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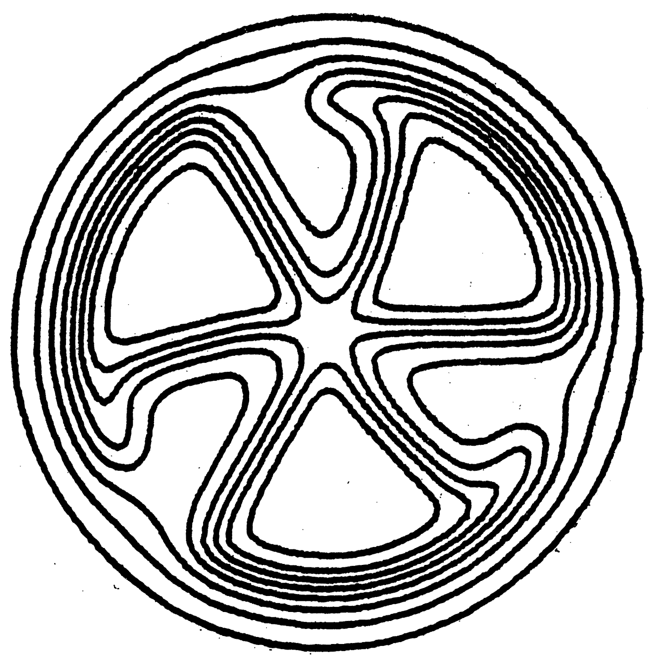

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The Strongest L=6 Transitions Observed in the (α,d) Reaction on Odd-Mass A=33-41 Target Nuclei*

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ABSTRACT

Angular distributions of the (α,d) reaction on ^{33}S, ^{35,37}Cl and ^{39,41}K have been measured at E_α=40 MeV. Excited states of the residual nuclei with the $[(\text{target})_{J=3/2} \otimes (1f_{7/2})^2_{J=7}]_{17/2^+}$ configuration are suggested to correspond to the strongest observed L=6 transition in each nucleus.

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Previous (α,d) experiments on even-even nuclei [1-4] have shown that the states most strongly populated in this reaction are those in which the transferred proton and neutron enter the same shell-model orbit and couple to the maximum angular momentum with zero isobaric spin. Levels with configurations $[(\text{core})_{J=0} \otimes (1d_{5/2})^2_{J=5}]_{5^+}$, $[(\text{core})_{J=0} \otimes (1f_{7/2})^2_{J=7}]_{7^+}$ and $[(\text{core})_{J=0} \otimes (1g_{9/2})^2_{J=9}]_{9^+}$ were identified based on three criteria: (a) largest cross section, (b) similar angular distributions, and (c) monotonic increase of the formation Q-value with mass number.

The present letter reports the extension of the search for the highest spin states of the $[(\text{core}) \otimes (1f_{7/2})^2_7]$ configuration to the A=35-43 odd-mass region. These levels are expected to be the most prominent in the spectra, and the corresponding transitions to be characterized by an L=6 angular distribution. The (α,d) reaction was carried out on enriched ^{33}S, ^{35,37}Cl and ^{39,41}K targets with a 40 MeV alpha-particle beam from the Michigan State University Cyclotron. The target thicknesses were determined by measuring the elastic scattering and normalizing to calculations with standard optical model parameters. Absolute cross sections thus obtained are estimated to be accurate to within $\pm$30%. The reaction products were detected in the focal plane of a split-pole magnetic spectrograph with a position-sensitive proportional counter. Figure 1 shows, as an example, a spectrum from the ^{33}S(α,d)^{35}Cl reaction. The resolution was about 60-80 keV. One level dominates the spectrum. The states corresponding to the largest peak in the (α,d) spectra on the different targets are at 9.02 MeV in ^{35}Cl, at 7.07 MeV in ^{37}Ar, at 5.54 MeV in ^{39}Ar, at 5.22 MeV in ^{41}Ca and at 4.61 MeV in ^{43}Ca.

