QED effects on the radiative electron capture in heavy ion - atom collisions

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In a collision between a heavy ion and a low-Z target atom, a target electron may be captured by the projectile, while a simultaneously emitted photon carries away the excess energy and momentum. This process is denoted as radiative electron capture (REC). Since a loosely bound target electron can be considered as quasi-free, the REC process is essentially equivalent to radiative recombination (RR) or its time-reversed analogon, the photoelectric effect. Experimental investigations of reactions of this type were performed at GSI Darmstadt [1], where bare projectiles up to U^{92+} with energies up to several hundred MeV/u were used. The relativistic theory of REC was considered in detail in [2, 3], and the results of this theory are in excellent agreement with experiment. In particular, the spin-flip contribution to REC, calculated in [2, 3], was recently identified in angular-differential measurements [4].

In view of the increasing experimental accuracy and the well-defined theoretical description, it is tempting to search for quantum electrodynamic (QED) effects supplementing the existing theory [2, 3]. Indeed, heavy ions are good systems for testing QED effects in strong electric fields. However, until now, such effects in heavy ions, for example the Lamb shift, were investigated only for bound states (see [5] and references therein). On the other hand, QED corrections to the photoeffect were considered only to the lowest order in αZ [6, 7]. Since calculations based on an αZ expansion are not valid for high-Z systems, it is necessary to perform calculations for the complete αZ-dependence.

A systematic QED theory of the RR process has been worked out in [8]. In the present paper, we apply this theory to derive complete formulas for the QED corrections of the first order in α to the cross section of the radiative recombination of an electron with a bare nucleus. We found that, in addition to the expressions derived previously in [6], there is a non-zero contribution from the reducible part of the diagram with the self-energy loop on the outgoing electron line. We analyse the infrared and ultraviolet divergences and discuss the application of these formulas to the REC process. In particular, we demonstrate that at a fixed incident electron energy the infrared divergence is eliminated in the total cross section by allowing for the emission of an unobserved soft photon with an energy less than the photon-energy resolution. We note that the contribution of soft photons to the cross section depends on the energy interval in which the photons are detected if this interval is much larger than the effective energy spread of the incident electrons. However, this is not the case for the present REC experiments [1, 4], where the energy spread of a quasi-free target electron is much larger than the finite photon-energy resolution. In that case, the QED correction to the total RR cross section depends on the form of the energy distribution of the target electron. Since the form of this distribution is not well determined, the only way to study the QED effects in REC processes is to investigate the cross section into a photon-energy interval which is chosen to be much larger than the effective energy spread of the quasi-free target electrons and much smaller than the energy of the emitted photon.

We numerically evaluated the Uehling part of the vacuum-polarization correction to the RR cross section and a part of the self-energy correction. Details of the calculation will be published in [9].

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