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INELASTIC SCATTERING OF PROTONS FROM ^{115}In

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The inelastic scattering of 19.98 MeV protons from ^{115}In has been studied using the proton beam from the Berkeley 88-inch cyclotron. The experiment was carried out using a 0.25 mg/cm^2, isotopically enriched target. The overall energy resolution of the experiment was approximately 30 keV. This resolution made it possible to obtain some information concerning individual members of the collective multiplets which arise from coupling of the odd proton-hole of ^{115}In to the excited states of the even-even tin core. For purposes of comparison, the scattering of 20-MeV protons from ^{116}Sn (the proposed core) was also studied. The results of this experiment are shown in Figs. 1 and 2. Figure 1 is a typical energy spectrum up to an excitation energy of approximately 2.9 MeV. The excitation energies and spins shown here are taken from Ref. 1. The strongest states observed are the first 2^+ and 3^- at excitation energies of 1.293 and 2.269 MeV, respectively. The angular distribution which was obtained for each of these states is shown in Fig. 2.

The weak-coupling model (Ref. 2) predicts that each of these collective states of tin will be split into a multiplet of states in indium, the number of members of the multiplet being $2j+1$, where j is either the indium ground state spin or the core state spin, whichever is smaller. For the present case (the indium ground state spin is 9/2) this means that the 2^+ core state should split into 5 states, the 3^- into 7. In addition, one expects the energy center-of-gravity of the multiplet to be equal to the excitation energy of the core state. Also each member of the multiplet should have an angular distribution which is similar in shape to that of the core state, and the strength of which is proportional to $2J+1$,

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where J is the spin of the indium state. Finally, the total strength of all members of the multiplet should equal the cross section for excitation of the core state. A part of the energy spectrum which one would then expect for the reaction ^{115}In(p, p') is shown in Fig. 3. It is clear that the strongest states would be expected to arise from coupling of the $g_{9/2}$ proton hole to the first 2^+ and 3^- states of tin, while a large number of much weaker states can result from coupling other excitations of the core to the proton hole. Only one of these weaker multiplets that based on the 5^- is represented in Fig. 3.

Previous studies of ^{115}In (Ref. 3) have indicated that all of the strength of the first 2^+ and 3^- states is accounted for in inelastic alpha scattering. The work of Ref. 3, however, had insufficient resolution to determine whether the number of individual states and their strengths were as predicted by the weak-coupling model. The better energy resolution of the present experiment makes it possible to obtain some of this information. This is particularly useful for the 3^- group, of which very little is known.

An energy spectrum for the ^{115}In (p, p') reaction is shown in Fig. 4. Excitation energies have been measured for 20 states of ^{115}In. Angular distributions have been obtained for 14 of these in addition to the ground state. These cross sections are shown in Figs. 5, 6, and 7.

The states shown in Fig. 5 all have angular distributions which are similar in shape to the 2^+ state of tin. To demonstrate this the tin cross section (with arbitrary normalization) is shown with each of the indium angular distributions. The number of states observed (5) is exactly that predicted by weak coupling. However, at least 4 states have been reported (Refs. 4 and 5) within an energy interval of 60 keV at 1.42, 1.45, 1.47, and 1.48 MeV. In fact, the proton group observed at 1.46 MeV gives indications of broadening in some spectra, so that additional $L = 2$ states probably exist.

Angular distributions for those states which are similar to the 3^- state of tin are shown in Fig. 6. Also shown with each one, for comparison is the tin 3^- cross section. Only 5 states are shown here, as compared with the 7 predicted by the weak-coupling model. It is probable, however, that other such states exist and are unresolved in the present experiment. This would not be surprising inasmuch as the states with spins 1/2 and 3/2 would be approximately the same strength as the multitude of states based on the other collective states of tin (5^- and two 4^+'s).

