Level density and structural changes in $^{20,22}Ne$

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Introduction:

The nuclear level density has been a very important aspect of both experimental and theoretical studies from the beginning of the development of nuclear physics. The contributions made by many scientists [1-7] have enriched our understanding of its various aspects and refinements incorporating realistic single particle levels including pairing and other interactions among the particles. The role of shell model in these calculations is remarkable. Its applications in the study of fast rotating nuclei[7,8] are fascinating. In ref.[9] including finite dimensional eigenspace emphasized that the entropy S and hence the level density are not ever increasing functions of excitation energy as also other statistical quantities like the statistical temperature T, where $1/T = \partial S/\partial E^*$, may even decrease and become negative when S(E) reaches a maximum and decreases after that due to finiteness of the eigenspace [10]. This is very important in the case of light nuclei. The present work is to extend the Monte Carlo method of actual counting[11] of complexions or configurations that yield the same energy E and spin J of the whole nucleus containing N available states for the n particles in the system, to the sd shell region[12] especially Ne isotopes. For light nuclei this method is more realistic provided shell models[13] and single particle levels incorporating proper parameters are used. In this calculation we are able to predict the most probable state of shape by studying the shift of maximum number of configurations.

Methodology

The method starts with the generation of single particle states ε_i as a function of z component of the single particle spins m_i shells using the Nilsson model[13] with Lund parameters κ and μ for the sake of simplicity. For rotating light nuclei, it has been assumed that the nucleons move in a triaxially deformed Nilsson harmonic oscillator potential with the deformation described by δ and θ. The axial deformation parameter δ ranges from 0 to 0.6. Rajasekaran et al. [9] gave a new formula which was given for nuclear level densities derived using the fundamental relation $\partial W/\partial E = \rho(E)$, where W(E) is the total number of configurations available for a given energy E and spin J of the system, $\rho(E^*) = (KTN_o \ln 2)^{-1} \exp[S(E^*)]$. The level density parameter(LDP) formula $a = S^2(E,J)/4E^*$ is used for calculating the LDP and the other formulae $a = S/2T$ and $a = E/T^2$ also calculated with the statistical temperature for T and the closeness of the different formulae yield good agreement at low excitation energies.

Results and Discussion

The nucleus ^{20}Ne shows a prolate shape ($\gamma = -120^o$; δ= 0.5) upto J = 3$\hbar$ and changes its shape to oblate (δ= 0.4) at J = 6$\hbar$ through spherical shape transmission(δ= 0.0), when Ω = 0.0$\hbar\omega$ since W_{max} shifts from prolate to spherical. In cranked Nilsson Model(CNM) at Ω = 0.05$\hbar\omega$, a similar shape change is identified with fluctuating deformations, but when Ω = 0.1$\hbar\omega$, the nucleus behaves as an oblate one (γ = -180^o; δ= 0.3) except at J = 0$\hbar$, where it is prolate in shape (δ= 0.6). A quite interesting result was obtained for the nucleus ^{22}Ne, which is prolate in shape (δ= 0.2) at J = 0-1$\hbar$ and becomes spherical from J = 2$\hbar$, at Ω = 0.0$\hbar\omega$. In CNM, when Ω = 0.05$\hbar\omega$ it changes its spherical shape to oblate (δ= 0.3) at J = 5$\hbar$, and when Ω = 0.1$\hbar\omega$ it shows a prolate shape at J = 0$\hbar$, and becomes oblate immediately with fluctuating deformations. The ground state prolate shape of ^{20}Ne with deformation δ= 0.5 may be correlated with the ^{18}O - α cluster configuration by GCM method [14].

The level density or entropy of ^{20}Ne is maximum at δ= 0.5 and γ = -120°, ie., prolate when Ω = 0.0 $\hbar\omega$ with W_{max} = 2.3222x10^6 around J = 3$\hbar$. So it is predicted that the nucleus ^{20}Ne would have a greater probability of remaining prolate when Ω = 0.0 $\hbar\omega$, since W_{max} occurs at δ= 0.5, for the given excitation energy 51.582 MeV. At Ω = 0.05 $\hbar\omega$, and Ω = 0.1 $\hbar\omega$, the system would have a greater probability of being spherical and oblate respectively with W_{max} = 10.6178x10^6 and W_{max} = 11.2982x10^6 at the given excitation energy 119.814MeV. Similar effect of level density maximum is obtained for ^{22}Ne when Ω = 0.0 $\hbar\omega$, and Ω = 0.05 $\hbar\omega$, around J = 3$\hbar$; ie., the nucleus is spherical in shape with W_{max} = 5.24622x10^6 and 26.5862x10^6 respectively. So the greater probability of remaining the nucleus in spherical shape at Ω = 0.0 $\hbar\omega$ and 0.05 $\hbar\omega$, is predicted since W_{max} occurs at δ= 0.0 at the given excitation energy 48.505MeV and 119.801 MeV respectively. The maximum probable shape occurrence in ^{20}Ne at Ω = 0.0 $\hbar\omega$ is plotted as 3D surface graph in fig.1 representing the Wmax corresponding to the respective angular momentum and energy.

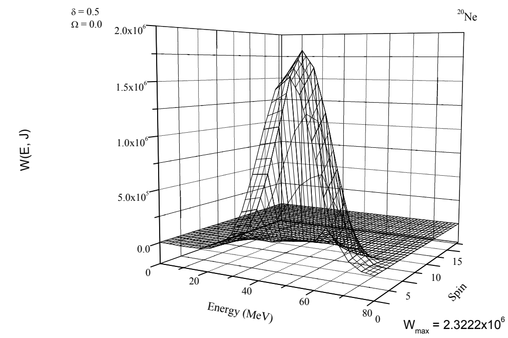

Fig.1 Maximum probable state of occurrence of ^{20}Ne; spin in units of $\hbar$ and Ω in $\hbar\omega$

From the nuclear level density we retrieve the level density parameter as usual from the equation $\rho = \exp(2(aE^*)^{1/2})$ where a is the level density parameter and E* is the excitation energy. The change in LDP with angular momentum is drawn in fig .2 and which shows a Gaussian nature.

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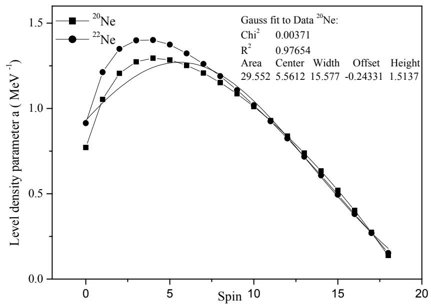

Fig.2 Level density parameter against spin(unit $\hbar$) fitted with Gaussian

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