IRRADIATION EFFECTS ON THE SURFACE OF ICY BODIES, J. Bénit and J-P Bibring, CSNSM, 91406 Orsay, France

Many observations have shown the wide spread combined presence of icy surfaces on most of the satellites of the outer planets and a large flux of high energy ions accelerated in the magnetospheres of the giants planets up to energies of the order of 1 MeV/amu, and fluxes as high as $10^6$ ions/cm². It seems very likely that many properties of these surfaces, as observed by Voyager, result from their irradiations. In particular, the chemical composition of the surface appear to evolve with time, through maturation processes similar to those found at the surface of the Moon bombarded by solar wind ions (1). Similarly, the cometary nuclei are likely to contain large organic grains, as identified by the in-situ analysis during the Halley fly-bys of the VEGA and Giotto probes. In this paper, we present some of our laboratory results concerning the physical and chemical irradiation effects that might play a role in the evolution of the icy solar system bodies.

In the last ten years (2-8) several groups including ours have been involved in researchs concerning irradiations of icy materials by means of high energy ions, in the keV and MeV energy range, as well as electrons and photons (9,10). In our experiments, the ices are analyzed, during their irradiation, by means of both infrared Fourier Transform spectrometry and time of flight mass spectrometry. The first detection technique allows to determine the chemical composition of the ice all along its irradiation and thus to monitor its evolution: erosion rates, synthesis of new compounds. The second one is designed to count simultaneously all ions desorbed from the surface as a result of the irradiation. We have used as targets H₂O ice, mixtures of H₂O + CO₂, H₂O + CO₂ + NH₃, and CH₄.

RESULTS:

H₂O. The erosion of the molecule has been studied versus the energy deposited in the film by the incoming ion (11). There is a strong dependence of the yield upon the energy as this one varies proportionnaly with the square of the electronic energy loss. This has been shown by us (12)but also by other groups using differents caracterisation technics (13). The results also show that the erosion proceeds from the ejection of H₂O, as well as from the release of species synthesized during the irradiation, both neutrals and ionized. H₂ and O₂ are the most abundant of the molecules. Among the ions, our most important result concern the presence of clusters, with mass up to several hundreds, synthesized and released with a very high efficiency. This efficiency seems to vary linearly with the energy loss of the incoming ion and has a value of about one molecule desorbed per ion when using a Krypton beam as its maximum energy loss. It is also noteworthy that the relative amount of large ions is rather big as there is about 50% of ions other than H⁺, the ions following a decreasing power law with a minus 2 slope for the positive ones and minus one third for the negatives (12). The overall ratio of neutral to ions released is close to $10^{-4}$, for incident ions in the MeV range.

CH₄. We have studied CH₄ as it is proposed to be one of the major components of the surface of satellites as Ariel for example. Upon irradiation with H⁺, the colour of the films change drastically from transparent to yellow then brownish to finish plain black. This is associated with a continuous change in the stoechiometric ratio starting at 4 and ending around 1 (14) as well as with the diminution of the CH₄ related IR bands;
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simultaneously, new features appear in the infrared spectra (15). This result has implications to interpret both the spectra of a number of objects in space and the visible images (albedo contrasts).

FEW IMPLICATIONS TO THE EVOLUTION OF ICY BODIES. The occurrence of dark regions correlated, from geological inferences, to higher exposure ages is in agreement with an origin for the darkening through surface processing. We propose that this weathering is dominated by irradiation processes. In the case of the satellites of the outer planets, this irradiation would originate from the acceleration of particles in the magnetospheric field. Thus, the surface of these objects would rather suffer maturation processes very similar to what is observed with, for example, the darkening with time of crater rays on the Moon. The irradiation effect involved for the icy surfaces would rather be the chemical modification of carbon-rich molecules, progressively polymerized and simultaneously darkened.

In the case of the cometary nuclei, as that of Halley for which the visible albedo is lower than 5%, the irradiation effects are also good candidates to explain the presence of polymerized species. However, the low albedo of the Halley nucleus favours a scenario in which the irradiation occurred during the accretion of the icy grains, when the nucleus accreted, rather than during the last interplanetary orbit of the nucleus. The contemporary solar wind and solar cosmic rays would affect only a very thin layer of the nucleus, down to less than a millimeter, very quickly released to space through sublimation close to the Sun. On the contrary, we believe that the nucleus is dark all over its volume. It would have acquired its properties when the primitive sun suffered huge mass losses, leading to irradiation effects up to saturation in the accreted grains. In favour of this model, the infrared spectra obtained by the IKS infrared spectrometer on board the VEGA soviet spacecraft exhibit a strong emission feature centered at 3.4 microns, attributed to CH rich compounds (16). These spectra are closely similar to that obtained in the laboratory.

References