CHARGE EXCHANGE

POLARIZATION TRANSFER MEASUREMENT FOR ^{19}F AND ^{39}K(p,n)

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The absolute transition rate of a nuclear reaction depends on many parameters that are usually imprecisely known. Even direct charge-exchange (p,n) reactions depend on the effective nucleon-nucleus interaction, the optical potential, and the nuclear structure overlap. Thus it is difficult to extract unambiguous information from cross section measurements alone. Polarization transfer (PT) studies, on the other hand, can provide certain information in a way that is insensitive to some parameters. For example, for charge exchange (p,n) reactions at small momentum transfer, the transverse polarization transfer coefficient D_{nn}, based on simple angular momentum arguments alone, is $-1/3$ for GT (*Gamow-Teller*) transitions and $+1$ for F (*Fermi*) transitions. Departures from these simple values indicate that other angular momentum couplings are involved. We have already verified that these simple expectations are realized for transitions that are expected to be pure F or pure GT (Ref. 1).

One important application of D_{nn} measurements is to GT strength studies. That GT strength can be inferred from (p,n) cross-section measurements was demonstrated a decade ago.[2] A reliable GT strength determination, however, depends on calibrating the particular spectrum against a known beta-decay transition. In most cases the IAS (*Isobaric Analog State*) provides the only possible calibration point. But a problem arises if the target has non-zero spin, as for odd-mass nuclei. The IAS peak can contain both GT and F components, and, even when the GT content is known, there is a remaining question of how accurately the GT/F interaction strength ratio determined from spin zero targets can be applied to spin > 0 targets.

An empirically discovered relationship for the ratio of GT/F strengths[3] has been extensively used to extract GT strengths relative to an IAS peak in the spectrum. This relationship is based mostly on measurements on even-mass nuclei and may be described as $R^2 \equiv \hat{\sigma}(GT)/\hat{\sigma}(F)$ and $R = E_p/E_0$, where $\hat{\sigma}(\alpha) \equiv \sigma(\alpha)/B(\alpha)$ (for $\alpha = GT$ or F) and E_p is the proton beam energy with E_0 a constant $\simeq$55 MeV. A firm theoretical underpinning has not been found so far for this empirical relationship.

A systematic study of the specific cross sections, $\hat{\sigma}(GT)$, revealed that for some odd-mass nuclei $\hat{\sigma}(GT)$ appears to be larger than for their even isotopes, and differences of as much as 50% have been observed for neighboring A values.[4] These "enhancements" are not understood in the context of DWIA, which predicts a smooth A-dependence for $\hat{\sigma}$. A recent measurement[5] suggests that some odd-A nuclei might have different GT/F ratio from the systematic value of even-nuclei. It is not clear, therefore, what part of the apparent enhancement is "real" and what part may be a reflection of an inappropriate use of the "universal" GT/F ratio.

Direct light can be shed on these issues with the a measurement of $D_{nn}(0^\circ)$ because it provides an independent method to separate the GT component in the mixed IAS peak. If the inteference terms from other non-central components can be ignored, the IAS peak is simply an incoherent sum of both GT and F. So the $D_{nn}(IAS)$ is simply the weighted average of $D_{nn}(GT)$ and $D_{nn}(F)$. Therefore the fraction of GT content in the IAS is given by $F_{gt} \equiv \sigma(GT)/\sigma(IAS) = 0.75\,(1 - D_{nn}(IAS))$, where we have used the fact that $D_{nn}(GT) = -1/3$ and $D_{nn}(F) = +1$.

^{19}F and ^{39}K provide two excellent test cases. ^{39}K is one of the few nuclei with a simple shell structure - a single $d_{3/2}$ hole in the doubly magic ^{40}Ca core. A special structure symmetry was also demonstrated for ^{19}F which has three $d_{5/2}$ particles in its outmost d shell.[6] Both targets have non-zero spins: $3/2^+$ for ^{39}K, and $5/2^+$ for ^{19}F. 35% enhancement of the specific cross section above the general trend was observed for ^{39}K in previous studies,[4] while no appreciable deviation found for ^{19}F.

