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Cite as: AIP Conference Proceedings **1231**, 183 (2010); <https://doi.org/10.1063/1.3428916>

Published Online: 04 May 2010

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Study of the ^{18}Ne and ^{11}Li Nuclei in a Three-body Model

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Abstract. We investigate the structure of the nuclei ^{18}Ne and ^{11}Li within a three-body model using Faddeev equations with the hyperspherical adiabatic expansion method. The ^{18}Ne system is described as an inert ^{16}O core and two protons. Besides reproducing the experimentally known bound states, two tentative states with $J^\pi=3^+$ and 1^- are predicted close to the two-proton separation threshold. We also find several low-lying resonances based on a 3^- excited state of the core. The ^{11}Li nucleus is treated using a $^9\text{Li}+n+n$ model. In this case, the lack of information of the $^9\text{Li}+n$ spectrum only allows us to obtain the ground state with enough accuracy. The calculated three-body wavefunction has been used to develop a simplified two-body model of the ^{11}Li nucleus (dineutron model). This model is found to reproduce very well the recent data for the electric transition probability, $B(E1)$.

Keywords: Few-body models, halo nuclei.

PACS: 21.45.-v, 21.60.Gx, 21.10.Gv

INTRODUCTION

One of the most active fields the last years in Nuclear Physics has been the study of exotic nuclei, which are characterized by an anomalously large ratio between protons and neutrons. This fact gives them special characteristics that make these nuclei very interesting. We can investigate their properties by either studying their decay modes or by measuring the distributions of the reaction products after a reaction with a stable nucleus. In this work, we present an example of each of these methods. On one hand, we consider the ^{18}Ne nucleus, whose 1^- excited state has been found to decay to ^{16}O via the simultaneous emission of two protons. On the other hand, we consider the ^{11}Li nucleus, motivated by the recent measurements of the $^{11}\text{Li}+^{208}\text{Pb}$ reaction performed at TRIUMF (Canada). In both cases, we expect to describe these nuclei within a three-body picture consisting on a core and two nucleons (i.e, $^{16}\text{O}+p+p$ and $^9\text{Li}+n+n$).

RESULTS

In order to understand the structure and the possible reaction channels we can calculate the wave functions for these nuclei using Faddeev equations for three-body systems. In this work, these equations are solved in configuration space using the hyperspherical adiabatic expansion method [1].

The main ingredient of these calculations are the two-body potentials. The n-n and p-p interactions are well known, and are parametrized in this work in terms of Gaussian potentials. The $p+^{16}\text{O}$ interaction is also represented by a Gaussian potential with central and spin-orbit components, and parameters adjusted to reproduce the two bound states of ^{17}F . With these ingredients, the positions of the bound states in ^{18}Ne are well reproduced. The spin and parity of the two first resonances for ^{17}F are not well reproduced keeping the core in its 0^+ ground state. This lead us to think that these states are mainly built on top of the 3^- excited state of the ^{16}O . This in turn can explain the structure of the 1^- resonance in ^{18}Ne , related to the two protons emission, among other resonances.

In the ^{11}Li case the lack of information about the two body levels only allowed us to determine accurately the ground state wave function. Hence, this model can not be used to predict in a reliable way the structure of the unbound states.

Our main motivation to study the ^{11}Li nucleus is the possibility of studying the reaction $^{11}\text{Li}+^{208}\text{Pb}$, measured recently at the TRIUMF facility. In principle, this reaction could be studied within the Continuum Discretized Coupled Channels (CDCC). However, four body CDCC calculations involving the ^{11}Li nucleus are still under development. In the meantime, one can tackle the problem using a simplified two-body model, similar to the di-neutron model recently proposed for ^6He [2]. In this model, one treats the two neutrons as a single entity and considers explicitly the motion between the neutrons and the ^9Li core. This model is expected to be realistic in the $^{11}\text{Li}+^{208}\text{Pb}$ reaction, since the Coulomb interaction, which is expected to play a dominant role, will act on this degree of freedom, tending to separate the neutrons from the ^9Li core. In this simplified picture, we describe the $2n-^9\text{Li}$ interaction using a Woods-Saxon potential, assuming a given geometry. Following the conventional separation method, one can determine the depth of this potential using the two-neutron separation energy $S_{2n}=0.37$ MeV. However, this procedure gives a too large mean separation between the neutrons and the core, and tends to overestimate the couplings to the continuum. Alternatively, one can adjust this depth to reproduce as best as possible the three-body wave function along the $2n-^9\text{Li}$ coordinate. This yields the effective binding energy $\epsilon_b=-0.54$ MeV. With this value we reproduce reasonably well the most recent measurements of the electric transition probability $B(E1)$ [3]. CDCC calculations for $^{11}\text{Li}+^{208}\text{Pb}$ using this dineutron model are now in progress.

ACKNOWLEDGMENTS

This work has been partially supported by the DGICYT under project FPA 2006-13807-C02-01. J.A. Lay acknowledges a Ph.D. grant from the University of Seville and financial support by the University of Aarhus.

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