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^{120}Sn(p,α)^{117}In and ^{121}Sb(p,α)^{118}Sn Reactions: Identification of the ^{117}In and ^{118}Sn Homologous States

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Abstract. To investigate the spectator role of the $d_{5/2}$ unpaired proton outside the Z=50 closed shell, the ^{120}Sn(**p**,α)^{117}In and ^{121}Sb(**p**,α)^{118}Sn reactions have been measured in high resolution experiments, performed with the 23 MeV proton beam of the Munich MP Tandem, using the Stern-Gerlach type polarized hydrogen ion source and the Q3D magnetic spectrograph.

1 Introduction

We have observed [1] an interesting behaviour for a number of transitions induced by (p,α) reactions on near magic target nuclei (odd-A nuclei) having one proton outside a completely filled magic shell (core). In this case the outside, slightly bound nucleon acts as a spectator in the process and some distinctive features are displayed:

a) at lower excitation energies weak population of residual nucleus levels, fed by the pickup of the spectator proton together with a neutron pair of the core;

b) at higher excitation energies population of multiplets of states. In this high excitation energy region the dominant contribution arises from a process in which the incident proton picks up a proton and a pair of neutrons from the core, while the valence proton outside the Z=50 shell acts as a spectator. The configurations of these multiplets result from the coupling of the spectator proton (not involved in the process) with the low-lying states excited in the core that we call parent states.

The parent states excited in (p,α) reactions on a magic target nucleus, e.g. ^{120}Sn and the multiplets of states observed in (p,α) reactions on near-magic target nucleus, e.g. ^{121}Sb are denoted as homologous states, i.e. states with a close structural relationship.

In the case of weak coupling between the parent state and the spectator nucleon it is expected that:

a) the angular distributions of cross sections and analyzing powers for transitions to homologous states are very similar in shape because the processes exciting these states are essentially the same;

b) the differential cross section for populating a parent state is approximately equal in magnitude to the sum of the cross sections (cumulative cross section) of the transitions to the multiplet of homologous states corresponding to the given parent state;

c) the relative cross section for the population of a homologous state with spin J_i in a given multiplet is proportional to $(2J_i + 1)$.

We have already studied these findings in Z=40, 50 and 82 regions. In order to investigate the spectator role also of the $d_{5/2}$ unpaired proton outside the Z=50 magic shell, the ^{120}Sn(**p**,α)^{117}In and ^{121}Sb(**p**,α)^{118}Sn reactions have been measured.

2 The experiment and the analysis

The angular distributions of cross sections and analyzing powers of the triton pickup reactions ^{120}Sn(**p**,α)^{117}In and ^{121}Sb(**p**,α)^{118}Sn have been measured in high resolution experiments using the 23 MeV proton beam of the Munich MP Tandem accelerator, the Stern-Gerlach source for intense, bright beams of negatively polarized hydrogen ions [2]. A beam current up to 700 nA, to save the Sn targets, with a beam polarization ∼ 75 % was used. The 41 μg/cm^2 thick ^{120}Sn and 56 μg/cm^2 thick ^{121}Sb isotopically enriched (99.6 and 99.53% respectively) targets were evaporated onto an 9 μg/cm^2 carbon backing. The reaction products were momentum separated by the Q3D magnetic spectrograph, with both spin-up and spin-down polarization in different magnetic field settings in order to reach the excitation energies of the residual nuclei ^{117}In and ^{118}Sn of 2000 keV and 5100 keV respectively. The setting of the spectrograph entrance slits provided a solid angle of 11.04 msr for $\theta \geq 10^o$.

Outgoing α-particles were identified by the new proportional counter [3] with cathode-strip readout for the Q3D focal plane, designed to detect light ions such as p, d, t, α with a position resolution of better than 0.1 mm, good particle identification and high count rate.