Measurements have been made at the IUCF Swinger Facility using a pulsed proton beam of averaged intensity of 50 nA and 75% polarization. Data have been taken at both 120 MeV and 160 MeV. The target used was a compound KF enriched to 99.96% for ^{39}K. The kinetic energy of the projectile neutron was determined by TOF with a 75 m flight path. The neutron polarization was measured with a neutron polarimeter consisting of two detector planes separated by 1 meter and placed transversely at the end of the flight path. The polarimeter was calibrated with $^{14}C(\vec{p},\vec{n})^{14}N$, $0^+ \to 0^+$ transition which has $D_{nn}(0^\circ) = 1$. Optimized cuts that maximize the figure-of-merit (FOM), $A_e^2\times$(total counts accepted), yielded an effective analyzing power $A_e = 0.29 \pm 0.02$. (The cuts that maximize FOM do not maximize A_e.) The energy spectrum for 160 MeV is shown in Fig. 1, where the typical energy resolution is about 1 MeV. The corresponding $D_{nn}(0^\circ)$ spectrum with error bars is also displayed in the same figure. The IAS peaks from the two nuclei, ^{19}F and ^{39}K, are separated by 3.3 MeV and cleanly resolved. There is no background problem in peak fitting. The region around 145 MeV is where the giant GT resonance from both nuclei should appear. The D_{nn} in that region very close to $-1/3$, demonstrating that the transitions are indeed dominated by GT.

The analyses for the IAS peaks are listed in the tables. Table I compares the measurement with DWIA calculations for $D_{nn}(0^\circ)$. ^{19}F agrees with calculation very well, but not ^{39}K which is opposite in sign. Two methods of separating GT from the IAS peak are compared in Table II, where F_{gt} is the GT fraction calculated from the empirical relation $R = E_p/E_o(= 55MeV)$, and F'_{gt} is from D_{nn} measurement. Again, we see that ^{19}F is consistent for both methods, but for ^{39}K the D_{nn} method yields a smaller GT content in the IAS peak. It is interesting to parametrize the D_{nn} results the same way as the ratio

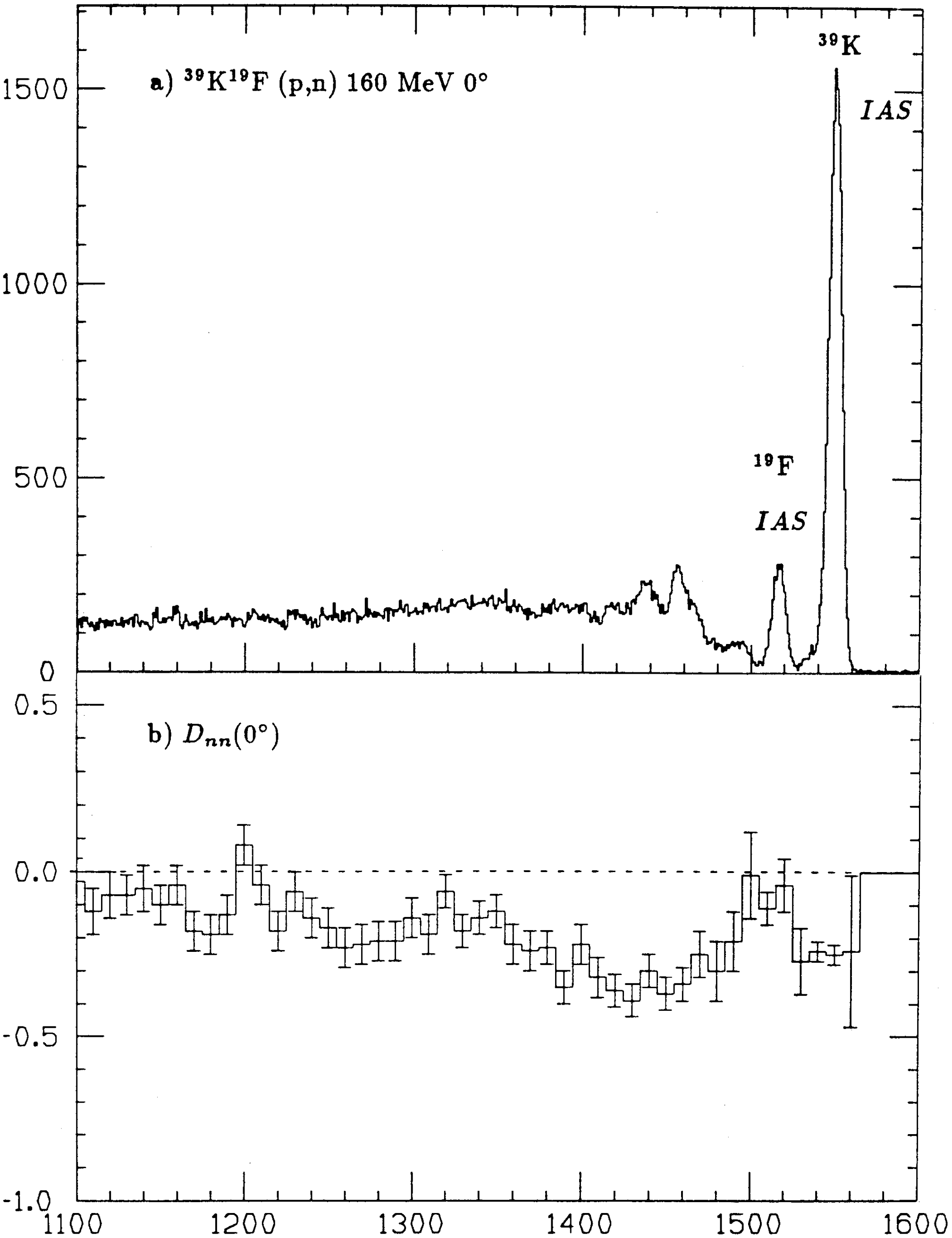

Figure 1. a) Energy spectrum for target KF at 0 degrees at 160 MeV. The typical energy resolution is about 1 MeV. *b)* D_{nn} spectrum vs. kinetic energy of the neutrons.

