The ^{6}Li (0^+, T=1) decay of the ^{10}B states populated in the resonance ^{9}Be+p interaction

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The T=1 states in ^{10}B were studied using the $^{9}Be(p,\alpha)^{6}Li^{*}$(T=1, 3.56, 0^+) reaction. This reaction was chosen due to its high selectivity with respect to T=1 states with large partial α width, Γ_α. Angular distributions were measured at 39 different energies, covering an excitation energy range of 8.8 MeV to 12.2 MeV in ^{10}B. Two prominent resonances have been observed.

Introduction

The main motivation for this experiment is to measure the cross section, evaluate background conditions, and determine the best energy regime for a future experiment in which the parity violating α-decay of the T=1, 0^+ 3.56 MeV state in ^{6}Li will be studied. The branching ratio for this parity-violating decay can be used to evaluate the weak πNN coupling constant, which dominates the isovector term of the parity-violating potential [1]. This potential emerges from the strangeness-conserving, non-leptonic sector of the weak interaction Hamiltonian. It was also pointed out in [2] that the M1 electromagnetic transition of the 3.56 MeV state in ^{6}Li into the $^{2}H+\alpha$ continuum is a great tool for exploring the properties of the two-neutron halo ground state of ^{6}He. (This is due to the fact that the 3.56 MeV 0^+ state in ^{6}Li is an isobaric analog of the ^{6}He g.s.).

However, because the ^{6}Li decay of ^{10}B is accompanied by the α particle, the specific results are related with the α- cluster structure in ^{10}B. Clustering phenomena in light nuclei represent many interesting and rich problems. The clustering phenomena provide an important insight into the interplay between the mean field and the cluster degrees of freedom. Recent theoretical developments, such as the antisymmetrized molecular dynamics (AMD) approach [3], describe cluster-like and shell-model-like configurations on an equal footing. This allows us to extend our understanding of the cluster degrees of freedom beyond the A=4n nuclei, which had been the main subject of cluster research in the past.

From an experimental perspective information on the cluster degrees of freedom in non-self-conjugate nuclei is scarce. However, there is now strong evidence that the cluster degree of freedom plays a significant role in the structure of light nuclei with A≠4n [4, 5]. In particular, the existence of a molecular-like α:2n:α band in the ^{10}Be nucleus was suggested in Ref. [3] and three states (at 6.18 MeV (0^+), 7.54 MeV (2^+) and 10.15 MeV (4^+)) were identified as members of this band. Two of the three states mentioned above have had their isobaric analog states identified in ^{10}B. These are the T=1, 0^+ at 7.56 MeV and the T=1, 2^+ at 8.9 MeV [4]. Therefore, one may suggest that these states are members of an isobaric analog, T=1 α:pn:α molecular-like band in ^{10}B. If this is the case then there should be a third member of this band at the excitation energy of ~11.5 MeV. The resonance reaction $^{9}Be(p,\alpha)^{6}Li^{*}$(T=1, 3.56, 0^{+}) appears to be an appropriate tool for the search for this state.

Experiment

The $^{9}Be(p,\alpha)^{6}Li$ excitation functions were measured using inverse kinematics. The experimental setup is shown in Fig. 1. The ^{9}Be beam was provided by the Tandem Van de Graaf accelerator, and polyethylene was used as a proton target. The total energy and scattering angle of ^{6}Li were measured by a resistive-layer, position-sensitive silicon detector with in front a gas ionization chamber for particle identification. Alpha particles were measured in coincidence with ^{6}Li by an array of silicon pin-diode detectors. This coincidence technique allows for the elimination of background and for the process of interest to be identified unambiguously. Measurements were performed at 39 different beam energies.

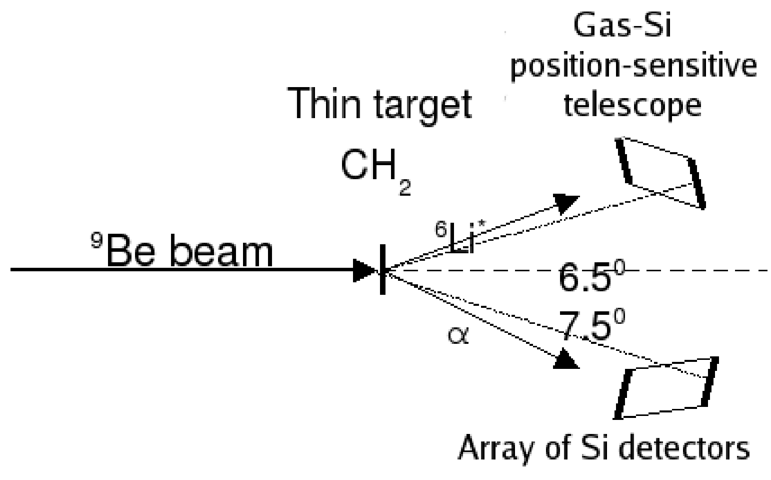

Figure 1. Experimental setup. Alpha particles and ^{6}Li from the $^{1}H(^{9}Be,\alpha)^{6}Li$ reaction were measured in kinematical coincidence.

