STRONG SPIN-FLIP TRANSITIONS IN (p,n) REACTIONS

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A striking feature of the data obtained so far from (p,n) reactions at IUCF is the dominance of spin-flip transitions at high energy. In the previous IUCF annual report we noted that in 62 MeV data from self-conjugate targets we were able to identify strong transitions to states that are the analogs of certain excited states of the target nuclei with large M1 widths (see fig. 1). We now see that at 120 MeV and 135 MeV those transitions dominate the spectra. The strong transitions are $^{12}C(p,n)^{12}N$(g.s.), $^{24}Mg(p,n)^{24}Al$(1.1 MeV), and $^{28}Si(p,n)^{28}P$(2.1 MeV). In $^{40}Ca(p,n)^{40}Sc$ there is no dominant peak, but $^{40}Ca(p,n)^{40}Sc$(3.3 MeV) has a forward peaked angular distribution and might be related to the strong transitions for the other targets.

An irony in these early results lies in the rationale used for the choice of first targets. We reasoned that with poor resolution broad giant resonances would be the most easily observable features of the spectra. In fact, the giant E1 resonance is barely discernible if present at all, yet sharp peaks tower above the continuum. The selectivity of the reaction makes up for the lack of resolution.

The prominent sharp peaks can be understood as spin-flip transitions induced by a spin-isospin dependent term in the effective projectile-target interaction. The main isospin dependent part of the effective interaction is

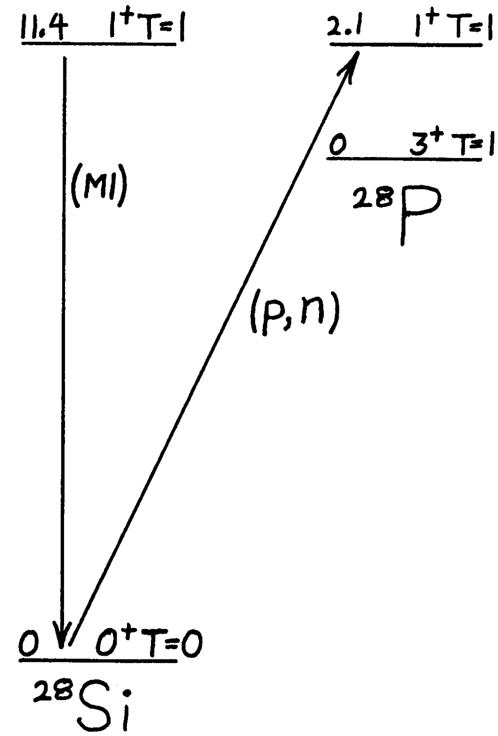

Fig. 1. The relevant energy levels in the mass 28 system.

$$V_{eff} = \Sigma_i [V_1 \tau \cdot \tau_i + V_2 (\sigma \cdot \sigma_i)(\tau \cdot \tau_i)]$$

where the subscripted operators refer to the target nucleons and the unsubscripted operators refer to the projectile.

The V_1 term is the Lane potential which gives rise to analog state transitions. It is inoperative on self-conjugate targets. The V_2 term, however, because of the spin operator, can cause transitions between a 0^+ target state and a 1^+

final state even for a T=0 target. It is such transitions that, we believe, are responsible for the dominant peaks in the spectra.

The strengths and distribution over energy of these peaks are structure sensitive. Roughly speaking these are transitions between spin-orbit pairs, e.g. $d_{5/2} \rightarrow d_{3/2}$ for ^{28}Si. (This is not wholly correct because the spin operator also connects $d_{5/2} \rightarrow d_{5/2}$). The total strength of the spin-flip transitions is a measure of the degree to which the proton and neutron spins are not paired. In ^{12}C and ^{28}Si this is largely due to spin-orbit splitting in the p shell and the d shell respectively. In ^{40}Ca there should be no unpaired spins insofar as the nucleus is doubly magic. However, pair excitations to the $f_{7/2}$ shell could create unpaired spins.

Detailed analysis of the data should yield information about the structure of the target nuclei and about the effective nucleon-nucleon interaction.

Figure 2 shows time-of-flight spectra for $^{27}Al(p,n)^{27}Si$ and $^{28}Si(p,n)^{28}P$. The largest peak in the ^{28}Si spectrum is for the 2.1 MeV state in ^{28}P as discussed above. The ^{27}Al spectrum appears qualitatively different from low energy (p,n) spectra in the 10-30 MeV range. The low energy spectra are dominated by the isobaric analog state transitions. The high energy spectra seem to be dominated by the spin-flip transitions. The V_2 term becomes relatively more important than the V_1 term at high energy.

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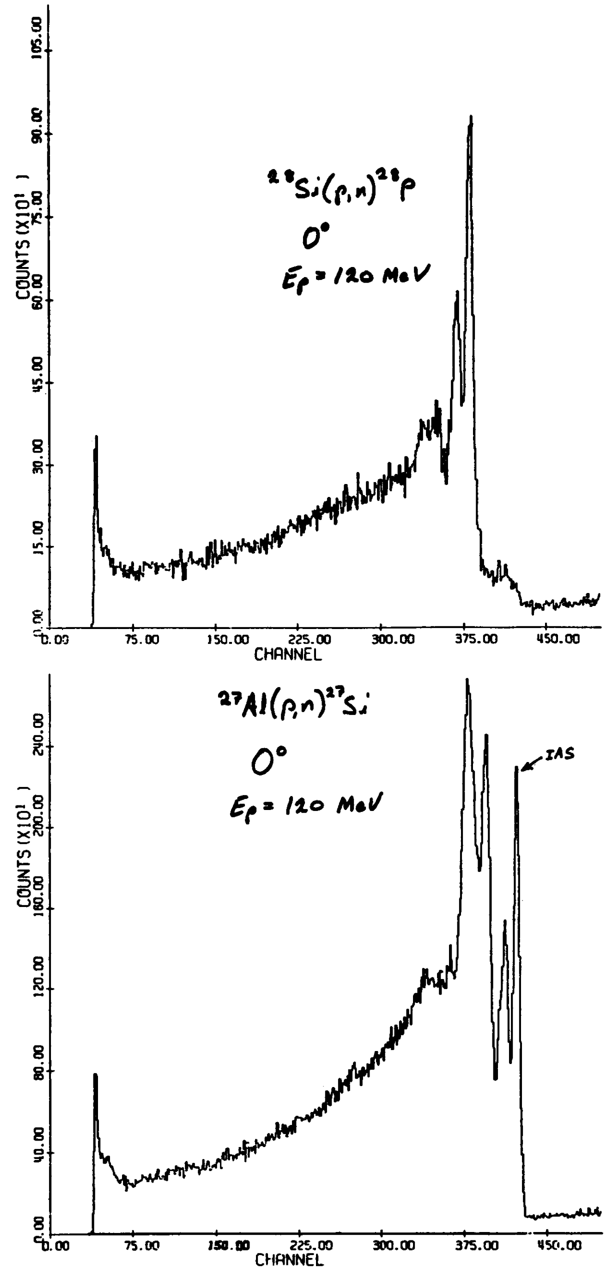

Figure 2. Time-of-flight spectra for $^{27}Al(p,n)^{27}Si$ and $^{28}Si(p,n)^{28}P$.