

Study of the s -Wave Properties for ^{10}Li through the Analysis of the Break-Up Reaction

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Introduction

Recent experimental developments provide us rich information about unstable nuclei, which are placed near the proton or the neutron drip-line. The ^{11}Li nucleus is the most typical one. The halo structure of ^{11}Li is explained in terms of the mixture of $(1s)^2$ and $(0p)^2$ configurations of the two valence neutrons. From the theoretical point of view, the Pauli-blocking mechanism, due to the occurrence of the pairing correlation in the ^9Li -core,¹⁾ is a good candidate to explain such the degeneracy of s - and p -orbit in ^9Li - n .

Among many experimental ways to investigate the nature of ^{10}Li , we focus on the break-up reaction of the unstable nuclear beam of ^{11}Li ,^{2),3)} and the break-up of the isobaric analogue state in ^{11}Be ,⁴⁾ since the effect of the ^9Li - n interaction is well pronounced in these break-up mechanisms. In this work, we study the s -wave property of ^{10}Li with the interaction of the Pauli-blocking model¹⁾ by applying several break up mechanisms: (i) two-step break-up (based on the R -matrix theory⁵⁾) and, (ii) the participant-spectator (PS) model.⁶⁾

Calculations and results

(i) Two-step break-up: In this break-up mechanism, the ^{11}Li beam is interact to the target and emits the one neutron, and the rest forms the “resonant state” of the ^{10}Li . Then the final two particle, ^9Li and n break up form the resonance. Since the information of the ^{11}Li is not necessary, we can employ the R -matrix approach to the final break-ups for investigating this process. The break-up cross-section based on the R -matrix approach⁵⁾ is expressed as follows:

$$\sigma_l(E) \propto \frac{\Gamma_l(E)}{(E - E_R)^2 + \frac{1}{4}\Gamma_l(E)^2} .$$

From $a_0 = -23$ to -5 fm, our calculation shows the good agreement for a general tendency to s -wave enhancement and p -wave resonance peak. (ii) The participant-spectator model: In this approach, the break-up cross section is expressed as the following form:⁶⁾

$$\sigma(E) \propto \sum_{\Sigma_i} |M_{s_{jk}\Sigma_{kj}\Sigma_i}(E)|^2 ,$$

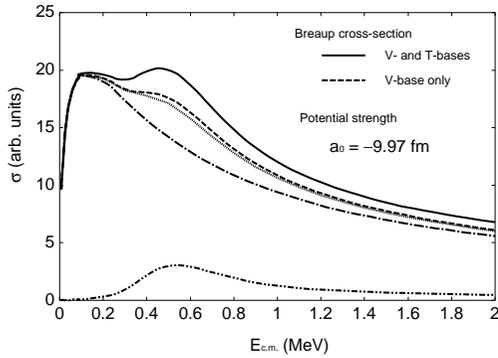


Fig. 1. The calculated break-up cross-section by using the PS model.

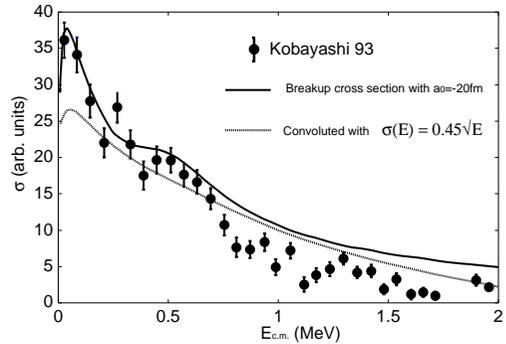


Fig. 2. The break-up cross-sections obtained by our calculation and the experiment.²⁾

with

$$M_{s_{jk}\Sigma_{kj}\Sigma_i}(E) = \left\langle \phi^{(jk+)}_{p'_{jk}s_{jk}\Sigma_{jk}}(E) e^{ip_{i,jk}r_{i,jk}} \chi_{s_i\Sigma_i} \left| \Psi^{JM} \right\rangle .$$

By using this break-up mechanism, we can investigate the contribution of each partial wave both in ^{10}Li and ^{11}Li , precisely. We use two kinds of basis set for solving ^{11}Li wave function; the COSM (V-base) and the ECM (T-base).

Figure 1 shows the contribution of each partial wave for V- and T-basis sets, for the potential strength of $a_0 = -9.97$ fm to the $^9\text{Li}-n$ interaction. It is shown that the main contribution to the break-up cross-section is the s -wave and p -wave in V-base, and other contributions are small. When we use the $a_0 = -20$ fm case, the agreement to the experiment of Kobayashi²⁾ becomes good.

We also investigate the correspondence to the experiments of Zinser et al.³⁾ and Shimoura et al.⁴⁾ by using the PS model, and obtained good agreements for both of them.

Conclusion

We investigated the break-up cross-section by using the microscopic interaction model, which is based on the Pauli-blocking effect. The agreement to the experiment is good. Therefore, we can conclude that our potential model is plausible. In future work, the coupled-channel analysis will be performed for this investigation.

References

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