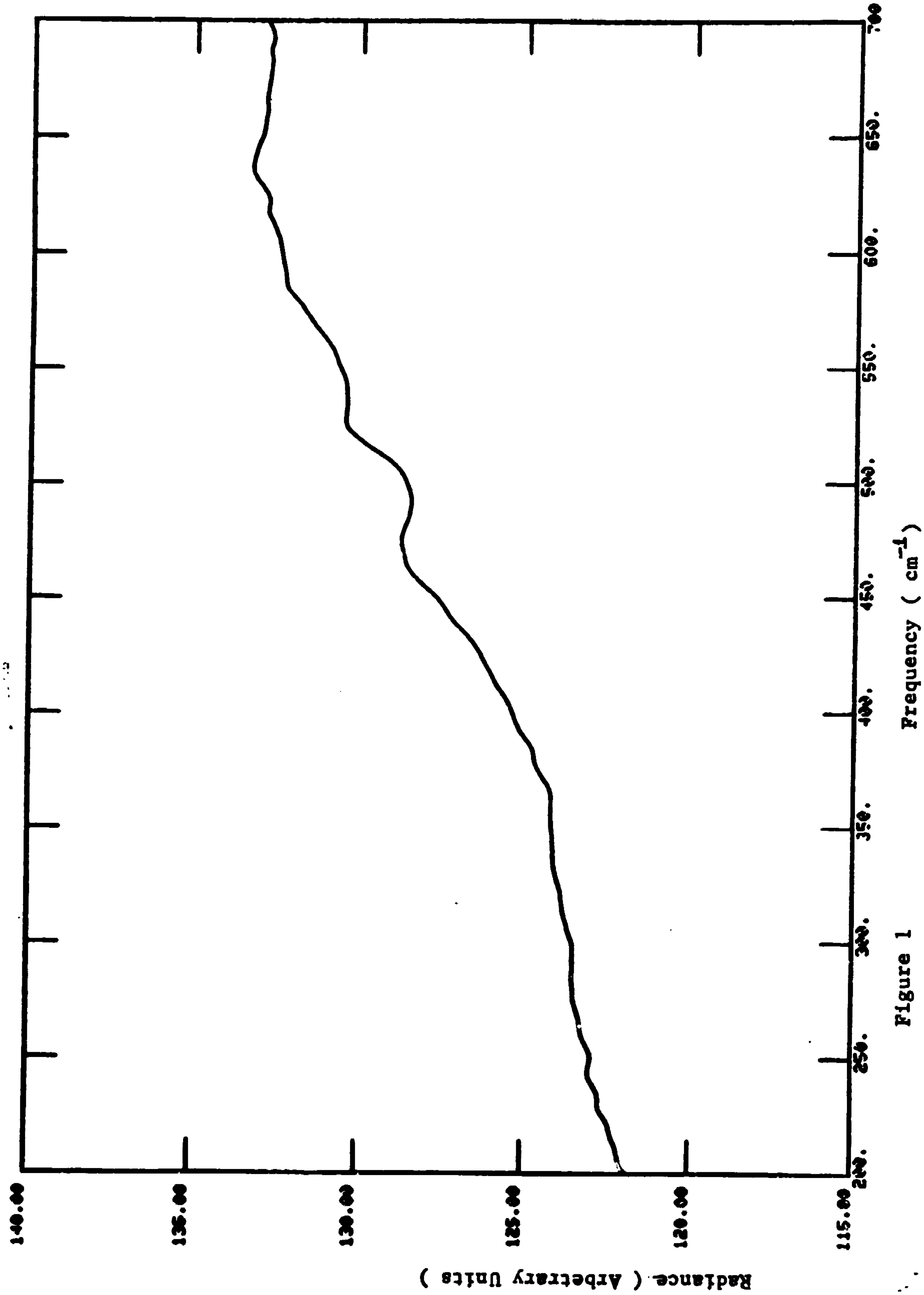

Figure 1

1. $Na_2S.9H_2O$
2. #1 dehydrated
3. K_2S
4. Na_2SO_3
5. Na_2SO_4
6. $NaHSO_4$
7. $KHSO_4$
8. $Na_2S_2O_3$
9. K_2SO_4
10. $K_2S_2O_3$
11. FeS_2 (mineral)
12. $CuFeS_2$ (mineral)
13. MgO
14. CaO
15. BaO
16. Fe_2O_3

Samples were prepared for the measurements in nujol mulls and KBr pellets. The effect of particle size on the band shapes was investigated in a qualitative manner by controlling the grinding time. Initial attempts were also made to record the emission spectra of Na_2SO_4 and Na_2SO_3 coated on a metal plate heated to ~600°C. (For this purpose the FTIR facility at Naval Surface Weapon Center, Silver Spring, Maryland was utilized.) Also, the spectra of some mixtures containing two or more compounds from the above list were obtained. All spectra were delivered to Dr. John Pearl, Goddard Space Flight Center, Greenbelt, Maryland.