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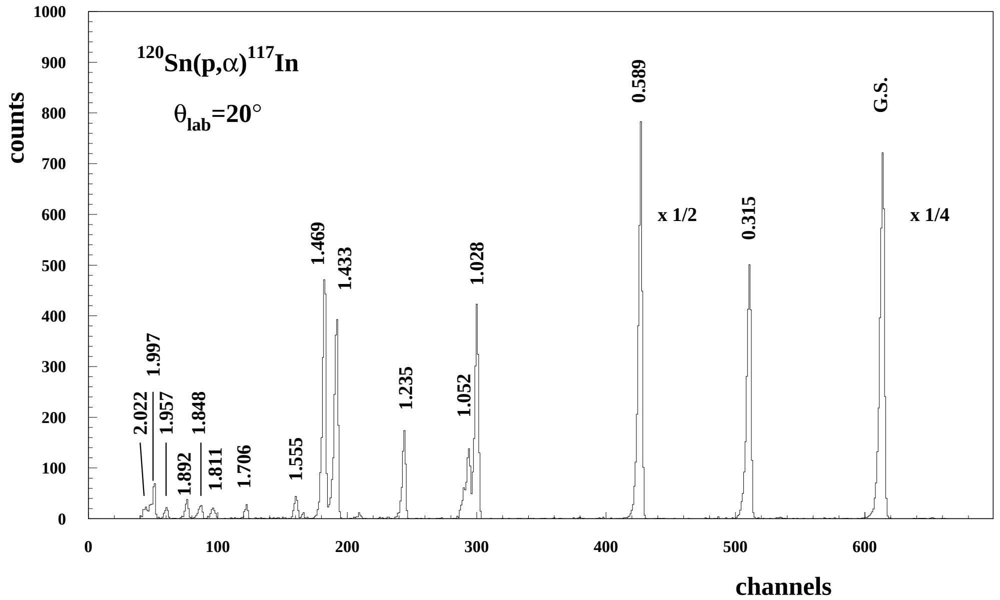

Fig. 1. Energy spectrum of α particles measured at 20^o for the ^{120}Sn($\mathbf{p}, \alpha$)^{117}In.

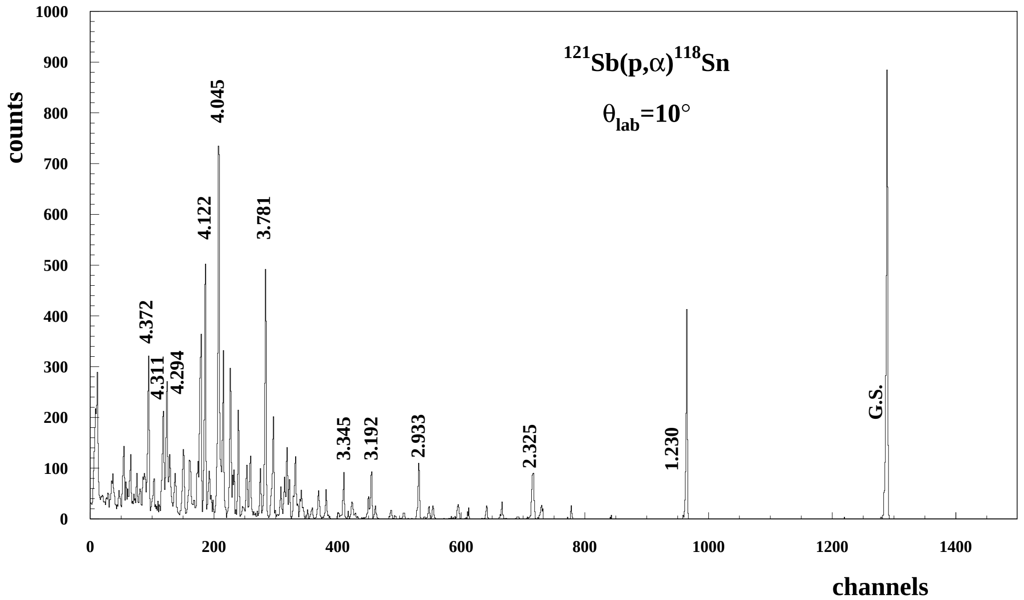

Fig. 2. Energy spectrum of α particles measured at 10^o for the ^{121}Sb($\mathbf{p}, \alpha$)^{118}Sn.

