USING CHEMISTRY AND SPECTROSCOPY OF LABORATORY SIMULANTS TO CONSTRAIN THE ORIGINS OF THE JUPITER TROJAN ASTEROIDS. A. Mahjoub[1], M. Poston[1,2], K. Hand[1], M. Brown[2], J. Blacksberg[1], J. Eiler[2], R. Hodyss[1], R. Carlson[1], B. Ehlmann[1,2], I. Wong[1]

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Introduction: Jupiter Trojan asteroids are a population of small bodies captured around the L4 and L5 Lagrangian points of the Sun-Jupiter system. The population among this family of asteroids can be categorized into two classes according to their Visible and Near-IR spectra: red Trojans and less red Trojans. The issue of how objects belonging to the same dynamical group have such diversity in their Vis-NIR spectra is tentatively linked to the origin and evolution of the Trojans asteroids. One hypothesis postulates that these objects were formed in the primordial trans-Neptunian disk and then migrated to their present position [1,2]. The surface chemical composition of objects in the primordial planetesimal disk between 15 and 35 A.U. is expected to be dependent on their orbital distance as well as their size. Wong & Brown [3] suggest that a H_2S sublimtion line located within the primordial trans-Neptunian disk divided objects in this region into two classes: sulfurous and sulfur-less. This sharp change in the surface composition of the common progenitor of both Trojans and KBO's, followed by UV and particle irradiation, would lead to the surface color bimodality as seen today for these two populations. The idea is that the energy released by irradiation of the organic ices drives a complex chemistry leading to the production of red crust. Space weathering alteration of the surface and the chemistry engaged in the development of such an organic layer has been investigated by very few laboratory simulation studies. While one experiment [4] shows that the irradiation of carbon containing molecules leads to a reddening of the initial ice, no laboratory studies have tested whether the addition of N or S containing molecules have an effect on the observed reddening. In this work we perform a set of experiments to explore the hypothesis advanced by Wong & Brown [2], that links the color bimodality in Jupiter's Trojans to the presence of H_2S in the surface of their precursors. During these experiments, CH_3OH-NH_3-H_2O (without H_2S) and H_2S-CH_3OH-NH_3-H_2O (with H_2S) ice films were irradiated under ultrahigh vacuum conditions.

Experimental Methodology: Electron irradiation experiments were carried out using the Icy World Simulation Laboratory at the Jet Propulsion Laboratory. The experimental setup used consisted of a high vacuum stainless steel chamber (base pressure ~ 1×10^{-8} torr). The ices were grown on a gold coated glass substrate attached to the cold finger of a closed-cycle helium cryostat. Ice films were grown by leaking the gas mixture into the chamber directly onto the 50 K gold mirror. An electron gun was mounted perpendicular to the substrate. High energy electrons (10 keV) were provided by this gun with a typical beam current of 0.5 μA in the present work. "with H_2S" and "without H_2S" mixed-ices were submitted to the same fluence of electron energy. After irradiation at 50 K, samples were warmed to 120 K at 0.5 K/min while continuing electron irradiation. Samples were then irradiated 1 hour at 120 K, the electron beam turned off, and then warmed at 0.5 K/min to 300 K. This experimental procedure simulated the irradiation and heating history of an icy surface scattered from the Kuiper Belt region (50 K) to Jupiter Trojans region (120 K). The chemical reactivity of the ice was monitored with a Midac Fourier Transform Infrared Spectrometer covering a wavenumber range 400-7000 cm^{-1} at 2 cm^{-1} resolution. A quadrupole mass spectrometer was used also to monitor the gaseous species released when the irradiated ices were warmed. Spectra in Vis-NIR range have been recorded in reflectance geometry for thick "with H_2S" and "without H_2S" samples in order to monitor color alteration. Samples have been illuminated at a 22 degree incidence angle and reflection collected at the same angle. Both samples left an organic residue after heating up to 300 K.

