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K-capture probability in the decay of ^{139}Ce(137·5d)

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Abstract. The K-capture probability (P_K) in the decay of ^{139}Ce (137·5d) has been determined from the analysis of the K x-ray gamma ray sum-peak observed with a Ge (Li) x-ray detector. Furthermore, P_K is estimated independently from the measurement of the K x-ray intensity in the decay, using the known conversion coefficients of the 165·8 keV transition. Using the weighted average of P_K measured as above, the mass difference between ^{139}Ce and ^{139}La is found to be 273^{+21}_{-13} keV.

Keywords. Decay of ^{139}Ce; K-capture probability.

1. Introduction

Following the systematic study of Wapstra and Gove (1971) the mass difference of ^{139}Ce and ^{139}La is listed as 275 ± 15 keV in Nuclear Data Sheets (1974). But the available data on the K-capture probability of ^{139}Ce (in table 1) show a very large variation in computed Q value. Notably, the Q value given by Schmidt-Ott and Fink (1972) is found to be too large (326 keV). Almost all of the capture probability measurements were made using the conventional coincidence technique. In view of the rather large variation of the Q value, we have reexamined the K-capture decay of ^{139}Ce using an altogether new technique developed by us (Dasmahapatra and Mukherjee 1974).

2. Experimental details

We used a 4·88 mm deep, 10 mm diameter Ge (Li) x-ray detector (ORTEC) coupled to a 4096 channel analyser (LABEN) for the analysis of the gamma ray

Table 1. Results of the measurement of P_K and Q^+ in the decay of ^{139}C$_e$ and comparison with the reported data

	Present work	Ketelle *et al* (1956)	Stanford *et al* (1960)	Marelius *et al* (1967)	Vatai and Hohmuth (1968)	Adamowciz *et al* (1968)	Schmidt-Ott and Fink (1972)
P_K	0·73±0·03*	0·73±0·01	0·83±0·04	0·68±0·02	0·69±0·02	0·75±0·01	0·78±0·03
Q_{EC} (keV)	273^{+21}_{-13}	270±6	>316	251±4			326^{+70}_{-30}

* Weighted average of P_K determined by two independent methods (see text).