Results

The excitation function of the $^{9}Be(p,\alpha)^{6}Li^{*}$(T=1, 3.56 MeV, 0^{+}) reaction is shown in Fig. 2. The most obvious feature of the excitation function is the resonance at 8.9 MeV of ^{10}B excitation energy. This is the known T=1, 2^{+} state [4]. The angular distribution at this resonance energy is shown in Fig. 3. It is compared with an angular distribution predicted by an R-matrix calculation for the 2^{+} state along with an admixture of the relatively weak T=1, 3^{-} state at 8.9 MeV. Note that the angular distribution for a pure 2^{+} state would be isotropic. It is the admixture of the 3^{-} state that causes the cross section to decrease slightly at higher angles.

A broad peak was observed at an excitation energy of ~11.5 MeV (Fig. 2). It appears at exactly the excitation energy expected from comparison with the isobaric analog 4^{+} state at 10.15 MeV in ^{10}Be [3]. The data are still under analysis at present and an angular distribution is not yet available for this state. However, based on the excitation energy of this state and its large partial width in the α-^{6}Li channel, we can conclude that it could be considered as a good candidate for the isobaric analog of the 4^+, 10.15 MeV state in ^{10}Be.

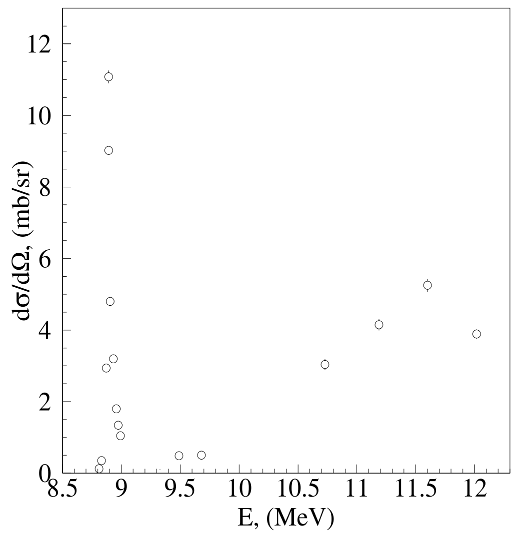

Figure 2. Excitation function of the ^{9}Be(p,α)^{6}Li*(T=1, 3.56 MeV, 0^+) reaction. X-axis represents excitation energy in ^{10}B. The low energy part (below 10 MeV) of the excitation function corresponds to 70+/-10 degrees in c.m. and the high energy part corresponds to 140+/-10 degrees in c.m. This is preliminary data and only a fraction of all the data points is shown.

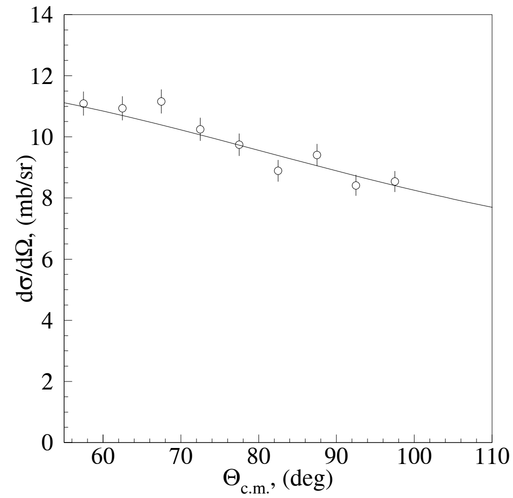

Figure 3. Angular distribution of the ^{9}Be(p,α)^{6}Li(3.56) reaction at the resonance energy for the 2^+, 8.9 MeV state in ^{10}B. The solid line is an R-matrix fit, that includes two known resonances [4], the 2^+ and 3^- both having excitation energy of 8.9 MeV.

Alpha particle partial widths of the observed states can be evaluated from the value of the measured cross section. Both resonances appear to be strong α-cluster states that exhaust significant fractions of the Wigner limit alpha width.

Conclusion

The measurement of the ^{9}Be(p,α)^{6}Li*(3.56, T=1) excitation function revealed two states with large α-^{6}Li(3.56, T=1) reduced widths at excitation energies of 8.9 and 11.5 MeV. The first is the known 2^+ state, and the second is a new state. The spin-parity of this state will be determined from the measured angular distribution. If it is determined that the spin-parity of this new state is 4^+ then both of these resonances could be considered as isobaric analogs of the molecular-like band recently suggested in ^{10}Be [3] and therefore have an exotic α:pn:α molecular-like structure. Both resonances can be used for the future search of the parity violation in the decay of ^{6}Li*.

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