FORMATION OF HIGHLY EXCITED ATOMS IN THE CHARGE-EXCHANGE PROCESS

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Highly excited atoms (atoms with principal quantum numbers n about 10 and higher) are similar in their structure to the hydrogen atom and should have longer lifetimes. One of the methods of registering such atoms is to ionize them in an electric field [1]. Although it is known that highly excited atoms of various elements exist [2], only the properties of highly excited hydrogen have been investigated in detailed [3 - 8]. In this paper we consider the formation of highly excited atoms of helium, nitrogen, oxygen, and neon during the process of charge exchange of fast He^+, N^+, O^+, and Ne^+ ions in magnesium vapor, and the distinguishing features of their ionization by an electric field.

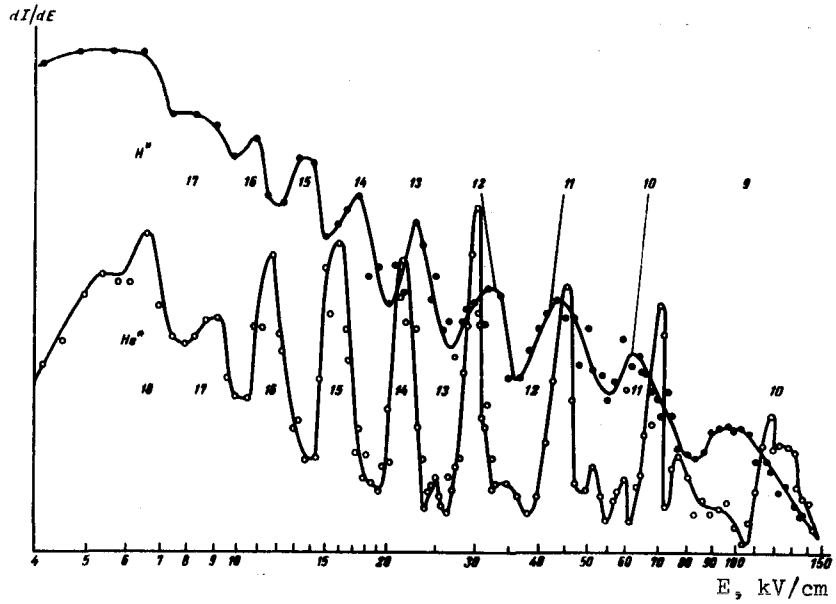
We used a previously-described experimental setup [3, 6]. A beam of fast atoms was obtained by charge exchange of fast ions in a chamber filled with magnesium vapor; the beam was rid of the charged particles and passed through a region with a strong electric field E, up to 200 kV/cm, which produced ionization of the highly excited atoms. We measured the ratio I of the number of atoms ionized in the field E to the total atom flux (the relative yield of the highly excited atoms). The values of I obtained for various atoms by charge exchange of the corresponding ions of velocity $v \approx 1.2 \times 10^8$ cm/sec and ionized in a field E = 120 kV/cm (in a time $t \approx 10^{-10}$ sec) are listed in the table:

Excited atom	H^*	He^*	N^*	O^*	Ne^*
I, %	0.5	0.6	1.5	1.0	0.75

An investigation of the I(E) dependence has shown that the value of I, just as in the case of proton charge exchange with formation of highly excited hydrogen atoms [3, 6, 8], is proportional to $\sqrt{E}$, corresponding to a highly-excited-state population proportional to n^{-3}. Highly excited N^* and O^* atoms were observed also in the dissociation of fast N_2^+ and O_2^+ ions in magnesium vapor. We were unable to observe highly excited long-lived N_2^* and O_2^* molecules.

We investigated in greater detail the production of highly excited helium atoms, obtained by charge exchange of He^+ ions, of 30 - 180 keV energy, with Ne, Na, or Mg atoms. We measured the cross section σ_c^n for the production of highly excited helium atoms (using the method described by us in detail in [6, 8]). It turned out that this cross section, just as in the case of production of highly excited hydrogen atoms by proton charge exchange, is maximal when the fast-ion velocity is equal to the velocity of the outer electron in the target atom, and the cross section at this velocity is proportional to $V^{-5/2}$, where V is the ionization potential of the target atom.

