Band head spin of rotational bands in ^{245}Pu

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Introduction

^{208}Pb is the heaviest known nucleus with a magic number of protons and neutrons. Beyond proton number Z=82, there is a considerable increase in the Coulomb repulsion between the protons. Nuclear structural studies are centered on the investigation of the next proton and neutron shells closures and as a result an island of greater stability. It is suggested that in order to create a chemical element, the composite nuclear system must last for 10-14 seconds. A superheavy element (SHE) is one for which the calculated macroscopic fission barrier would results to the lifetime lesser than this time limit. SHE existence is entirely based on the shell effects that provide it finite lifetime and greater stability. The discovery of the elements with Z = 110-116 [1, 2] has been helpful in the search for SHE. The shell-correction energy sets the stability of the SHE by lowering the ground state and so forming a barrier against fission. The shell-correction energy is applied because of the clustering of single-particle orbitals and region of the low level density. The narrow cross-sections significantly hinder the synthesis of super-heavy elements (SHE), offering insufficient experimental data to support the theoretical predictions. Due to advance facilities the measurement of $\alpha - \gamma$ or α conversion-electron coincidence is now accessible[3–9]. Experiments on the SHE have been made possible by the in-beam studies, providing new experimental information on the alignment characteristics, moment of inertia, and rotational bands. Spin values are assigned to the observed states of all rotational bands by fitting the bands using the experimental kinematic moment of inertia [10]. The A $\sim$ 250 mass region has been well-characterized by the particle number conserving cranked shell model (PNC-CSM)[11, 12]. Nowadays, several rotational bands have been noticed in the heavy nuclei [13]. In this present work, the band head spin for rotational bands in ^{245}Pu (1,2,3,4) is computed by employing VMI model.

Formalism

The VMI model, proposed by Mariscotti et al. [14], computes the energy level with angular momentum as a combination of the rotational and potential energy terms. Each nucleus is described by its restoring force constant (C) and band head moment of inertia ($\Im_0$) in the VMI model.

$$E_I(\Im) = \frac{1}{2}C(\Im_I - \Im_0)^2 + \frac{1}{2}\left[\frac{I(I+1)}{\Im_I}\right]. \quad (1)$$

The expression for the band head energy level of the rotational bands (I_0) is as follows:

$$E_I(\Im) = E_0 + \frac{1}{2\Im_I}[I(I+1) - I_0(I_0+1)] + \frac{1}{2}C(\Im_I - \Im_0)^2, \quad (2)$$

where E_0 and $\Im_0$ is the band head energy and the ground moment of inertia of the rotational bands. The variable moment of inertia may be determined in an equilibrium state as

$$\frac{\partial E(\Im_I)}{\partial \Im_1} = 0, \quad (3)$$

which leads to

$$\Im_I^3 - \Im_I^2\Im_0 - [I(I+1) - I_0(I_0+1)]/2C = 0. \quad (4)$$

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Combining equations (2) and (4), we obtain the equation, which has one real root for any positive value of $\Im_0$ and C.

$$E_I = E_0 + \left[\frac{I(I+1) - I_0(I_0+1)}{2\Im_0}\right] \times \left[1 + \frac{I(I+1) - I_0(I_0+1)}{4C(\Im_0)^3}\right]. \quad (5)$$

TABLE I: The band head spin (I_0) obtained from VMI Model for 4 rotational bands in ^{245}Pu. Here 1, 2, 3 and 4 in parenthesis represent band 1, band 2, band 3 and band 4 respectively.

Rotational Bands	$E\gamma$ (keV)	VMI Model (I_0)	Ref.[13] (I_0)
$^{245}Pu(1)$	138	4.5	4.5
$^{245}Pu(2)$	162	5.5	5.5
$^{245}Pu(3)$	154	4.5	4.5
$^{245}Pu(4)$	129	3.5	3.5

Results and Discussion

The experimentally noticed transition energies of four rotational bands in ^{245}Pu listed in ENSDF database [13] have been fitted in VMI model [14] to obtain the band head spin (I_0). The attained band head spin (I_0) of four rotational bands in ^{245}Pu computed from VMI model are specified in Table I. From Table I it has been noticed that the VMI model is efficient in reproducing the experimental band head spin of ^{245}Pu(1,2,3,4) rotational bands.

Conclusion

In this present work, we have utilized VMI model in order to deduce the band head spin (I_0) of four rotational bands in ^{245}Pu. It is concluded from present study that the VMI model works very well to explain the general nature of ^{245}Pu(1,2,3,4) rotational bands.

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