The particles were stopped in a 7 mm thick plastic scintillator (NE-104) which ensured both ΔE-E particle identification and good position resolution.

The good energetic characteristics of the accelerator, the spectrograph and the focal plane detector allowed for the measurement of high-resolution energy spectra. The energy resolution was 12 keV FWHM in the detection of the outgoing α-particles.

In Fig.s 1 and 2 the energy spectra of α-particles measured at 20^o for the reaction ^{120}Sn(**p**,α)^{117}In and at 10^o for the reaction ^{121}Sb(**p**,α)^{118}Sn, are shown. The excitation of the most prominent peaks is indicated.

The excitation energies are determined through the calibration of the spectra using a polynomial of rank 2, whose parameters are set by reproducing the well-known excitation energies of levels of ^{117}In [4] and ^{118}Sn [5] determined in γ-decay experiments and identified in our α spectra. Quoted energies are estimated to have an uncertainty of 3 keV.

Starting from ~ 3.6 MeV of excitation energy in ^{118}Sn , we have identified levels homologous to the lowest energy levels of ^{117}In, by comparing angular distributions of cross sections and asymmetries with the respective distributions for the parent states in ^{117}In, i.e. $\frac{9}{2}^+$ G.S., $\frac{1}{2}^-$ 0.315 MeV, $\frac{3}{2}^-$ 0.589 MeV. The angular distributions of cross sections and asymmetries of these parent states are significantly different from each other, and this allows a reliable discrimination between the multiplets of homologous states.

We assigned the spin values to the ^{118}Sn homologous levels following the $(2J + 1)$ rule. Because of the coupling of the $d_{5/2}$ proton with the positive or negative parity parent states, the parity of the ^{118}Sn daughter states is positive or negative respectively.

In this contribution we present the results concerning the ^{118}Sn levels homologous of the ^{117}In $\frac{9}{2}^+$ G.S.and $\frac{1}{2}^-$ 0.315 MeV parent states.

A DWBA analysis of angular distributions of cross sections and analyzing powers for the ^{120}Sn(**p**,α)^{117}In reaction using the code TWOFNR [6] has been performed in finite range approximation assuming a semi-microscopic triton cluster pickup mechanism and a Gaussian proton-triton interaction potential, as shown in fig.3 for some of the identified ^{117}In levels.

In the case of this even-even target nucleus ^{120}Sn, only one transferred orbital and total angular momentum l and j contribute to the excitation of a given final level, thus greatly simplifying the theoretical calculations. The dependence of angular distributions of cross sections and asymmetries of the emitted particles on the transferred total angular momentum j is of greatest importance for identifying the spin and parity of the levels excited in a nuclear reaction.

In the case of an odd-mass target nucleus as ^{121}Sb and for transitions to states with spin values different from 0, several l and j are allowed for a transition to a given final state. Exploiting the orthonormality of Clebsch-Gordan coefficients in evaluating the transition amplitude and the conservation of parity which allows only one l for a given j, one has to consider the incoherent sum of these contributions in a DWBA calculation. The high number of three-particle configurations involved complicates the analysis and reduces the accuracy of spectroscopic information obtainable. On the contrary, in the case of homologous states, one has only one l and j transfer, that is given by the transition to the corresponding parent state, so gaining a great advantage: the homology concept allows for odd-mass target nuclei to single out a dominant transition amplitude and consequently to identify spin and parity.

