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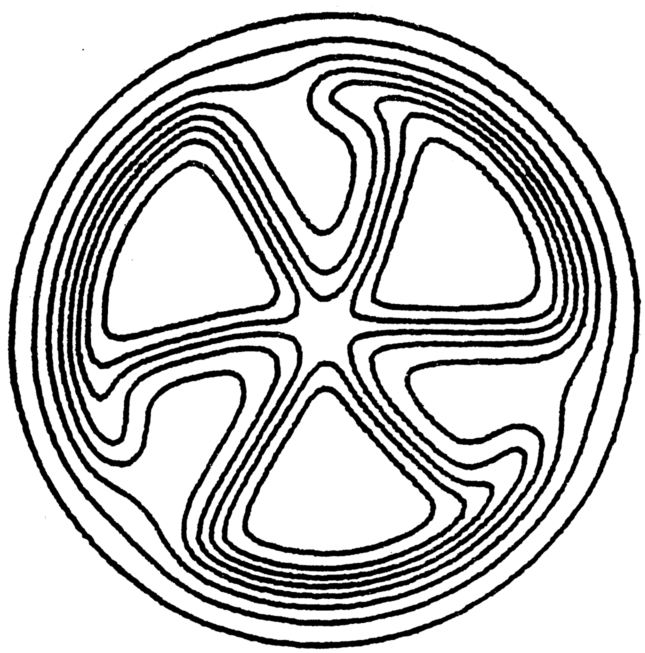

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Comment on 'Prediction of Weak-Coupling Structure from a Shell-Model Basis'

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The theoretical predictions of Wildenthal, Nann and Seth about weak coupling relations between the $0^+_{1,2}$ states of ^{32}S and the $3/2^+_1$ and $3/2^+_3$ states have been experimentally verified, and the weak-coupling picture shown to extend to a quadruplet of states in ^{33}Cl which have significant parentage in the 2^+_1 state of ^{32}S

It was demonstrated in a recent letter[1] that calculations for the (p,t) reaction on odd mass targets, made with mixed-configuration shell-model wave functions for sd-shell nuclei,[2] yielded anomalously pure L=0 (p,t) angular distributions for selected excited states as well as for the ground states. The calculated results strongly resembled phenomena observed in (p,t) experiments on odd and even mass fp shell nuclei[3,4] which had been interpreted in terms of weak-coupling relation between the first excited 0^+ state in an even-mass residual nucleus and an excited state of $J^\pi = J^\pi$ (target g.s.) in the adjacent residual odd-mass nucleus. The weak-coupling explanation for the phenomena

was confirmed in the case of the calculated results for sd-shell nuclei by computing single-nucleon overlaps between the excited 0^+ states and the excited $\vec{J}^\pi = \vec{J}^\pi$ (target g.s.) states. In this comment we present experimental results of the (p,t) reaction on the sd-nuclei previously treated theoretically. These results verify the predictions of the theory, in particular those aspects which can be interpreted as weak-coupling structure. They also suggest a similar relationship between the first excited 2^+ state and the multiplet of $\vec{J}^\pi = \vec{2}^+ \otimes \vec{J}^\pi$ (target g.s.) states in the adjacent odd-mass nucleus.

The reactions $^{35}Cl(p,t)^{33}Cl$ and $^{34}S(p,t)^{32}S$ were studied at E_p=40 MeV at the Michigan State University Cyclotron, using a split pole spectrograph with a single-wire proportional counter in its focal plane. The ^{35}Cl target was prepared from NaCl (enriched in ^{35}Cl), and the sandwich type ^{34}S target was evaporated from enriched ^{34}S. An energy resolution of about 30 keV FWHM, was achieved. In order to resolve ^{21}Na levels from those ^{33}Cl, auxiliary runs (with an energy resolution of about 15 keV) were made in certain excitation energy regions with a position-sensitive silicon detector.

In Fig. 1 we show the measured differential cross sections for the two reactions. The uncertainty in the absolute cross sections is estimated to be about ±15%. The curves in Fig. 1 show the cross sections predicted by DWBA calculations using wave functions from Ref. 2 and optical model parameters from Ref. 1. Considering the fact that (p,t) cross sections are extremely sensitive to interferences between pick-up of different configurations and that we have used a single normalization constant for all DWBA curves shown in Fig. 1, the agreement with data is quite good. Agreement between experimental and theoretical integrated cross sections is also generally within a factor of two as indicated in Table 1.

