Abstract

The main purpose of the doctoral dissertation was to determine the charge density distribution of He atoms (determination of the He atoms excited states), excited by electron capture in He^+–He collisions, in the intermediate energy range. The intermediate energy range corresponds to kinetic energies where the projectile velocities are of the order of the atomic unit of speed, and are comparable with bound-electron velocities of atoms. This is the cause of major difficulties in the quantum description of such a collision. Therefore, the data obtained in this work are valuable in their understanding.

Using anticrossing spectroscopy, the "anticrossing spectra" were recorded for 6 kinetic energies of helium ions: 10, 15, 20, 23, 26 i 29 keV. The measurements were carried out using the linear accelerator and the Penning ion source to produce helium ions. The impact with thermal helium atoms and the observation of the selected spectral line took place in a specially constructed collision chamber. The ion-beam was crossed with the thermal He atomic beam in the collision region, in the presence of an electric field, set in parallel and antiparallel to the direction of the velocity of He^+ ion-beam. The voltages with opposite polarity were applied to the two ring-shaped electrodes. We assume that collision with electron-capture process is independent of the low external electric field. The intensity of the spectral line (proportional to the population of excited state) was recorded as a function of the axial electric field that varied from -30 $kVcm^{-1}$ to +30 $kVcm^{-1}$. The observation region was situated behind the collision region, and due to the speed of observed emitting atoms, it was 10 mm wide. In this way photons emitted by excited thermal and fast He atoms were well separated. To analyze the collision process, the spectral line $\lambda(1s4l\ {}^3D \rightarrow 1s2p\ {}^3P) \approx 447.2$ nm of helium atom was chosen, and selected from the spectrum using an interference filter with a half-width of 2 nm. As a light detector, the photomultiplier working in the single photon counting mode, was used. The "anticrossing spectra" were normalised according to the ion beam intensity (Faraday-cup current). To ensure the well beam collimation and the single-collision conditions, the vacuum in the experimental set-up was about 10^{-7} mbar (without colliding beams).

To find the theoretical intensity function of the selected spectral line, the intensity of this line was calculated, assuming selective excitation of helium atom state (spherical, parabolic) – thus, the set of base intensities (base signals) was obtained. These types of calculations were very complex and time-consuming, because when using the laws of quantum mechanics, one must take into account the evolution of the quantum system (excited atom) in the electric field region and outside it over a distance of more than 20 mm.

Next, the theoretical intensity function was obtained, with the linear combination of base signals taken into account. In order to find the linear combination coefficients, the least-square fitting procedure was used (base signals were fitted to the measured "anticrossing spectra"). Having determined the excited states of helium atoms for 6 kinetic energies, the relative one-electron capture cross-sections into these states have been determined and the electric dipole moments of fast excited helium atoms were calculated.

According to measurements carried out in this work, the average electric dipole moment of fast helium atoms formed in a one electron capture process is small, compared to the electric dipole moment of the excited thermal atoms. Moreover, the electric dipole moments of fast He atoms are oriented opposite to the excited He target atoms. This result allows us to conclude that, apart from the classically considered Paul-trap mechanism, there are other processes influencing the electron capture by the helium ions in the intermediate energy range.

Thus, presented doctoral dissertation provides a basis for further research, related to impact excitation of atoms and ions in the intermediate energy range. This can broaden our understanding of the processes occurring in the plasma and interstellar space.

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