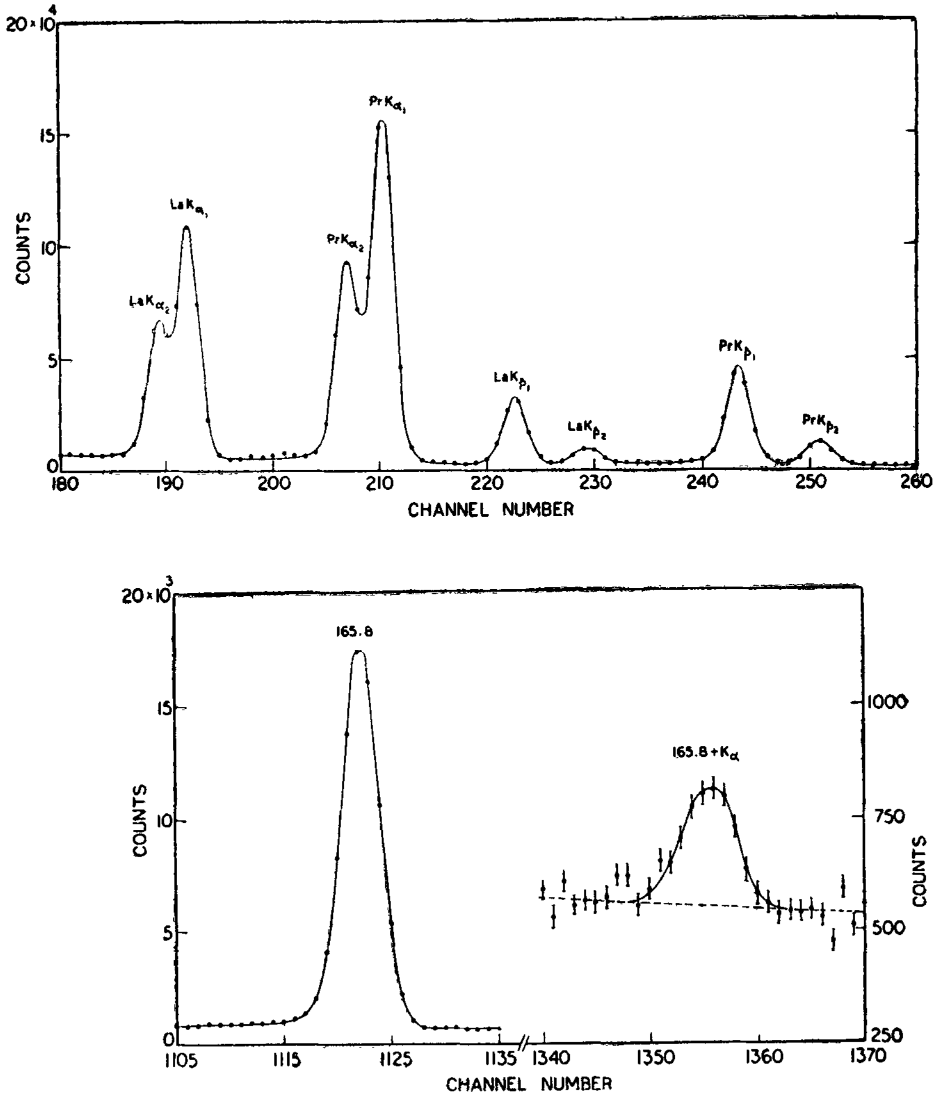

Figure 1. A typical gamma ray spectrum of ^{139}Ce obtained with a 4·88 mm depth, 10 mm diameter Ge (Li) x-ray detector in the close-geometry set up. The source contains ^{141}Ce as impurity.

spectrum. The ^{139}Ce source (obtained from the Department of Atomic Energy, Bombay) was placed at a distance of 2 mm from the thin Be-window of the Ge (Li) detector, the Ge (Li) crystal itself being 5 mm behind the Be-window. Figure 1 shows a typical spectrum. The source contains the isotope ^{141}Ce(32·4d) as impurity. However, ^{141}Ce has a single gamma ray (145·4 keV) and because of the high resolution (500 eV at 122 keV) of the gamma ray detector both the gamma ray and the K x-ray peaks could be easily resolved and thus the presence of ^{141}Ce does not affect the present work.

The absolute efficiency of the K_α x-rays entering into the expression (eq. 1) for the area under the sum-peak $(165{\cdot}8 + K_\alpha)$ keV is determined using a

^{133}Ba (10·4y) source, the details of which have been described earlier (Dasmahapatra and Mukherjee 1974).

We have neglected the contribution of random events to the area under the sum-peak since the strength of the source is fairly low ($\sim 0{\cdot}02\,\mu$C). Also, we have not observed the sum-peak arising out of two 165·8 keV (or 145·4 keV in ^{141}Ce) gamma rays or the K x-ray gamma ray sum-peak in the decay of ^{141}Ce.

3. Results and discussions

The area under the sum-peak (165·8 + K_α) keV can be expressed as

$$N^{\text{sum}}_{165.8+K_\alpha} = \omega_K\, f_{K_\alpha} \epsilon_{K_\alpha} P_K N_{165\cdot 8} \tag{1}$$

where N is the peak area, ω_K is the K-fluorescence yield in La, f_{K_α} is the ratio of the intensity of the K_α x-rays to the total K x-rays and ϵ_{K_α} is the absolute efficiency for the K_α x-rays. Using the values of ω_K and f_{K_α} from Martin and Blichert-Toft (1970) and Hansen *et al* (1970) respectively and ϵ_{K_α} as described earlier, we get from equation (1)

