Systematic study of asymmetric parameter from asymmetric rotor model for Ni to Sn region

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The nuclear structure of Ni to Sn nuclei with Z=28-50 and N=28-50-82 region is very interesting because it comprises over the three magic number at 28, 50 and 82. The nuclear shape changes from axially symmetric to triaxial shape, when asymmetry parameter (γ) increases from 0° to 30° and in terms of interacting boson model (IBM) [1], it can be understood by considering the transition from SU(5) or Vibrational model (VM) to SU(3) rotational limit (RM) via O(6) limit. The asymmetric rotor model (ARM) [2] had been used for rare earth region (Nd-Hg) [3] and light mass region (Te-Sm) [4] to search a correlation between nuclear structure variation with N, Z and γ and internal consistency in the predictions of the ARM for transition probabilities. In this work ARM is applied for Ni- Sn region.

The Model

The Hamiltonian of ARM [1] is:

$$H=\sum_{\lambda=1}^{3}\frac{AJ_{\lambda}^{2}}{2\sin^{2}(\gamma-\frac{2\pi\lambda}{3})}$$

, where A= $\hbar^2/4B\beta^2$ has the dimensions of energy. The J_{λ}^{2} are the projections of angular momentum operators on the axes of coordinate system related to the nucleus. The rotational level energies for spin I = 2, 3, 5,… and the reduced transition probabilities between these energy levels had been calculated by assuming the nucleus as a triaxial ellipsoid. The γ varies between 0° to 30° and determines the deviation of nuclear shape from axial symmetry.

There are various methods for calculating γ as discussed in ref. [3]. The **γ** is calculated using the equation:

$$\gamma = (1/3)\sin^{-1}[(9/8)\{1-((R\gamma-1)/(R\gamma+1))^2\}].$$

Where the energy ratio $R\gamma = E_{2\gamma}/E_{2g}$ and the values energies are taken from [5].

Results and Discussions

1. The variation of γ vs. R_4 is shown in Fig.1. When R_4 is increasing from 1.4 to 3.33 the γ increases only from 22° to 30°. The SU(5), O(6) and SU(3) limits are shown at R_4 =2, 2.5 and 3.33, respectively. We have only 7 nuclei for $R_4 \geq 8/3$. The shape of these nuclei is far from axially symmetric shape (at γ=0°) but close to triaxial shape (at γ=30°).
2. The variation of γ vs. N for Ni to Sn nuclei for N= 28 to 82 is shown in Fig.2. All the data points lie between γ = 22° and 29°. There are some peaks for Sr, Zr and Mo nuclei being triaxial in shape.
3. The variation of γ vs. N for Ni to Sn nuclei for N= 28 to 50 is shown in Fig.3. For Ni, Zn, Ge and Se nuclei, γ decreases on increasing N from 28 to 38 i.e. mid of shell and if N is increased 38 to 50, the γ is constant for Ni (Z=28) and increases for Zn, Ge and Se nuclei, indicating that these nuclei are much deformed at mid shell.
4. The variation of γ vs. N for Ni to Sn nuclei for N= 50 to 82 is shown in Fig.4.
5. The variation of γ vs. N for Ru to Sn nuclei for N= 60 to 78 is shown in Fig. 5. For Cd, Pd and Sn, the γ decreases on increasing N from 56 to 64 i.e. mid of shell and if N is increased 64 to 78, the γ is constant for Sn (Z=50) and increases for Cd and Pd nuclei. A valley is formed at N=64 for Pd-Cd-Sn indicating maximum deformation. However, Ru forming a peak at N=64 indicating minimum deformation.
6. The variation of γ vs. N for Sr, Zr and Mo nuclei for N= 50 to 64 is shown in Fig. 6. These nuclei have identical behavior and attaining maxima at N=64 like Ru.

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References

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[5] Chart of Nuclides, http://www.nndc.bnl.gov/chart.

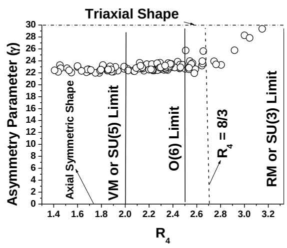

Fig. 1 The variation of Asymmetry parameter (γ) vs. R4 for Ni to Sn nuclei. The axially symmetric and triaxial shapes are shown for γ = 0° and 30°.

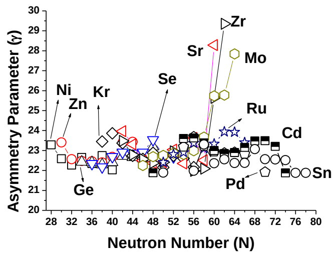

Fig. 2 The variation of γ vs. N for Ni to Sn for N= 28 to 80.

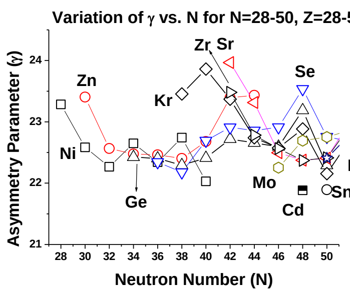

Fig. 3 The variation of γ vs. N for Ni to Sn nuclei for N= 28 to 50.

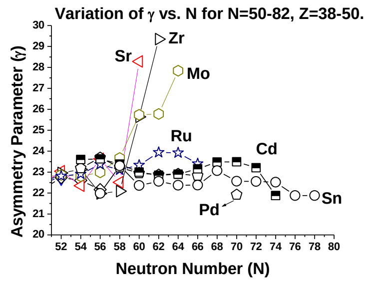

Fig. 4 The variation of γ vs. N for Ni to Sn nuclei for N= 50 to 82.

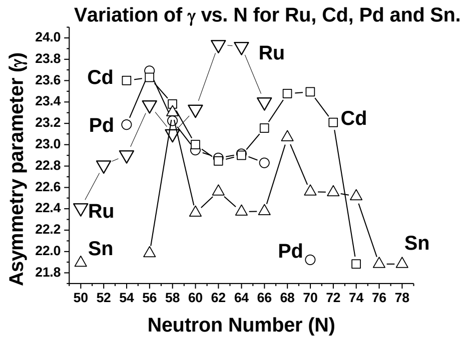

Fig. 5 The variation of γ vs. N for Ru to Sn nuclei for N= 60 to 78.

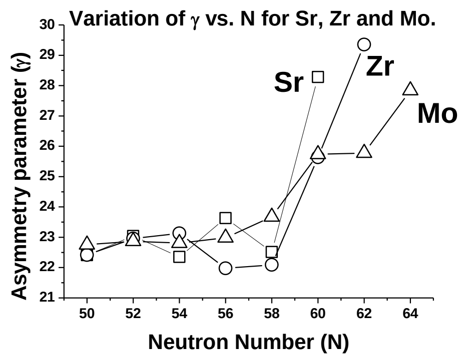

Fig. 6 The variation of γ vs. N for Sr to Mo nuclei for N= 50 to 64.