Orbital electron capture of stored highly charged ^{122}I ions

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The β-decay studies of highly charged ions require experimental facilities such as GSI / Darmstadt or IMP / Lanzhou since the radioactive nuclei in high atomic charge states have to be produced, separated from unwanted contaminants and stored for extended periods of time. Previous experimental studies and theoretical considerations showed that the orbital electron capture (EC) decay rates of ions may be strongly dependant on the atomic charge state. This was measured in both ^{140}Pr and ^{142}Pm nuclides. The both parents decay by pure allowed Gamow-Teller transitions ($1^+ \rightarrow 0^+$) with more than 95% probability to the ground state of the corresponding bare daughter ions. It turned out that the measured ratio of hydrogen-like (H-like) to helium-like (He-like) EC-decay constant $\lambda_{\rm EC}^{\rm H-like}/\lambda_{\rm EC}^{\rm He-like} \approx 1.5$ [1, 2], which was not expected from the standard scaling of the density of the s-electrons at the nucleus. Studies showed that these experimental results could be explained by taking into account the conservation of both the total angular momentum and its projection of the nucleus plus leptons system [3, 4]. We have extended our experimental study to H-like ^{122}I [5]. As in the cases of ^{140}Pr and ^{142}Pm, the spin-parity of the ground state of ^{122}I atoms is 1^+. However, only about 82% of the decay strength goes to the ground state of the fully ionized daughter ^{122}Te ions ($1^+ \rightarrow 0^+$) while the remaining decay strength is distributed over several excited states in ^{122}Te nuclei. The transitions $(F_i = \frac{1}{2},\ I_i = 1^+) \rightarrow (F_f = \frac{1}{2},\ I_f = 0^+)$ conserve the total angular momentum. We expect that *allowed* Gamow-Teller transitions $(I_i = 1^+) \rightarrow (I_f = 2^+)$, become forbidden, since for this case it is impossible to form a final state $F_f = \frac{1}{2}$.

The experiment was performed using the FRS-ESR facility and employing the Schottky Mass Spectrometry (SMS) technique. In total, 5 measurements with bare ^{122}I^{53+} ions and 9 measurements with H-like ^{122}I^{52+} ions were performed. Due to a small production yield no successful measurement of He-like ions could be performed.

After production, the H-like ^{122}I ions could be in both hyperfine states with total angular momenta $F_i = 1/2$ or $F_i = 3/2$, respectively. Since the measured magnetic moment of ^{122}I is positive ($\mu = +0.94(3)\mu_{\rm N}$), the hyperfine ground state is $F_i = 1/2$. The hyperfine splitting energy has been estimated to $\Delta E_{hf} \approx 0.28$ eV, which corresponds to a relaxation half-life ($F_i = 3/2 \rightarrow F_i = 1/2$) of about $t_{1/2} = 1.95$ s. Therefore the beginning of the analysis was set to t_0 = 24 s after the injection into the ESR to ensure that all parent ions are in the hyperfine ground state.

All measurements have presented consistent results. The measured EC-decay rate in H-like ^{122}I amounts to $\lambda_{\rm EC} = 7.4(3) \cdot 10^{-4}$ s^{-1} which equals within error bars the one measured in neutral ^{122}I atoms ($\lambda_{\rm EC}^{\rm neutral} = 7.0(5) \cdot 10^{-4}$ s^{-1}) although there are 52 additional bound electrons.

Theoretical estimations of the EC-decay rate in He-like ^{122}I have been performed in order to investigate the contributions of the $(I_i = 1^+) \rightarrow (I_f = 2^+)$ transitions which is expected to be first forbidden. However, the large error bars do not allow to take any conclusion on this latter hypothesis. Half-lives of more suitable nuclei should be measured to test such a hypothesis, like e.g. H-like ^{143}Sm, which decays with about 92 % by a single Gamow-Teller transition from its ground state ($F_i = 1$) to the ground state of ^{143}Pm ($F_f = 2$ or $F_f = 3$).

References

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