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Fragmentation of CH_4 molecules induced by 46 keV/u N^+ and N_2^+ projectiles

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Synopsis Fragmentation of methane was studied by the impact of N^+ and N_2^+ projectiles with the same velocity. Energy and angular distribution of the charged fragments was measured. The differences between the yields obtained with atomic and molecular ion projectiles significantly depend on the energy of the fragment ions.

Fragmentation of small molecules has major importance in molecular physics, astrophysics and in biophysics. For example, when radiations interact with living tissues, free radicals are produced in the fragmentation processes. Secondary biochemical processes caused by those free radicals may largely contribute to DNA lesions in living cells. For heavy ion therapy (e.g., carbon), the relevant processes in the target area, fall in the energy range of the Bragg peak located around 300keV/u. At the low energy side of the Bragg peak, the equilibrium charge state of the decelerating ions is small: $\langle q \rangle$ =2 at 100keV/u and close to zero below 10 keV/u [1]. Singly charged, Z=6-8 ions in the 10-100 keV/u impact energy range provided by electrostatic accelerators ideally cover this energy region. Collisions of these ions with small molecules are also of fundamental interest, though the large number of multi-electronic processes is a hard challenge for theories.

In the last few years we developed an experimental setup designed specifically for molecule fragmentation experiments in Atomki, Debrecen [2]. In the present work, we report on measurements, which were carried out with CH_4 target. The beams of 650 keV N^+ and 1.3 MeV N_2^+ projectiles were provided by the 5 MV VdG accelerator in Atomki. The charged fragments emitted from the reaction volume were analyzed by an energy dispersive electrostatic spectrometer [2]. Double differential cross sections have been determined for ion emission in the 30-150° angular and in the 0.3-200 eV energy range.

In this study we compare the fragmentation spectra and the distribution of the degree of ionization between atomic and molecular impact. It is prevalent in atomic collisions that single charged diatomic (Z>>1) molecular projectiles simply double the yield of the single charged atomic ions with the same Z and velocity. In such cases, the effect of the molecular ion is considered as that of two independently acting atomic ions.

Fig. 1 clearly demonstrates that it is not the case in our study with CH_4 molecular target.

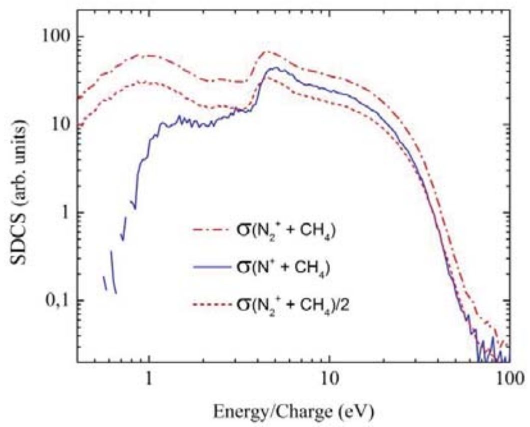

Figure 1. Fragment ion energy spectra of CH_4 integrated over the observation angles. All heavy fragments appear below 2 eV, and above 3 eV H^+ is the dominant fragment. The energy of the H^+ fragments increases with the degree of ionization.

The normalized yield per nitrogen atom is higher for the N_2^+ molecular ion than for N^+ below 4 eV and above cca. 40 eV. In between (practically in the energy region of double and triple ionization), the atomic ion projectile is the more efficient ionizing agent. This fragment energy dependence can be a useful test for theories, which include both the detailed collision geometry and screening effects. The interpretation of the data is in progress. Work was supported by the Hungarian OTKA Grant (K73703) and by the TAMOP-4.2.2/B-10/1-2010-0024 project co-financed by EU and ESF.

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