Level Density and structural changes in the neutron deficient doubly magic nucleus $^{100}S_n$

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Introduction

A number of experimental and theoretical studies are currently focused on nuclear structure evolution far from the line of stability. The shell structure of atomic nuclei is associated with 'magic numbers' and originates in the nearly independent motion of neutrons and protons in a mean potential generated by all nucleons. In particular, the structure of neutron-deficient nuclei near the N=Z line is impacted by protons and neutrons occupying the same shell model orbitals. Probably ^{100}Sn is the heaviest doubly magic nucleus with equal numbers of protons and neutrons. Though the formation of ^{100}Sn is very difficult, Hinge et al.[1] have produced it in a projectile fragmentation reaction of a ^{124}Xe primary beam impinging on a Beryllium target with an energy of 1GeV, and obtained the half life of $T_{1/2}$ = 1.16 ± 0.20s. Guastalla *et al.* [2] discussed the evolution of nuclear structure of ^{100}Sn and the result was reproduced by shell model predictions which indicates a shell closure at *N*=*Z*=50. Isakov[3] studied the neutron deficient ^{100}Sn to neutron excess ^{132}Sn isotopes extensively in the HF+BCS approach and compared with experimental data, available at present.

The investigation of the nuclear structure of doubly magic nuclei and their neighbouring nuclei is of great interest since they are an ideal testing ground for nuclear structure models because the modeling of these systems can be reduced to the coupling of a few particle- or hole-states to the closed core. Doubly magic nuclei with an identical number of protons and neutrons are of special interest since protons and neutrons occupy the same orbitals and thus the spatial wave functions are identical. The doubly magic nucleus $^{100}S_{n50}$ is most probably the heaviest N=Z nucleus which is stable against the emission of protons and alpha particles[4]. The doubly magic character of ^{100}Sn manifests itself by the large energy gap of approximately 6 MeV to the next shell for protons and neutrons which is caused exclusively by the spin-orbit-interaction of the $g_{9/2}$ and the $g_{7/2}$ orbitals.

In the ^{100}Sn region the Gamow-Teller decay is the only allowed decay channel and there is also the possibility of beta-delayed proton emission. With increasing distance from the valley of stability towards the proton drip line the proton separation energies decrease and Q-values of the beta-decay increase. The conversion of a $g_{9/2}$ proton into a $g_{7/2}$ neutron may populate final states in the daughter nucleus which are situated several MeV above the proton separation energy[1].

It is highly interesting to know the structural effects of ^{100}Sn, against temperature. In this work, statistical theory is followed to study the structural changes of the hot rotating ^{100}Sn at different angular momentum.

Statistical theory

The statistical quantities like excitation energy, level density parameter and nuclear level density which play the important roles in the nuclear structure and nuclear reactions, can be calculated theoretically by means of the Statistical or Partition function method. In this work we have followed the statistical model approach to probe the dynamical properties of the nucleus in the microscopic level.

The entropy of the system is given by,

$S = S_Z + S_N$, where, $S_{Z(N)} = -\sum_i [n_i^{Z(N)} l_n n_i^{Z(N)} + (1-n_i^{Z(N)})\, l_n(1-n_i^{Z(N)})]$, where, the $n_i^{Z(N)}$ is the average occupation probability for proton (neutron).The total excitation energy is obtained using

$$E_{ex} = U(M,T) = U_{eff}(T) + E_{rot}(M)$$

The single particle level density parameter a(M,T) is extracted using the equation a(M,T) $=S^2(M,T)$ /4 U(M,T). The expression for the neutron(proton) separation energy is,

$S_{N(P)} = TN(Z)/\{\sum_i[(1 - n_i^{N(Z)})n_i^{N(Z)}]\}$

From the above expressions it is possible to calculate the nuclear level density, back shift energy and hence the spin cut-off parameter using Gilbert-Cameron expression[4], and were extracted and studied for the doubly magic nucleus ^{100}Sn.

Result

The deformation of the nucleus is found to be spherical and unaltered till the spin J=20ℏ and up to the temperature T=3MeV. The excitation energy increases with spin and temperature and the occurrence of shape transition beyond temperature T=1.0MeV is almost at a particular spin (J≈26ℏ) and hence the role of temperature in the shape transition beyond T=1.0MeV is relatively negligible. The proton and neutron separation energies have its own importance in the isotopic transition. Our calculations show that the proton separation energy decreases with increasing spin and is around E_x=14MeV at spin J≈30ℏ at all temperatures, which may be correlated to the possibility of transition from Sn to In around this spin. Around J≈20ℏ, the neutron separation energy becomes almost constant, shown in Fig.2, i.e., the particle emission get saturated even if the temperature is increased, and the shape evolution get started slowly. Nuclear reaction calculations based on standard nuclear reaction models play an important role in determining the accuracy of various parameters of theoretical models and experimental measurements. Especially, the calculations of nuclear level density parameters (ldp) for the isotopes can be helpful in the investigation of reaction cross-sections. For ^{100}Sn the level density parameter "a" calculated at different temperatures are plotted against spin, (Fig.3), which shows a peak in ldp at around J=20ℏ and T=0.7MeV, and which increases smoothly with temperature. The observed peaks refer a shape transition from spherical to oblate with minimal axial deformation.

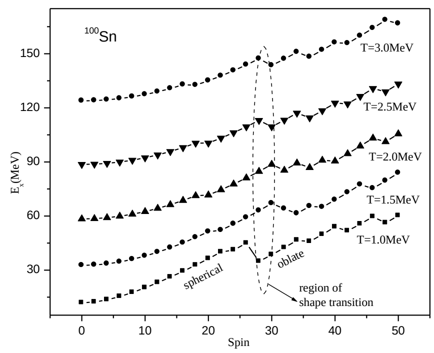

Fig.1. E_x Vs spin at different temperatures.

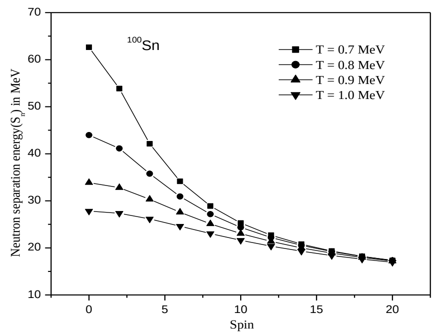

Fig.2. Role of spin on S_n at diff. temperatures

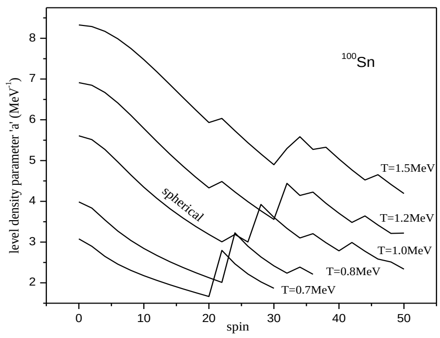

Fig.3. LDP of $^{100}S_n$ at diff. temperatures

References

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