Shape evolution in even-even Sr and Kr isotopes

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Introduction

Atomic nuclei, composed of interacting fermions exhibits collective excitation such as rotation and vibration as well as single particle excitation. Rigid rotor and harmonic vibrator are the limiting ideal case of rotational and vibrational behaviour respectively. Nuclei show shape transition as a function of spin, temperature, nucleon number etc. Regan *et al* [1] proposed a simple method to distinguish the evolution of vibrational and rotational structure in nuclei as a function of spin. In this method, the gamma ray energy(E_γ) divided by the corresponding spin is plotted as a function of spin, known as the E-GOS curve. The curvature of the curve distinctly separates the vibrational and rotational nuclei. This method highlighted the danger of potential risk in assuming rotational behaviour at low spin while studying high spin behaviour. However, it should be noted that this method is only suitable to study the shape evolution along the y-rast line and upto the first band-crossing. In this contribution, we use E-GOS method to study the systematics of the shape evolution of neutron deficient even-even Kr and Sr isotopes as a function of spin and neutron number. In literature, there exists many macroscopic as well as microscopic studies such cranked Hartree-Fock-Bogouilov calculation, Interaction Boson model and other phenomenological model used to study the shape transition of nuclei in this mass region[2, 3].

Method

For an axially symmetric rotor nuclei, the gamma ray energy is given by $E_\gamma(I \to I-2) = \frac{\hbar^2}{2J}(4I-2)$ where J is the moment of inertia, and for a harmonic vibrator $E_\gamma(I \to I-2) = \hbar\omega$. The ratio $R = \frac{E_\gamma}{I}$ provides an efficient way to differentiate the two modes of excitation.
For a vibrator

$$R = \frac{\hbar\omega}{I} \xrightarrow{I\to\infty} 0 \qquad (1)$$

whereas for a rotor

$$R = \frac{\hbar^2}{2J}(4-\frac{2}{I}) \xrightarrow{I\to\infty} 4\frac{\hbar^2}{2J} \qquad (2)$$

. So for large values of I, the value of R decreases hyperbolically towards zero for a harmonic vibrator and it increases from $3(\hbar^2/2J)$ to a constant value of $4(\hbar^2/2J)$ A schematic represenation of the E-GOS plot for a vibrator, having $E(2^+) = 500$ keV and for a rotor having $E(2^+)$=100 keV is shown in Fig.1.

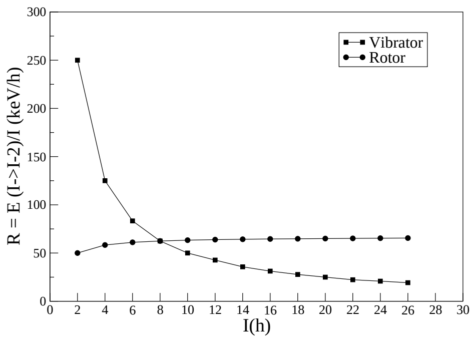

FIG. 1:

Results

Using the ENSDF datasets[4], we have plotted the E-GOS curve for six isotopes of Sr(Z=38), from N= 38 to N= 48. Fig.2 shows the corresponding plots. For Kr(Z=36)

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isotopes, E-GOS curve is plotted for N=38 to N=48, which is given in Fig.3. In this mass region, the structure is primarily determined by $1g_{9/2}$, $2p_{1/2}$, $1f_{/2}$ and $2p_{5/2}$ orbitals of which the $1g_{9/2}$ orbital is responsible for the deformation and other features observed. Nillsson diagram shows prominent shell gap at N=Z=34,36 and 38 at large deformation, hence addition or removal of few nucleons brings sharp shape transition. Table I shows the $R_{4/2}(\frac{E_4^+}{E_2^+})$ ratio and ground state deformation parameter β_2 for these these isotopes of Kr and Sr. Comparing Fig.2 with Fig.1, we see that ^{76}Sr, ^{78}Sr and ^{80}Sr shows rotational behaviour beginning from the low spins. However ^{82}Sr shows transitional behaviour as a function of spin. Interestingly ^{84}Sr shows vibrational behaviour at low spin which slowly evolves with increasing spin to a deformed rotor. Due to lack of sufficient data, we could only see that ^{86}Sr behaves as a vibrator below I $\leq$8. It can be concluded from this systematics that as neutron number increases from 38 to 48, below shell closure N=50, there is a shape transition from a deformed rotor to a near spherical vibrator. For

	^{76}Sr	^{78}Sr	^{80}Sr	^{82}Sr	^{84}Sr	^{86}Sr
$R_{4/2}$	2.85	2.81	2.54	2.32	2.23	2.07
β_2	-	0.440	0.287	0.290	0.211	0.144
	^{74}Kr	^{76}Kr	^{78}Kr	^{80}Kr	^{82}Kr	^{84}Kr
$R_{4/2}$	2.22	2.44	2.46	2.32	2.34	2.37
β_2	0.254	0.290	0.256	0.269	0.203	0.153

TABLE I: $R_{4/2}$ ratio and β_2 of Kr and Sr isotopes

Kr isotopes also we see similar trend of shape transition. From Fig.3 it can be concluded that ^{76}Kr and ^{78}Kr show rotational behaviour with increasing spin, ^{80}Kr behaves as a vibrator at low spin and as spin increases it evolves to a rotor. ^{82}Kr and ^{84}Kr shows vibrational character at spin I $\leq$8.

Conclusion

E-GOS method has been used to study the systematic of shape transition as a function of spin and neutron number. It is evident from both the systematic of Sr and Kr isotopes there is a shape transition from a deformed rotor to spherical vibrator, as neutron number approaches N=50 the nuclei become more vibrational in nature. It would be interesting to study the neutron rich isotopes having N=50-60 and other nearby isotopes in this mass region using the same approach to understand their shape evolution.

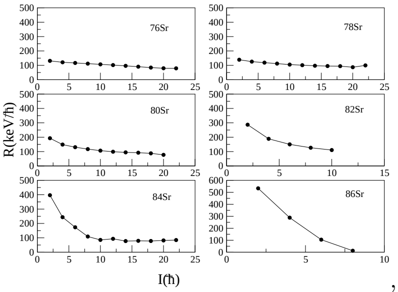

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FIG. 2: EGOS plot for $^{76-86}$Sr isotopes

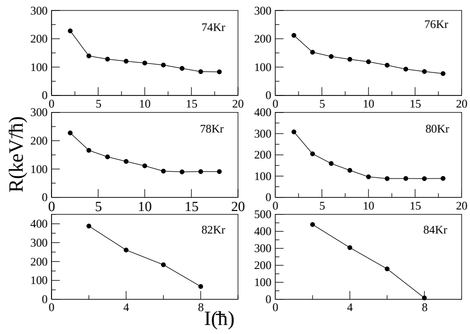

FIG. 3: EGOS plot for $^{74-84}$Kr isotopes

References

[1] P.H. Regan Phys. Rev. Lett.,**90**, 152502(2003)

[2] W. Nazarewicz *et al.* Nucl. Phys.A**435**,397(1985)

[3] R. Rodriguez *et al.* Phys. Lett. B **691**,202-207(2010)

[4] w.w.w.nndc.bnl.gov.in/ensdf