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GAMOW-TELLER STRENGTH IN SIMPLE NUCLEI AND RENORMALIZATION OF THE AXIAL-VECTOR COUPLING CONSTANT

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The model of the nucleus as an assemblage of Z protons and N neutrons has for the most part been very successful, but the degree to which these bound nucleons retain the characteristics of free nucleons has remained the subject of much fascinating conjecture and little hard evidence. Recent experiments at IUCF have shed new light on the subject.

Coupling to the weak field is an attribute of nucleons that is amenable to study in both the bound and the free state. Thus, comparisons of measured and calculated beta decay ft values have been the prime source of information concerning the free and bound coupling constants.[1,2] The limitation in using a beta decay ft value is that it applies to a transition between a particular pair of states and, thus, the calculated value depends on the model wave functions for both states. For that reason simple nuclei are specially important to study. For example, there is little room for model uncertainty in nuclei with double-closed shells plus or minus one nucleon.

Mass 39 is, thus, a good case to study. The beta decay of ^{39}Ca has been measured. According to the shell model, the ground state transition is a transformation from a $d_{3/2}$ neutron hole to a $d_{3/2}$ proton hole. For that transition the reduced Gamow-Teller transition probability B(GT) must be 3/5. The other 12/5 of the required sum strength of 3 must go to the $d_{3/2} \rightarrow d_{5/2}$ transition. The accepted value of log ft = 3.60±0.02 for the ground-state transition yields B(GT) = 0.35 rather than 0.60, which means either the axial-vector coupling is quenched by nearly a factor of 2 or the model is wrong.

We have studied the reaction ^{39}K(p,n)^{39}Ca in order to determine the distribution of GT strength. We chose

KF as the target material because of the desire to avoid the difficulty of handling the chemically active potassium and because of the simplicity of the spectrum from $^{19}F(p,n)$. The neutron spectrum from the KF target is shown in Fig. 1, and a spectrum with the fluorine contribution subtracted is shown in Fig. 2. The fluorine spectrum was obtained from a teflon (CF_2) target and, therefore, also contains a contribution from carbon. This creates a strong negative peak in the subtracted spectrum at the position of the $^{12}C(p,n)^{12}N$ ground state transition.

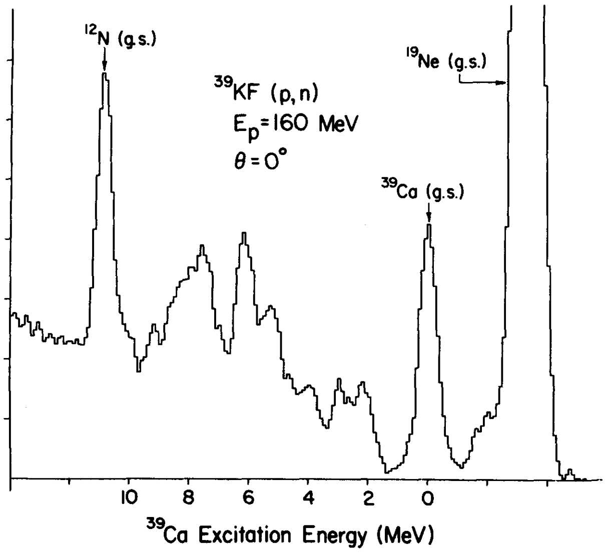

Figure 1. Neutron energy spectrum from a ^{39}KF target.

The $^{39}K \rightarrow ^{39}Ca$ ground-state mirror transition is quite evident in the spectrum and serves to normalize the cross section for deducing GT strength. It is evident that the $d_{3/2} \rightarrow d_{5/2}$ strength is fragmented. The double peak in the 5 to 6 MeV region seems to contain most of the strength. Fragmenting of the $d_{5/2}$ strength has been observed in pickup reactions.[3,4] According to both references, about two thirds of the $d_{5/2}$ hole strength lies in the 5 to 6 MeV states. Our (p,n) data yield B(GT) = 0.50.

