Level density of new chemical element 117

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Introduction

The discovery of new chemical element with atomic number Z=117 is very recently reported by Oganessian et al.[1]. They have produced the isotopes $^{293}117$ and $^{294}117$ in fusion reaction between ^{48}Ca and ^{249}Bk and identified the decay chains involving 11 new nuclei by means of the Dubna gas-filled recoil separator. It is of essential importance for the successful synthesis of superheavy nuclei to select the isotopic composition of projectile and/or target so as the mass difference of fission and neutron emission saddle points as large as possible. Liu and Jing [2] analysed the possible combination of target and the projectile nuclei for the synthesis of superheavy nucleus Z=117. The stability of nucleus depends not only on the charge number but also with mass number. Hence an analysis of two isotopes of the nucleus Z=117 has been performed using statistical method and the results obtained by us support the argument of Liu and Jing[2] in the context of ER cross section. We have also extended our calculation to different temperature regions (upto 2.0 MeV) and spin (upto 20$\hbar$). Since the shell effects play an important role in the structural stability of superheavy nuclei the shape changes is also analysed.

Calculations

The rotational energy E_{rot} is given as $E_{rot}(M,T) = E(M,T) - E(0,T)$ and hence the effective excitation energy $U_{eff}(T) = U(T) - \delta B$ where $\delta B = -\delta E_{shell}$ is the ground state shell correction. This is due to the fact that a part of the excitation energy is used up to overcome the shell forces which are deformation dependent. 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) as a function of angular momentum M and temperature T is extracted using the equation $a(M,T) = S^2(M,T) / 4\,U(M,T)$. The nuclear level density can be described in terms of thermodynamic concepts and the entropy of the system is given by $S = S_Z + S_N$; $S_Z = -\sum_i [n_i^Z l_n n_i^Z + (1-n_i^Z) l_n(1-n_i^Z)]$ and $S_N = -\sum_i [n_i^N l_n n_i^N + (1-n_i^N) l_n(1-n_i^N)]$ where n_i^Z and n_i^N are the average occupation probability for proton and neutron respectively and S_Z and S_N are the proton and neutron separation energies.

Results and Discussion

The results obtained by the statistical calculations reveal that both the nuclides are spherical at their ground state and the shape change is occurred at ≈ 8$\hbar$ and they behave as oblate shape ($\delta = 0.1$; $\gamma = -180^o$) with increase of angular momentum. The stability at lower spin is high for $^{294}117$ while at higher spin (>8$\hbar$) $^{293}117$ shows higher stability (fig.1).The probability of neutron emission is high for $^{293}117$ than $^{294}117$ at lower spin. The separation energy is high when the nuclides are oblate in shape.(fig.2). Hence the most probable shape of existence may be deformed oblate shape. The spin effect on the level density parameter is also calculated (fig.3) and our results show that the level density parameter for the studied nuclides deviates at lower spins and it is very close at higher spins (>8$\hbar$) which may be due to the shape transition from spherical to oblate.

The value of the level density parameter can be determined, under statistical assumptions, by the relation between excitation energy and temperature. Suraud et al. [3] calculated the level density of a hot nucleus plus confining gas system and subtracted the level density of the gas, they found that the parameter (a/A) stays constant upto T=5MeV, then increases by about 6% for T=8MeV. This result is consistant with conclusions from Hartree-Fock[4] and Extended Thomas Fermi [5] calculations on hot nuclei.

Dean and Mosel[6] calculated the entropy S of a nuclear system at excitation energy E_{ex} by relating the level density parameter to the entropy, $S^2 = 4aE_{ex}$, and they found an opposite trend, namely that a/A remains constant (=1/13.5)MeV upto T=5MeV and then decreases by about 8% at T=10MeV.

In the superheavy region the existence of nuclei at very high temperature is unpredictable. We have calculated the level density parameter for $^{293,\,294}$117 at different temperatures upto T = 2.0 MeV in steps of 0.1MeV. For the nucleus ^{293}117 (fig.4), the level density parameter a(M,T) decreases for low temperatures upto T= 0.5 MeV and then increases for higher temperature upto 25% at Temperature T = 2.0 MeV ; this result is in consistant with Hartree-Fock[4] and Extended Thomas Fermi [5] calculations. The level density parameter at low temperature was found to decrease with increasing temperature which is in qualitative agreement with experiment. Such a decrease with increasing T may be interpreted as a signature for the collapse of nuclear residual interactions [7].

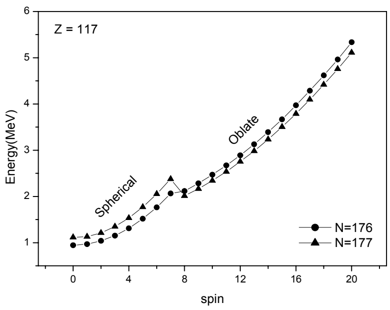

Fig. 1 Excitation energy Vs spin (ħ) with shape transition

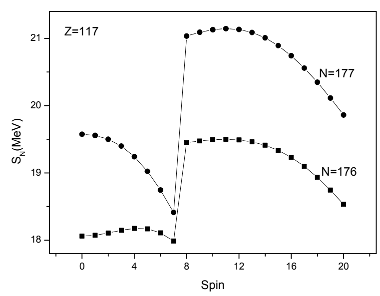

Fig. 2 Neutron Separation Energy Vs spin (ħ). The hike is due to shape transition

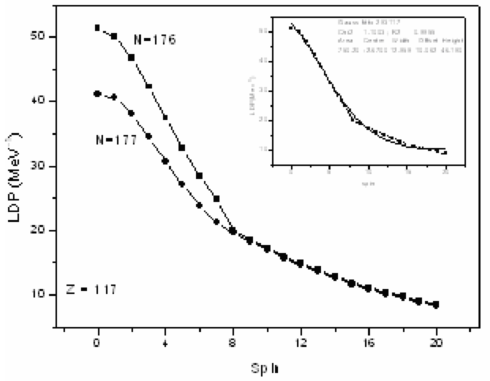

Fig. 3. Change in level density parameter with spin (ħ). The plot inside is fitted with Gaussian for ^{293}117.

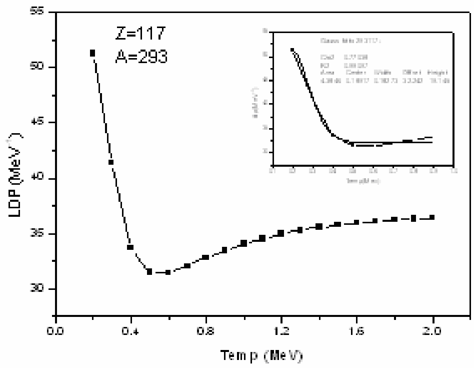

Fig. 4. Temperature dependence of level density parameter. The plot inside is fitted with Gaussian for lower temperature upto T = 1.0 MeV.

References

[1] Yu. Ts. Oganessian et al., Phys. Rev. Lett. **104**, 142502 (2010).

[2] Z. H. Liu and Jing-Dong Bao, Phys. Rev. **C80**, 034601 (2009).

[4]. P. Bonche, S. Levit, D. Vautherin, Nucl. Phys. **A427**, 278 (1984).

[3]. E. Suraud, P. Schuck, R. W. Hasse, Phys. Lett. **B164**, 212 (1985).

[5] J. bartel, M Brack, M. Durand, Nucl. Phys. **A445**, 263 (1985).

[6]. D.R. Dean, U. Mosel, Z. Phys. **A322**,647 (1985).

[7]. R. W. Hasse and P.Schuck, Phys. Lett. **B179**, 313 (1986).