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CHARGE EXCHANGE OF PROTONS IN ALKALINE METAL VAPOR WITH FORMATION OF HIGHLY EXCITED HYDROGEN ATOMS

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Highly excited hydrogen atoms with principal quantum number n close to 10 can be ionized by a strong electric field $\vec{E}$ or by an equivalent field $\vec{E}' = \vec{v} \times \vec{B}$ ($\vec{v}$ - atom velocity, $\vec{B}$ - magnetic induction). This form of ionization is used to accumulate plasma in certain type of traps [1]. One can expect that one of the relatively effective methods of obtaining highly excited hydrogen atoms would be charge exchange of protons with atoms of alkaline and alkali-earth metals [2]. We have therefore investigated the charge exchange of 10 - 180 keV protons in vapor of Li, Na, K, Cs, and Mg.

The atomic beam, obtained by charge exchange of the protons in the vapor of these metals and purified to eliminate the charged particles, was fed into a region with strong electric field, of intensity $E \leq 160$ kV/cm. We measured the ratio of the current of the secondary protons, produced upon ionization of the highly excited atoms in the field E, to the total current of the atoms I(E). This ratio characterizes the relative charge-exchange yield of the highly excited atoms. In individual experiments we measured the total cross section σ_0 for proton charge exchange and the ratio of the total number of atoms produced by charge exchange to the number of protons in the primary beam - Φ_0. It was shown in[3] that from the values of I(E) and Φ_0 it is possible to determine the cross section for charge exchange accompanied by production of highly excited atoms with principal quantum number $n(\sigma_0)$, and that I(E) and Φ yield the number of the same atoms referred to the primary proton beam (Φ_n). It follows from the experimental data that the quantities σ_c^n and Φ_n are proportional to n^{-3}. We therefore present below the values of $n^3\sigma_c^n$ and $n^3\Phi_n$, as results that are independent of n.

Figures 1 and 2 show plots of $\sigma_0(T)$ and $n^3\sigma_c^n(T)$ obtained by us (T is the proton energy). For comparison, Fig. 2 shows besides the data for metallic targets also the plots of $n^3\sigma_c^n(T)$

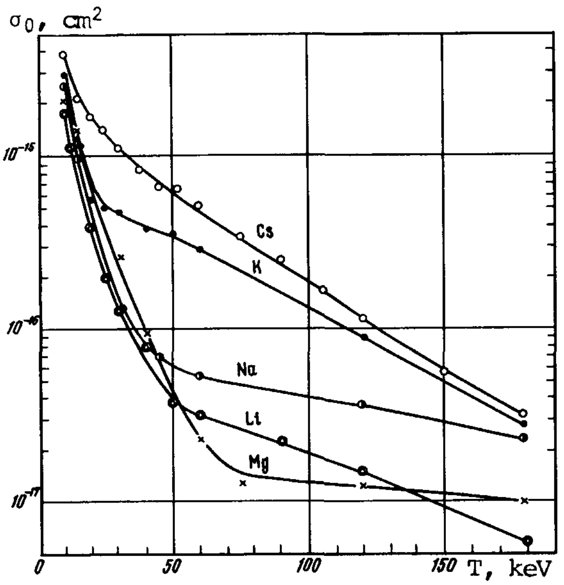

Fig. 1. Total cross section $\sigma_0(T)$ for proton charge exchange vs. proton energy.

obtained by us for He, Ne, Ar, and H_2. We see from the Figures that the cross sections σ_0 and $n^3\sigma_c^n$ for alkaline metals and for magnesium above 15 keV decrease with increasing energy. A characteristic kink is observed on both the $\sigma_0(T)$ and the $n^3\sigma_c^n(T)$ curves in the region 30 - 70 keV, beyond which the decrease of the cross sections slows down. The presence of the kink on the curves can be attributed to the fact that at low energies the outer weakly-bound electron of the metal atom takes part in the charge exchange, while at high energies a greater role is played by charge exchange with participation of the electrons from the filled shell, analogous to the outer shell of an inert gas. The latter is confirmed by the similarity of the plots of $n^3\sigma_c^n(T)$ for the alkaline metals and magnesium and the similar plots for inert gases at high energies. The maxima on the plots of $n^3\sigma_c^n(T)$ for magnesium and gases are observed at proton velocities equal to the velocities of the outer electrons in the atomic targets.

