Resonant Transfer and Excitation for H-like U Ions: A Case Study for Electron-Electron Interaction at Strong Central Fields

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Structure and dynamics for the heaviest atomic systems differ significantly from those of lighter ions due to the extremely strong central fields at the high atomic numbers Z. In particular relativistic effects are essential. There, for instance, the electron-electron interaction is governed beyond the Coulomb forces by the current or magnetic interactions (Breit term) which may change the corresponding Auger emission drastically [1]. Collisions of highly-charged heavy ions with quasi-free electrons from light target atoms provide a unique tool to investigate the electron-electron interaction in the relativistic domain via resonant capture and excitation. This resonant transfer and excitation (RTE) is the time reversal of the Auger process and leads first to a doubly excited state. For high-Z ions the intermediate doubly excited state stabilizes by x-ray emission due to the high radiative rates, cf. [2] [3].
The electron-electron interaction can by studied in an unperturbed manner for incoming H-like ions interacting with one target electron. Therefore, we have investigated this pure case at the ESR gas target for the heaviest possible system, for H-like U^{91+} projectiles colliding with hydrogen. For hydrogen as gas target the momentum distribution of the quasi-free electron determining the RTE resonance width (Compton profile) is the smallest possible. Fig. 1 shows the three $KL_jL_{j'}$ resonances (top) where one electron is captured into a L_j level and the K electron is excited resonantly to a $L_{j'}$ level – with j, j' = 1/2, 3/2 – and the following radiative decay modes (bottom). Satellite and hypersatellite x-ray lines (one and two initial K vacancies) can be separated by the Ge(i) x-ray detectors used.

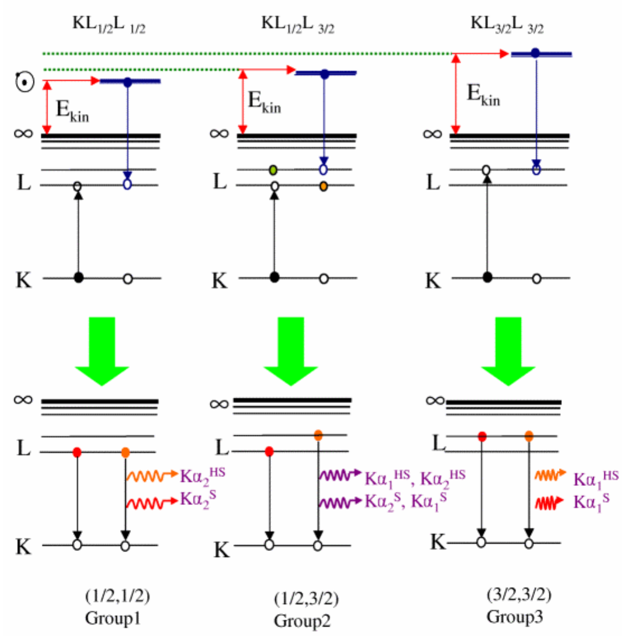

Fig.1: $KL_jL_{j'}$ RTE resonances and their radiative decays for incoming H-like U^{91+} ions.

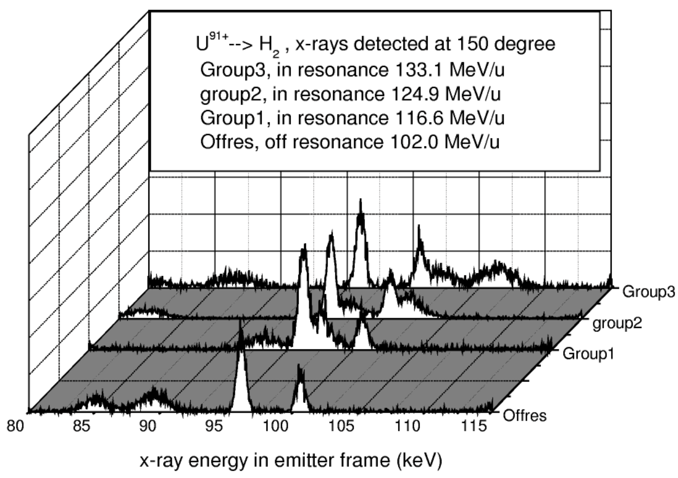

Fig. 2: X-ray spectra observed at 150^0 for U^{91+} - H collisions.

We have determined the x-ray emission pattern induced by U^{91+} - H collisions using six different observation angles (from ≈ 12^0 to 150^0) for the three RTE resonance maxima and for one off-resonance ion energy, cf. Fig. 2. For the off-resonance data at 102 MeV/u ion energy we find in the x-ray spectrum the L_j -REC lines with j = 3/2 and 1/2 (at ≈ 85 and 89 keV) and the subsequent $K\alpha_2$ and $K\alpha_1$ cascade lines (at ≈ 96 and 100 keV). With higher ion energies the REC lines shift correspondingly to higher x-ray energies. At the $KL_{1/2}L_{1/2}$ resonance – group 1 at 116.6 MeV/u in Fig. 2 – the $L_{1/2}$-REC line coincides with the $K\alpha_2{}^H$ hypersatellite line caused totally by RTE (at ≈ 97 keV). At 124.9 MeV/u, the $KL_{1/2}L_{3/2}$ -RTE resonance (group 2), both L_j-REC lines coincides with both the $K\alpha_i{}^H$ hypersatellites each. Finally, for the $KL_{3/2}L_{3/2}$ resonance at 133.1 MeV/u (group 3) the $L_{3/2}$ -REC line (at ≈ 102 keV) coincides with the $K\alpha_1{}^H$ hypersatellite line; the $L_{1/2}$ -REC line (at ≈ 106 keV) is here already beyond the region of interest.
The data are presently being evaluated in order to extract both total rate coefficients for the electron-electron interaction at strong fields and to get the angular distributions of the x-ray emission. From the emission patterns the j dependent level population of the doubly excited intermediate states can be deduced giving detailed insight into the electron-electron interaction mechanism in the relativistic domain. Calculations for this system are presently being performed by the theory group in Giessen, cf. [4].

References

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