Study of Compressibility modulus of $Z = 117$

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Introduction

The compressibility of the nuclear matter has received a significant attention in the last decade and various approaches have been employed to extract the compression modulus. However, a clear determination of the compression modulus of the nuclear matter has remained difficult due to a lesser sensitivity of the giant monopole resonance to the compressibility [1] [2]. The only method to calculate the compressibility for infinite nuclear systems like neutron star is to study of finite nuclear compressibility. That is the reason why now-a-days the study of Isoscalar giant monopole resonance (IGMR) is important.

The IGMR is commonly known as breathing mode of nucleons, where protons and neutrons are oscillate in same phase in the form of density. Excitation energy of the IGMR is directly related to the compressibility of the nucleus by the following relation,

$$E^s = \sqrt{\frac{C_m}{B_m}}, \qquad (1)$$

where, C_m and B_m are taking their usual meaning. In leptodermous expansion, the compressibility of the finite nucleus can be written as,

$$K_A = K_\infty + K_{surf} A^{1/3} + K_\tau I^2 + K_{coul} Z^2 A^{-4/3},$$

where $I = (N - Z)/A$ isospin asymmetry, and K_∞ is the infinite nuclear matter compressibility. The Compression modulus of nuclear matter, K_{nm} is important in the description of properties of nuclei, supernovae explosions, neutron stars, and heavy ion collisions. The value of K_{nm} can be obtained directly from the energies of the IGMR in nuclei [3]. Isospin has a large effect on the EOS (Equation of state), so it is very instructive to study variation of compressibility with isotopic chain for super heavy region. For the study, we have taken recently experimentally synthesized nuclei $Z = 117$ as super-heavy element and calculated the compressibility of its isotopic chain.

Formalism

We used relativistic mean field (RMF) formalism with NL3 parameter set to study the ground state properties of the nuclear system. Density is calculated in semi-classical approximation like Relativistic Thomas-Fermi (RTF) and Relativistic Extended Thomas-Fermi (RETF) approaches. In Relativistic extended Thomas-Fermi calculation, surface properties is taken care by extra correction term on top of Relativistic Thomas-Fermi calculations. For the calculations, we have used the Relativistic Extended Thomas-Fermi(RETF) Hamiltonian. The RETF Hamiltonian is written as:,

$$\mathcal{H} = \mathcal{E} + \frac{1}{2} g_s \phi \rho_s^{eff} + \frac{1}{3} b\phi^3 + \frac{1}{4} c\phi^4 + \frac{1}{2} g_v V\rho + \frac{1}{2} g_\rho R\rho_3 + \frac{1}{2} e\mathcal{A}\rho_p,$$

here, $\mathcal{H}_f$ is the free part of the Hamiltonian. The total density ρ is the sum of proton ρ_p and neutron ρ_n densities. In order to study the monopole vibration of the nucleus, we have scaled the baryon density. The normalized form of the scaled baryon density is given by,

$$\rho_\lambda(\mathbf{r}) = \lambda^3 \rho(\lambda r),$$

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here, λ is the collective co-ordinate associated with the monopole vibration. With this scaled density, we can write the RETF Hamiltonian in scaled form. The compressibility can be obtained from the derivative of the scaled Hamiltonian with respect to the scaled co-ordinate λ. The restoring force C_m is written as [6]:

$$\begin{aligned} C_m &= \int dr \Big[-m\frac{\partial \tilde{\rho_s}}{\partial \lambda} + 3\Big({m_s}^2\phi^2 + \frac{1}{3}b\phi^3 \\ &- {m_v}^2V^2 - {m_\rho}^2R^2 \Big) - (2{m_s}^2\phi + b\phi^2) \\ &\frac{\partial \phi_\lambda}{\partial \lambda} + 2{m_v}^2V\frac{\partial V_\lambda}{\partial \lambda} + 2{m_\rho}^2R\frac{\partial R_\lambda}{\partial \lambda} \Big]_{\lambda=1}, \end{aligned}$$

We are interested to calculate the monopole excitation energy which is defined as $E^s = \sqrt{\frac{C_m}{B_m}}$ with C_m is the restoring force and B_m is the mass parameter. The second order derivative in the expansion is related with the constrained compressibility modulus for finite nucleus K_A^c as,

$$ {K_A}^c = \frac{1}{A}{R_0}^2\frac{\partial^2 E\eta}{\partial R_\eta}, \quad (2)$$

and the constrained energy ${E_m}^c$ as,

$$ {E_m}^c = \sqrt{\frac{AK_A^c}{B_m^c}}. \quad (3)$$

Results

In this section, we discuss our obtained results of compressibility modulus for $Z = 117$ We calculated the compressibility modulus using $NL3$ parameter in the frame work of RMF for $Z = 117$ isotopic chain. Our obtained results are given in figure 1. It is clear that when we increases the number of neutrons then scaling compressibility modulus and constraint compressibility modulus decreases but the amount of decrease is very small in their isotopic chain (0.2 MeV). The change in compressibility modulus with isotopic chain is very

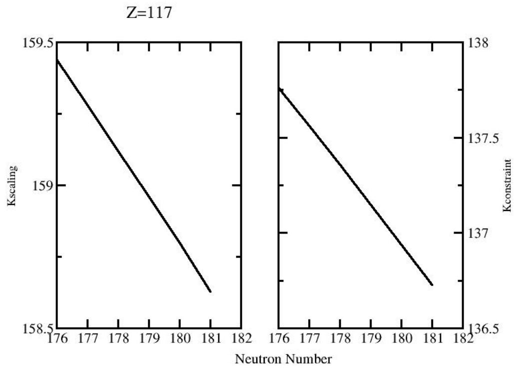

FIG. 1: Compressibility modulus for superheavy nucleus Z=117.

small because it depend on IGMR which is collective properties of the nucleus. The variation in collective properties of the large systems such as super heavy are small in compare to medium or lighter nuclear system. In this calculations compressibility modulus difference($K = K_s - K_c$) is less than 22 MeV.

Conclusion

We have observed the variation of compressibility in the isotopic chain of $Z = 117$. From our observation it is well found that the compressibility decreases in neutron drip-line regions. Such observations motivate us for further calculation in IGMR.

References

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