Alignment Studies for Electron Capture into Bare Uranium Ions

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In relativistic collisions between bare uranium and light gaseous targets a strong anisotropy of the Lyα_1 transition ($2p_{3/2} \rightarrow 1s_{1/2}$) induced by radiative electron capture (REC) was observed. As a result we concluded that REC favors the population of $\mu = \pm 1/2$ magnetic substates in qualitative agreement with theoretical predictions [1]. More refined theoretical investigations which also account for the **M2** decay branch of the $2p_{3/2}$ state result in a quantitative agreement between experiments and theory [2]. It turned out that multipole mixing between the leading **E1** and the **M2** decay strongly amplifies the anisotrope emission pattern of the transition.

Here, we report on a recent measurement of the alignment of the $2p_{3/2}$ state of H-like uranium populated by electron capture in collisions with an N_2 target. This measurement is an extension of former studies, made at high beam energies (200 to 400 MeV/u), to lower energies where the nonradiative electron capture (NRC) contributes significantly [3]. The experiment was performed at the jet target of the ESR for uranium projectiles at energies of 98, 132, 190, and 400 MeV/u by measuring the photon angular distribution of the Lyα_1 radiation ($2p_{3/2} \rightarrow 1s_{1/2}$; for details of the experimental technique applied we refer to [1]). The alignment of the $2p_{3/2}$ level can be described in terms of the alignment parameter β_A [2]

$$\beta_A = \frac{1}{2} \cdot \frac{\sigma(\frac{3}{2}, \pm\frac{3}{2}) - \sigma(\frac{3}{2}, \pm\frac{1}{2})}{\sigma(\frac{3}{2}, \pm\frac{3}{2}) + \sigma(\frac{3}{2}, \pm\frac{1}{2})} \qquad (1)$$

where $\sigma(\frac{3}{2}, \pm\mu)$ is the cross section for the population of the substate μ.

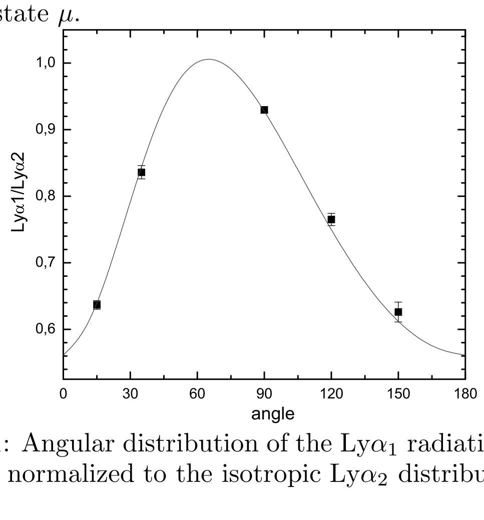

Figure 1: Angular distribution of the Lyα_1 radiation at 98 MeV/u, normalized to the isotropic Lyα_2 distribution.

For the $2p_{3/2} \rightarrow 1s_{1/2}$ transition it leads to an anisotropic emission pattern which is described by

$$W(\theta) \propto 1 + \beta_A^{eff}(1 - \frac{3}{2}\sin^2\theta) \qquad (2)$$

where θ is the relative angle between the projectiles direction and the emission direction of the photon and $\beta_A^{eff} = f(\mathbf{E1}, \mathbf{M2}) \cdot \beta_A$, respectively. Here $f(\mathbf{E1}, \mathbf{M2})$ represents a correction factor which accounts for the **E1/M2** multipole mixing. For the case of the $2p_{3/2}$ state in U^{91+}, f amounts to 1.28 [2]. In the laboratory frame this distribution is Doppler shifted with respect to the angles and energies. For normalization purposes we plot in Fig. 1 the Lyα_1/Lyα_2 intensity ratio as a function of observation angle. Note, the Lyα_2 line is known to be isotropic in the emitter frame. The data were observed at the energy of 98 MeV/u. In addition, the solid line given in Fig. 1 refers to a χ^2 adjustment of the Lorentz transformed Eq. 2 (see e.g. [1]) to the experimental data.

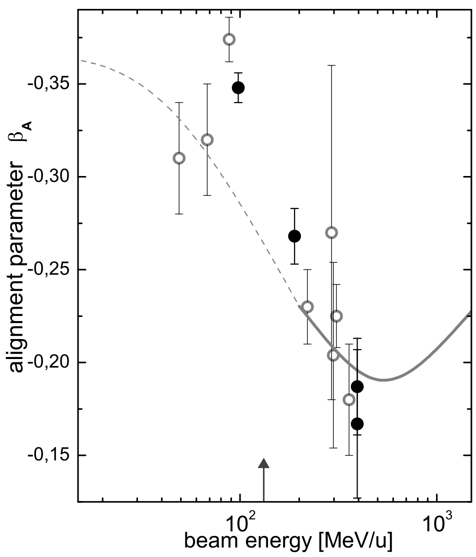

Figure 2: Alignment parameter as a function of energy. Full circles represent preliminary results from the last experiment in October 2002 (data at 132 MeV/u not jet analyzed, energy indicated by arrow)

In Fig. 2 all available data for the alignment of the $2p_{3/2}$ state of U^{91+} populated in $U^{92+} \rightarrow N_2$ collisions are given as function of beam energy. The line in figure 2 refers to the theoretical alignment of the REC process taking into account multipole mixing (in the energy regime of the dashed line NRC contributes significantly). In the figure, an increasing alignment is observed with decreasing beam energy with a maximum located close to 90 MeV/u. At such energies, NRC is the dominant mechanism which populates the $2p_{3/2}$ state via capture into high excited states and subsequent cascade transitions. Because alignment transfer via cascades are known to reduce the overall alignment, our experimental findings are quite surprising and currently subject of detailed theoretical studies.

References

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