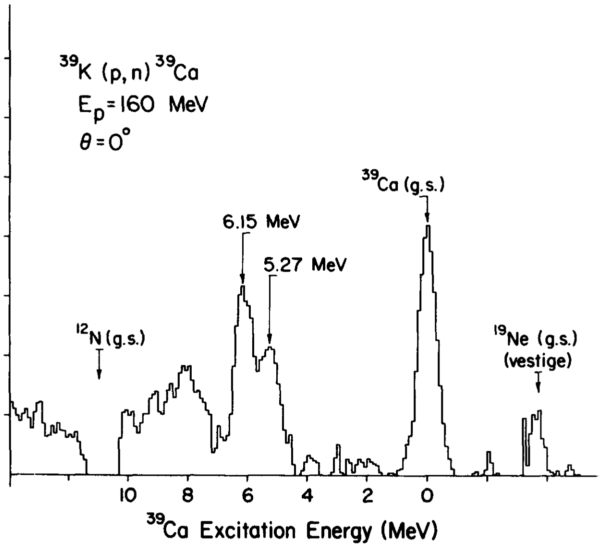

Figure 2. Neutron spectrum from a ^{39}KF target with the fluorine contribution subtracted. The fluorine spectrum was obtained from a teflon target. Thus, a negative peak is generated from the carbon contribution.

There are several possible avenues of interpretation of the data. Suppose we assume that there is a state-independent GT quenching factor and we deduce its value from the $d_{3/2} \rightarrow d_{3/2}$ transition. This factor is then about 0.5. Since the summed B(GT) for $d_{3/2} \rightarrow d_{5/2}$ should be 2.4, when we apply the quenching factor we should expect to find a summed strength of 1.2. Thus, more than half of the $d_{3/2} \rightarrow d_{5/2}$ strength must lie outside the 5 to 6 MeV peaks. This point of view is not wholly inconsistent with the (p,n) spectrum which shows excess counts in the ~8 MeV region of excitation above the well-defined peaks. This is inconsistent with the claim of the pickup reaction analysis that two-thirds of the $d_{5/2}$ hole strength lies inside the 5 to 6 MeV region.

Alternatively, suppose we choose to accept the figure from the pickup data that 2/3 of the $d_{5/2}$ hole strength lies in the 5 to 6 MeV region and allow the quenching factor to be state dependent. Then, the quenching factor for the $d_{3/2}\rightarrow d_{5/2}$ transition is 0.31. The correct interpretation is not at all clear at this time. Analysis of the data is continuing and additional experiments are contemplated.

The ^{19}F(p,n)^{19}Ne spectrum also provides interesting information on the GT strength distribution. In this case almost all of the GT strength is in the mirror transition. This puts severe restrictions on the symmetry of the ground state of ^{19}F. A shell model calculation reproduces this concentration of strength reasonably well. In this case the quenching factor deduced from the mirror transition is 0.55.

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ASYMMETRY MEASUREMENTS IN THE ^{90}Zr($\vec{p}$,n)^{90}Nb AND ^{208}Pb($\vec{p}$,n)^{208}Bi REACTION

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We have found that at IUCF energies the forward angle neutron energy spectra for (p,n) reactions on medium and heavy nuclei are characterized by spinflip, isovector collective states riding on a large continuum. Concentrations of Gamow-Teller (GT) strength have been identified via angular distributions of differential cross sections consistent with a $\Delta L=0$ transition and a bombarding energy dependence characteristic of a transition mitigated by the $\vec{\sigma}\cdot\vec{\sigma}\ \vec{\tau}\cdot\vec{\tau}$ operator. This strength is fragmented in the ^{90}Zr(p,n)^{90}Nb reaction, in which 1^+ strength is located at 2.33 and 8.7 MeV.[2] In the ^{208}Pb(p,n)^{208}Bi reaction only the dominant "giant" GT state can be identified at an excitation energy above that of the IAS.[3] An additional feature of these (p,n) data is that a $\Delta L=1$, $\Delta S=1$ resonance has also been identified at an even higher excitation energy.[4]

During the past year we have extended our study of these isovector modes of excitation to the measurement of vector analyzing powers (A_y) for the (p,n) reaction on targets of ^{90}Zr and ^{208}Pb. For the ^{90}Zr target, angular distributions of A_y have been measured in the angular range from 0° to 24° and 24° to 48° using two neutron detector stations having neutron flight paths