COULOMB DEEXCITATION OF EXCITED MUONIC HYDROGEN

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The study of the kinetics of excited muonic hydrogen is of special interest for muon catalysed fusion since it provides the important information about the energy distribution of muonic hydrogen atoms in the ground and excited states [1]. Determination of the energy distribution function requires the knowlege of the cross sections of the processes responsible for the deexcitation of muonic hydrogen. Radiative and Auger

deexcitation processes have been considered in a number of papers [2]. In this paper we consider Coulomb deexcitation for which there are contradictory results in the current literature [3,4].

In general the calculation of the cross sections of the processes contributing to the kinetics of muonic hydrogen, requires the solution of a multidimensional system of Schroedinger equations, which is a tedious task. However, for the excited states one can use the WKB approximation, which is valid for principal quantum numbers $n \geq 2$.

In this approach the Coulomb transitions

$$(p\mu)^*_n + p \rightarrow (p\mu)^*_{n-1} + p'$$

are considered to take place at the complex distance R_c between the nuclei, the interacting particles moving along the classical trajectory with the impact parameter ρ. The cross section is expressed as

$$\sigma = 2\pi \int_0^{\rho_{max}^2} \exp(-2\delta)\,[\,1 - \exp(-2\delta)\,]\,d\rho^2,$$

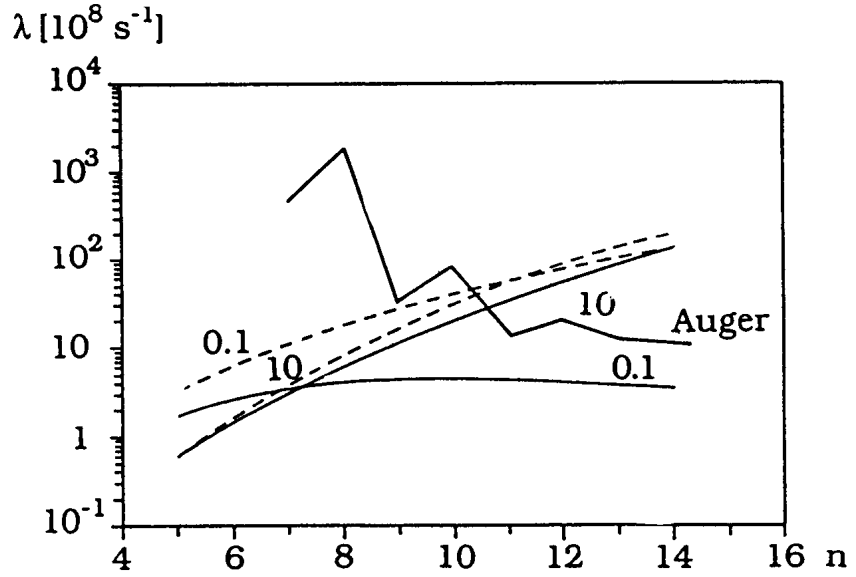

Fig. Coulomb deexcitation rates λ_{3n} calculated for $\varepsilon = 0.1$ and $10\,eV$ with electron screening (solid line) and without it (dashed line) for target density $N = 1.27 \cdot 10^{-3}$ of liquid hydrogen density (1 atm)

where the Massey parameter

$$\delta = |\int_C \mathrm{Im}\, p_R\, dr\,|.$$

Here $p_R = p_R(\varepsilon,\rho)$ is a radial momentum and R is the inter-nuclear distance. The integration in δ is performed in the complex R plane over the contour C beginning at the real axis and going round the terms crossing point R_c. The value ρ_{max} is determined by the condition that p_R is real along the trajectory. According to [5], to calculate the cross section for the Coulomb deexcitation it is enough to consider only the T - series of the branch points of the terms of the two-centre problem, which connects the terms with equal n_1 and different n_2 (n_1 and n_2 — parabolic quantum numbers). Using the approximate coordinates of the branch points [6], one can obtain the simple expression for the cross section of the reaction as a function of energy and the principal quantum number n:

$$\sigma_n(\varepsilon) = 33\pi n^2(n-1)(n-3)\left[1 - \frac{1}{\varepsilon n(n-1)^2}\right] f(\nu,\xi),$$

where $\nu = a_2/(a_1 + a_2)$, $a_i = 1 - u^{(i)}/\varepsilon$

$$\xi = \frac{16(n-1/2)}{n^2(n-1)\,V\,a_2},\quad f(\nu,\xi) = \int_{\nu}^{1} \frac{1-x}{x^3}\,\exp(-\xi\,x)\,dx$$

$u^{(i)}$ is the i-th term of the two centre problem, V is the relative velocity of atoms at infinite R. Fig. presents calculated rates $\lambda = \sigma_n\,V\,N$ for $p\mu$ -atoms, where $N = 1.27\times10^{-3}\,N_0$ ($N_0 = 4.25\times10^{22}\,cm^{-3}$ is the liquid hydrogen density) corresponds to 1 *atm* pressure at room temperature.

According to our calculations the rates of the Coulomb deexcitations show a strong n - dependence, similar to the one obtained in ref. [3]. Radial transitions ($\Delta\,m = 0$) contribute mainly to the process, not Coriolis ones ($|\,\Delta m\,| = 1$). The rates obtained are rather high, so the process should be taken into account together with Auger deexcitation.

References

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