Dielectronic recombination of the helium ion

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Dielectronic recombination of the helium ion under conditions of intersecting beams is observed for the first time. Two peaks are observed in the energy dependence of the cross section of the process. The dielectronic recombination cross section is comparable to the cross section for excitation of the resonant level of the helium ion.

Dielectronic recombination (DR) plays an important role in astrophysical and laboratory plasma. Until recently, however, it was studied primarily theoretically, based on an analysis of the plasma parameters, (see the review in Ref. 1). To understand completely the mechanism of this process, experimental data on DR cross sections, which would also permit estimating the degree of applicability of different calculations, are required. Direct experimental studies of DR involve a number of difficulties and they have heretofore been performed only for several heavy, singly charged ions,[2,3] which greatly complicates their theoretical interpretation. In this connection, the simplest ion He^+ is of great interest. A detailed calculation of the DR cross section of the helium ion is performed in Ref. 4.

In this paper we present the experimental results of studies of DR under conditions of intersecting beams of electrons and He^+ ions. The experiment was performed on a setup described previously in Ref. 5 under the following conditions. The beam of 13-keV ions with current density 8×10^{-4} A/cm^2 under high-vacuum conditions ($\sim10^{-7}$ mm Hg) intersected the electron beam, whose current density was 2×10^{-2} A/cm^2 (energy range 30–50 eV). The interval of energy inhomogeneity was 2.5 eV, at a right angle. The radiation, observed at an angle of 90° to the plane of intersection of the beams, was separated by a grazing-incidence vacuum monochromator with inverse linear dispersion 1 nm/mm. The radiation detector consisted of a secondary-electron multiplier that operated in the counting regime. The useful signal was separated with a signal-to-background ratio of 1/7–1/23 by using the technique of modulating the beams with phase shifted pulses.

These experiments ultimately established that at electron energies lower than the threshold for excitation of the resonant level of the helium ion (40.8 eV), radiation is observed in the region 30–32 nm, arising only when helium ions are present in the collision chamber. Previously, in experiments on the passage of a beam of fast helium ions through a foil,[6] a large number of spectral lines was also observed in the region 30–32 nm, which was identified as optical transitions from doubly excited states of He I. The use of a wide (2 mm) input slit of the monochromator (due to the small ion and electron densities and, therefore, small useful signal) in our experiments did not permit wavelength-separation of the observed radiation.

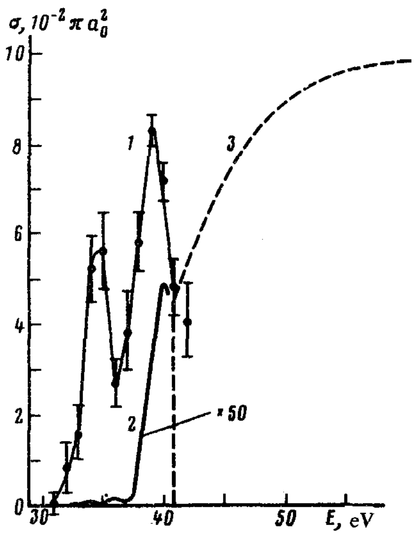

FIG. 1. Energy dependences of the dielectronic recombination cross section [our data (1); calculation in Ref. 4 (2)] and excitation cross section of the $2p$ level of the helium ion [experiment[5] (3)].

The measured energy dependence of the radiation intensity is shown in Fig. 1. The points on the experimental curve are a result of averaging 5–7 measurements, and the measurement time for a single point, required to accumulate an adequate statistical sample amounted to 1000 s and longer. The vertical bars denote the mean-square error of the relative measurements. It is evident that there are two peaks on the curve (at electron beam energies of 35 and 39 eV), which (taking into account the energy inhomogeneity of the electrons) correlate with groups of low- and high-lying doubly excited states of He I that converge to the threshold $n = 2$ He II.[7]

To determine the absolute magnitude of the DR cross section, the intensity of this radiation was compared, under identical experimental conditions, with the intensity of the radiation of the resonance line of He II, whose excitation cross section is known with adequate accuracy.[5] The excitation cross section of dielectronic satellites, which were determined in this manner, turned out to have a maximum of the same order of magnitude as the direct excitation of the resonance line of He II.

Comparison of our results with the data in Ref. 4, in which the DR cross section of the helium ion is calculated taking into account 50 states of $2snl$ and $2pnl$ ($n \leqslant 5$) showed that the measured value of the DR cross section exceeds the theoretical value by more than an order of magnitude. We note that this situation also occurs for the DR cross section of the Mg^+ ion. It is true that for this case many more doubly excited states of Mg I (up to $n \leqslant 64$) were included in the calculations,[3] and the disagreement between the experimental and theoretical DR cross sections turned out to be less than for the helium ion.

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