R. The derived E_o values are listed in Table III. The value 54 ± 2 MeV for ^{19}F is consistent with the systematic value 55 MeV. The E_0 is only 43 ± 2 MeV for ^{39}K, but this result is consistent with recent measurement[5] where the preliminary results showed that ^{51}V, ^{87}Rb, ^{113}In and ^{141}Pr have typically $E_0 \approx 44 \pm 2$ MeV while ^{118}Sn has $E_0 = 51 \pm 3$ MeV.

Table I. Comparison of $D_{nn}(0^\circ)$ measurements with DWIA calculation at 160 MeV.

Target	Experiment	DWIA
^{19}F	-0.25 ± 0.02	-0.257
^{39}K	-0.05 ± 0.04	$+0.051$

Table II. Comparison of fraction of GT in *IAS* deduced from two methods. f_{gt} is the result from the emperical relation $R^2 \equiv \hat{\sigma}(GT)/\hat{\sigma}(F) = (E_p/55.0(\text{MeV}))^2$, and f'_{gt} is the result from $0.75(1 - D_{nn}(IAS))$.

Target	E_x	$B(GT)$	f_{gt}	f'_{gt}	f_{gt}/f'_{gt}
^{19}F	0	1.635±0.016	0.936±0.015	0.93±0.02	1.01±0.02
^{39}K	0	0.274	0.79±0.02	0.70±0.02	1.13±0.03

Table III. Parameter E_0 yielded from the parametization of D_{nn} into $R = E_p/E_0$ for $E_p = 160$ MeV.

Target	E_0 (MeV)
^{19}F	54±2
^{39}K	43±2

Why odd-mass nuclei have different GT/F ratio is not yet clear. An experiment aiming at understanding important tensor effects will be underway at IUCF in which non-zero degree D_{nn} will be measured for ^{19}F and ^{39}K.

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P-A MEASUREMENTS IN THE ^{48}Ca(p,n)^{48}Sc REACTION AT 135 MeV

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We measured the polarization (P) and the analyzing-power (A_y) for the ^{48}Ca(p,n)^{48}Sc reaction at 135 MeV with the beam-swinger facility at the Indiana University Cyclotron Facility (IUCF). The experiment was performed using the improved transmission from the polarized ion source. The beam intensity was 400-600 nA of protons with a polarization of about 72%. The KSU neutron polarimeter[1] was located along the 0° swinger line at a flight path of 37 m; the energy resolution was about 1 MeV. This polarimeter uses three BC-517L liquid scintillator neutron analyzers together with six plastic scintillator "side" detectors and provides an analyzing power of about 0.35 for neutrons of about 120 MeV. These measurements extend our earlier cross section,[2] analyzing-power,[3] and spin-transfer[4] measurements for this reaction.

The target nucleus, ^{48}Ca, is understood to be a relatively good closed-shell nucleus and the transitions induced by the (p,n) reaction are to predominantly one particle, one-hole (1p1h) states. The 1^+ state at 2.52 MeV in ^{48}Sc is believed to be predominantly $(f_{7/2},f^{-1}_{7/2})$ and the 1^+ state at 16.8 MeV is believed to be predominately $(f_{5/2},f^{-1}_{7/2})$. The difference in the dominant 1p1h structures of these two 1^+ excitations is expected to affect the difference $P - A_y$ strongly. Love and Comfort[5] shows that for transitions with a single shell, one of the nonvanishing form factors for $P = A$ is specified by the matrix element of the operator $< i\vec{L}\times\vec{\sigma} >$. They show that this matrix element will vanish for j(initial) = j(final); thus, P and A_y are expected to be the same for the low-lying 1^+ excitation, but we expect a significant difference for the state at 16.8 MeV. "Standard" nonrelativistic DWIA calculations support these expectations, in fact, the signs of P and A_y are predicted to be opposite over the entire angular range for the high-lying 1^+ excitation.

Results for σ, σP, and σA for the ^{48}Ca(p,n)^{48}Sc reaction at 5° are shown in Fig. 1. These results are qualitatively in agreement with the arguments presented above. The low-