The angular distributions for the transitions to these states are displayed in Fig. 2. In order to identify the expected L=6 angular distributions, an experimental L=6 shape was obtained from the ^{40}Ca(α,d) reaction [5] leading to the known 7^+ state in ^{42}Sc at 0.62 MeV [6]. This shape is superimposed in dashed line on the distributions of the present data. It is clear that all of the displayed angular distributions exhibit L=6 patterns. It can thus be concluded that the proton-neutron pair is transferred in these cases in the $(1f_{7/2})^2_{J=7}$, T=0 configuration, since only this configuration produces a pure L=6 angular distribution. Basically, the spin and parity values of states belonging to the simple configuration $[(\text{core})\otimes(1f_{7/2})^2_{J=7}]$ can vary from $11/2^+$ to $17/2^+$, since in all cases studied here the target spin is $J^\pi=3/2^+$. However, the fact that all transitions to the states discussed have significantly the largest cross sections strongly suggests a $17/2^+$ assignment. Possible $17/2^+$ assignments for the levels at 7.07 MeV in ^{37}Ar [7] and 5.22 MeV in ^{41}Ca [8] have already been discussed in the literature. The largest cross section for the $17/2^+$ coupling arises from the following causes:
(a) In a stripping reaction, the cross section is proportional to the spin-statistical factor $(2J_f+1)$, where J_f is the spin of the final state. (b) These highest spin states have purer configurations, since possibilities for mixing with other configurations are minimal.

The assumption of the very pure nature of these states is supported by the fact that the magnitudes of the observed

differential cross sections are approximately equal. The spectroscopic amplitudes for $(1f_{7/2})^2_{7,0}$ transfer on ^{33}S, ^{35,37}Cl and ^{39}K are 1.0 assuming that the target wave functions are of pure $(sd)^n$ configurations and the final state wave functions can be described as $[(\text{target})\otimes(1f_{7/2})^2_{J=7}]$. In ^{41}K, there are already two particles in the $1f_{7/2}$ shell yielding a reduction of the spectroscopic amplitude to 0.866. These spectroscopic amplitudes, together with the Q-value and mass dependence, account well for the observed differential cross sections.

In earlier (α,d) work [2-4] it was noted that the (absolute) Q-value of formation of the 7^+ states in the A=26-44 mass region whose particle configuration is $[(\text{core})_{J=0}\otimes(1f_{7/2})^2_{J=7}]$ decreases linearly with the mass of the residual nucleus. Figure 3 shows a plot of -Q(d,α) as a function of the residual mass for these 7^+ states (points). Included as crosses are the Q-values for the most strongly populated levels observed in the present experiment. Actually, since the total strength of the $[(\text{core})_{3/2}\otimes(1f_{7/2})^2_7]_{J_f}$ configuration is distributed over many states, the centroid of the L=6 strength is perhaps the more appropriate quantity. However the L=6 component of lower spin states cannot be extracted with great accuracy. The fact that the deviations of the $(17/2)^+$ states from the straight line fit through the points for the 7^+ states is small gives additional support for our interpretation of these states.

The present (α,d) results on the $J^\pi=3/2^+$ nuclei in the A=33-41 mass region can be summarized as follows:

(a) The most prominent peak in each spectrum belongs to levels at 9.02 MeV in ^{35}Cl, at 7.07 MeV in ^{37}Ar, at 5.54 MeV in ^{39}Ar, at 5.22 MeV in ^{41}Ca and at 4.61 MeV in ^{43}Ca, respectively.

(b) The transitions to these levels show an unambiguous L=6 angular distribution.

(c) The discussion above argues that these states have a predominant $[(\mathrm{core})_{J=3/2} \otimes (1f_{7/2})^2_{J=7}]$ configuration, and spin assignments of $17/2^+$ are suggested.

