Study of odd mass neutron-deficient xenon isotopes

*Shivali Sharma and Rani Devi
Department of Physics, University of Jammu, Jammu-180006, India
**email: shivalisharma0004@gmail.com*

Introduction

The low-lying structure of neutron-deficient isotopes near the shell closure is mostly investigated by alpha decay technique. The most neutron-deficient isotope of xenon that is ^{109}Xe has been identified for the first time by Liddick et al [1]. The ground state of ^{109}Xe is tentatively assigned as $I^{\pi} = 7/2^{+}$. ^{113}Xe is the most neutron-deficient odd xenon isotope in which the level scheme has been identified by Scraggs et al [2]. The low spin structure of ^{115}Xe has been investigated by Paul et al [3]. The ground state bands in ^{109,111,113,115}Xe isotopes have been predicted to be of positive parity. The band head spins in ^{113,115}Xe have been assigned as $5/2^{+}$. However, the higher odd mass xenon isotopes have been predicted to have $11/2^{-}$as the ground state bands. The study of low-energy structure of neutron-deficient isotopes is important for testing the existing nuclear models. The experimental data is scarce for lighter mass xenon isotopes, so in the present paper an attempt has been made to study the odd mass $^{109\text{-}115}$Xe isotopes. The authors of the ref. [2] describe that bands 6 and 7 are based on the $\nu g_{7/2}$ orbital for ^{113}Xe isotope and same is described for bands a and b for ^{115}Xe isotope in ref. [3]. The experimental results for band heads and excitation energies for ^{113,115}Xe isotopes agree well with the present calculations that are performed by employing projected shell model (PSM) framework [4,5]. The calculation has also been extended to the more neutron-deficient side by performing calculations for ^{109,111}Xeisotopes in the same framework.

Theoretical Framework

Generally, in most of the neutron-deficient xenon nuclei, the single particle orbitals that lie close to the fermi surface are derived from $2d_{5/2}$, $1g_{7/2}$ and $1h_{11/2}$ subshells for both protons and neutrons. In order to study the spectroscopic properties of the $^{109\text{-}115}$Xe isotopes in the PSM framework [4,5], we have taken into account three major harmonic oscillator shells for both protons and neutrons with N=3,4,5.

The Hamiltonian used in the present calculation consists of quadrupole-quadrupole, the monopole pairing and quadrupole pairing interactions. The quadrupole and hexadecapole parameters employed in the present calculations are taken from ref. [3].

Results and discussion

In fig. 1, the calculated yrast energies are compared with the experimental ones. In fig. 1(a), the predicted band head spins and yrast energies of ^{109,111}Xe are displayed. The predicted band head spin of $5/2^{+}$ in these isotopes is same as in ^{113,115}Xe isotopes. The yrast energies show almost the identical pattern in these two isotopes. The calculated yrast energies in ^{113,115}Xe isotopes show reasonable agreement with the experimental ones.

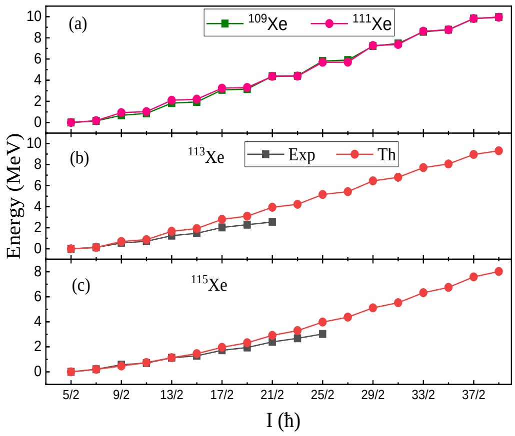

Fig. 1 Comparison of available experimental (Exp) and theoretical (Th) yrast energies of (a) ^{109}Xe and ^{111}Xe (b) ^{113}Xe and (c) ^{115}Xe isotopes.

Fig. 2 presents the comparison of calculated E(I)-E(I-1) energies with the experimental data and reproduces well the observed staggering pattern. The staggering pattern of these isotopes may be due to the mixing of low K=$1/2$, $3/2$ components of $g_{7/2}$ orbital with $d_{5/2}$ band.

