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Properties of the Intermediate Structure in ^{71}As

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The spins and parities of the five reported $l=0$, $J^\pi=\frac{1}{2}^+$ substructures nested within the broad $l=0$ analog resonance in ^{71}As at $E_p=5.05$ MeV have been measured. Three of the five substructures were determined as having J^π different from $\frac{1}{2}^+$, casting doubt on the interpretation of this resonance as an example of intermediate structure.

In a Letter, Temmer *et al.*[1] reported an unusual and, to date, unique type of intermediate structure which had widths *below* the rank of analog states but *larger* than the ultimate fine structure. Experimentally, they observed five substructures superimposed on a broad analog state near 5.05 MeV bombarding energy in ^{70}Ge+p elastic scattering, with four of these substructures identified as having the $l=0$, $J^\pi=\frac{1}{2}^+$ character of the broad analog state. This, coupled with the fact that the substructures were correlated in several inelastic proton channels, led these authors to propose these substructures as possible candidates for "hallway" states coupled to the broad analog or doorway states. Today, these remain as one of only three[2,3] reported candidates for intermediate structure in charged-particle scattering and hence are of unusual interest. Baudinet-Robinet and Mahaux[4] appled statistical criteria to unpublished high-resolution cross-section data and determined that at least three of these substructures were statistically significant. Hence, these states can legitimately be considered to be candidates for an intermediate-structure interpretation. However, the substructures must have the same J^π assignment as the doorway (analog) state for such an interpretation and to date these assignments are based only on the analysis of cross-section data. Because of the importance of the J^π assignments here, we undertook in the present work to measure the spins of the structures in a more conclusive way than has been done previously. Our measurements consisted of $(p,p'\gamma)$ angular correlation measurements over the structures most prominent in the inelastic proton channel leading to the 2^+ first excited state of ^{70}Ge and, additionally, analyzing-power measurements for the elastic proton channel over the entire energy region of interest. Our results show that three of the substructures have spins other than $\frac{1}{2}^+$, excluding the possibility that they are members of the intermediate-structure state.

The $(p,p'\gamma)$ angular correlations were measured in the Goldfarb-Seyler geometry[5] at several energies over the two most prominent structures observed in the p_1 channel at 5.04 and 5.14 MeV. As in our previous utilizations of this technique[6] we did not observe any appreciable strength for the decay of a $\frac{1}{2}^+$ state through a 2^+ decay channel, probably because of barrier-penetrability suppression. The ratio of the A_4 to A_0 polynomial coefficients, obtained in fits to the angular correlation data, rose from zero off resonance to a value of ~ 0.4 on the resonance peaks. These results indicated $J \geq \frac{5}{2}$ for both of these resonances. Details of these measurements will be published elsewhere.

Glashausser *et al.*[2] reported on the evidence for intermediate structure in the inelastic scattering of polarized protons from ^{26}Mg and ^{27}Al. They point out that the lack of selectivity in the (p,p') reaction mechanism makes it difficult to observe definitely nonstatistical peaks in cross-section excitation functions. However, they noted that the analyzing power (A_y) is a sensitive indicator of coherent structure. For this experiment on the structure in ^{71}As, analyzing-power measurements should be particularly conclusive in determining the spins of the substructures since the analyzing power over a $J^\pi=\frac{1}{2}^+$ resonance is identically zero. Consequently, values of A_y different from zero within the structure should provide evidence for spins other than $\frac{1}{2}^+$.

The elastic-scattering experiments were carried out using protons from the Ohio State University polarized-ion source.[7] The analyzing

powers (A_y) were measured as excitation curves at four scattering angles simultaneously for the protons scattered elastically from a target enriched to 98.8% in ^{70}Ge. The target thickness was ~3 keV for protons selected to be considerably less than the widths of both the broad analog state (~70 keV) and the substructures (~20 keV). The experimental procedures were generally similar to those described by Detomo *et al.*[8] Briefly, an ~60-nA proton beam, with transverse polarization $p_y \sim 0.7$, was incident on the Ge target. The scattered protons were detected by pairs of symmetrically located surface-barrier detectors at 105°, 115°, 125°, and 135°. The spectra utilized the eightfold channel PACE-ADC input to an IBM 1800 on-line computer. After recording spectra for the eight detectors for a fixed charge, the scattering chamber was rotated precisely about the beam-momentum axis by 180° according to the proper spin-flip criteria of Ohlsen and Keaton[9] so that the four pairs of detectors were interchanged.

The cross-section and analyzing-power results are shown in Figs. 1 and 2. A_y is near zero over most of the energy range indicating that some substructures most likely have the same $\frac{1}{2}^+$ spin assignments as the broad analog state. However, in the vicinity of the structures near 4.97, 5.04, and 5.14 MeV, A_y differs appreciably from a null value at all angles of measurements. The 5.04- and 5.14-MeV resonances are at energies corresponding to the structures prominent in the inelastic proton channel over which we had measured the angular correlations. An analysis of the A_y and $\sigma(\theta)$ data was carried out using a program[10] which permits more than two levels of the same J^π value to be included in the calculation using an approximate product S-matrix calculation.

Calculations were carried out for J^π assignments up to $\frac{9}{2}^+$ and compared to the data by a visual-fit method. The Γ_p/Γ parameters were varied to minimize χ^2. Our best simultaneous fits to the cross-section and analyzing-power excitation curves are shown in the figures as solid lines and the corresponding level parameters listed in Table I. All other assignments produced a substantially poorer description of the data set. The substructures at 5.04 and 5.14 MeV were found to have $J^\pi = \frac{5}{2}^+$ assignments consistent with our angular-correlation work whereas the 4.974-MeV resonance, which was too weak for angular correlation measurements, had a J^π of $\frac{3}{2}^-$. The statistical analysis of Baudinet-Robinet and Mahaux also indicated that the spin of the 5.14-MeV resonance was other than $\frac{1}{2}$.

