POSITIVE PARITY LEVELS IN \(^{36}\)S OBSERVED IN THE \(^{37}\)Cl(d, \(^3\)He)\(^{36}\)S REACTION*

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Transitions to the \(^{36}\)S ground state and excited states at 3.30, 4.57, 6.51, 7.11 and 7.69 MeV were observed in the reaction \(^{37}\)Cl(d, \(^3\)He)\(^{36}\)S at a bombarding energy of 28.9 MeV. Using distorted wave analysis, \(l\)-values and strength coefficients \(C^2S\) were extracted from the measured angular distributions. The results are in reasonable agreement with calculations by Glaudemans et al.

The nucleus \(^{36}\)S\(^{20}\) is interesting from the shell model point of view. The neutron number 20 corresponds to a major shell closure, and one expects among the low-lying levels positive-parity states with configurations resulting from the coupling of four proton holes in the 2s-1d shell. The experimental information previously available for this nucleus has come from an unpublished investigation of the \(^{34}\)S(t, p)\(^{36}\)S reaction [1]. We have studied the \(^{37}\)Cl(d, \(^3\)He)\(^{36}\)S reaction in order to identify levels in \(^{36}\)S formed by the removal of an additional proton from the ground state of \(^{37}\)Cl, which presumably has a predominant three-hole configuration.

A carbon-backed target consisting of NaCl enriched to more than 99\% in \(^{37}\)Cl was bombarded with 28.9 MeV deuterons from The University of Michigan 83-inch cyclotron. In most cases, the \(^3\)He ions were detected either in nuclear emulsions following magnetic analysis, or in a surface barrier counter telescope used in conjunc-

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Fig. 1. Angular distributions measured for transitions in the reaction \(^{37}\)Cl(d, \(^3\)He)\(^{36}\)S at \(E_d = 28.9\) MeV leading to states in \(^{36}\)S. The solid lines are predictions from the distorted wave calculation discussed in the text.
tion with a pulse multiplier for particle identification. Additional forward-angle data were taken with a position-sensitive detector placed in the focal plane of the magnetic spectrograph. We observe transitions to the $^{36}$S ground state and excited states at $3.30 \pm 0.015$, $4.57 \pm 0.015$, $6.51 \pm 0.015$, $7.11 \pm 0.020$ and $7.69 \pm 0.025$ MeV*. Our excitation energies are in good agreement with those obtained for the first two levels by Puttaswamy and Yntema in a recent $^{37}$Cl($d$, $^3$He)$^{36}$S experiment [2].

The measured angular distributions are shown in fig. 1. The solid lines are local, zero-range distorted wave predictions computed with the Oak Ridge code JULIE. The deuteron optical parameters were taken from the average set of ref. 4 and the $^3$He parameters are those of ref. 5 for $^{40}$Ca.

* These energies have been corrected from preliminary values reported in ref. 3.

Our results are summarized in table 1. For completeness the levels quoted in ref. 1 are included. Only the ground state and the level at $3.30$ MeV are observed in both the ($t$,p) and ($d$, $^3$He) experiments. The extracted strength coefficients $C^2S$ are listed together with the sums for pickup from the three $2s$-$1d$ orbitals. The single-particle cross sections were calculated with the usual bound-state radius and diffuseness parameters taken to be 1.20 fm and 0.65 fm, respectively. This choice of bound-state parameters and our use of the local and zero-range approximations lead us to expect that the strengths we obtain are upper limits to the true ones [7].

Levels with configurations $(2s_\uparrow)^n(1d_\uparrow)^m$ have been calculated for nuclei from $^{26}$Si to $^{40}$Ca by Glaudemans et al. [6]. For comparison the levels predicted for $^{36}$S are given together with the resulting strength coefficients $C^2S$ for pickup of a $2s_\uparrow$ or $1d_\uparrow$ proton from $^{37}$Cl. The experimental

| Table 1 | Summary of the known level structure of $^{36}$S, compared with the predictions of Glaudemans et al. The probable dominant configurations and strength coefficients $C^2S$ are deduced from the present experiment. |
|---------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| $^{34}$S ($t$,p)$^{36}$S | $^{37}$Cl($d$, $^3$He)$^{36}$S present work | | |
| $E_x$, $J^\pi$ | $E_x$, $J^\pi$ | $t_p$ | probable dominant configuration | $C^2S$ | $E_x$, $J^\pi$ | $C^2S(d_\uparrow)$ | $C^2S(s_\uparrow)$ | $C^2S(d_\uparrow)$ |
| 0.00, 0$^+$ | 0.00, 0$^+$ | 2 | $(d_\uparrow)^{-4}$ | 1.41 | 0.00, 0$^+$ | 0.91 |
| 2.00, 0$^+$ | 3.30, (1,2)$^+$ | 0 | $(d_\uparrow)^{-3}(s_\uparrow)^{1}$ | 1.14 | 2.83, 2$^+$ | 1.04 |
| 2.89, 2$^+$ | 3.30, (1,2)$^+$ | 0 | $(d_\uparrow)^{-3}(s_\uparrow)^{1}$ | 1.14 | 4.28, 0$^+$ | 0.05 |
| 3.38, 0$^+$ | 4.57, (1,2)$^+$ | 0 | $(d_\uparrow)^{-3}(s_\uparrow)^{1}$ | 1.35 | 5.75, 1$^+$ | 0.70 | 0.03 |
| 4.30 | | | | | 6.23, 2$^+$ | 0.12 | 0.13 |
| 6.51, (1,2,3,4)$^+$ | 2 | $(d_\uparrow)^{-3}(d_\uparrow)^{-1}$ | 0.28 | | | | |
| 7.11, (1,2,3,4)$^+$ | 2 | $(d_\uparrow)^{-3}(d_\uparrow)^{-1}$ | 0.61 | | | | |
| 7.69 | | | | | | | |
| $\sum C^2S(d_\uparrow)$ | = 1.41 | $\sum C^2S(s_\uparrow)$ | = 2.49 | $\sum C^2S(d_\uparrow)$ | = 0.89 |
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References