$$P_K = 0{\cdot}74 \pm 0{\cdot}06.$$

It is interesting to note that the EC feeding to the 165·8 keV state of ^{139}Ce is 100% and this state decays to the ground state through the 165·8 keV transition only. Thus, the total P_K determined from the measurement of the K x-ray intensity should be equal to the P_K for the 165·8 keV state of ^{139}La. The intensities of the different K x-rays measured in the present work are as follows: $I_{K_\alpha} = 80{\cdot}6 \pm 3{\cdot}5$, $I_{K\beta_1} = 16{\cdot}10 \pm 0{\cdot}69$ and $I_{K\beta_2} = 4{\cdot}35 \pm 0{\cdot}19$ (normalised with respect to the intensity of the 165·8 keV γ-ray taken as 100). Using the K x-ray intensity measured as above and the adopted conversion coefficients of the 165·8 keV transition from Nuclear Data Sheets (1974) P_K is determined from the equation given below.

$$P_K = \frac{I_{KX}/\omega_K - \alpha_K I_{165\cdot 8}}{I_{165\cdot 8}\,(1 + \alpha_T)} \tag{2}$$

The value ($0{\cdot}72 \pm 0{\cdot}04$) of P_K obtained from eq. (2) is in good agreement with that obtained from the analysis of the sum-peak.

The electron capture decay energy (Q_{EC}) is determined from the theoretical relation (Martin and Blichert-Toft 1970) of Q_{EC} with P_K shown graphically in figure 2. The dashed line shows the same relation but including the correction due to exchange (Bahcall 1963). From the weighted average ($0{\cdot}73 \pm 0{\cdot}03$) of P_K determined as above, the Q_{EC} is observed to be 103^{+19}_{-12} keV without considering the contribution of exchange and 107^{+21}_{-13} keV with the exchange taken into account. If we take the contribution of exhange, the mass difference of ^{139}Ce and ^{139}La is found to be $Q^+ = 273\,^{+21}_{-13}$ keV.

In table 1 we have compared our present results with the reported data. Our value of P_K favours the data of Kettelle *et al* (1956) and Adamowciz *et al* (1968). Though other reported values agree within experimental uncertainty that of Stanford *et al* (1960) appears to be too large. The mass difference of ^{139}Ce and ^{139}La as estimated by Stanford *et al* and also by Schmidt-Ott and Fink (1972) is

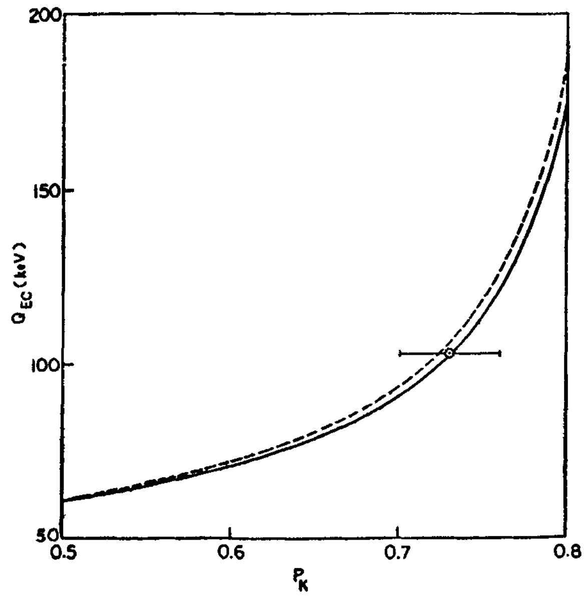

Figure 2. Theoretical curve of the electron capture energy (Q_{EC}) as a function of K-capture probability (P_K) for $^{139}Ce \rightarrow ^{139}La$ decay. The dashed line shows the same relation but including the correction due to exchange (see text).

higher than that found by us. The present data support the Q^+ measured by Ketelle *et al* and Marelius *et al* (1967). The value of $Q^+ = 273^{+21}_{-13}$ keV estimated in the present work is found to be very close to $Q^+ = 275 \pm 15$ keV adopted in the Nuclear Data Sheets (1974) following the systematic study by Wapstra and Gove (1971).

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