In Fig. 1 the fit to the L=0 transition to the 0_1^+(g.s.) state in ^{32}S is good but the fit to the much weaker 0_2^+ transition is poor. This indicates that the wave functions and/or the reaction theory used are by no means perfect. The data for the $3/2_1^+$ and $3/2_3^+$ states in ^{33}Cl show pronounced L=0 enhancements. The DWBA fits are once again not perfect but they clearly bear out the large L=0 enhancements observed for these two states. What is equally important, no L=0 enhancement is observed for $3/2_2^+$ state, in agreement with the theoretical predictions.

The rather pure L=2 shape of the observed angular distribution to the 2.35 MeV $3/2_2^+$ state (see Fig. 1) led us to examine whether the shell-model wave functions from the same calculation[2] suggest similar weak-coupling relationships between the 2_1^+ state of the ^{32}S core and the quadruplet of low-lying states (Fig. 2) with $J^\pi = 1/2^+, 3/2^+, 5/2^+$ and $7/2^+$ in ^{32}Cl i.e., if $|J^\pi, {}^{33}\mathrm{Cl}\rangle = |2_1^+, {}^{32}\mathrm{S}\rangle \otimes (d_{3/2})_\pi$. As discussed before in Ref. 1, this conjecture can be examined by calculating the $d_{3/2}$ single-proton spectroscopic factors between states J^π in ^{33}Cl and 2_1^+ in ^{32}S. The results are given in Table 1. The spectroscopic factors for $1/2_1^+$, $5/2_1^+$ and $3/2_2^+$ states are indeed very large--as large as that between the ground states of ^{32}S and ^{33}Cl. The corresponding value for the $7/2_1^+$ state, while smaller is still significant. Further, it is

of states does not have significant single-nucleon overlaps with other excited states. In particular, the $d_{3/2}$ overlaps of the $5/2^+$ and $7/2^+$ states with the 4^+ states of ^{32}S are small. Thus the shell-model calculations also support this proposed weak-coupling picture to a remarkable extent. It must be realized, of course, that this picture is far from unique or complete. For example, the first $1/2^+$ state in ^{33}S is equally appropriately to be thought of as an $1s_{1/2}$ particle "weakly coupled" to the ^{32}S ground state.

As stated earlier, (p,t) cross sections are extremely sensitive to interference between pick-ups of different configurations. Therefore one does not expect a (2J+1) weighting of observed cross sections. The more meaningful comparison is in terms of single particle overlaps, as we have already done. However, since our "weak coupling" multiplet is far from being degenerate it is still meaningful to ask how its energy centroid compares with the core 2^+ energy. This centroid is $\langle E\rangle = \Sigma\sigma_J E_J/\Sigma\sigma_J = 2.44$ MeV, as compared to 2.23 MeV for the core 2^+ state in ^{32}S. Perhaps fortuitously, this centroid shift of 210 keV is the same as the energy difference between the other two weak-coupling partners, $E(3/2_3^+) - E(0_2^+) = 200$ keV.

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1. B.H. Wildenthal, H. Nann, and K.K. Seth, Phys. Rev. Lett. 32, 794(1974).

2. B.H. Wildenthal, et al., Phys. Rev. C4, 1708(1971).

3. Kamal K. Seth, et al., Phys. Rev. Lett. 30, 132(1973).

Table 1. $d_{3/2}$ single particle spectroscopic factors between low-lying states in ^{32}S and ^{33}Cl. Energies and integrated cross sections in parentheses are from theory. The (p,t) cross sections were integrated between 4 and 52 and normalized to 100 for the transition to the ^{32}S (g.s.).

^{33}Cl / ^{32}S	E^*-MeV	0.00 (0.00)	3.98 (3.61)	0.81 (1.00)	1.99 (2.02)	2.35 (2.31)	2.84 (2.74)	2.98 (2.71)	^{32}S relative σ	
E^*-MeV	J^π	$3/2_1^+$	$3/2_3^+$	$1/2_1^+$	$5/2_1^+$	$3/2_2^+$	$5/2_2^+$	$7/2_2^+$	Expt.	(Theory)
0.00(0.00)	0_1^+	0.70	0.00			0.05			100*	(100)*
3.78(3.68)	0_2^+	0.60	0.36			0.70			1.8	(13.3)
2.23(2.20)	2_1^+	0.00	0.02	0.68	0.82	0.63	0.07	0.28	44.3	(99.1)
4.28(4.55)	2_2^+	0.02	0.08	0.15	0.00	0.01	0.26	0.00		
^{33}Cl relative σ	Expt.	89.0	23.3	6.1	4.9	3.6		23.3		
	(theory)	(76.2)	(42.8)	(14.3)	(3.3)	(5.7)		(42.8)		

* Normalized

Fig. 1.--Differential cross sections at E_p=40 MeV for the reactions $^{34}S(p,t)^{32}S$ (open circles-data, dashed lines--DWBA predictions) and $^{35}Cl(p,t)^{33}Cl$ (points-data, solid lines--DWBA predictions).

