## On the Isomerism of $Kr^{85}$

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OF great interest for the nuclear shell theory is $Kr^{85}$, since the neutron number is 49; i.e., it represents the filled 50 shell minus one nucleon. Two different activities of this isotope with half-lives 4.5 hr. and 9.4 yr. have been reported[1] indicating an isomeric pair. Two $\gamma$-rays of energies 0.17 and 0.37 Mev and a $\beta$-continuum with the upper limit of 1.0 Mev have been assigned to the shorter activity by absorption measurements.[1] The upper limit[1] for the $\beta$-spectrum of the longer activity is 0.74 Mev (abs.). No $\beta$-spectrometer measurements have been reported previously.

By using the electromagnetic isotope separator[2] and the high transmission $\beta$-spectrometer[3] of this Institute, we have studied the 4.5-hr. activity of $Kr^{85}$ produced in uranium fission. The experimental technique was the same as that recently described[4] in an investigation of $Kr^{83m}$.

The $\beta$-spectrometer results are presented in Fig. 1 and Table I. The $\gamma$-rays of energies 149 and 300 kev are probably the same as those reported by Hoagland and Sugarman[1] (0.17 and 0.37 Mev abs.). The Fermi plot is a straight line from the upper limit 817 down to about 35 kev, where the backscattering effect in the collector foils (0.15 mg $Al/cm^2$) probably begins. Thus the $\beta$-spectrum is simple and $f\cdot t\sim 1\cdot 10^5$ corresponding to an allowed unfavored transition.[5]

The $K_1$ and the Auger electrons but not the $K_2$ electrons are in coincidence with the $\beta$-spectrum ($e^-\beta^-$-coincidence measurements in $\beta$-spectrometer). The half-lives for all the lines are the same as for the $\beta$-spectrum ($\sim$4.5 hr.). The possibility of an isomeric state with a short half-life in $Rb^{85}$ cannot be definitely excluded by internal conversion considerations. Because of the presence of the other $\gamma$-ray this question can hardly be decided by critical absorption measurements. As we also found a weak (25 c/min. close to a $\beta$-tube) very long activity in our separated $Kr^{85}$ sample and no isomer of $Rb^{85}$ has been reported, it is most probable that the 300-kev $\gamma$-ray is emitted in an isomeric transition in $Kr^{85}$. This conclusion is also supported by the decay scheme of Fig. 2 as will follow from the discussion below.

For the isomeric transition $l=5$ seems to be consistent with out measurements. From Bethe's formula we estimate the half-life $\tau_{\frac{1}{2}}$ for the $\gamma_2$-transition. Thus $\tau_{\frac{1}{2}}=3.10^7$ sec. for $l=5$ and 35 sec. for $l=4$. $\tau_{\frac{1}{2}}$ for electric radiation can also be calculated using the experimental intensity ratio $e^-/\beta^-$ for the $K_2$ line, the total half-life 4.5 hr., $N_K/N_L$ (Hebb and Nelson) and the conversion coefficient $\alpha_K$ of Rose *et al.* In this way we obtain $\tau_{\frac{1}{2}}=2\cdot 10^5$ sec. for $l=5$ and $7\cdot 10^4$ sec. for $l=4$. The first $l$-value is in good agreement with the curves of Axel and Dancoff.[6] From the data above the branching ratio $\lambda_2/\lambda_1$ is about 0.19.

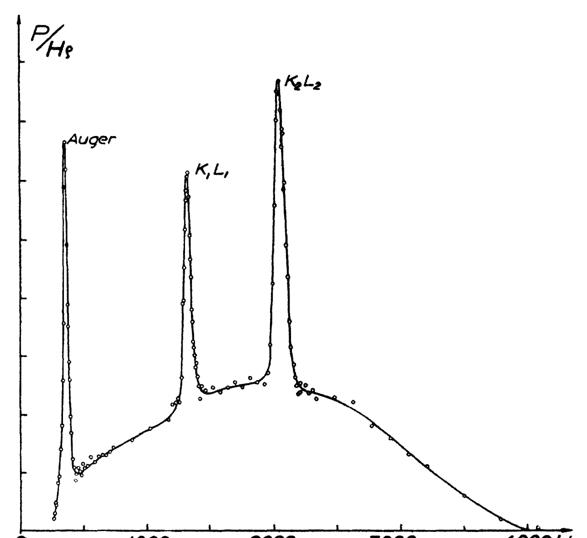


FIG. 1. $\beta$-spectrum of $Kr^{85}$ (4.4 hr.).