More detailed information on the character of the level population within a single value of n can be obtained by investigating the differential relation $dI/dE = f(E)$, which



Differential dependence dI/dE = f(E) for highly-excited He* atoms (principal quantum numbers n = 10 - 18) and H* atoms (n = 9 - 17). I - relative yield of highly excited atoms; E - ionizing electric field. Energy of He* and H* atoms 120 keV. Target - magnesium vapor.

represents a sui generis "electric" spectrum of the atom. This spectrum was registered by superimposing on the constant ionizing field E a small additional field ΔE (in the form of rectangular pulses) and measuring the relative addition ΔI by counting the individual ions. Such a spectrum was plotted for the highly excited helium atoms produced by charge exchange of fast 120-keV He^+ ions in magnesium vapor (see the figure). The figure shows also for comparison the spectrum of highly excited hydrogen atoms obtained under analogous conditions (the values of dI/dE are given in arbitrary units which are different for hydrogen and for helium). In both cases, the curves reveal clearly the maxima corresponding to different n, but the shapes of these maxima differ. In the case of hydrogen, the character of the curve and the positions of the maxima on it agree well with other analogous experimental data [3 - 5] and with theoretical calculations [9]; the maxima are quite broad and their shapes can be interpreted for assuming statistical population of the Stark levels (i.e., levels characterized by a difference of the parabolic quantum numbers n_1 and n_2) within a single value of n. In the case of helium, the maxima corresponding to each n are narrower, of a width closer to that of one Stark level [4], and are accompanied by additional maxima of smaller height.

One of the causes of the difference between the electric spectra of helium and hydrogen is the following: Owing to the degeneracy of the hydrogen-atom levels, the linear Stark effect takes place for large n even in very weak fields (for example, about 0.2 V/cm for n = 10) [10]. For large n, therefore, it is the Stark levels that become populated at the instant of collision and not the levels characterized by the orbital quantum numbers ℓ; in addition, these levels have finite widths, owing to the short collision duration. In the case of helium, on the other hand, it is probable that the capture takes place in states characterized by orbital quantum numbers, and the spectrum dI/dE = f(E) is a reflection of such an initial population.

Thus, highly excited atoms of different elements resemble the highly excited atoms of

hydrogen in many properties that depend on the principal quantum number n. However, when properties connected with other quantum numbers (ℓ, n_1, n_2) are considered, noticeable differences appear between hydrogen and other elements.

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RESONANT ABSORPTION, SCATTERING, AND EMISSION OF ELECTRON-HOLE DROPS IN GERMANIUM IN THE REGION OF THEIR PLASMA FREQUENCY

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It is indicated in [1] that formation of a new phase, namely an electron-hole condensate of a metallic type, is possible in a large-radius exciton system with high exciton concentration and at sufficiently low temperatures. Experimental observation, in the region of interband transitions, of the condensed phase in germanium, as revealed by optical observation was reported in [2] and [3]. We have investigated the optical properties of the condensed state in germanium in the far infrared (IR), i.e., in the region of possible plasma resonance.

The experiments were performed on p-Ge samples with residual impurity density $\sim 1 \times 10^{12}$ cm^{-3}, area 2 - 4 cm^2, and thickness d = 0.04 cm, immersed in liquid helium. The electron-hole pairs were produced by radiation from a 100-W incandescent lamp (through a KDP filter); the radiation power was determined with an IMO-1 calorimeter. In the absorption investigations, the directly-measured quantity was the ratio of the transmission of the optically-excited sample to its dark transmission in the wavelength range from 60 to 1000 μ [4, 5].

The indicated measurements, made in a rather wide far-IR spectral range, revealed a decrease in the transmission of germanium optically excited at low temperature ($T \leq 1.6°K$). The character of the decrease in the transmission was such that it could not be connected with absorption by free carriers or with plasma reflection. Nor could it be attributed to absorption by compensated impurities in the samples. The measurement results recalculated in terms of the quantity αd, i.e, the decrease of the intensity of the long-wave IR passing through the sample, are shown in Fig. 1. It is seen from the figure that the measured spectrum has