Although most of the investigated substances have absorption features in the region 200-700 cm^{-1}, none of these provides an exact match with any of the features in the Voyager data. It is noted, however, that the absorption maximum for Na_2SO_4 at ~615 cm^{-1} (Figure 2) corresponds closely with a spectral peak in the Io's spectrum, suggesting that the Io data should be interpreted as an emission rather than an absorption spectrum. The fact that SO_2 has an absorption maximum at ~517 cm^{-1} (Anderson and Campbell, 1977) which

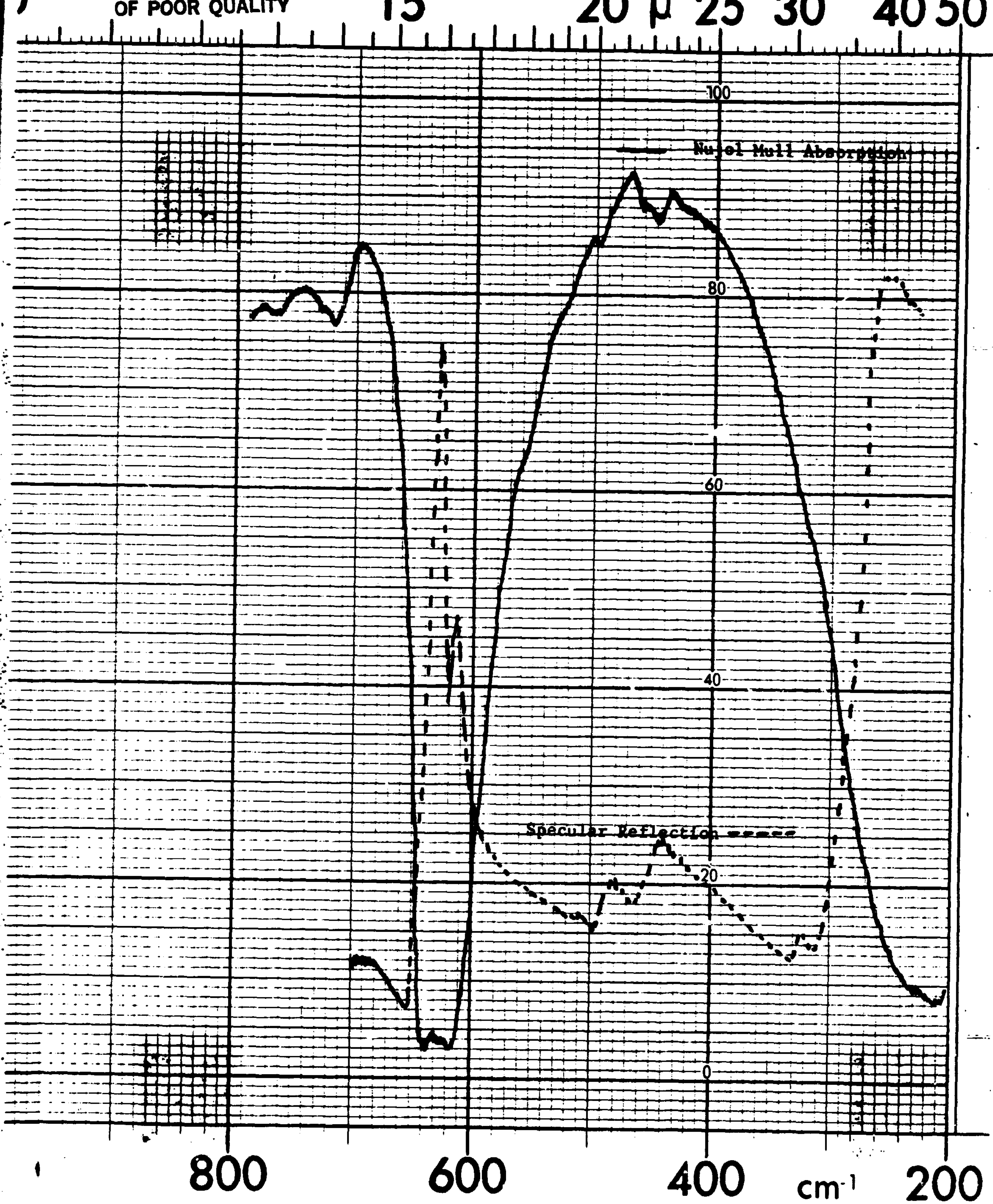

Figure 2. Infrared Spectrum of Na_2SO_4

also falls very near to a peak in the Io's spectrum, strengthens this assignment. Under this interpretation the broad bands of MgO and CaO may also contribute to the background profile in the Voyager data. Since the particle size affects the band shapes and positions of the characteristic bands, a careful study of such effects may be required to provide a detailed fit of the observed thermal spectrum of Io.

Conclusions

Although not all of the spectral features in the thermal spectrum of Io have been satisfactorily explained, two important results have been obtained.

1) Based on a correspondence with absorption bands of Na_2SO_4 and possibly SO_2, the infrared data on Io in the region 700-200 cm^{-1} appear to represent an emission, rather than an absorption spectrum.

2) Although Na_2SO_4 has been tentatively suggested as a surface constitnent for Io based on interpretation of the near-IR reflectance spectrum of Io (Nash and Fanale, 1977), the present study appears to provide the first strong evidence for its presence.

Given the strong evidence for an oxidized crustal environment (the presence of sulfur, oxygen and possbily SO_2 in the torus; and the direct observation of gaseous and solid SO_2 on the satellite), and the presence of sodium in the Io torus, the occurrence of sodium sulfate should be expected. A useful extension of the present research would be to study the chemistry of an oxidizing system of sodium and sulfur, in order to determine the crustal thermodynamic conditions and to determine other likely constitnents of the surface material.