Figure 7 shows angular distributions for the remaining states which do not resemble either the 2^+ or 3^- states of tin. Some of these appear to resemble the 4^+ and 5^- states of tin, however, for the most part they are rather weak and probably suffer also from the presence of other unresolved states. In particular the group at 2.308 MeV appears to represent at least a doublet.

Figures 8 and 9 compare the strength of the excitations in indium with those of the core states. Figure 8 shows the total strength of all $L=2$ states compared with the 2^+ of tin and all $L=3$ states compared with the 3^- of tin. The figure clearly demonstrates that reasonable agreement is obtained. The value R shown in Fig. 8 is the ratio of the integrated cross section for indium to that for tin. Inasmuch as the value of R is no more accurate than 15 percent (due to target thickness uncertainties) the agreement is rather good. One might attribute the missing 3^- strength to the two members of the $L=3$ multiplet which were not detected.

Figure 9 compares the strength of individual states to that which is expected on the basis of weak coupling. This appears to be the most serious disagreement between experiment and theory. In the $L=2$ multiplet, three of the members are stronger than any individual state is predicted to be, while one state (1.603 MeV) is considerably weaker. In the $L=3$ group a similar situation exists, with the 2.464 MeV state being nearly twice as strong as any weak-coupling state ought to be. For the remaining members of the multiplet, some are approximately the proper strength, however, an experiment with better energy resolution is necessary before any definite statement concerning these strengths can be made.

