Laboratory simulation of heavy-ion irradiation effects in astrophysical ices*

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In space, ices such as H_2O, CO, CO_2, and NH_3 are omnipresent on comets, moons of giant planets, and dust grains in dense clouds (the birthplaces of stars and planetary systems). They are exposed to cosmic rays, which in turn induce radiolysis, i.e., molecule fragmentation, formation of radicals, and subsequent synthesis of new molecular species. Even complex pre-biotic molecules such as amino acids can be formed [1]. Due to their high electronic energy loss, the heavy ion fraction in cosmic rays yields non negligible contributions to sputtering and radiolysis, even if protons and alpha particles are more abundant [1,2]. In the laboratory heavy ions accelerated to high energies allow us to simulate the specific effects induced by the heavy ion fraction of cosmic radiation. A first test experiment was successfully performed at the M-branch of the UNILAC exposing CO_2 ice (deposited at approx. 35K on a CsI substrate) to 570-MeV Ti ions. Molecular changes such as destruction and synthesis of new species were monitored by Fourier transform infrared absorption spectroscopy (FTIR) (Fig. 1). Simultaneously, sputtered and outgassing species released from the ice surface were identified and monitored by quadruple mass spectrometry (QMS).

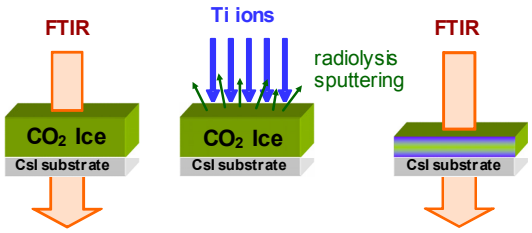

Figure 1: Laboratory simulation of heavy-ion irradiation effects in ices monitored by infrared spectroscopy.

Figure 2 shows the change of column densities ("thickness") of CO_2 (top) and CO (bottom) during ion irradiation. The amount of CO_2 decreases exponentially with a corresponding destruction cross section of $\sigma_d = 4.3\times10^{-14}$ cm^2. The initial density increase is assumed to result from a change of optical properties of the ice due to compaction [1]. One of the daughter molecules appearing during irradiation is CO. The formation cross section deduced from the exponential increase is $\sigma_f = 1.2\times10^{-14}$ cm^2. Synthesis of CO_3, O_3, and C_3 is also observed [2]. Taking into account the amount of deposited energy in the ice by electronic energy loss, the observed cross sections are in good agreement with values observed for 50-MeV Ni ions used earlier at the Ganil facility in France [2].

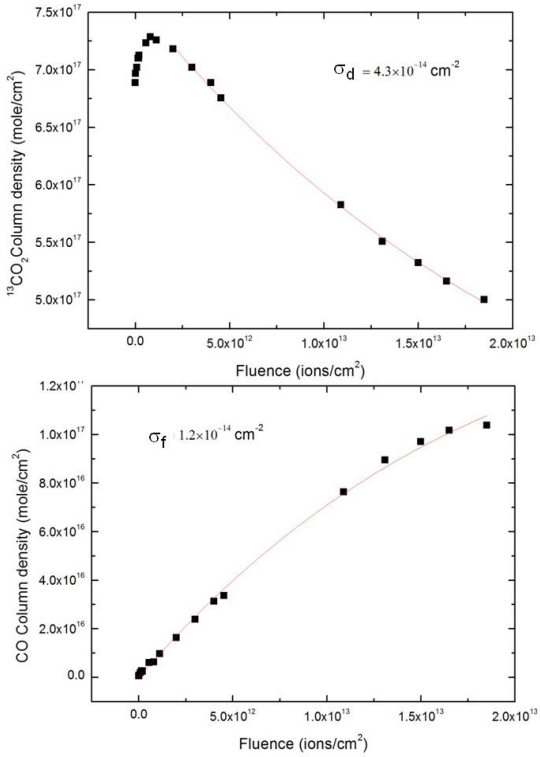

Figure 2: Irradiation of CO_2 ice with 570-MeV Ti ions. Preliminary results of column density of CO_2 (top) and CO (bottom) as a function of ion fluence.

References

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