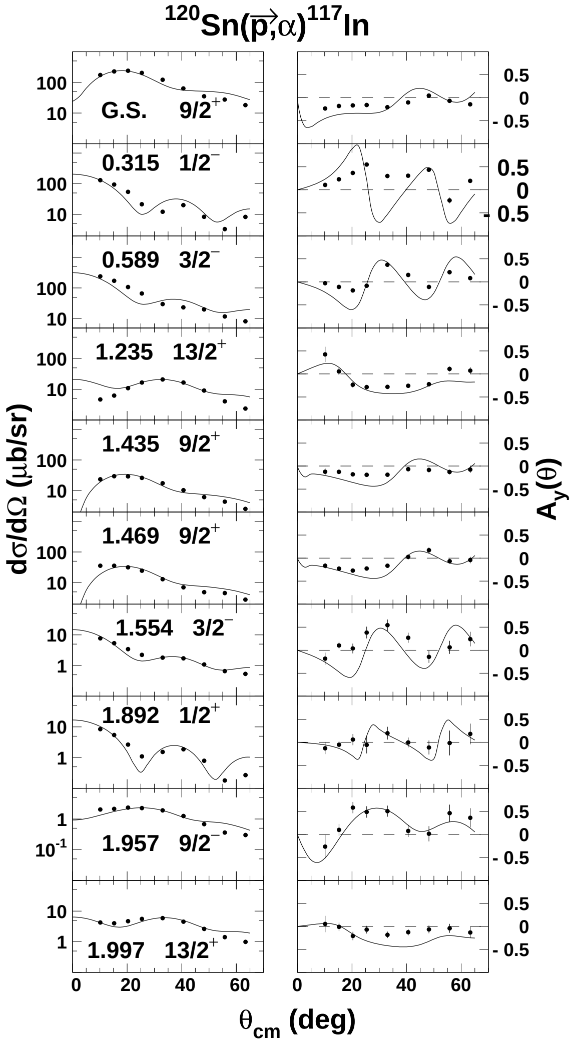

Fig. 3. Angular distributions of cross sections and asymmetries for some ^{117}In states populated in the ^{120}Sn(**p**,α)^{117}In reaction. Dots refer to the experimental values and solid lines to the cluster DWBA calculations.

3 The results

The study of ^{120}Sn(**p**,α)^{117}In reaction aims to obtaining accurate measurements of angular distributions of cross sections and asymmetries for comparison with those measured in the ^{121}Sb(**p**,α)^{118}Sn reaction. The homologous states arise from the coupling of the $d_{5/2}$ unpaired proton with the