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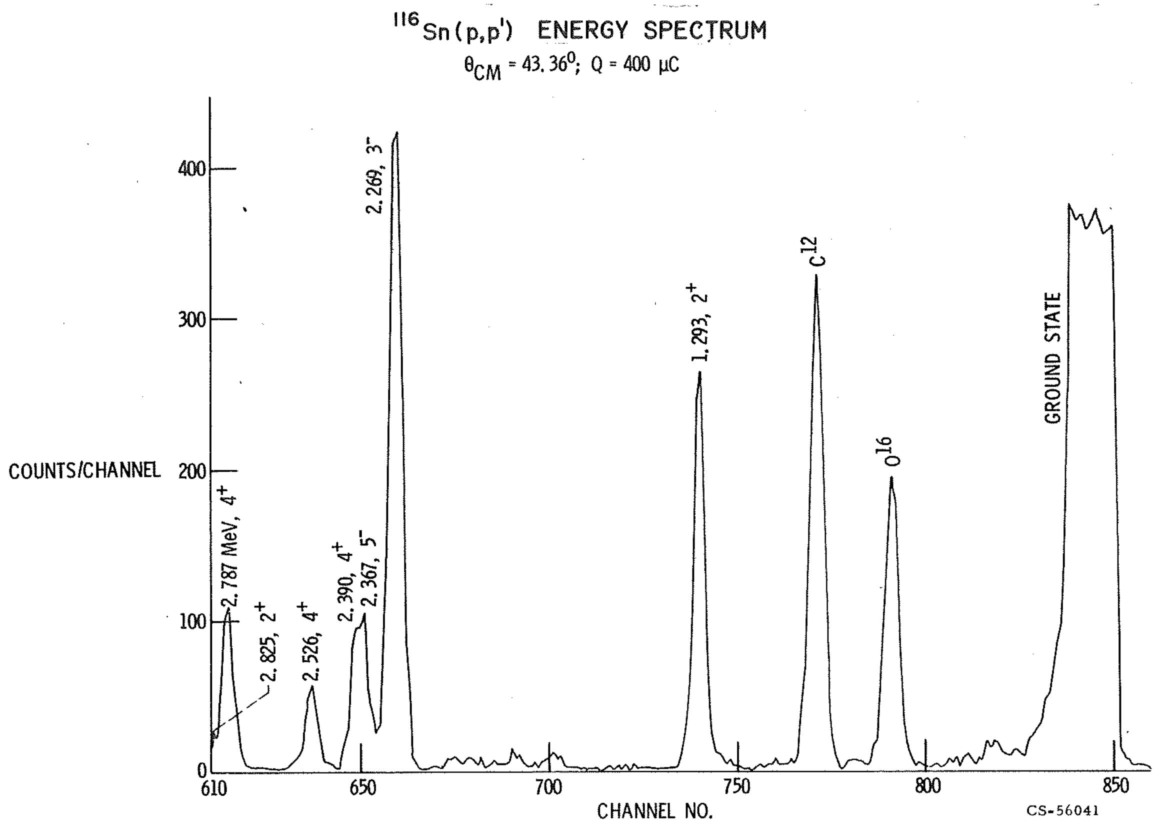
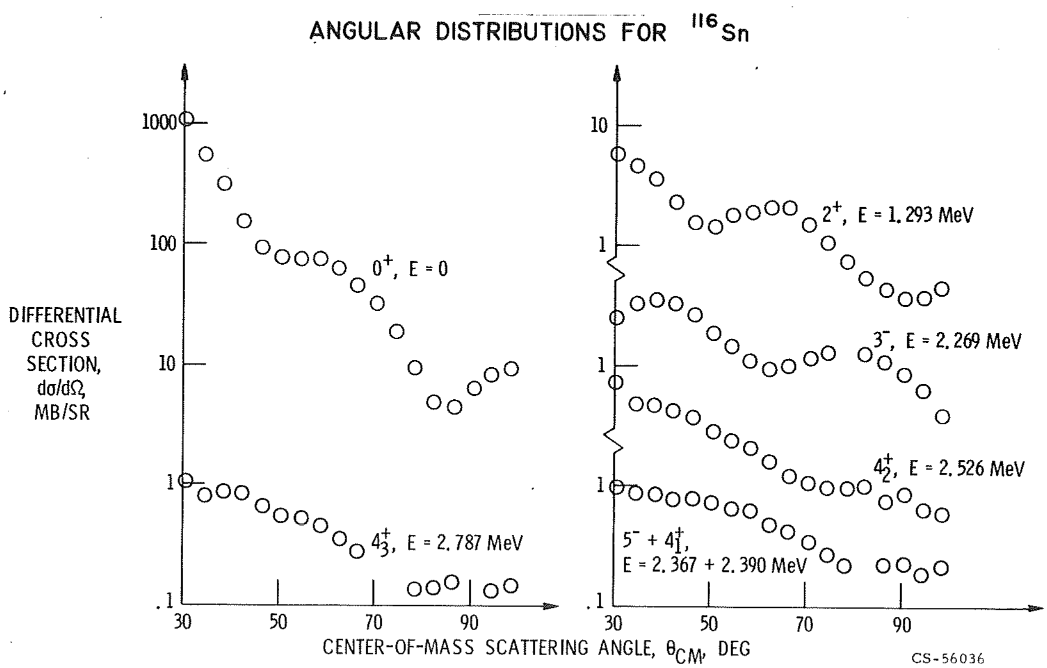


$^{116}Sn(p,p')$ ENERGY SPECTRUM
θ_{CM} = 43.36°; Q = 400 μC
COUNTS/CHANNEL
CHANNEL NO.
2.787 MeV, 4+
2.825, 2+
2.526, 4+
2.390, 4+
2.367, 5−
2.269, 3−
1.293, 2+
C12
O16
GROUND STATE
CS-56041

Fig. 1



ANGULAR DISTRIBUTIONS FOR ^{116}Sn
DIFFERENTIAL CROSS SECTION, dσ/dΩ, MB/SR
0+, E = 0
4+3, E = 2.787 MeV
2+, E = 1.293 MeV
3−, E = 2.269 MeV
4+2, E = 2.526 MeV
5− + 4+1,
E = 2.367 + 2.390 MeV
CENTER-OF-MASS SCATTERING ANGLE, θ_{CM}, DEG
CS-56036

