PHYSICAL REVIEW VOLUME 119, NUMBER 6 SEPTEMBER 15, 1960

Nuclear Structure Effects in Cs^{133}†

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(Received April 20, 1960)

The 79-kev transition in Cs^{133}, which is known to be l-forbidden ($\Delta l=2$) magnetic dipole ($M1$), has been analyzed for penetration effects suggested by Church and Weneser. A value of 6.5 ± 2.6 is found for λ, the ratio of the matrix element due to penetration of the atomic electron into the nucleus and the matrix element due to $M1$ gamma emission. This value of λ is to be compared with the range 5–10 obtained by Church and Weneser for l-forbidden ($\Delta l=2$) transitions using empirical gamma matrix elements and single-particle wave functions to evaluate the electron matrix element.

CHURCH and Weneser[1] have suggested that the internal conversion process should be sensitive to nuclear structure through a contribution due to the penetration of the atomic electrons into the nucleus. The structure effects should be especially large for the so-called l-forbidden magnetic dipole ($M1$) transitions. Identification of these effects requires precise knowledge of the conversion coefficient.

We have analyzed recent experimental results on the 79-kev transition in Cs^{133} for evidence of a penetration contribution to internal conversion. This transition has been established[2] to occur between $d_{5/2}$ and $g_{7/2}$ states and hence is an l-forbidden ($\Delta l=2$) magnetic dipole transition. The K-conversion coefficient for this transition has been measured[3] rather accurately to be 1.51 ± 0.05. The $E2/M1$ amplitude mixing ratio, δ, has been found to be -0.16 ± 0.01 from angular correlation studies.[4] The total K-conversion coefficient for a mixed $M1$-$E2$ transition can be written in the usual notation as

$$\alpha_K=\frac{1}{1+\delta^2}[\beta(M1)+\delta^2\alpha(E2)], \tag{1}$$

from which we obtain

$$\beta(M1)=\alpha_K(1+\delta^2)-\delta^2\alpha(E2). \tag{2}$$

Substituting for α_K and δ, and taking the theoretical value[5] $\alpha(E2)=2.1$, we get $\beta(M1)=1.49\pm0.05$.

The effects on internal conversion due to penetration depend on the details of the nuclear structure. For $M1$ transitions Church and Weneser[1] write

$$\lambda=m_e/m_\gamma, \tag{3}$$

where m_e is that part of the matrix element due to the penetration of the electron into the nucleus and m_γ is the matrix element for $M1$ gamma emission. In terms of λ, the corrected $M1$ conversion coefficient is given approximately by

$$\beta(\lambda)\sim\beta(1)[1-(\lambda-1)C(Z,k)]^2, \tag{4}$$

where $\lambda=1$ means that the currents are confined to the nuclear surface (Sliv's assumption). $C(Z,k)$ can be determined from the corrected table of Church and Weneser.[6]

For the 79-kev transition in Cs^{133} the experimental value of $\beta(\lambda)$ is 1.49, the value of $\beta(1)$, according to Sliv,[7] is 1.66, and for $Z=55$ and $k=0.15$, $C(Z,k)=7.9\times10^{-3}$. Putting these numbers in Eq. (4), we obtain $\lambda=+6.5\pm2.6$.

This result shows that the penetration matrix element is about 7 times as large as the gamma matrix element. Church and Weneser[1] evaluated λ for $\Delta l=2$, $M1$ transitions for odd-Z nuclei using empirical gamma matrix elements and using single-particle wave functions to evaluate m_e. They found values of λ falling between 5 and 10, corresponding to a change of $\beta(\lambda)$ [increase or decrease depending on the sign of λ] up to 20% for $Z=55$. The observed value of 8–12% for this reduction in the case of Cs^{133} ($Z=55$) is in this region.

ACKNOWLEDGMENT

I would like to thank Professor P. S. Jastram for helpful criticism of the manuscript.

† This work was supported by the U. S. Atomic Energy commission.

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