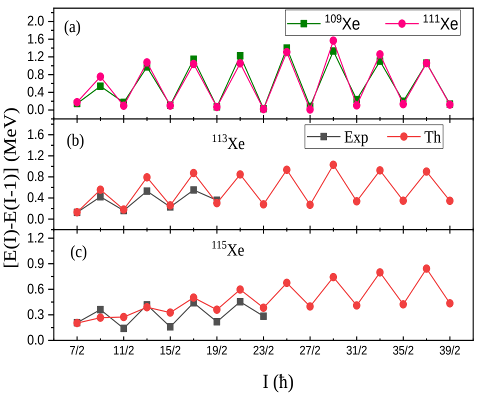

Fig. 2 Comparison of available experimental (Exp) and theoretical (Th) dipole transition energies of yrast band of (a) ^{109}Xe and ^{111}Xe (b) ^{113}Xe and (c) ^{115}Xe isotopes.

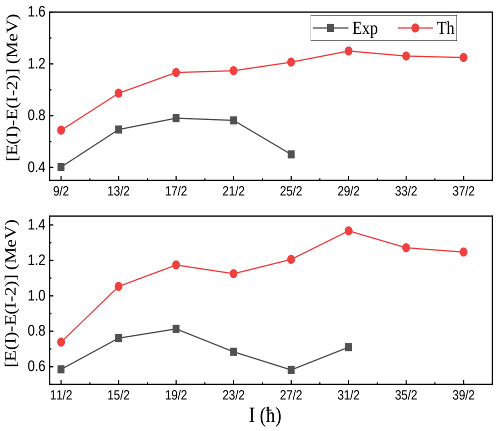

Fig. 3 Comparison of theoretical and experimental (Exp) transition energies of band 7 and band 8 [2] of ^{113}Xe isotope.

Figures 3 and 4, represent the comparison of E(I)-E(I-2) transition energies with the experimental data. The transition energies in these isotopes are overestimated but the trend is reproduced well up to spin $23/2^+$ in all the xe isotopes. The decrease in transition energies at spin $23/2^+$ is reproduced by the theoretical results and it may be due to the mixing of different components of neutron $d_{5/2}$ and $g_{7/2}$ bands.

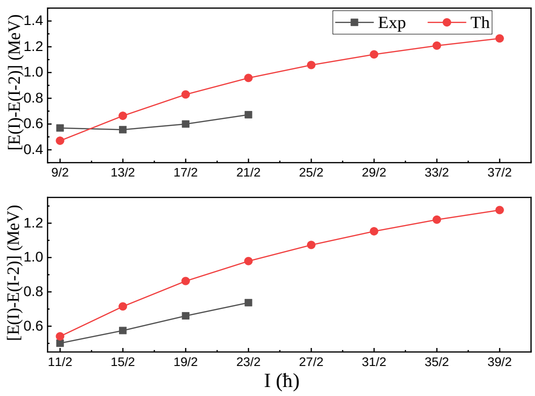

Fig. 4 Comparison of theoretical and experimental (Exp) transition energies of band a and band b of ref. [3] of ^{115}Xe.

Conclusions

The low-lying structure of odd-mass neutron deficient $^{109-115}$Xe isotopes is investigated by employing PSM framework. The band head spins and yrast energies in ^{113,115}Xe isotopes are reproduced well by the present calculations. The band head spins and yrast energies of ^{109,111}Xe isotopes are predicted which may be useful for planning future experiments. The positive parity yrast bands of all these isotopes show staggering pattern due to mixing of low K= $1/2$, $3/2$ component of $g_{7/2}$ orbital to $d_{5/2}$ orbital.

Acknowledgements

One of the authors' (Rani Devi) is grateful to the Science and Engineering Research Board for financial support under the Core Research Grant No. CRG/2019/000326.

References

[1] S.N. Liddick *et al.*, Phys. Rev. Lett.**97**, 082501 (2006) 1.
[2] H.C. Scraggs *et al.*, Phys. Rev. C**61**, 064316 (2000) 1.
[3] E.S. Paul *et al.*, Phys. Rev. C**53**, 2520 (1996) 53.
[4] Y. Sun and K. Hara, Comp. Phys. Commun. **104**, (1997) 245.
[5] K. Hara and Y. Sun, Int. J. Mod. Phys. E**4** (1995) 637.