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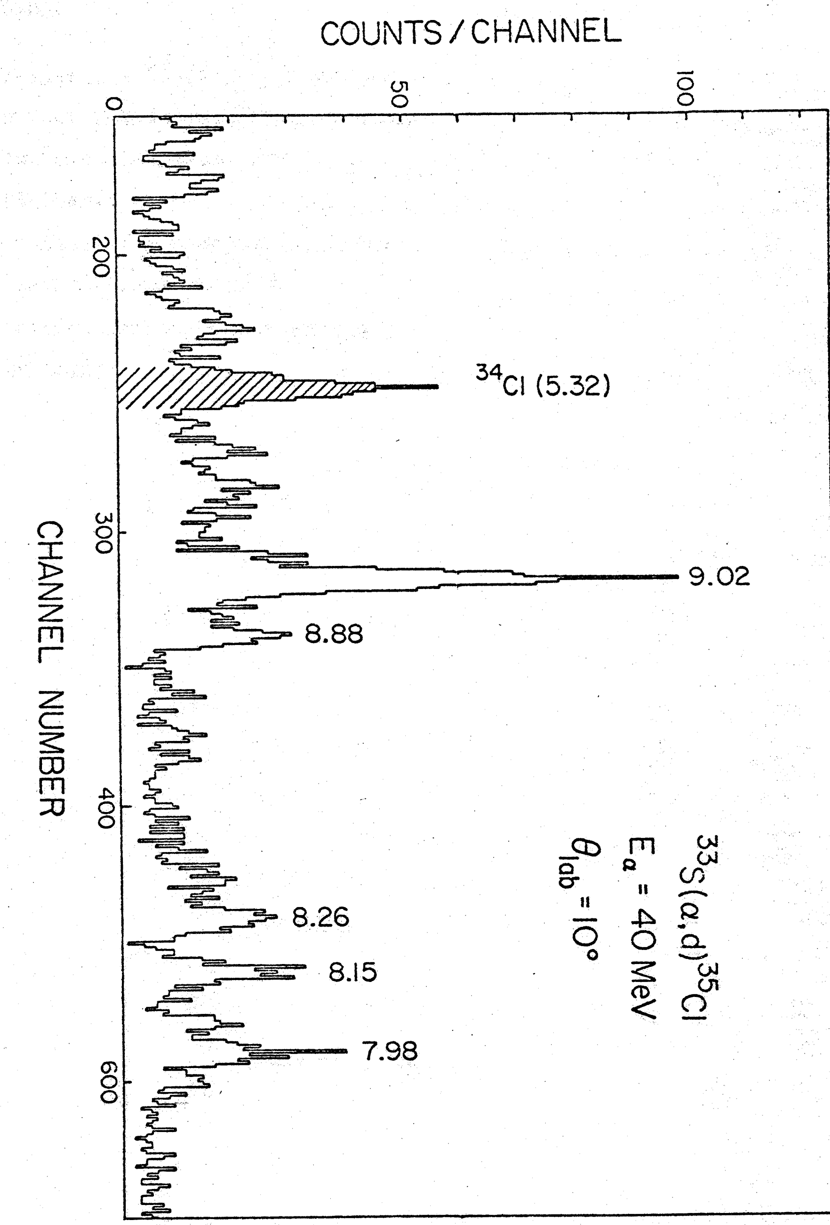
FIGURE CAPTIONS

Figure 1.--Alpha-particle spectrum from the $^{33}S(\alpha,d)^{35}Cl$ reaction.

Figure 2.--The strongest L=6 angular distributions for the various odd-mass A=33-41 target nuclei. The dashed lines represent experimental L=6 shapes.

Figure 3.--Relationship between the mass of the residual nucleus and the Q-value of formation of levels with $[(core) \otimes (1f_{7/2})^2_7]_{J_{max}}$ configurations most strongly populated in the (α,d) reaction.