TABLE I. $\beta$-spectrometer results for $Kr^{85}$.

| | $H\rho$ | $E(e^-)$ (kev) | $h\nu$ or $E_{max}$ (kev) | $e^-/\beta^-$ | $f\cdot t$ |
|---|---|---|---|---|---|
| Lines | | | | | |
| $A_1$ | 350 | 10.7 | | | |
| $K_1$ | 1311 | 134 | 149 | 0.09 ±0.01 | |
| $K_2$ | 2033 | 285 | 300 | 0.051 ±0.006 | |
| $\beta$-spectrum | | | | | |
| $\beta_1$ | | | 817 | | $\sim 10^5$ |
| $\beta_2$ | | | 666[a] | | $\sim 10^{9}$[b] |

[a] Obtained from the decay scheme of Fig. 2.
[b] The half-life of Thode *et al.* was used (reference 1).

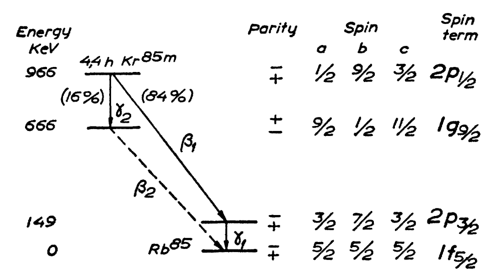


FIG. 2. Decay scheme of $Kr^{85}$, showing spin and parity discussed in text. Spin term according to M. G. Mayer (reference 7).

The internal conversion coefficient 0.051 of the 149-kev $\gamma$-ray indicates a mixture of electric $2^2$ pole and magnetic $2^1$ pole radiation (spin change = 1, no parity change). Using the tables of Rose *et al.* we obtain $\alpha_{K2}=0.17$ and $\beta_{K1}=0.037$.

From the known spin 5/2 of $Rb^{85}$ and the spin changes at the $\gamma_1$-, $\gamma_2$-, and $\beta_1$-transitions we arrive at the spin and parity relations shown in Fig. 2. All spin alternatives with $J>11/2$ have been excluded and spin alternative $c$ can be ruled out since it is unlikely to find the spin 11/2 in the nucleon number region to which $Kr^{85}$ belongs.[7] If the $\gamma_2$-transition is associated with no parity change the spin difference would be 5 leading to impossible $(-\frac{1}{2}, 19/2)$ and unprobable (11/2) spins of the ground state of $Kr^{85}$. Assuming instead parity change this would give the spins $\frac{1}{2}$ and 9/2 for the lowest levels of $Kr^{85}$. Spin alternative $a$ is in excellent agreement with the nuclear shell model of Mayer and Jensen *et al.*[7] When the $L$ conversion coefficient calculations of Rose *et al.*[7] When the $L$ conversion coefficient calculations of Rose *et al.* are available this alternative can experimentally be established by measuring $N_K/N_L$ with high resolving power.

Another consequence of our decay scheme will be that the $\beta_2$-transition would occur with a spin change of 2 and with change in parity. Shull and Feenberg[8] have given the formula $(W_0^2-1)$. $f\cdot t\sim 10^{10}$ for a $\beta$-transition of the type mentioned. From our decay scheme we get the upper limit for $\beta_2=666$ kev, which gives $(W_0^2-1)f\cdot t=0.4\cdot 10^{10}$ (using the half-life 9.4 yr. measured Thode[1]), in good agreement with the suggested spin and partity relations. The $\beta_2$-spectrum would then have the forbidden shape and will soon be measured here with a much stronger sample.

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