Fig. 2

ANTICIPATED ENERGY SPECTRUM OF ^{115}In

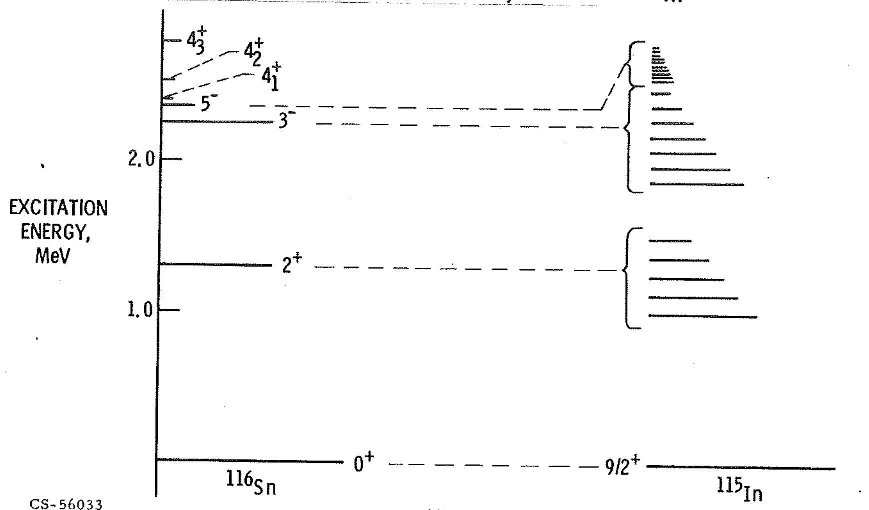


Fig. 3

^{115}INDIUM (p,p') ENERGY SPECTRUM

θ_{CM} = 58.42 MeV; Q = 1200 μC

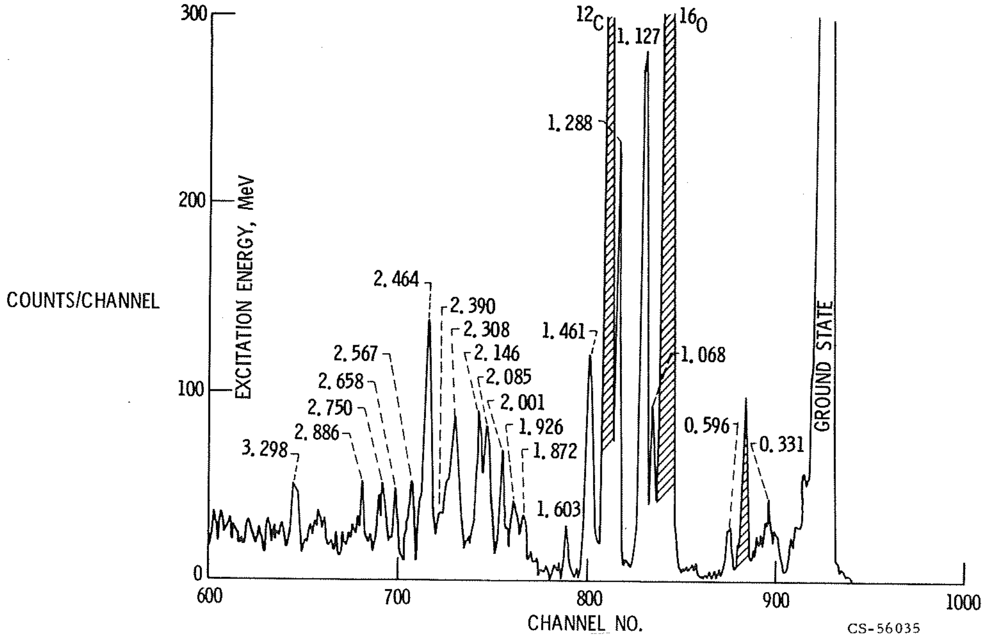


Fig. 4

STATES OF ^{115}In HAVING $l = 2$ ANGULAR DISTRIBUTIONS