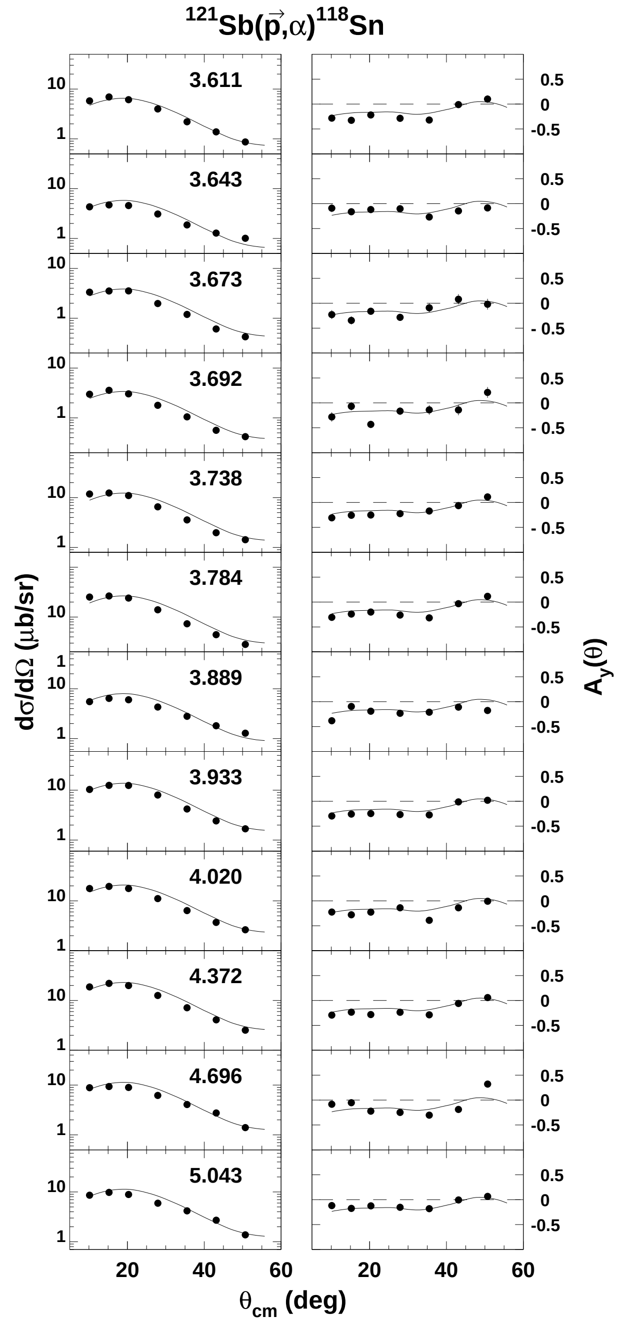

Fig. 4. Angular distributions of cross sections and asymmetries for some of the 23 positive parity daughter states of ^{118}Sn homologous to the G.S. $9/2^+$ ^{117}In parent state. Dots refer to the experimental values of the daughter states and solid lines to the experimental values of the parent state.

configurations excited in ^{117}In. The homology between the low lying states of ^{117}In and the higher energy states of ^{118}Sn allows to assign spin and parity to these latter states, on the basis of the weak coupling model.

The identification of homologous states is in progress. We have identified many levels of ^{118}Sn homologous to the ^{117}In $9/2^+$ G.S., more than the sextet of positive parity states expected, from 2^+ to 7^+, by the weak coupling model, pointing out the presence of an important fragmentation of the parent ^{117}In $9/2^+$ G.S. strength. The cumulative cross section of these daughter states of ^{118}Sn accounts for 82% of the cross section associated with the population of the parent state. Some of them are given in fig.4, showing that the angular distributions of cross sections and analyzing powers for transitions to homologous states are very similar in shape because the process exciting these states are essentially the same.

We have also identified the doublet of ^{118}Sn at 4.045 MeV 3^- and 4.121 MeV 2^-, homologous to the 0.315 MeV $1/2^-$ ^{117}In parent state. The angular distributions of cross sections and asymmetries for these two levels are reported in fig.5.

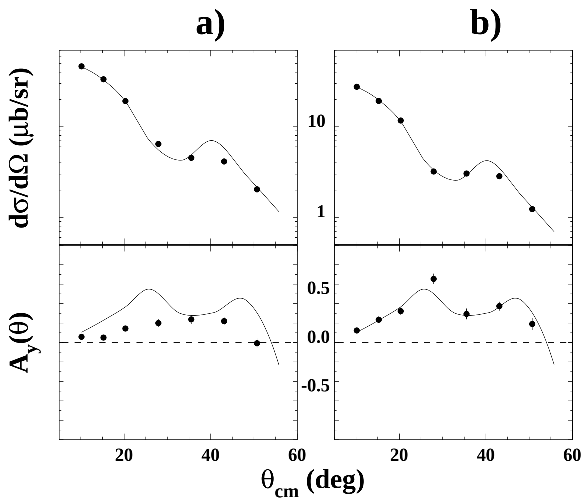

Fig. 5. Angular distributions of cross sections and asymmetries for the ^{118}Sn 4.045 MeV 3^- (a) and 4.121 MeV 2^- (b) daughter states homologous to the 0.315 MeV $1/2^-$ ^{117}In parent state. Dots refer to the experimental values of the daughter states and solid lines to the experimental values of the parent state.

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