In conclusion, we note the formal analogy between the problem of the production of fermion pairs from vacuum and the problem of resonant excitation of atomic levels in the field of a strong optical wave, recently considered by D. F. Zaretskii and V. P. Krainov. The reason for this analogy is that the quasienergy of a two-level system in the field (1) is given by $E_{1,2}(t) = \pm(\varepsilon/2)\sqrt{1 + \beta^2\phi^2(\tau)}$, which recalls the relativistic dispersion law $E(t) = \pm\sqrt{m^2 + p^2(t)}$ in a field $\phi_1(\tau) = \phi'(\tau)$. If excitation of multilevel atomic systems is considered, the spectrum of the quasienergies $E_i(t)$ has a more complicated form, and this analogy no longer holds.

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MECHANISMS OF INELASTIC ION-ATOM COLLISIONS

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We investigate the effective charge-exchange and ionization cross sections in the systems Li^+-He, Li^+-Ne, H^+-He, and H^+-Ne at low collision energies. It is shown that the cross sections of the inelastic processes depend strongly on the relative placements of the curves of the potential energies of the ground and excited states of the quasimolecules produced in the collisions. Hypotheses are advanced concerning the probabilities of the mechanisms responsible for inelastic processes in these systems.

We present here the results of an investigation of the mechanisms of inelastic ion-atom collisions at low energies (100 - 1000 eV).

To obtain information on the dependence of the cross sections on the inelastic-collision mechanisms we have investigated the charge-exchange and ionization processes in two types of ion-atom systems: (a) H^+-He, H^+-Ne and (b) Li^+-He, Li^+-Ne. From an examination of the adiabatic correlation diagrams and the existing theoretical data on the potential energies of certain systems [1 - 3] it follows that the relative positions of the potential energy curve of the ground state and of the excited states are different in cases (a) and (b). It is known that in case (b) the ground-state potential-energy curves interact with the intermediate-quasimolecule excited-state curves either because of the Σ-Σ radial coupling that appears near the pseudocrossing, or owing to the Σ-Π rotational coupling. In case (a) the ground states are not coupled with the excited states. One can therefore expect the mechanisms of the inelastic processes to be different in these two cases.

Using the experimental methods developed by us [4] for the registration of the secondary ions and free electrons produced when an ion beam passes through a gas, we measured the cross sections of the following processes:

$$H^+ + He \rightarrow H + He^+ \quad (1a)$$
$$H^+ + He \rightarrow H^+ + He^+ + e \quad (1b)$$
$$H^+ + Ne \rightarrow H + Ne^+ \quad (2a)$$
$$H^+ + Ne \rightarrow H^+ + Ne^+ + e \quad (2b)$$
$$Li^+ + He \rightarrow Li + He^+ \quad (3a)$$
$$Li^+ + He \rightarrow Li^+ + He^+ + e \quad (3b)$$
$$Li^+ + Ne \rightarrow Li + Ne^+ \quad (4a)$$
$$Li^+ + Ne \rightarrow Li^+ + Ne^+ + e \quad (4b)$$

Our results are shown in the figures (E_L is the energy in the laboratory frame). Figure 1 shows the charge-exchange and ionization cross sections for the pairs Li^+-He and H^+-He,and Fig. 2 the charge-exchange and ionization cross sections for the Li^+-Ne and H^+-Ne pairs. The relative error in the cross sections is 20% at $E_L > 200$ eV and 100% at $E_L < 200$ eV, with the exception of the H^+-Ne ionization cross section, for which the error is 20% at $E_L > 400$ eV and 100% at $E_L < 400$ eV. The absolute values of the cross sections were determined accurate to a factor of 2. To estimate the absolute charge exchange cross sections in H^+-He and H^+-Ne, our cross sections at E_L = 900 eV were normalized to the corresponding data of [6].

It is seen from Figs. 1 and 2 that the cross sections of the inelastic processes in the systems (a) H^+-He, H^+-Ne and (b) Li^+-He, Li^+-Ne have significantly different dependences on the collision energy. Investigations of the ionization of the K and L shells of the atoms by ions of medium energy (several dozen keV) and high energy (several MeV) reveal great differences in the cross sections of processes that proceed via the "Coulomb excitation" mechanism and the excitation due to promotion of electrons upon adiabatic crossing of the energy levels of the ion-atom system (see, e.g., [7 - 9]). It follows from our present data that at low collision energies the cross sections for the excitation and ionizations of the outer shells of the atoms also depend strongly on the mechanisms of the inelastic processes. We propose that the inelastic processes in H^+-He and H^+-Ne in our range of energies are due to the so-called "direct collision effects" [10]. One of these effects, for example, may be connected with direct energy exchange between the incoming proton and the atomic electron. In the systems Li^+-He and Li^+-Ne the population of the excited levels proceeds primarily by the promotion mechanism. In this case, the inelastic processes are due to the radial or rotational couplings between the terms of the intermediate quasimolecule.

An analysis of the data shown in Figs. 1 and 2 allow us to draw the following conclusions: 1) The cross sections of the inelastic processes due to the promotion mechanism are larger than the cross sections of the processes due to "direct collision effects"; 2) near the thresholds of the processes, the cross sections of the inelastic processes produced by the first of these mechanisms depend more strongly on the energy than the cross sections of the processes based on the second mechanism.