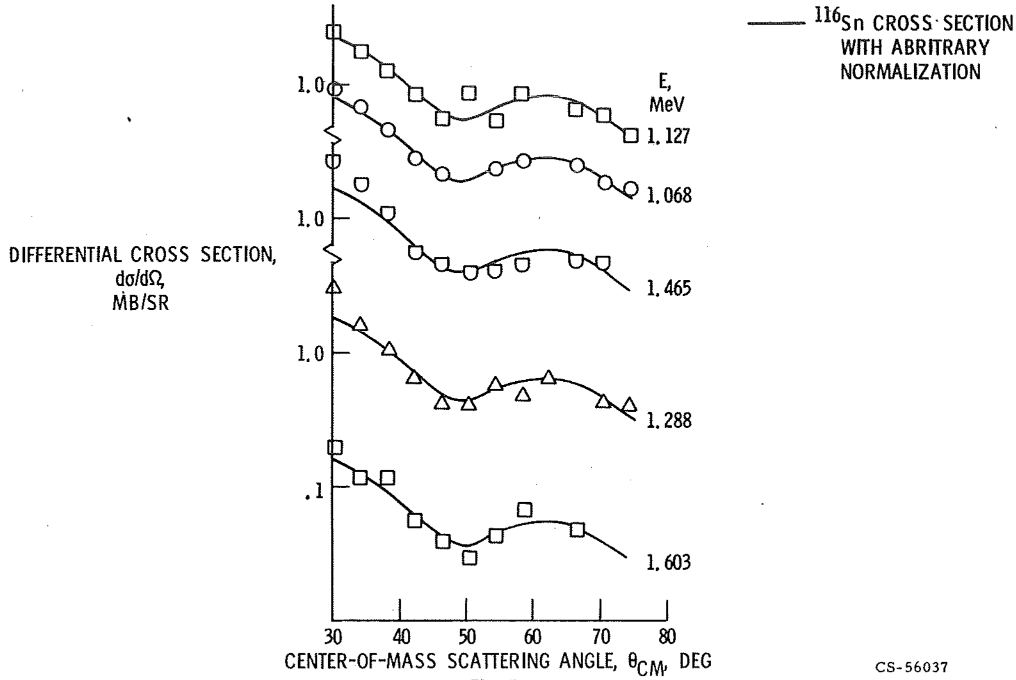


Fig. 5

STATES OF ^{115}In HAVING $l = 3$ ANGULAR DISTRIBUTIONS

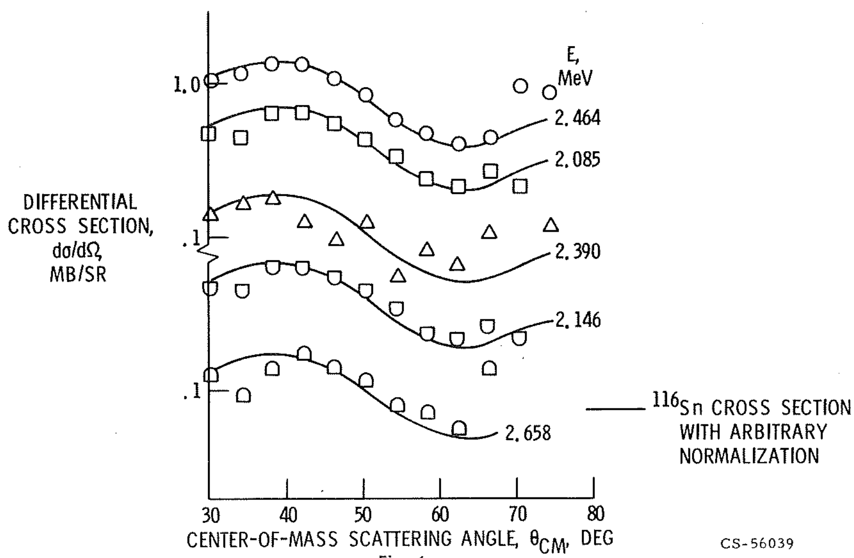


Fig. 6

OTHER ^{115}In ANGULAR DISTRIBUTIONS

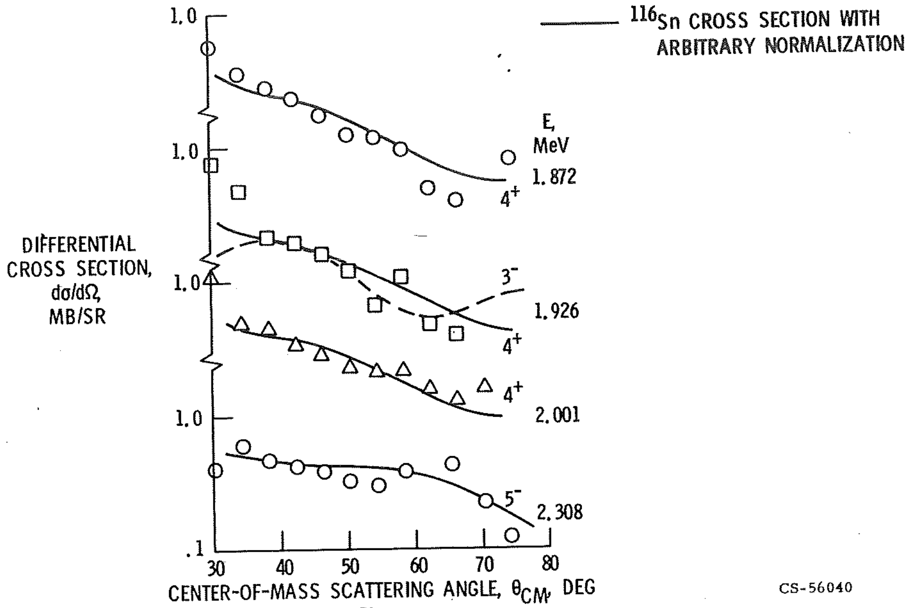


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Fig. 7

