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Detailed spectroscopy of ^{113}Cd through transfer reactions

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Abstract

High energy resolution studies of ^{113}Cd have been performed with the (d,p) and (d,t) reactions, using polarized beams. In both reactions, a large number of levels (about 80) have been observed up to 2.6 MeV excitation energy, for many of them unambiguous spin and parity assignment being made. Together with previous data from other experiments, the level scheme has probably become essentially complete up to this energy. A detailed comparison is made between the experimental levels and calculations performed with the interacting boson–fermion model-1 (IBFM-1) and with the quasiparticle phonon model (QPM), which allows a good understanding of the level scheme up to about 2 MeV excitation. This nucleus is a special case for the QPM, where due to a strong anharmonicity rather complex configurations must be taken into account in order to get a good description even at low excitation energies. The multiplet structures arising from the coupling of the $3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, and $1g_{7/2}$ neutron orbitals to the quadrupole one-phonon excitation of the core nucleus ^{112}Cd have been assigned, and the possible identification of $1/2^+$ and $3/2^+$ "intruder" states (based on two particle–two hole excitations of the core) is discussed. The observation of many $\ell = 1$ transitions above 2 MeV excitation gives a clue to the way by which the $11/2^-$ isomeric state can be populated in the (n,γ) and (γ,γ') reactions.

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1. Introduction

High resolution experiments of transfer reactions with light particles remain a very important source of detailed knowledge for the nuclear structure of the nuclei close to the valley of stability. In particular, the one-nucleon (e.g., one-neutron) transfer reactions are very sensitive probes for learning about the microscopic (single-particle) structure of the final levels. By adding such data to the information that can be deduced from other possible nuclear reactions, each one with its specific selectivity in populating the excited states, one may hope to obtain, on one hand, the complete level scheme up to a certain spin and excitation energy, and on the other hand, clear evidence for different basic excitation modes of the nuclei.

The Cadmium isotopes with neutron numbers around the middle of the 50–82 shell constituted for many years a good ground for such detailed studies. In particular, the even–even isotopes ^{112}Cd [1] and ^{114}Cd [2] have been the object of many experimental studies, which allowed to disentangle several excitation modes up to an excitation energy of about 2.6 MeV. At lower excitation energy they behave like anharmonic vibrators, exhibiting one-, two-, and three-phonon multiplets. But other excitation modes have been recognized too. For example, in ^{112}Cd, an intruder band based on a 0^+ two particle–two hole excitation state at low-energy (about 1.2 MeV) has been observed, and above 2 MeV excitation mixed-symmetry states, octupole phonon and hexadecapole phonon states have been proposed; the corroboration of different types of experiments aimed to 'read out' all this structure information is very nicely illustrated in Ref. [3].

Such a rich variety of excitations should manifest itself also in the neighboring odd-A nuclei, like the odd-A Cd isotopes. In an odd-mass Cd nucleus, since one has to couple an odd neutron which may occupy any of the five available single-particle orbitals ($3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, $1f_{7/2}$ and $1h_{11/2}$) the resulting low-energy level scheme is rather rich; for example, by coupling these orbitals only to the quadrupole one-phonon state 2_1^+ of the even–even Cd core one expects five level multiplets with a total of 21 excited states spread over several hundreds of keV above 0.5 MeV excitation. Therefore, to study such complicated structures one needs experiments with very good energy resolution and sensitivity.

The present article presents such an experimental approach to the structure of ^{113}Cd. Apart from the nuclear structure physics, briefly sketched above, this nucleus is also of special interest for the astrophysics (nuclear synthesis in the Cd–In–Sn region). This latter aspect has been emphasized in previous papers, for example in Refs. [4,5], and resides in the fact that once formed from the β-decay of ^{113}Ag, ^{113}Cd decays either to the ground state, or to the $11/2^-$ isomer at 263 keV (half life of 14 years), which leads to the population of ^{114}Cd (by thermal neutron capture from the g.s.) and of ^{113}In (by β-decay of the isomer), respectively. The relative population of the two nuclei is also influenced by