Projectile electron losses in the collisions with neutral targets

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An approach based on the sudden-perturbation approximation (SPA) is presented for the treatment of multiple electron losses of high and intermediate energy projectiles in their collisions with neutral targets. Using this approach, we calculate multiple electron loss cross sections of U^{10+} and U^{28+} projectiles in their collisions with N_2 and Ar targets. In this paper we will assume that the projectile electrons remain non-relativistic before and after collision and each electron is described by the hydrogen-like wavefunction, while target electrons are described via Dirac-Hartree-Fock-Slater one-electron orbitals [1]. Using the SPA consider the averaged one-electron loss probability

$$p\left(b\right)=\frac{1}{n_0}\sum_{n=1}^{n_0}\frac{1}{M_n}\sum_{l,m}\int d^3\mathbf{k}\left|\int d^3\mathbf{r}\,\psi^*_{\mathbf{k}}\left(\mathbf{r}\right)\exp\left\{\frac{2iZ_a}{v}\sum_{i=1}^{3}A_iK_0\left(\alpha_i\left|\mathbf{b}-\mathbf{s}\right|\right)\right\}\psi_{nlm}\left(\mathbf{r}\right)\right|^2,$$

where summing is performed over the all possible values of the orbital momentum, l, and its projection, m, for a given nth shell, M_n is the number of such values, n is the principal quantum number, n_0 is the number of shells, $\mathbf{k}$ is the momentum of the electron in the continuum, $\mathbf{s}$ is the projection of $\mathbf{r}$ onto the impact parameter, $\mathbf{b}$, plane, v is the velocity of the projectile, Z_a is the target atomic number, A_i and α_i are the constants [1] which can be extracted from proper tables and $K_0\left(x\right)$ is the Macdonald's function. Then for the (N_p-N)-loss probability, we have

$$W^{(N_p-N)+}\left(b\right)=\frac{N_p!}{(N_p-N)!N!}p\left(b\right)^{N_p-N}\left(1-p\left(b\right)\right)^N=\frac{N_p!}{(N_p-N)!}\sum_{m=0}^{N}\frac{(-1)^m}{(N-m)!m!}p\left(b\right)^{N_p-N+m},$$

where N_p and N are the initial and final number of projectile electrons. To obtain the corresponding cross section, we should integrate $W^{(N_p-N)+}$ over the whole impact parameter plane. For $N_p\gg 1$, $N_p-N\gg 1$ this integral can be estimated using the Laplace method assuming that the function $p\left(b\right)$ has one maximum located inside or on the (left) boundary of the integration interval, $b=0$. Let $p\left(b\right)^M=\exp\left\{-Mf\left(b\right)\right\}$, then for $M\gg 1$:

$$\int\limits_{b_0}^{b_1}\exp\left\{-Mf\left(b\right)\right\}g\left(b\right)db\sim\frac{G}{\mu}\Gamma\left(\frac{\lambda}{\mu}\right)\exp\left\{-Mf\left(b_0\right)\right\}\left[\frac{1}{FM}\right]^{\frac{\lambda}{\mu}},$$

where $\Gamma\left(x\right)$ is the Gamma-function. G, μ, λ, F are the numbers determined from the behaviour of the functions $f\left(b\right)$ and $g\left(b\right)$ near the maximum of $p\left(b\right)$, b_0: $f\left(b\right)-f\left(b_0\right)\sim F\left(b-b_0\right)^{\mu}$, $g\left(b\right)\sim G\left(b-b_0\right)^{\lambda-1}$. Then for the total cross section of (N_p-N)-electron loss, we have [2]

$$\sigma^{(N_p-N)+}=\frac{N_p!\sigma^{N_p+}}{(N_p-N)!}\sum_{m=0}^{N}\left(\frac{Z^*_{N_p}}{Z^*_{N_p-N+m}}\right)^2\frac{(-1)^m}{(N-m)!m!}\left(\frac{N_p}{N_p-N+m}\right)^{\frac{\lambda}{\mu}}p\left(b_0\right)^{m-N},$$

where $Z^*_{N_p-N+m}$ is the effective charge for (N_p-N+m)-electron loss. This equation allow us to calculate projectile electron loss of any multiplicity, using some two known cross sections. $(N_p-N)\gg 1)$

References

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