A few of the substructures we observed can be compared with parent states in ^{71}Ge. For in-

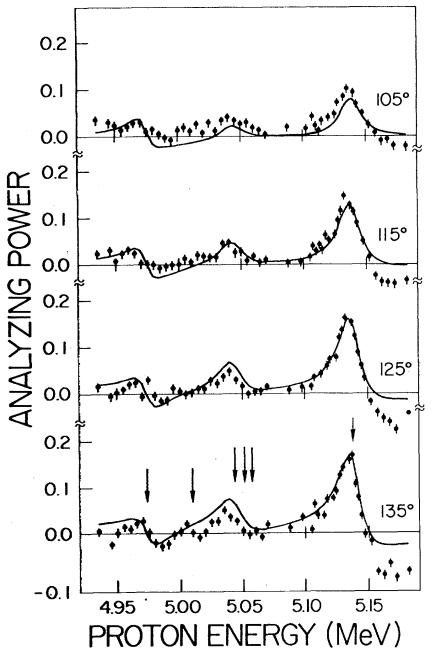

FIG. 1. Analyzing-power results at four laboratory angles measured over the region of the broad $l=0$ resonance in ^{71}As centered at $E_p = 5.052$ MeV. The solid curves are fits using the parameters of Table I. The arrows point to the energies of the six resonances involved.

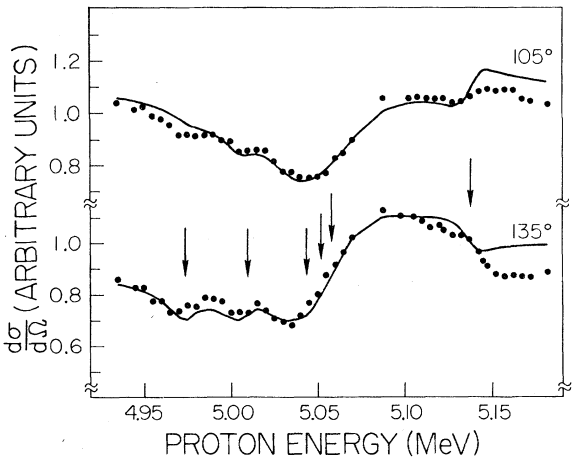

FIG. 2. The ^{70}Ge$(p,p_0)^{70}$Ge elastic-scattering-yield curves. The solid curves are fits using the parameters of Table I. The arrows point to the energies of the six resonances involved.

TABLE I. Resonance parameters for the large $l=0$ state at 5.05 MeV and the five substructures located within this state.

E_p [a,b] (MeV)	E_p [c] (MeV)	Γ [a] (MeV)	Γ [c] (MeV)	$(\Gamma)_p/\Gamma$ [a]	$(\Gamma)_p/\Gamma$ [c]	J^π [a]	J^π [c]
4.974	4.982	0.018	0.018	0.055	0.09	$3/2^-$	$1/2^+$
5.010	5.015	0.017	0.017	0.082	0.08	$1/2^+$	$1/2^+$
5.044	5.044	0.025	0.028	0.032	0.24	$5/2^+$	$1/2^+$
5.052	5.050	0.063	0.063	0.33	0.30	$1/2^+$	$1/2^+$
5.068	5.068	0.028	0.021	0.039	0.20	$1/2^+$	$1/2^+$
5.138	5.132	0.021	... [d]	0.10	... [d]	$5/2^+$	... [d]

[a] Present work.
[b] Laboratory bombarding energy, ± 10 keV.
[c] Ref. 1.
[d] Observed, but not assigned.

stance, the $\frac{5}{2}^+$ resonance at 5.138 MeV appears to be the analog of the $l_n=2$ parent state observed in the reaction ^{70}Ge$(d,p)^{71}$Ge at 2.27 MeV excitation energy[11]; the $\frac{3}{2}^-$ resonance at 4.974 MeV is a good candidate for the analog of the state at 2.12 MeV excitation in ^{71}Ge which had a tentative $l_n=3$ assignment from the (d,p) experiment. The parent state of the $\frac{5}{2}^+$ resonance at 5.044 MeV is probably obscured in the (d,p) experiment by the intense $l_n=0$ state at 2.22 MeV excitation. The important fact is, however, that the spins of these three resonances are other than $\frac{1}{2}^+$ and this excludes their interpretation as being members of the intermediate-structure system.

Two other substructures here show null magnitudes of A_y, a situation that can arise if there is no interference in the entrance channel between at least two states of differing J^π, or if the states have $J^\pi=\frac{1}{2}^+$. Because three of the five substructures, all of which have comparable widths, did show interference phenomena, the most probable interpretation is that these two remaining substructures at 5.010 and 5.068 MeV are $J^\pi=\frac{1}{2}^+$ states. Thus, although the impact of the discovery by Temmer *et al.* of this unique form of intermediate structure is tempered by the presence of the two $\frac{5}{2}^+$ and one $\frac{3}{2}^-$ resonances, the two remaining states of $\frac{1}{2}^+$ character do appear to be genuine candidates for the intermediate-structure interpretation. However, if the $\frac{3}{2}^-$ and $\frac{5}{2}^+$ resonances are indeed analog of the parent states in ^{71}Ge, then the argument that this is an example of intermediate structure based upon the widths of the substructures is somewhat clouded by the fact that all five substructures have comparable widths.

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