Fig. 2.--States of ^{32}S and ^{33}Cl. States connected by dashed lines are related via weak coupling according to the present experiment. (Energies in parantheses are from the shell model calculations of Ref. 1.)

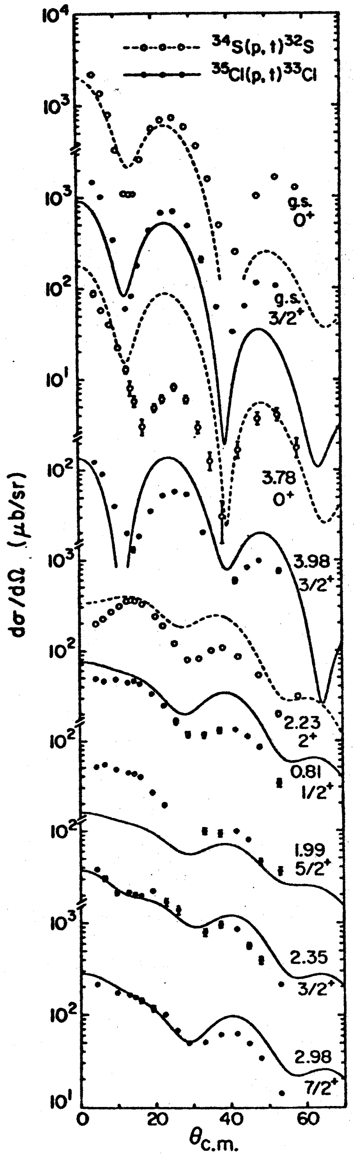
$^{34}S(p,t)^{32}S$
$^{35}Cl(p,t)^{33}Cl$
dσ/dΩ (μb/sr)
$\theta_{c.m.}$
g.s. 0+
g.s. 3/2+
3.78 0+
3.98 3/2+
2.23 2+
0.81 1/2+
1.99 5/2+
2.35 3/2+
2.98 7/2+

Fig. 1

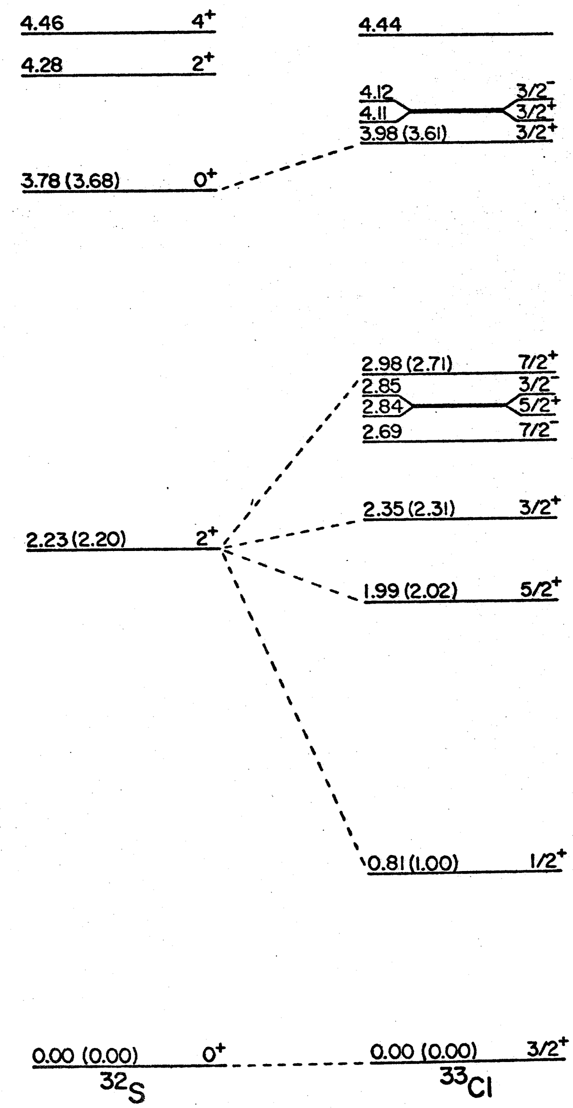
4.46 4+
4.28 2+
3.78 (3.68) 0+
2.23 (2.20) 2+
0.00 (0.00) 0+
^{32}S
4.44
4.12 3/2−
4.11 3/2+
3.98 (3.61) 3/2+
2.98 (2.71) 7/2+
2.85 3/2−
2.84 5/2+
2.69 7/2−
2.35 (2.31) 3/2+
1.99 (2.02) 5/2+
0.81 (1.00) 1/2+
0.00 (0.00) 3/2+
^{33}Cl

Fig. 2