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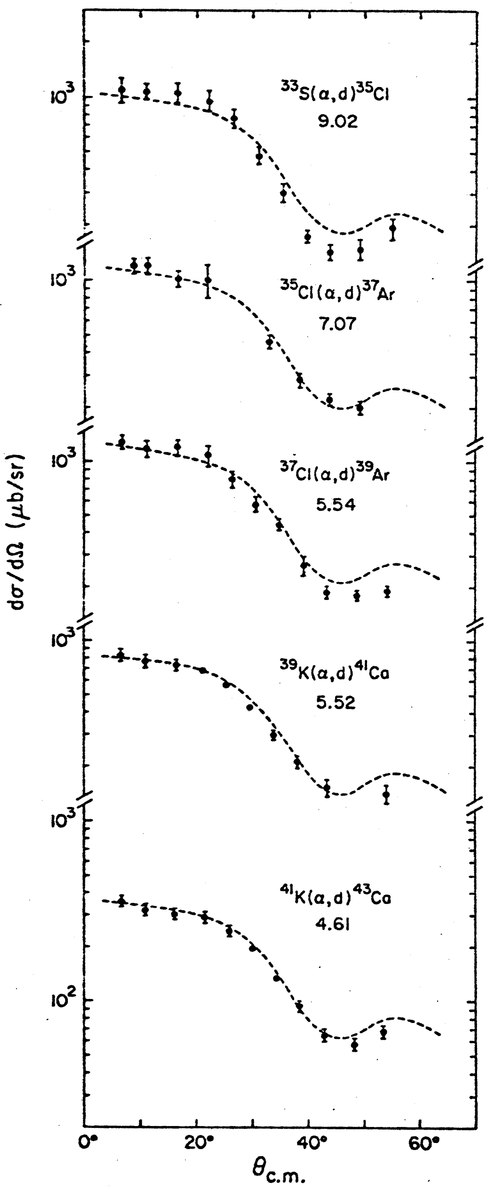
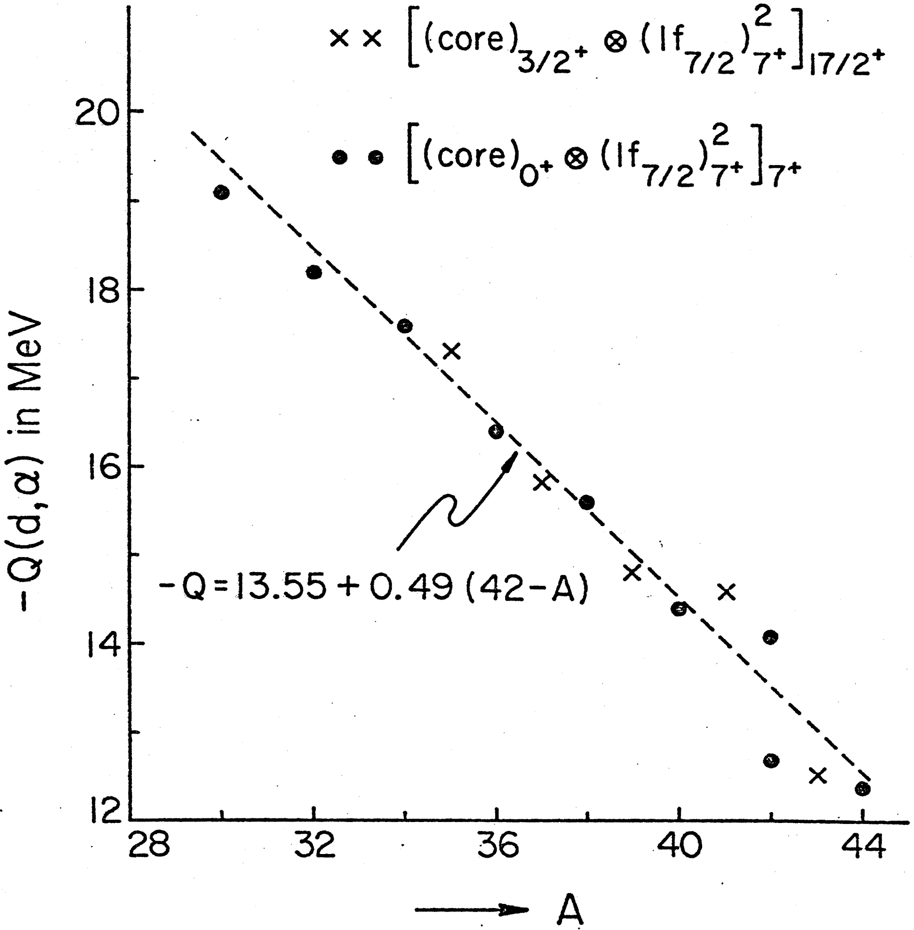


$^{33}S(\alpha,d)^{35}Cl$
9.02
$^{35}Cl(\alpha,d)^{37}Ar$
7.07
$^{37}Cl(\alpha,d)^{39}Ar$
5.54
$^{39}K(\alpha,d)^{41}Ca$
5.52
$^{41}K(\alpha,d)^{43}Ca$
4.61
$d\sigma/d\Omega$ ($\mu b/sr$)
10^3
10^2
0°
20°
40°
60°
$\theta_{c.m.}$

10



× × $\left[(\text{core})_{3/2^+} \otimes (1f_{7/2})^2_{7^+}\right]_{17/2^+}$
● ● $\left[(\text{core})_{0^+} \otimes (1f_{7/2})^2_{7^+}\right]_{7^+}$
$-Q = 13.55 + 0.49\,(42-A)$
$-Q(d,\alpha)$ in MeV
20
18
16
14
12
28
32
36
40
44
→ A