EXPERIMENTAL INVESTIGATION OF THE EXCITATION OF THE HELIUM-ION RESONANCE LINE IN ELECTRON-ION COLLISIONS

A. I. Dashchenko, I. P. Zapesochnyi, and A. I. Imre
Uzhgorod State University
Submitted 15 January 1974
ZhETF Pis. Red. 19, No. 4, 223 – 225 (20 February 1974)

The excitation function of the λ = 30.4 nm resonance line of the helium ion was measured by the method of intersecting modulated electron and ion beams. The experimental results are compared with calculations in the first and second Coulomb-Born approximation and in the strong-coupling approximation.

Information on the features and excitation cross sections of the energy levels of the helium ion are of fundamental significance in the theory of slow electron collisions, and are also of importance in the solution of many applied problems. Yet the experimental study of this process, as in general of elementary processes in electron-ion collisions, is a very complicated problem. When it comes to helium ions, the experiment becomes even more complicated, because emission from the most effectively excited levels falls in the vacuum ultraviolet region of the spectrum. Apparently, there is only one published experimental paper [1] on the excitation of the metastable 2s level of He^+ by electron impact.

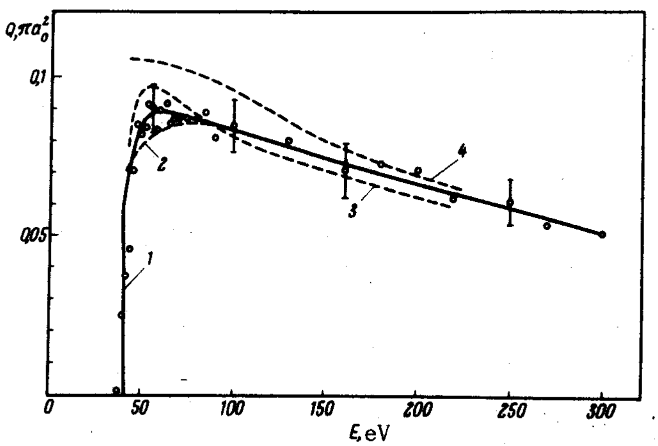
We present here results, obtained for the first time, on the character of the excitation of the λ = 30.4 nm resonance line of the He^+ ion; this excitation is the result of the optically allowed 1s - 2p transition in the process

$$e + He^+(1s) \to He^{+*}(2p) + e\,. \qquad (1)$$

The experiments were performed with a highly modernized mass-spectrometer installation with intersecting beams, on which experiments were previously made on the study of the Ar II and Kr II laser lines in electron-ion collisions [2].

The helium ions were drawn out by an electric field from a gas-discharge source, passed through the chamber of a 180° mass spectrometer with a non-uniform magnetic field, and then entered a differentially-pumped collision chamber, where they intersected an electron beam at right angles. The helium ion concentration in the beam-intersection region was $\sim 10^8$ cm^{-3} at an energy 14 keV, and the current density of the electrons, the energies of which ranged from 30 to 300 eV, was $\sim 10^{-2}$ A/cm^2. The energy inhomogeneity of the electrons at half-height of the distribution curve was $\sim$ 2 eV.

The resonant radiation was extracted from the collision chamber with the aid of a vacuum monochromator with glancing incidence of the beams (effective spectral region 25 – 70 nm), which



Energy dependence of the excitation cross section of the He^+ 2p level: 1 – experimental curve, 2 – calculation in the second Coulomb-Born approximation [5], 3 – calculation in the strong-coupling approximation [6], 4 – calculation in the first Coulomb-born approximation [5].

was constructed in our laboratory, and was then detected with a secondary electron multiplier in a regime in which individual photoelectrons were counted. To separate the useful signal from the noise due to the collisions of the electrons and ions with the residual gas, we used double modulation of the electron and ion beams by rectangular phase-shifted pulses, with synchronous registration in two counting channels [3].

The results of our measurements of the energy dependence of the efficiency of excitation of the He II resonance line are shown in the figure. The experimental curve shows the 90% confidence interval of the relative measurements. The electron energies in the intersecting beams were calibrated against the well established threshold of excitation of the resonance line λ = 58.4 nm of the neutral helium atom. The appearance of radiation somewhat ahead of the threshold (40.8 eV) of process (1) is due to the energy scatter of the electrons in the beams. The experimental curve was therefore corrected in the immediate vicinity of the threshold by taking into account the energy distribution of the electrons and the finite values of the ion excitation cross sections at the threshold. The possible contribution to the population of the resonant level from the spontaneous transitions from higher levels should not be large (e.g., it is about 10% for the analogous level of the hydrogen atom [4]). We can therefore assume that the curve obtained by us actually represents the excitation function of the helium ion resonant level. This gives grounds for comparing the experiment with the theory on electron excitation on the 2p level of He^+.

The experimental results are compared in the figure with the published calculations in the first and second Coulomb-Born approximation [5], and also in the strong-coupling approximation [6]. The experimental curve was normalized to the calculation in the second Coulomb-born approximation, starting already with an electron energy near 100 eV. At lower energies, the experimental data are intermediate between the calculations obtained in the strong-coupling approximation and in the second Coulomb-Born approximation.

[1] D. F. Dance, M. F. A. Harrison, and A. C. H. Smith, Proc. Roy. Soc. (London) A-290, 74 (1966).

[2] I. P. Zapesochnyi, A. I. Imre, A. I. Dashchenko, V. S. Vukstich, F. F. Danch, and V. A. Kel'man, Zh. Eksp. Teor. Fiz. 63, 2000 (1972) [Sov. Phys.-JETP 36, 1056 (1973)].

[3] A. I. Dashchenko, E. P. Stakhno, and A. I. Imre, Prib. Tekh. Eksp. No. 4, 196 (1972).

[4] D. J. T. Morrison and M. R. H. Rudge, Proc. Phys. Soc. 89, 45 (1966).

[5] A. Burgess, D. G. Hummer, and J. A. Tully, Philos. Trans. Roy. Soc. (London), A266, No. 1175, 225 (1970).

[6] P. G. Burke, D. D. McVicar, and K. Smith, Proc. Phys. Soc. 83, 397 (1964).