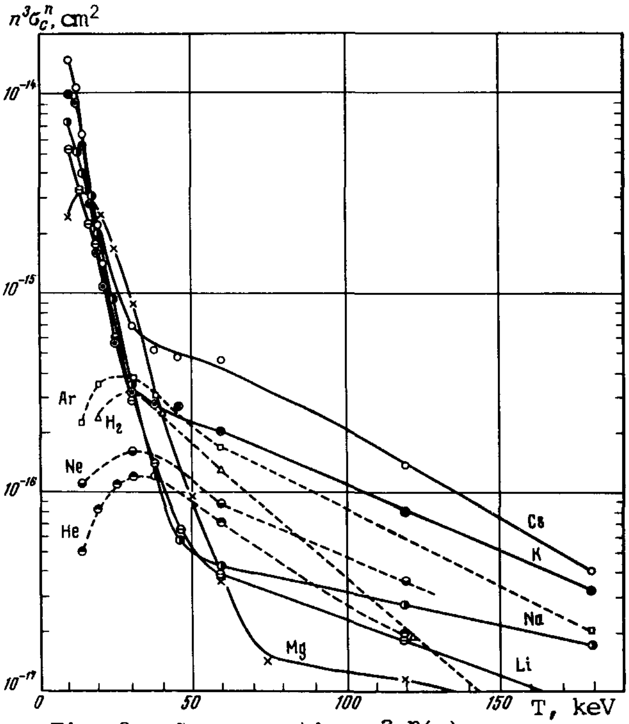

Fig. 2. Cross section $n^3\sigma_i^n(T)$ for proton charge exchange with formation of highly excited hydrogen atoms with principal quantum number n vs. proton energy.

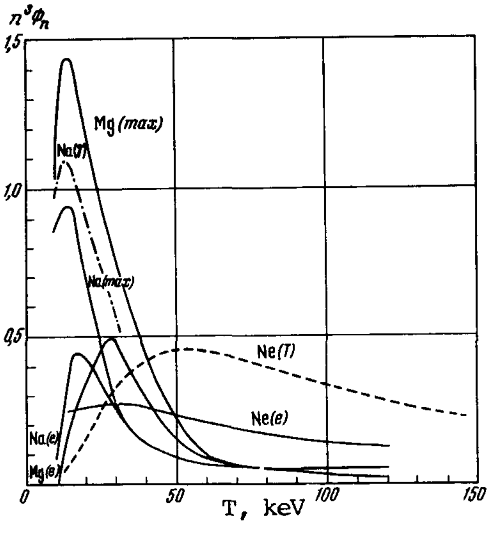

Fig. 3. Yield $n^3\Phi_n(T)$ of highly excited atoms in a state with principal quantum number n, referred to the primary proton beam, vs. the proton energy.

An investigation of the dependence of the yield of the highly excited atoms in the n-state relative to the primary proton beam (Φ_n) on the thickness of the target ($p\ell$) was carried out in Na and Mg vapor and in Ne. It was found that at low energies $\Phi_n(p\ell)$ has a maximum in Na ($T < 30$ keV) and in Mg ($T \leq 60$ keV). For gases, and also in the case of metals at high energies, the plot of $\Phi(p\ell)$ tends monotonically to an equilibrium value. Figure 3 shows the dependences of the equilibrium and maximum values of $n^3\Phi_n$ on the proton energy. In addition, the same Figure shows the calculated values of $n^3\Phi_n$ for Na and Ne from [4]. We see from the Figure that the theory exaggerates the value of Φ. The experimental data obtained in the present work are marked as follows: e - equilibrium target, max - target thickness ensuring maximum yield of highly excited atoms, T - calculated results [4]. It follows from the experimental data that 0.4% of the 15-keV protons undergoing charge exchange in Mg is converted into atoms with $10 \leq n \leq 13$ ($20 \leq E \leq 80$ kV/cm).

The main conclusion that can be drawn from an examination of Figs. 2 and 3 is that vapors of alkaline and alkali-earth metals are more suitable targets for the production of highly excited atoms of hydrogen at energies below 50 keV, and that molecular hydrogen and inert gases are preferable at higher energies.

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ELECTROMAGNETIC PROPERTIES OF MESONS IN BROKEN SU(6) SYMMETRY

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Unitary symmetry broken only by electromagnetic interaction leads to definite relations between the radiative-decay probabilities and the magnetic moments of vector mesons [1]. It is of interest to assess the degree to which these relations change when account is taken of medium-strong interaction that leads to observable mass splitting within unitary multiplets.

Within the framework of SU(3) symmetry, the electromagnetic current describing the radiative decays is a linear combination of octets and singlets, made up of the tensors of vector and pseudoscalar mesons and of the tensor $\delta^A_B + aT^A_B$, where $T^A_B = \delta^A_3\delta^3_B$ corresponds to the medium-strong interaction. In addition to the equations that follow from G-parity conservation

$$g(\rho^{\pm 0} \to \pi^{\pm 0}\gamma) = g(\rho\pi);\ g(K^{*\pm} \to K^{\pm}\gamma) = g(K^*_c K_c);\ g(K^{*0} \to K^0\gamma) = g(\overline{K}^{*0} \to \overline{K}^0\gamma) = g(K^*_n K_n) \quad (1)$$

this current yields in the general case only one relation [2]