Empirical calculations for ground state band level energies of ^{76}Kr and ^{74}Se nuclei

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Introduction

The neutron deficient nuclei ^{76}Kr and ^{74}Se (N=40) in the mass region A=80 exhibit interesting properties like shape coexistence, triaxiality, large quadrupole deformation patterns, strong upbends in kinetic moment of inertia of yrast bands and complex band structure. The spectroscopy of these nuclei is of special interest because both the proton and neutron shells are partially filled which results in large deformation in the ground state [1-2].

To evaluate the level energies of ground state band of even-even nuclei, a simple two parameter VMI model was proposed by Mariscotti et al. (1968). Energy of a level with angular momentum I is given by

$$E(I) = \frac{C(\vartheta_I-\vartheta_0)^2}{2} + \frac{\hbar^2 I(I+1)}{2\vartheta_I} \qquad (1)$$

where ϑ_0 is the ground-state moment of inertia. C is restoring force constant and ϑ_I (moment of inertia state I) is determined by the equilibrium condition

$$\frac{\partial E}{\partial I} = 0 \qquad (2)$$

Combining equations (1) and (2) moment of inertia for state with angular momentum I is given by

$$\vartheta_I = \frac{\vartheta_0}{1-(\hbar^2 I(I+1)/2C\vartheta_I{}^3)} \qquad (3)$$

From equations (2) and (3) the energy of state with angular momentum I is

$$E(I) = \frac{[\hbar^2 I(I+1)]}{2\vartheta_I}\left[1 + \frac{I(I+1)}{4C\vartheta_I^3}\right] \qquad (4)$$

involves two parameters ϑ_0 and C. Both moment of inertia ϑ_I and E(I) are increasing functions of I. The quantity σ (relative increase of moment of with angular momentum I ie $(1/\vartheta)(d\vartheta/dI)$) is given by

$$\vartheta^{-1}(d\vartheta/dI) = [(2I+1)/2C\,\vartheta^2(3\vartheta - 2\vartheta_0) \qquad (5)$$

For particular case I=0,

$$\sigma = \frac{1}{2C\vartheta_0{}^3} \qquad (6)$$

provides the measure of the softness of the nucleus.

VMINS3 is the improvement over VMI model and instead of using the eq. condition (2), moment of inertia for the state with angular momentum I is expanded about the ground state value ϑ_0 by Taylor series expansion

$$\vartheta_I = \vartheta_0[1 + \sigma_1 I + \sigma_2 I^2 + \cdots] \qquad (7)$$

where $\sigma_1 = \frac{1}{\vartheta_0}\frac{\partial\vartheta_0}{\partial I}$, $\sigma_2 = \frac{1}{2!\vartheta_0}\frac{\partial^2\vartheta_0}{\partial I^2}$ are the first order and second order softness parameters respectively.

If we take softness up to first order only then the energy for state with angular momentum I is given as

$$E(I) = \frac{\hbar^2 I(I+1)}{2\vartheta_0(1+\sigma_1 I)} + \frac{C\vartheta_0{}^2\sigma_1{}^2 I^2}{2} \qquad (8)$$

ϑ_0,C and σ_1 can be determined by least square fitting of known energy levels E(2), E(4) and E(6). In terms of both parameters σ_1 and σ_2 energy E(I) gets reduced to

$$E(I) = \frac{\hbar^2 I(I+1)}{2\vartheta_0(1+\sigma_1 I+\sigma_2 I^2)} + \frac{C\vartheta_0{}^2(\sigma_1+\sigma_2 I)^2 I^2}{2} \qquad (9)$$

C, ϑ_0, σ_1 and σ_2 are determined by using E(2), E(4), E(6) and E(8). The expressions (8) and (9) had been referred as VMINS3 and VMINS4 respectively [3-4].

Results and discussion

For ^{76}Kr the value of R_{42} i.e. E_4/E_2 is 2.43 and for ^{74}Se its value is found to be 2.146. Hence VMINS3 and VMINS4 model can be used to determine the ground state band level energies of ^{76}Kr and ^{74}Se nuclei. We have determined C, ϑ_0 and σ_1 by least square fitting of E (2), E(4) and E(6). The values obtained are given in table 1.Then the higher level energies of ground state band are then determined and are summarized in the following table 2.

But VMINS4 model could not fit the level energies of ground state band. We did not find the values of C, ϑ_0, σ_1 and σ_2 suitable enough so that the higher level energies can be obtained. Hence, higher order softness does not exist in these nuclei.

Triaxiality in ^{76}Kr and ^{74}Se nuclei accounts for the absence of second order softness. That's why VMINS4 could not fit the ground state band level energies. So, we noticed that VMINS4 model is not applicable to triaxial ^{76}Kr and ^{74}Se nuclei .

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References

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Table 1: Values of C, ϑ_0 and σ_1 using VMINS3 model

	C($\times 10^5$MeV^3)	ϑ_0(MeV$^{-1)}$	σ_1
^{76}Kr	0.004265030	2.37736	1.49923
^{74}Se	0.00914322	1.35282	1.47224

Table 2 :Level energies of ground state band of ^{76}Kr and ^{74}Se nuclei

E(I)	Empirical values of g.s band level energies for ^{76}Kr in MeV	Experimental values of g.s band level energies for ^{76}Kr in MeV	Empirical values of g.s band level energies for ^{74}Se in MeV	Experimental values of g.s band level energies for ^{74}Se in MeV
E(8)	2.89918	2.8787	3.2432	3.198
E(10)	4.15569	4.0679	4.39933	4.256
E(12)	5.6287	5.3470	5.70015	5.443
E(14)	7.31832	6.647	7.14584	6.735
E(16)	9.22457	7.9963	8.73646	8.1167
E(18)	11.3475	9.396	10.4721	9.6805
E(20)	13.6871	10.930	12.3527	11.360
E(22)	16.2434	12.686	14.3783	13.202
E(24)	19.0164	14.735	16.549	--------
E(26)	22.0062	17.159	18.8647	--------
E(28)	25.2126	19.952	21.3255	--------
E(30)	28.6357	23.159	23.9313	--------