Shell-model description of nuclear structure and isomeric states in Cd isotopes

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Introduction

In recent years, the study of nuclear structure properties of Cd and Te isotopes has increased both from the experimental and theoretical sides because they are in the vicinity of the ^{100}Sn. The study of nuclear properties in Cd-isotopes is also important for the understanding of stellar nucleosynthesis. Several similarities are pointed out experimentally, like electromagnetic transition probabilities and excitation energy spectra in Sn and Cd isotopic chain. The shell-model theory provides a better platform to verify these properties.

We have investigated different properties of Cd isotopes like excitation energy, reduced electromagnetic transition probabilities, isomeric states, electric quadrupole, and magnetic moments from neutron-deficient isotopes (near the proton drip line) to the neutron-rich isotopes. Several new experimental data are available in Cd isotopic chain for low-lying spin states. In this paper, we have presented results for ^{98,100}Cd. We will also present our results with *ab initio* approaches for Cd isotopes.

Formalism

The shell-model effective Hamiltonian [1] can be expressed in terms of single-particle energies and two-body matrix elements,

$$H = \sum_{\alpha} \epsilon_\alpha c^\dagger_\alpha c_\alpha + \frac{1}{4} \sum_{\alpha\beta\gamma\delta JT} \langle j_\alpha j_\beta | V | j_\gamma j_\delta \rangle_{JT} \times c^\dagger_\alpha c^\dagger_\beta c_\delta c_\gamma \quad (1)$$

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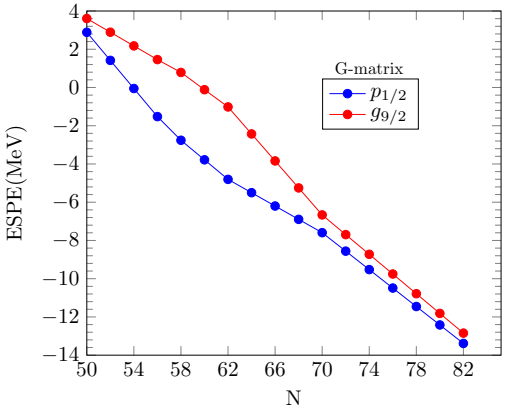

FIG. 1: Variation in the effective single-particle energies in Cd isotopes corresponding to the G-matrix interaction.

where $\alpha = \{n, l, j, t\}$ denote the single-particle orbitals and ϵ_α are corresponding single-particle energies. The c_α and $c^\dagger_\alpha$ stand for the fermion annihilation and creation operators. $\langle j_\alpha j_\beta | V | j_\gamma j_\delta \rangle_{JT}$ are the antisymmetrized two-body matrix elements coupled to spin J and isospin T.

We have studied the structure of even-even Cd isotopes with the mass number A = 98-130 using the G-matrix effective interaction [2], which is constructed by the effective microscopic interaction derived from a charge-symmetry breaking nucleon-nucleon potential [3] and another interaction from [4]. Further monopole modifications have been implemented in this interaction. This interaction consist of $1p_{1/2}$, $0g_{9/2}$ proton orbitals and $1d_{5/2}$, $2s_{1/2}$, $1d_{3/2}$, $0g_{7/2}$, $0h_{11/2}$ neutron orbitals with core ^{88}Sr, where we have completely filled proton orbitals below Z=38 and neutron orbitals below N=50. In this interaction, the single-particle energies are taken

from [4]. The shell-model code KSHELL has been used for our calculations to diagonalize the matrices. The highest dimension is 9.56×10^8 for ^{114}Cd. We have performed our calculations with the G-matrix interactions without any truncation.

In Fig. 1, we have shown the change in effective proton single particle energy (ESPE) with respect to neutron number in Cd-isotopes for the G-matrix interaction.

Results and discussion

We have compared the experimental low-lying energy states of ^{98,100}Cd isotopes with the G-matrix interaction shown in Fig. 2.

In the case of ^{98}Cd, the location of 2_1^+ and 4_1^+ states are reproduced well with our calculation. The isomeric states 6_1^+ and 8_1^+ are also comparable with the experimental data. Our calculated half-life of the 6_1^+ state is 1.92 ns, which is very close to the experimental half-life, $T_{1/2} = 13(2)$ ns [5]. The configuration of 6_1^+ and 8_1^+ state is $\pi(p^2_{1/2}g^8_{9/2})$ with 100% contribution. Both states are formed by one pair breaking of the $\pi(g_{9/2})$ orbital. So, the seniority(ν) is 2 for 6_1^+ and 8_1^+ states.

In ^{100}Cd, the 2_1^+, 4_2^+, 6_2^+ and 8_1^+ states are comparable with the experimental data from the G-matrix interaction. Location of the 4_1^+ and 6_1^+ states are slightly compressed from the experimental data. With our calculation, 10_1^+ state lies 0.393 MeV lower than experimental data. The neutron occupancies corresponding to 2_1^+ state are 1.259, 0.138, 0.446, 0.141 and 0.016 in $d_{5/2}$, $s_{1/2}$, $g_{7/2}$, $d_{3/2}$ and $h_{11/2}$ orbitals, respectively. Here, $d_{5/2}$ orbital is dominating in the formation of the 2_1^+ state. From our calculation, the wave function corresponding to 8_1^+ isomeric state is $\pi(p^2_{1/2}g^8_{9/2})\otimes\nu(d^2_{5/2})$ with 55.0% contribution and the neutron occupancies for 8_1^+ state are 1.185, 0.079, 0.573, 0.143 and 0.020 in $d_{5/2}$, $s_{1/2}$, $g_{7/2}$, $d_{3/2}$ and $h_{11/2}$ orbitals, respectively. With the G-matrix interaction, 8_1^+ state arises because of the proton pair breaking in $g_{9/2}$ orbital, thus $\nu = 2$. The configuration of 6_1^+ state is $\pi(p^2_{1/2}g^8_{9/2})_{0^+}\otimes\nu(g^1_{7/2}d^1_{5/2})_{6^+}$ with 82.4% contribution, which shows predominant neutron

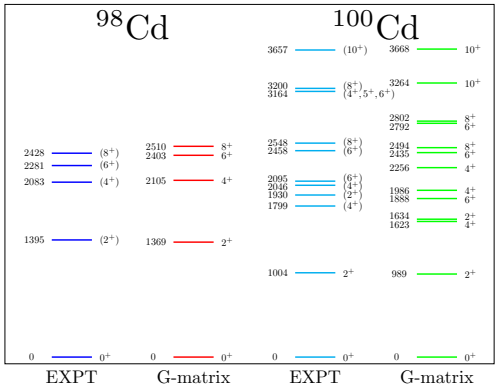

FIG. 2: Comparison between calculated and experimental energy levels [6] for ^{98,100}Cd.

character of the 6_1^+ state. But, the configuration of 6_2^+ state is $\pi(p^2_{1/2}g^8_{9/2})_{6^+}\otimes\nu(d^2_{5/2})_{0^+}$ with 73.3% contribution. Here, the 6_2^+ state is formed by one proton pair breaking in $g_{9/2}$ orbital. So, the 6_2^+ state has more resemblance to the 8_1^+ proton isomer in ^{100}Cd.

We acknowledge financial support from MHRD, Government of India, and SERB (India), CRG/2019/000556. We would like to thank the National Supercomputing Mission (NSM) for providing computing resources of PARAM Ganga at the Indian Institute of Technology Roorkee, implemented by C-DAC and supported by the Ministry of Electronics and Information Technology (MeitY) and Department of Science and Technology (DST), Government of India.

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