Direct proof of electron capture decay of ^{258}Db*

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Besides spontaneous fission (sf) and α emission, electron capture (EC) decay is the third essential decay mode of transuranium nuclei, providing valuable information on their nuclear structure. Experimental data are, however, quite scarce in the region of Z > 100. The heaviest nucleus for which so far nuclear structure information was obtained is ^{253}Md, produced by EC decay of ^{253}No [1].

Study of EC decay is also of interest from an other point of view: for a couple of odd-odd nuclei sf branches are reported, among them the members terminating the α - decay chains assigned to start from odd-odd nuclei of elements with Z = 113, 115 and 117, produced in actinide based 'hot fusion' reactions. Because of the strong hindrance of sf of odd-odd nuclei due to two unpaired nucleons, it can be assumed that the terminating sf activities stem from even-even nuclei produced by EC decay. As the latter is a secure source for emission of K X-rays, the proof of EC decay would go along with an unambiguous Z - identification - which is still missing for all elements Z > 112 - of the decaying nucleus and its precursors up to the head of the decay chain. If, further, EC decay populates excited states in the daughter nucleus it also will be a tool for nuclear structure investigations complementary to α emission.

A candidate suited to test the technical feasibility is ^{258}Db, which can be produced in the reaction ^{209}Bi(^{50}Ti,n)^{258}Db with a relatively large cross-section of $\sigma \approx 4$ nb. For that nucleus an EC branch of $\approx 33\%$ was assumed from the ratio of α decays and sf events which were ascribed to sf of ^{258}Rf, the EC-decay daughter of ^{258}Db [2]. A direct proof of this assumption had already been attempted in 1982 at SHIP by measuring delayed coincidences between γ - rays and sf - events; indeed, some candidates for K X-rays were observed as shown in Fig. 1a, but the result was not not regarded as a completely convincing proof [3].

A new experiment was performed in may 2014 at SHIP. In an experimental run of about 200 h irradiation time roughly 1250 sf events were collected. The spectrum of γ - rays (in coincidence with conversion electrons) preceeding an sf event within $\Delta t \leq 39$ ms is shown in Fig. 1b; clearly the $K_{\alpha 1,\alpha 2}$ and $K_{\beta' 1}$ - lines of rutherfordium are visible. From the time distributions (γ-sf) a half-life of 13±11 ms was extracted for the sf activity, which is in-line with the value $14.7^{+1.2}_{-1.0}$ ms [4], reported for ^{258}Rf. The observation of conversion electrons in coincidence with the X-rays further proves the population of at least one excited level in ^{258}Rf, their energy distribution suggest an excitation energy range of $\approx 400 - 500$ keV. Assuming population of the ground-state rotational band this would lead to population of the 8^+ or a higher-spin state.

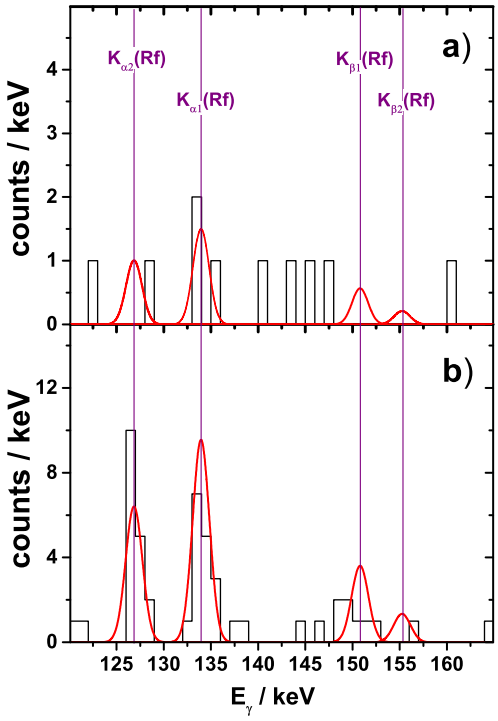

Figure 1: Energy spectra of γ - events observed in delayed coincidence with sf - events a) SHIP experiment in 1982 [3], $\Delta t(\gamma\text{-sf}) \leq 30$ ms, b) SHIP experiment in 2014, $\Delta t(\gamma\text{-sf}) \leq 39$ ms, electron occuring in prompt coincidence with γ - event required; the full red lines represent the expected spectra using the theoretical X-ray energies [5] and a detector resolution of 2 keV(FWHM).

References

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