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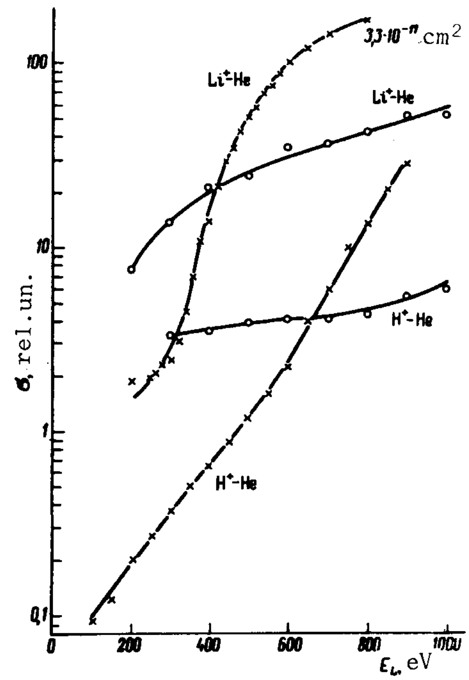

Fig. 1. ×) Effective charge-exchange cross sections vs. the collision energy for He^+-He and Li^+-He, o) effective ionization cross sections for H^+-He and Li^+-He.

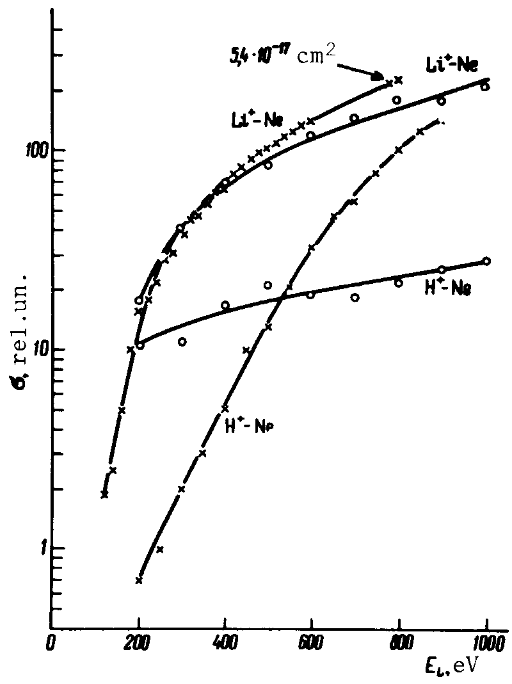

Fig. 2. ×) Effective charge-exchange cross sections for H^+-Ne and Li^+-Ne, o) effective ionization cross sections for H^+-Ne and Li^+-Ne.

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PION CONDENSATION IN NEUTRON STARS

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An expression is obtained for the energy density of nuclear matter in the presence of π-condensate of arbitrary density. This expression differs strongly from that obtained in [5]. It is shown that the second-order phase transition proposed in [5], with formation of π-condensate, is not realized. It is proved that the proposed model is also stable with respect to a first-order phase transition.

1. Introduction

It was shown in [1] that a phase transition with formation of a -condensate is produced in a sufficiently dense nucleon medium. A method of finding the spectrum of the pions in nuclear matter was developed in [2], where it was shown that an electrically-neutral condensate of π^0, π^+, and π^- mesons is produced at N = Z and at a nucleon density $n_c < n_0$ (n_0 is the nuclear density). The same method was used in [3] and [4] to consider the case Z << N (neutron stars). A condensate of π^0 mesons is produced at a density $n \simeq 0.6n_0$ and an electrically-neutral $\pi^+\pi^-$ condensate is produced at approximately the same density. The π^--meson condensate proposed in [5] is not produced. We show here where the authors of [5] have made their mistake. It is obvious that the expression obtained in [5] for the energy density is incorrect, since this expression shows a non-analytic dependence on the interaction constant even at a density lower than critical! The spectra of the π^0, π^+, and π^- mesons for Z << N are given in [3] and [4]. The condition for the second-order phase transition is the appearance of instability in these spectra. To assess the feasibility of a first-order phase transition with immediate formation of a condensate of finite density it is necessary to find the energy of the system at an arbitrary density of the condensate and to compare this energy with that of a system in which no phase transition has occurred, or (if $n > n_c$) with the energy of a system in which the indicated second-order phase transitions have taken place.

We shall determine the system energy in a model consisting of nucleons and a π^--meson condensate with wave vector $\vec{k}$. An attempt to solve this problem was made in [5]. However, in addition to a crucial calculation error, which will be dealt with later, the average-field method used in [5], even if correctly applied, cannot yield quantitative results and should be replaced by a more accurate method in which the effective Lagrangian of the pions is determined. It will be shown that the model considered here is stable with respect to a first-order phase transition. A second-order phase transition occurs in this model under the condition $\omega(k) < \varepsilon_F$ ($\omega(k)$ is the energy of the ions in the medium), which is not realized in the real case [3]. We note that all the objections advanced so far against the method developed in [2] turned out to be untenable (see [4]).

2. The Average-Field Method

For the sake of brevity, we use a symbolic notation, omitting the momentum and spin indices. The Hamiltonian H can then be expressed in the form ($\hbar = c = m_\pi = 1$)

$$H = \Sigma E^{(n)} n^+ n + \Sigma E^{(p)} p_0^+ p_0 + \omega_0 a^+ a + iM(np_0^+ a^+ - n^+ p_0 a), \quad (1)$$

where $M = fk/\sqrt{\omega_0}$; n, p_0, and a are the operators of the neutron, proton, and pion fields, and