Excitation of He, H_2, and N_2 by fast H^- ions

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At energies $E_{H^-} = 100$ keV–2 MeV the cross section for the light emission of He, H_2, and N_2 as a result of interaction with H^- ions behaves in a manner similar to the cross section for protons, but the ratio of the cross sections is $\sigma_H / \sigma_p \approx 3$.

There is virtually no experimental information about the mechanism for the excitation of atoms or molecules by fast negative ions. It was reported in Ref. 1 that at energies E_H keV the cross section for excitation of the $3p$ level of He atoms by protons and X ions have similar values. It is not possible to obtain from this result a conceptual understanding of the mechanism for excitation at high energies of X ions or, especially, to generalize it to other targets.

We report here the results of an experimental study of the emission of light from Xe, N_2, and H_2 as a result of interaction with X ions in the energy interval $E_H = 100$ keV–2 MeV and with protons of energy E_p/, MeV. The pulsed beams of X ions or protons of required energy were selected at the accelerator output by means of a magnetic analyzer, were sent to the interaction chamber with a controlled working-gas

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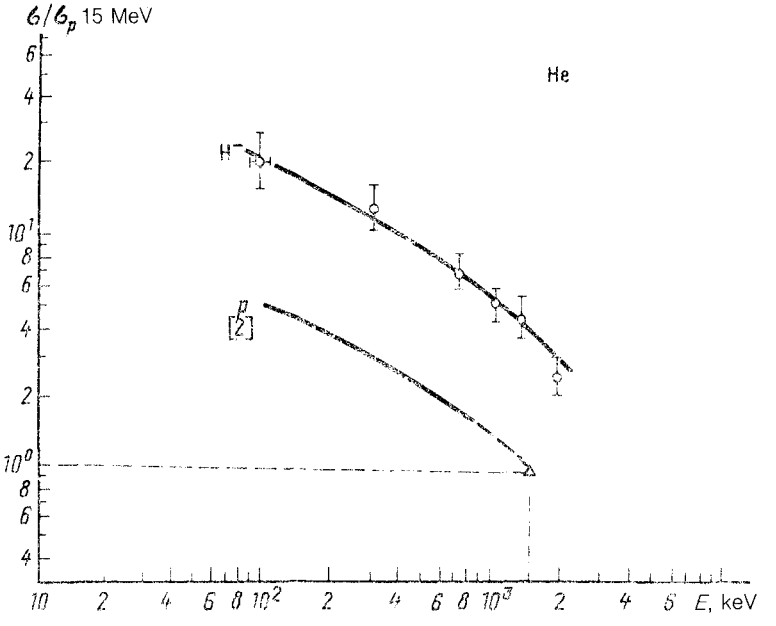
σ/σ_p 15 MeV
He
H^-
p
[2]
E, keV

FIG. 1.

