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# Beta Decay as a Test of the $Sr^{88}$ $3^-$ Wave Function

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Allowed $\Delta T = 1$ Gamow-Teller $\beta$ decay from the $Rb^{88}$ $2^-$ ground state to the $Sr^{88}$ $3^-$ level at 2.73 MeV is calculated. A one-particle–one-hole description of the latter state requires the $[2p_{1/2}^{-1}(n)2d_{5/2}(n)]_{T=6}^{J=3^-}$ component in order to predict the observed log$ft$ value of 6.7. The decay rate is extremely sensitive to the amplitude of this term.

One of the main reasons for the considerable recent interest in the mass-88 region is the neutron-shell closure at the magic number of 50 (completing the $1g_{9/2}$ shell). This closure forms a basis for the theoretical studies of $Sr^{88}$ by Hughes,[1] Shastry and Saha,[2] and Shastry.[3] Hughes[1] and Refs. 2 and 3 differ, however, in their treatment of the 38 protons. It is appealing to treat the $2p_{3/2}$ proton shell as closed at 38. This doubly magic picture of the $Sr^{88}$ ground state simplifies calculations and is an additional assumption in Refs. 2 and 3. The $3^-$ level at 2.73 MeV is especially interesting, as it is strongly collective.[4] This state is built up in Ref. 2 out of 14 proton 1p-1h components, and in Ref. 3 three neutron 1p-1h terms are added. (Reference 1 does not consider negative-parity levels.) Because of these neutron components there is a substantial improvement in the calculated energy of the $3^-$ state and its $B(E3)$ to the ground state.[3] In the present paper we test the importance of these neutron terms by calculating the allowed $\Delta T = 1$ Gamow-Teller (GT) $\beta$ decay to the $3^-$ level from the $2^-$ ground state of $Rb^{88}$.

Shreve[5] finds that 60–70% of the $Sr^{88}$ $3^-$ state corresponds to the coupling of a $1g_{9/2}$ proton to the $Rb^{87}$ ground state. This agrees qualitatively with the calculations of Refs. 2 and 3, which predict that the component $2p_{3/2}{}^{-1}(p)1g_{9/2}(p)$ comprises about 90% of the wave function. Since the $1g_{9/2}(p)$ cannot partake in the allowed GT $\beta$ decay, we are considering a transition to a state that can be reached only through the small terms in its wave function. The calculation should therefore be very sensitive to the relative sizes and phases of these terms.

The $Rb^{88}$ ground state may most simply be described as a proton hole in the $Sr^{88}$ core plus an added neutron. Experimentally[6] the most likely state for this neutron is $2d_{5/2}$. While the $2p_{3/2}^{-1}(p)$ and $1f_{5/2}^{-1}(p)$ states compete, both energetics[7] and magnetic-moment evidence[8] indicate that the former predominates. Shreve,[5] in an extension of the calculation of Ref. 1, has determined that the $Rb^{87}$ ground state is 85% $2p_{3/2}^{-1}(p)$. This strongly supports the simple $2p_{3/2}^{-1}(p)2d_{5/2}(n)$ assignment as dominant in the $Rb^{88}$ ground state.

The $ft$ value is given by[9]

$$ft = 5300/|\vec{\sigma}|^2 , \qquad (1)$$

where $|\vec{\sigma}|^2$ is the sum over final and the average over initial states of the square of the nuclear matrix element of the GT operator given by

$$|\langle J=3^-,\ T=6|\sum_k (\sigma_{1m})_k \tau_k^- |J=2^-,\ T=7\rangle|^2 . \qquad (2)$$

The initial state is

$$|J=2^-,\ T=7\rangle = a|[2p_{3/2}^{-1}(p)2d_{5/2}(n)]_{T=7}^{J=2^-}\rangle + b|[1f_{5/2}^{-1}(p)2d_{5/2}(n)]_{T=7}^{J=2^-}\rangle, \quad (3)$$

where $a$ and $b$ are the amplitudes. Some of the proton 1p-1h components in the daughter state are above the neutron excess and introduce $T=7$ components. However, the isospin coupling rule of French[10] indicates that these are negligible, and the $3^-$ state is essentially pure $T=6$.

In Ref. 2 four components of the $3^-$ state can be reached in the decay. As a first try we consider $a^2=1$ in Eq. (3). The result is $|\vec{\sigma}|=12.7\times10^{-2}$ ($\log ft=5.5$). The experimental value is $|\vec{\sigma}|=3.26\times10^{-2}$ ($\log ft=6.7$).[8] Including the second term in Eq. (3) does not significantly alter this result. This is because the additional contributions to $|\vec{\sigma}|$ have comparable magnitude but opposite sign. In particular, if $a^2=b^2=0.5$ (which is very unlikely) the $\log ft$ is only increased to 5.8.

In Ref. 3 the component

$$0.161|[2p_{1/2}^{-1}(n)2d_{5/2}(n)]_{T=6}^{J=3^-}\rangle$$

appears and it contributes to the decay. The amplitudes of the comparable proton 1p-1h components in Refs. 2 and 3 are not drastically different; but the contribution from the neutron 1p-1h component is large, and because of its phase we obtain a significant cancellation. Considering $a^2=1$ in Eq. (3) the result is $|\vec{\sigma}|=0.454\times10^{-2}$ ($\log ft=8.4$). As in the preceding case, even large components of the second term in Eq. (3) have very little effect.

Our calculation has assumed a constant $\beta$-decay coupling strength, and any enhancement or reduction of the transition rate is due to the nuclear matrix element. Adding neutron 1p-1h states has turned a large enhancement into a substantial hindrance. However, if the pertinent neutron component had an amplitude of $\approx0.10$ instead of 0.161, we would get roughly the experimental $\log ft$. While this work supports that of Shastry,[3] it demonstrates the strong sensitivity of the $\beta$ decay to this particular neutron amplitude. Lastly, it would be interesting to see a structure calculation along the lines of Hughes[1] to test the possible importance of 2p-2h admixtures for both the $\gamma$ and $\beta$ decay.

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