Energy losses of fast structural multicharged ions at collisions with polyatomic molecules and nanotubes

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Summary

In this paper the nonperturbative theory of energy losses by fast structural multicharged ions (projectile) in a collisions with polyatomic molecules and the nanotubes (target) is developed. In calculating the energy losses of ions at collisions with molecules, in contrast to the case of collisions of ions with single atoms, it is necessary to take into account the effects due to multiple collisions [1] and the orientation of the axis of the target molecules. Energy losses $\kappa^{(p)}$ of fast structural ions on the excitation of their electronic shells (with an arbitrary fate of the target) at collisions with diatomic molecules were considered in [1]. Summarizing the results of [1] to the case of N-atomic targets for energy losses $\kappa^{(p)}$, with a fixed orientation of the target, we can write

$$\kappa^{(p)} = \frac{N_p}{2}\int(\sum_{m=1}^{N}\mathbf{q}_m)^2 d^2\mathbf{b} = \sum_{m=1}^{N}\kappa_m^{(p)} + \Delta\kappa,$$

where N_p – number of ion's electrons, $\mathbf{b}$ – impact parameter of ion, $\kappa_m^{(p)} = \frac{N_p}{2}\int \mathbf{q}_m^2 d^2\mathbf{b}$ – energy losses of ion in a collision with an isolated m-th target atom, $\Delta\kappa = \frac{N_p}{2}\int \sum_{m,n=1}^{N}(\mathbf{q}_m\mathbf{q}_n) d^2\mathbf{b}$ – the correction to the energy losses due to multiple collisions, and $\mathbf{q}_m$ – the momentum transferred to each projectile's electron in a collision with m-th target atom. The Dirac-Hartree-Fock-Slater model [2] is used to describe the distribution of electron density in target atoms.

Under this theory, we carried out calculations of energy losses of fast ions in collisions with various polyatomic molecules, as well as with nanotube C_{300}. Calculations showed that the correction $\Delta\kappa$ substantially depends on the orientation of the target's axis relative to the direction of movement of ions, and takes larger values when two or more atoms in a target located along one or more straight lines, parallel ion velocity. Thus, for example, the average energy losses of ions, colliding with the nanotube C_{300} at the energy 1000 MeV/nucleon, increased by 8,6 times with the changing orientation of the nanotube's axis from perpendicular to parallel relative to the direction of movement of ions. Furthermore, under the parallel orientation of the nanotube's axis the resulting energy losses $\kappa^{(p)}$ are 9,1 times as large than the total energy losses $\sum_{m=1}^{N}\kappa_m^{(p)}$ on the individual atoms of nanotube.

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References:

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