COMPARISON OF In AND TIN CROSS SECTIONS

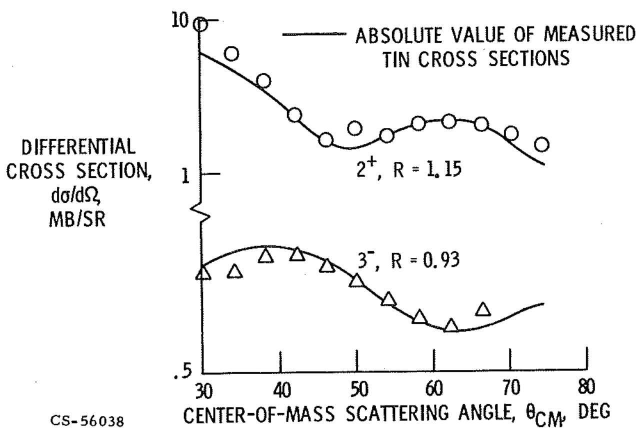

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Fig. 8

RELATIVE ^{115}In CROSS SECTIONS

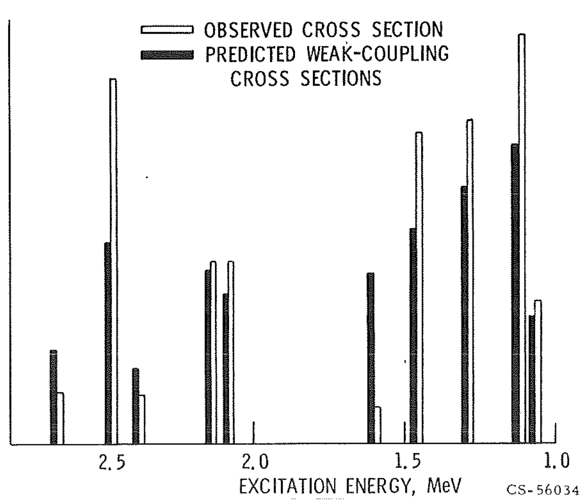

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Fig. 9