Results:

Chemical characterization [5]: Figure 1 presents mid-IR spectra of the "with H_2S" mixture as deposited and after electron irradiation at T= 50 K. We note a significant decrease of bands of initial reactive molecules and new products appear in the spectrum of the irradiated sample. Among products of irradiation we observe the same molecules produced after irradiation of "without H_2S" mixture (CO, CO_2, OCN^-, HCOOH, CH_2OH and CH_4). After irradiation, an intense band appears at 2040 cm^{-1}. This band is assigned to the C=O stretching mode of OCS. OCS can be a product of reactions between a CO (which is produced from the dissociation

of methanol) and an S atom or HS radical produced by photo-dissociation of H_2S.

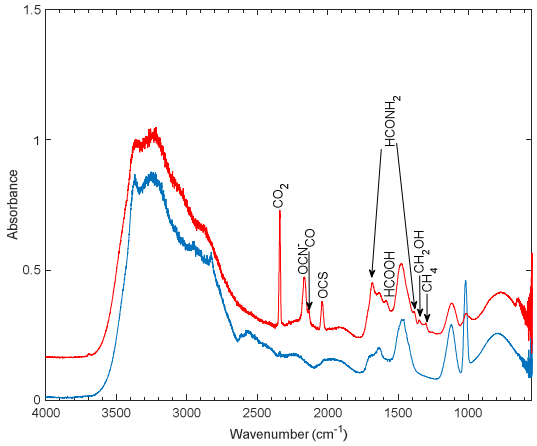

Figure 1: mid-IR spectra of H_2S-CH_3OH-NH_3-H_2O (3:3:3:1) deposited on a cold substrate (50 K) before (blue) and after (red) electron irradiation.

Figure 2 presents the evolution of the integrated bands of the main irradiation products during the irradiation and heating of the "with H_2S" mixture. We note that the production of OCS molecules reaches a maximum after about 400 min of irradiation time and then stays almost constant during the irradiation phase of the experiment. This is probably explained by a rapid dissociation of the majority of the H_2S molecules within the first 400 minutes of the irradiation. In the experimental data presented in Figure 2 we irradiate the sample for 8 hours to test the stability of the irradiation products to heat and electron bombardment, mimicking the migration scenario of an icy object from the primordial tran-Neptunian disk to the Trojans' current position. About 70 % of the initial amount of OCS remained after heating the system to 120 K while continuing electron irradiation. This amount remains stable during the test period where the temperature is fixed at 120 K for 16 h. This indicates that OCS molecules might be produced in the icy surface of an outer solar system object that contains both methanol (CH_3OH) and hydrogen sulfide (H_2S) and is exposed to electron radiation and then remain.

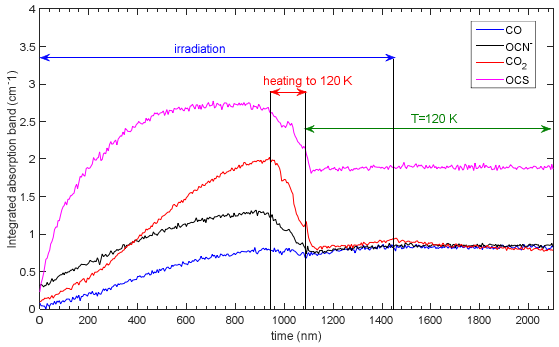

Figure 2: Evolution of integrated bands of OCS, OCN^-, CO, and CO_2 during irradiation and heating of "with H_2S" mixture.

Color Characterization [6]: The Vis-NIR spectra show a reddening (positive slope) induced by irradiation of ice with and without H_2S. The reddening slope is much greater when the initial mixture contains H_2S while both samples have been exposed to the same electron fluence. These results suggest that the sulfur-related chemistry may play an important role in the colors of both the KBOs and Trojans as observed today.

Summary and Conclusions: The irradiation and heating of laboratory analogues of the icy surface with and without H_2S results in a rich chemistry. Vis-NIR spectra demonstrate that when H_2S is present in the initial mixture, an important red slope is observed as result of irradiation. The generation of molecules like OCS, OCN^-, and $HCONH_2$, and their stability under irradiation and heating (simulating the migration of an object from the Kuiper belt region to Jupiter's orbital distance) can be helpful for choosing target molecules for potential future missions to the Jupiter-trojan asteroids.

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