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A note on the higher order effects in the nonunique first forbidden beta decays of ^{125}Sb, ^{186}Re and ^{152}Eu

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Abstract. An attempt is made to determine the higher order effects in the nonunique first forbidden beta decays of ^{125}Sb, ^{186}Re and ^{152}Eu with matrix element parameters obtained using Simms' formalism. The experimental values of the CVC ratio are not in agreement with Fujita's estimate and support the view that the neglection of the nondiagonal matrix elements in the operator for the Coulomb potential is not valid. From the experimental values, limits are set on the magnitude of the correction factors and these provide a measurement of the higher order matrix element parameters.

In the past the nuclear matrix element parameters governing the nonunique first forbidden beta decays were determined using Kotani's formalism (Kotani 1957). In the formalism of Kotani the nucleus is assumed to be of point size and so the higher order matrix element parameters arising out of the finite size of the nucleus are neglected. More recently the determination of the nuclear matrix element parameters was effected by using the formalism of Simms (1965). In Simms' formalism in addition to the usual six matrix element parameters additional matrix element parameters due to (i) the finite size of the nucleus, (ii) third forbidden matrix elements and (iii) screening effects were taken into consideration. However, the experimental accuracies do not warrant the inclusion of the matrix element parameters due to (ii) and (iii). So in effect in the Simms' formalism also only the matrix element parameters due to the finite size of the nucleus are included, in addition to the first order matrix elements.

Very recently Smith and Simms (1970) suggested that it is possible to estimate the order of magnitude of the higher order matrix element parameters x' and u' (the definitions of these higher order matrix element parameters can be found in Simms 1965) using the modified version of the conserved vector current (CVC) theory due to Damgaard and Winther (1966). In the present note an attempt is made to determine the higher order effects in the nonunique first forbidden beta decays of ^{125}Sb, ^{186}Re and ^{152}Eu. For this purpose we used the first forbidden matrix element parameters in the decays of the above nuclei reported by us in our earlier works (Narasimha Raju *et al* 1970, Appalacharyulu *et al* 1969). These matrix element parameters were obtained using Simms' formalism. The experimental values of the CVC ratio Λ/ξ ($\Lambda = \int\xi\boldsymbol{\alpha}/\int i\boldsymbol{r}$ and $\xi = \alpha z/2R$) for the above three decays are given below.

^{125}Sb	$3{\cdot}4 \leqslant \Lambda/\xi \leqslant 4{\cdot}6$
^{186}Re	$0{\cdot}96 \leqslant \Lambda/\xi \leqslant 1{\cdot}2$
^{152}Eu	$0{\cdot}79 \leqslant \Lambda/\xi \leqslant 1{\cdot}5.$

It can be seen that these experimental values of Λ/ξ are not in agreement with Fujita's estimate ($= 2.4$) (Fujita 1962). This disagreement seems to support the criticism of Damgaard and Winther that the approximation of neglecting the nondiagonal matrix elements in H_c, the operator for the Coulomb potential, is not valid. Smith and Simms have expressed the correction term to Fujita's result which must be made when the method of Damgaard and Winther is used in the calculation as follows:

$$\Lambda_{\text{corr}} = \Lambda^0_{\text{CVC}} + \frac{\alpha z}{2R}(0{\cdot}6 - \lambda) \tag{1}$$

where

$$\Lambda^0_{\text{CVC}} = 2{\cdot}4\xi + (W_0 - 2{\cdot}5) \tag{2}$$

and

$$\lambda = \frac{\int r(r/R)^2}{\int r} = \frac{\int ir(r/R)^2}{\int ir}. \tag{3}$$

Thus the relationship for Λ^0_{CVC} is a special case of the more generalized expression (1) which takes into consideration the remarks of Damgaard and Winther on the CVC theory.

Now using expression (1) it is possible to estimate the magnitude of the correction term λ. Using the linear relationship between Λ_{corr} and λ, Λ_{corr} is plotted as a function of λ for the three transitions. Using the experimental values of Λ the following limits can be set for the magnitude of the correction factors:

^{125}Sb	$-1{\cdot}6 \leqslant \lambda \leqslant -0{\cdot}4$
^{186}Re	$1{\cdot}78 \leqslant \lambda \leqslant 2{\cdot}03$
^{152}Eu	$0{\cdot}75 \leqslant \lambda \leqslant 1{\cdot}25.$

The experimental value of λ provides a measurement of the higher order matrix element parameters x' and u', since the operators x and u have the same form for the radial wavefunction it is reasonable to assume that the ratio of u' and u is nearly the same as the ratio x' and x. From the definition of λ this ratio is just the parameter λ. Thus for ^{125}Sb $x' \simeq x$ and $u' \simeq u$ for ^{186}Re $x' \simeq 1{\cdot}9x$ and $u' \simeq 1{\cdot}9u$ and for ^{152}Eu $x' \simeq 1{\cdot}25\,x$ and $u' \simeq 1{\cdot}25u$.

This information on the relative magnitudes of the matrix element parameters is a useful new result in nuclear structure studies. The matrix element parameters governing the beta transitions are nuclear model dependent. Here the parameters with primes arise out of the finite size of the nucleus. Any successful model of the nucleus should be able to explain the relationships between x and x' and u and u' besides the normal matrix element parameters.

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