Identification of the Slow E3 Transition $^{136m}Cs \rightarrow {}^{136}Cs$ with Conversion Electrons ◇

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In ^{136}Cs ($T_{1/2} = 13.16$ d) only two states are known, the ground state with spin 5^+ and an isomeric state with a halflife of $T_{1/2} = (19 \pm 2)$ s [1] and spin 8^- [2].

In order to determine the energy and the multipolarity of the transition, γ rays and conversion electrons from the isomeric level have been measured at the ISOLDE facility at CERN. ^{136m}Cs was produced by 1.4 GeV protons hitting a uranium carbide target. The reaction products were ionized, accelerated to 40 keV and then mass separated in the ISOLDE HRS. The $A = 136$ beam was sent to an aluminum catcher foil. Due to the high production rate of $A = 136$ nuclei one proton pulse per supercycle with a rather low intensity of $3 \cdot 10^{12}$ p/pulse was sufficient.

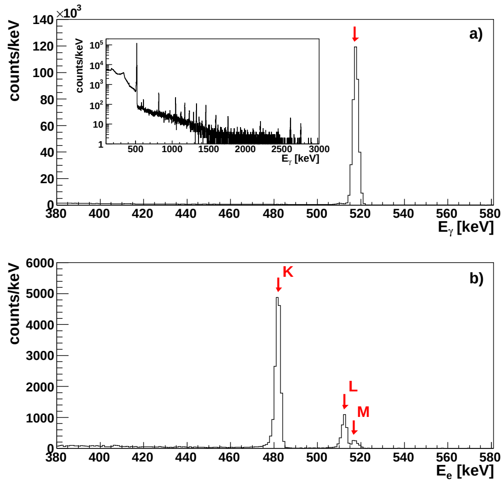

Fig. 1: a) ^{136m}Cs γ ray spectrum measured in 25 min. The 518 keV line is the $8^- \rightarrow 5^+$ transition from the isomeric to the ground state of ^{136}Cs. The inset shows the total γ spectrum. The small lines originate from the β decay of ^{136}Cs to ^{136}Ba and natural radioactivity. b) Corresponding conversion electron energy spectrum. Conversion electron lines from the K-shell (binding energy 36 keV), the L-shell (6 keV) and the M-shell (1 keV) can be distinguished.

Fig. 1 shows the γ ray and conversion electron spectra measured in 25 min. We determined the excitation energy of the isomeric state to be (518.2 ± 0.2) keV. In order to determine the multipolarity of the transition, the conversion coefficients for the K, L and M shell have been measured. The γ decay was measured with a Ge detector (photo peak efficiency $\epsilon_{ph}(518 \text{ keV}) = 0.187$ %). Simultaneously, conversion electrons were registered in a liquid N_2 cooled Si(Li) detector (distance to target foil 91 mm, efficiency 0.43 %). From the relative intensities of γ and conversion electron radiation the conversion coefficients $\alpha_{K,L,M,...} = I_e^{K,L,M,...}/I_\gamma$ can be determined. Since the conversion coefficient depends on the multipolarity of the transition, α can be used to determine the multipolarity of the $8^- \rightarrow 5^+$ transition in ^{136}Cs. Table 1 shows the results of the measurement together with theoretical Band-Raman internal conversion coefficients [3] for the two possible multipolarities E3 and M4. Conversion electrons from the M and N shell cannot be resolved due to the small binding energies of the electrons, only the sum of α_M and α_N can be measured. Since the conversion coefficients for magnetic M4 transitions are about an order of magnitude larger than for electric E3 transition, the unknown multipolarity of the $8^- \rightarrow 5^+$ transition can easily be deduced. The measured conversion coefficients agree within the error with the calculated values for a E3 transitions, thus we conclude that the 518 keV $8^- \rightarrow 5^+$ transition is of pure E3 character.From the now known multipolarity and halflife the transition strength can be calculated. The long halflife $T_{1/2} = (19 \pm 2)$ s [1] results in a very small $B(\text{E3}; 8^- \rightarrow 5^+) = (6.43 \pm 0.68) \cdot 10^{-3}\ e^2\text{fm}^6$ value. With only $(5.85 \pm 0.62) \cdot 10^{-6}$ W.u., the $^{136m}Cs \rightarrow {}^{136}Cs$ transition is by far the slowest E3 transition known in this mass range. In the entire chart of nuclides there are only two known E3 transitions that are slower, ^{177m}Lu and ^{179m2}Hf, which are both K-isomers. There may be other slow E3 transitions which are not observable due to competing faster transitions.

In addition to the 518.2 keV ground-state transition, a 413.2 keV γ transition, which is a factor of 800 weaker, and the corresponding conversion electrons have been found. By measuring the conversion coefficients of this line we could conclude that this transition with $\alpha_K = 0.49 \pm 0.05$ is a M4 transition. We also observed 105 keV γ rays and coincidences between these and 377 keV K conversion electrons. This suggests that we have found a new level between the isomeric state at 518.2 keV and the ground state.

References

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[2] C. Thibault *et al.*, Nucl. Phys. **A367** (1981) 1
[3] http://www.nndc.bnl.gov/bricc/

shell	E_e [keV]	α_{exp}	BRICC E3	BRICC M4
K	482	$(1.84 \pm 0.04) \cdot 10^{-2}$	$(1.89 \pm 0.03) \cdot 10^{-2}$	$(2.19 \pm 0.03) \cdot 10^{-1}$
L	512	$(3.73 \pm 0.10) \cdot 10^{-3}$	$(3.74 \pm 0.05) \cdot 10^{-3}$	$(4.30 \pm 0.06) \cdot 10^{-2}$
M	517		$(7.89 \pm 0.11) \cdot 10^{-4}$	$(9.22 \pm 0.13) \cdot 10^{-3}$
N	518		$(1.64 \pm 0.02) \cdot 10^{-4}$	$(1.94 \pm 0.03) \cdot 10^{-3}$
M + N	517	$(9.35 \pm 0.38) \cdot 10^{-4}$	$(9.53 \pm 0.11) \cdot 10^{-4}$	$(1.12 \pm 0.01) \cdot 10^{-2}$

Table 1: Theoretical [3] and experimental conversion coefficients for the 518 keV transition in ^{136}Cs. Since the binding energies for electrons in the M (1 keV) and N (0.2 keV) shell cannot be resolved in the experiment, only the sum of α_M and α_N can be measured.

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