References

Anderson, A., and Campbell, M.C.W., 1977. 'Infrared and Raman Spectra of Crystalline Sulfur Dioxide'. Jour. Chem. Phys. 9, 4300-4302.

Bridge, H.S., et al., 1979. 'Plasma Observations near Jupiter. Science, 204, 987-991.

Broadfoot, A.L., et al., 1979. 'Extreme Ultraviolet Observations from Voyager 1 encounter with Jupiter'. Science, 204, 979-982.

Brown, R.H., 1974. 'Optical Line emission from Io's in Explanation of the Planetary System', IAU Symposium 65, A woszizyk and C. Iwaniszewski, eds; Reidel, Dordrecht, pp. 527-531.

Fanale, F.P.; Brown, R.H., Cruikshank, D.P., and Clarke, R.N., 1979. 'Significance of Absorption Features in Io's IR reflectance Spectrum'. Nature, 280, 761-763.

Hanel, R., et al., 1979. 'Infrared Observations of the Jovian System from Voyager 1'. Science, 204, 972-976.

Krimigis, S.M., et al., 1979. 'Low Energy Charged Particle Environment at Jupiter: A First Look'. Science, 204, 998-1003.

Kupo, I., et al., 1976. 'Detection of Ionized Sulfur in Jovian Magnetosphere'. Ap.J., 205, L51-L53.

Morabito, L.A., et al., 1979. 'Discovery of Currently Active Extraterrestrial Volcanism'. Science, 204, 972.

Nash, D.B. and Fanale, F.P., 1977. 'Io Surface Composition Based on Reflectance Spectra of Sulfur/Salt Mixtures and Proton Irradiated Experiments'. Icarus, 31, 40-80.

Pearl, J., et al., 1979. 'Idetification of Gaseous SO_2 and New Upper Limits for other Gases on Io'. Nature, 280, 755-758.

Sagan, C., 1979. 'Sulfur Flows on Io'. Nature, 280, 750-753.

Smith, B.A., et al., 1979. 'The Jupiter System Through the Eyes of Voyager 1'. Science, 204, 951-972.

Vogt, R.E., et al., 1979. 'Voyager 1: Energetic Ions and Electrons in the Jovian Magnetosphere'. Science, 204, 1003-1007.