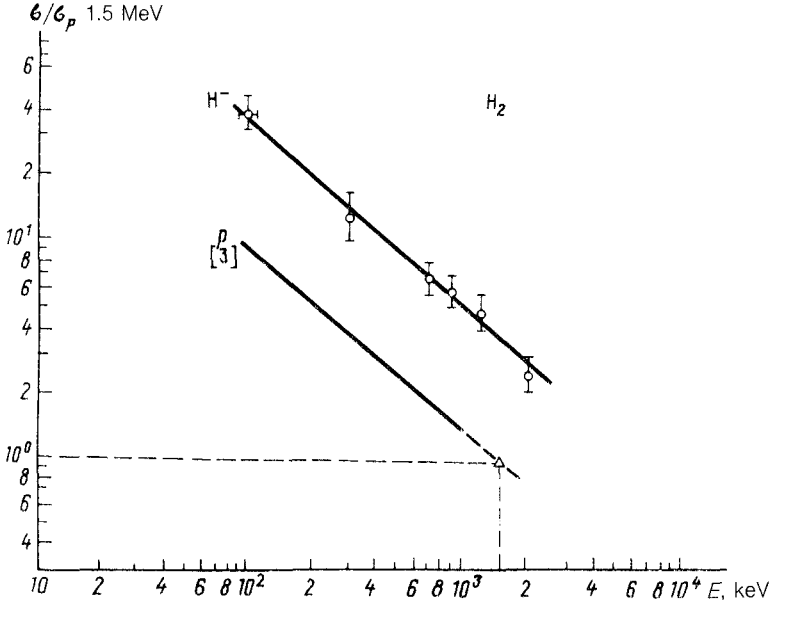
σ/σ_p 1.5 MeV
H^-
H_2
p
[3]
E, keV

FIG. 2.

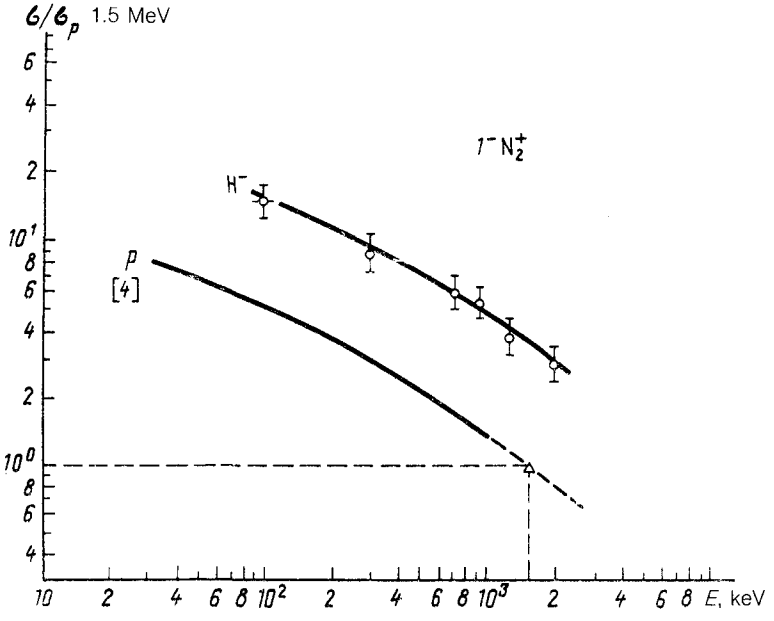

FIG. 3.

pressure, and were detected by a collector current detector. The electron emission from the collector was effectively suppressed by a transverse magnetic field during the detection of ions. The photons from the interaction region were detected by a photomultiplier PM-110, which was calibrated and checked for linearity using the light emitted from the working gases as a result of bombardment by a 1.5-MeV proton beam. The interaction chamber was filled with working gas to a level of the target density at which the reduction of the current at the collector as a result of stripping of H^- ions did not exceed the natural dispersal of the beam current. We have obtained experimentally the linear dependence of the ratio of the current signals at the output of the photomultiplier and the H^--ion collector as a function of the gas pressure in the interaction chamber. The ratio σ_H/σ_p (1.5 MeV) of the cross sections for the emission of He, H_2, and N_2 in the recording wavelength range of PM-110 was determined within 15% from the slope of the curves for the H^- ions and protons. The wavelength range of the I^- band of nitrogen was isolated by means of a light filter.

The results in Figs. 1–3 show that the curve of the cross section versus the energy of H^- ions is similar to the standard curve for protons; here the ratio of the cross sections is $\sigma_H/\sigma_p \approx 3$. For protons we give a fit to an energy of 1.5 MeV of the results obtained in Refs. 2–4. Analysis of the known experimental and theoretical results shows that the cross sections for excitation by fast electrons and protons incident on the target at equal velocities have similar values. At the same time, the relative intensity of the principal spectral lines of He, H_2, and N_2 emission does not depend, in the wavelength range under consideration, on the type of the incident particle. Taking this

circumstance into account, the results obtained by us clearly show that fast H^- ions excite the target as three individual particles (two electrons and a proton) that form it.

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