Journal of Physics: Conference Series **488** (2014) 042010 doi:10.1088/1742-6596/488/4/042010

Electronic relativistic effect on inner-shell ionization by electron impact

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Synopsis The K-shell ionization cross sections by electron impact are calculated in the relativistic binary-encounter approximation. The electronic relativistic effect is estimated as a function of incident energy and compared with relativistic correction factors in other theoretical models.

A large number of simple analytic models for K-shell ionization cross sections by electron impact have been developed using classical and semi-classical formulations and found to be useful for wide range of incident electron energies. Basically these formulations are nonrelativistic and the relativistic effect is usually taken into account through a multiplicative correction factor. The correction factor is obtained empirically from the best fits of its parameters to the experimental data.

However, there has been reported no test for these empirical relativistic correction factors. It is the purpose of the present work to compare these correction factors with the relativistic cross sections. The relativistic K-shell ionization cross sections are calculated in the binary-encounter approximation (BEA) and the relativistic effect is estimated as the ratio of the relativistic to nonrelativistic BEA cross sections.

The BEA cross section for ionization by electron impact with exchange and interference effects is given by Vriens [1]. When v_1 and v_2 are the velocities of the incident electron and the K-shell electron in atomic units, respectively, and $u = v_0^2$ is the ionization potential of the K-shell electron in rydberg, the ionization cross section as a function of $s = v_1/v_0$ and $t = v_2/v_0$ can be expressed as

$$Q(s,t) = \frac{4\pi a_0^2}{(s^2+t^2+1)\,u^2}\left[\frac{s^2-1}{s^2} + \frac{2t^2}{3}\left(\frac{s^4-1}{s^4}\right) - \frac{\Phi \ln s^2}{s^2+1}\right], \quad (1)$$

where $\Phi = \cos\{[1/(s^2u+u)]^{1/2}\ln s^2\}$ and a_0 is the Bohr radius. The final expression for K-shell ionization cross section as a function of incident electron energy is given by

$$Q(s) = 2\int_0^\infty f(t)\,Q(s,t)\,u^{1/2}\,dt\,, \quad (2)$$

where $f(t)$ is the momentum distribution function for the K-shell electron. The screened hydrogenic model is used to calculate $f(t)$ and the relativistic expression is given in [2]. The relativistic effect is obtained as a function of reduced kinetic energy of the incident electron s^2.

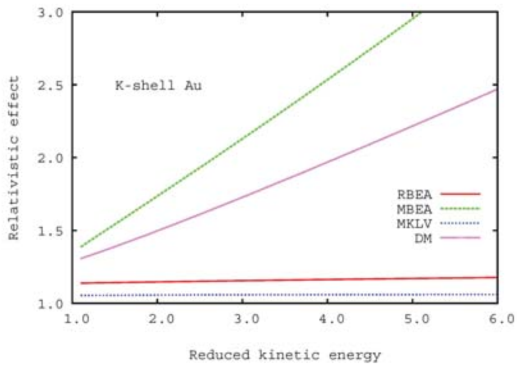

Figure 1. Relativistic effect as a function of reduced kinetic energy of the incident electron.

In Fig. 1 the present results (RBEA) for K-shell ionization of Au are plotted and compared with the relativistic correction factors in the modified binary-encounter model (MBEA) [3], the modified Kolbenstvedt model (MKLV) [4], and the Deutsch-Märk model (DM) [5]. It is clear that the correction factors in MBEA and DM overestimate the electronic relativistic effect considerably.

References

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